Appendix E – Business Use (BU) Requirements and Benefits

This assessment evaluates requirements and benefits of enhanced elevation data for 27 Business Uses:

1. Natural Resources Conservation
2. Water Supply and Quality
3. River and Stream Resource Management
4. Coastal Zone Management
5. Forest Resources Management
6. Rangeland Management
7. Wildlife and Habitat Management
8. Agriculture and Precision Farming
9. Geologic Resource Assessment and Hazard Mitigation
10. Resource Mining
11. Renewable Energy Resources
12. Oil and Gas Resources
13. Cultural Resources Preservation and Management
14. Flood Risk Management
15. Sea Level Rise and Subsidence
16. Wildfire Management, Planning and Response
17. Homeland Security, Law Enforcement, and Disaster Response
18. Land Navigation and Safety
19. Maritime Navigation and Safety
20. Aviation Navigation and Safety
21. Infrastructure and Construction Management
22. Urban and Regional Planning
23. Health and Human Services
24. Real Estate, Banking, Mortgage, Insurance
25. Education K-12 and Beyond
26. Recreation
27. Telecommunications

Appendix E summarizes the requirements and benefits data received for each of the 27 Business Uses from: (1) 34 Federal agencies with 104 Functional Activities documented in Appendix B; (2) 50 states with 329 Functional Activities documented in Appendix C; (3) 57 counties, 17 cities and towns, 11 tribes and 22 regional governments with a total of 144 Functional Activities also documented in Appendix C; and (4) the 11 other not-for-profit and private businesses with 13 Functional Activities documented in Appendix D. As noted in the following business use descriptions, State agencies were asked to identify their 5-6 highest value Functional Activities only. It is expected that a more exhaustive process would have identified additional, lower priority activities, with additional benefits.

This Appendix summarizes the following for each BU:

- Definition of the BU as defined in this assessment

- Background information pertaining to each BU
- Graphic example(s) to help illustrate how elevation data supports each BU
- Elevation Data Requirements and Benefits Table that summarizes the numerous Functional Activities (defined in their own words by Federal agencies, states, local governments, other not-for-profit and private companies, etc. in their Appendices) relevant to each BU. This table also includes the elevation data Quality Levels (QLs) and update frequency required for each Functional Activity, summary of mission-critical requirements for enhanced elevation data, and explanation of tangible and intangible benefits. *Mission-critical* was defined for this assessment as "indispensable for mission accomplishment and/or essential for effective/efficient operations in accomplishing the core mission of the organization."
- Analysis of dollar benefits for each BU

The dollar benefits are documented in two ways:

- The conservative benefits as used in the benefit/cost analyses. For the benefit/cost analysis, each Functional Activity has requirements and benefits linked to spatial files that define specific geographic areas for which the requirements and benefits pertain. The conservative benefits do not include the sampling of Functional Activities from county, regional, city and Tribal governments.
- The potential benefits that accompany explanations of why the conservative estimates are probably understated. These potential benefits are not used in the benefit/cost analysis because the requirements and benefits are not linked to spatial files that define specific geographic areas for which the requirements and benefits pertain. Limited benefits projections were made for county, regional, city and Tribal governments that did not participate in the state interviews/workshops.

Even these potential benefits are believed to be vastly understated and could be one or more order of magnitudes greater if the study had included the expected benefits of every county, region, city and Tribal government, and other industries nationwide. Specific Functional Activities, with spatial files linked to requirements and benefits, were only obtained from 57 of the 3,143 counties and county equivalents (e.g., parishes, boroughs); from 22 of the 450+ regional councils/governments; from 17 of the 30,000+ incorporated towns and cities; and 11 of the 564 Tribal entities recognized and eligible for funding and services from the Bureau of Indian Affairs. As another example, it is already known that the majority of LiDAR data downloads from the OpenTopography Portal (where LiDAR is available for portions of the U.S.) are from individual land surveyors who use the data in lieu of traditional topographic surveys. The savings to surveyors is not estimated and captured in this report but may be a significant savings nationally. Furthermore, as LiDAR data become available nationwide, individual citizens will be geo-enabled in 3-D, much as they are now geo-enabled in 2-D with their in-car navigation devices and cell phones. Such benefits to individuals, nationwide, may also be considerable.

BU#01 – Natural Resources Conservation

Scope of BU#1

Business Use #1 is defined in terms of Functional Activities that preserve the health of soil and vegetation, minimize soil erosion and runoff into streams, and preserve wetlands. Working in partnership with others, the Natural Resources Conservation Service (NRCS), within the U.S. Department of Agriculture (USDA), is an agency that has many activities that fall into this category, but other Federal, state and local agencies also have a number of related responsibilities for conservation of natural resources.

Background Information

A founding motto of the NRCS, originally the Soil Conservation Service (CSC), is: "*If we take care of the land, it will take care of us.*" DEM derivatives (slope, aspect, and curvature) are the three principal parameters in NRCS' LiDAR-Enhanced Soil Survey (LESS) model, for example, which improves the precision of soil surveys. Furthermore, DEMs and DEM derivatives are mission-critical for the conservation of soil, wetlands, and other natural resources for many other Federal and state agencies listed below.

Approximately 70% of the land in the U.S. is privately owned, making stewardship by private landowners absolutely critical to the health of our nation's environment. NRCS works with private landowners through conservation planning and assistance designed to benefit the soil, water, air, plants and animals that result in productive lands and healthy ecosystems. Other Federal, state and local agencies have similar but different environmental stewardship responsibilities for Federal, state, local, Tribal and privately owned lands, and they all require enhanced elevation data, primarily LiDAR, for this purpose.

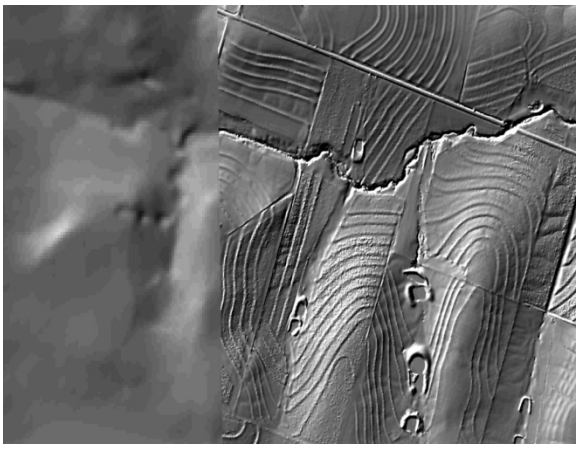

Figure E.1. Compared to the National Elevation Dataset (NED) as shown on the left, federal and state agencies require higher-resolution, higher-accuracy LiDAR DEMs as shown on the right for natural resources conservation. Image courtesy of NRCS.

Figure E.1 compares a low-resolution (10-meter), low-accuracy DEM, currently available in the National Elevation Dataset (NED) shown on the left, with high-resolution (1-meter), high-accuracy LiDAR data shown on the right. In this example, the elevations and slopes of farm terraces can be measured and reviewed in the office by NRCS staff, helping them avoid the time and costs associated with expensive on-site field visits or field surveys, and enabling the NRCS to support many more customers with the same budget.

Summary of Requirements and Benefits

Table E.1 lists Functional Activities, pertaining to Natural Resources Conservation. The NRCS performed a thorough analysis of dollar benefits from enhanced elevation data and determined the annual savings

to NRCS to be between $79M/year and $169M/year. Another agency estimated savings of $28M/year, while some agencies that either manage or assess natural resources were unable to estimate time/cost benefits other than stating they would be "major." Each of these government agencies is *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity touched on in this Appendix is explained in detail in Appendices B, C and D.

Table E.1. Elevation Data Requirements and Benefits for BU#1, Natural Resources Conservation

Geo-enabled User & Functional Activity **Quality Level (QL)** **Update Frequency**	**Summary of BU#1 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.**	**Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.**
NRCS **Conservation Engineering and Practices** **Mostly QL2 LiDAR; some QL5 IFSAR** **6-10 years**	For modernization of Conservation Technical Assistance programs and 69 conservation engineering practices that rely upon DEMs and DEM derivative products (primarily slope, aspect and curvature).	***Operational Benefits***: Enhanced LiDAR and IFSAR data will enable the NRCS to modernize its engineering practices, reduce field surveys and on-site visits for conservation engineering practices including grade stabilization, ponds, grassed waterways, heavy use area protection, pipelines, riparian forest buffers, terracing, waste transfer, and wetland restoration.
		$ Benefits: $60M/year to $150M/year
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Major
NRCS **Specialized Mapping Applications** **QL2 and QL3 LiDAR; QL5 IFSAR for Alaska** **6-10 years**	For soils mapping, floodplain mapping, and mapping of cultural and natural resources, e.g., wetlands, grasslands, forests and wildlife habitat. Note: slope, aspect and curvature are the three most important parameters used for LiDAR Enhanced Soils Surveys (LESS).	***Operational Benefits***: LiDAR data will enable the NRCS to efficiently produce accurate soils maps, floodplain maps, and maps of natural resources used by private land owners that serve as stewards for 70% of the land in the U.S.
		$ Benefits: $18.82M/year
		Customer Service Benefits: Major
		Public/Social Benefits: Minor
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Moderate
USFS **Soils and Geology Inventory** **QL2 LiDAR of FS lands; QL5 in Alaska** **>10 years**	For soil inventories for the 16 million acres of USFS lands that remain to be completed. USFS soils inventory procedures rely upon DEMs, slope, aspect and curvature to model soil types.	***Operational Benefits***: LiDAR and IFSAR data will enable the USFS to provide accurate soil and geology inventory maps for non-government lands nationwide.
		$ Benefits: $800,000/year
		Customer Service Benefits: Moderate
		Public/Social Benefits: Moderate
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Moderate
USFS **Wetlands Mapping and Characterization**	For slope calculations and wetlands delineations which are used for habitat analysis.	***Operational Benefits***: Hydro-enforced LiDAR and IFSAR data will enable the USFS to map and characterize wetlands.
		$ Benefits: $10,000/year
		Customer Service Benefits: Moderate

QL2 LiDAR of FS lands; QL5 in Alaska **6-10 years**		***Public/Social Benefits***: Minor
		Environmental Benefits: Major
		Strategic/Political Benefits: Unknown
USGS **Mapping, Monitoring and Assessment of Biological Carbon Stocks** **QL1 LiDAR of forested counties; QL2 LiDAR of non-forested** **6-10 years**	For quantitative characterization of vegetation structural attributes in support of the USGS mission to assess, monitor and map land biomass and biological carbon stocks nationwide.	***Operational Benefits***: LiDAR data will improve USGS' ability to address reporting requirements under the Energy Independence Security Act (EISA), while benefiting other activities related to climate and land use change, ecosystems, energy, minerals and environmental health.
		$ Benefits: $13M/year
		Customer Service Benefits: Major
		Public/Social Benefits: Moderate
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Moderate
NOAA **Coastal and Marine Resources Conservation** **QL2 LiDAR plus bathymetry** **4-5 years**	Both topographic and bathymetric LiDAR are required of coastal areas for habitat delineation, assessment, and analysis; for location of sample sites; and for management of protected areas.	***Operational Benefits***: Topographic and bathymetric LiDAR data will enable NOAA to conserve coastal and marine resources.
		$ Benefits: $1.4M/year
		Customer Service Benefits: Major
		Public/Social Benefits: Moderate
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Moderate
EPA **Environmental Protection, Land Cover Characterization and Runoff Modeling** **QL2 LiDAR; QL5 IFSAR in Alaska** **4-5 years**	For modeling land cover characteristics and hydrodynamics of streams and estuaries, and to make decisions on how to protect and/or restore the air we breathe, the water we drink, and/or the environment that sustains us.	***Operational Benefits***: LiDAR and IFSAR data will enable the EPA to perform runoff and urban area modeling (relevant to the Clean Water Act and Clean Air Act activities), land use/land cover (LU/LC) mapping, and land cover characterization.
		$ Benefits: $12.9M/year
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Major
FWS **Wetlands Inventory and Mapping** **Satellite Differential InSAR (DInSAR)** **6-10 years**	For monitoring the extent and status of wetlands for management, research, policy development, education, and planning through the National Wetlands Inventory (NWI).	***Operational Benefits***: Repeat Pass satellite DInSAR data could enable the FWS to map water level changes in wetlands which has a major impact for fisheries and wildlife management as well as for flood forecasting, water supplies and other applications where water quantity changes can be mapped instead of relying of stream point gages.
		$ Benefits: Major; cannot quantify
		Customer Service Benefits: Major
		Public/Social Benefits: Moderate
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Moderate
NPS **Preservation and Protection of Natural**	For diverse activities such as engineering plans/designs for restoration of watersheds,	***Operational Benefits***: LiDAR and IFSAR data will enable the NPS to model natural resources within NPS units and provide the public with objective, science-based, and timely information on the condition of those natural

and Cultural Resources **QL1 LiDAR (NPS forested); QL3 LiDAR (non-forested); QL5 IFSAR in Alaska** **6-10 years**	stream banks, wetlands, forests, dams and infrastructure on NPS lands.	resources and how they change over time. ***$ Benefits***: Major, but unable to estimate ***Customer Service Benefits***: Major ***Public/Social Benefits***: Moderate ***Environmental Benefits***: Major ***Strategic/Political Benefits***: Major
BIA **Protection and Enhancement of American Indian Trust (AIT) Assets** **QL3 LiDAR** **6-10 years**	For management of forest, water and other natural resources on AIT lands and watersheds flowing into and out from AIT lands.	***Operational Benefits***: Along with 21st century GIS technology, LiDAR data will enable the BIA and Tribal governments (as stewards of AIT lands) to inventory and model their natural resources and make wise decisions on land use and/or development. ***$ Benefits***: Major, but unable to estimate ***Customer Service Benefits***: Major ***Public/Social Benefits***: Major ***Environmental Benefits***: Major ***Strategic/Political Benefits***: Major
USACE **Protection and Management of the Natural Environment** **QL3 LiDAR** **6-10 years**	For the environmental stewardship of watersheds that flow into USACE reservoirs; for protection of wetlands, rivers and streams, dunes, beaches, and habitat and for cleanup of Formerly Utilized Sites contaminated by chemical, radiological, biological and other wastes.	***Operational Benefits***: LiDAR data will enable USACE to execute its environmental stewardship responsibilities with an estimated 10% increase in effectiveness, and to administer provisions of the Clean Water Act and Federal wetland regulations. ***$ Benefits***: $2.16M/year ***Customer Service Benefits***: Major ***Public/Social Benefits***: Major ***Environmental Benefits***: Major ***Strategic/Political Benefits***: Major. LiDAR data will enable USACE to clean-up contaminated soils and hazardous areas of Formerly Utilized Sites.
TVA **Natural and Cultural Resource Management and Conservation** **QL1 LiDAR** **2-3 years**	For NEPA environmental assessment and impact studies, non-point source pollution modeling, reservoir shoreline stabilization and stream bank erosion.	***Operational Benefits***: LiDAR data will enable the TVA to efficiently and effectively manage and conserve natural resources within the TVA area of responsibility. ***$ Benefits***: $150,000/year ***Customer Service Benefits***: Moderate ***Public/Social Benefits***: Major ***Environmental Benefits***: Major ***Strategic/Political Benefits***: Moderate
BLM **Multi-Use Land Management in Alaska** **QL5 IFSAR** **>10 years**	For multi-use land management in Alaska, including management of floodplains and wetlands, safe operations of aircraft, delineation of rights of ways and easements, base mapping for wild land fire suppression, mapping of potential oil and gas infrastructure areas, and	***Operational Benefits***: Major ***$ Benefits***: Unknown ***Customer Service Benefits***: Major ***Public/Social Benefits***: Moderate ***Environmental Benefits***: Moderate ***Strategic/Political Benefits***: Unknown

	support of cadastral surveys.	
28 State **Functional Activities** **QL1 LiDAR: 3** **QL2 LiDAR: 9** **QL3 LiDAR: 12** **QL4 Image DEMs: 3** **QL5 IFSAR: 1** **Variable update frequencies**	For government programs in AR, AK, CT, FL (2), HI (2) IA (2), ID, IL, KS, MD (2), ME (2), MT (2), MO, MN, NC, NV, NY, SD, TX, UT, VT, and WV, budgeted at $713 million in 2011. Note: some states have more than one Functional Activity for this Business Use.	***Operational Benefits***: All forms of enhanced elevation data will enable these state and territorial governments to be more efficient and/or effective in managing their natural resources while providing additional dollar benefits to the public.
		$ Benefits: $10.872M/year government benefits plus $31.055M/year in added benefits for others. A total of 15 State FAs included estimated $ benefits. Twenty nine states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.
1 County **Functional Activity** **QL3 LiDAR: 1** **6-10 years**	For a land and water resources program in one county in Wisconsin, budgeted at $500,000 in 2011.	***Operational Benefits***: LiDAR data will enable Outagamie County to better conserve its natural resources.
		$ Benefits: Dollar benefits could not be estimated
3 Regional **Functional Activities** **QL2 LiDAR: 1** **QL3 LiDAR: 2**	For regional planning for natural resources conservation for three programs, budgeted at $5.6 million in 2011.	***Operational Benefits***: LiDAR data will enable wetland classification, biological and hydrological modeling, and natural resources conservation planning for three regional governments.
		$ Benefits: $300,000/year in regional government benefits
1 City **Functional Activity** **QL2 LiDAR: 1** **4-5 years**	For the Town of Newington, CT to regulate development based on steep slopes over 15%, with a program budgeted at $436,000 in 2011.	***Operational Benefits***: LiDAR data will enable the Town of Newington to evaluate land suitable for development, increase the town's fiscal assets, eliminate the need to spend time on general data collection, increase the accuracy of the data used for analysis, and substantiate claims.
		$ Benefits: Dollar benefits could not be estimated
3 Tribal **Functional Activities** **QL2 LiDAR: 1** **QL3 LiDAR: 2** **Variable update frequencies**	For the Southern Ute Indian Tribe (Colorado), the Alaska Village Initiatives, and the Lower Elwha Klallam Tribe (Washington) to conserve and protect natural resources on Tribal lands.	***Operational Benefits***: LiDAR data will enable these tribes to develop efficient procedures that perform erosion change detection, execute carbon exchange, preserve salmon habitat, and operate Tribal conservation districts.
		$ Benefits: $7.5M/year for the tribes.
The Nature Conservancy **Healthy Watersheds** **QL2 LiDAR** **6-10 years**	QL2 LiDAR is required of buffer areas around selected streams and ecosystems for restoration of natural and beneficial functions of floodplains and restoration of wetlands.	***Operational Benefits***: LiDAR data will enable TNC to identify priority areas for floodplain and wetland restoration. It will enable TNC to evaluate alternatives for restoring wetlands that filter out agricultural nutrients and animal waste that pollute our streams and key ecosystems like the Chesapeake Bay and Gulf of Mexico.
		$ Benefits: $10.07M/year
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Major
Agren	For development of	***Operational Benefits***: LiDAR data will enable the provision

Agricultural and Environmental Services **QL2 LiDAR** **6-10 years**	wetlands, ponds, basins and waterways that provide diverse environmental benefits.	of expert environmental consulting services via virtual visits, rather than expensive on-site visits; subsequently provides detailed plans, consistent with NRCS' best management practices, and cost estimates in less than an hour that typically require 10-20 hours without LiDAR.
		$ Benefits: Cannot estimate nationwide benefits
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Moderate

Dollar Benefits for BU#1

From Table E.1, the conservatively estimated dollar benefits for BU#1 equal $159.225M/year.

These BU#1 benefits are probably understated for the following reasons:

- Federal Level: Under BU#1, the FWS, NPS and BIA were unable to estimate dollar benefits from the LiDAR and/or IFSAR data considered to be *mission-critical,* although they specified major time/cost savings for programs budgeted at billions of dollars per year. Recognizing that their Functional Activities would be performed much more effectively and/or efficiently as enhanced elevation data become available nationwide, if the dollar benefits of enhanced elevation data were just 0.1% of their program budgets with *mission-critical* requirements for either LiDAR or IFSAR, the value of these potential additional Federal benefits could be $5M/year and probably much more. Furthermore, NRCS had already provided conservatively estimated benefits of $60M/year and potential estimated benefits of $150M/year for its major Functional Activity, adding an extra $90M/year.
- State Level: Considering all of their Departments and agencies, each state was asked to identify only their top 5-6 Functional Activities with *mission-critical* requirements for enhanced elevation data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. Under BU#1, 22 states identified a total of 28 Functional Activities as documented in Table E.1 above, and 13 of these 28 were unable to estimate dollar benefits. For these reasons, it is believed that the state benefits documented in Table E.1 could be doubled, equaling total potential state benefits of $21.744M/year to the states and $62.110M/year to others.
- Local and Tribal Government Levels: A small percentage of city, county, regional and Tribal governments were sampled in this assessment. For BU#1, 1 city, 1 county, 3 regions and 3 tribes identified Functional Activities with estimated dollar benefits totaling $7.8M/year. Potential benefits were estimated to be at least 5 times higher, i.e., $39M/year.
- Other Organizations (Not-For-Profit and Private Companies): Agren and The Nature Conservancy were the only two "other organizations" interviewed for this assessment, with Functional Activities relevant to BU#1; if time and resources were available to interview the thousands of other large and small organizations and businesses that would benefit from enhanced elevation data for this Business Use, the additional dollar benefits would be significant.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#1 equal approximately $335.152M/year.

BU#02 – Water Supply and Quality

Scope of BU#2

Business Use #2 is defined in terms of Functional Activities that ensure the availability of water where and when required, ensure that drinking water is safe, ensure that aquatic ecosystems remain healthy, and reduce causes for water pollution. Many Federal and state agencies and nongovernmental organizations are responsible for Functional Activities relevant to water supply and quality.

Background Information

Figure E.2. Withlacoochee River Wastewater Treatment Plant, Valdosta, GA. LiDAR is vital for proper locating of water and wastewater facilities, or, in this case, the relocation of the plant. Image courtesy of the Georgia Geospatial Advisory Council (GGAC).

America's sources of safe drinking water are constantly vulnerable to contamination, as demonstrated with this example. The Withlacoochee River Wastewater Treatment Plant in Valdosta, GA serves 70% of the city. This plant is located outside the FEMA 100-year floodplain. However, during the March/April 2009 flood event, 1/3 of the plant was under water and an emergency berm had to be constructed to save the main pump station. Various options were considered regarding repair and future flood prevention, but the only viable option was to relocate the plant at a conservative cost of $94.5 million (see Figure E.2).

Many Federal, state and local governmental agencies, as well as private sector companies, are responsible for water supply and quality, to include reductions in farm runoff and/or establishment of wetlands that filter runoff into streams that supply us with water that sustains life.

Summary of Requirements and Benefits

Table E.2 lists Functional Activities, pertaining to Water Supply and Quality, with mission-critical requirements for enhanced elevation data. The USBR and EPA estimate dollar benefits of $3.63M/year, while other agencies that either manage or assess water supply and/or quality were unable to estimate time/cost benefits other than stating they would be "major." Each of these government agencies is *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity is explained in detail in Appendices B, C and D.

Table E.2. Elevation Data Requirements and Benefits for BU#2, Water Supply and Quality

Geo-enabled User & Functional Activity **Quality Level (QL)** **Update Frequency**	**Summary of BU#2 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.**	**Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.**
NRCS	For modernization of	***Operational Benefits***: LiDAR and IFSAR data will enable the

Conservation Engineering and Practices **Mostly QL2 LiDAR; some QL5 IFSAR** **6-10 years**	conservation practices pertaining to agricultural areas, pastures, feedlots, chicken farms, etc. where farm runoff and animal waste pollutes our streams and wetlands.	NRCS to develop GIS-based tools to assist farmers, ranchers and others to reduce farm runoff and animal waste that are leading causes for water pollution and unhealthy streams.
		$ Benefits: Previously credited to BU#1
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Major
USBR **Management of Resources Related to Delivery of Water and Power** **QL2 LiDAR** **2-3 years**	For monitoring river flows and fish habitats, reservoir volume calculations, water forecasting, habitat mapping, identification of stream restoration opportunities, and modeling and analysis.	***Operational Benefits***: LiDAR data will enable the USBR to perform accurate hydrodynamic modeling, dam inundation modeling, groundwater and surface water modeling, hydrologic and hydraulic modeling and sediment and flow modeling for the western U.S.
		$ Benefits: $3.35M/year
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Moderate
USGS **Water Resource Planning and Management** **QL1 LiDAR; QL2 LiDAR; and QL3 LiDAR plus bathymetry** **4-5 years**	For a broad range of surface water, groundwater, and water quality investigations designed to support state and local agencies with water resource planning and management needs.	***Operational Benefits***: LiDAR data will enable the USGS Water Discipline, with a $228 million annual budget, to improve the timeliness and accuracy of results from a wide variety of hydrologic investigations pertaining to water supply and water quality.
		$ Benefits: Major, but unable to estimate
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Moderate
EPA **Environmental Protection, Land Cover Characterization and Runoff Modeling** **QL2 LiDAR; QL5 IFSAR in Alaska** **4-5 years**	For hydrologic modeling of watersheds, catchment areas, wetlands, and swamps; for nutrient loading from farm runoff and industrial point source and non-point source pollution; for well head protection and pro-active management of land to assess and mitigate potential risks posed to well water quality.	***Operational Benefits***: LiDAR data will enable the EPA to efficiently and effectively execute these "LiDAR killer applications" for EPA programs (funded at over $500 M/year) with mission-critical requirements for high-accuracy LiDAR data.
		$ Benefits: Previously credited to Business Use #1.
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Major
EPA **Broad Area Air and Water Quality Research** **QL5 IFSAR** **6-10 years**	QL5 IFSAR is required for EPA's broad area research projects pertaining to air and water quality, health and human services.	***Operational Benefits***: IFSAR data will enable the EPA to model parameters needed for research into water quality and health.
		$ Benefits: $280,000/year
		Customer Service Benefits: Moderate
		Public/Social Benefits: Minor
		Environmental Benefits: Major
		Strategic/Political Benefits: Minor
USACE	For feasibility studies and	***Operational Benefits***: LiDAR data will enable the USACE to

Restoration of Aquatic Ecosystems **QL2 LiDAR** **6-10 years**	Environmental Impact Assessments; for mapping, modeling, assessment and restoration of aquatic ecosystems.	restore sensitive aquatic ecosystems vital for water supply and quality.
		$ Benefits: $11.72M/year
		Customer Service Benefits: Major
		Public/Social Benefits: Minor
		Environmental Benefits: Major
		Strategic/Political Benefits: Moderate
28 State **Functional Activities** **QL1 LiDAR: 4** **QL2 LiDAR: 10** **QL3 LiDAR: 13** **QL4 Imagery DEMs: 2** **Variable update frequencies**	For government programs in AL, AZ (3), FL, GA, IL, IN (2), LA, MD, MN, MT, NE, NJ (2), OH, OK, OR (2), ND, RI, SC, UT, and WY (3), budgeted at $722 million in 2011. Note: some states have more than one Functional Activity for this Business Use.	***Operational Benefits***: LiDAR data and imagery DEMs will enable these governments to be more efficient and/or effective in managing water supply and quality while providing added dollar benefits to the public.
		$ Benefits: $16.735M/year government benefits plus $53.435M/year in benefits for others. A total of 10 State FAs included estimated $ benefits. Thirty states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.
4 County **Functional Activities** **QL2 LiDAR: 4** **Variable update frequencies**	For county government water quality programs in 4 counties, budgeted at $4 million in 2011.	***Operational Benefits***: LiDAR data will enable these four counties to better control water quality.
		$ Benefits: $62,000/year
1 Region **Functional Activity** **QL3 LiDAR: 1** **4-5 years**	For an in-state water resources project in Nevada, budgeted at $6.8 million in 2011.	***Operational Benefits***: LiDAR data will enable an accurate watershed assessment for the Southern Nevada Water Authority.
		$ Benefits: Cannot estimate dollar benefits
3 Tribal **Functional Activities** **QL1 LiDAR: 1** **QL3 LiDAR: 1** **QL4 Image DEM: 1** **Variable update frequencies**	For the Southern Ute Indian Tribe, Kickapoo Tribe of Oklahoma, and Choctaw Tribe of Oklahoma to establish modern procedures for management of water supply and quality on Tribal lands, enhancing programs funded at $195,750 in 2011.	***Operational Benefits***: LiDAR data will enable the tribes to operate the Pine River Irrigation Project, perform non point source assessments, and select water quality monitoring sites to assist Tribal governments in carrying out effective water pollution control programs.
		$ Benefits: $29,000/year for the tribes plus $48,000/year for others.
Agren **Agricultural and Environmental Services** **QL2 LiDAR** **6-10 years**	For development of plans for building of wetlands that remove nitrogen from farm and pasture surface and tile runoff to improve water quality and restore beneficial functions of floodplains.	***Operational Benefits***: LiDAR data will enable efficient planning and cost estimates for development of wetlands that are the most viable solution to water pollution from animal wastes and farm runoff; avoid the need for expensive on-site visits; subsequently provide detailed plans, consistent with NRCS' best management practices, and cost estimates in less than an hour that typically require 10-20 hours without LiDAR.
		$ Benefits: Cannot estimate nationwide benefits
		Customer Service Benefits: Major

		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Moderate

Dollar Benefits for BU#2

From Table E.2, the conservatively estimated dollar benefits for BU#2 equal $85.288M/year.

These BU#2 benefits are probably understated for the following reasons:

- Federal Level: Under BU#2, the USGS Water Discipline, with a $228 million annual budget, was unable to estimate time/cost benefits from enhanced elevation data for which they specified major dollar benefits for their *mission-critical* requirements. Recognizing that USGS' Water Resource Planning and Management Functional Activity would be performed more effectively and efficiently as LiDAR data become available nationwide, and if the dollar benefits of LiDAR were even 0.1% of the total estimated program budgets with *mission-critical* requirements for LiDAR, the value of these potential Federal benefits would equal $228,000/year. Although their mission-critical requirements are more directly aligned to other Business Uses, the BIA, FWS, NPS, NRCS, and USFS are all believed to have additional requirements for LiDAR data for Functional Activities that support BU#2, Water Supply and Quality, on Federal, state, local and/or Tribal lands, and these programs would also benefit as a result of enhanced elevation data for which dollar benefits are undetermined.
- State Level: Considering all of their Departments and agencies, each state was asked to identify only their top 5-6 Functional Activities with *mission-critical* requirements for enhanced elevation data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. Under BU#2, 20 states identified 28 Functional Activities as documented in Table E.2 above, and 19 of these 28 were unable to estimate dollar benefits. Other states had requirements for this Business Use that were binned in the geodatabase with other, related Business Uses. For these reasons, it is believed that the state benefits documented in Table E.2 could be doubled, equaling total potential state benefits of $33.47M/year to the states and $106.84M/year to others.
- Local and Tribal Government Levels: Only a small percentage of the county, regional, city and Tribal governments in the U.S. were represented in the surveys and workshops conducted by the states. Only 4 counties, 1 region and 3 tribes identified Functional Activities for BU#2, and over half of them were unable to estimate dollar benefits for the Functional Activities that they identified with *mission-critical* requirements for enhanced elevation data. The conservative benefits are $139K/year. Potential benefits were estimated to be at least 5 times higher, i.e., $695K/year.
- Other Organizations (Not-For-Profit and Private Companies): The Nature Conservancy did not specify a BU#2 Functional Activity beyond Healthy Watersheds documented for BU#1; however, TNC seeks to use LiDAR data to identify lands on which restoration of habitat and hydrological function would have the greatest benefit for people and nature. This would improve water supply and quality by removing nutrients and sediment from rivers; but dollar benefits are unknown.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#2 equal approximately $156.351M/year.

BU#03 – River and Stream Resource Management

Scope of BU#3

Business Use #3 is defined in terms of Functional Activities that ensure America's rivers and streams sustain economic, recreational and subsistence activities and their other beneficial functions. There is no clear nationwide champion for this Business Use; many Federal, state and local agencies share responsibilities for relevant Functional Activities that typically include hydrologic and/or hydraulic modeling of rivers and streams.

Background Information

Figure E.3 shows an example of a DEM used for delineation of watersheds. DEMs are extensively used for hydrologic and hydraulic modeling. Hydrologic modeling is the computer modeling of rainfall and the effects of land cover, soil conditions, and terrain slope to estimate rainfall runoff in streams and lakes. Hydraulic modeling of rivers and streams is typically the use of rainfall runoff data from hydrologic models, surface roughness data, and information on hydraulic structures (e.g. bridges, culverts, dams, weirs, sewers) to predict flood levels and manage water resources.

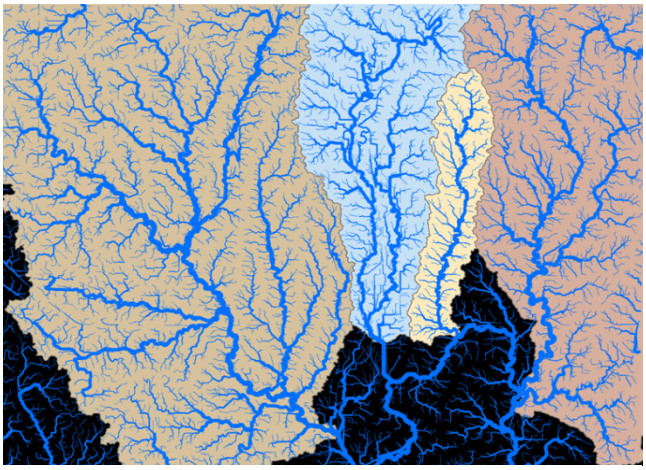

Figure E.3. LiDAR DTMs are ideal for hydrologic modeling to determine where water flows. Such streams need to be hydro-enforced to allow water in the model to pass beneath bridges (that appear as dams in a LiDAR dataset) and to enforce the continuous, downstream gradient of river/stream shorelines. Image courtesy of USGS.

LiDAR and IFSAR data help improve the National Hydrography Dataset (NHD), the surface water component of The National Map. The NHD is a digital vector dataset used by geographic information systems (GIS). It contains features such as lakes, ponds, streams, rivers, canals, dams and stream gages. These data are designed to be used in general mapping and in the analysis of surface-water systems.

In mapping, the NHD is used with other data themes such as elevation, boundaries, and transportation to produce general reference maps. The NHD is often used by scientists using GIS. GIS technologies take advantage of a rich set of attributes imbedded in the NHD to generate specialized information. These analyses are possible because the NHD contains a flow network that allows for tracing water downstream or upstream. It also uses an addressing system based on reach codes and linear referencing to link specific information about the water such as water discharge rates, water quality, and fish population. Using basic NHD features like flow network, linked information, and other characteristics, it is possible to study cause and affect relationships, such as how a source of poor water quality upstream might affect a fish population downstream.

Summary of Requirements and Benefits

Table E.3 lists Functional Activities, pertaining to River and Stream Resource Management, with mission-critical requirements for enhanced elevation data. Most agencies that either manage or assess river and stream resources were unable to estimate time/cost benefits other than stating they would be "major." Each of these government agencies is *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity is explained in detail in Appendices B and C.

Table E.3. Elevation Data Requirements and Benefits for BU#3, River and Stream Resource Management

Geo-enabled User & Functional Activity Quality Level (QL) Update Frequency	Summary of BU#3 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.	Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.
USGS **Water Resource Planning and Management** **QL1 LiDAR; QL2 LiDAR; and QL3 LiDAR plus bathymetry** **4-5 years**	For a broad range of surface water, groundwater, and water quality investigations designed to support state and local agencies with water resource planning and management needs.	***Operational Benefits***: LiDAR data will enable the USGS Water Discipline to improve the timeliness and accuracy of results from a wide variety of hydrologic investigations pertaining to river and stream management.
		$ Benefits: Major, but cannot estimate
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Moderate
USBR **Management of Resources Related to Delivery of Water and Power** **QL2 LiDAR** **2-3 years**	For monitoring river flows and fish habitats, reservoir volume calculations, water forecasting, habitat mapping, identification of stream restoration opportunities, and modeling and analysis.	***Operational Benefits***: LiDAR data will enable the USBR to perform accurate hydrodynamic modeling, dam inundation modeling, groundwater and surface water modeling, hydrologic and hydraulic modeling and sediment and flow modeling for the western U.S.
		$ Benefits: Previously credited to Business Use #2.
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Moderate
USFS **Watershed Analysis** **QL3 LiDAR; QL5 IFSAR in Alaska** **6-10 years**	For hydrologic and hydraulic modeling and mapping of floodplains on USFS lands; for improved ecosystem management and NEPA/EIS reporting.	LiDAR data will enable the USFS to perform more-efficient and effective hydrologic and hydraulic modeling and mapping of floodplains on USFS lands and for improved ecosystem management.
		$ Benefits: Over $1M/year
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Minor
		Strategic/Political Benefits: Major
TVA **Navigation and Flood Risk Mitigation** **QL1 LiDAR**	For inland waterway navigation channel maintenance.	LiDAR data will enable the TVA to effectively and efficiently operate and maintain inland waterways within TVA areas of responsibility.
		$ Benefits: Credited to Business Use #14
		Customer Service Benefits: Major
		Public/Social Benefits: Moderate

4-5 years		***Environmental Benefits***: Minor ***Strategic/Political Benefits***: Moderate
11 State **Functional Activities** **QL1 LiDAR: 4** **QL2 LiDAR: 4** **QL3 LiDAR: 3** **Variable update frequencies**	For government programs in AL, AR (2), CA (2), DE, IL, MA (2), OR and WI, budgeted at $155.8 million in 2011. Note: some states have more than one Functional Activity for this Business Use.	***Operational Benefits***: LiDAR data will enable these governments to be more efficient and/or effective in management of state rivers and streams while providing added dollar benefits to the public. ***$ Benefits***: $18.885M/year state government benefits plus $18.587M/year in benefits for others. A total of 7 State FAs included estimated $ benefits. Forty two states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.
5 County **Functional Activities** **QL3 LiDAR: 5** **Variable update frequencies**	For county government programs in 5 counties, budgeted at $24 million in 2011.	***Operational Benefits***: LiDAR data will enable these five county governments to better manage their rivers and streams. ***$ Benefits***: $70,000/year county government benefits plus $42,000/year in benefits for others.
2 Region **Functional Activities** **QL2 LiDAR: 1** **QL3 LiDAR: 1** **Variable update frequencies**	For regional stormwater management projects in project areas in Oklahoma and South Dakota, budgeted at $4.6 million in 2011.	***Operational Benefits***: LiDAR data will enable storm water quality management, regulatory compliance, and erosion and sediment control for projects for Oklahoma City and Association of Central Oklahoma Governments and the South Dakota Planning and Development District 3. ***$ Benefits***: $400,000/year regional government benefits plus $200,000/year in benefits for others.
1 City **Functional Activity** **QL2 LiDAR: 1** **6-10 years**	For the City of Farmington, NM to model impervious surface water runoff, for a program budgeted at $200,000 in 2011.	***Operational Benefits***: Without any means to do so at present, LiDAR data will enable the city to accurately assess developer plans for controlling storm water runoff in new residential and commercial developments. ***$ Benefits***: $10,000/year city government benefits plus $2,000/year in benefits for others.
2 Tribal **Functional Activities** **QL1 LiDAR: 2** **Variable update frequencies**	For the Confederated Tribes of Grande Ronde (OR) and Lower Elwha Klallam Tribe (WA) to efficiently manage their river and stream resources, enhancing programs funded at $3.7 million in 2011.	***Operational Benefits***: LiDAR data will enable the tribes to perform stream channel mapping, establish accurate stream buffers, and provide supply planners, Natural Resource staff and BIA with critical information on stream and forest health. ***$ Benefits***: $184,000/year benefits for the tribes plus $184,000/year benefits for others.

Dollar Benefits for BU#3

From Table E.3, the conservatively estimated dollar benefits for BU#3 equal $38.422M/year.

These BU#3 benefits are probably understated for the following reasons:

- Federal Level: Under BU#3, the USGS Water Discipline was unable to estimate time/cost benefits from enhanced elevation data for which they specified major dollar benefits for their *mission-critical* requirements for Water Resources Planning and Management. Furthermore,

although their *mission-critical* requirements are more directly aligned to other Business Uses, the BIA, FWS, and NPS are all believed to have additional requirements for LiDAR data for Functional Activities that support BU#3, River and Stream Resource Management, on Federal, state, local and/or Tribal lands for which benefits are undetermined. Recognizing that these USGS, BIA, FWS and NPS Functional Activities would be performed much more effectively and/or efficiently as enhanced elevation data become available nationwide, if the dollar benefits of enhanced elevation data were just 0.1% of their program budgets with *mission-critical* requirements for LiDAR, the value of these potential additional Federal benefits could be $5.228M/year or more.

- State Level: Considering all of their Departments and agencies, each state was asked to identify only their top 5-6 Functional Activities with *mission-critical* requirements for enhanced elevation data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. Under BU#3, 8 states identified 11 Functional Activities as documented in Table E.3 above, and 4 of these 11 were unable to estimate dollar benefits. Other states had requirements for this Business Use that were binned in the geodatabase with other, related Business Uses. For these reasons, it is believed that the state benefits documented in Table E.3 could be doubled, equaling total potential state benefits of $37.77M/year to the states and $37.174M/year to others.
- Local and Tribal Levels: Only a small percentage of the county, regional, city and Tribal governments in the U.S. were represented in the surveys and workshops conducted by the states. Only 5 county, 2 regional, 1 city and 2 Tribal governments were sampled, and over half of them were unable to estimate dollar benefits for the Functional Activities that they identified with *mission-critical* requirements for enhanced elevation data. The conservative benefits are $1.092M/year. Potential benefits were estimated to be at least 5 times higher, i.e., $5.460M/year.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#3 equal approximately $86.582M/year.

BU#04 – Coastal Zone Management

Scope of BU#4

Business Use #4 is defined in terms of Functional Activities that ensure America's coastal zones sustain economic, recreational and subsistence activities and their other beneficial functions. Within the Department of Commerce (DOC), the National Oceanic and Atmospheric Administration (NOAA), often working in partnership with the Joint Airborne LiDAR Bathymetry Technical Center of Expertise (JALBTCX), is an obvious champion for this Business Use. JALBTCX is an excellent example of multiple Federal agencies (USACE, NOAA, USGS and U.S. Navy) working together to solve common coastal mapping needs.

Background Information

NOAA's *Digital Coast*, launched in 2008, is used to address timely coastal issues, including land use, coastal conservation, coastal hazards, marine spatial planning, and climate change. One of the goals behind the creation of the *Digital Coast* was to unify groups that might not otherwise work together. The Digital Coast Partnership, led by NOAA's Coastal Services Center, includes the American Planning Association, Association of State Floodplain Managers, Coastal States Organization, National Association of Counties, National States Geographic Information Council, The Nature Conservancy, and coordinating councils within individual states. The partnership network is building not only a website, but also a strong collaboration of coastal professionals intent on addressing coastal resource management needs. In addition to LiDAR and other remote sensing data, the Digital Coast also provides the tools, training, and information needed to turn these data into the information most needed by coastal resource management professionals, to include: (1) coastal inundation toolkit, (2) offshore renewable energy planning, (3) spatial techniques for conserving coastal wetlands for sea level rise adaptation, (4) sea level rise and coastal flooding impacts viewer, (5) Digital Coast webinar series, and (6) "Introduction to LiDAR" on-line training.

Figure E.4 shows topographic/bathymetric LiDAR data with an extracted shoreline in blue. As opposed to aerial photography, where a shoreline would be derived based on visual identity of a feature (such as the wet/dry line), LiDAR data provide the advantage of deriving a true datum-based shoreline such as the Mean Higher High Water (MHHW), Mean High Water (MHW), or Mean Lower Low Water (MLLW) lines used in different states to separate privately-owned lands from state-owned lands. Shorelines and/or dune lines are used to establish setback lines where people can build.

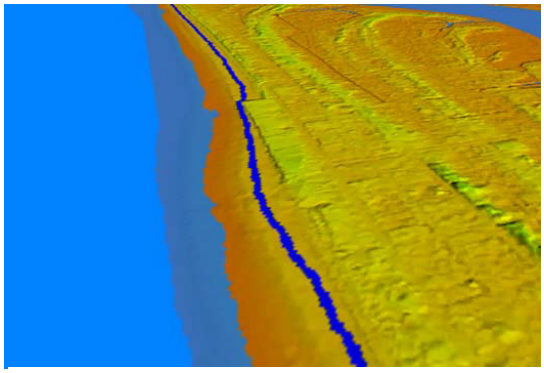

Figure E.4. LiDAR data used to derive the official shoreline (in blue) that divides privately-owned land from state-owned land. Image courtesy of NOAA.

Summary of Requirements and Benefits

Table E.4 lists Functional Activities, pertaining to Coastal Zone Management, with mission-critical requirements for enhanced elevation data. Most agencies that either manage or assess coastal resources were unable to estimate time/cost benefits other than stating they would be "major." Each of these government agencies is *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity is explained in detail in Appendices B, C and D.

Table E.4. Elevation Data Requirements and Benefits for BU#4, Coastal Zone Management

Geo-enabled User & Functional Activity **Quality Level (QL)** **Update Frequency**	**Summary of BU#4 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.**	**Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.**
NOAA **Coastal Mapping and Modeling** **QL2 LiDAR (coastal counties) and QL5 IFSAR (coastal states) plus bathymetry from JALBTCX** **4-5 years**	For modeling, mapping and forecasting coastal hazards; tsunami modeling and warnings; and support of NOAA's initiatives including the Integrated Ocean and Coastal Mapping initiative.	***Operational Benefits***: Topographic and bathymetric LiDAR data will enable NOAA to map, model and preserve coastal areas of the U.S. with greater efficiency.
		$ Benefits: $9.8M/year, primarily savings to coastal communities.
		Customer Service Benefits: Moderate
		Public/Social Benefits: Moderate
		Environmental Benefits: Major
		Strategic/Political Benefits: Moderate
USGS **Coastal Zone Management and Sea Level Rise and Subsidence** **QL2 LiDAR plus bathymetry from JALBTCX** **4-5 years**	For land use planners to establish building set-backs; for inventory of coastal wetlands; and to identify tsunami, flood and hurricane hazard zones.	***Operational Benefits***: Topographic and bathymetric LiDAR data will improve USGS' ability to map and model predicted and actual results of hurricane tidal surges, tsunamis, coastal erosion, and the effects of sea level rise and subsidence in coastal zones that cause billions of dollars annually in property damages.
		$ Benefits: Major (potentially $billions); unable to estimate
		Customer Service Benefits: Moderate
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Major
USACE **National Coastal Mapping Program** **Topo/bathy LiDAR from JALBTCX** **2-3 years**	For support of coastal environmental issues and work performed by NOAA, NASA, FEMA, USGS, EPA, universities, US Navy, and The Nature Conservancy.	***Operational Benefits***: Topographic and bathymetric LiDAR for the National Coastal Mapping Program will enable USACE and JALBTCX to work closely with agencies listed to address coastal environmental issues that have major public/social and strategic/political implications.
		$ Benefits: Major but unknown
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Major
18 State + PR & VI **Functional Activities** **QL1 LiDAR: 8** **QL2 LiDAR: 9**	For government programs in CA, CT, HI, LA, MS, NJ (4), NY (4), OH, RI, TX, VA (2) plus Puerto Rico and U.S. Virgin Islands,	***Operational Benefits***: LiDAR data will enable these state governments to be more efficient and/or effective in management of their state coastal zones while providing added dollar benefits to the public.
		$ Benefits: $4.555M/year state government benefits plus

QL3 LiDAR: 3 **Variable update frequencies**	budgeted at $56.3 million in 2011. Note: some states have more than one Functional Activity for this Business Use.	$3.6M/year in benefits for others. A total of 11 State FAs included estimated $ benefits. Thirty nine states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.
1 County **Functional Activity** **QL3 LiDAR: 1** **6-10 years**	For a GIS mapping program in one parish in Louisiana, budgeted at $250,000 in 2011.	***Operational Benefits***: LiDAR data will enable Terrebonne Parish to better perform mission-critical hydrologic and hydraulic modeling. ***$ Benefits***: Dollar benefits could not be estimated
1 Region **Functional Activity** **QL3 LiDAR: 1** **6-10 years**	For a coastal management project in Alaska, budgeted at $2 million in 2011.	***Operational Benefits***: LiDAR data will enable coastal zone modeling and control of non-sustainable development in the Kenai Peninsula Borough. ***$ Benefits***: Dollar benefits could not be estimated
The Nature Conservancy **Coastal Stewardship and Resiliency** **QL2 LiDAR of coastal counties including the Great Lakes out to 30' contours** **4-5 years**	QL2 LiDAR is required of coastal counties including the Great Lakes (out to the 30 foot contour line) for restoration of natural and beneficial functions of coastal wetlands, to mitigate the effects of sea level rise and subsidence, to mitigate the effects of human development that adversely impact our coastal zones, and promote coastal resiliency.	***Operational Benefits***: Periodic updates of LiDAR data will enable TNC to evaluate the changes in coastal wetlands, coastal erosion, loss of land due to sea level rise and subsidence, and develop plans for mitigating the effects of SLR, subsidence and human development. ***$ Benefits***: $5.83M/year ***Customer Service Benefits***: Major ***Public/Social Benefits***: Major ***Environmental Benefits***: Major ***Strategic/Political Benefits***: Major

Dollar Benefits for BU#4

From Table E.4, the conservatively estimated dollar benefits for BU#4 equal $23.785M/year.

These BU#4 benefits are probably understated for the following reasons:

- Federal Level: Under BU#4, NOAA estimated LiDAR dollar benefits of $9.8M/year, closely linked to sea level rise as well. USGS was unable to estimate time/cost benefits from enhanced elevation data for Coastal Zone Management for which they specified Major dollar benefits for their *mission-critical* requirements. Considering their *mission-critical* value, these dollar benefits would be higher, as previously discussed for BU#2, above. Furthermore, although their *mission-critical* requirements are more directly aligned to other Business Uses, the BIA, FWS, NPS, NRCS and USFS are all believed to have additional requirements for LiDAR data for Functional Activities that support BU#4, Coastal Zone Management, on Federal, state, local and/or Tribal lands. With most agencies agreeing that LiDAR data of coastal areas need to be updated every 2-3 years or 4-5 years, the actual dollar benefits of LiDAR would be at least doubled that of NOAA's estimate, i.e., $19.6M/year.

- State Level: Each state was asked to identify only their top 5-6 Functional Activities with *mission-critical* requirements for enhanced elevation data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. Under BU#4, 11 states plus Puerto Rico and the U.S. Virgin Islands identified 20 Functional Activities as documented in Table E.4 above, and 9 of these 20 were unable to estimate dollar benefits. For these reasons, it is believed that the state benefits documented in Table E.4 could be doubled, equaling total potential state benefits of $9.11M/year to the states and $7.2M/year to others.
- Other states had requirements for this Business Use that were binned in the geodatabase with other, related Business Uses.
- Local and Tribal Government Levels: Only a small percentage of the county, regional, city and Tribal governments in the U.S. were represented in the surveys and workshops conducted by the states, and none of them were able to estimate dollar benefits for the Functional Activities that they identified with *mission-critical* requirements for enhanced elevation data. This means that the potential additional local benefits cannot be estimated either.
- Other Organizations (Not-For-Profit and Private Companies): The Nature Conservancy (TNC) was the only other organization interviewed for this assessment, with Functional Activities relevant to BU#4; if time and resources were available to interview the thousands of other large and small organizations and businesses that would benefit from enhanced elevation data for this Business Use, the additional dollar benefits would be significant.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#4 equal approximately $41.740M/year.

BU#05 – Forest Resources Management

Scope of BU#5

Business Use #5 is defined in terms of Functional Activities that ensure America's forests sustain economic, recreational and subsistence activities and their other beneficial functions. Working in partnership with others, the U.S. Forest Service (USFS), within the U.S. Department of Agriculture (USDA), is an obvious champion for this Business Use, but other Federal, state and local agencies have related responsibilities for management of forest resources, as do commercial timber companies.

Background Information

The mission of the USFS is to "sustain the health, diversity, and productivity of the nation's forests and grasslands to meet the needs of present and future generations." This mission includes forest inventories (inventory metrics include hardwood/conifer discrimination, canopy height, mean diameter, volume, biomass, basal area, canopy density) and forest assessments (including forest health) of USFS lands as well as forested areas in non-USFS lands. Other agencies and commercial timber companies assess forest resources in different ways for different purposes, e.g., BIA for timber harvests on Indian lands, NPS for monitoring changes in forests in national parks, FWS for analyzing changes in wildlife habitat (see Business Use #7), or BLM for wildfire management (see Business Use #16).

Clearly, the commercial timber industry has major interests in sustainable forestry for the $20B/year timber, paper and forest products industry in the U.S. A timber tract is a parcel of land used for the purpose of growing timber for harvesting on a long rotation cycle. According to www.manta.com, there are over 5,000 timber tracts companies in the U.S., categorized by company revenue in the following table. Using the average revenue within each size bin, the total revenues are over $9B/year.

Number	Company Revenue	Average Subtotals	Number	Company Revenue	Average Subtotals
1	> $1B/year	$1,000M	105	$5M to $10M/year	$788M
8	$100M to $500M/year	$2,400M	206	$2.5M to $5M/year	$772M
8	$50M to $100M/year	$600M	318	$1M to $2.5M/year	$556M
25	$20M to $50M/year	$875M	405	$500K to $1M/year	$304M
49	$10M to $20M/year	$735M	3,994	< $500K/year	$998M

LiDAR is the only technology that penetrates through openings in the forest canopy to map the terrain beneath. LiDAR Quality Level 1 was added as a Quality Level in this National Enhanced Elevation Assessment because of the need to penetrate dense forest canopy where studies have concluded that high-density LiDAR data, with 8 points per square meter, is required for forest inventories and topographic mapping in dense forests. Figure E.5 shows an example of a LiDAR point cloud and transect used to determine forest metrics.

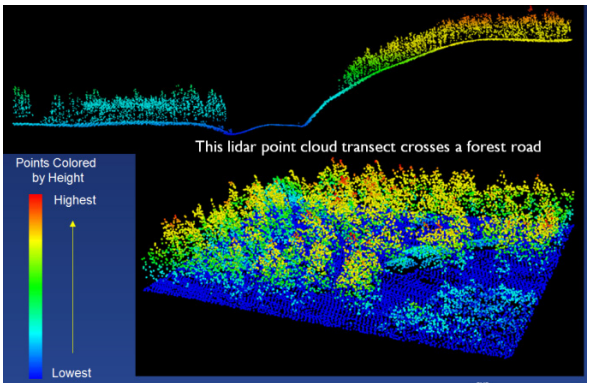

Figure E.5. LiDAR point clouds map the forest canopy, understory and bare-earth terrain beneath the canopy; transects, as shown at the top, enable the measurement of many forms of forest metrics. Image courtesy of the USFS.

Summary of Requirements and Benefits

Table E.5 lists Functional Activities, pertaining to Forest Resources Management, with mission-critical requirements for enhanced elevation data. Although $10 million in annual benefits were estimated by the USFS for forest inventory and assessment (FIA) activities, most other agencies that either manage or assess forest resources were unable to estimate time/cost benefits other than stating they would be "major." Private timber companies were able to estimate their benefits, per acre, from LiDAR. Each of these government agencies and organizations is *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity is explained in detail in Appendices B, C and D.

Table E.5. Elevation Data Requirements and Benefits for BU#5, Forest Resources Management

Geo-enabled User & Functional Activity **Quality Level (QL)** **Update Frequency**	**Summary of BU#5 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.**	**Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.**
USFS **Forest Inventory and Assessment (FIA)** **QL1 LiDAR; QL5 IFSAR in Alaska** **4-5 years**	For vegetation inventories and forest inventory analysis in all forested lands to evaluate whether current forest management practices are sustainable and to assess whether current policies will allow the next generation to enjoy America's forests as we do today.	***Operational Benefits***: LiDAR data will enable the USFS to calculate accurate forest metrics nationwide and perform accurate and complete FIA activities of all forested areas of the U.S., with major cost savings compared to traditional stand exams of small sample areas.
		$ Benefits: $10M/year
		Customer Service Benefits: Moderate
		Public/Social Benefits: Moderate
		Environmental Benefits: Major
		Strategic/Political Benefits: Moderate
USGS **Mapping, Monitoring and Assessment of Biological Carbon Stocks** **QL1 LiDAR of forested counties; QL2 LiDAR of non-forested** **6-10 years**	For quantitative characterization of vegetation structural attributes in support of the USGS mission to assess, monitor, and map land biomass and biological carbon stocks nationwide.	***Operational Benefits***: LiDAR data will help the USGS to comply with mission requirements under the Energy Independence Security Act (EISA) while enabling those who use USGS maps of carbon stocks and fluxes to realize major dollar benefits.
		$ Benefits: Major customer benefits credited to BU #1.
		Customer Service Benefits: Major
		Public/Social Benefits: Moderate
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Moderate
14 State **Functional Activities** **QL1 LiDAR: 5** **QL2 LiDAR: 2** **QL3 LiDAR: 6** **QL5 IFSAR: 1** **Variable update frequencies**	For government programs in CA (2), CO, CT, KS, MS, NV, OH, OR (2), PA, TN and VA (2), budgeted at $381 million in 2011. Note: some states have more than one Functional Activity for this Business Use.	***Operational Benefits***: LiDAR and IFSAR data will enable these governments to be more efficient and/or effective in management of their forest resources while providing added dollar benefits to the public.
		$ Benefits: $6.650M/year state government benefits plus $6.5M/year in benefits for others. A total of 4 State FAs included estimated $ benefits. Ten of 14 Functional Activities were unable to estimate dollar benefits, though Major. Thirty nine states did not choose this among their top 5-6 Business Uses and therefore did not submit their

		elevation data requirements and benefits.
1 Region **Functional Activity** **QL2 LiDAR: 1** **Event driven**	For an unfunded regional GIS mapping project in Colorado.	***Operational Benefits***: LiDAR data will enable multiple Functional Activities to be performed more efficiently, including forest resources management, for the San Luis Valley GIS/GPS Authority.
		$ Benefits: Dollar benefits could not be estimated
1 Tribal **Functional Activity** **QL3 LiDAR: 1** **6-10 years**	For the Penobscot Indian Nation (Maine) to efficiently manage their forest resources, wildlife habitat and fisheries with programs currently unfunded.	***Operational Benefits***: LiDAR data will enable the Penobscot Indian Nation to perform forest management planning, water quality monitoring and design, and sampling management.
		$ Benefits: Unable to estimate dollar benefits.
Plum Creek Timber Company **Sustainable Timberlands** **QL1 LiDAR initially, then QL2 LiDAR thereafter** **Annually**	For forest inventory and assessment and planning for sustainable timberlands.	***Operational Benefits***: Periodic updates of LiDAR data will enable Plum Creek and other timber companies to evaluate tree stand information, calculate forest metrics, plan for sustainable tree harvesting and regrowth, and perform wildfire modeling.
		$ Benefits: $1M/year based on an average benefit of $3/acre for approximately 335,000 acres targeted annually for potential harvesting.
		Customer Service Benefits: More efficient monitoring and planning for contractors performing tree harvesting.
		Public/Social Benefits: None
		Environmental Benefits: None
		Strategic/Political Benefits: None
Mendocino and Humboldt Redwood Companies **Sustainable Forestlands** **QL1 LiDAR** **6-10 years**	For forest inventory and assessment and planning for sustainable redwood and Douglas fir and tan oak forests. For mapping of crowns and identification of individual trees to be harvested.	***Operational Benefits***: Periodic updates of LiDAR data will enable MRC, HRC and other timber companies to evaluate tree stand information, calculate forest metrics, assess forest health, plan for sustainable tree harvesting and regrowth, and perform wildfire modeling.
		$ Benefits: $139,454/year
		Customer Service Benefits: Better planning for sustainable harvesting.
		Public/Social Benefits: Minor
		Environmental Benefits: Minor
		Strategic/Political Benefits: Minor
The Nature Conservancy **Forest Species Distribution Modeling** **QL3 LiDAR** **4-5 years**	For modeling of forest species and their distribution. Forest species distribution modeling is used for a wide variety of forest conservation applications.	***Operational Benefits***: Periodic updates of LiDAR data will enable TNC to evaluate the changes in forest species and their distribution; will enable the modeling of species for diseases such as the ongoing pine beetle outbreak; and will enable the mapping of canopy height, understory and biomass for wildfire management and modeling and estimates of standing carbon.
		$ Benefits: $19.66M/year
		Customer Service Benefits: Moderate
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Major

Dollar Benefits for BU#5

From Table E.5, the conservatively estimated dollar benefits for BU#5 equal $43.949M/year.

These BU#5 benefits are probably understated for the following reasons:

- Federal Level: Although their mission-critical requirements are more directly aligned to other Business Uses, the BIA, BLM, FWS, NPS, and NRCS are all believed to have additional requirements for LiDAR data for Functional Activities that support BU#5, Forest Resources Management, on Federal, state, local, Tribal and private lands.
- State Level: Considering all of their Departments and agencies, each state was asked to identify only their top 5-6 Functional Activities with *mission-critical* requirements for enhanced elevation data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. Under BU#5, 11 states chose 14 Functional Activities as documented in Table E.5 above, and 10 of these 14 were unable to estimate dollar benefits. Other states had requirements for this Business Use that were binned in the geodatabase with other, related Business Uses. For these reasons, it is believed that the state benefits documented in Table E.5 could be doubled, equaling total potential benefits of $13.3M/year to the states and $13M/year to others.
- Local and Tribal Government Levels: Only a small percentage of the county, regional, city and Tribal governments in the U.S. were represented in the surveys and workshops conducted by the states, and none of them were able to estimate dollar benefits for the Functional Activities that they identified with *mission-critical* requirements for enhanced elevation data. This means that the potential additional local benefits cannot be estimated either.
- Other Organizations (Not-For-Profit and Private Companies): Of the 5,000+ timber tract companies in the U.S. with combined revenues over $9B/year, only three timber companies were interviewed for this assessment – one large company (Plum Creek) and two smaller, sister redwood companies. It was estimated that only the 402 largest companies (the size of Mendocino Redwood Company or larger) would use LiDAR for timber tract assessments. If it had been possible to interview the 399 other timber tracts companies with annual revenues of $2.5M and above, the commercial benefits of LiDAR could multiply 5-fold, yielding potential benefits of 5 x $1.139 = $5.695M/year for the commercial timber industry.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#5 equal approximately $61.655M/year.

BU#06 – Rangeland Management

Scope of BU#6

Business Use #6 is defined in terms of Functional Activities that ensure America's rangelands are managed and sustained for their beneficial functions. BLM and NRCS serve as champions for this Business Use on Federal and private lands respectively.

Background Information

Rangelands are vast natural landscapes in the form of grasslands, shrublands, woodlands, and deserts. Types of rangelands include tallgrass and shortgrass prairies, desert grasslands and shrublands, woodlands, savannas, chaparrals, steppes and tundras. Rangelands are not: barren desert, farmland, closed canopy forests, or land covered by solid rock and/or glaciers. Rangelands are important for America's livestock and wildlife habitat.

The Federal Land Policy Management Act (FLPMA) of 1976 formally recognized what BLM had been doing for many years – managing the public lands under principles of multiple use and sustained yield. This includes rangeland management. Livestock grazing, an important use of public lands, is central to the livelihood and culture of many local communities; a significant portion of the cattle and sheep produced in the West graze on public lands managed by BLM; however, BLM indicated that it does not currently use or require LiDAR data for rangeland management but is content with the National Elevation Dataset (NED).

On the other hand, NRCS assists private landowners with rangeland management and considers LiDAR as an essential tool. LiDAR data provide an efficient method to map and monitor the various forms of rangelands, vegetation, and hydrographic features that nourish them; to assess changes in topography; to map erosional features such as gully cross-sections; and to assess changing morphology resulting from a shift from grassland to shrubland vegetation, for example. Figure E.6 shows one such example where the DTM (bare-earth) surface is subtracted from the DSM (top reflective surface) to quantify and convert acres to percent for different vegetation types per Planning Land Unit (PLU). This can be used with other terrain derivatives and soil information for brush management planning and improved estimation of potential stocking rates.

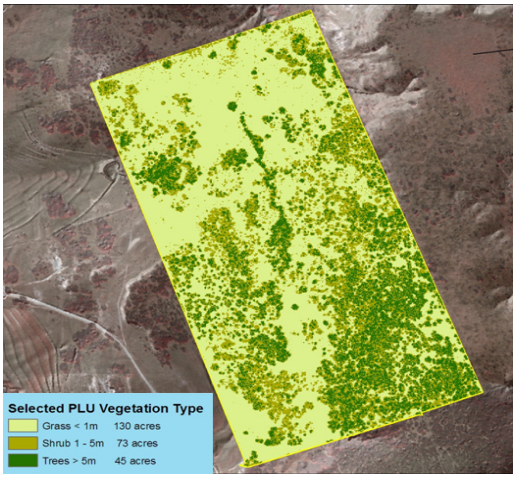

Figure E.6. Example of how NRCS uses LiDAR elevation data for quantification of vegetation types in rangeland. The number of acres of shrub and tree vegetation types can be estimated by spatial analysis map algebra functions. Image courtesy of the NRCS.

Summary of Requirements and Benefits

Table E.6 lists a Functional Activity, pertaining to Rangeland Management, with mission-critical requirements for enhanced elevation data. BLM requirements for Rangeland Management are currently

satisfied by the NED, and NRCS' dollar benefits were previously credited to Business Use #1, Natural Resources Conservation. NRCS is *geo-enabled* with specialized decision-support tools that require enhanced elevation data for increased efficiency and/or effectiveness.

Table E.6. Elevation Data Requirements and Benefits for BU#6, Rangeland Management

Geo-enabled User & Functional Activity **Quality Level (QL)** **Update Frequency**	**Summary of BU#6 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.**	**Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.**
NRCS **Conservation Engineering and Practices** **Mostly QL2 LiDAR; some QL5 IFSAR** **6-10 years**	For preservation and management of rangelands on non-Federal lands; for helping state, local and private land owners to be wise stewards of rangelands.	***Operational Benefits***: LiDAR and IFSAR data will enable NRCS specialists to perform detailed terrain and vegetation analyses of Planning Land Unit (PLU) rangelands from the office, avoiding time-consuming and costly field visits.
		$ Benefits: Credited to Business Use #1.
		Customer Service Benefits: Minor
		Public/Social Benefits: Minor
		Environmental Benefits: Minor
		Strategic/Political Benefits: Minor
State, County, Regional, City, or Tribal No state chose BU#6 among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits. Similarly, no county, region, city or tribe submitted requirements for BU#6.		

Dollar Benefits for BU#6

From Table E.6, the conservatively estimated dollar benefits for BU#6 equal $0/year. This estimate of cost benefits is obviously conservative.

These BU#6 benefits are probably understated for the following reasons:

- Although their mission-critical requirements are more directly aligned to other Business Uses, the BIA, FWS, NPS, and USFS are all believed to have additional requirements for LiDAR data for Functional Activities that support BU#6, Rangeland Management, on Federal and/or Tribal lands.
- NRCS dollar benefits were previously credited to BU#1, Natural Resources Conservation, which accumulated dollar benefits from a broad array of Conservation Engineering and Practices, including Rangeland Management.
- BLM did not specify a Functional Activity for Rangeland Management because the current National Elevation Dataset (NED) was considered minimally acceptable for its rangeland management responsibilities. Though not considered to be mission-critical, LiDAR data would enable the BLM to better monitor the changing vegetation on BLM rangelands if LiDAR data were available.

The potential dollar benefits of enhanced elevation data for BU#6 remains at $0/year.

BU#07 – Wildlife and Habitat Management

Scope of BU#7

Business Use #7 is defined in terms of Functional Activities that sustain economic, recreational and subsistence activities of wildlife habitats. Working in partnership with others, the U.S. Fish and Wildlife Service (FWS), within the Department of Interior, is an obvious champion for this Business Use, but other Federal, state and local agencies have related responsibilities for wildlife habitat.

Background Information

The mission of the FWS is, working with others, to conserve, protect and enhance fish, wildlife, and plants and their habitats for continuing benefit of the American people.

Figure E.7 shows how the FWS used LiDAR datasets from 2001 and 2007 to map the rapid gain (bright red) and loss (bright blue) of Loblolly pine forest habitat in Craven County, NC. Loblolly pines are the most important commercial timber in the southeastern U.S.; they are planted in mine reclamation areas; they stabilize soil and reduce erosion; their biomass is being studied as a possible alternative source for energy; and they provide excellent wildlife habitat for many animals and birds.

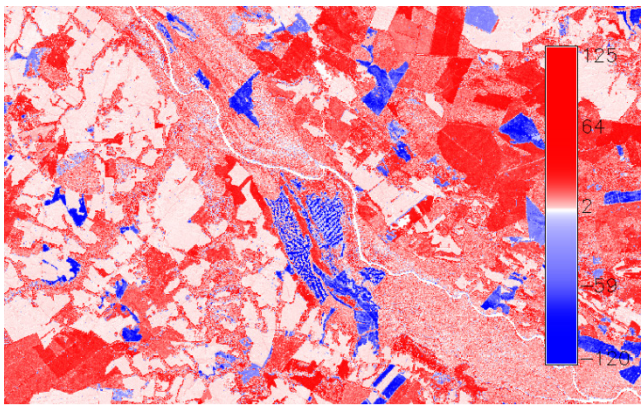

Figure E.7. LiDAR-derived differences in Loblolly pine canopy heights of ±120 feet over a 6-year period in Craven County, NC. New growth (red) and timber harvest (blue) map additions and deletions to wildlife habitat for animals and birds. Image courtesy of the FWS.

Summary of Requirements and Benefits

Table E.7 lists Functional Activities, pertaining to Wildlife and Habitat Management, with mission-critical requirements for enhanced elevation data. These agencies that require LiDAR data to either manage or assess wildlife were unable to estimate time/cost benefits other than stating they would be "major." Each of these government agencies is *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity is explained in detail in Appendices B and C.

Table E.7. Elevation Data Requirements and Benefits for BU#7, Wildlife and Habitat Management

Geo-enabled User & Functional Activity Quality Level (QL) Update Frequency	Summary of BU#7 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.	Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.
FWS **National Wildlife**	For management of wildlife and habitat in the FWS' National Wildlife	***Operational Benefits***: LiDAR data and derivative products (e.g., slope, aspect) will enable the FWS to model vegetation, potential restorable wetlands, hydrologic

Refuge System **QL1, QL2, and QL3 LiDAR; QL5 IFSAR in Alaska** **6-10 years**	Refuge System (NWRS); for developing alternatives for Comprehensive Conservation Plans and supporting Refuge operational activities.	drainage patterns, and wildlife habitat, and to perform habitat vulnerability assessments and climate change scenarios that impact the fragile ecosystems within the NWRS.
		$ Benefits: Major but cannot quantify.
		Customer Service Benefits: Moderate
		Public/Social Benefits: Moderate
		Environmental Benefits: Major
		Strategic/Political Benefits: Major
FWS **Endangered Species and Fisheries and Habitat Conservation** **QL3 LiDAR; QL5 IFSAR for Alaska** **6-10 years**	For National Wetland Inventory (NWI) mapping and analyses; for critical habitat conservation and management of fisheries and threatened and endangered species in streams, wetlands, and vegetated habitats nationwide; for better computer models for conservation and habitat preservation.	***Operational Benefits***: LiDAR and IFSAR data will enable efficient and accurate delineations of restorable and existing wetlands, saving time and money that would have been used in traditional mapping approaches. The value of LiDAR data for preserving wildlife and habitat for the Great Lakes, Everglades, Chesapeake Bay, Gulf Coast, California Bay and other major and minor ecosystems, cannot be estimated.
		$ Benefits: Major but cannot quantify; millions of dollars were saved for NWI mapping in Minnesota alone.
		Customer Service Benefits: Major
		Public/Social Benefits: Moderate
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Moderate
FWS **Wetlands Inventory and Mapping** **Satellite Differential InSAR (DInSAR)** **6-10 years**	For monitoring the extent and status of wetlands for management, research, policy development, education, and planning through the National Wetlands Inventory (NWI).	***Operational Benefits***: Repeat pass satellite DInSAR data could enable the FWS to map water elevation changes down to a few inches, as demonstrated in the Florida Everglades.
		$ Benefits: Major but cannot quantify
		Customer Service Benefits: Major
		Public/Social Benefits: Moderate
		Environmental Benefits: Major
		Strategic/Political Benefits: Moderate
FWS **Migratory Birds** **QL3 LiDAR; QL5 IFSAR for Alaska** **6-10 years**	For nationwide conservation and management of diverse migratory bird habitats. Bird surveys, survey design, navigation for pilots, and spatially referenced survey data are reliant on accurate surface and elevation data.	***Operational Benefits***: LiDAR and IFSAR data will enable the FWS to target wetland and grassland restoration projects to enhance wetland restoration for migratory birds, water quality of lakes and rivers, with the collateral benefit of flood abatement; and manage coastal impounded and natural wetlands in the face of sea level rise and climate change.
		$ Benefits: Cannot quantify
		Customer Service Benefits: Major
		Public/Social Benefits: Moderate
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Moderate
USGS **Mapping, Monitoring and Assessment of Habitat**	For quantitative characterization of terrain and vegetation and structural attributes in support of the USGS mission to assess, monitor	***Operational Benefits***: LiDAR data will enable the USGS to model wildlife habitats in improved ways nationwide and provide the public with objective, science-based, and timely information on the distribution and condition of wildlife habitat and how they change over time.
		$ Benefits: Undetermined

QL1 LiDAR of forested counties; QL2 LiDAR of non-forested **6-10 years**	and map wildlife habitat conditions nationwide.	***Customer Service Benefits***: Major
		Public/Social Benefits: Moderate
		Environmental Benefits: Major
		Strategic/Political Benefits: Moderate
12 State **Functional Activities** **QL2 LiDAR: 7** **QL3 LiDAR: 5** **Variable update frequencies**	For government programs in AL (2), AZ, IL, KS, LA, MA, MT, OK. VA (2) and WY, budgeted at $15.2 million in 2011. Note: some states have more than one Functional Activity for this Business Use.	***Operational Benefits***: Enhanced elevation data will enable these state governments to be more efficient and/or effective in management of wildlife and habitat while providing added dollar benefits to the public.
		$ Benefits: $754,000/year state government benefits plus $756,000/year in benefits for others. A total of 3 State FAs included estimated $ benefits. Forty states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.

Dollar Benefits for BU#7

From Table E.7, the conservatively estimated dollar benefits for BU#7 equal $1.51 M/year.

These BU#7 benefits are probably understated for the following reasons:

- Federal Level: Under BU#7, the FWS and USGS have program budgets that in aggregate may totalover $1B/year for which they were unable to estimate time/cost benefits from enhanced elevation data even though they specified Major dollar benefits for their *mission-critical* requirements. Recognizing that Functional Activities are expected to be performed more effectively and efficiently as LiDAR data become available nationwide, and if the dollar benefits of LiDAR were even 0.1% of the total estimated program budgets with *mission-critical* requirements for LiDAR, the value of these benefits would exceed $1M/year. Furthermore, although their mission-critical requirements are more directly aligned to other Business Uses, the BIA, NPS, NRCS, and USFS are all believed to have additional requirements for LiDAR data for Functional Activities that support BU#7, Wildlife and Habitat Management, on Federal and/or Tribal lands.
- State Level: Considering all of their Departments and agencies, each state was asked to identify only their top 5-6 Functional Activities with *mission-critical* requirements for enhanced elevation data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. Under BU#7, 11 states chose 12 Functional Activities as documented in Table E.7 above, and 9 of these 12 were unable to estimate dollar benefits. Other states had requirements for this Business Use that were binned in the geodatabase with other, related Business Uses. For these reasons, it is believed that the state benefits documented in Table E.7 could be doubled, when taking all 50 states into account, equaling total potential benefits of $1.508M/year to the states plus $1.512M/year to others.
- Local and Tribal Government Levels: No requirements were reported at any level for BU#7, yet protection of wildlife and habitat is a priority for many local communities. Nevertheless, potential additional local benefits cannot be estimated.

- Other Organizations (Not-For-Profit and Private Companies): The Nature Conservancy and Agren both have mission-critical requirements that are more directly aligned to other Business Uses but which also support BU#7, Wildlife and Habitat Management.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#7 equal approximately $4.02M/year.

BU#08 – Agriculture and Precision Farming

Scope of BU#8

Business Use #8 is defined in terms of farming systems that use new technology to allow a closer, more site-specific management of the factors affecting crop production and farm run-off. Although the U.S. Department of Agriculture (USDA) promotes technologies that reduce agricultural costs, increase agricultural productivity and efficiency, and/or reduce environmental impacts, the implementation of "Precision Ag," as it is popularly referenced, is largely left to the private sector where the farmers themselves make business decisions without government direction. Precision Ag is championed by organizations such as the Precision Ag Institute, the Fertilizer Institute, various types of Precision Ag businesses, including: Precision Ag consultants and manufacturers of Precision Ag technologies such as GPS; electronic controllers for application of seed, fertilizer, lime, pesticides; yield monitoring systems; and irrigation systems. Many state universities also have Precision Agriculture Centers with Precision Ag research goals to "get the right product – at the right rate – in the right place – at the right time."

Background Information

Figure E.8 demonstrates site-specific Precision Ag farming methods. These methods evolve over time as each farmer adopts a new level of understanding based on improved knowledge from prior record keeping, including knowledge of site-specific application of seed, fertilizer, lime, pesticides, and resulting farm yields. This also includes knowledge of soil type, soil wetness, drainage and topographic variations within farm fields that can affect crop yield. Without such site-specific methods, the uniform treatment of wheat, corn, soybean and cotton fields, for example, is wasteful and uses an excess of costly resources in the form of fertilizers, pesticides, and herbicides, with potentially excessive farm run-off. Any area as large as a farm field can contain wide spatial variations in soil types, soil wetness, nutrient availability, and other important factors; not taking these variations into account can result in a loss of productivity. An important effect of Precision Ag is the high environmental benefit from using chemical treatments only where and when they are necessary. The promotion of environmental stewardship is a key component of the new attitudes in Precision Ag.

Figure E.8. Precision Ag is practiced on small and medium farms – not just on large farms. The farmer shown at the top of this graphic is using a map display that includes a high-resolution DEM. Potential LiDAR benefits for Precision Ag are believed to be hundreds of millions of dollars annually. Image courtesy of the University of Missouri Extension.

Shawn Kasprick, Area Precision Ag Manager for J.R. Simplot in Grafton, ND, is an industry leader for LiDAR applications in Precision Agriculture. When interviewed for this study, he indicated that nationwide LiDAR would have "tremendous" financial benefits for Precision Ag, measured in tens of millions of dollars annually in his (extremely flat) area alone, and potentially hundreds of millions of dollars annually nationwide, and potentially billions of dollars. He indicated that topographic data are

used to assess soil moisture, which may cause farmers to delay planting, shift crop type, experience nutrient loss or physical crop damage, and/or delayed harvest. LiDAR data are largely used to identify areas that need surface ditching, tile drainage or grass waterways, for example, to reduce saturated soils and crop damage. DEM derivative products are also valuable for Precision Ag: (1) slope data are used to minimize soil erosion; (2) aspect data are used to identify areas of solar heating where soils are more wet or dry; and (3) landscape position (curvature) data are used to identify areas of high/low soil moisture content.

Referencing a Red River Valley drainage study[9] in 1988, Mr. Kasprick provided updated data for 2010 in the first four columns in the table below that assesses the impact of crop losses due to potentially-avoidable drainage issues. The numbers in the 5th column are from the National Agricultural Statistics Service (NASS) that provides statistics on acres planted annually, by crop, along the Red River Basin in North Dakota and Minnesota in 2007. The numbers in the right column identify the value of these two crops, alone, that could potentially be saved with improved grading and modern treatment of drainage issues identified by LiDAR. Obviously, there are many other crops planted annually in the U.S. that also experience drainage issues that adversely impact farm yields.

Estimated Corn/Wheat Crop Loss Impact from Farm Drainage Issues

Crop	Input Costs $/Acre	Lost Yield/Acre	Lost $/Acre	2007 Acres Planted	Potential Value of Lost Yields
Corn	$275 - $375	24.5 bushels	$91.87	3,821,000	$351,035,027
Wheat	$150 - $250	11 bushels	$52.25	4,129,800	$215,782,050

From this table, the authors of this report are not suggesting that LiDAR would save over $100 million annually in corn and wheat yields; but we are suggesting that farm drainage issues cost American farmers $100+ millions of dollars in crop production losses annually, and that LiDAR data and Precision Ag technologies could dramatically reduce drown outs and over-saturated soils while addressing the other benefits of Precision Ag for application of seed, fertilizer, pesticides, etc. If nationwide LiDAR could solve just 10% of the farm drainage problems for these acres of corn and wheat, that value to American farmers would be hundreds of millions of dollars annually. Furthermore, if LiDAR data were readily available nationwide, it is believed that John Deere and/or other equipment manufacturers would develop LiDAR-specific applications as they now have for variable-rate fertilizing, spraying, etc. Because LiDAR data are currently available only for a small percentage of total farmlands in the U.S., the full benefits of LiDAR for Precision Ag cannot be fully realized.

Summary of Requirements and Benefits

Table E.8 lists Functional Activities, pertaining to Agriculture and Precision Farming, with mission-critical requirements for enhanced elevation data. Each Functional Activity is explained in detail in Appendices C and D.

[9] Steven Edwardson, David Watt, and Lowell Disrud, "Laser-controlled land grading for farmland drainage in the Red River Valley: An economic evaluation," *Journal of Soil and Water Conservation*, 1988 43(6); 486-490

Table E.8. Elevation Data Requirements and Benefits for BU#8, Agriculture and Precision Farming

Geo-enabled User & Functional Activity Quality Level (QL) Update Frequency	Summary of BU#8 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.	Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.
3 State **Functional Activities** **QL1 LiDAR: 1** **QL2 LiDAR: 1** **QL3 LiDAR: 1** **Variable update frequencies**	For government programs in AL, ND and WI, budgeted at $27.4 million in 2011.	***Operational Benefits***: LiDAR data will enable these three governments to be more efficient and/or effective in management of farm-related programs while providing added dollar benefits to the public.
		$ Benefits: $5.100M/year state government benefits plus $500,000/year in benefits for others. A total of 2 State FAs included estimated $ benefits. Forty seven states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.
1 Tribal **Functional Activity** **QL4 Image DEM: 1** **4-5 years**	For the Choctaw Nation of Oklahoma to efficiently manage their agricultural lands, enhancing programs budgeted at $300,000 in 2011.	***Operational Benefits***: LiDAR data will enable the Choctaw Nation to perform detailed in-office assessments of tracts of agricultural lands for suitability for leasing as pasture or recreational use, and identification of fencing and other features used in determining lease value, to include pasture terrain/slopes, soil suitability, availability of water and type (stream/pond).
		$ Benefits: $15,000/year benefit to the nation; and $15,000/year benefit to others.
J.R. Simplot Company **Precision Agriculture** **QL3 LiDAR** **6-10 years**	For topographic analysis of slope, aspect, curvature and soil wetness of all agricultural lands and resultant site-specific application of seed, fertilizer, lime, pesticides and water to optimize farm yields; and for control of pasture and farm runoff into streams.	***Operational Benefits***: LiDAR data and derivative products (e.g., slope, aspect) in the public domain will enable small, medium and large farms to benefit from Precision Ag to increase farm yields; save on costs of seed, fertilizers, pesticides, etc.; drain soils when too wet; retain moisture when too dry; reduce soil erosion and pasture and farm runoff that pollutes streams.
		$ Benefits: $116.7M/year conservative benefits; $2B/year potential benefits.
		Customer Service Benefits: Major
		Public/Social Benefits: Moderate
		Environmental Benefits: Major
		Strategic/Political Benefits: Moderate
Ellingson Drainage **(see text box within J.R. Simplot's Appendix)** **Agricultural Drainage Solutions** **QL3 LiDAR** **6-10 years**	For topographic analysis of elevations, slope and curvature that control soil wetness and saturation of soils that are a major cause of lost farm yields. (Whereas full topographic surveys typically cost up to $1,000/acre, surveys of farm fields cost only about $5/acre but are still expensive for large areas.)	***Operational Benefits***: LiDAR data will enable the development of solutions for surface and subsurface drainage issues on farms without the need for hiring land survey crews to survey the topography.
		$ Benefits: $5/acre x unknown (hundreds of) millions of agricultural acres with drainage problems.
		Customer Service Benefits: Major
		Public/Social Benefits: Moderate
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Moderate

Agren **Agricultural and Environmental Services** **QL2 LiDAR** **6-10 years**	For an array of GIS-based agriculture and environmental services pertaining to ag and non-ag lands consistent with NRCS best engineering practices, e.g., Pond Builder, WetlandBuilder, Basin Builder, WaterwayBuilder, and RUSLE2 (Revised Universal Soil Loss Equation) calculator.	***Operational Benefits***: LiDAR data will enable conservation planning and implementation tasks to be performed in 30-60 minutes that would typically require 10-20 hours without LiDAR and avoids the need for on-site field surveys.
		$ Benefits: Major $ savings for landowners, but cannot estimate.
		Customer Service Benefits: Major
		Public/Social Benefits: Moderate
		Environmental Benefits: Major
		Strategic/Political Benefits: Moderate

Dollar Benefits for BU#8

From Table E.8, the conservatively estimated dollar benefits for BU#8 equal $122.3M/year.

These BU#8 benefits are probably understated for the following reasons:

- Federal Level: The USDA is vitally interested in farm productivity; however Precision Ag is primarily left in the hands of the private sector. Manufacturers of Precision Ag farm machinery are reluctant to invest millions of dollars into developing new equipment until they are assured that LiDAR data will be available to justify their investments. As LiDAR data become available nationwide and Precision Ag equipment is developed to exploit this new technology, major benefits will be realized that will benefit USDA and others in numerous ways.
- State Level: Considering all of their Departments and agencies, each state was asked to identify only their top 5-6 Functional Activities wit*h mission-critical* requirements for enhanced elevation data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. Under BU#8, only 3 states (AL, ND, WI) chose 3 Functional Activities as documented in Table E.8 above, and these are just a few of the primary agricultural states expected to benefit from Precision Ag as the technology matures to include LiDAR data. The J.R. Simplot write-up, however, appears to cover state Precision Ag benefits well, so no additional potential benefits are estimated.
- Local and Tribal Government Levels: Only the Choctaw Nation envisioned BU#8 benefits from LiDAR data. As the technology matures and LiDAR data become available nationwide, agricultural counties, regions, and tribes will receive added benefits. Nevertheless, potential additional local benefits cannot be estimated at this time.
- Other Organizations (Not-For-Profit and Private Companies): For J.R. Simplot estimated savings, the conservative benefits were estimated at $116.7M/year and the potential benefits were estimated at $2B/year. In estimating the most conservative value of the LiDAR benefits, Dewberry estimated that the value for Precision Ag was worth at least the $252.67/mi^2 cost for acquisition and production of QL3 LiDAR deliverables – applied only to that percentage of each 7.5-minute topographic quad consisting of agricultural fields. For the Benefit Cost Analysis, Dewberry estimated $116.7/year spread among 295.6M acres (461,875 square miles) of

agricultural lands; the National Agricultural Statistical Service (NASS) computes 262.3M acres, excluding fallow land and hay fields. Benefits were then spread nationwide as a percent of each quad map determined to be agricultural lands, as derived by USGS from Landsat-derived crop data. The source of agricultural acres and dollar benefits are based on % crops/quad from Cropstats. During his interview, Max Fuxa of Ellingson Drainage agreed with the J.R. Simplot benefits and estimated further dollar savings of $5/acre x unknown (hundreds of) millions of agricultural acres with drainage problems. (Ellingson Drainage does not have its own Appendix, but comments are included as a text box within the J.R. Simplot Appendix). If all farm acres had drainage problems, the savings would come to nearly $1.7 billion, but the actual acreage is unknown. If we assume that 1/10th of farm acreage has drainage problems, and if the $170 million benefits are spread over 30 years, this would amount to $5.7M/year in additional potential benefits. Lastly, during their interview, Stan and Tom Buman of Agren stated major dollar savings for landowners, but benefits could not be estimated.

Although not used in the Benefit Cost Analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#8 equal approximately $2.011B/year.

BU#09 – Geologic Resource Assessment and Hazards Mitigation

Scope of BU#9

Business Use #9 is defined in terms of Functional Activities that map, inventory and assess geologic resources, and mitigate geologic hazards such as earthquakes, tsunamis, landslides, and volcanoes. Working in partnership with others, the U.S. Geological Survey (USGS), within the Department of Interior, is an obvious champion for this Business Use, but other Federal, state and local agencies have related responsibilities for this Business Use.

Background Information

In explaining how geologic maps are produced, largely from knowledge of slopes and outcrops, a brochure from the Pennsylvania Geologic Survey states: "LiDAR data provides a wealth of information not discernible on photography or even in the field." The same is true for seismic fault detection. The discovery of over a dozen new faults in western Washington over the last decade through the use of LiDAR (see Figure E.9) identified surface ruptures from past earthquakes previously hidden from view by thick vegetation. LiDAR is also widely used for mapping of landslide hazards nationwide. Both LiDAR and IFSAR are used for mapping of active volcanoes in the U.S.

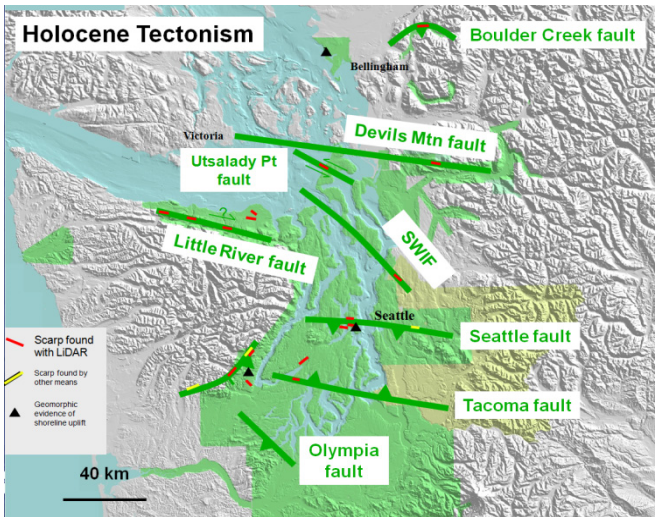

Figure E.9. LiDAR has revolutionized geologic science worldwide, by mapping geologic formations and seismic faults not detected from imagery or field surveys, including these faults near Seattle. LiDAR has also detected previously unknown earthquake faults near a $12 billion nuclear waste treatment plant and a $735 million suspension bridge under construction across the Tacoma Narrows, both in Washington. Image courtesy of USGS.

Summary of Requirements and Benefits

Table E.9 lists Functional Activities, pertaining to Geologic Resource Assessment and Hazards Mitigation, with mission-critical requirements for enhanced elevation data. Financial benefits for this Business Use alone are believed to be hundreds of millions of dollars annually, largely from geologic hazards mitigation. Each of these government agencies is *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity is explained in detail in Appendices B and C.

As shown in Appendix B of this report, it should be noted that the USGS identified the need for LiDAR data for assessment of seismic hazards of central to western Virginia prior to the magnitude 5.8 earthquake of August 23, 2011 that centered on Mineral, VA and caused the extended shutdown of a nearby nuclear power plant that had been designed to withstand lower-magnitude earthquakes.

Table E.9. Elevation Data Requirements and Benefits for BU#9, Geologic Resource Assessment and Hazards Mitigation

Geo-enabled User & Functional Activity	Summary of BU#9 Mission-Critical	Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual

Quality Level (QL) Update Frequency	Requirements for Enhanced Elevation Data. See individual Appendices for details.	Appendices for additional details and examples.
USGS **Geologic Mapping** **QL1 LiDAR; QL5 IFSAR in Alaska** **6-10 years**	For geologic mapping, particularly for young deposits and landforms which are those most essential to understanding earth hazards, groundwater, climate change, and sand and gravel resources. The resolution and accuracy of elevation data limit the thematic resolution of geologic maps.	***Operational Benefits***: LiDAR data will enable USGS to improve the precision of geologic maps and their speed of production, expediting the production of more and better maps with the same resources, and better serving all users of geologic maps.
		$ Benefits: $5M/year for USGS; plus $5M/year for users of improved geologic maps.
		Customer Service Benefits: Major
		Public/Social Benefits: Moderate
		Environmental Benefits: Major
		Strategic/Political Benefits: Major
USGS **Seismic Hazards** **QL1 LiDAR** **6-10 years**	For the National Earthquake Hazards Reduction Program that defines the location and relative activity of active faults and to define and map areas of past surface ruptures.	***Operational Benefits***: LiDAR data will enable USGS seismologists to identify dozens of new faults, not visible when walking the terrain, prior to construction of critical infrastructure. Seismologists recently identified previously-unknown active faults in the vicinity of a $12 billion nuclear waste treatment plant and a $735 million suspension bridge already under construction in Washington.
		$ Benefits: Cannot determine, but believed to be hundreds of millions of dollars annually.
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Major
USGS **Landslide Hazards** **QL1 LiDAR** **4-5 years**	For the Landslide Hazards Program that defines the location and relative activity of landslide processes, and to define the spatially limited, steepest extents of watersheds as well as hill-slope roughness characteristics to assess activity.	***Operational Benefits***: LiDAR data will enable USGS to map map many andslide hazards that were previously unmapped, and to develop strategies for mitigation of landslide hazards. In Oregon alone damages have been reported to total hundreds of millions of dollars annually.
		$ Benefits: $20.25M/year
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Major
USGS **Volcano Hazards** **QL1, QL2, and QL3 LiDAR** **4-5 years**	For improvement of volcano hazard maps, geologic maps, and flow models that use topography as a model parameter; post-eruption topography will better characterize new hazards from slope and lava dome instability.	***Operational Benefits***: LiDAR data will enable USGS and other agencies and municipalities to experience major cost savings from the combined uses of these data for modeling everything from volcanic debris flow hazards, to identifying buildings at risk from volcanic ash deposits based on roof size and structure.
		$ Benefits: $1M/year for USGS; $10M/year for USGS customers.
		Customer Service Benefits: Moderate
		Public/Social Benefits: Minor
		Environmental Benefits: Minor

		Strategic/Political Benefits: Minor
USFS **Soils and Geology Inventory** **QL2 LiDAR; QL5 IFSAR of FS lands in Alaska** **>10 years**	For geology inventories for USFS lands that remain to be completed. USFS geology inventory procedures rely upon DEMs, slope, aspect and curvature to model geologic structures.	***Operational Benefits***: LiDAR data will enable the USFS to produce geology inventory maps for USFS lands and other Federal forested lands; these maps are used largely for landslide prediction and public safety.
		$ Benefits: Previously credited to Business Use #1.
		Customer Service Benefits: Moderate
		Public/Social Benefits: Moderate
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Moderate
NRC **Nuclear Power Plant Site Natural Phenomena Hazard Assessment and Risk Mitigation** **QL1 LiDAR** **6-10 years**	For seismologic, geologic and hydrologic safety reviews for nuclear power reactor licensing and safe operations. With current nuclear technology, nuclear power reactors no longer need to be located next to rivers or oceans, but could be anywhere.	***Operational Benefits***: LiDAR data will enable the NRC to model worst-case scenarios for predicting the effects of earthquakes, tsunamis and seismic faults that could impact the safe operations of nuclear power plants nationwide.
		$ Benefits: Moderate but undetermined.
		Customer Service Benefits: Moderate
		Public/Social Benefits: Moderate
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Moderate
NSF **EarthScope Initiative** **QL1 LiDAR** **>10 years**	For the study of seismic faults and their causes and effects; also for the dissemination of high-density LiDAR data to the public, via the OpenTopography Portal, for diverse science requirements.	***Operational Benefits***: QL1 LiDAR will enable NSF scientists at EarthScope to perform basic research on seismic faults. Internationally, scientists have tried using elevation data of lesser accuracy and resolution and have concluded that LiDAR data comparable to QL1 are required to map seismic faults that are not visible when walking the terrain on top of such faults.
		$ Benefits: Between $5M/year and $20M/year.
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Major
37 State + VI **Functional Activities** **QL1 LiDAR: 9** **QL2 LiDAR: 12** **QL3 LiDAR: 15** **QL4 Image DEMs: 2** **Variable update frequencies**	For government programs in AK, AL, AZ, CA (2), CO, CT, DE, FL, HI, ID, IL, IN (2), KS, KY (2), ME (2), MO, MN, MT, NH, NV, OH, OR, TN, TX, UT, VA, VT (2), WA, WI, WY (3) and U.S. Virgin Islands, budgeted at $63 million in 2011. Note: some states have more than one Functional Activity for this Business Use.	***Operational Benefits***: Enhanced elevation data will enable these governments to be more efficient and/or effective in geologic resource assessment and hazard mitigation while providing added dollar benefits to the public.
		$ Benefits: $4.870M/year government benefits plus $3.15M/year in benefits for others. A total of 22 State FAs included estimated $ benefits. Twenty states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.

Dollar Benefits for BU#9

From Table E.9, the conservatively estimated dollar benefits for BU#9 equal $51.75M/year.

These BU#9 benefits are probably understated for the following reasons:

- Federal Level: For BU#9, government agencies provided program budget numbers that totaled $billions/year for programs that are expected to receive Major or Moderate time/cost benefits from LiDAR for *mission-critical* requirements, but were not able to quantify these benefits. However, if LiDAR was estimated to provide even a program efficiency gain of 0.1%, the resulting benefits would be in the millions of dollars annually. Under their Seismic Hazards Functional Activity, USGS stated that LiDAR data has enabled USGS seismologists to identify dozens of new geologic faults. Using QL1 LiDAR, seismologists recently identified previously unknown active faults in the vicinity of a $12 billion nuclear waste treatment plant and a $735 million suspension bridge already under construction in Washington. Dewberry estimates that Customer Service or public benefits of LiDAR for identification of seismic hazards by the USGS and other organizations could exceed $1 billion per year. Lastly, although their mission-critical requirements are more directly aligned to other Business Uses, the BIA, NPS, FERC and NRCS are all believed to have additional requirements for LiDAR data for Functional Activities that support BU#9 on Federal, state, Tribal and/or private lands. Furthermore, the National Science Foundation's EarthScope Initiative estimated benefits between $5M/year (conservative) and $20M/year (potential).
- State Level: Considering all of their Departments and agencies, each state was asked to identify only their top 5-6 Functional Activities wit*h mission-critical* requirements for enhanced elevation data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. However, that was not the case with BU#9. A large percentage of the states (3 states and USVI) chose BU#9 Functional Activities as one of their top priorities, as documented in Table E.9 above. This demonstrates that there is already wide recognition at state level that LiDAR is extremely valuable for geologic resource assessment and hazards mitigation.
- Local and Tribal Government Levels: Few counties, regions, cities or tribes have their own geologists; therefore there were no BU#9 requirements stated at local or Tribal levels. Potential additional local benefits cannot be estimated at this time.
- Other Organizations (Not-For-Profit and Private Companies): Although they may not yet be aware of LiDAR capabilities, many private companies will benefit from being able to use LiDAR data for projects such as the engineering design of critical infrastructure near seismic faults.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#9 equal approximately $1.067 billion/year.

BU#10 – Resource Mining

Scope of BU#10

Business Use #10 is defined in terms of Functional Activities that ensure that surface mines are operated in a manner that protects citizens and the environment during mining, and assures that the land is restored to beneficial use following mining. The Office of Surface Mining Reclamation and Enforcement (OSM), within DOI, is an obvious champion for this Business Use; but many of the 36 coal-mining states now have the primary responsibility to regulate surface coal mining on lands within their jurisdictions.

Regulations pertaining to hardrock, industrial minerals, gravel, etc. are not handled under a single regulatory authority like coal is. All coal mines are regulated by the Surface Mining Control and Reclamation Act of 1977. In contrast, BLM and USFS are the primary authorities for mining regulations on lands where they are the surface management agency (i.e., most of the west) and for private surface ownership, the individual State Departments of Natural Resources (these names vary widely by state) generally regulate these mines. Various Federal and state regulations govern these mines based on the Mining Law of 1872, the Federal Land Policy and Management Act (FLPMA), the Clean Water Act (CWA), the National Environmental Policy Act (NEPA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), etc.

Background Information

Elevation datasets are required for reviewing and issuing mine permits, monitoring mining operations for ongoing reclamation compliance, and reviewing post-mining conditions for permit compliance. Elevation data are used by OSM for the following:

- Existing pre-mining contours and volumetric analyses are needed as the baseline against which to measure permit proposals, set bond amounts, and measure restoration activities.
- As mining operations continue, ongoing data collection is used to monitor backfill and grading activities and determine whether incremental reclamation activities have met permit requirements, thereby being eligible for release of bond monies. See Figure E.10.
- At the end of mining activities, elevation data are used to determine if reclamation is adequate and the landscape has been restored to its "original" condition within the requirements of the legislation.

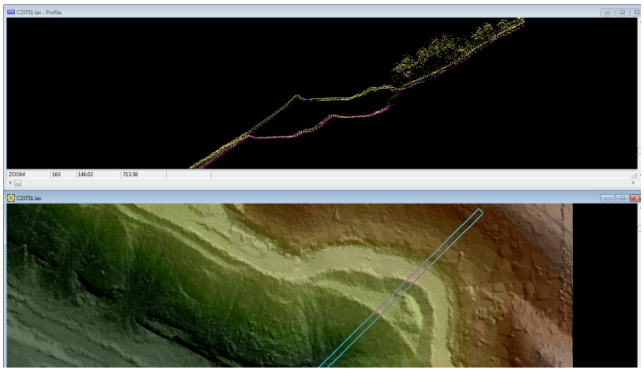

Figure E.10. This image shows a LiDAR cross-section in Pennsylvania after only one month of mining. LiDAR is ideal for evaluation of slopes for safe mining operations, environmental protection, and for comparisons between baseline surfaces (prior to mining) and final surfaces (after reclamation). OSM and state partners conduct thousands of inspections annually for which LiDAR data are needed for effective and efficient monitoring of compliance with the Surface Mining Control and Reclamation Act. Image courtesy of Dewberry.

Elevation data that are currently required to accomplish these activities correctly are collected using traditional photogrammetric methods, LiDAR, or GPS field surveys, when funds permit.

Currently, OSM monitors the approximately 7,600 active mine permits in 27 states on a quarterly basis, performing less-accurate "virtual visits" with satellite imagery. Other activities, including abandoned mine lands (AML) remediation, occur within the 36 states with current or past mining activities; annual or bi-annual data are needed for these activities. In 2010, OSM and its state partners conducted 80,089 field inspections nationwide. Field inspections typically require one to five days per site at costs that range from $500 to $10,000 per site, but elevation data to perform thorough inspections would cost much more per site and would be considered unaffordable on a quarterly or semi-annual basis. Where LiDAR is available, Bureau scientists could perform more-accurate "virtual inspections" using CAD or GIS software to ensure reclamation is correct and erosion is minimized. Areas of concern could be identified in the office and targeted field inspections could be performed as needed, thereby reducing travel time and costs as well as time required in the field.

A Return on Investment (ROI) study was conducted by OSM and the West Virginia Department of Environmental Protection and published in 2009. This study compared costs for performing similar activities using three methodologies – GPS field collection, photogrammetry, and LiDAR – for an area in West Virginia. The study revealed that the LiDAR method was by far the most cost effective method:

- Post-processed field-collected low density GPS data cost $50,815/site
- Photogrammetric high density DEMs cost $72,267/site
- LiDAR highest density DEMs cost $26,763/site ($24,052 less than the least-expensive, and least-effective alternative)

No one is suggesting that $24,000 could be saved for each of 80,000+ annual inspections. Most of the 80,000+ annual inspections, executed during continuing mining operations, are performed without the benefit of current elevation data from low-density GPS surveys or higher density aerial surveys from photogrammetry or LiDAR. Furthermore, even when acquired, LiDAR datasets would not be updated on a quarterly or semi-annual basis to coincide with OSM/state inspection cycles. Yet, it is safe to say that for each of 7,600 active mines, one LiDAR dataset per mine is needed to establish the baseline against which to measure permit proposals, set bond amounts, and measure restoration activities; and a second LiDAR dataset per mine is needed at the end of mining operations to determine if reclamation is adequate and the landscape has been restored to its "original" condition within the requirements of the legislation. OSM estimates that QL2 LiDAR would save $0.1747/acre or $186,447/year. Coal mines in Appalachia are usually active for approximately 10 years. The larger coal mines in the West are typically active for 20 years or more.)Between the start and end of mining operations, intermediate LiDAR datasets would help in monitoring the safety of mining operations and potential damage to streams, for example, from mine spill and erosion.

Summary of Requirements and Benefits

Table E.10 lists Functional Activities, pertaining to Resource Mining, with mission-critical requirements for enhanced elevation data. The Office of Surface Mining (OSM), as well as local communities and mining companies, would be *geo-enabled* with specialized decision-support tools that require LiDAR elevation data. Each Functional Activity is explained in detail in Appendices B and C.

Table E.10. Elevation Data Requirements and Benefits for BU#10, Resource Mining

Geo-enabled User & Functional Activity Quality Level (QL) Update Frequency	Summary of BU#10 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.	Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.
OSM **Regulation and Reclamation of Coal Mining Activities** **QL2 LiDAR** **Annually**	For reviewing and issuing mine permits, monitoring mining operations for ongoing reclamation compliance, and reviewing post-mining conditions for permit compliance.	***Operational Benefits***: More cost-effective than the two alternative methods, LiDAR data will enable OSM to reduce field inspections and perform virtual inspections to ensure reclamation is correct and erosion is minimized. LiDAR cross-sections would be compared with permit requirements to ensure compliance.
		$ Benefits: $186,447/year
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Major
4 State **Functional Activities** **QL1 LiDAR: 1** **QL3 LiDAR: 2** **QL4 Image DEMs: 1** **Variable update frequencies**	For government programs in NV, VA and WY (2), budgeted at $26.5 million in 2011. Note: Wyoming has more than one Functional Activity for this Business Use.	***Operational Benefits***: LiDAR data plus imagery DEMs will enable these governments to be more efficient and/or effective in management of their mine resources while providing added dollar benefits to the public.
		$ Benefits: $1.500M/year government benefits only. Only one State FA included estimated $ benefits. Forty seven states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.

Dollar Benefits for BU#10

From Table E.10, the conservatively estimated dollar benefits for BU#10 equal $1.686M/year.

These BU#10 benefits are probably understated for the following reasons:

- Federal Level: OSM estimates that LiDAR data would save $186,477/year when compared with contours from minimally-acceptable satellite imagery. For optimum analyses of before/after conditions, if compared with GPS surveys or airborne photogrammetry, LiDAR benefits would be at least 10 times higher, i.e., $1.864M/year. For industrial minerals, hardrock and gravel mines and quarries, for example, additional benefits would undoubtedly accrue and undoubtedly increase the benefits cited above.
- State Level: Considering all of their Departments and agencies, each state was asked to identify only their top 5-6 Functional Activities wit*h mission-critical* requirements for enhanced elevation data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. Under BU#10, only 3 states (NV, VA and WY) chose BU#10 Functional Activities as documented in Table E.10 above, and only Virginia was able to estimate their dollar benefits. For these reasons, it is believed that the state benefits documented in Table E.10 could be doubled, equaling total potential benefits of $3.0M/year to the states.

- Local and Tribal Government Levels: There were no BU#10 requirements stated at local or Tribal levels. Potential additional local benefits cannot be estimated at this time.
- Other Organizations (Not-For-Profit and Private Companies): In addition to dollar benefits to OSM, similar benefits would accrue to surface coal mine operators who also need to ensure that they are in compliance with applicable regulations

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#10 equal approximately $4.864M/year.

BU#11 – Renewable Energy Resources

Scope of BU#11

Business Use #11 is defined in terms of Functional Activities that analyze solar energy potential and placement of solar farms and individual solar panels, wind energy potential and placement of wind farms, and hydroelectric energy potential for placement and/or safe operation of hydro-electric power plants. The Department of Energy (DOE) promotes renewable energy technologies and practices that reduce the use of fossil fuels. However, the implementation of renewable energy programs is largely left to the private sector.

Background Information

Enhanced elevation data from LiDAR, photogrammetry or IFSAR could be suitable for siting of industrial wind farms and solar farms. However, designers of wind farms prefer IFSAR for nationwide consistency of DSM data; and high-resolution LiDAR data are needed for individual homeowners considering the efficiency of their own home and property for solar panels. New York City, Denver, and Los Angeles County are among the major metropolitan areas that provide LiDAR-based solar maps for individuals considering the installation of solar panels.

For the Los Angeles County Solar Map, Figure E.11 shows an example home selected at random. Individuals can zoom in and see exactly which parts of their roof are good for solar – then print the results in a report. The LA County Solar Map is based upon the most accurate large-scale solar model in the world, with solar radiation calculated every 5 feet.

Figure E.11. Example of a Los Angeles County Solar Map, available on line, for which home owners can easily print a report for their home/property explaining its potential for solar energy and/or solar water heating, and potential cost savings and carbon savings as well as estimated installation costs. Image courtesy of Los Angeles County.

Measurements taken from LiDAR include shading from trees, roof features (chimneys, other stories), roof pitch and aspect, nearby buildings and mountains. For each home/building, the web-based report provides the total roof area; area suitable for solar; solar photo-voltaic (PV) potential, electric savings and carbon savings per year; solar water heating potential, gas savings and carbon savings per year; cost estimates and other information to encourage installation of solar panels.

Summary of Requirements and Benefits

Table E.11 lists Functional Activities, pertaining to Renewable Energy Resources, with mission-critical requirements for enhanced elevation data. Financial benefits for government agencies are relatively minor, but the public availability of personalized information that encourages the private use of renewable energy supports national goals to reduce reliance on fossil fuels. The organizations listed are *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity is explained in detail in Appendices B, C and D.

Table E.11. Elevation Data Requirements and Benefits for BU#11, Renewable Energy Resources

Geo-enabled User & Functional Activity Quality Level (QL) Update Frequency	Summary of BU#11 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.	Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.
TVA **Siting of Wind and Solar Generation Facilities** **QL4 DEMs from imagery, or better** **6-10 years**	For planning and siting of future wind and solar power generation.	***Operational Benefits***: DEMs from imagery or LiDAR will enable the TVA to plan and site future wind and solar generation facilities.
		$ Benefits: $50,000/year for TVA alone
		Customer Service Benefits: Minor
		Public/Social Benefits: Moderate
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Moderate
2 State **Functional Activities** **QL3 LiDAR: 2** **Variable update frequencies**	For government programs in RI and TN, budgeted at $120,000 in 2011.	***Operational Benefits***: LiDAR data will enable these state governments to evaluate the potential for renewable energy within their states.
		$ Benefits: Dollar benefits could not be estimated for either of these two Functional Activities. Forty eight states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.
NextEra Energy **Wind Farm Siting and Design** **QL5 IFSAR** **2-3 years**	For planning and siting of future wind farms for which topography, slope and surface roughness are important in Computation Flow Dynamics (CFD) models and maximization of wind farm efficiency.	***Operational Benefits***: IFSAR data will enable NextEra to site and design wind farms for maximum efficiency
		$ Benefits: $10M/yr if IFSAR succeeds in achieving just 10% of its estimated savings in efficiency.
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Major
WindLogics **Solar Farm Siting and Design** **QL3 LiDAR** **2-3 years**	For assessment of solar energy potential for which topography, slope and aspect, as well as top surfaces of individual buildings and trees are important for identifying areas shaded from the sun.	***Operational Benefits***: LiDAR data will enable solar consultants to assess solar energy potential for maximum efficiency of solar farms.
		$ Benefits: Estimated savings from the use of LiDAR for improved efficiency cannot be estimated.
		Customer Service Benefits: Unknown
		Public/Social Benefits: Unknown
		Environmental Benefits: Unknown
		Strategic/Political Benefits: Unknown

Dollar Benefits for BU#11

From Table E.11, the conservatively estimated dollar benefits for BU#11 equal $10.05M/year.

These BU#11 benefits are probably understated for the following reasons:

- Federal Level: Federal agencies themselves are expected to test innovative renewable energy systems for improved efficiency and become early beneficiaries of wind and solar energy.
- State Level: Considering all of their Departments and agencies, each state was asked to identify only their top 5-6 Functional Activities wit*h mission-critical* requirements for enhanced elevation data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. Under BU#11, only 2 states (RI and TN) chose BU#11 and neither was able to estimate annual dollar benefits from LiDAR. Many states are expected to benefit from potential wind and solar farms of the future on state-owned lands.
- Local and Tribal Government Levels: There were no BU#11 requirements stated at local and Tribal levels. However, New York City, Denver and Los Angeles County already provide property owners with solar maps, available on line, for which they can easily print a report for their home/property explaining its potential for solar energy and/or solar water heating, potential cost savings and carbon savings, as well as estimated installation costs. With this precedent, there is every reason to believe that such energy-saving initiatives will expand nationwide.
- Other Organizations (Not-For-Profit and Private Companies): If NextEra Energy achieves 100% of its goal, as opposed to the 10% used for the conservative estimate above, the potential benefits would equal $100M/year for this major provider of wind energy.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#11 equal approximately $100.05M/year.

BU#12 – Oil and Gas Resources

Scope of BU#12

Business Use #12 is defined in terms of Functional Activities that select sites for oil/gas wells and facilities, for pipeline routing and construction planning, and for environmental impact assessments and mitigation. The Department of Energy (DOE) performs research and development of future fossil energy technologies, and the Federal Energy Regulatory Commission (FERC) regulates the interstate transmission of natural gas and oil via development of safe, reliable and efficient energy infrastructure that serves the public interest. However, the publicly-responsible acquisition and safe delivery of oil and gas to generate electricity, heat our homes, and power our transportation systems, is largely left to the private sector.

Background Information

LiDAR data are used by the oil and gas industry for: (1) seismic programs and exploration, (2) locating well sites, facilities and pipelines based on slope data, (3) selection of well locations and pipeline routes, (4) location and classification of buildings and other objects within special protection zones, (5) identification of land cover and timber removal calculations to minimize tree cutting, (6) asset inventories, (7) encroachment control, (8) construction planning, and (9) fast checking of critical heights of ground coverage when combined with existing sub-surface data.

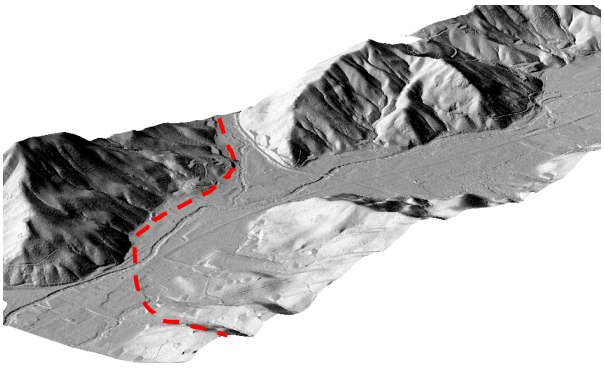

Figure E.12. LiDAR slope data is essential for pipeline routing across mountain ranges and beneath rivers (as shown here), construction planning, encroachment control, and asset inventories. LiDAR is especially good for estimation of timber removal requirements along alternative routes.

LiDAR is used to pre-select suitable locations in the office, which is quicker, safer and more cost-effective than sending survey crews to the field to search for suitable well locations and pipeline routes. The challenges of safe pipeline routes can be visualized with Figure E.12. With the 2011 Exxon-Mobile oil spill in the Yellowstone River in Montana, Americans came to realize that the pipelines transporting oil to our refineries not only cross mountain ranges spanning thousands of miles, but these pipelines are also buried beneath rivers.

Summary of Requirements and Benefits

Table E.12 lists Functional Activities, pertaining to Oil and Gas Resources, with mission-critical requirements for enhanced elevation data. Financial benefits for government agencies are relatively minor, but it is most helpful when the oil and gas companies, as well as the FERC which regulates them, all have access to the same accurate and consistent source of LiDAR data for oil and gas project planning and permitting purposes. The government agencies listed, as well as local communities, are *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity is explained in detail in Appendices B, C and D.

Table E.12. Elevation Data Requirements and Benefits for BU#12, Oil and Gas Resources

Geo-enabled User & Functional Activity Quality Level (QL) Update Frequency	Summary of BU#12 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.	Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.
FERC **Pipeline Routing and Facility Siting** **QL1 LiDAR; QL5 IFSAR in Alaska** **>10 years**	For geological hazards and topographic features analysis for gas pipeline routing, facility sitings, and NEPA compliance.	***Operational Benefits***: LiDAR data will enable the FERC and applicants to review the same authoritative data in hazards analysis and route selection by enabling geologic fault and landslide analysis for linear facilities routing.
		$ Benefits: None for FERC as a regulatory agency; major but unknown benefits for private oil and gas companies.
		Customer Service Benefits: Moderate
		Public/Social Benefits: Moderate
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Moderate
BOEM **Mapping of Coastal Baseline Points** **Topographic/ bathymetric LiDAR is technically unable to identify coastal baseline points at MLLW** **>10 years**	For mapping of coastal baseline points and boundaries used for preparation of Outer Continental Shelf (OCS) leasing maps, coordinates of all natural features (rocks, sand or gravel bars) that protrude above the water at Mean Lower Low Water (MLLW) tide levels are required along all coastal areas of the U.S.	***Operational Benefits***: For technical reasons, traditional topographic and bathymetric LiDAR probably would not enable the BOEM to map small coastal baseline points at mean lower low water (MLLW).
		$ Benefits: Potentially Major
		Customer Service Benefits: Major
		Public/Social Benefits: Minor
		Environmental Benefits: Minor
		Strategic/Political Benefits: Major
1 State **Functional Activity** **QL1 LiDAR: 1** **2-3 years**	For a government program in Louisiana, budgeted at $500,000 in 2011.	***Operational Benefits***: LiDAR data will enable Louisiana to build geospatial infrastructure for oil spill prevention, planning, response, and damage assessment.
		$ Benefits: Dollar benefits could not be estimated for this Functional Activity. Forty nine states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.
1 County **Functional Activity** **QL2 LiDAR: 1** **6-10 years**	For a pipeline mapping program in one county in North Dakota, budgeted at $20,000 in 2011.	***Operational Benefits***: LiDAR data will enable McKenzie County to execute a pipeline mapping project.
		$ Benefits: Dollar benefits could not be estimated
Anonymous Oil and Gas Company	For well site location suitability analyses; pipeline and road route selections; seismic program planning;	***Operational Benefits***: Major. LiDAR data will enable oil and gas companies to save significant amount of field visits and survey time. Better results in shorter time. Large impact on employee and contractor safety. Less

Oil and Gas Operations **QL3 LiDAR; QL5 IFSAR in Alaska** **6-10 years**	hazard identification, and timber cut requirements.	requirement to visit the field, and when field visits are needed, they know exactly what to expect and where potential dangers exist.
		$ Benefits: Major. Potential savings (for this relatively small company): $100,000's to $1,000,000's annually depending on number and size of projects the company undertakes. When considering other global industry giants, benefits are at least $10M/year.
		Customer Service Benefits: Potentially Major. Higher accuracy data provides higher confidence in analysis results and better mapping products. Allows for more focused efforts by planning and engineering teams.
		Public/Social Benefits: Moderate. Less intrusion on members of the public; less trespassing on private lands; better selection of well, facility and pipeline locations to reduce impact on public, including safety concerns.
		Environmental Benefits: Moderate. Reduced environmental 'footprint' by conducting the work in the office rather than the field.
		Strategic/Political Benefits: Minor

Dollar Benefits for BU#12

From Table E.12, the conservatively estimated dollar benefits for BU#12 equal $10M/year.

These BU#12 benefits are probably understated for the following reasons:

- Federal Level: The Department of Homeland Security has responsibilities for oil spill contingency planning that needs accurate and current elevation data, preferably from LiDAR.
- State Level: Considering all of their Departments and agencies, each state was asked to identify only their top 5-6 Functional Activities wit*h mission-critical* requirements for enhanced elevation data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. Only one state (LA) chose BU#12 for oil spill prevention, and it was unable to estimate annual dollar benefits from LiDAR. Other states had requirements for this Business Use that were binned in the geodatabase with other, related Business Uses. Many other states would benefit from LiDAR for oil spill contingency planning and for planning of pipelines through the various states, but benefits cannot be estimated.
- Local and Tribal Government Levels: McKenzie County, ND, was the only local government to specify a requirement for LiDAR, for planning a potential pipeline through the county. Many other counties, regions and tribes would potentially benefit from LiDAR for the same reason.
- Other Organizations (Not-For-Profit and Private Companies): The one, relatively-small and anonymous oil and gas company interviewed for this assessment indicated dollar benefits for this one company alone "from $100,000's to $1,000,000's annually depending on number and size of projects the company undertakes." When considering other global industry giants and political and economic pressures to reduce foreign imports, and initiatives to increase domestic oil and gas production, it is reasonable to assume that the potential benefits will be $100M/year for the broader industry.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#12 equal approximately $100M/year.

BU#13 – Cultural Resources Preservation and Management

Scope of BU#13

Business Use #13 is defined in terms of Functional Activities that identify evidence of past human activity, to include pioneer homes, buildings or old roads; prehistoric village sites; historic or prehistoric artifacts or objects; or earthworks such as battlefield entrenchments, prehistoric canals or mounds. The National Park Service (NPS) is an obvious champion for this Business Use, but other Federal, state and local agencies have related responsibilities for Cultural Resources Preservation and Management.

Background Information

Figure E.13 shows a brochure from the NPS, explaining how LiDAR was used to map the Sny Magill Mound Group Effigy Mounds National Monument in Iowa.

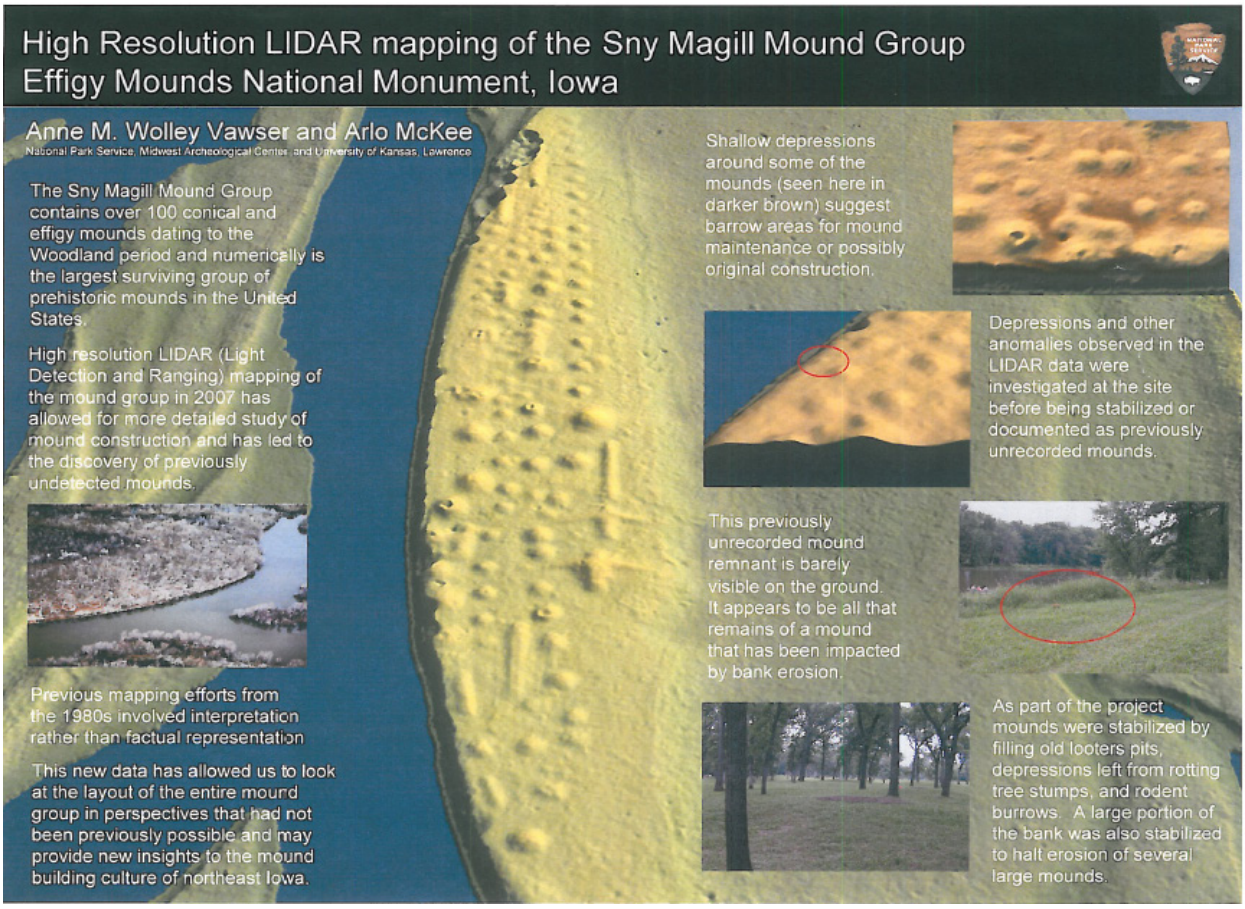

Figure E.13. National Park Service brochure that explains the LiDAR mapping of prehistoric Indian mounds in Iowa. Image courtesy of the NPS.

Research by archeologists in forested areas has found that: (1) LiDAR can be effectively used, as a pre-field method, to detect cultural features such as mounds and pits in a forested environment; (2) although ephemeral surface features can be detected, effectiveness increases with degree of slope, depth or elevation of feature, and spatial area covered by the feature; and (3) incorporation of LiDAR into the GIS environment produces effective navigational tools for use in field work and for the recordation of collected digital spatial data.

Summary of Requirements and Benefits

Table E.13 lists Functional Activities, pertaining to Cultural Resources Preservation and Management, with mission-critical requirements for enhanced elevation data. Financial benefits for government agencies are unknown. The government agencies listed are *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity is explained in greater detail in Appendices B and C.

Table E.13. Elevation Data Requirements and Benefits for BU#13, Cultural Resources Preservation and Management

Geo-enabled User & Functional Activity **Quality Level (QL)** **Update Frequency**	**Summary of BU#13 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.**	**Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.**
NPS **Preservation and Protection of Natural and Cultural Resources** **QL1 LiDAR (NPS forested), QL3 LiDAR (NPS non-forested); QL5 IFSAR (NPS Alaska)** **6-10 years**	For cultural resource site identification and management on NPS lands.	***Operational Benefits***: LiDAR data will enable the NPS to map cultural resources to be preserved and protected for present and future generations.
		$ Benefits: Unknown
		Customer Service Benefits: Major
		Public/Social Benefits: Moderate
		Environmental Benefits: Major
		Strategic/Political Benefits: Major
TVA **Natural and Cultural Resource Management and Conservation** **QL1 LiDAR** **2-3 years**	For cultural resource site identification and management in TVA area of operations.	***Operational Benefits***: LiDAR data will enable the TVA to locate historic, cultural resources, as well as new roads and trails, and siting for recreation areas such as camping.
		$ Benefits: Previously credited to Business Use #1.
		Customer Service Benefits: Moderate
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Moderate
4 State **Functional Activities** **QL1 LiDAR: 1** **QL2 LiDAR: 2** **QL3 LiDAR: 1** **Variable update frequencies**	For government programs in FL, GA (2) and TN, budgeted at $150,000 in 2011. Note: Georgia has more than one Functional Activity for this Business Use.	***Operational Benefits***: LiDAR data will enable these state governments to identify, preserve and manage their cultural resources more efficiently and effectively.
		$ Benefits: Dollar benefits could not be estimated for these Functional Activities. Forty seven states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.
1 Tribal	For the Eastern Band of Cherokee Indians to	***Operational Benefits***: Because elevation data plays a critical role in the location and protection of Indian

Functional Activity **QL1 LiDAR: 1** **4-5 years**	efficiently operate their Tribal GIS system that maps the location of Indian heritage sites, enhancing a program budgeted at $1,350,000 in 2011.	heritage sites, LiDAR data will enable the Cherokee Indians to identify such sites and provide bounding area information for preservation of the sites. The Tribal GIS System serves sites in NC and nine other states. ***$ Benefits***: $500,000/year benefit to the nation; and $300,000/year benefit to others.

Dollar Benefits for BU#13

From Table E.13, the conservatively estimated dollar benefits for BU#13 equal $0/year.

These BU#13 benefits are probably understated for the following reasons:

- Federal Level: Facilitated by LiDAR, the preservation and protection of cultural resources are of vital importance to the NPS, NRCS, BIA, BLM and other Federal agencies. Just because it is very difficult to identify credible financial benefits for cultural resources does not mean that there are no benefits. The NPS alone has a program budget of over $3B/year for which they specified major time/cost benefits of LiDAR for Preservation and Protection of Natural and Cultural Resources, but NPS was unable to estimate dollar benefits from LiDAR data they determined to be *mission-critical*. Recognizing that their cultural resources Functional Activities would be performed much more effectively and efficiently as LiDAR data becomes available nationwide, and if the dollar benefits of LiDAR were even 0.1% of the total estimated program budgets with *mission-critical* requirements for LiDAR, the value of these benefits would exceed $3M/year.
- State Level: Considering all of their Departments and agencies, each state was asked to identify only their top 5-6 Functional Activities wit*h mission-critical* requirements for enhanced elevation data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. Only three states (FL, GA, TN) chose BU#13 for one of their most important Functional Activities to be documented, and they were unable to estimate annual dollar benefits from LiDAR. The same would be true for other states wanting to use LiDAR for this Business Use. Other states had requirements for this Business Use that were binned in the geodatabase with other, related Business Uses.
- Local and Tribal Government Levels: The Eastern Band of Cherokee Indians was the only local or Tribal government to specify a requirement for LiDAR -- using LiDAR to operate their Tribal GIS system that maps the location of Indian heritage sites. These benefits could multiply five-fold when applied to other tribes with similar needs, increasing the nationwide benefits to $4M/year.
- Other Organizations (Not-For-Profit and Private Companies): The Nature Conservancy is among not for profit companies that promote the preservation of cultural artifacts, but dollar benefits were not estimated.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#13 equal approximately $7M/year.

BU#14 – Flood Risk Management

Scope of BU#14

Business Use #14 is defined in terms of Functional Activities that mitigate flood risks, including dam, dike, and levee safety. Although the Federal Emergency Management Agency (FEMA) is a champion for this Business Use, other Federal, state and local agencies are also responsible for relevant Functional Activities.

Background Information

The National Flood Insurance Program (NFIP) was established to reduce future flood damage through hazard identification and mapping, effective community floodplain management, and insurance protection for property owners. FEMA's Risk MAP (Mapping, Assessment, and Planning) approach integrates risk assessment, mitigation planning, risk communication, and actionable mitigation. It emphasizes updating the flood hazard data and maps of the nation's coastal areas; a reevaluation of the level of protection provided by levees; and watershed-based updates to reflect changes since current Flood Insurance Rate Maps (FIRMs) were produced. FIRMs are utilized 20-30 million times a year by communities issuing permits for building in high risk flood zones and mitigation planning; lenders in their enforcement of the insurance purchase requirement; Federal agencies under EO 11988 (Floodplain Management); developers who build in and near the high risk areas; emergency responders and those making decisions on where and how to recover and rebuild after disasters; and individuals who rely on insurance offered by the NFIP as a financial backstop to their most valuable investment, their homes.

Two recent studies by the National Research Council (NRC) emphasized the high value of LiDAR data for the NFIP. The first NRC study, in 2007, entitled "Elevation Data for Floodplain Mapping," documented the fact that existing elevation data were inadequate and that *Elevation for the Nation*, based on LiDAR with 2-foot contour accuracy or better, is needed for accurate mapping of floodplains and coastal areas. The second NRC study, in 2009, entitled "Mapping the Zone: Improving Flood Map Accuracy," documented 19 benefits of improved map accuracy – benefits that reduce loss of life, property and business, and reduce issues pertaining to the purchase of flood insurance by improved public confidence in the accuracy and legitimacy of FIRMs. Finding 1 from NRC's 2009 study states: "Topographic data are the most important factor in determining water surface elevations, base flood elevation, and the extent of flooding and, thus, the accuracy of flood maps in riverine areas;" and Recommendation 1 from NRC's 2007 study states: "*Elevation for the Nation* should employ LiDAR as the primary technology for digital elevation data acquisition."

In part as a result of these recommendations the FEMA Risk MAP program has implemented new elevation standards for flood map updates and increased coordination with other federal agencies on elevation acquisition and planning. According to FEMA, the decisions and actions taken by communities that participate in the NFIP contribute to an estimated $1.6 billion in losses avoided each year. This would not be possible without sound and accurate elevation data (primarily LiDAR) used for production of FIRMs. In addition to the benefits from FEMA's use of LiDAR for Risk MAP, many other federal and state organizations have flood risk management responsibilities.For example, the International

Boundary and Water Commission (IBWC) estimates $14.3 million in damages avoided annually along the Rio Grande River alone because of LiDAR.

FEMA has identified many areas throughout the country where the flood hazards shown on the older FIRMs understate the true risk of flooding. Those who have built to standards on those older maps are in fact subject to a higher probability of flooding. FEMA has also found that in some areas flood hazards on the older maps overstated the true risk (see Figure E.14a) which means those properties insured under the NFIP are paying more than they should be paying. Figure E.14b illustrates the improvements in map accuracy attained by the use of LiDAR data; over 300 structures, some of which are outlined in red, were removed from the Special Flood Hazard Area (SFHA) in Towns County, GA through the use of higher accuracy LiDAR data. In other locations nationwide, additional structures are added to SFHAs as a result of more-accurate data and modeling. Whether flood risks are currently understated or overstated, the NRC concludes that higher accuracy from LiDAR yields the following benefits: (1) structures insured at appropriate levels; (2) most consistent insurance ratings through better information about risk; and (3) more insurance purchased because of improved understanding of risk.

Figure E.14a. Old SFHA (shown under water), pre-LiDAR. This image shows homes that were previously required to purchase flood insurance. Images courtesy of the Georgia Geospatial Advisory Council (GGAC).

Figure E.14b. New SFHA, post-LiDAR. This image shows homes (outlined in red) that are no longer required to purchase flood insurance, though still recommended. Most LiDAR datasets demonstrate more homes require insurance.

An essential component in preparing accurate flood maps is the topographic data used to determine various flood recurrence probabilities. Some states, like North Carolina, have partnered with FEMA and invested some of their own funds to acquire and produce highly accurate flood hazard data and maps. However, this is the exception, and many areas of the nation have outdated flood risk data. North Carolina's decision to make this investment was based on a benefit/cost analysis which showed for every dollar spent on mapping there would be two dollars in benefits, such as lower damages and reduced disaster costs due to future flooding.

Summary of Requirements and Benefits

Table E.14 lists Functional Activities, pertaining to Flood Risk Management, with mission-critical requirements for enhanced elevation data. FEMA estimated internal benefits of $13.5 million annually if it did not need to purchase its own LiDAR. The IBWC estimated $14.3 million in annual benefits to

communities along the Rio Grande River, and NOAA estimated $24.3 million in annual benefits directly attributed to LiDAR for the National Weather Service's Advanced Hydrologic Prediction Service (AHPS) used for hydrologic modeling, flood forecasting and warning. The Tennessee Valley Authority (TVA) estimates $100,000 in annual benefits for flood risk mitigation; and the U.S. Army Corps of Engineers (USACE) estimates $30.86M/year. Other agencies with Functional Activities pertaining to Flood Risk Management were unable to estimate time/cost benefits other than stating they would be "major." Each of these government agencies is *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity is explained in detail in Appendices B, C and D.

Table E.14. Elevation Data Requirements and Benefits for BU#14, Flood Risk Management

Geo-enabled User & Functional Activity **Quality Level (QL)** **Update Frequency**	**Summary of BU#14 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.**	**Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.**
FEMA **Flood Risk Analysis** **QL3 LiDAR for Highest Risk and High Risk areas; QL4 DEMs from imagery for Moderate Risk areas; and QL5 IFSAR for Low Risk areas – based on 10 criteria for flood risk assessments.** **6-10 years**	For hydrologic and hydraulic modeling and analyses of rivers and coasts; computation of water surface elevations (WSEs), base flood elevations (BFEs), and the extent of Special Flood Hazard Areas (SFHAs) on Flood Insurance Rate Maps (FIRMs). FIRMs are used to determine who needs to purchase flood insurance when applying for Federally-guaranteed mortgages.	***Operational Benefits***: LiDAR data will enable FEMA to produce FIRMs with much higher accuracy, thereby reducing losses of life, property and business; increasing confidence in the credibility of FIRMs; providing more consistent insurance ratings and better communication of flood risks; ensuring that structures are insured at appropriate levels; and causing more insurance to be purchased because of improved understanding of risk.
		$ Benefits: $13.5M/year for FEMA if it does not need to acquire its own LiDAR data.
		Customer Service Benefits: Major.
		Public/Social Benefits: Moderate
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Major
USACE **Flood Risk and Emergency Management** **QL3 LiDAR of floodplains; QL2 LiDAR of dams, levees and seawalls** **6-10 years**	QL2 LiDAR for dam and levee safety programs of the Corps; QL3 LiDAR for hydrologic and hydraulic modeling and flood risk assessments and mapping; and for Corps decision support during ongoing flood events.	***Operational Benefits***: LiDAR data will enable the Corps to manage dam and levee safety programs, to estimate depths of flooding from predicted river flood stages, to perform dam breach or levee breach analyses, and to make informed decisions regarding flood control systems and release of impounded waters.
		$ Benefits: Major. When assuming a conservative 2% savings from LiDAR data determined to be mission critical, the dollar benefits would equal $30.86M/year.
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Minor
		Strategic/Political Benefits: Major
NOAA **Advanced Hydrologic Prediction Service**	For hydrologic modeling, flood forecasting and warning, and flood inundation mapping of	***Operational Benefits***: Combined with NWS weather forecasts, LiDAR data will enable NOAA to produce inundation maps for river forecast locations; save lives and property by showing the impact of forecast flood

Static Inundation Mapping **QL3 LiDAR for FEMA's Highest Risk and High Risk areas; QL4 DEMs from imagery for FEMA's Moderate Risk areas; and QL5 IFSAR for FEMA's Low Risk areas** **4-5 years**	riverine areas for which the National Weather Service (NWS) provides Advanced Hydrologic Prediction Service (AHPS) inundation mapping as well as river and flood forecasts at approximately 4,000 locations nationwide and issues watches and warnings to protect life and property.	events; and provide enhanced decision support tools to the emergency management community, law enforcement officials, and disaster officials who ensure public safety.
		$ Benefits: $24M/year
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Minor
		Strategic/Political Benefits: Moderate
USGS **Flood Risk Management** **QL3 LiDAR** **4-5 years**	For production of static flood inundation map libraries with flood extent and depth, created in advance of a flood based on pre-determined stream stage intervals that are ready to be served through the Internet. USGS' flood inundation maps are developed at stream-gaged locations where the NWS has co-located their forecast points.	***Operational Benefits***: Combined with USGS' stream gage data, LiDAR data will enable the USGS to pre-compile libraries of flood inundation maps (flood extent and depth) and provide the public with real-time or forecast stage data from a USGS stream gage or NWS flood forecast point to quickly determine their pending flood risk.
		$ Benefits: $10M/year
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: None
		Strategic/Political Benefits: Moderate
IBWC **Flood Risk Mapping** **QL2 LiDAR** **4-5 years**	For hydraulic modeling, dam break, levee assessments, levee failure analyses, and environmental compliance along the Rio Grande River and border with Mexico.	***Operational Benefits***: LiDAR data will enable the IBWC to perform accurate evaluation, levee design, and flood modeling, and execute effective flood operations management for the Department of State.
		$ Benefits: $14.3M/year for Rio Grande Valley communities
		Customer Service Benefits: Major
		Public/Social Benefits: Minor
		Environmental Benefits: Major
		Strategic/Political Benefits: Major
USFS **Watershed Analysis** **QL3 LiDAR; QL5 IFSAR in Alaska** **6-10 years**	For hydrologic and hydraulic modeling and mapping of floodplains on USFS lands and for improved ecosystem management.	***Operational Benefits***: LiDAR data will enable the USFS to perform more-efficient and effective hydrologic and hydraulic modeling and mapping of floodplains on USFS lands.
		$ Benefits: Previously credited to Business Use #3.
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Minor
		Strategic/Political Benefits: Major
TVA **Navigation and Flood Risk Mitigation**	For flood risk analysis resulting from catastrophic dam failures (e.g., due to acts of terrorism, seismic	***Operational Benefits***: LiDAR data will enable the TVA to calculate economic damages and populations at risk with added certainty.
		$ Benefits: $100,000/year

QL2 LiDAR **4-5 years**	events, or floods).	***Customer Service Benefits***: Major ***Public/Social Benefits***: Moderate ***Environmental Benefits***: Minor ***Strategic/Political Benefits***: Moderate
54 State + VI **Functional Activities** **QL1 LiDAR: 6** **QL2 LiDAR: 19** **QL3 LiDAR: 28** **QL4 Image DEMs: 1** **QL5 IFSAR: 1** **Variable update frequencies**	For government programs in AL, AK, AR (3), AZ, CA (3), CO, FL, ID, IL (2), IN (2), KS, KY (2), MA, MD (2), ME (2), MI, MO, MN, MS, MT, NC, ND, NE, NH (2), NV (2), OH, OK (2), OR (2), RI, SC (2), TN, TX (2), UT, VA (2), VT (2), WI, WV, and the U.S. Virgin Islands. Note: some states have more than one Functional Activity for this Business Use.	***Operational Benefits***: Enhanced elevation data will enable these governments to be more efficient and/or effective in executing responsibilities for flood risk management while providing added dollar benefits to the public. ***$ Benefits***: $134.872M/year government benefits plus $193.384M/year in benefits for others. A total of 30 State FAs included estimated $ benefits.
29 County **Functional Activities** **QL1 LiDAR: 5** **QL2 LiDAR: 9** **QL3 LiDAR: 15** **Variable update frequencies**	For county flood mapping programs in 29 counties, budgeted at $508 million in 2011.	***Operational Benefits***: LiDAR data will enable these 29 county governments to perform accurate flood risk mapping. ***$ Benefits***: $11.64M/year county government benefits plus $6.152M/year in benefits for others.
2 Regional **Functional Activities** **QL2 LiDAR: 2** **Variable update frequencies**	For regional governments to perform hazard mitigation planning and provide GIS support for regional governments in Virginia and Kentucky, budgeted at $2.4 million in 2011.	***Operational Benefits***: LiDAR data will enable effective emergency management planning and floodplain and stormwater management activities for the Hampton Roads Planning District Commission and the Metropolitan Sewer District and the Louisville/Jefferson County Information Consortium. ***$ Benefits***: $600,000/year regional government benefits.
9 City **Functional Activities** **QL1 LiDAR: 9** **QL2 LiDAR: 5** **QL3 LiDAR: 9** **Variable update frequencies**	For the cities of Savannah, GA; Farmington, NM; Fargo, ND; Austin, TX; Huntsville, AL; Springfield, OR; Lansing, MI; Wichita, KS; and the Town of Amherst, MA to perform stormwater management, flood control, and flood hazard mitigation for programs budgeted at $13 million in 2011.	***Operational Benefits***: LiDAR data will enable these cities to perform more-accurate and less-expensive hydrologic and hydraulic modeling for flood studies, retention dam design, dam breach studies, stormwater management and engineering; identification of vulnerable properties within the floodplain, provide for better floodplain management decisions, and educate the public on true flood risks. New benefits will be the ability to generate 3-D models to show the potential impact of a 100-year flood. ***$ Benefits***: $1M/year city government benefits plus $325,000/year benefits for citizens.
2 Tribal **Functional Activities** **QL1 LiDAR: 1** **QL3 LiDAR: 1**	For the Pueblo of Sandia (NM) and the Quinault Indian Nation (WA) to perform hydrologic and hydraulic modeling and flood risk mapping on	***Operational Benefits***: LiDAR data will enable the Pueblo of Sandia and the Quinault Indian Nation to accurately map their flood risk to preserve life and property and to accurately model and illustrate flood risks. ***$ Benefits***: $120,000/year benefit to the tribes.

4-5 years	Indian lands, supporting programs budgeted at $420,000 in 2011.	
The Nature Conservancy **Healthy Watersheds** **QL2 LiDAR for buffer areas** **6-10 years**	QL2 LiDAR is required of buffer areas around selected streams and ecosystems for restoration of natural and beneficial functions of floodplains.	***Operational Benefits***: LiDAR data will enable TNC to evaluate levee setback or removal to restore natural and beneficial functions of floodplains and reduce overall flood damages.
		$ Benefits: Previously credited to Business Use #1.
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Major

Dollar Benefits for BU#14

From Table E.14, the conservatively estimated dollar benefits for BU#14 equal $294.706M/year.

These BU#14 benefits are probably understated for the following reasons:

- Federal Level: FEMA has not counted any potential internal benefits from reductions in Letters of Map Amendment (LOMAs). FEMA processes approximately 30,000 LOMAs annually, submitted by homeowners who believe that inaccurate Flood Insurance Rate Maps (FIRMs) dictate requirements to purchase flood insurance, causing them to hire surveyors to prove that their lowest adjacent grade (LAG) is higher than the Base Flood Elevation (BFE) shown on FIRMs, thereby exempting them from the mandatory flood insurance purchase. Three major benefits are currently not accounted for: (1) LiDAR will cause new FIRMs to be more accurate in the first place, causing potential homeowners to have greater faith in their legitimacy; (2) LiDAR enables the mass production of LOMAs, allowing an estimated half of the 30,000 applicants per year to avoid the $500-$750 cost of a land-surveyed Elevation Certificate that proves the LAG is higher than the BFE; and (3) reductions in processing costs to FEMA in having far fewer LOMAs to process annually. The saving of $500 per Elevation Certificate x 15,000 certificates per year would save homeowners an estimated $7.5M/year. FEMA would probably save an additional $1M/year in reduced processing costs.
- State Level: Considering all of their Departments and agencies, each state was asked to identify only their top 5-6 Functional Activities wit*h mission-critical* requirements for enhanced elevation data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. For 37 states plus the U.S. Virgin Islands, a total of 55 Functional Activities were documented as requiring LiDAR for BU#14. Other flood prone states did not appear to include BU#14 among their top priorities; however research indicated that many had requirements for this Business Use that were binned in the geodatabase with other, related Business Uses. As with other Business Uses, there is variability among all states in estimating dollar benefits for similar Functional Activities.
- Local and Tribal Government Levels: A total of 29 counties, 2 regions, 9 cities, and 2 tribes documented their requirements for LiDAR data for BU#14. When considering that flooding is a ubiquitous problem, these benefits are at least ten times this number, equaling total potential local and Tribal benefits of $198.37M/year.

- Other Organizations (Not-For-Profit and Private Companies): Realtors, bankers, mortgage and insurance companies will all benefit from FIRMs, produced with LiDAR, that are more accurate.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#14 equal approximately $501.576M/year.

BU#15 – Sea Level Rise and Subsidence

Scope of BU#15

Business Use #15 is defined in terms of Functional Activities that model and/or mitigate the effects of sea level rise (SLR) and subsidence that cause the loss of land. The U.S. Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), U.S. Army Corps of Engineers (USACE) and Environmental Protection Agency (EPA) are well represented in this Business Use. USACE, NOAA and USGS are all sponsors of the Joint Airborne LiDAR Bathymetry Technical Center of Expertise (JALBTCX) which systematically acquires topographic/bathymetric LiDAR of coastal areas of the U.S.

Background Information

Because of the warming climate, SLR rates are increasing worldwide above the norm for prior centuries. Projected SLR rates vary for the U.S., especially when combined with subsidence. The maximum rate of predicted SLR is 2 meters for this century, but the actual rate is more likely to be around 80 centimeters to 1 meter by the end of this century. Regardless of the rate, SLR has caused major concerns for coastal states and communities planning for an unstoppable sea threat; Federal and state agencies are working closely together to mitigate this threat, and LiDAR is a major part of this effort.

Subsidence involves the sudden collapse of the land or the slow subsidence typically caused by extraction of subsurface water (especially in California's Central Valley), oil or gas (especially in Louisiana and Texas) where extracted fluids previously helped to hold the ground up. Mine subsidence can be defined as the movement of the ground surface as a result of readjustments of the overburden due to collapse or failure of underground mine workings. Surface subsidence often takes the form of sinkholes or troughs. Some sinkholes or troughs are caused by leaking sewer pipes or water mains. Florida has thousands of natural limestone sinkholes caused by water erosion that provides a route for surface water to disappear underground. These limestone sinkholes provide a primary pathway for rainwater to replenish subsurface groundwater; they are an important part of the aquifer system that supplies 95% of Florida's drinking water; and if left unprotected, polluted surface water can drain into sinkholes and easily contaminate the aquifers. Subsidence impacts over 17,000 square miles in the U.S.

Figure E.15 provides examples of how LiDAR data are used to model the past or future effects of SLR and subsidence. Sinkholes, not illustrated, are also mapped from LiDAR.

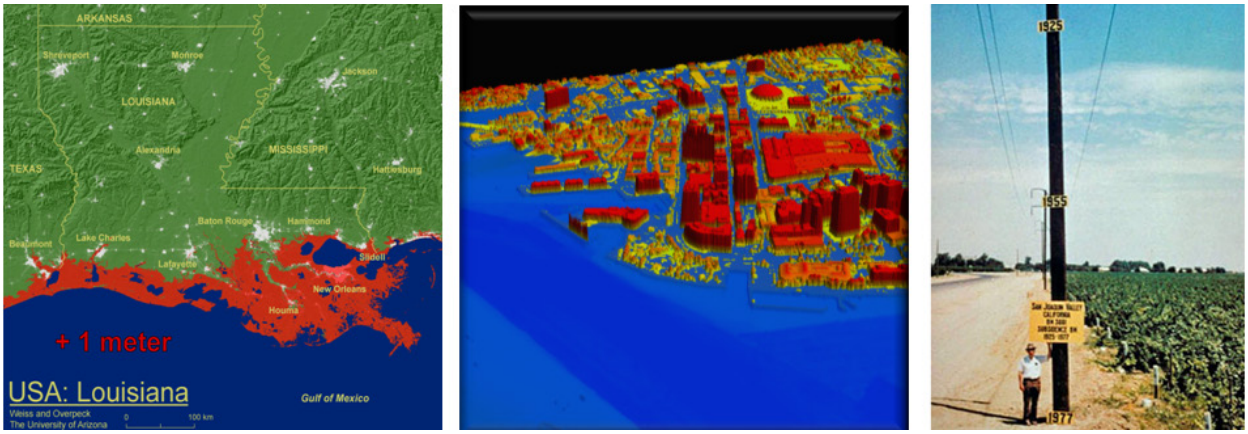

Figure E.15. The left image shows the huge predicted loss of land from 1 meter of SLR in southern Louisiana. The central image shows how coastal cities are modeled with "what-if" scenarios for different rates of SLR. The right image shows over 20 feet of subsidence in Central California over a 52 year period, caused by extraction of subsurface water for irrigation. Images courtesy of USGS and NOAA.

Summary of Requirements and Benefits

Table E.15 lists Functional Activities, pertaining to Sea Level Rise and Subsidence, with mission-critical requirements for enhanced elevation data. Each of these government agencies is *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity is explained in detail in Appendices B, C and D.

Table E.15. Elevation Data Requirements and Benefits for BU#15, Sea Level Rise and Subsidence

Geo-enabled User & Functional Activity **Quality Level (QL)** **Update Frequency**	**Summary of BU#15 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.**	**Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.**
NOAA **Coastal Mapping and Modeling** **QL2 LiDAR plus bathymetry from JALBTCX** **4-5 years**	For modeling, mapping and forecasting the effects of SLR. This includes the development of "what-if" scenarios that model coastal cities for various levels of SLR and enable government officials to visualize the potential threats to their communities.	Topographic and bathymetric LiDAR data will enable NOAA to model the effects of SLR while reducing losses for coastal communities by avoiding siting of municipal infrastructure in areas vulnerable to SLR.
		$ Benefits: Credited to Business Use #4.
		Customer Service Benefits: Moderate
		Public/Social Benefits: Moderate
		Environmental Benefits: Major
		Strategic/Political Benefits: Moderate
USACE **National Coastal Mapping Program** **Topo/bathy LiDAR from JALBTCX**	For support of SLR work performed by NOAA, NASA, universities, US Navy, FEMA, USGS, EPA and The Nature Conservancy.	***Operational Benefits***: The National Coastal Mapping Program will enable USACE and JALBTCX to work closely with agencies listed to address coastal environmental issues that have major public/social and strategic/political implications, especially SLR.
		$ Benefits: Major but unknown
		Customer Service Benefits: Major
		Public/Social Benefits: Major

2-3 years		***Environmental Benefits***: Major
		Strategic/Political Benefits: Major
USGS **Coastal Zone Management and Sea Level Rise and Subsidence** **QL2 LiDAR plus bathymetry from JALBTCX** **4-5 years**	For land use planners to establish building set-backs; for inventory of coastal wetlands; and to identify tsunami, flood and hurricane hazard zones.	***Operational Benefits***: Topographic and bathymetric LiDAR data will help enable the USGS to better map and model predicted and actual results of hurricane tidal surges, tsunamis, coastal erosion, and the effects of SLR and subsidence in coastal zones that cause billions of dollars annually in property damages.
		$ Benefits: Cannot accurately estimate, but SLR benefits to coastal communities are believed to be many millions of dollars/year (credited to BU#4).
		Customer Service Benefits: Moderate
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Major
EPA **Sea Level Rise Vulnerability Assessments** **QL2 LiDAR** **6-10 years**	For spatially explicit vulnerability maps and estimates of populations, land cover types, infrastructure and economic activities affected by SLR, and steps taken to mitigate these vulnerabilities.	LiDAR data will enable the EPA to work with coastal communities to take proactive steps to mitigate SLR by informed siting of drinking water, waste water and other infrastructure facilities, helping communities to save billions of dollars in the decades ahead.
		$ Benefits: $5.6M/year for EPA; potentially billions of dollars in the years ahead for coastal communities.
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Moderate
FWS **Landscape Conservation Cooperatives (LCCs)** **QL1 LiDAR** **6-10 years**	For biological planning, conservation design, inventory and monitoring program design, and other types of conservation-based scientific research, planning and coordination for LCC coastal areas.	***Operational Benefits***: LiDAR data will enable the FWS and its partners to model climate change factors and SLR, urban growth, and other factors affecting habitat conservation, and to establish common goals and priorities so they can be more efficient and effective in targeting the right science in the right places.
		$ Benefits: Moderate; cannot quantify
		Customer Service Benefits: Major
		Public/Social Benefits: Moderate
		Environmental Benefits: Major
		Strategic/Political Benefits: Major
3 State + PR **Functional Activities** **QL1 LiDAR: 1** **QL2 LiDAR: 2** **QL3 LiDAR: 1** **Variable update frequencies**	For government programs in AZ, FL, NC and Puerto Rico, budgeted at $4.281 million in 2011.	***Operational Benefits***: LiDAR data will enable these governments to monitor and model SLR and subsidence while providing only minor dollar benefits to the public at this time.
		$ Benefits: $80,000/year state government benefits plus $100,000/year in benefits for others. A total of 2 State FAs included estimated $ benefits. Forty seven states and other US territories did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.
1 Regional **Functional Activity** **QL2 LiDAR: 1**	For a regional government in New Hampshire to perform a SLR adaptation change study, budgeted at	***Operational Benefits***: LiDAR data will enable the Rockingham Planning Commission to perform SLR hazards analysis for its communities.
		$ Benefits: $20,000/year regional benefits to communities.

4-5 years	$5,000 in 2011.	
The Nature Conservancy **Coastal Stewardship and Resiliency** **QL2 LiDAR of coastal counties including the Great Lakes out to the 30' contour** **4-5 years**	For mitigation of the effects of SLR and to promote coastal resiliency.	***Operational Benefits***: Periodic updates of LiDAR data will enable TNC to evaluate coastal erosion, loss of land due to SLR and subsidence, and mitigate the effects of SLR, subsidence and human development. ***$ Benefits***: Previously credited to BU#4. ***Customer Service Benefits***: Major ***Public/Social Benefits***: Major ***Environmental Benefits***: Major ***Strategic/Political Benefits***: Major

Dollar Benefits for BU#15

From Table E.15, the conservatively estimated dollar benefits for BU#15 equal $5.780 M/year.

These BU#15 benefits are probably understated for the following reasons:

- Federal Level: EPA estimated dollar benefits of $5.6M/year for EPA and potentially billions of dollars in the years ahead for coastal communities. USGS indicated that major SLR and subsidence benefits could not be estimated but were believed to be many millions of dollars/year. USACE was unable to estimate its major but unknown dollar benefits of the National Coastal Mapping Program for SLR. DISDI indicated that DoD is planning for SLR of 1 meter during the current century, with dramatic effects on Navy and Marine Corps bases. Although LiDAR dollar benefits for BU#15 cannot be predicted with any degree of certainty, the following points are clear:
    - SLR and subsidence are already happening and will continue this century at an increased rate. Major areas of southern Louisiana will be underwater, and populations will need to elevate and/or move inland.
    - Existing structures and infrastructure are at risk, and future structures and infrastructure should be built at higher elevations to mitigate the effects of SLR and subsidence.
    - Elevations are especially critical for sewage treatment plants and water facilities that often cost approximately $100M each.
    - LiDAR is mission-critical for wise decision-making by all coastal communities to mitigate the inevitable effects of SLR and subsidence.
    - With most agencies agreeing that LiDAR data of coastal areas need to be updated every 2-3 years or 4-5 years for mitigating the effects of SLR and subsidence, the actual dollar benefits of LiDAR would be at least double that of EPA's estimate, to $11.2M/year.
- State Level: Considering all of their Departments and agencies, each state was asked to identify only their top 5-6 Functional Activities wit*h mission-critical* requirements for enhanced elevation data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. Only three states (AZ, FL, NC) plus Puerto Rico chose BU#15 for one of their most

important Functional Activities to be documented. Arizona is concerned about subsidence, whereas Florida, North Carolina and Puerto Rico are concerned about SLR. Other states had requirements for this Business Use that were binned in the geodatabase with other, related Business Uses. For coastal states, it is known that SLR is a major concern in statehouses. While still in office, Governor Schwarzenegger worked with multiple Federal agencies to acquire topographic/bathymetric LiDAR of the entire California coastline in order to address SLR issues. Clearly, southern Louisiana is the most severely threatened by SLR. The benefits of LiDAR to Louisiana and other coastal states in preparing for inevitable SLR may in fact be measured in terms of billions of dollars, as estimated by EPA, but this remains too uncertain to be recorded as such a major potential benefit.

- Local and Tribal Government Levels: The Rockingham Planning Commission in New Hampshire documented the needs for LiDAR for performing SLR hazards analysis for its communities and estimated regional benefits of $20,000/year. There are 285 counties along the Atlantic Coast, 142 counties along the Gulf Coast, and 87 counties along the Pacific Coast, for a total of 514 coastal counties, excluding the Great Lakes. If all of them had LiDAR needs and benefits similar to Rockingham's, then the total potential benefits would equal $10.28M/year.
- Other Organizations (Not-For-Profit and Private Companies): Every private business and individual homeowner near a U.S. coastline, and low or subsiding areas such as southern Louisiana, deserves to know whether their property is threatened by potential SLR this century so that they can take steps to ensure they do not make unwise investments. Dollar benefits cannot be estimated.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#15 equal approximately $21.660M/year.

BU#16 – Wildfire Management, Planning and Response

Scope of BU#16

Business Use #16 is defined in terms of Functional Activities that determine forest fuel and fire susceptibility for wildfire modeling and suppression activities. Working with the National Interagency Fire Center (NIFC), the Bureau of Land Management (BLM) is a champion for this Business Use, supported by state and other Federal agencies managing wildfires on lands in their areas of responsibility.

Background Information

The American public regularly sees images of wildfires (see example at Figure E.16) without recognizing that digital elevation data have anything to do with fighting those fires. Wildfire modeling software requires: (1) DEMs, (2) slope, (3) aspect, (4) canopy cover, (5) fuels models, (6) weather, (7) wind, and (8) fuel moisture. Items (1) through (5) all come from LiDAR which is well known for determining fuel biomass statistics. In addition to the obvious damages and threats to homes and communities, wildfires also leave the terrain more susceptible to landslides.

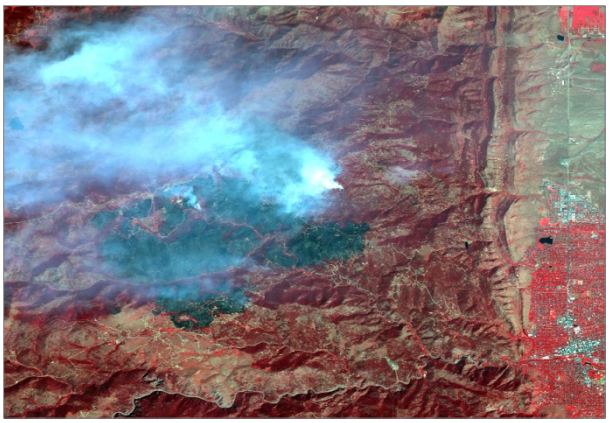

Figure E.16. This is a WorldView-2 satellite image of the Four Mile Canyon wildfire burning west of Boulder, CO on 9/7/10. Although such imagery can show the current status, wildfire managers need LiDAR data, as well as wind and weather data for predicting fire behavior. LiDAR provides fuel biomass information, as well as slope and aspect data used in wildfire modeling to determine firefighting strategies to save forests, homes and communities at risk. Image courtesy of Digital Globe.

Summary of Requirements and Benefits

Table E.16 lists Functional Activities, pertaining to Wildfire Management, Planning and Response, with mission-critical requirements for enhanced elevation data. Each of these government agencies is *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity is explained in detail in Appendices B and C.

Table E.16. Elevation Data Requirements and Benefits for BU#16, Wildfire Management, Planning and Response

Geo-enabled User & Functional Activity **Quality Level (QL)** **Update Frequency**	**Summary of BU#16 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.**	**Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.**
USFS **Wildfire Management** **QL1 (FS lands) and QL3 LiDAR for other forests in US, except**	For fire modeling, post-fire response planning, and ground fuel mapping.	***Operational Benefits***: LiDAR data will enable the USFS to provide Burned Area Emergency Response (BAER) mapping, improve fire behavior modeling, and predict peak runoff flows and sediment delivery, allowing for improved post-fire remediation prescriptions.
		$ Benefits: $1M/year
		Customer Service Benefits: Major

QL5 IFSAR for Alaska **QL1: 4-5 years;** **QL3: 6-10 years;** **QL5: >10 years**		***Public/Social Benefits***: Moderate ***Environmental Benefits***: Moderate ***Strategic/Political Benefits***: Moderate
BLM **Wildland Fire Fighting** **QL3 LiDAR** **Event driven**	For computer simulation of wildland fires in order to understand and predict fire behavior. Wildfire modeling aids wildland fire suppression, increases safety of firefighters and the public, reduces risk, and minimizes damage. Wildfire modeling can also aid in protecting ecosystems, watersheds, and air quality.	***Operational Benefits***: LiDAR data will enable BLM and the National Interagency Fire Center (NIFC) to determine fuel loading, slope and aspect data needed for wildfire computer modeling and simulation. ***$ Benefits***: Cannot be determined ***Customer Service Benefits***: Major ***Public/Social Benefits***: Major ***Environmental Benefits***: Unknown ***Strategic/Political Benefits***: Unknown
USGS **Mapping, Monitoring and Assessment of Biological Carbon Stocks** **QL1 LiDAR of forested counties; QL2 LiDAR non-forested** **6-10 years**	For quantitative characterization of vegetation structural attributes in support of the USGS mission to assess, monitor and map land biomass and biological carbon stocks nationwide.	LiDAR data will enable the USGS to better determine vegetation biomass data which are vital for accurate wildfire modeling. ***$ Benefits***: Previously credited to Business Use #1. ***Customer Service Benefits***: Major ***Public/Social Benefits***: Moderate ***Environmental Benefits***: Moderate ***Strategic/Political Benefits***: Moderate
8 State **Functional Activities** **QL1 LiDAR: 2** **QL3 LiDAR: 3** **QL4 Image DEMs: 2** **QL5 IFSAR: 1** **Variable update frequencies**	For state government firefighting programs in AL, CA (2), CO, KS, MI, OR and TX, budgeted at $1.155 billion in 2011. Note: California has more than one Functional Activity for this Business Use.	***Operational Benefits***: Enhanced elevation data will enable state governments to be more effective in wildfire management, planning and response, while providing obvious financial benefits to the public when threatened by active wildland fires. ***$ Benefits***: $25.24M/year state government benefits plus $57.46M/year in benefits for others. A total of 6 State FAs included estimated $ benefits. Forty three states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.
1 County **Functional Activity** **QL3 LiDAR: 1** **6-10 years**	For an emergency services program in one county in Colorado, budgeted at $1 million in 2011.	***Operational Benefits***: LiDAR data will enable Pueblo County to execute an effective fire risk mapping project. ***$ Benefits***: $300,000/year county government benefits plus $250,000/year in benefits for others.

Dollar Benefits for BU#16

From Table E.16, the conservatively estimated dollar benefits for BU#16 equal $75.700M/year.

These BU#16 benefits are probably understated for the following reasons:

- Federal Level: None of the Federal agencies have determined how many lives were saved, or the value of homes and possessions saved as a result of accurate wildfire modeling, compared with inaccurate wildfire modeling. Benefits are extremely difficult to quantify.
- State Level: Considering all of their Departments and agencies, each state was asked to identify only their top 5-6 Functional Activities wit*h mission-critical* requirements for enhanced elevation data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. Only seven states chose BU#16 for one of their most important Functional Activities to be documented, and many wildfire-prone states were not included. Therefore the potential benefits to all fire-prone states are estimated to be double those of the seven states reporting, totaling $50.48 M/year potential benefits to the states plus $114.92M/year benefits to others, primarily individual homeowners and/or insurance companies.
- Local and Tribal Government Levels: Pueblo County, CO, is the only local government that specified LiDAR for wildfire modeling, and it claimed $300,000/year county government benefits plus $250,000/year in benefits for others, for a total of $550,000/year in benefits. If this one county estimate is anywhere close to correct, surely the benefits to all the other counties nationwide would be at least 100 times greater than the benefits to this single county. Therefore, the potential additional benefits to all counties could be around $55 M/year; however, this potential benefit was not applied because of the potential double-counting with the $57.46M/year in state benefits to others in the prior paragraph above.
- Other Organizations (Not-For-Profit and Private Companies): The commercial timber companies interviewed for this assessment all indicated that wildfire modeling was an important benefit of LiDAR data for their businesses, but dollar benefits were not estimated.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#16 equal approximately $158.950M/year.

BU#17 – Homeland Security, Law Enforcement and Disaster Response

Scope of BU#17

Business Use #17 is defined in terms of Functional Activities that promote homeland security, minimize threats from terrorism and criminal activities, and respond to natural or manmade disasters. The Department of Homeland Security (DHS), which includes the Federal Emergency Management Agency (FEMA), is a logical champion for this Business Use. For this Business Use, the DHS is assisted by other Federal, state and local agencies.

Background Information

Many agencies responsible for homeland security use LiDAR data for viewshed analyses to determine "what can be seen from where" because many threats are based on intervisibility between points with different elevations; this application is relevant to most aspects of infrastructure protection, border protection, search and rescue, and special security events.

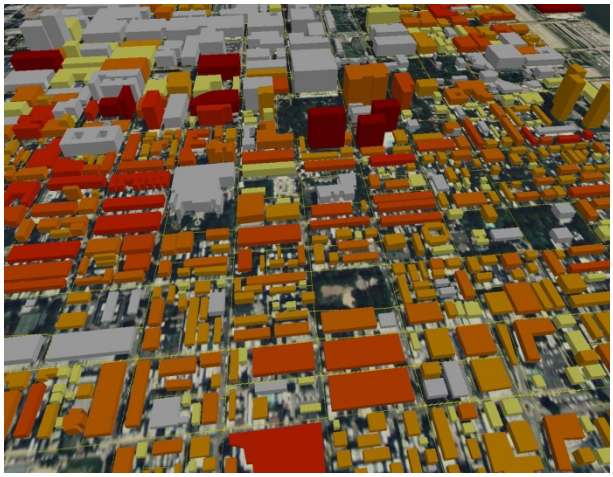

Figure E.17. Example use of LiDAR for modeling of population distribution and dynamics, using LandScan USA developed by the DOE for the DHS. Such models are used for disaster response planning and execution for major cities of the U.S. Image courtesy of DOE.

High-resolution population distribution data are critical for homeland security because operational activities and policy decisions are significantly influenced by the number of people impacted at different times of the day when incidents occur. LandScan USA data, produced from LiDAR and census data as well as ancillary datasets (e.g., land cover, roads, slope, urban areas, village locations, and image analysis) are used to estimate the number of people in residential and non-residential structures at different hours of the day, with phased increases in populations in the morning hours and phased decreases in the evening hours. These models are used for planning and execution of emergency response plans for major urban areas. See Figure E.17.

Summary of Requirements and Benefits

Table E.17 lists Functional Activities, pertaining to Homeland Security, Law Enforcement and Disaster Response, with mission-critical requirements for enhanced elevation data. Each of these government agencies is *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity is explained in detail in Appendices B and C.

Table E.17. Elevation Data Requirements and Benefits for BU#17, Homeland Security, Law Enforcement and Disaster Response

Geo-enabled User & Functional Activity	Summary of BU#17 Mission-Critical Requirements for	Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.

Quality Level (QL) Update Frequency	Enhanced Elevation Data. See individual Appendices for details.	
DHS **Infrastructure Protection** **QL1 LiDAR (coastal), QL3 LiDAR (inland)** **6-10 years**	For maritime awareness and security as well as infrastructure 3-D modeling, simulation and analyses.	***Operational Benefits***: LiDAR data will enable the DHS to create effective 3-D models used for simulation and analysis of risks to critical infrastructure. Digital Surface Models (DSMs) are used for viewshed and line-of-sight analyses and aerosol spread models, whereas Digital Terrain Models (DTMs) are used for analysis of chemical spills, floods and hurricane tidal surges.
		$ Benefits: Major; dollar benefits cannot be estimated.
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Minor
		Strategic/Political Benefits: Major
DHS **Border Protection** **QL3 LiDAR** **>10 years**	For U.S. Customs and Border Protection (USCBP) elevation models along the Canadian and Mexican borders are used for vulnerability assessments, siting and placement of towers and sensors, and to support human patrols and drones.	***Operational Benefits***: LiDAR data will enable the USCBP to understand vulnerabilities, to better deploy field agents, to determine where sensors should be placed for optimum effect and where human patrols could physically observe border intrusions with infrared sensors and night vision goggles, for example, and to assist in search and rescue operations along International borders.
		$ Benefits: Dollar benefits cannot be estimated.
		Customer Service Benefits: Moderate
		Public/Social Benefits: Moderate
		Environmental Benefits: None
		Strategic/Political Benefits: Moderate
DHS **Coastal Search and Rescue** **QL3 LiDAR** **>10 years**	For the U.S. Coast Guard *Rescue 21* advanced command, control and communications system, to triangulate to vessels in distress and determine their location, and to better model radio reception for the *Rescue 21* program.	***Operational Benefits***: For over 5,000 search and rescue operations annually, LiDAR data will enable the USCG to more-rapidly determine the location of mariners in distress and experience significant (often critical) time savings in deploying rescue vessels or aircraft to distress locations.
		$ Benefits: Major dollar benefits cannot be estimated
		Customer Service Benefits: Major (timeliness of response)
		Public/Social Benefits: Major
		Environmental Benefits: None
		Strategic/Political Benefits: Major
DHS **Special Security Events** **QL2 LiDAR (133 Urban Areas)** **Annually**	For U.S. Secret Service (USSS) 3-D modeling, viewshed analyses, and placement of surveillance equipment and/or agents.	***Operational Benefits***: LiDAR data will enable the USSS to reduce the critical time spent finding, validating, and manipulating data (from disparate sources) needed to determine where to place surveillance devices that will not be blocked by unexpected berms, buildings or trees, and/or where to place USSS agents; and to quickly respond to changing circumstances.
		$ Benefits: Major dollar benefits cannot be estimated.
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: None
		Strategic/Political Benefits: Major
FBI	FBI requirements, satisfied	***Operational Benefits***: LiDAR data will enable the FBI to

3-D Modeling and Analysis **QL2 LiDAR (133 Urban Areas)** **4-5 years**	by NGA, are for 3-D modeling and analysis in support of law enforcement.	perform topographic mapping, area familiarization, and 3-D modeling and analysis of sites as incidents occur, supporting tactical teams and court room presentations. ***$ Benefits***: Cannot determine ***Customer Service Benefits***: Major ***Public/Social Benefits***: None ***Environmental Benefits***: None ***Strategic/Political Benefits***: None
NGA **Homeland Security and Disaster Preparedness** **QL2 LiDAR (133 Urban Areas)** **4-5 years**	For disaster response, law enforcement, homeland security, research, and 3-D modeling, simulation, and analysis, especially for the 133 major urban areas of the U.S.	***Operational Benefits***: When produced to common specifications, LiDAR data will enable the NGA to support the DHS and other Federal, state and local agencies with accurate, consistent and interoperable 3-D data vital for homeland security and disaster preparedness. ***$ Benefits***: Major dollar benefits cannot be estimated. ***Customer Service Benefits***: Major ***Public/Social Benefits***: Major ***Environmental Benefits***: Major ***Strategic/Political Benefits***: Major
DOE **Population Distribution and Dynamics** **QL1 LiDAR (133 Urban Areas); QL3 LiDAR elsewhere** **4-5 years**	For support of DHS' LandScan USA extraction of building footprints, heights and characteristics, to model populations at risk for emergency response and evacuation planning and execution.	***Operational Benefits***: LiDAR data will enable the DOE to model two cities for DHS for the price of one, enhancing the value of the Homeland Security Information Program (HSIP). ***$ Benefits***: $1M/year minimum benefit ***Customer Service Benefits***: Major ***Public/Social Benefits***: Major ***Environmental Benefits***: None ***Strategic/Political Benefits***: Major
DOE **Emergency Management Program Oversight, Response and Recovery** **QL3 LiDAR** **4-5 years**	For provision of accurate 3-D data for emergency management program oversight and emergency response and recovery planning between state, county, and local jurisdictions surrounding DOE's Oak Ridge Reservation (ORR).	***Operational Benefits***: LiDAR data will enable DOE and surrounding jurisdictions to plan for and respond to events that occur on the ORR where hazardous activities result from construction or demolition events, malevolent or natural phenomena events, or hazardous material releases. ***$ Benefits***: Dollar benefits cannot be estimated. ***Customer Service Benefits***: Minor ***Public/Social Benefits***: Moderate ***Environmental Benefits***: Moderate ***Strategic/Political Benefits***: Moderate
USACE **Flood Risk and Emergency Management** **QL2 LiDAR of dams and levees** **6-10 years**	For hydrologic and hydraulic (H&H) modeling and flood risk assessments; for dam and levee safety programs of the Corps; for emergency response from terrorist attacks or natural disasters.	***Operational Benefits***: LiDAR data will enable the USACE to perform accurate and efficient H&H modeling; perform remote monitoring and assessments of levees for safety; and perform comprehensive dam and levee breach inundation mapping under diverse *what-if* scenarios. ***$ Benefits***: Benefits previously credited to BU#14. ***Customer Service Benefits***: Major ***Public/Social Benefits***: Major ***Environmental Benefits***: Minor ***Strategic/Political Benefits***: Major
FERC	For mapping for	***Operational Benefits***: LiDAR data will enable the FERC to

Flood Risk Mapping for Hydroelectric Dam Break Failures and Analysis **QL3 LiDAR; QL5 IFSAR for two watersheds in Alaska** **6-10 years**	hydroelectric dam break failures and analyses to mitigate impact to public safety and natural and built environments.	expedite its analyses of the consequences of dam failures for non-Federally owned hydroelectric dams. ***$ Benefits***: Dollar benefits cannot be estimated. ***Customer Service Benefits***: Major ***Public/Social Benefits***: Major ***Environmental Benefits***: None ***Strategic/Political Benefits***: Minor
17 State **Functional Activities** **QL1 LiDAR: 2** **QL2 LiDAR: 6** **QL3 LiDAR: 9** **Variable update frequencies**	For government programs AL (2), FL, IA, IL, KS, LA, MD, MO, MS (2), NC, NY (2), PA, SC, and TN, budgeted at $328 million in 2011. Note: some states have more than one Functional Activity for this Business Use.	***Operational Benefits***: LiDAR data will enable state governments to be more efficient and/or effective in executing responsibilities for homeland security, critical infrastructure protection, and disaster response, while providing added benefits to others. ***$ Benefits***: $3.325M/year state government benefits plus $5.725M/year in benefits for others. A total of 2 State FAs included estimated $ benefits. Thirty six states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.
6 County **Functional Activities** **QL1 LiDAR: 2** **QL2 LiDAR: 2** **QL3 LiDAR: 2** **Variable update frequencies**	For county emergency management services in 6 counties.	***Operational Benefits***: LiDAR data will enable these 6 county governments to modernize their emergency management services. ***$ Benefits***: $350,000/year county government benefits.
1 City **Functional Activity** **QL1 LiDAR: 1** **Event driven**	For the City of Ardmore, OK to perform municipal mapping, with a program budgeted at $5 million in 2011.	***Operational Benefits***: LiDAR data will enable the City of Ardmore to maintain, construct and develop all municipal projects where elevation data play a role. ***$ Benefits***: $40,000/year in city government benefits plus $4,000/year benefits for citizens.

Dollar Benefits for BU#17

From Table E.17, the conservatively estimated dollar benefits for BU#17 equal $9.975 M/year.

These BU#17 benefits are probably understated for the following reasons:

- Federal Level: Because of the sensitivity of their programs, only one Federal agency (DOE) estimated the value of LiDAR for homeland security, law enforcement or disaster response, but most indicated their benefits would be major. Although FEMA was unable to provide a Functional Activity for BU#17, , it is well known that FEMA relies upon before/after imagery and before/after LiDAR data for disaster preparedness, response and recovery activities, and the potential benefits would be major, but unknown.
- State Level: Considering all of their Departments and agencies, each state was asked to identify only their top 5-6 Functional Activities wit*h mission-critical* requirements for enhanced elevation

data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. For BU#17, fourteen states chose 17 Functional Activities to be documented, estimating $3.335M/year in state government benefits plus $5,725M/year in benefits to others, with all benefits coming from two states (AL and IL); dollar benefits could not be estimated for the remaining 15 Functional Activities. When considering comparable benefits to all states, especially those with higher populations, the additional potential benefits are estimated at 10 times higher than benefits from AL and IL, i.e., $33.25M/year in state government benefits plus $57.25M/year in benefits to others.

- Local and Tribal Government Levels: Six counties reported combined savings of $350,000/year in using LiDAR to modernize their emergency management services. With over 3,000 counties in the U.S., surely the potential benefits to all counties would be at least an additional 100 times greater, i.e., an additional $35M/year nationwide. The City of Ardmore, OK alone estimated $44,000/year in benefits to this one city alone.
- Other Organizations (Not-For-Profit and Private Companies): Outside of government agencies, no input was received for this Business Use.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#17 equal approximately $126.469M/year.

BU#18 – Land Navigation and Safety

Scope of BU#18

Business Use #18 is defined in terms of Functional Activities that promote safe and economical navigation and commerce on America's roads and railroads. State Departments of Transportation (DOTs) and private industry serve as champions for the use of enhanced elevation data to satisfy requirements for this Business Use.

Background Information

Everybody wants America's roads and railroads to be safe and for traffic to flow smoothly, and everybody wants wise use of transportation funds. Figure E.18 (left) shows how both imagery and LiDAR are used to safely survey and map existing roads, avoiding land surveys where surveyors are frequently injured or killed by passing motorists. Figure E.18 (right) shows how LiDAR is used to select routes for new roads, design new roads with proper grades and curves, estimate cut/fill for earthmoving operations, and provide data for conventional construction stakeout or modern GPS machine control where grade stakes are not required.

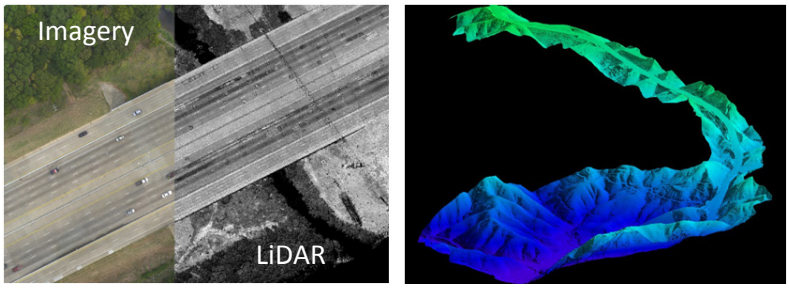

Figure E.18. These images show how LiDAR is used to efficiently and safely survey and map existing roads (left) and proposed roads (right) to determine cut/fill analyses and plan efficient construction of safe roads by conventional methods or modern machine control. Each LiDAR return provides x/y/z coordinates and intensity value. Images courtesy of Tuck Mapping Solutions.

U.S. Federal Highway Administration (FHWA) Publication Number FHWA-HRT-10-073[10], Roadway Geometry and Inventory Trade Study for IntelliDrive℠ Applications, published in November of 2010, documents IntelliDrive data needs for IFSAR and LiDAR for improved safety and fuel efficiency.

TomTom is the world's leading provider of in-car location and navigation products and services and is actively involved in Intelligent Transportation System (ITS) and Advanced Driver Assistance System (ADAS) initiatives. In anticipation of increased fuel efficiency standards, and based partly on research performed by TomTom engineers in Germany, they have estimated that they can reduce fuel consumption between 4% and 12% by building vehicles that use elevation and slope data from LiDAR, combined with transmission-control technology and in-vehicle location and navigation products, to down-shift and up-shift transmissions in anticipation of gradients ahead. The trucking industry is apparently supportive of such ADAS technology. The same LiDAR datasets used to reduce fuel consumption would also be used to reduce accidents and deaths. These LiDAR-based innovations are expected to save Americans billions of dollars annually. Gas and diesel consumption statistics are at http://www.fhwa.dot.gov/policyinformation/pubs/pl10023/fig5_2.cfm. These statistics show that Americans consume approximately 175 billion gallons of gasoline and diesel fuel per year nationwide for

[10] See http://www.fhwa.dot.gov/publications/research/safety/10073/001.cfm

cars, trucks and busses, of which over 530 million gallons are consumed annually in Alaska. If new transmission-control technology caused just 1% savings in fuel consumption (rather than 4% to 12%), and if the average cost of fuel is $3.50/gallon, the estimated savings would be as follows:

- Nationwide Fuel Savings: 1.75 billion gallons x $3.50/gallon = $6.125B/year
- Alaska Fuel Savings: 5.3 million gallons x $3.50/gallon = $18.55M/year

Although it is believed that elevation-based ITS/ADAS technology will be introduced commercially starting in 2014, the $6.125B/year benefits are all applied to potential benefits, rather than conservative benefits, because the rate at which this new technology will be introduced to, and adopted by the commercial marketplace is unknown.

Summary of Requirements and Benefits

Table E.18 lists Functional Activities, pertaining to Land Navigation and Safety, with mission-critical requirements for enhanced elevation data. Each of these organizations is *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity is explained in detail in Appendices C and D. The future in-car application will someday be in the hands of individual Americans.

Table E.18. Elevation Data Requirements and Benefits for BU#18, Land Navigation and Safety

Geo-enabled User & Functional Activity **Quality Level (QL)** **Update Frequency**	**Summary of BU#18 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.**	**Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.**
1 State +PR **Functional Activities** **QL1 LiDAR: 2** **Variable update frequencies**	For government programs in Wyoming and Puerto Rico, budgeted at $4.3 million in 2011.	***Operational Benefits***: LiDAR data will enable state governments to be more efficient and/or effective in transportation infrastructure planning and road design.
		$ Benefits: $316,000/year state government benefits for WY and PR. Both Wyoming and Puerto Rico included estimated $ benefits. Forty nine states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.
TomTom **Location and Navigation Services** **QL2 LiDAR; QL5 IFSAR in Alaska** **4-5 years**	For car navigation and safety features that notify or warn drivers when there are steep curves or other dangerous conditions ahead; and for future car innovations that anticipate approaching slopes and curves for transmission gear shifting and improved fuel efficiency of 4% to 12%. Note: only 1% was used to compute potential benefits of $6.125B/year, and	***Operational Benefits***: LiDAR data will enable auto manufacturers to design cars that actually test drivers' alertness to navigate roads ahead based on gradients and curves, etc., saving human lives; car transmissions will automatically upshift or downshift in anticipation of slopes ahead while saving 4-12% in fuel consumption when driving in hilly to mountainous terrain.
		$ Benefits: $6.125B/year potential benefits, when estimating only a 1% savings in fuel consumption compared with the 4% to 12% estimated by car manufacturers.
		Customer Service Benefits: In addition to major savings in fuel consumption, the automotive industry expects to save many lives annually as a result of driver fatigue

	$0/year was used as the conservative benefits in the Benefit/Cost Analysis.	technology enabled by elevation data.
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Moderate

Dollar Benefits for BU#18

From Table E.18, the conservatively estimated dollar benefits for BU#18 equal $191K/year.

These BU#18 benefits are probably understated for the following reasons:

- Federal Level: Even though it published the referenced study entitled: Roadway Geometry and Inventory Trade Study for IntelliDrive℠ Applications, which documents the use of IFSAR and LiDAR, the U.S. Department of Transportation, Federal Highway Administration (FHWA), did not participate in this survey, so Federal benefits from this key department are undetermined.
- State Level: Considering all of their Departments and agencies, each state was asked to identify only their top 5-6 Functional Activities wit*h mission-critical* requirements for enhanced elevation data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. Only two states (CT and FL) chose BU#17 for one of their most important Functional Activities to be documented, estimating $316,000/year state government benefits for WY and PR. This under-reporting is probably because the use of LiDAR for highway management and design is still evolving.
- Missouri DOT Study: In October, 2010, the Missouri Department of Transportation (MODOT), Sanborn Map Company, and HDR Engineering released Organizational Results Research Report OR11.007, *Light Detection and Ranging (LiDAR) Technology Evaluation.* This report provided an analysis on the current state of laser-based technology and its applicability, potential accuracies and information content with respect to MODOT applications. The study involved collection of Airborne LiDAR, Static (terrestrial) LiDAR, and Mobile LiDAR over a known project area with existing control and check data sets and provided an assessment of accuracy, cost and feasibility for MODOT projects. In comparing the relative advantages and disadvantages of these three laser-based technologies, the following acquisition cost comparisons were provided for traditional land surveys, photogrammetric surveys, and these three types of LiDAR surveys:
    1. $29,258 per linear mile for static, terrestrial LiDAR corridors
    2. $18,798 per linear mile for traditional ground surveys of road corridors
    3. $ 9,933 per linear mile for mobile LiDAR corridors
    4. $ 8,321 per linear mile for aerial LiDAR corridors
    5. $ 7,891 per linear mile for aerial photogrammetric corridors

  MODOT's recommended implementation plan and objectives all focused on LiDAR because of safety, accuracy, speed, and overall cost savings from reduced construction costs by providing a more-accurate ground model and earthwork quantities, compared with photogrammetry that does not map through trees to provide accurate ground elevations. But even the $8,321 per linear mile is a very high cost when compared with QL1 LiDAR that costs less than 10% of that price per square mile. With 1-foot contour accuracy and 8 points per square meter, nationwide QL1 LiDAR would cost far less than $1,000 per square mile and would include all roads, and not just selected road corridors. But QL1 LiDAR data would not provide information on road signs

and ultra high density survey points (hundreds of points per square meter) provided by mobile or terrestrial LiDAR. Aerial mapping of all roads would undoubtedly reduce the number of land surveyors killed each year while performing traditional ground surveys along roads. Although current state DOT expenditures for all forms of ground and aerial surveys are unknown, the authors of this study believe that this application is potentially the single largest way for nationwide LiDAR to save money for U.S. taxpayers – potentially in excess of $1B/year in avoiding traditional land and aerial surveys of linear corridors but instead using aerial LiDAR available everywhere.

- Local and Tribal Government Levels: No local or Tribal governments reported on this Business Use and benefits cannot be estimated beyond those for state DOTs in the prior paragraph.
- Other Organizations (Not-For-Profit and Private Companies): Americans currently consume 175,000,000,000 gallons of fuel annually for their cars, trucks and busses, and new ITS and ADAS technology, based on LiDAR, is estimated by TomTom to save between 4% and 12% of this fuel consumption. At $3.50 per gallon, this comes to $612.5 billion/year for fuel. If we achieved only 1% fuel economy savings instead of the 4% to 12% increase in fuel economy expected by the new LiDAR-based technology being developed by the automotive industry, this would still equal annual benefits of $6.125B/year. All of this is applied as future, potential benefits because of uncertainty on the dates and rates for implementation of these new technologies

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#18 equal approximately $7.125B/year.

BU#19 – Marine Navigation and Safety

Scope of BU#19

Business Use #19 is defined in terms of Functional Activities that promote safe and economical navigation and commerce on America's waterways. The National Oceanic and Atmospheric Administration (NOAA) serves as the champion for the use of bathymetric LiDAR data to satisfy requirements for this Business Use.

Background Information

Bathymetric LiDAR can map the elevations of submerged surfaces down to about 2 times the *Secchi depth*, an intuitive water clarity measure that is the depth at which a standard black and white disc, deployed over the side of a boat, is no longer visible to the human eye. Bathymetric LiDAR does not work in turbid waters. Where and when waters are clear, bathymetric LiDAR provides NOAA with modern, accurate hydrographic survey data with which to update nautical charts. It also provides relative seabed reflectivity for habitat mapping.

As documented in the August, 2011 issue of *Sea Technology Magazine*, Figure E.19 shows an area off the west coast of Puerto Rico surveyed with bathymetric LiDAR for NOAA's Office of Coast Survey, sounded at four-by-four meter laser spot spacing. Maximum depths to 55 meters were measured before the reef dropped off quickly, and consistent depths of 35 to 40 meters were achieved throughout the area surveyed by Fugro LADS. This area was previously surveyed by the National Ocean Service, partly between 1900 and 1939 by lead line, and partly between 1940 and 1989 by single-beam echosounder (sonar).

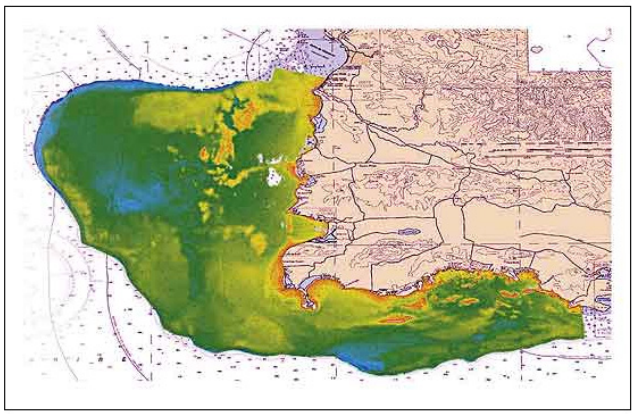

Figure E.19. The August 2011 issue of *Sea Technology Magazine* reports that bathymetric LiDAR identified 47 new dangers to navigation (DTON) and over 1,000 additional significant differences with published nautical charts for the 675 square kilometer area surveyed off the west coast of Puerto Rico.

The referenced *Sea Technology Magazine* article states: "During the most recent survey, 47 new dangers to navigation (DTON) were found and differences between the survey and the existing charts identified. A DTON is an inadequately charted feature that a field hydrographer identifies as potentially dangerous to navigation, taking into account the general vessel traffic and largest scale chart produced for the area. Some examples of DTON as outlined by NOAA's Office of Coast Survey include: submerged features with depths less than 11 fathoms (66 feet) in navigable waters; items found to be significantly shoaler than charted; incorrect or uncharted clearances on bridges or overhead cables; and floating or fixed aids off position or incorrectly labeled.

"In addition to the specific DTON, a large number of other significant differences between the survey and charts were also identified and reported for each of the survey areas. Although not as notable as DTON, these items of significant difference also demonstrate the importance of conducting modern

surveys to improve the knowledge of the area and enhance navigational safety. The total number of DTON and significant differences totaled 1,099 items in the 675 square kilometers that were surveyed in Puerto Rico. In addition to DTON and chart differences, a number of general recommendations regarding differences between the survey and chart were made for certain parts of the survey area. These included differences between the surveyed and charted coastlines by up to 150 meters, cultural details such as buildings, wharfs, recreational jetties and seawalls, which were not shown on the chart or where the charted position differed by up to 80 meters. Some of these differences between the survey and the chart were of greater or lesser importance, but they serve to demonstrate the huge amount of detail which has been surveyed and was not previously correctly shown on the chart."

Marine navigation and safety in coastal areas is important for both commerce and recreation. Business Use #4, Coastal Zone Management, previously described NOAA's Coastal Mapping and Modeling and USACE's National Coastal Mapping Program Functional Activity that overlap with Business Use #19 for Marine Navigation and Safety.

Summary of Requirements and Benefits

Table E.19 lists Functional Activities, pertaining to Marine Navigation and Safety, with mission-critical requirements for enhanced elevation data. Each of these government agencies is *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity is explained in detail in Appendices B and C.

Table E.19. Elevation Data Requirements and Benefits for BU#19, Marine Navigation and Safety

Geo-enabled User & Functional Activity **Quality Level (QL)** **Update Frequency**	**Summary of BU#19 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.**	**Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.**
NOAA **Coastal Mapping and Modeling** **Bathymetric LiDAR from JALBTCX** **4-5 years**	For mapping of near-shore bathymetry that poses potential hazards to marine navigation.	***Operational Benefits***: Topographic and bathymetric LiDAR data will enable NOAA to map, model and preserve coastal areas of the U.S.
		$ Benefits: Previously credited to Business Use #4.
		Customer Service Benefits: Moderate
		Public/Social Benefits: Moderate
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Moderate
USACE **National Coastal Mapping Program** **Bathymetric LiDAR from JALBTCX** **2-3 years**	For implementation of regional sediment management practices at USACE coastal navigation projects as well as other activities: USACE flood damage reduction, asset management, regulatory, emergency operations, and environmental stewardship; USGS coastal	***Operational Benefits***: Topographic and bathymetric data will enable USACE to implement regional sediment management practices at USACE coastal navigation projects.
		$ Benefits: Major but unknown
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Major

	and marine geology and extreme storm studies; and NOAA nautical chart production.	
DHS **Coastal Search and Rescue** **QL3 LiDAR** **>10 years**	For the U.S. Coast Guard *Rescue 21* advanced command, control and communications system, to triangulate to vessels in distress and determine their location, and to better model radio reception for the *Rescue 21* program.	***Operational Benefits***: For over 5,000 search and rescue operations annually, LiDAR data will enable the USCG to more-rapidly determine the location of mariners in distress and experience significant (often critical) time savings in deploying rescue vessels or aircraft to distress locations.
		$ Benefits: Major dollar benefits cannot be estimated.
		Customer Service Benefits: Major (timeliness of response)
		Public/Social Benefits: Major
		Environmental Benefits: None
		Strategic/Political Benefits: Major
TVA **Navigation and Flood Risk Mitigation** **QL2 LiDAR** **4-5 years**	For inland waterway navigation channel maintenance in TVA's area of responsibility. This Functional Activity overlaps with Business Use #14, Flood Risk Management.	***Operational Benefits***: Accurate and up-to-date topographic and bathymetric data are needed to enable the TVA to make better decisions regarding a variety of navigation projects in TVA's area of responsibility.
		$ Benefits: Previously credited to Business Use #14.
		Customer Service Benefits: Major
		Public/Social Benefits: Moderate
		Environmental Benefits: Minor
		Strategic/Political Benefits: Moderate
U.S. Virgin Islands **Functional Activity** **QL2 LiDAR: 1** **Event driven**	For government programs in the U.S. Virgin Islands, budgeted at $1 M/year.	***Operational Benefits***: Enhanced elevation data will enable the U.S. Virgin Islands to develop an ocean observing capability.
		$ Benefits: Dollar benefits could not be estimated for this Functional Activity. None of the 50 states chose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.

Dollar Benefits for BU#19

From Table E.19, the conservatively estimated dollar benefits for BU#19 equal $0/year.

These BU#19 benefits are <u>understated</u> for the following reasons:

- <u>Federal Level</u>: Nautical charts are often less accurate than mariners expect them to be.
    - It is impossible to place a value on accurate charting of previously unidentified "Dangers to Navigation (DTON)" in navigable waters that could cause ships to run aground or lack necessary clearance from bridges or overhead cables, for example.
    - It is impossible to place a value on the correction of "significant differences" in prior navigation charts regarding the location of navigation aids, coastlines, wharfs, jetties and seawalls.
    - The true value of accurate nautical charts is unrecognized until nautical accidents occur.
- <u>State Level</u>: Considering all of their Departments and agencies, each state was asked to identify only their top 5-6 Functional Activities wit*h mission-critical* requirements for enhanced elevation data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. No state chose BU#19, perhaps leaving this to USACE, NOAA and JALBTCX to address state needs for marine navigation and safety.

- Local and Tribal Government Levels: No local or Tribal government requirements were received for this Business Use, though it is certain that coastal counties will benefit from topographic/bathymetric data.
- Other Organizations (Not-For-Profit and Private Companies): Outside of government agencies, no input was received for this Business Use.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#19 remain at $0/year.

BU#20 – Aviation Navigation and Safety

Scope of BU#20

Business Use #20 is defined in terms of Functional Activities that promote safe terminal and enroute aerial navigation and commerce. The Federal Aviation Administration (FAA) is the champion for the use of enhanced elevation data to satisfy requirements for this Business Use.

Background Information

The FAA, supported by the National Geodetic Survey (NGS), utilizes LiDAR data for preparation of aeronautical surveys, Airport Obstruction Charts (AOCs) and related products used in development of instrument approach and departure procedures at airfields. With examples at Figure E.20, LiDAR DSMs are ideal for digital airspace obstruction analysis, which includes modeling the mathematical airspace surfaces defined by FAA FAR Part 77 that depicts airspaces surrounding and emanating from airports. These include (1) approach and departure surfaces, (2) transitional zones, (3) primary zones, and (4) horizontal surfaces above the airport; these surfaces must be free of trees, towers, and other obstructions. High-density LiDAR is used to detect potential obstacles that penetrate Obstruction Identification Surfaces (OISs), as shown at Figure E.20 (left). AOCs are graphics that depict OISs as well as aircraft movement and apron areas, navigational aids, prominent airport buildings, and a selection of roads and other planimetric detail in the airport vicinity; also included are tabulations of runway and other operational data. Figure E.20 (right) shows a flight simulator used in Alaska where there is a major initiative to reduce Controlled Flight Into Terrain (CFIT) accidents caused by dangerous flying conditions where elevation data from the NED are unacceptable.

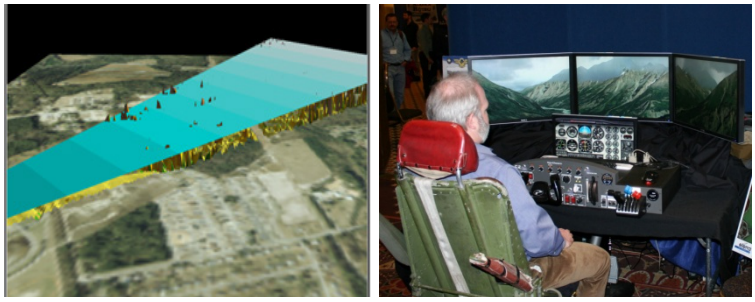

Figure E.20. LiDAR is used to detect potential obstacles that present hazards to air navigation and safety. Left image courtesy of Fugro EarthData; right image, courtesy of e-Terra, shows a flight simulator in Alaska where IFSAR is required to reduce Controlled Flight Into Terrain (CFIT) accidents.

Many education/training programs use 3-D simulations of the terrain for diverse purposes. Flight simulators are probably the best known, and they are needed in Alaska more than anywhere else.

Alaska is a larger landmass than all of central Europe, and 82% of its villages have no connection to the national road system. In nearly 600,000 square miles of Alaska's land there are less than 5,000 miles of roads, and only one single-track railroad-line. All commerce and essential services, all personal transportation with these villages, is done by airplanes. These are mostly small, piston-engine airplanes that are not pressurized and cannot go into known icing conditions. With these and other factors, they cannot reasonably fly straight over the mountains (up to 20,000 feet high in Alaska). Instead, the planes fly through mountain passes and they cannot use Instrument Flight Rule IFR-airways or radio-navigation while doing that. These tools work only for turbine aircraft such as airliners flying high over the terrain. Alaska in general has not been mapped accurately enough in 3-D to use GPS for terrain avoidance. With

weather such as icing and clouds above the mountain passes, a flight through a pass is like flying through a tunnel that has numerous dendritic dead end junctions. One wrong turn can lead into a dead-end box canyon, too narrow to turn around in and too steep to climb out of. Due to all these factors Alaska's pilots require different skill sets than pilots elsewhere. Most flight-training in the USA is done with Common Flight Simulators made to simulate IFR conditions and aircraft system failures. They are made to train the turbine-engine-airline-IFR environment (high above all terrain and weather). In harsh contrast, aircraft simulators for Alaska are made to simulate Alaska's unforgiving mountains and passes in photo-realism and harsh weather conditions that too-often lead to Controlled Flight Into Terrain (CFIT) accidents. Simulators, such as shown at Figure E.20 (right), require elevation data draped with imagery. In a sense of "look-before-you-fly," Alaska's pilots learn their way through the mountains in the simulator and gain experience easily that otherwise would require a steep learning curve.

Summary of Requirements and Benefits

Table E.20 lists Functional Activities, pertaining to Aviation Navigation and Safety, with mission-critical requirements for enhanced elevation data. FAA and its stakeholders are *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Stakeholders of FAA products and services include air traffic controllers; airport authorities; carriers; shippers; foreign, state and local governments; aerospace manufacturers; military aviation; commercial space launch companies; and others such as the National Transportation Safety Board (NTSB), OMB and Congress. Each Functional Activity is explained in detail in Appendices B, C and D.

Table E.20. Elevation Data Requirements and Benefits for BU#20, Aviation Navigation and Safety

Geo-enabled User & Functional Activity **Quality Level (QL)** **Update Frequency**	**Summary of BU#20 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.**	**Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.**
FAA **Terminal Instrument Procedure Development** **QL1 LiDAR for thousands of airfields** **4-5 years**	For development of aviation instrument approach and departure procedures, to include hardcopy and digital Visual Flight Rule (VFR) and Instrument Flight Rule (IFR) charts, for safe navigation around or above obstacles near airfields.	***Operational Benefits***: Accurate and high-density LiDAR data of airfields will enable the FAA to experience major database improvements that would allow the obstacle database to become eTOD (Electronic Terrain and Obstacle Database) compliant while saving considerable time and costs in field surveys and research. FAA products that rely on elevation data are downloaded from an FAA web site approximately 60,000 times per week.
		$ Benefits: $12M/year savings for the FAA; plus $10M/year for other Federal/state/local governmental organizations, airport authorities, and other stakeholders.
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Major
FAA **Enroute Instrument**	For development of enroute instrument procedures as required to	***Operational Benefits***: Airborne IFSAR data will enable the FAA to standardize DEM datasets for terrain verification, and expedite production of more-accurate Minimum Safe

Procedure Development **QL5 IFSAR** **4-5 years**	meet DEM accuracy requirements called for in ICAO (International Civil Aviation Organization) Annex 15 for Area 2.	Altitude Warning (MSAW) and General Terrain Monitor (GTM) maps.
		$ Benefits: Cannot estimate the value of safer enroute navigation.
		Customer Service Benefits: Major
		Public/Social Benefits: Moderate
		Environmental Benefits: Major
		Strategic/Political Benefits: Major
4 State **Functional Activities** **QL1 LiDAR: 2** **QL2 LiDAR: 1** **QL5 IFSAR: 1** **Variable update frequencies**	For government programs in AK (2), DE and WI, budgeted at $103 million in 2011.	***Operational Benefits***: Enhanced elevation data will enable these state governments to map airport obstructions and improve aviation safety, providing benefits to the public.
		$ Benefits: State dollar benefits could not be estimated for any of these Functional Activities, but estimated $10M/year in benefits for others in Alaska. Forty seven states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.
E-Terra LLC **Alaska Aviation Safety Project** **QL5 IFSAR of Alaska** **>10 years**	For enroute instrument procedures including Capstone navigation and terrain awareness avionics; ICAO Area 2 compliance for terminal safety approaching over 1000 (mostly very small) airfields in Alaska; aircraft search, rescue and recovery operations; and realistic flight simulators for training pilots on the harsh realities of flight in Alaska.	***Operational Benefits***: Avoid loss of life (valued at $2M each); avoid costs of search and rescue operations that cost multiple millions per incident.
		$ Benefits: $3M/year to $24M/year
		Customer Service Benefits: Reduce aviation accidents from pilots not knowing where they are located relative to the terrain; aviation accidents in Alaska 2000-2009: 1186 aviation accidents, 107 fatal crashes, resulting in 236 fatalities. Save approximately half of 23 lives lost per year.
		Public/Social Benefits: Major public service when accurate elevation data are available to support Capstone navigation and terrain awareness avionics.
		Environmental Benefits: None
		Strategic/Political Benefits: Moderate

Dollar Benefits for BU#20

From Table E.20, the conservatively estimated dollar benefits for BU#20 equal $35M/year.

These BU#20 benefits are probably understated for the following reasons:

- Federal Level: It is impossible to place a dollar value on the U.S. becoming fully compliant with aviation safety requirements of the FAA and/or the International Civil Aviation Organization (ICAO), especially in Alaska where there are a high rate of incidents of Controlled Flight Into Terrain.
- State Level: Considering all of their Departments and agencies, each state was asked to identify only their top 5-6 Functional Activities wit*h mission-critical* requirements for enhanced elevation data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. Only AK, DE and WI identified this as a priority, and this is a major priority for Alaska which suffers a high rate of accidents caused by Controlled Flight Into Terrain where the pilot may know exactly where his/her aircraft is located, but does not know where the

mountains are because they are currently so poorly mapped. Alaska did already indicate $10M/year in benefits.

- Local and Tribal Government Levels: No local or Tribal government requirements were received for this Business Use which is seen as a Federal or state issue.
- Other Organizations (Not-For-Profit and Private Companies): In Appendix D, e-Terra provided a range of benefits from $3M/year to $24M/year. For the conservative estimate, $3M/year was used; for the potential benefits, $24M/year was used.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#20 equal approximately $56M/year.

BU#21 – Infrastructure and Construction Management

Scope of BU#21

Business Use #21 is defined in terms of Functional Activities that support all forms of infrastructure and construction management needs of Federal, state, local and Tribal governments, not-for-profits, private industry and individuals. As used herein, *infrastructure* consists of the basic physical structures or systems needed for the operation of a society or enterprise. There is no clear champion for this Business Use because no one organization is responsible for management, nationwide, of water, sewer, telephone and electric utilities; buildings, roads, railroads, dams, reservoirs, and levees, for example. Furthermore, no one organization is responsible for management of construction projects that could extend from a major U.S. Army Corps of Engineers project to a private landowner wanting to improve drainage on his/her property. Infrastructure and construction projects are ubiquitous – present nearly everywhere.

Background Information

Nationwide, accurate topographic survey data from LiDAR have become mission-critical in support of infrastructure and construction management. Here's why:

- Infrastructure projects such as water and sewer projects, reservoirs, dams, levees and seawalls, require accurate topographic data.
- Construction projects, especially those that include earth-moving, require accurate topographic data to solve drainage issues, to estimate cut and fill requirements, and to develop preliminary construction plans and design grades.
- Complex hydrologic models, or simple assessments of "where water will go," are *killer-apps* for LiDAR.
- When LiDAR data are readily available, the needs for traditional topographic land surveys are minimized at great cost savings to the public.
- Modern earth-moving equipment (dozers, scrapers, graders) utilize GPS machine control guidance systems that have tolerances as small as 2-3 centimeters, making them extremely accurate in achieving design grades compared to relying on the operator's skill level. Because the machine's GPS system knows when it is off the design grade determined from LiDAR data rather than traditional construction surveys, this reduces time and costs. Indeed, the LiDAR data, used for determining design grades, often eliminates the requirement for construction stake-out surveys that construction machine operators traditionally used for visual reference.
- The engineering and surveying contractor that for several decades has performed site facility management for a single DOE facility, the Oak Ridge National Laboratory (ORNL), indicates that LiDAR data would save an estimated $560,000 annually for the ORNL alone, with estimated savings between 20% and 75% of facility management costs for other government facilities. When considering that there are thousands of Federal, state, local and Tribal government facilities nationwide, the availability of LiDAR data could save hundreds of millions of dollars annually for U.S. taxpayers.

The North American Electric Reliability Corporation (NERC) regulates the *bulk power system*, the facilities and control systems necessary for operating an interconnected electric energy supply and transmission network, including over 450,000 miles of bulk transmission lines but excluding smaller lines used for local distribution of electricity. Without specifically requiring LiDAR, NERC standards are commonly interpreted to endorse the use of airborne LiDAR for: (1) *line rating*, based on actual field conditions that determine changes in power line catenaries due to thermal and mechanical loads, and (2) *transmission line vegetation management*, based on monitoring of transmission line vegetation clearance to proactively prevent line-vegetation arcs and subsequent cascade system failures. NERC Standard FAC-003-2, Requirement 7, states: "Each Transmission Owner shall execute a flexible annual vegetation work plan to ensure no vegetation encroachments occur within the MVCD (Minimum Vegetation Clearance Distance)." Satisfied most cost-effectively with LiDAR, Lewis Graham of GeoCue estimates this would cost $675M/year for America's electric utility companies and consumers who pay their electric bills. These costs would be greatly reduced whenever there is a fresh collect of nationwide LiDAR for individual areas. The Tennessee Valley Authority (TVA) alone estimates that it would save $600,000/year from such LiDAR. For LiDAR surveys of bulk transmission lines, the acquisition date and time for each flightline must be available so that operators can reconstruct the ambient temperature and power line loading at the time the LiDAR was acquired because these factors all impact the transmission line sag which is compared with the designed sag.

The three parts of Figure E.21 (courtesy of Earth Eye LLC) show where aerial surveys with LiDAR are cost effective for reducing transmission outages caused by vegetation. NERC tracks vegetation-related transmission outage in three categories: (1) *Category 1 – Grow-ins*: Outages caused by vegetation growing into lines from vegetation inside and/or outside of the ROW; (2) *Category 2 – Fall-ins*: Outages caused by vegetation falling into lines from inside the ROW; and (3) *Category 3 – Fall-ins*: Outages caused by vegetation falling into lines from outside the ROW. The blue and red areas in the two right images identify vegetation inside and outside the ROW that encroach within the MVCD.

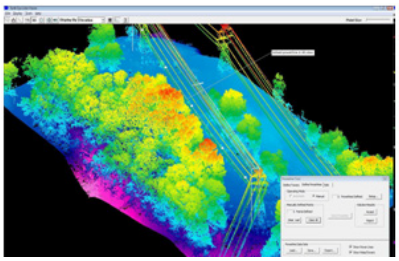

Figure E.21 (left). LiDAR best for aerial mapping of transmission lines and accurate measurement of catenaries

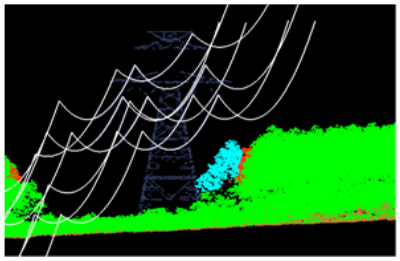

Figure E.21 (center). PLS-CADD used for identification of "grow in" and "fall in" candidates.

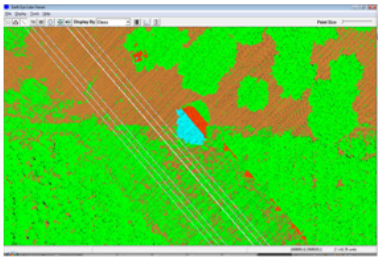

Figure E.21 (right). "Grow in" and "fall in" areas mapped for field crews.

Summary of Requirements and Benefits

Table E.21 lists Functional Activities, pertaining to Infrastructure and Construction Management, with mission-critical requirements for enhanced elevation data. They are each *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity is explained in detail in Appendices B, C and D.

Table E.21. Elevation Data Requirements and Benefits for BU#21, Infrastructure and Construction Management

Geo-enabled User & Functional Activity Quality Level (QL) Update Frequency	Summary of BU#21 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.	Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.
USACE Infrastructure and Construction Management **QL1 LiDAR** **6-10 years**	QL1 LiDAR is required of Army and Air Force installations for planning, feasibility studies and benefit/cost ratios to decide if projects should receive funding and proceed to construction phases. Land surveys are still required for final construction design and stakeout.	***Operational Benefits***: LiDAR data, available in advance, will enable USACE to typically reduce design schedules by 20%, which in turn saves significant costs. LiDAR topographic surveys are ideal for project planning, preliminary design of drainage features, cut and fill calculations, tree removal estimates, and cost estimation. LiDAR often eliminates topographic survey costs in the planning stages of construction projects.
		$ Benefits: When assuming a conservative 1% savings as a result of having LiDAR data already available for planning, estimating of cut and fill and tree removal, and drainage design, the savings amount to $15.58M/year.
		Customer Service Benefits: Major
		Public/Social Benefits: Moderate
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Moderate
DISDI **Defense Installation Geospatial Information and Services** **QL2 of cantonment areas; QL3 of other areas on military installations/sites** **6-10 years**	For effective and efficient management of installations and the environment for 480 DoD sites and installations. These responsibilities impact 22 of the 27 Business Uses considered for the National Enhanced Elevation Assessment.	***Operational Benefits***: LiDAR data will enable the DISDI Community of Interest (DoD installations/sites) to manage their infrastructure and comply with extensive environmental regulations that pertain throughout DoD.
		$ Benefits: $35M/year to $45M/year
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Major
USFS **Infrastructure Management** **QL1 LiDAR;** **QL5 IFSAR for Alaska** **4-5 years**	For design and placement of infrastructure (e.g., roads, trails, culverts, buildings, outhouses, campgrounds, fish passages, etc.) on USFS lands.	***Operational Benefits***: The availability of high accuracy elevation products will reduce the amount of time presently consumed by resource specialists to manually compute and assess topographic conditions to use in assessing appropriate structure design and logistics of design implementation. The amount of necessary field survey will be reduced, while a higher accuracy of estimates for these resource conditions based on topographic mapping will be realized. One engineer estimated that he could have saved a month's worth of his time if he had a LiDAR survey instead of a ground based survey in a particular watershed he was working on. That equates to a salary savings of $8,000 for one person on one project.
		$ Benefits: $10M/year

		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Minor
		Strategic/Political Benefits: Moderate
DOE **Site Facility Management** **QL3 LiDAR** **4-5 years**	For accurate topographic mapping, evaluation of drainage, vegetation, infrastructure and environmental management, site cleanup and remediation.	***Operational Benefits***: LiDAR data will enable DOE facility managers to avoid the need for expensive land surveys and save considerable time otherwise lost in searching for piecemealed information from multiple non-authoritative sources.
		$ Benefits: Efficiency improvements between 20% and 75%, with estimated savings of $560,000/year for the Oak Ridge National Laboratory alone.
		Customer Service Benefits: Unknown
		Public/Social Benefits: Minor
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Minor
TVA **Power Generation, Transmission Line and Vegetation Management** **QL1 LiDAR** **2-3 years**	For planning of new power generating facilities and transmission lines, site development, transmission line vegetation management, transmission line uprate studies, and studies of risks to power plants and substations, e.g., Kingston Ash Spill failure or similar fossil, hydro, or nuclear emergencies.	***Operational Benefits***: LiDAR data will enable the TVA to comply with NERC regulations to improve vegetation management, and rating, uprating or reconductoring decisions; reduce operational costs; restore facilities following tornado damages; and make better decisions for planning and management of power generating facilities and transmission lines.
		$ Benefits: $600,000/year
		Customer Service Benefits: Moderate
		Public/Social Benefits: Moderate
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Moderate
40 State **Functional Activities** **QL1 LiDAR: 13** **QL2 LiDAR: 12** **QL3 LiDAR: 15** **Variable update frequencies**	For government programs in AL, AZ, CA, CO, FL, HI (2), IA (4), ID, IL, IN, KS, KY (2) , LA, MA, MI, MO (2) , MN, MS, MT, NC, ND, NM, NY, OH, OK, OR, SD, TN, TX, VT, WI, and WV (2), budgeted at $26.9 billion in 2011. Note: some states have more than one Functional Activity for this Business Use.	***Operational Benefits***: Enhanced elevation data will enable these state governments to be more efficient and/or effective in managing their infrastructure and construction projects while providing added dollar benefits to the public.
		$ Benefits: $92.754M/year state government benefits plus $16.91M/year in benefits for others. A total of 19 State FAs included estimated $ benefits. Eighteen states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.
11 County **Functional Activities** **QL1 LiDAR: 1** **QL2 LiDAR: 2** **QL3 LiDAR: 8** **Variable update frequencies**	For county infrastructure and construction management services in 11 counties, budgeted at $62.7 million in 2011.	***Operational Benefits***: LiDAR data will enable these 11 county governments to modernize their county engineering services that include stormwater management, site planning, land base maintenance, road construction planning and maintenance.
		$ Benefits: $512,000/year county government benefits plus $30,000/year in benefits for others.
5 Regional	For infrastructure planning projects for 5 regional	***Operational Benefits***: LiDAR data will enable basemap maintenance, transportation planning, stormwater

Functional Activities **QL1 LiDAR: 2** **QL2 LiDAR: 2** **QL3 LiDAR: 1** **Variable update frequencies**	governments in PA, NM, OK, KY and WV, budgeted at $22.3 million in 2011.	modeling and utility infrastructure management. ***$ Benefits***: $1.315M/year regional government benefits and $1M/year in benefits to others.
6 City **Functional Activities** **QL1 LiDAR: 2** **QL3 LiDAR: 4** **Variable update frequencies**	For the cities of Springfield, OR; Olympia, WA; Farmington, NM; and the towns of York, ME and South Kingstown, RI to perform public works, technical services (GIS, GPS surveys), engineering, transportation, and environmental services with program budgets totaling $138 million in 2011.	***Operational Benefits***: LiDAR data will enable these cities to perform efficient wastewater and stormwater infrastructure design, design of roads and drainage networks, stormwater mapping and modeling for low impact development analysis, and all forms of capital improvements. The 3-D spatial data infrastructure is currently not available to most cities for execution of their most basic physical infrastructure and construction management responsibilities. ***$ Benefits***: $2.81M/year in city government benefits plus $1.74M/year benefits for citizens of these cities
Duquesne Light Company **Transmission Line Vegetation Clearance** **QL1 LiDAR** **4-5 years, though preferred annually**	For comparing actual line sags with design sags; for vegetation clearance on transmission lines; and for identification of ROW encroachments.	***Operational Benefits***: LiDAR data will enable Duquesne to determine if actual sags vary from design stage; to maintain vegetation clearance, and identify ROW encroachments. Other electric utility companies will have similar benefits. ***$ Benefits***: Only 1/10th, or $67.5M/year, of the $675M/year nationwide benefits estimated by Lewis Graham are used for the conservative estimate of cost savings because of uncertainties in the cost estimation parameters used. ***Customer Service Benefits***: Minor ***Public/Social Benefits***: None ***Environmental Benefits***: None ***Strategic/Political Benefits***: Major

Dollar Benefits for BU#21

From Table E.21, the conservatively estimated dollar benefits for BU#21 equal $206.212M/year.

These BU#21 benefits are probably understated for the following reasons:

- Federal Level: DISDI provided a range of $35M - $45M/year; $35M/year was used for the conservative estimate. Furthermore, the Facility Manager for the Oak Ridge National Laboratory (ORNL) estimates $560,000/year benefits to the ORNL alone in not having to repeatedly hire land surveyors to perform topographic surveys for diverse infrastructure management and construction planning tasks. The benefits to this one government facility should be multiplied at least 100 times to count savings for other governmental and civil Facility Managers nationwide, outside of DISDI. The GSA dataset of 2007, for example, includes records for 11,740 GSA facilities, many of which would benefit in ways similar to those of the ORNL Facility Manager. In addition to the $10M/year additional potential benefits for DISDI, the potential additional

benefits to other governmental and civil Facility Managers is estimated at 100 x $560,000 = $56M/year.

- State Level: Considering all of their Departments and agencies, each state was asked to identify only their top 5-6 Functional Activities wit*h mission-critical* requirements for enhanced elevation data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. Under BU#21, thirty two states identified 40 Functional Activities for which 21 of 40 were unable to estimate dollar benefits. The 19 state Functional Activities with conservatively estimated benefits of $92.754M/year for state government benefits plus $16.910M/year for others were further estimated to have potential benefits that are 50% higher than the above, i.e., total potential benefits of $139.131M/year for the states plus $25.365M/year potential benefits for others.
- Local and Tribal Government Levels: Virtually every local and Tribal government that manages land areas, infrastructure or construction projects, and thousands of not-for-profits, private companies and individuals managing their own properties, infrastructure or construction projects, could experience the types of benefits summarized above. The OpenTopography Portal (OTP), that provides LiDAR point cloud data (where available) to the public, reports that land surveyors are the major users who download LiDAR point cloud data from the OTP. This is proof that land surveyors recognize the value of LiDAR for commonly-used topographic surveys required for preliminary design, drainage design, cut and fill estimates, etc.
- Other Organizations (Not-For-Profit and Private Companies): The estimated NERC benefits were discounted from $675M/year to $67.5M/year for the conservative estimate above. The full potential benefits of $675M/year are restored. Only 10%, or $67.55M/year, of the $675M/year nationwide benefits estimated by Lewis Graham are used for the conservative estimate of cost savings because of uncertainties in the cost estimation parameters and assumptions used.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#21 equal approximately $941.951M/year.

BU#22 – Urban and Regional Planning

Scope of BU#22

Business Use #22 is defined in terms of Functional Activities that support diverse forms of urban and regional planning and development. There is no nationwide champion for this Business Use.

Background Information

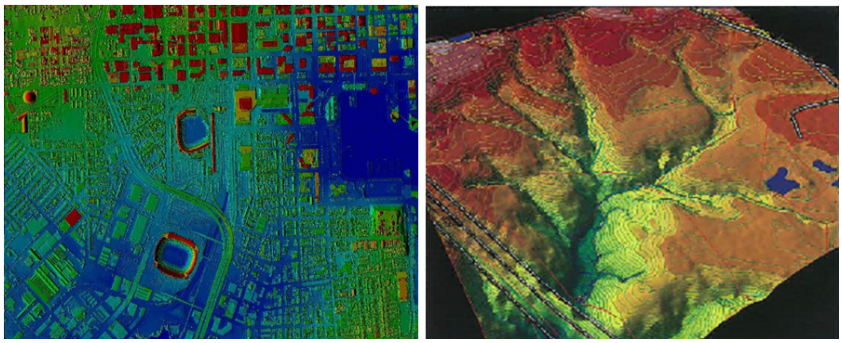

Figure E.22. The left image is a color-coded LiDAR 3-D model of Baltimore, Maryland, used for urban planning; image courtesy of the Army Geospatial Center. The right image shows a 150-acre site under consideration for development in Richland County, SC where LiDAR saved the county $140,000 for a traditional topographic survey; image courtesy of ESRI.

Elevation data are critical in urban and regional planning, often because of the need to address potential drainage issues when considering sites for future development. Figure E.22 (left) shows color-coded elevations in Baltimore, MD where the brightest blue shows the lowest elevations and the brightest red shows the highest elevations. Figure E.22 (right) shows a potential economic development site in Richland County, SC, where a technology company had narrowed its search for a billion dollar production facility to two locations and asked the county to pay $140,000 for a topographic survey to assess the elevation, slope, and drainage characteristics prior to making a site selection. Because the county already had LiDAR data of the area, slope, aspect, shading, two-foot contours, and potential drainage were all calculated from the LiDAR data and provided to the client within 24 hours, saving the county $140,000. This example was documented in "Measuring Up: The Business Case for GIS," published in 2004 by the ESRI Press. In Table E.22, 13 counties, 18 regions and 5 cities documented their benefits of LiDAR for urban and regional planning.

Summary of Requirements and Benefits

Table E.22 lists Functional Activities, pertaining to Urban and Regional Planning, with mission-critical requirements for enhanced elevation data. All communities nationwide are *geo-enabled* with enhanced elevation data required for effective urban and regional management. See Appendix C for further details.

Table E.22. Elevation Data Requirements and Benefits for BU#22, Urban and Regional Planning

Geo-enabled User & Functional Activity Quality Level (QL) Update Frequency	Summary of BU#22 Mission-Critical Requirements for Enhanced Elevation Data. See Appendix C for details.	Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.
15 State + 2 PR	For government programs in AZ, CA (2), GA, HI, IL,	***Operational Benefits***: Enhanced elevation data will enable state governments to be more efficient and/or effective in

Functional Activities **QL1 LiDAR: 3** **QL2 LiDAR: 5** **QL3 LiDAR: 8** **QL4 Image DEMs: 1** **Variable update frequencies**	MA, MD, MO (2), MS, OR (2), TN, VA, and Puerto Rico (2), budgeted at $31 million in 2011. Note: some states have more than one Functional Activity for this Business Use.	executing responsibilities for urban and regional planning while providing added dollar benefits to the public. ***$ Benefits***: $3.805M/year state government benefits plus $567,500/year in benefits for others. A total of 8 State FAs included estimated $ benefits. Thirty eight states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.
13 County **Functional Activities** **QL1 LiDAR: 4** **QL2 LiDAR: 5** **QL3 LiDAR: 4** **Variable update frequencies**	For urban and regional planning activities in 13 counties, budgeted at $20.4 million in 2011.	***Operational Benefits***: LiDAR data will enable these 13 county governments to develop comprehensive plans for land development and zoning, develop parcel slope models for subdivision runoff, perform climate change adaptation planning, perform proposed cellular structure viewshed analysis, rectify imagery for production of digital orthophotos, and perform municipal mapping of building footprints and impervious surfaces. ***$ Benefits***: $353,000/year county government benefits plus $400,000/year in benefits for others.
18 Regional **Functional Activities** **QL1 LiDAR: 4** **QL2 LiDAR: 5** **QL3 LiDAR: 8** **QL5 IFSAR: 1** **Variable update frequencies**	For community planning for 18 regional governments in ME, WA, NV, OK, AR, GA, VT, CO, IL, AK, MD, TX, VA, ND and SD, budgeted at $40 million in 2011.	***Operational Benefits***: LiDAR data will enable all forms of GIS/GPS services, comprehensive planning, transportation planning, land use planning, land development design, municipal government operations, and suitability analyses. ***$ Benefits***: $1.49M/year regional government benefits plus $800,000/year in benefits to others.
5 City **Functional Activities** **QL1 LiDAR: 1** **QL2 LiDAR: 1** **QL3 LiDAR: 3** **Variable update frequencies**	For Salt Lake City, UT; Sandy City, UT and the cities of Austin, TX; Minot, ND; and Lansing, MI to perform urban and regional planning activities with program budgets totaling $3 million in 2011.	***Operational Benefits***: LiDAR data will enable these cities to extract building footprints and tree crowns and develop 3-D models for planning and for parks users; perform land development preliminary design; and develop land use and transportation plans – all simple tasks that cannot currently be performed without LiDAR data. ***$ Benefits***: Unable to estimate dollar benefits.

Dollar Benefits for BU#22

From Table E.22, the conservatively estimated dollar benefits for BU#22 equal $4.197M/year.

These BU#19 benefits are probably understated for the following reasons:

- Federal Level: BLM, NPS, FWS, and USFS are among the Federal agencies that manage large land holdings, and presumably perform some form of urban and regional planning, but none documented *mission-critical* requirements for BU#22, apparently considering this as *non-mission-critical* or a Business Use more relevant to state and local governmental agencies.
- State Level: Considering all of their Departments and agencies, each state was asked to identify only their top 5-6 Functional Activities wit*h mission-critical* requirements for enhanced elevation

data. This meant that lower value Functional Activities within most of the 27 Business Uses were not reported. For BU#19, 12 states plus Puerto Rico documented 17 Functional Activities for which 9 of 17 were unable to estimate dollar benefits. The eight states that did estimate their benefits for BU#22 identified savings of $3.805M/year state government benefits plus $0.567M/year in benefits to others. When taking all 50 states into account, the potential benefits were doubled, equaling total potential benefits of $7.61M/year for the states and $1.134M/year for others.

- Local and Tribal Government Levels: ESRI's example, above, saving $140,000 for Richland County, SC, pertained to only one small project in one community. Similar savings would be routinely realized by thousands of communities annually if LiDAR datasets were available nationwide. In Table, E.22, 13 counties estimated benefits of $753,000/year, averaging $57,923/year per county; and 18 regions estimated benefits of $2.29M/year, averaging $127,222/year per region. The five cities were unable to estimate their cost savings. If we assumed 3,000 counties/parishes/boroughs in the U.S. could use publicly-available LiDAR data to annually avoid just one small topographic survey costing $20,000, this alone would collectively save those communities a total of $60M/year.
- Other Organizations (Not-For-Profit and Private Companies): No additional potential benefits were identified for this Business Use.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#22 equal approximately $68.569M/year.

BU#23 – Health and Human Services

Scope of BU#23

Business Use #23 is defined in terms of Functional Activities that identify unhealthy environments, improve air quality, mitigate the spread of diseases and contaminants, and promote occupational health and safety. Within the Department of Health and Human Services (HHS), the Centers for Disease Control (CDC) serve as the nationwide champion for this Business Use. LiDAR and IFSAR data enable the CDC to respond to public health emergencies with the best available 3-D geospatial data needed to assess conditions that caused the emergency and/or to respond decisively with corrective actions.

Background Information

Vectors are agents that spread disease, e.g., ticks, mosquitoes, flies, animals, humans, and birds (West Nile disease). Whereas both LiDAR and IFSAR have value for mapping of specific habitats, LiDAR is especially effective in mapping the structure of forests, vegetation and wildlife habitat. Differential LiDAR, collected in different years, enables the mapping of changes to wildlife habitat including vector habitat. Centimeter-level digital terrain model (DTM) data can be derived from LiDAR data that enable the CDC to detect fine-scale sink-holes that can hold standing water. The CDC can determine how long sink-hole water remains stagnant enough to be utilized as mosquito habitats in geographic information system (GIS) environments with LiDAR-derived fine-scale DTM, soil characteristics (e.g., water penetration rate), climatic variables such as wind direction and speed, and other potential data sets.

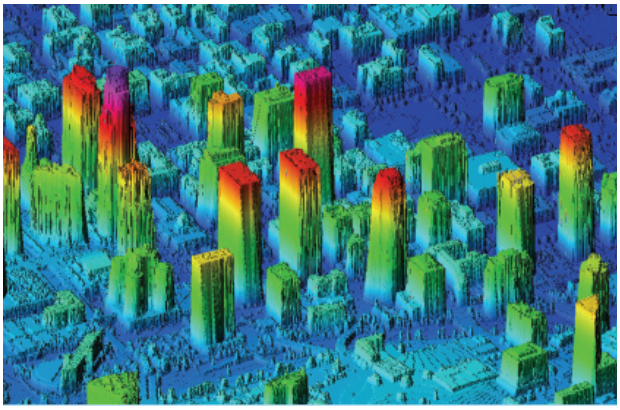

Figure E.23. A 3-D model of Los Angeles produced from LiDAR. Data can be used to model populations at risk from chemical, biological or radiological hazards; aerosols, or air-borne diseases. Image courtesy of ASPRS.

LiDAR data enable the modeling of cities and rural areas that could be subjected to chemicals from crop dusting, from smog and unclean air conditions, and/or for modeling of areas affected by accidental chemical spills or terrorist activities that could include the use of chemical, biological or radiological weapons. LiDAR provides ancillary information for extracting buildings from remote sensing imagery in a more accurate manner. Extracted buildings can be utilized to estimate population at a local scale, which in turn will be valuable input data for human exposure analysis against environmental pollution. LiDAR-driven footprints and heights of individual buildings are essential data to use in spatial epidemiology research in urbanized areas, e.g., traffic noise research. LiDAR enables the modeling of dam breaks and plans for mitigating the effects of potential breaks. LiDAR provides significant benefits for occupational safety and health by enabling many tasks to be performed in an office environment that were previously performed in the field under dangerous or unhealthful conditions. For example, the need for land surveys for highway construction projects (with numerous traffic deaths annually) is largely eliminated by the use of LiDAR surveys. Similarly, the need for on-site visits and collection of sample data for

environment-related activities is often replaced by the use of LiDAR and other forms of remote sensing, reducing human exposure to field hazards.

As previously explained for Business Use #17, Homeland Security, Law Enforcement and Disaster Response, the LandScan USA program uses LiDAR data to model buildings in 3-D and to estimate dynamic populations at risk during different hours of each day.

Figure E.23 shows a color-coded 3-D model of Los Angeles, produced from LiDAR data. Such models are used for multiple purposes. One such purpose is to model the potential spread of aerosols as a function of variable wind speeds and directions. This could be invaluable during a potential health threat from a natural or terrorist-caused disaster.

Summary of Requirements and Benefits

Table E.23 lists Functional Activities, pertaining to Health and Human Services, with mission-critical requirements for enhanced elevation data. They are each *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity is explained in detail in Appendices B and C.

Table E.23. Elevation Data Requirements and Benefits for BU#23, Health and Human Services

Geo-enabled User & Functional Activity **Quality Level (QL)** **Update Frequency**	**Summary of BU#23 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.**	**Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.**
CDC **Human, Animal and Environmental Health** **QL3 LiDAR, plus IFSAR for Alaska** **6-10 years**	For health emergency response activities, environmental modeling, vector habitat modeling, and disease prevention planning. For public health and safety that enables workers in diverse occupations to perform their jobs in a safe office environment rather than under hazardous and unhealthful field conditions.	***Operational Benefits***: Enhanced elevation data will enable the CDC to respond to public health emergencies with the best 3-D geospatial technologies, to map specific vector habitats, and to model cities and rural areas subjected to harmful conditions from chemicals and terrorist activity.
		$ Benefits: Unable to estimate
		Customer Service Benefits: Moderate
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Moderate
CDC **Waterborne Disease Prevention** **Satellite Differential InSAR (DInSAR)** **6-10 years**	For prevention of waterborne diseases, to include health emergency response activities, environmental modeling, and vector habitat modeling.	***Operational Benefits***: Repeat pass satellite DInSAR data will enable the CDC to respond to public health emergencies pertaining to waterborne diseases and to specifically identify standing water and changes to water surface elevations that create breeding grounds for mosquitoes and other vectors that spread disease.
		$ Benefits: Unable to estimate
		Customer Service Benefits: Moderate
		Public/Social Benefits: Major

		Environmental Benefits: Major
		Strategic/Political Benefits: Moderate
EPA **Broad Area Air and Water Quality Research** **QL5 IFSAR** **6-10 years**	QL5 IFSAR is required for EPA's broad area research projects pertaining to air and water quality, health and human services.	***Operational Benefits***: IFSAR data will enable the EPA to model parameters needed for research into air quality and health.
		$ Benefits: Previously credited to Business Use #2.
		Customer Service Benefits: Moderate
		Public/Social Benefits: Minor
		Environmental Benefits: Major
		Strategic/Political Benefits: Minor
DOE **Population Distribution and Dynamics** **QL1 LiDAR (133 Urban Areas); QL3 LiDAR elsewhere** **4-5 years**	For support of DHS' LandScan USA extraction of building footprints, heights and characteristics, to model populations at risk and emergency response to chemical, biological, or radiological hazards and/or air-borne diseases.	***Operational Benefits***: LiDAR data will enable the DOE and DHS to develop LandScan USA which models cities for the Homeland Security Information Program (HSIP) and potentially saves lives during national emergencies.
		$ Benefits: Previously credited to Business Use #17. Could potentially save thousands of lives following a terrorist attack or other emergency that involves chemical biological, radiological hazards or air-borne diseases.
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: None
		Strategic/Political Benefits: Major
1 State **Functional Activity** **QL4 Image DEM: 1** **>10 years**	For a government air quality program in Arizona, budgeted at $43 million in 2011.	***Operational Benefits***: Enhanced elevation data will enable the state of Arizona to perform air quality modeling to address pollution issues.
		$ Benefits: Dollar benefits could not be estimated for this Functional Activity. Forty nine other states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.

Dollar Benefits for BU#23

From Table E.23, the conservatively estimated dollar benefits for BU#23 equal $0/year. This is believed to be too conservative, inferring no financial benefits.

These BU#19 benefits are probably understated for the following reasons:

- Federal Level: None of the Federal agencies are able to estimate financial benefits:
  - The CDC has no way to estimate the number of lives saved annually as a result of enhanced elevation data used for human, animal and environmental health and/or waterborne disease prevention.
  - Neither DOE nor DHS is able to estimate the number of lives saved annually as a result of LiDAR used for LandScan USA extraction of building footprints, heights and characteristics, to model populations at risk and emergency response to chemical, biological, or radiological hazards and/or air-borne diseases. In the event of a terrorist attack, hundreds or thousands of lives could be saved.
  - The EPA is unable to estimate the number of lives saved annually as a result of enhanced elevation data used for air quality research.

    - If just one life was saved annually as a result of using elevation data for these programs, the nominal cost benefit would be estimated at $1M/year, based on the estimated earnings that a person would have earned by age 65 if they died at an average age
- State Level: Only one state (Arizona) identified the use of enhanced elevation data for air quality modeling, but could not estimate dollar benefits.
- Local and Tribal Government Levels: Statistics are unavailable to document the number of land surveyor lives that would be saved annually by using airborne LiDAR instead of traditional land survey procedures for surveying along dangerous highways.
- Other Organizations (Not-For-Profit and Private Companies): No input was received for this Business Use from other organizations.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#19 equal approximately $1M/year.

BU#24 – Real Estate, Banking, Mortgage, Insurance

Scope of BU#24

Business Use #24 is defined in terms of Functional Activities that identify and mitigate risks from natural disasters – risks that need to be known by home owners and business owners as well as representatives of the real estate, banking, mortgage and/or insurance industries. There is no nationwide champion for this Business Use.

Background Information

Whereas most homeowners have mandatory fire insurance, there is a greater risk of severe damage to the average home from other natural disasters than from fires. Figure E.24 graphs the major 4-fold increase in natural disasters during the past 30 years. In order for the real estate, banking, mortgage and insurance industries to properly serve American homeowners, it is important for all to recognize risks from natural disasters, and many of those risks depend on the geographic location and/or topography of the terrain on which homes are built.

In 2010 alone:

- Thunderstorms and tornadoes caused 56 fatalities, with $13.2B in estimated overall losses, of which $9.5B in losses were insured.
- Winter storms caused 64 fatalities, with $3.7B in estimated overall losses, of which $2.6B in losses were insured.
- Floods caused 68 fatalities, with $2.9B in estimated overall losses, of which $1.1B in losses were insured.
- Wildfires caused 1 fatality, with $314M in estimated overall losses, of which $210M in losses were insured.
- Earthquakes caused no fatalities, but caused $200M in estimated overall losses of which $128M in losses were insured.
- Hurricanes caused 8 fatalities, caused $200M in estimated overall losses of which $120M in losses were insured. (2010 was an unusually light year for hurricanes.)

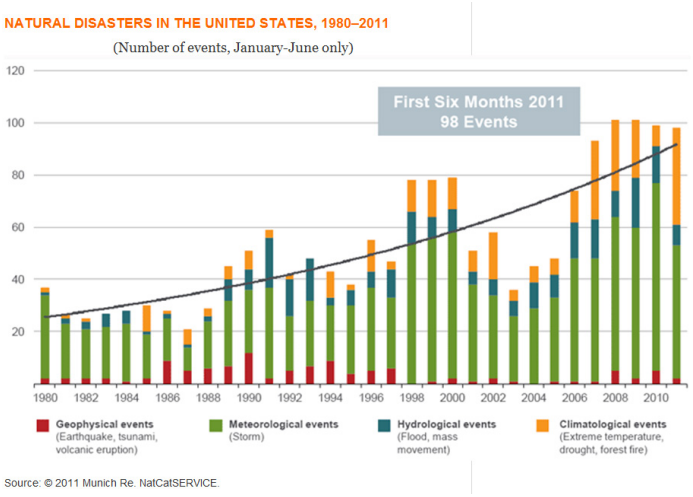

Figure E.24. Since 1980, the U.S. has experienced a 4-fold increase in natural disasters from geophysical, meteorological, hydrological and climatological events. LiDAR data is commonly used to identify and/or analyze risks from such hazards. Image courtesy of Munich Re.

Hurricanes normally cause the greatest losses, with Hurricane Katrina in 2005 having insured losses of over $45B in 2009 dollars. The 1994 earthquake in Northridge, CA, caused insured losses of $17.2B in 2009 dollars; and many areas of the U.S. are in close proximity to seismic faults that are now more-readily detectable with LiDAR.

During the first half of 2011 alone, insured catastrophe losses in the U.S. totaled $17.6B according to figures from Munich Reinsurance America, Inc. With the deadliest season in over 50 years, losses from

thunderstorms and tornadoes were over $16B, far above the 2001-2010 January-June average loss of $6.4B. During the second half of 2011, losses are still being calculated from the droughts, earthquakes and hurricanes that devastated much of the U.S.

Homeowners, bankers, and mortgage companies all need to know when properties are at elevated risk of natural disasters. Whereas fire insurance is mandatory for all, only flood insurance is mandatory for buildings in Special Flood Hazard Areas when mortgages are Federally-guaranteed. As with the flood risks, other natural hazards can also be identified and/or analyzed with LiDAR data.

Summary of Requirements and Benefits

Table E.24 lists a single Functional Activity, pertaining to Real Estate, Banking, Mortgage, Insurance, with mission-critical requirements for enhanced elevation data. All local governments could be *geo-enabled* with specialized decision-support tools that require enhanced elevation data. This Functional Activity is explained in detail in Appendix C.

Table E.24. Elevation Data Requirements and Benefits for BU#24, Real Estate, Banking, Mortgage, Insurance

Geo-enabled User & Functional Activity **Quality Level (QL)** **Update Frequency**	**Summary of BU#24 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.**	**Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.**
No Federal		No Federal agency chose BU#24 with *mission-critical* requirements for enhanced elevation data.
No State		No state chose BU#24 among their top 5-6 Business Uses and they therefore did not submit their elevation data requirements and benefits.
1 County **Functional Activity** **QL3 LiDAR: 1** **4-5 years**	For a GIS mapping program in one county in Minnesota, budgeted at $200,000 in 2011.	***Operational Benefits***: LiDAR data will enable Clay County to execute a GIS mapping project required for building permitting. ***$ Benefits***: Dollar benefits could not be estimated.

Dollar Benefits for BU#24

From Table E.24, the conservatively estimated dollar benefits for BU#24 equal $0/year.

By inferring no financial benefits, these BU#24 benefits are probably understated for the following reasons:

- Federal Level: FEMA and individual homeowners could benefit significantly if LiDAR data were used by FEMA for mass production of Letters of Map Amendment (LOMAs). FEMA processes approximately 30,000 LOMAs annually as a result of homeowners, with homes mapped within the Special Flood Hazard Area (SFHA), hiring land surveyors and paying from $500 - $750 each for Elevation Certificates to certify that their home's Lowest Adjacent Grade (LAG) is higher than the Base Flood Elevation (BFE) on FEMA's Flood Insurance Rate Maps (FIRMs). Of 30,000 LOMAs processed annually, about 63% have LAGS >1' above the BFE, and about 42% have LAGS >2'

above the BFE. If QL2 LiDAR was available nationwide, about 18,000 LOMAs/year could be avoided, saving at least $9M/year for homeowners. If QL3 LiDAR was available nationwide, about 12,600 LOMAs/year could be avoided, saving at least $6.3M/year for homeowners. This would also avoid FEMA's high costs for individual LOMA processing and would be a "win-win" for all involved. An average of $7.5M/yr was already credited to BU #14 above.

- State Level: Many states do not currently understand their threats from seismic hazards. Whereas threats from hurricanes, tsunamis, hurricanes, floods and wildfires are reasonably well understood, threats from seismic faults and earthquakes are now much more accurately modeled as a result of LiDAR. Future research is expected to one day predict tornadoes as a function of topography, wind and climate conditions.
- Local and Tribal Government Levels: Even if FEMA does not initiate the mass production of LOMAs, LiDAR data, when available to the public via the OpenTopography Portal or USGS' CLICK site for example, would help enable individual homeowners to determine whether or not it is worth the expense of hiring a land surveyor to produce the Elevation Certificates required for LOMA applications. The decision on whether or not to spend $500 to $750 dollars for an Elevation Certificate is much easier if the homeowner has strong reason to believe that his/her LOMA application will be approved. This is an excellent example of how publicly-available LiDAR data empowers individual citizens.
- Other Organizations (Not-For-Profit and Private Companies): Banks, mortgage and insurance companies are all interested in assessing risks to their real estate investments. Although flood risks have been considered for decades in determining whether flood insurance should be mandatory for Federally guaranteed mortgages, risks from other types of hazards can now also be assessed using enhanced elevation data. Dollar benefits cannot be estimated at this time.

  The real estate community was not interviewed for the National Enhanced Elevation Assessment although it is widely recognized that real estate values are often based (positively) on viewsheds and (negatively) on proximity to natural hazards. As LiDAR becomes widely available, land developers and architects will be geo-enabled to design homes to optimize scenic views and to also use elevation-based information regarding the four basic types of natural hazards to either avoid such hazards or to design buildings to mitigate the risks involved. We have no way to assess the value of enhanced elevation data for the real estate community although examples abound regarding the unwise siting of key infrastructure and individual homes in unsafe locations, especially areas of predictable flood hazards and landslide hazards.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#24 remains at $0M/year.

BU#25 – Education K-12 and Beyond

Scope of BU#25

Business Use #25 is defined in terms of Functional Activities that educate the public about the world in which they live or train them to exploit the virtual earth to solve human problems. This includes basic research in sciences that may not clearly align with any of the other Business Uses.

Background Information

> *Why are continents shaped the way they are? How and why are the continents moving; how fast are they moving? Why does the North Pole keep moving? How did the Ice Age shape today's topography? What happens when glaciers melt? How can you tell when mountains are relatively new or old? What will the land look like in the future? Why does the Earth's gravity field and magnetic field keep changing? Why does climate change cause sea level rise in most places but sea level drop in Alaska? How will the changing climate also change our lives? What can we do about it? Are humans reshaping the biosphere and physical environment, triggering potentially devastating and currently unpredictable consequences? What do I need to know about the topography, rivers and vegetation that might save lives? How can I use high resolution topographic information to my advantage? How do I acquire the topographic information I need?*

Educators start answering basic geography questions in elementary school. Visitor Centers at the National Park Service (NPS) and many other federal, state and local agencies and other not-for-profit and private companies have educational programs that address many of these questions, often with the assistance of 3-D map displays and simulators. Many of these questions deal with geodesy and geophysics taught in graduate school, often accompanied by university research programs. Understanding the size and shape of the Earth and its gravity field – or more appropriately, understanding the changing size and shape of the Earth and its changing gravity field – is necessary for answering these types of questions.

For the National Enhanced Elevation Assessment, Dewberry considered the advancement of science as part of Business Use 25. Figure E.25 identifies NASA's LiDAR Surface Topography (LIST) as one such program. The National Science Foundation (NSF) NEON project is another.

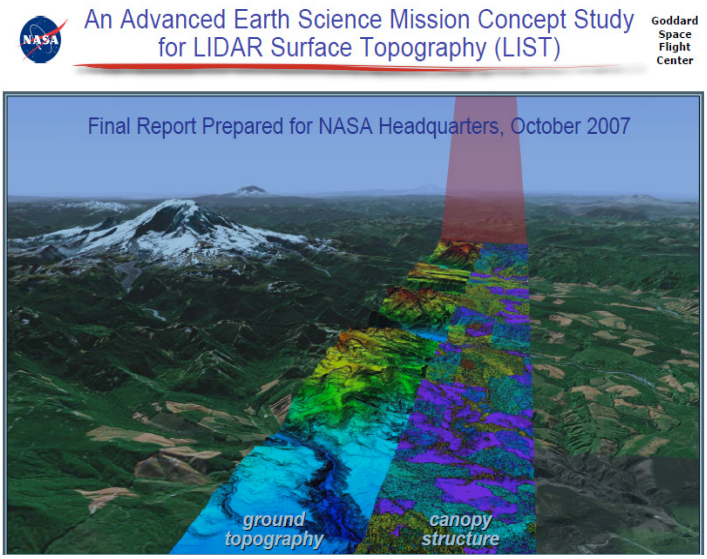

Figure E.25. NASA's satellite-based LIST project will benefit from airborne LiDAR for sensor calibration and other benefits.

For life-or-death reasons, Marines, soldiers and airmen are frequent users of simulators to educate them about the terrain on which they will train in the U.S. or operate overseas. LiDAR data are used for training of military personnel to understand different landforms, to

perform viewshed analyses, to determine line-of-sight for our weapon systems used against the enemy and line-of-sight for enemy weapon systems used against us, to position telecommunications and weapon systems for our advantage, to perform cross-country movement analyses, to assess the advantages and disadvantages of forested areas, etc. Military teaching points can be best explained when virtual battlefields include real-world elevation datasets combined with imagery.

Summary of Requirements and Benefits

Table E.25 lists Functional Activities, pertaining to Education, K-12 and Beyond, with mission-critical requirements for enhanced elevation data. Many educational and research projects would be *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity is explained in detail in Appendices B and C.

Table E.25. Elevation Data Requirements and Benefits for BU#25, Education K-12 and Beyond

Geo-enabled User & Functional Activity **Quality Level (QL)** **Update Frequency**	**Summary of BU#25 Mission-Critical Requirements for Enhanced Elevation Data. See individual Appendices for details.**	**Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.**
NSF **National Ecological Observatory Network (NEON)** **QL2 LiDAR** **4-5 years, but annually preferred**	For understanding and forecasting the impacts of climate change, land use change, and invasive species on continental-scale ecology – beyond the 60 sites monitored by NEON with their Airborne Observation Platform (AOP) LiDAR sensors.	***Operational Benefits***: Nationwide LiDAR data will enable the NSF to evaluate all U.S. territory, well beyond the relatively small areas sampled by NEON's LiDAR sensor for 60 representative sites, removing uncertainties caused by extrapolation into unknown areas.
		$ Benefits: Unable to estimate
		Customer Service Benefits: Major
		Public/Social Benefits: Unknown
		Environmental Benefits: Major
		Strategic/Political Benefits: Unknown
NASA **Advanced Earth Science Mission Support** **QL2 LiDAR** **QL5 IFSAR of Alaska** **4-5 years**	For calibration and validation of NASA sensor systems and existing datasets; and to serve as the ground topography base for comparison with re-observed canopy structure from the LIDAR Surface Topography (LIST) sensors for 4-D mapping of changing land cover. (The 4 dimensions are latitude, longitude, elevation, and time).	***Operational Benefits***: LiDAR data will enable NASA to calibrate and validate NASA sensor systems and existing datasets and to serve as the ground topography base for comparison with re-observed canopy structure from the LIST sensors for 4-D mapping of changing land cover. IFSAR data enable NASA to map the bare earth terrain in Alaska to support NASA optical sensors that cannot map through near-perpetual clouds and fog in some areas.
		$ Benefits: Cannot quantify
		Customer Service Benefits: Major.
		Public/Social Benefits: Major. The public's $1B investment in the LIST will yield major benefits via data of higher accuracy when coupled with the use of QL2 LiDAR for system calibration and validation and when the LiDAR and IFSAR data provide the most accurate ground topographic surfaces with which canopy structure from the LIST is periodically updated and compared to determine changes.
		Environmental Benefits: Major

		Strategic/Political Benefits: Major
DISDI **Defense Installation Geospatial Information and Services (IGI&S)** **QL2 of cantonment areas; QL3 of other areas on military installations/sites** **6-10 years**	For diverse training simulators used by Marines, soldiers and airmen to learn how to exploit the terrain to their advantage, first at military schools and training sites in the U.S. and then to operational battlefields overseas.	***Operational Benefits***: LiDAR data will enable Army, Marine Corps and Air Force installations to develop training simulators for their terrain for use in education and training programs on how to exploit the terrain to our advantage in a safe environment prior to learning them on a battlefield where it may be too late.
		$ Benefits: We have no way to estimate the number of lives saves through realistic battlefield simulators.
		Customer Service Benefits: Major, for all Services.
		Public/Social Benefits: Major, for gaining public support that our warriors are well trained.
		Environmental Benefits: None
		Strategic/Political Benefits: Major, force multiplier.
7 State **Functional Activities** **QL1 LiDAR: 4** **QL2 LiDAR: 3** **Variable update frequencies**	For government programs in AK, HI, MS (2), UT, WI and WV, budgeted at $125 million in 2011. Note: Mississippi has more than one Functional Activity for this Business Use.	***Operational Benefits***: LiDAR data will enable these states to perform university research and GIS outreach activities.
		$ Benefits: $507,500/year state government benefits plus $7,500/year in benefits for others. A total of 3 State FAs included estimated $ benefits. Forty four states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.

Dollar Benefits for BU#25

From Table E.25, the conservatively estimated dollar benefits for BU#25 equal $264,000/year.

These BU#25 benefits are probably understated for the following reasons:

- Federal Level: The NSF is unable to estimate the dollar benefits of LiDAR data to augment the National Ecological Observatory Network (NEON) program; and NASA is unable to estimate the dollar benefits of LiDAR data for the multi-billion-dollar Advanced Earth Science Mission. Additionally, for diverse Federal agencies, billions of dollars are spent annually on simulators that reproduce all or some aspect of a job or task, generally recreated in a 3-D environment that is safe for the learner. Simulators are widely used by the U.S. Army, Navy, Air Force, and Marine Corps to: (1) evaluate performance, (2) determine performance metrics, (3) measure training effectiveness, and (4) measure skill retention. LiDAR data of military bases are used for realism, but the dollar benefits of having accurate and realistic 3-D data are unknown. Although there are reports on costs avoided by using simulators instead of training with real aircraft, tanks, ships, or construction equipment, for example, there are no known reports on the dollars saved or number of lives saved as a result of having accurate and realistic simulation of the real-world terrain when compared with inaccurate and totally-simulated terrain. Lastly, LiDAR and/or IFSAR data enable the NPS, FWS, USACE and other Federal, state and/or local Visitor Centers or Nature Centers to present educational programs based on real-world 3-D datasets and models of volcanoes, gorges, glaciers, earthquake faults, mountains and other unique geologic features; and for educating the public on changing geophysical, hydrological, meteorological and climatological processes. The enhancement value of nationwide LiDAR to the NSF for NEON, and to NASA for the LIST, is estimated to be at least $1M/year.

- State Level: LiDAR and/or IFSAR data provide the basis for hundreds (perhaps thousands) of university research projects annually, enabling universities to solve everyday problems, developing our *brain trust*, and geo-enabling America which helps our global competitiveness. Again, the educational and research value of such LiDAR data is estimated to be at least $1M/year for combined university research projects.
- Local and Tribal Government Levels: No local or Tribal government requirements were received for this Business Use, though it is certain that local community colleges will benefit from enhanced elevation data when publicly available.
- Other Organizations (Not-For-Profit and Private Companies): As with e-Terra for BU#20 which includes aircraft simulator training, many not-for-profit and private companies are expected to benefit from enhanced elevation data when publicly available.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#25 remain at $2.264M/year.

BU#26 – Recreation

Scope of BU#26

Business Use #26 is defined in terms of Functional Activities that support recreational activities for which elevation data and/or derivatives (e.g., slope, aspect, curvature) are design factors.

Background Information

LiDAR data have long been used for design of lakes and ski slopes; but LiDAR is now being used for design and mapping of golf courses as well as professional auto racetracks and trails used by hikers, bikers, snowmobiles or all terrain vehicles (ATVs). If elevation data or derivative products (e.g., slope, aspect, and curvature) are important, or if detailed information regarding forests or vegetation is needed, LiDAR has become the technology of choice. DTMs are often required with centimeter level precision for design of professional golf courses and subsequently for golf course mapping, navigation and simulation systems. Not all recreational facilities are privately funded; many of the larger recreational lakes in the U.S., for example, were built with taxpayer dollars for better management of water resources.

The images at Figure E.26 were obtained from a 3-D Golf Course web site at www.3dgolfcourse.com/3d-technology. Golf course terrain and topographic data from LiDAR are vital features in production of patented golf course mapping and navigation systems and simulators. Instead of artificial landscape creations or artist renditions, accurate 3-D terrain and 3-D object models are produced of mapped golf courses. LiDAR is used to geoprocess 3-D terrain and imagery models for maximum horizontal and vertical accuracy and realism. Mobile GPS devices, such as Apple iPhone or Apple iPad, are used to see the course ahead and plan strategies.

Figure E.26. For professional golf courses, LiDAR data, combined with imagery, is vital for accurate and realistic mapping and navigation systems and simulators. Images courtesy of Terra Imaging.

Many video games, including *Microsoft Flight Simulator*, model the 3-D earth as realistically as possible and become even more realistic when they use actual 3-D data.

Summary of Requirements and Benefits

Table E.26 lists Functional Activities, pertaining to Recreation, with mission-critical requirements for enhanced elevation data. They are each *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity is explained in detail in Appendices B, C and D.

Table E.26. Elevation Data Requirements and Benefits for BU#26, Recreation

Geo-enabled User & Functional Activity	Summary of BU#26 Mission-Critical Requirements for	Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.

Quality Level (QL) Update Frequency	Enhanced Elevation Data. See individual Appendices for details.	
DISDI **Defense Installation Geospatial Information and Services (IGI&S)** **QL2 of cantonment areas; QL3 of other areas on military installations/sites** **6-10 years**	For development of golf courses, hiking trails, bike paths, lakes and other recreational facilities on military installations; and to develop wetlands that promote biodiversity and healthy habitats for hunting and fishing.	***Operational Benefits***: LiDAR data will enable DoD installations to manage natural resources and develop recreational opportunities for military personnel while promoting healthy habitat for hunting and fishing.
		$ Benefits: Cannot be quantified in dollar terms.
		Customer Service Benefits: Moderate
		Public/Social Benefits: Moderate
		Environmental Benefits: Moderate
		Strategic/Political Benefits: Minor
2 State **Functional Activities** **QL3 LiDAR : 2** **Variable update frequencies**	For government programs in AR and TN, budgeted at $4 million in 2011.	***Operational Benefits***: Enhanced elevation data will enable these state governments to prepare mapping guides and resource management in support of state recreational programs.
		$ Benefits: $50,000/year state government benefits plus $50,000/year in benefits for others. Only one State FA included estimated $ benefits. Forty eight states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.
TomTom **Location and Navigation Services** **QL2 LiDAR** **QL5 IFSAR for Alaska** **4-5 years**	For new products and services for golfers, runners, bikers, rock climbers, skiers, and drivers of all-terrain vehicles and snowmobiles.	***Operational Benefits***: LiDAR data will enable TomTom to develop specialized GPS-based recreational products that consider slopes, vertical feet of climb, safe travel speeds, etc., similar to a Sports Watch for runners.
		$ Benefits: Cannot be estimated
		Customer Service Benefits: Moderate
		Public/Social Benefits: Minor
		Environmental Benefits: Minor
		Strategic/Political Benefits: None

Dollar Benefits for BU#26

From Table E.26, the conservatively estimated dollar benefits for BU#26 equal $50,000/year.

By inferring no benefits, these BU#26 benefits are probably understated for the following reasons:

- Federal Level: The Federal government constructs and maintains many lakes used for recreational purposes. LiDAR data are mission-critical for determining a lake's size and depth; drainage area; location, length, height and shape of the dam; pipe sizes; tree removal requirements if any; construction costs, etc. LiDAR data enable those with specialized software to select optimal dam locations, lake sizes, etc. and estimate construction costs without the need for expensive topographic surveys, saving money for taxpayers who often pay for such projects. However, the estimated cost savings are unknown.

- State Level: State governments also build and maintain lakes used for recreational purposes. The benefits cited above for Federal lakes apply at the state level as well.
- Local and Tribal Government Levels: Local and Tribal governments also build and maintain lakes used for recreational purposes. Federal benefits apply at the local and Tribal level as well.
- Other Organizations (Not-For-Profit and Private Companies): For private ski resorts, LiDAR data are mission-critical for determining the slope, aspect and curvature of the bare-earth terrain, as well as DSMs of forest and vegetation canopies, vital for ski slope design. LiDAR data enable the efficient design of ski resorts and ski slopes without the need for expensive topographic surveys. For private golf courses, LiDAR data enable the efficient design of golf courses and efficient mapping of as-built professional golf courses to include navigation systems and simulators. For trails for hiking, biking and off-road recreational vehicles, LiDAR data enable the cost-effective design of trails so that the slopes do not exceed design grades or, in some cases, to achieve specified levels of difficulty for ATVs and/or snowmobiles, for example. For auto racetracks, LiDAR data enable safer operation of auto racetracks that have the correct banking on curves (currently up to 36 degrees) relative to racecar speeds. For all of these recreational applications, the estimated dollar benefits from LiDAR are unknown.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#26 remain at $50,000/year.

BU#27 – Telecommunications

Scope of BU#27

Business Use #27 is defined in terms of Functional Activities that support telecommunications spectrum management and frequency coordination. The Federal Communications Commission (FCC) is the champion for this Business Use.

Background Information

Elevation data are needed to determine line-of-sight conditions between transmit and receive locations for broadcast, microwave, cellular, WiFi and WiMAX users. Elevation data are also used as inputs to automated propagation prediction software. IFSAR is ideal for this purpose because it provides both the Digital Terrain Model (DTM) and Digital Surface Model (DSM) that could interfere with wireless telecommunications, and because it is consistent and available nationwide. The current data in the National Elevation Dataset (NED) are inaccurate, inconsistent and obsolete, and the NED does not include the elevations of trees, buildings and other manmade features that could interfere with telecommunications.

Figure E.27. Using a LiDAR DSM, a 9.5 foot antenna would have line-of-sight to the areas shown in red. The simulated antenna viewpoint can be elevated to any level necessary to achieve line-of-sight coverage to a large percentage of the total service area desired. Image courtesy of USGS.

Figure E.27 demonstrates how elevation data can be used to determine where line-of-sight exists and doesn't exist for antenna viewpoints simulated at different heights. This example demonstrates a short antenna, only 9.5 feet high; as the antenna is elevated by simulation, much broader areas become visible.

Because the FCC is a regulatory agency, primary benefits of IFSAR would accrue to FCC's customers.

Summary of Requirements and Benefits

Table E.27 summarizes the requirements for and benefits from enhanced elevation data for Functional Activities that pertain to Telecommunications. Federal, state and local organizations are *geo-enabled* with specialized decision-support tools that require enhanced elevation data. Each Functional Activity is explained in detail in Appendices B and C.

Table E.27. Elevation Data Requirements and Benefits for BU#27, Telecommunications

Geo-enabled User & Functional Activity Quality Level (QL)	Summary of BU#27 Mission-Critical Requirements for Enhanced Elevation Data. See individual	Examples of Tangible and/or Intangible Benefits from Enhanced Elevation Data. See individual Appendices for additional details and examples.

Update Frequency	Appendices for details.	
FCC **Spectrum Management and Frequency Coordination** **QL5 IFSAR** **>10 years**	For determination of line-of-sight conditions between transmit and receive locations; and for input to automated propagation prediction software.	***Operational Benefits***: IFSAR data will enable those with automated propagation prediction software to perform accurate and consistent frequency interference analyses that would agree with FCC's own analyses, reducing conflicts and delays.
		$ Benefits: Unknown
		Customer Service Benefits: Major
		Public/Social Benefits: Major
		Environmental Benefits: Major
		Strategic/Political Benefits: Moderate
NTIA **Spectrum Management and Frequency Coordination** **NED is acceptable at this time**	The NTIA may reconsider its requirements if the FCC is able to demonstrate the improved utility of IFSAR.	***Operational Benefits***: None
		$ Benefits: None
		Customer Service Benefits: None
		Public/Social Benefits: None
		Environmental Benefits: None
		Strategic/Political Benefits: None
4 State **Functional Activities** **QL3 LiDAR: 2** **QL4 Image DEMs: 1** **QL5 IFSAR: 1** **4-5 years**	For government programs in AL, CT, TN and WV, budgeted at $4.295 million in 2011.	***Operational Benefits***: Enhanced elevation data will enable state governments to perform line-of-sight analysis and broadband mapping to optimize wireless communications.
		$ Benefits: $125,000/year state government benefits plus $60,000/year in benefits for others. A total of two State FAs included estimated $ benefits. Forty six states did not choose this among their top 5-6 Business Uses and therefore did not submit their elevation data requirements and benefits.
1 City **Functional Activity** **QL1 LiDAR: 1** **2-3 years**	For Sandy City, UT to perform 3-D line-of-sight analysis for police and information services. This project is unfunded.	***Operational Benefits***: LiDAR data will enable Sandy City to build a MESH network of pole-mounted antennas that allow officers in vehicles to tie into cameras mounted at intersections, parks, etc., so they can observe sites "live" without being on-site. LiDAR will allow the placement of cameras and antennas to achieve good line-of-sight connectivity, avoiding trees and structures.
		$ Benefits: Unable to estimate dollar benefits.
1 Tribal **Functional Activity** **QL3 LiDAR: 1** **6-10 years**	For the Coeur d'Alene Tribe (ID) to determine line-of-site models for broadband, supporting a program budgeted at $300,000 in 2011.	***Operational Benefits***: LiDAR data will enable the Coeur d'Alene Tribe to minimize ground surveys for initial planning, and enable efficient line-of-site evaluations and analyses.
		$ Benefits: Unable to estimate dollar benefits.

Dollar Benefits for BU#27

From Table E.27, the conservatively estimated dollar benefits to the FCC for BU#27 equal $185,000/year.

These BU#27 benefits are probably understated for the following reasons:

- Federal Level: The FCC raises billions of dollars through spectrum auctions and worked through tectonic industry developments that changed America from a hardwired voice-oriented nation

to a hybrid voice-data wireless world power. Better elevation data will enable the FCC to perform better spectrum management, frequency coordination and licensing of non-Federal radio communications facilities and make better use of the available spectrum.

- State Level: From four states documenting their BU#27 requirements, two states estimated $125,000/year state government benefits plus $60,000/year benefits for others. These benefits are believed to be applicable as well to all states for which potential benefits would be at least 10 times higher, i.e., $1.25M/year benefits to the states and $600,000/year benefits for others.
- Local and Tribal Government Levels: No local r Tribal government requirements were received for this Business Use.
- Other Organizations (Not-For-Profit and Private Companies): Although they were not interviewed for this assessment, the primary benefits of IFSAR would accrue to the FCC's customers, with unknown dollar benefits, because:
    - More-accurate propagation studies would be conducted by applicants for radio licenses
    - Simpler and quicker approvals would be received when the FCC and applications all use the same, nationwide coverage of IFSAR data for frequency interference analyses.
    - Better use of the spectrum benefits all who use broadband services for improved productivity and competitiveness
    - The public benefits when elevation data help to harness communications technologies to spur economic growth, job creation, U.S. competitiveness, and public safety.

Although not used in the benefit-cost analysis in Appendix F, the potential dollar benefits of enhanced elevation data for BU#27 equal approximately $1.850M/year.

Summary of Business Use Financial Benefits

Table E.28 summarizes the conservatively estimated benefits versus potential benefits of enhanced elevation data for each of the 27 Business Uses. Only the conservatively-estimated dollar benefits were used in the benefit-cost analyses for the scenarios developed in this assessment and described in Appendix F. Note: Even conservative benefits will not be fully realized unless every Functional Activity receives the optimal Quality Level and update frequency required. Appendix F documents how the Cost Benefit Analyses were implemented to determine optimal combinations of Quality Levels and update frequencies based on the highest Net Benefits and Benefit/Cost Ratios.

Table E.28. Estimated Annual Benefits, by Business Use, from Enhanced Elevation Data

BU#	BU Name	Enhanced Elevation Data Annual Benefits	
		Conservative Benefits	Potential Benefits
1	Natural Resources Conservation	$159.225M	$335.152M
2	Water Supply and Quality	$85.288M	$156.351M
3	River and Stream Resource Management	$38.422M	$86.582M
4	Coastal Zone Management	$23.785M	$41.740M
5	Forest Resources Management	$43.949M	$61.655M
6	Rangeland Management	$0	$0
7	Wildlife and Habitat Management	$1.510M	$4.020M
8	Agriculture and Precision Farming	$122.330M	$2,011.330M
9	Geologic Resource Assessment and Hazard Mitigation	$51.750M	$1,066.750M
10	Resource Mining	$1.686M	$4.864M
11	Renewable Energy Resources	$10.050M	$100.050M
12	Oil and Gas Resources	$10.000M	$100.000M
13	Cultural Resources Preservation and Management	$0M	$7.000M
14	Flood Risk Management	$294.706M	$501.576M
15	Sea Level Rise and Subsidence	$5.780M	$21.660M
16	Wildfire Management, Planning and Response	$75.700M	$158.950M
17	Homeland Security, Law Enforcement, Disaster Response	$9.975M	$126.469M
18	Land Navigation and Safety	$0.191M	$7,124.875M
19	Marine Navigation and Safety	$0	$0
20	Aviation Navigation and Safety	$35.000M	$56.000M
21	Infrastructure and Construction Management	$206.212M	$941.951M
22	Urban and Regional Planning	$4.197M	$68.569M
23	Health and Human Services	$0	$1.000M
24	Real Estate, Banking, Mortgage, Insurance	$0	$0.000M
25	Education K-12 and Beyond	$0.264M	$2.264M
26	Recreation	$0.050M	$0.050M
27	Telecommunications	$0.185M	$1.850M
	Total Estimated Annual Dollar Benefits	**$1,180.224M**	**$12,980.707M**