The 3D Elevation Program Initiative Plan

Prospectus

A 3D Elevation Program (3DEP) initiative to collect high quality light detection and ranging (lidar), data in the conterminous U.S. (CONUS), Hawaii, and the U.S Territories; and interferometric synthetic aperture radar (ifsar) data in Alaska; and to create elevation data products (figure 1) and services over eight years is being undertaken by the U.S. Federal Government. The initiative includes Federal agencies, States, and Tribal partners who will work together to build on the success of existing programs. The 3DEP initiative is far reaching as it strives to address the needs of the Nation through a partnership framework. The governance structure includes an executive oversight committee and a multi-agency coordinating committee. The U.S. Geological Survey (USGS) is leading the initiative that calls for funding to be increased to $146 million annually, returning more than $690 million annually in new benefits to the private sector directly, and to citizens through improved government program services. Current investments in publically available lidar and ifsar data are approximately $50 million annually by all funding organizations. These funding levels are insufficient to achieve the objectives of national elevation data coverage or the benefits that would come from 3DEP.

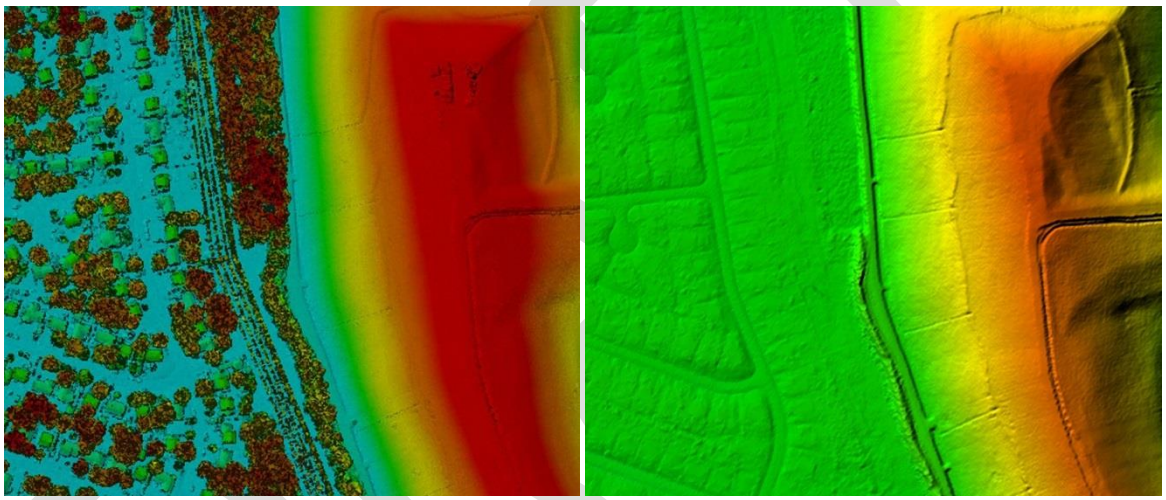

Figure 1. The lidar classified point cloud on the left and Digital Elevation Model (DEM) on the right are of a residentail community in Norfolk, Virgina. The trees and homes can be seen in the lidar image. The DEM is of the bare earth with trees and structures removed. The elevation is color coded by elevation, clearly showing the earthen flood control structure in red and the lower elevation residential streets in green. Images courtesy of Dewberry, Inc.

A National Enhanced Elevation Assessment (NEEA) study identified more than 600 requirements for 3D elevation data to address the mission critical requirements of 34 Federal agencies, all 50 states and for a sample of private sector companies, Tribes, and local governments. Many requirements were identified where high quality 3D elevation products are needed but would never be affordable if the data had to be acquired to solely meet a specific need. For example, the wind power industry requires large volumes of very high quality surface data over large areas to plan for wind farms and to determine ideal placement of wind turbines. It would be inconceivable to think that this industry could fund the acquisition of high quality lidar data to solely support that purpose. Yet, when all of the needs for other applications are considered in these same areas, a national program is more than justified. The NEEA study identifies many applications that are similar to the wind energy example. In contrast, funding for data collection today comes from agencies in the Federal government and in states where mission specific needs are driving data acquisitions. While this is strategy has benefitted individual projects and programs, it cannot comprehensively address the needs or achieve the benefits as documented in the NEEA report.

Many have asked the question about funding and whether or not a program of this scope could be achieved. They have also asked whether or not funds that have been historically directed to very mission specific needs are going to be compromised. More specifically, they want to know if 3DEP will meet their needs if they pool their limited resources to meet the goal of a national program. It is clear that to meet the goal to acquire data over the entire country in eight years that investments will need to increase. It is estimated that the production rates will need to increase by three fold in order to accomplish this. Improved program efficiencies and advancements in technology to increase data collection rates will help. The 3DEP initiative will achieve a 25 percent efficiency gain by moving toward larger projects where data collection costs are inherently lower. In order to create the level of participation from cooperating agencies, and to assure that mission needs can be addressed, the initiative proposes to:

1. Increase overall investments through budget and other initiatives in order to provide more incentives for partner participation.
2. Assure that the mission needs of partner agencies and states are addressed by incorporating their requirements into the three year planning strategy.
3. Acknowledge that participation in 3DEP is voluntary and that it will not always be possible to address every need. Individual agencies will, at times, collect mission specific data to address time sensitive or product specific needs.
4. Achieve efficiencies and lower costs through larger area acquisition projects.
5. Manage 3D elevation data and make it freely available for everyone.

The USGS is the Office of Management and Budget (OMB), designated lead Federal agency for terrestrial elevation data (OMB Circular A-16). The 3DEP initiative is designed to fulfill that coordination responsibility and to assure that as a Nation, we are addressing the needs of government. This role cannot be met by USGS alone and the 3DEP initiative should not be considered to be solely a USGS activity. From the beginning, partnerships with Federal agencies, States, and Tribes have been a cornerstone of the planning and initiative development process. The program initiative strives to build on the historical success of the cooperative National Digital Elevation Program and other programs in the Federal government and State agencies.

Background

The USGS, as the lead Federal agency for terrestrial elevation data, has managed the National Elevation Dataset (NED) and coordinated its activities through the National Digital Elevation Program (NDEP). The NED has represented the standard of quality for elevation data in the United States for more than 15 years. Today, new elevation data are acquired using modern technologies to replace elevation data that are on average more than 30 years old. Through the efforts of the NDEP, a project-by-project data acquisition approach has resulted in improved, publicly available data for 30 percent of the conterminous United States and 15 percent of Alaska over the past 13 years (figure 2).

While the NDEP efficiently coordinates among Federal agencies and other partners, the rate of data collection and the typical project specifications are insufficient to address many data requirements of government, the private sector, and others. Technologies for collecting and managing elevation data have changed significantly. Lidar and ifsar data have made it feasible to collect large quantities of data that map the earth's surface, including infrastructure and vegetation. These technology changes create an opportunity to address a wider range of needs and a challenge to modernize the way USGS defines and carries out its mapping activities. The potential to address requirements for natural hazards assessment and mitigation, natural resource conservation, infrastructure development, agricultural production, national security and environmental protection, and other applications requires a fresh perspective. An ambitious 3DEP initiative by USGS and partner Federal, State, Tribal, and private organizations, is responding to these needs. 3DEP represents a significant opportunity to support the Nation's resource managers, scientists, and environmental professionals. They will increase the efficiency of government programs and advance technologies for key industries such as precision agriculture and alternative energy development. The need for 3DEP is well supported by a yearlong

National Enhanced Elevation Assessment (NEEA) completed by USGS and partner agencies, (Dewberry, 2011) to assess the national requirements for elevation data and the benefits that would be realized from improved elevation data.

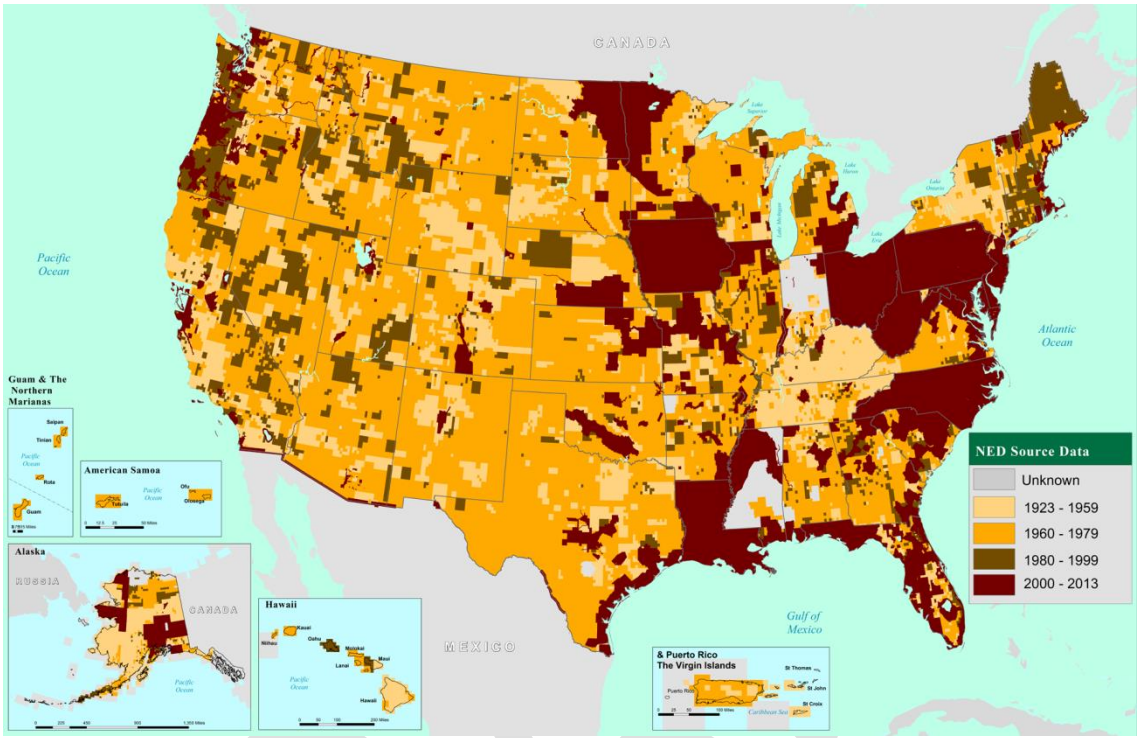

Figure 2. The National Elevation Dataset (NED) is maintained at multiple resolutions for the United States. Generally, DEMs are derived from lidar data after 2000 covering 30 percent of the conterminous US and Hawaii. Alaska has DEMs derived from Ifsar data for about 15 percent of the state. The remaining areas have coarser resolution DEMs created prior to 2000 from scanned USGS Topographic Map sheet contours. NED status graphic is current as of October 2013.

Fulfillment of FGDC A-16 Commitments

The OMB Circular A-16, "Coordination of Geographic Information and Related Spatial Data Activities," provides for improvements in the coordination and use of spatial data, and describes effective and economical use and management of spatial data assets in the digital environment for the benefit of the Federal Government and the Nation. Circular A-16 designates the Department of Interior (DOI), USGS as the lead agency for the coordination and management of the Nation's terrestrial elevation data and designates the Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) as the lead agency for bathymetric data. 3DEP continues and improves upon this commitment to coordinate terrestrial elevation data collection and manage this important national asset.

The OMB circular A-16 supplemental guidance was used throughout the planning and program development process. Though terminology may vary; the steps, intermediate products, and expected outcomes of 3DEP are intended to fully implement and be compliant with the guidance. This plan covers one complete geospatial data lifecycle as outlined in the guidance (figure 3). However, it is neither the beginning, nor is it the end.

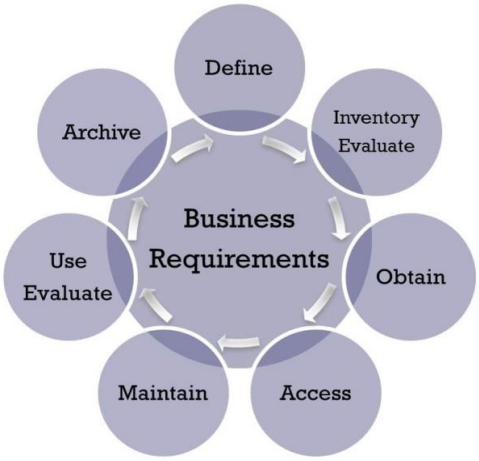

Figure 3. OMB circular A-16 Supplemental Guidance, Geospatial Data Lifecycle.

The USGS has a long history of managing elevation data and 3DEP is a natural extension to address a wide range of new and emerging needs. 3DEP embodies the model of cooperative programs that further reduce redundant data collection and improve efficiency across all levels of government. The USGS, in its theme coordination role, will facilitate an NDEP review of existing and new datasets to determine which managed datasets will be designated as National Geospatial Data Assets (NGDA) under the OMB Circular A-16. In fulfillment of its A-16 responsibilities and to track program implementation progress, an annual state of the elevation data report will be completed.

It is the intent of the 3DEP to fully coordinate the management of terrestrial elevation data with the programs responsible for bathymetric data at NOAA. There are multiple committees working to bring these two historically separate terrestrial and bathymetric data activities together. It is not as simple as building integrated datasets – this is being accomplished, in part, under a cooperative effort to build a Coastal National Elevation Dataset (CoNED) - it is more about understanding respective missions and creating datasets that address the broader needs of Federal, State, local and Tribal governments and the private sector. There is a growing dialogue between NOAA and the USGS. Today, both agencies participate in elevation data coordination activities, share a system to inventory available elevation data and are working collaboratively to plan for a more integrated data future.

Assessment of Requirements

The National Enhanced Elevation Assessment (NEEA), completed in December, 2011 was conducted to (1) document national-level requirements for improved elevation data; (2) estimate the benefits and costs of meeting those requirements; and, (3) evaluate multiple national-level program-implementation scenarios. The assessment was sponsored and funded by the NDEP's member agencies. The study participants included 34 Federal agencies, agencies from all 50 States, selected local government and Tribal offices, and private and not-for-profit organizations. A total of 602 mission-critical activities were summarized by major business uses (figure 4) that need significantly more accurate data than are currently available. The results of the assessment indicate that these improved enhanced elevation data have the potential to generate $13 billion in new benefits annually.

Figure 4. The 602 mission-critical activities identified in the NEEA study were organized under 27 business uses. The illustrations show examples of six business uses including precision agriculture, land navigation and safety, geologic resources and hazards mitigation, natural resource conservation, infrastructure management, and flood risk mitigation.

All organizations identified key functional activities, described in their own words, with mission-critical requirements for enhanced elevation data, along with their elevation data requirements by quality level (QL, table 1), update frequency, and geographic area. Each functional activity was linked to the business use that was most similar to the described activity. These data were collected by an on-line questionnaire, followed by an interview or workshop process, and finalized with a validation process that resulted in the formal documentation of each organization's requirements and benefits. All of these data were entered into a master geodatabase. The full NEEA report includes detailed documentation for 104 functional activities from Federal agencies, 329 functional activities from States and U.S. territories plus 144 functional activities from local and Tribal governments within each State. Twelve private companies and one not-for-profit organization documented 25 more functional activities.

Quality Level	Source	Vertical RMSEz	Nominal Pulse Spacing (NPS)	Nominal Pulse Density	DEM Post Spacing
QL1	Lidar	9.25 cm	0.35 m	8 points/sq. meter	1 meter
QL2	Lidar	9.25 cm	0.7 m	2 points/sq. meter	1 meter
QL3	Lidar	≤18.5 cm	1.4 m	0.7 points/sq. meter	3 meters
QL4	Imagery	46.3 cm – 139 cm	5 m	0.04 points/sq. meter	5 meters
QL5	Ifsar	92.7 cm – 185 cm	5 m	0.04 points/sq. meter	5 meters

Table 1. Data Quality Level and Related Accuracies. These elevation data collection parameters were used in the NEEA study, which categorized elevation source data into five quality levels (QL). QL3 is the base level specification for lidar collected by the USGS through FY13. The specification is under revision to reflect QL2 as the base level product, in accordance with the 3DEP initiative recommendation.

All elevation data requirements were aggregated and analyzed and benefits for each functional activity and business use were determined. Each functional activity was summarized for its mission-critical elevation data requirements by QL and update frequency; and its tangible and intangible benefits to include annual dollar benefits. The conservative benefits total $1.2 billion per year and the potential benefits total $13.0 billion per year. Partial benefits may be realized if users receive poorer QL data or update frequencies than optimally required for each functional activity. State requirements and benefits varied for similar activities. For example, one state reported significantly higher benefits for coastal flood risk management than did other coastal states, and some states significantly underestimated or were unable to assign any benefits for flood risk management.

The total benefits (table 2) documented in the NEEA study were calculated as conservative and potential. Conservative benefits are believed to be significantly lower than they might actually be for several reasons:

- The assessment did not identify and capture all applications for elevation data.
- Approximately half of the organizations were unable to estimate expected dollar benefits, even though most of these same organizations reported that they expected moderate or major benefits.
- Environmental or ecosystem service benefits usually fell into the category of unquantifiable.
- Benefits were sometimes provided as a range of dollars, and in such cases the number representing the low end of the range was used.
- Benefits used in the cost benefit analysis do not include county, regional, city, and tribal governments because the sample pools for these organizations were too small to support national projections.

The potential benefits are also believed to be underestimated and could be one or more orders of magnitude greater if the study had included the expected benefits of every county, regional, city, and tribal government and other industries nationwide.

DRAFT

Rank	Business Use	Annual Benefits in Millions	
		Conservative	Potential
1	Flood Risk Management	$294.7	$501.6
2	Infrastructure and Construction Management	$206.2	$942.0
3	Natural Resources Conservation	$159.2	$335.2
4	Agriculture and Precision Farming	$122.3	$2,011.3
5	Water Supply and Quality	$85.3	$156.4
6	Wildfire Management, Planning and Response	$75.7	$159.0
7	Geologic Resource Assessment and Hazard Mitigation	$51.8	$1,066.8
8	Forest Resources Management	$43.9	$61.7
9	River and Stream Resource Management	$38.4	$86.6
10	Aviation Navigation and Safety	$35.0	$56.0
11	Coastal Zone Management	$23.8	$41.7
12	Renewable Energy Resources	$10.1	$100.1
13	Oil and Gas Resources	$10.0	$100.0
14	Homeland Security, Law Enforcement, Disaster Response	$10.0	$126.5
15	Sea Level Rise and Subsidence	$5.8	$21.7
16	Urban and Regional Planning	$4.2	$66.6
17	Resource Mining	$1.7	$4.9
18	Wildlife and Habitat Management	$1.5	$4.0
19	Education K-12 and Beyond	$0.3	$2.3
20	Land Navigation and Safety	$0.2	$7,124.9
21	Telecommunications	$0.2	$1.9
22	Recreation	$0.1	$0.1
23	Cultural Resources Preservation and Management	$0.0	$7.0
24	Health and Human Services	$0.0	$1.0
25	Marine Navigation and Safety	$0.0	$0.0
26	Real Estate, Banking, Mortgage, Insurance	$0.0	$0.0
27	Rangeland Management	$0.0	$0.0
	Total for all Business Uses	**$1,180.4**	**$12,979.3**

Table 2. The functional activity benefits identified by assessment participants were aggregated into 27 business uses. When benefits were identified as a range, the conservative number represents the lower end of the range and the potential number represents the high end of the range. With the exception of the potential benefit of $7 billion associated with Land Navigation and Safety, all of the dollar benefits represent immediate needs. The land navigation benefit is realized from vehicle fuel reductions that can be achieved by intelligent vehicle navigation systems that could begin to appear in the market place as early as 2014.

Benefit Cost Analysis and Recommended Data Acquisition Scenario

The mission critical data needs were mapped for each functional activity and a geodatabase was created to support the analysis. The data requirements were aggregated into one degree by one degree cells and the benefits of a national program for each of 25 scenarios was determined for every cell. Where data were required for a portion of a cell at a particular QL, the benefit was prorated such that benefits would not be overstated for any cell. Multiple program scenarios were considered that would optimize QLs and replacement cycles for a Federal only program and national strategies that considered all needs. While it was possible to lower costs slightly, none of these other scenarios offered the benefits of national consistency or addressed the needs of numerous environmental and ecosystem services needs that were identified. Since environmental and ecosystem services were generally not quantified, they did not contribute to the benefit analysis. The benefit cost analyses conducted for each of the program implementation scenarios were based on the conservative benefit estimates.

The estimated costs for each scenario include those for data collection and life-cycle management. Each scenario would implement a national data-collection strategy to achieve cost efficiencies and meet the requirements of multiple organizations. The final analysis yielded 10 leading scenarios (figure 5). A mid-range recommended scenario offers a conservative benefit-to-cost ratio of 4.7 to 1, uniform mid-quality lidar data, and an 8-year acquisition cycle. All of the scenarios assumed ifsar data coverage in Alaska where cloud cover and remoteness preclude consideration of lidar data acquisition for much of the State. A detailed overview of each of the leading scenarios can be found in the full NEEA report (Dewberry, 2011).

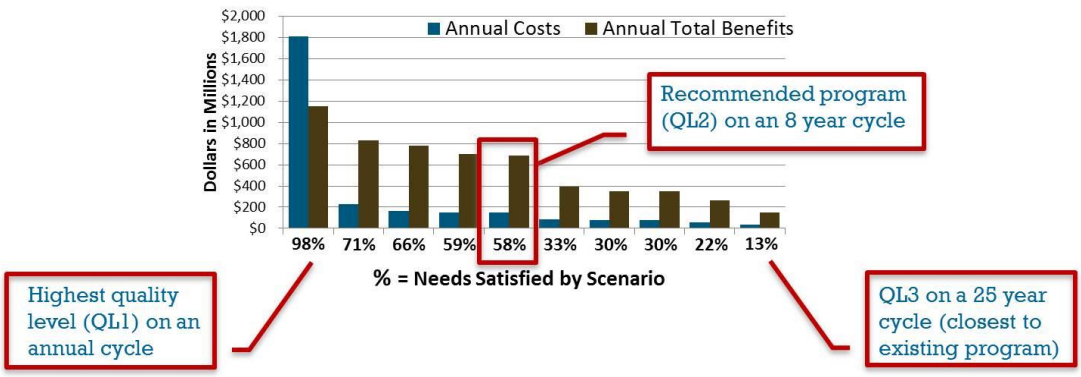

Figure 5. Ten program scenarios were analyzed for different investment levels and resulting benefits (needs met). On the left side of the chart, QL1 data acquired annually is represented in the graph. For this scenario, the costs significantly exceed the benefits. To the far right, a QL3 program for data collected over a 25 year period has a favorable benefit cost ratio with corresponding low benefits. The recommended program would achieve about 58 percent of the benefits. The depicted costs and benefits are average annual costs and benefits for a fully operational program.

The cell by cell benefit cost ratio for the recommended QL2 lidar data collection initiative collected over eight years is shown in figure 6. For Alaska, ifsar QL5 data would be collected over five years as part of the Alaska mapping initiative. For this scenario, nearly all cells have a positive benefit to cost ratio. The exceptions include arid regions of the US that are predominantly in Federal ownership. While the benefits in these areas are negative when an eight year replacement cycle is considered, most of the needs could be addressed with a one-time QL2 data collection activity. A longer replacement cycle would be a better alternative to lower quality data collects in these areas. Figure 7 shows the results of an analysis of return on investment for the recommended QL2 data collection program. Every cell shows a positive return on investment in fourteen years or less. Since the data collection three year planning strategy favors areas with higher returns on investments, it is likely that these areas would be collected later. Considering that data collection costs, continue to decline, it is likely the benefit ratio will improve by the time these areas are collected. In other words, it does not seem prudent at this time to recommend a data collection program of lower quality or longer replacement cycles in these areas solely based on the conservative benefit analysis.

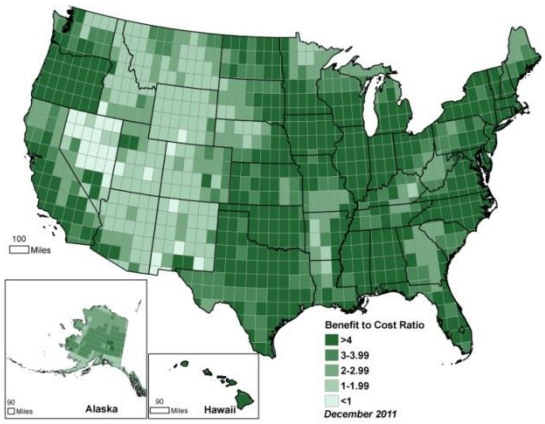

Figure 6. The recommended program would acquire uniform QL2 data for CONUS and Hawaii and QL5 data over Alaska. The benefit cost ratio varies across the country as illustrated in this map. The benefits are based on the conservative estimates and generally do not include environmental and ecosystem service benefits. The darkest shades represent the higher benefits

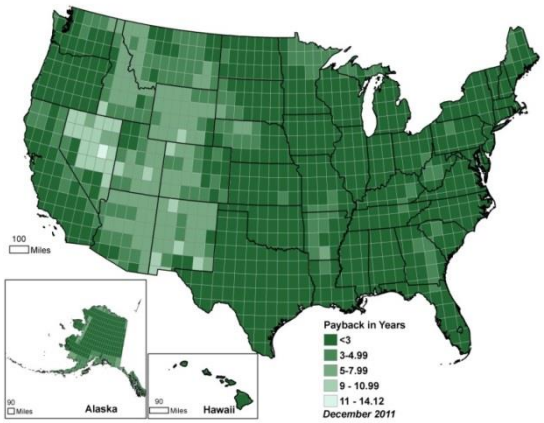

Figure 7. For the recommended QL2 data collection program in CONUS and Hawaii and QL5 data in Alaska, the return on investment is less than three years for most of the country. The lowest return on investment can be found in some of the arid western states where a 14 year return on investment is possible. The darker shades represent the shortest return on investment.

3D Elevation Program (3DEP)

The 3D Elevation Program (3DEP) was recommended by the National Digital Elevation Program (NDEP) committee and its 12 Federal member agencies and has been endorsed by the National States Geographic Information Council (NSGIC), the National Geospatial Advisory Committee (NGAC), and the Management Association for Private Photogrammetric Surveyors (MAPPS). The 3DEP initiative responds to the documented need for high-quality topographic data and a wide range of other three-dimensional representations of the Nation's natural and constructed features. The primary goal of the program is to systematically collect 3D elevation data over the United States and the territories. Private-sector data-acquisition companies have the capacity and will mobilize to respond to these lidar and ifsar data needs and that the products and services will be accessible to all levels of government and the public. Based on the respective agency identified benefits in the NEEA study, the Federal agencies poised to realize the highest benefits to their mission from enhanced elevation data include the Natural Resources Conservation Service, the U.S. Army Corps of Engineers, the Defense Installation Spatial Data Infrastructure, the U.S. Geological Survey, the National Oceanic and Atmospheric Administration, the Federal Emergency Management Agency, the Environmental Protection Agency, the U.S. Forest Service, the Federal Aviation Administration, and the National Geospatial-Intelligence Agency. States and other partners will be able to participate in 3DEP and could fund higher quality data where needed.

3DEP is a cooperatively funded national elevation initiative led by the USGS. The initiative is expected to continue to function as an activity under *The National Map* that is coordinated by a successor 3DEP Coordinating Committee to the NDEP. A two-tiered governance model will solidify 3DEP partner agency roles and data acquisition strategies, program expectations, and constraints. 3DEP is being designed to meet the mission-critical data needs of the 3DEP partners and other user communities. The target state would be fully realized in eight years (2022) with national coverage of QL2 or better lidar data in 49 states and territories, and QL5 or better ifsar data in Alaska. Derived products would be available to address high priority needs and customers would be able to access and use the original data to create their own value added products and services.

A steady state operational activity will be in place by January 2015 with an initial set of data, new products, and services. Legacy program activities to include the NDEP committee, the National Elevation Dataset (NED), the Center for Lidar Information Coordination and Knowledge (CLICK), Coastal NED (CoNED), related research activities, and potentially other enhanced elevation data and services will become participants of the 3DEP cooperative initiative. The CLICK services have been discontinued and lidar point cloud data are now available through the USGS, EarthExplorer data portal service. Under the 3DEP initiative, lidar, ifsar, and derived elevation products will become available through *The National Map* data portal. Some programmatic activities are being consolidated to improve overall program efficiencies. Partner Federal agencies, States, and Tribal organizations will actively participate in cooperative data acquisition projects and defining the multi-year priorities of the program.

3DEP includes a program of data collection, management and delivery of products and services that encompasses one complete geospatial data lifecycle as described by the OMB A-16 Supplemental Guidance. It should not be interpreted to mean that the 3DEP will end after 2023. The plan intentionally addresses a period of time and an accomplishment which can be realized. It is expected that technology will change and that data sensors will become more prolific and may include space platforms and be cheaper to deploy in the future. Ten years from now, 3DEP will look quite different and it will be time again to assess and evaluate where this important national program needs to go. It is also expected that billions of dollars in benefits to the nation will have been realized and that ongoing and new needs will shape the future of the next generation 3DEP.

Project Schedule and Milestones

The project milestones (table 3) represent major and time sensitive accomplishments leading to the successful implementation of 3DEP. There are assumptions of funding success as outlined in the growth section of this document and additional assumptions of a small but well defined product and service offering as described in the Product and Services section. While every attempt has been made to accurately represent the current status and direction of 3DEP, it is expected that the product suite, data

acquisition plans, and operational capabilities will change over time and the budget will likely be different from what is projected in this document. Current information about the 3DEP will continue to be available on *The National Map* web site for 3DEP at http://nationalmap.gov/3DEP/.

3DEP Implementation Milestones	Planned Completion Date
Establish the 3DEP Executive Forum	May 2013 – complete
Implement 3DEP coordination functions	January 2015
Products and Services- Initial planned product and services offering identified	October 2013 - complete
Data Delivery - NED operations modernization – product release	April 2014
Data Delivery -Lidar and ifsar operations modernization – product release	October 2014
Data Delivery - 3DEP products and services release	January 2015
Data Sources – Quality level 2 base level data acquisition specification complete	May 2014
Data Acquisition – Publish three year acquisition strategy (updated annually)	May 2014
Data Acquisition – New Geospatial Products and Services Contracts approved	November 2014

Table 3. 3DEP schedule and key milestones. Detailed explanations for the identified milestones can be found in the respective sections within this plan.

Leadership, Outreach, and Growth

The program of operations will be executed – initially as a series of implementation projects – to transition from the current NED activities to an operational state where lidar, ifsar and various elevation products are created, managed and made available to a broad customer base. The cooperative aspects of the program will be supported by an Executive Forum comprised of senior executives from cooperating agencies and a 3DEP Coordinating Committee to facilitate their participation in 3DEP.

Outreach will be a primary aspect of the program which is highly dependent on a broad base of support and participation from Federal agencies and State government. Initially, outreach has been and will continue to be directed toward building support and a funding base to move the program forward. Equally important is the need to reach out to a growing user base to ensure that the program is responsive to the needs of government to provide the services which will allow the partner organizations to realize the potential benefits that they have identified.

Funding for 3DEP will continue to rely heavily on partnership contributions. Overall, national investments in source data need to be increased about threefold. Based on the annual inventory of publically available lidar and ifsar data and average acquisition costs, it is estimated that about $50 million are spent annually by all sources to acquire new data. The program estimates that the data collection and life cycle management investment levels need to increase to about $146 million per year. A key component of the strategy is to increase funding to a level that allows the program partners to implement a directed national acquisition strategy without compromising individual partner mission needs. This would replace the historical opportunistic acquisition strategy that while efficient at the individual project level, will not result in the data coverage that is critical to the success of 3DEP.

Leadership

The 3DEP Executive Forum is comprised of senior officials from Federal agencies. For the USGS, the senior official is the Associate Director for Core Science Systems who chairs the committee. The Executive Forum will formulate new policy or review and approve policies and priorities as may be recommended by the 3DEP Coordinating Committee. The Executive Forum members will develop and champion funding initiatives to advance the 3DEP. This fills a void of executive oversight and accountability for coordination of resources under a single national elevation program. It is a goal of 3DEP to include representatives from state and other organizations on the Executive Forum or to have a formal method for providing input to the committee as may be allowed by the Federal Advisory Committee Act (FACA).

The 3DEP Coordinating Committee will be comprised of the partner agencies and other organizations as approved by the Executive Forum. The implementation of 3DEP as a national program will be different from today's NDEP process that primarily emphasizes information sharing about agency acquisition plans. It will instead focus on developing a joint multi-year 3DEP acquisition plan to meet the

needs of the participating agencies. Thus, a primary responsibility of the 3DEP Coordinating Committee will be to provide input to the data acquisition plan, and to prioritize enhanced elevation data collection projects. The committee will manage the long term data collection priorities and will provide critical input on 3DEP product and services needed by their respective organizations. The NDEP sub-committees and its members may fulfill the roles and responsibilities for 3DEP coordination.

A committee of the Inter-agency Working Group on Ocean and Coastal Mapping (IWG-OCM) is developing a National Coastal Mapping Strategy (NCMS) that includes topographic and bathymetric lidar coordination and data collection for the coastal zone. The coordination activities of the IWG-OCM and 3DEP overlap in the coastal zone. It is proposed that there be joint planning activities and that coordination issues be resolved during the early stages of the 3DEP implementation.

Outreach

The communications plan for 3DEP will set a schedule and milestones for communicating across 3DEP audiences (table 4) about the initiation of the program. The plan deliverables include a timeline, definition of communication roles and list of materials needed for a successful 3DEP roll out.

Audience	Description	Key Touch Points
Federal Executives	Decision-makers and overseers of Federal programs and budgets	• 3DEP Executive Committee • Federal budget planning process (DOI, OMB, other Federal Departments) • Office of Science and Technology Program (OSTP)
Partners	Collaborate on data acquisition to leverage program dollars	• 3DEP Coordinating Committee • Federal Geographic Data Committee and Federal Geospatial Advisory Committee
Geospatial user community	Use 3D elevation data to meet mission objectives	• Esri International and Federal User Conferences • Outreach events related to business uses with significant benefits from a national 3D elevation program
Potential new industry users	Industries that would benefit from 3D elevation data outside of the current geospatial elevation data user community	• Vehicle Navigation • Precision Agriculture • Forest Products • Renewable energy • Others to be determined
Professional community	Groups that provide a venue for communicating opportunities and issues associated with a given professional field	• American Association of Geologists • American Association of Photogrammetry and Remote Sensing • Association of State Floodplain Managers • Coalition of Geospatial Organizations • MAPPS • National Society of Professional Surveyors • National States Geographic Information Council • Others
Legislative	Determine Federal and state budgets	• USGS, DOI informational visits to Congress members and staffers • Outreach by 3DEP stakeholders
Media and public	Raise 3DEP awareness across user communities and the general public	• Trade publications (ex. Directions Magazine, POB) • Newspapers, television • 3DEP website and factsheets

Table 4, The communications and outreach strategy for 3DEP includes a wide range of partners and other constituents. Outreach is needed to gain community support and to successfully implement the partnership approach for data acquisition.

Defining the branding relationship of 3DEP to other *National Map* components and the positioning of products and services will be an important aspect of 3DEP outreach and general communications. The branding process will define how 3DEP nests within *The National Map* and relates to other 3DEP community and USGS organizational components. Deliverables will include updates to and expansion of

DRAFT

the 3DEP style guide. A series of outreach products will be developed to include program, state and industry factsheets. The 3DEP web site will be maintained and kept current.

3DEP spokesperson training will be conducted for the NDEP committee, Executive Forum, USGS geospatial liaisons and other key USGS staff. When completed, individuals and organizations working to implement or support 3DEP should be able to provide consistent messages about the direction, scope and status of the initiative. Training materials will be created and training activities will be performed. Special events will be used to reach out to existing and potential 3D elevation data users and to solicit feedback on the 3DEP planned products and services. Advances towards 3DEP goals, development of infrastructure at USGS to support 3DEP, and future directions would be among the topics highlighted.

Growth

The 3DEP plan is predicated on the assumption of moderate growth for FY13 and FY14 and accelerated growth in subsequent years (figure 8). Investments in lidar and ifsar data acquisition over the past four years have been in the range of $50 million annually when all public domain government sources are considered. USGS investments are a small portion of the total investment. Data lifecycle management costs for these investments are not known given the distributed nature of local, State and Federal government programs that manage their own data assets. The proposed operational program, to be fully realized will require a $1,168 million investment.

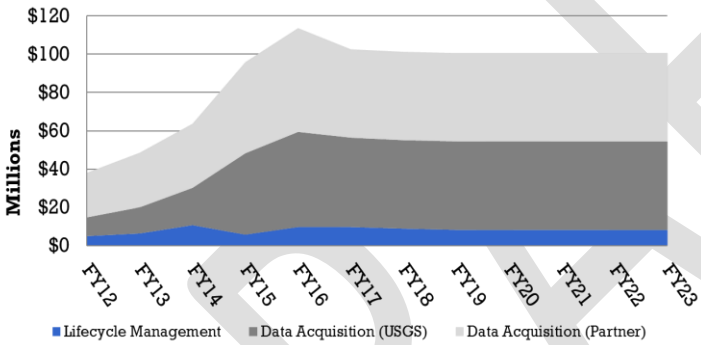

Figure 8. The projected growth model for 3DEP assumes USGS or a Federal agency consortium will see moderate investment growth with corresponding but lower growth in lidar and ifsar investments from others. Total investments from all sources are estimated to be $1,168 million. 3DEP will become operational in FY15 and national coverage will be completed in 8 years. Investments peak in FY16 due to the accelerated objective to complete statewide ifsar in Alaska

There are numerous assumptions that went into this investment model and they could change over time. The key assumptions are as follows:

- QL2 lidar data will be collected over the conterminous US over 8 years once the program is fully operational.
- Higher quality lidar may be acquired through partner buy up options. These costs are not included in the basic program funding assumptions.
- QL5 ifsar data will be collected over Alaska.
- Acquisition costs will be reduced by 25 percent by acquiring large blocks of data.
- Approximately 9 percent of total program costs will be required for lifecycle management activities to include a limited research budget to address operational research needs. These are preliminary estimates based on infrastructure sizing and management projections from the NEEA study.
- All costs and budget estimates are based on 2012 constant dollars.

The program planning and funding model for the 3DEP is based on additional assumptions as follows:

- There will continue to be slow but continuous growth in lidar and ifsar investments by partner institutions. The investment growth for partners will lag USGS investments initially and catch up in out years as partners anticipate matching funds and plan for future acquisitions.
- A consortium of Federal agencies committed to 3DEP will see modest growth in investments in FY14 with accelerated growth in FY15.
- Full operational funding levels will be achieved in FY17.
- The objective to complete the recommended coverage in eight years starts in January, 2015 when 3DEP becomes operational.

- Lidar and ifsar collections under the legacy NED program will be included in the 3DEP and may or may not be replaced during the ensuing years depending on funding and other factors.

The transition to a steady state 3DEP operating function was initiated in 2012 with the decision to begin the consolidation and modernization of existing elevation and source lidar and ifsar data activities. The proposed 3DEP initiative budget is based on 2012 constant dollars and as documented in the NEEA report. The proposed budget anticipates an average 25 percent decline in acquisition costs due primarily to efficiencies gained from larger area collects. The acquisition cost per square mile has declined in 2012 and in 2013 as contractors improve their processing software and data collection platforms. The overall costs are at or slightly above the initiative estimates which assumed a 25 percent cost reduction over the eight year life of the initiative. The overall program initiative budget will be reevaluated in the future if costs continue to decline.

Source Data, Products and Services

Users will access and use 3D elevation products and services to directly address their business needs or they will develop other value added products and services that combine services with other geospatial data and applications. For example, a private company could access lidar classified point cloud data, calculate roof top solar exposure and serve the needs of the solar energy industry. Analysts could access 1 meter DEMs and other resource data to run complex flood inundation models to create new flood risk map. Scientists would use the point cloud data and land cover data to refine their biomass models. These second tier or advanced uses will be supported by data products and services. It is not the intent of 3DEP to provide advanced application services but to rely heavily on the private sector and others in government to expand their offerings and to integrate elevation services into their standard business practices. In this model, the private sector opportunity to innovate and to provide new services is a key benefit of a national 3DEP initiative. The boundary between standard products and services, and advanced products and services provided by others will always be fuzzy; but the general principle is that when a product or service from 3DEP must be combined with other data, it falls outside of the program scope.

The target state for 3DEP includes coverage of QL2 lidar data for 49 states and the US territories and QL5 ifsar data in Alaska. For the assumed funding levels, the target state would be achieved in 2023. Source data inputs to 3DEP include, QL2 full lidar point cloud, orthorectified lidar intensity images, breaklines (if collected for hydro flattening), and orthorectified ifsar intensity images. Source data include enhanced spatial metadata. DEMs will be generated from QL2 lidar (CONUS, Hawaii, select areas of Alaska, and territories) or QL5 ifsar (Alaska only) source data and will be hydro-flattened to improve water feature definition and properly represent the topographic surface. Digital Surface Models (DSMs) are deliverables of ifsar acquisition projects, and may also be deliverables of lidar projects. Source data and the initial DEMs are generally acquired through contracted services to the private sector. Until national coverage is completed there will be large areas where QL2 source data are not available. For these areas, the standard products will be comprised of legacy data. Existing lidar, ifsar and NED data will transition to 3DEP and become part of *The National Map* operations. As new data are acquired they will be used to update the legacy datasets. Older source DEMs will remain accessible as historical data. Definitions of the source data and derived data types can be found in Appendix A.

The standard products, as outlined in table 5, will be released upon completion of the phased implementation of the NED, lidar, and ifsar modernization activities. While the product and service offerings will grow over time, they will be limited to products and services that can be created directly from the source lidar and ifsar data and from the derived DEMs. Standard products will initially be pre-generated to set specifications and limited formats and staged for viewing and download through *The National Map* viewer and download platform. Bulk distribution services are available for large data requests and for some source datasets that are not available through the download platform. A spot elevation query service will also be available. In 2014 and 2015 on-demand product generation and delivery services will be evaluated in order to provide customers with a richer use experience. Provision of on-demand product services could begin as early as 2015. The provisioning of data-as-a-service is being evaluated and will depend, in part, on the emerging cloud service model and the Geospatial Platform under development by the Federal Government.

Product Name	Planned Coverage on Release Date	Source(s)	Planned Product	Planned Availability and Product Release Dates
Lidar Full Point Cloud - Unclassified	Partial Coverage - US	Lidar – QL1, QL2, QL3	Project areas by special request	EROS by special request pre-2014 data now. NGTOC for new data in April 2014
Lidar Full Point Cloud - Classified	Partial Coverage – US	Lidar - QL1, QL2, QL3	Project tiles by download	Earth Explorer now. *The National Map* in October 2014
Ifsar Digital Surface Model	Partial Coverage – Alaska	Ifsar – QL5	Project tiles by download	NGTOC by special request in April 2014 and *The National Map* in January 2015
Orthorectified Ifsar Intensity Image	Partial Coverage – Alaska	Ifsar – QL5	Project tiles by download	NGTOC by special request in April 2014 and *The National Map* in January 2015
Source resolution DEM	Partial Coverage US and some Territories	Lidar, Ifsar	Project tiles by download	*The National Map* in April 2014 (new data) and TBD for pre-2014 data
1 meter DEM	Partial Coverage US and some Territories	Lidar, Ifsar	Tiles (TBD) by download	*The National Map* in January 2015 (new data) and TBD for pre-2014 data
5 meter DEM	Partial Alaska	Ifsar	Tiles (TBD) by download	Earth Explorer in October 2013, from *The National Map* in April 2014
1/9 arc-second DEM - legacy	Partial Coverage US and some Territories	Lidar, Ifsar, Photogrammety	15 min block by download	*The National Map* now
1/3 arc-second DEM	CONUS, HI, some Territories, partial Alaska	Lidar, Ifsar, Photogrammety	1x1 degree block by download	*The National Map* now
1 arc-second DEM	CONUS, HI, AK and US Territories	Lidar, Ifsar, Photogrammety	1x1 degree block by download	*The National Map* now
2 arc-second DEM	Alaska	Lidar and Ifsar, Photogrammetry	1x1 degree block by download	*The National Map* now
Elevation Point Query	CONUS, HI, some Territories, AK	1/3 arc-second, 1 arc-second in AK	Application service	*The National Map* now
Hillshade	CONUS, HI, some Territories, AK	1/3 arc-second, 1 arc-second in AK	Viewing service	*The National Map* now
5 to 120 foot Contours	CONUS, HI, some Territories, AK	1/3 arc-second, 1 arc-second in AK	1 degree block by download and viewing service	*The National Map* now

Table 5. Standard products. The initial product offering will include standard DEM and source data products. Geographic coverage will be limited for many products due to limited availability of source data and all dates are preliminary planning dates that may change. Contour interval is dependent on local topographic relief as published on the US Topo map product. Earth Resources Observation and Science (EROS) Center is located in Sioux Falls, South Dakota and the National Geospatial Technical Operations Center (NGTOC) has locations in Denver, Colorado and Rolla, Missouri. Special request products are available by contacting either EROS or NGTOC. Earth Explorer and *The National Map* products and services are available online. See appendix A for definitions and additional specifications.

For the lidar classified point cloud and the DEMs, there will be multiple data products. For example, the NED consists of 2, 1, 1/3 and 1/9 arc-second DEM products that are tiled for download. The 2 arc-second (Alaska only), 1 arc-second and 1/3 arc-second DEMs will continue to be seamless products created from the source hydrologically flattened DEMs. The 1/9 arc-second product will likely be managed as a legacy product and new source DEMs will gradually replace the 1/9 arc second product with a 1 meter DEM product. The 1 meter DEM product will begin production by January 2015 for newly acquired data. In addition to these products, a small number of new products may be released as part of the 3DEP standard product and service offering. Such products could include slope, aspect, profiles/cross sections, breaklines or others. The NEEA study and future input from data users will be the basis for determining future product requirements and preliminary product specifications. An assessment of production feasibility and probable cost will be completed for each proposed product or service.

Existing Data and Annual Inventory

An integral part of planning and monitoring the 3DEP data acquisition effort is the United States Interagency Elevation Inventory (USIEI). The USIEI was originally developed during the NEEA study to determine the status and availability of high-resolution lidar and ifsar data in the United States. The inventory contains information for both terrestrial and bathymetric data organized by data acquisition project boundaries. Since the completion of the NEEA study, the USIEI has been jointly-maintained by NOAA and USGS, and has been updated annually. Each year, USGS geospatial liaisons review high-resolution lidar and ifsar projects, and provide edits to existing inventory data, as well as new project information (figure 9). The criteria for inventory are that the lidar or ifsar data need to be publically available and cover an area that is at least 300 square miles or a full county. The data must be available, under contract, or planned and funded. This information is reviewed and refined at USGS, then provided to NOAA. The resulting inventory data are stored in a GIS-ready format, and are available for download into desktop GIS software for display and analysis. Additionally, NOAA maintains a publically-available web-based viewer (http://www.csc.noaa.gov/digitalcoast/tools/inventory) for quick geographic display of USIEI information. USGS and NOAA are engaged in on-going dialog and coordination efforts to identify process efficiencies for maintaining the USIEI as a viable program management tool to support 3DEP acquisition planning.

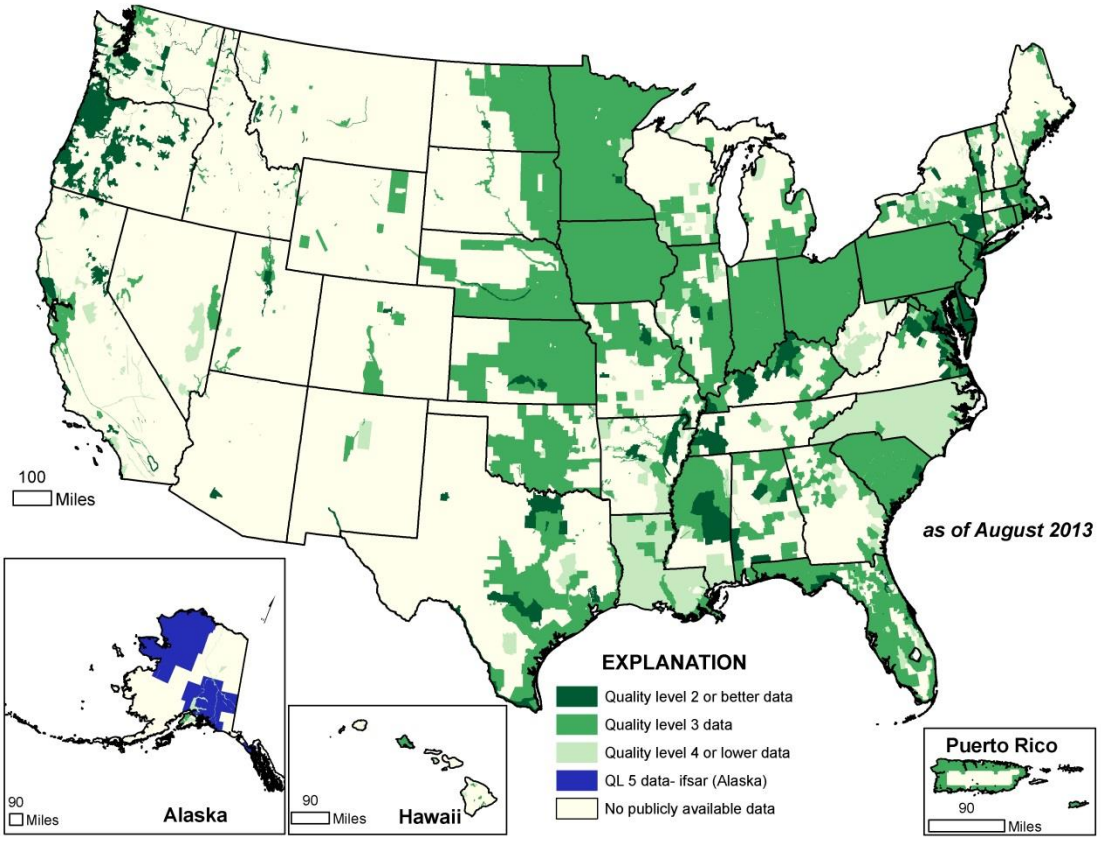

Figure 9. The map depicts public sources of lidar in all states plus ifsar data in Alaska and includes in progress and planned with funding projects as of 2013. Approximately 30 percent of the conterminous US has lidar and 15 percent of Alaska has ifsar coverage. The average collection rate for the US is approximately 4 to 5 percent per year

Data Acquisition Planning and Partnerships

Acquisition of elevation data has long relied on coordination and partnerships among Federal, State, local and Tribal organizations. The NDEP has coordinated data acquisition and promoted data sharing to avoid duplication among Federal agencies with varying mission needs and plans. Among the states,

there are a wide range of acquisition and partnership strategies at various stages of implementation. Federal, state, local and other organizations frequently partner on a project-by-project basis to leverage funding and increase coverage areas.

In order to achieve national coverage on an aggressive 8-year cycle, the 3DEP initiative must build on existing relationships to establish a systematic and more unified process for data acquisition partnerships. The USGS will collaborate with Federal and state partners to define a process with the following general steps, which will begin to be implemented in FY15:

1. **Solicit annual and multi-year plans** – The 3DEP Coordinating Committee will solicit priorities and plans from federal and state agencies to form annual, and to the extent possible, multi-year projections. Opportunities for partnering to increase coverage area or quality level will be identified from the compiled map of plans, and the following criteria:
   - Areas with the highest net benefits identified in the NEEA requirements study
   - Areas included in a federal, state or regional partner elevation data acquisition plan
   - Areas with no lidar (or ifsar in Alaska) coverage
   - Areas with existing coverage that do not meet the quality requirements of 3DEP
   - Areas with existing lidar (conterminous US and Hawaii) coverage greater than 8-years old
   - Areas with significant topographic change
   - Areas subject to serious and significant hazards (earthquakes, landslides, volcanic activity, coastal flooding, sea level rise)

   Annual and multi-year plans will be published and maintained at the 3DEP website.
2. **Announce an annual solicitation of partnerships** – The USGS will manage a process to accept partnership proposals to meet the jointly defined priorities. Partners will propose an acquisition approach that best meets their needs: either they will use the USGS Geospatial Products and Services Contract (GPSC) or their own authorities and contracts to acquire data that meet the 3DEP specification.
3. **Select partnership proposals for funding** – Proposals will be evaluated, prioritized and selected based on the jointly defined criteria and priorities. Projects that support statewide and or regional collection plans will receive higher consideration than projects in a limited geographic area. The preferred project will cover between 1,500 and 5,000 square miles with increasing emphasis on larger projects. Acquisition projects that are 5,000 square miles will accommodate the need for all but the smallest states to spread their acquisition strategies over multiple years.

Another avenue for agencies to contribute to 3DEP goals is to provide data that meet 3DEP specifications to the national database. These data may be acquired through the USGS GPSC or partner contracts. The USGS will implement a standard procedure for reviewing and accepting the datasets, and will provide feedback to contributors on production schedules for releasing the data and new derived products. Contributed data will be reported together with partnership data in the 3DEP annual plan.

The data acquisition partnership process will depend on several significant changes to the way coordination and partnerships are implemented today:

- **Earlier and more comprehensive reporting of priorities** – Federal and State agencies will be encouraged to report their data priorities on a cyclical basis. It is acknowledged that some agencies currently work on a project-by-project basis, and that all agency budgets and plans are subject to change. However, where priorities and plans can be identified the process will increase efficiency and cost savings to the partnering agencies, and contribute to 3DEP coverage goals. Agencies will be encouraged to implement advance planning to the degree possible depending on their unique situations.
- **Federal agencies will be asked to participate on a flexible but unified plan –** It is acknowledged that partner agency mission objectives for data acquisition must be honored and

drive the acquisition process. Partner agency funding will continue to be focused on their specific mission needs, while USGS funding will be used to increase coverage areas and where necessary, quality levels, to meet 3DEP objectives, around partner projects. Mission needs are not a barrier to, but central to developing a unified plan that is flexible as budget pictures and mission needs develop and change over time.

- **State agencies will be asked for statewide plans and coordination –** Because the partnership process will depend on state and regional coordination, the states are encouraged to coordinate with local and other entities to build funding coalitions and plans that feed into the national process, and to ensure multiple needs are met at that level. The 3DEP planning approach is intended to provide the lead time that states need to enable funding initiatives to be passed in their respective states. The three year planning strategy for 3DEP will also, over time, create a more predictable funding source that will provide states further incentives for moving ahead with statewide acquisition strategies that are necessary to complement the partnership model. Active participation by the states will result in higher quality data overall and help assure that the objectives of a national strategy can be achieved. Geospatial liaisons will provide states with technical assistance when needed and coordination support to facilitate participation in 3DEP data collection activities.

Federal Roles and Responsibilities

Success of the 3DEP initiative depends on the active support of Federal agencies to fulfill the following roles and responsibilities.

- Federal agencies will coordinate and facilitate development of annual and multi-year plans for their agencies nationally.
- Federal agencies will act as spokespeople to their stakeholder communities for the 3DEP initiative and the goal of achieving nationwide coverage.
- Federal agencies will participate in the planning process of the 3DEP Coordinating Committee and contribute to 3DEP by participating in partnerships or by contributing 3DEP-specification data.

State Roles and Responsibilities

The States are major contributors of data and often lead statewide acquisition programs. The 3DEP planning approach is intended to encourage expanded use of state level partnerships. As a 3DEP initiative participant, the states will have certain roles and responsibilities. State roles and structures vary across the country. It is incumbent upon the Federal agencies to recognize this and to accommodate the variation that exists. The state roles, when adopted, will help assure the success of a national program that will be beneficial to all partners.

- A state will coordinate and facilitate the development of local and regional partnerships.
- A state will advocate for a national program and support the goal of achieving nationwide coverage.
- A state will participate in partnership data acquisition projects. When a state is responsible for acquiring data, the state will adopt national specifications and standards and make resulting data available to the national program. A state may collect data to a higher quality specification.
- A state will develop a statewide program strategy and seek funding to participate in partnership activities.

As outlined, the 3DEP data acquisition partnership approach will be beneficial in the following ways.

- The level of investments will increase, improving cost efficiency of acquisition and providing a greater return on individual agency investments in terms of data coverage and quality.
- Economic benefits directly attributable to high quality 3D elevation data will be greater and realized sooner.

DRAFT

- The three year planning strategy will give the states ample time to prepare budget initiatives and to participate fully in 3DEP.
- Common and standard data collection specifications will be implemented to ensure that data are compatible and support geographic analyses across state lines and project boundaries.
- Data acquisition project size of 5,000 square miles allows for state multi-year acquisition strategies.
- Coverage will be complete and the patch work quilt effect will be minimized through larger areas data collection projects.
- The higher QL2 data acquisition specification under 3DEP provides for a lower cost upgrade path for states or other partners that want QL1 data.
- The approach addresses findings in the GAO report on geospatial information coordination and reducing duplication (GAO-13-94, 2012) though a unified and well-communicated process of coordination and partnerships.

Data Acquisition Contracts and Specifications

Source data will be acquired by contractors and from partner organizations electing to acquire data using equivalent (or better) specifications. Data acquisition projects managed by the USGS use a suite of Qualifications Based Selection (QBS), Indefinite Delivery, Indefinite Quantity (IDIQ) contracts called the Geospatial Products and Services Contract (GPSC). There are seven prime contractors under the suite of GPSC contracts with a combined delegated procurement authority of $250M. Each prime contractor has multiple subcontractors on its GPSC team. The contracts include acquisition, processing, and quality assurance of lidar and other source geographic data. The acquisition specification calls for a number of standard deliverables to be created by the contractors to include classified point cloud data and derived DEMs. These contracts were awarded beginning in the fall, 2009 for one year with four available option years. The GPSC will be re-competed in 2014. While funding partners will be encouraged to utilize the services of the USGS GPSC, they may elect to use their own contracting capabilities. When 3DEP acquisitions are managed through contracts other than GPSC, the acquiring agency will require that their contract's project deliverables meet the minimum 3DEP acquisition specifications.

Lidar data acquired by the USGS for entry into the NED, after September 2012, meet the specifications prescribed by the LiDAR Base Specification Version 1.0 (Heidemann, 2012). The minimum specifications ensure that bare earth models (DEMs) derived from lidar data are suitable for the NED and meet QL3 accuracy requirements. The specification also ensures that the point cloud source data are handled in a consistent manner by all data providers and delivered to the USGS in clearly defined formats. The specification is being updated to add QL2 acquisition requirements. The American Society of Photogrammetry and Remote Sensing (ASPRS) Accuracy Standards for Digital Geospatial Data is under development and it is the intent that the USGS lidar base specification will align with that emerging standard. The requirement for a hydro-enforced DEM is known, however, the procedures for creating this product are not defined sufficiently to create a specification. A high priority research topic has been identified to address this issue. The Lidar Base Specification Version 1.0 includes mandatory deliverables per project as follows:

- Raw Point Cloud - project as swaths, fully calibrated, controlled to ground, local coordinate reference system, unclassified
- Classified Point Cloud - as project tiles (no geographic overlap), local coordinate reference system, classified
- Bare Earth Surface (Raster Digital Elevation Model) - hydro-flattened, topographic DEMs, typically a 1 meter grid cell (may also be 2 or 3 feet). QL3 as defined by NEEA.
- Breaklines – only when used for hydro-flattening
- Metadata

The lidar base specification is being revised to upgrade collection criteria to meet QL2 requirements.

- Accuracy Improvements to reduce RMSEz from ≤18.5 centimeters to ≤ 9.25 centimeters
- Nominal pulse spacing (NPS) from 2 meters to 0.7 meters
- Establish a new measurement methodology and specifications for Relative Accuracy

Other revisions and additional requirements are under consideration as follows:

- Tighten requirements for classification accuracy from 98 percent to 99 percent (no more than 1 percent of dataset sampled points can be misclassified) or better
- Develop specifications for delineation of wetland/swamp/marsh and intermittent ground areas (as a separate polygon feature class)
- Require delivery of basic hydro-flattening breaklines and additional breaklines to support advanced hydro treatments for the USGS, National Hydrography Dataset (NHD) and other applications.
- Require additional classification of lidar data to include bridge decks, "exclusion" classes for points near specific types of breaklines, road surface, vegetation (high, medium, and low), buildings and other structures
- Delineation of intermittent ground/water areas (tidal, flood, etc.) as polygon features
- Add requirements for tidal coordination for all coastal projects

Data Quality Control and Acceptance

The USGS performs quality control (QC) inspection of all elevation data to ensure compliance with contract specifications. For data that the USGS receive from other organizations, an assessment is completed to determine whether or not it meets the minimum specifications. The QC includes:

- Inspection of all delivered files (lidar and ifsar project and data files, metadata, DEMs, imagery, and other required files) to identify corrupt or missing data and improper formats,
- Automated and visual assessment of project and file metadata for completeness and accuracy,
- Visual inspection of DEMs and lidar point cloud data for surface continuity, proper hydrographic feature treatment, vegetation and building removal, point classification and other characteristics and,
- Vertical accuracy testing for compliance with specifications.

Projects with missing, inaccurate, or improperly processed data are returned to the contractor with an inspection report identifying and describing the problems (or examples of the problems). Subsequent deliveries are rechecked and accepted if problems are corrected to specification. The USGS may correct minor problems if it is more cost effective to the government. Similar QC checks will continue with the 3DEP; however, because the volume of data will be five to six times greater per year than quality controlled historically, efficiency improvements are part of the planned data management modernization activities. They include some or all of the following:

- Additional storage, high-performance workstations, and more efficient QC software
- Design and implementation of a statistically sound QC sampling process
- Increased automation to identify elevation surface anomalies (e.g., poor swath joins or clusters of vegetation or buildings using automated surface roughness/continuity analysis)

Elevation data that are contributed to the USGS may require editing to resolve various anomalies in the data. Historically, the edited source data were resampled into the 1/9 arc second dataset. These edited (modified) source data were not retained as they were considered to be intermediate work products. The NED modernization project will change this practice and source DEM edits will be retained in the future.

Data Processing and Product Creation

The 3DEP operational infrastructure will be established to meet acquisition, processing, information management, and delivery requirements. Figure 10 illustrates the 3DEP concept of operations including acquisition, quality control and acceptance, storage, and processing of data and creation and delivery of products. Product options and delivery service components will be modified as the product requirements are refined and finalized according to the user product needs assessment and continued product research.

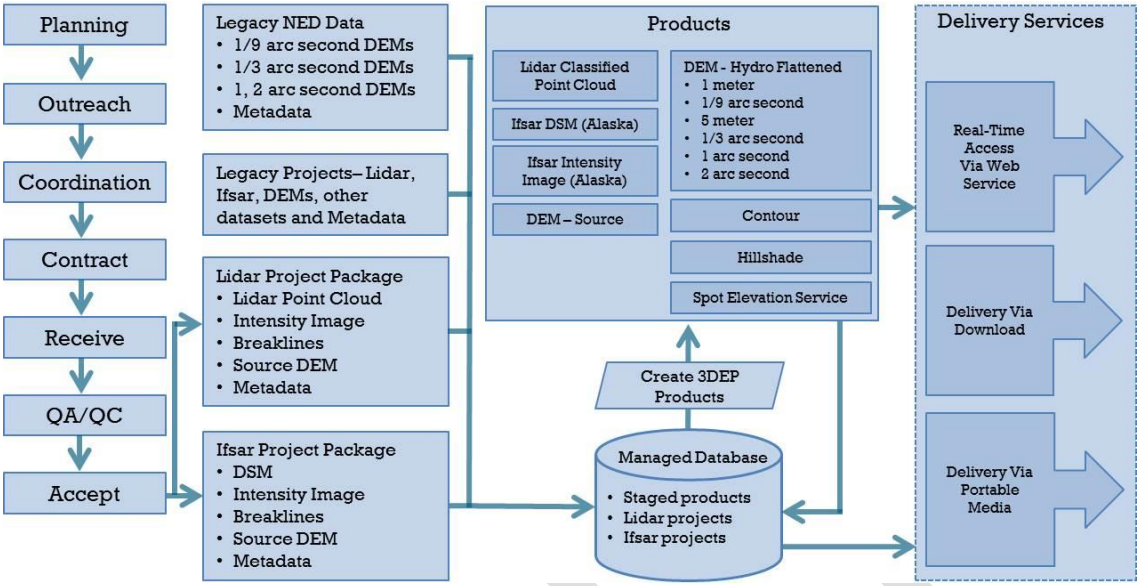

Figure 10. 3DEP Concept of Operation. The operations workflow assumes a transition from the legacy NED products to a new operational state. The diagram is intended to illustrate the concept of operation. Specific products, workflow, and delivery services will be determined during the detailed requirements and design phase. For the full list of planned products and expected delivery dates see Table 5.

The USGS will manage source data in the native form (projection, coordinate system, and horizontal post spacing) by project or project tiles for lidar, ifsar, source DEMs and other data types as delivered by contractors or contributing partners. Customers will generally be able to access these data via online download services. The timing of these services will vary by data type and source data condition. In particular, older dataset quality and completeness is highly variable and a planned assessment will determine how feasible it will be to provide future access to those data.

For ifsar data in Alaska and for new lidar data projects acquired to the QL2 specification, all new DEM products will be supported. From ifsar, five meter, 1 arc- second and 2 arc-second DEMs will be created in Alaska. In the conterminous US and Hawaii, standard 1 meter, 1/3 arc-second and 1 arc-second DEMs will be supported. Support for the 1/9 arc second DEM will likely be phased out as the 1 meter DEM product becomes available, although legacy 1/9 arc second data will be retained and available through download services. Products may be created on demand or staged for public access. The exact mix of staged and on demand products will be determined based on system performance and storage trade off assessments.

Native-resolution DEMs may not be available for all areas of pre-existing 1/9 arc second coverage. The 1/9 arc-second layer is presently created from high-resolution DEMs that have been edited to correct various surface anomalies. These edits are not saved back to the original source DEM; they are only preserved in the 1/9 arc second data layer. Consequently, the 1/9 arc second layer may be the only edited and quality controlled data in those areas where the original source DEM edits were discarded. In most cases however, the unedited higher resolution source data will be available for download. As outlined above, the edited source DEMs will be preserved in the future. Production of a staged 1/9 arc-second DEM will likely be discontinued as newer 1 meter DEMs created from QL2 lidar data become available. This will reduce the cost of resampling and maintaining the DEMs in a common geographic coordinate system. By storing the data in a native format, users will be able to easily convert the data to meet their application specific requirements. This will minimize the number of coordinate system transformations and the errors that might be introduced. Updating the seamless 1/3 arc-second DEMs, and deriving custom high-resolution products directly from the original data will also improve the accuracy of those datasets by eliminating resampling errors.

Capability to deliver elevation products is planned for January 2015 or sooner. The standard products include the lidar classified point cloud, contours, 2 arc-second DEM (Alaska), 1 arc-second DEM, 1/3 arc-second DEM and 1/9 arc-second DEM and other products as identified in table 5. Distribution of the classified point cloud tiles will be operational in October 2014. Presently, the lidar classified point cloud data are distributed in the same tiles and form as they are received from vendors. Hillshades will be retained as a viewing service. The work to refine requirements as outlined in the NEEA will result in a set of prioritized products to be included in future product releases. It is expected that 2 or 3 new products will become available on January 2015 and that additional products will roll out in subsequent months depending on identified needs and available funding. For delivery, DEMs and lidar point cloud data will be processed into pre-tiled, staged files. The pre-staged files will be managed from the public cloud or internal storage, and accessed through *The National Map* viewer and other web applications. Additional delivery mechanisms, such as on-demand rendering and real-time delivery via the web or customizable large volume data rendering and delivery via less immediate delivery channels, will be phased in based on customer requirements, cost efficiency, and system capability.

Phase one – NED, Lidar and Ifsar Operations Modernization

The NED production system will utilize new technologies to improve production workflows and overall product quality. With this new technology, it will be possible to expand the product and service offering at a lower initial cost. Development of the system has begun and will be operational by April 2014. Esri's mosaic dataset functionality will be used for data storage solution for DEMs and products derived from DEMs. Multiple solutions are under consideration for managing and provisioning the LAS point cloud datasets and ifsar source data. Key capabilities to be assessed will include the ability to handle the anticipated 3DEP data volumes, new product types and performance requirements.

Phase two – 3DEP Development

General research and development priorities and plans for Phase 2 development will evolve as part of the program annual planning activity. Specific requirements, schedules, resources, and plans will follow from the fiscal year planning decisions. Major issues requiring investigation and development are described in this section.

The list of prioritized products and services, to include preliminary product specifications (i.e., formats, resolutions) will be determined from ongoing user needs assessments. The Products and Services section describes the process for obtaining this information which will become the primary requirement for customer products and services. Based on user requirements, a feasibility assessment and probable cost projections are completed. Elevation data production and delivery systems will be built to deliver the high priority products. The NED modernization project will continue to support staged tile products. It is expected that future products will be either staged or created on-demand to optimize production workflows, processing and data management. Cost and system performance tradeoffs will impact the direction of these development activities. For example, rendering of elevation profiles may be most efficiently provided as an on-demand service because the output volume is low and profile generation is fast. In contrast, high demand for large volumes of first return lidar surfaces (digital surface models) may require up-front processing and storage for all (or high demand areas of) lidar projects. Development of the expanded product generation and delivery capability will be initiated following the release of Phase one NED and point cloud distribution development efforts.

To keep pace with the increased collection rate and volume of data anticipated, QC procedures and software applications are being improved. The increased efficiency will be achieved through advanced statistical sampling and automated error identification and correction. Software will be acquired or developed by experts in production quality control. The QC process must accommodate expected data throughput rates and ensure high quality results.

Risk Mitigation Strategies

The 3DEP initiative is designed to minimize risks by building on more than 15 years of experience with digital elevation data and in utilizing partnerships to achieve the program objectives. Fourteen risk areas

were identified during the planning process and specific risk mitigation strategies were built into the plan to address potential problem areas. The identified risks are as follows:

- Insufficient funding significantly increases the timeframe to achieve national coverage leaving gaps and areas with lower quality or older data.
- Rate of funding increase is too slow to promote partnerships and large area collections so that the momentum needed to establish a national program is not achieved, perpetuating the opportunistic, project-based approach for acquiring new data.
- Funds are not allocated to the development of information management or technology infrastructure to meet growing needs.
- Funds are not allocated to meet support staff development and management oversight needs.
- Varying budget cycles among partner agencies impedes an effective annual planning and coordinated data acquisition process.
- Partners resist participating in a unified plan in favor of maintaining their independent plans and processes.
- Lack of national plans and coordination within Federal partner agencies impedes the unified planning process.
- The majority of states are unable to implement state lidar plans resulting in low participation rates from state partners.
- Different collection strategies and specifications among data collectors results in reduced partnership development (e.g. topographic specifications verses topobathymetric specifications within the coastal zone).
- Conflicting priorities for data acquisition, both near- and long-term results in partnership development too low to achieve a national program.
- User requirements are inadequate to fully define products and services resulting in unrealized user benefits.
- Products or services are delayed due to resource or technology limitations.
- Information technology acquisition policies or protracted delays in contracting results in significant product rollout delays.
- Information technology development falls behind schedule or is technologically flawed.

Strategy 1 – A 3DEP Executive Committee and Coordinating Committees comprised of partner organizations will participate in the decision making process.
Strategy 2 - The 3DEP initiative will be designed and executed to scale to any funding level up to the proposed $1.2 billion over 8 years.
Strategy 3- Participation in the 3DEP initiative is voluntary, reducing risk exposure to any agency's mission critical activity.
Strategy 4 – Systems development will be managed to small, low risk projects with usable products for customers at the conclusion of each phase.
Strategy 5 – Information technology investments will be minimized and flexible by utilizing cloud services and taking advantage of lease options when technology or services are acquired.

Research Requirements

The 3DEP planning process identified numerous issues or questions in which additional assessments, evaluations, or research is required. For purposes of this document, the term research has been broadly defined to cover issues and questions which need resolution. The acquisition, processing, archive and distribution of data for 3DEP require operational developments and some fundamental and applications research. The near term and immediate need requirements have been identified as high priority.

1. High priority – Evaluate on-demand product generation and delivery services as an alternative to staging data products for download. The research objective is to determine if quality and product consistency can be maintained since many of the staged products include some

operator involvement during the production process. Total product lifecycle costs and system performance for the alternative approaches will be evaluated.

2. High priority - Acquire or develop data management solutions for lidar point cloud files. Evaluate alternative data management and product generation systems for lidar data and lidar derivative products. This evaluation may include existing vendor products or a mix of vendor and newly developed capabilities for managing LAZ compressed lidar files and generating products directly from LAZ files. Assessment criteria will include the ability to handle the projected 3DEP data volumes, new product types and system performance.
3. High priority - Provision legacy high resolution source DEMs. Evaluate alternative solutions, probable costs and benefits of releasing pre-2014 source DEMs. These DEMs were used to produce lower resolution 1/9 arc second DEMs and were not maintained as edited source DEMs.
4. High priority - Hydrologically enforced or conditioned DEMs have been identified as one of the highest priority new products. A hydrologically enforced DEM is required to support hydrologic modeling and mapping requirements. The research objective is to create a specification for a hydrologically enforced DEM and production procedures that will address the primary needs of hydrologists. This requirement is significant in that it has the potential to impact the acquisition requirements (and costs) for lidar, ifsar and the derived DEM products.
5. High priority - A USGS research objective is to improve the integration of elevation and hydrography data. A range of alternative solutions will be considered to include new edit tools to align hydrography features with elevation data, and advanced data models and procedures to create derived hydrographic networks that are integrated with elevation data.
6. Medium priority – A USGS strategy is needed to implement ongoing changes to the National Spatial Reference System (NSRS) which includes NOAA NGS geoid models being developed out of the GRAV-D program. Planned adjustments to the NSRS will have significant impacts on the elevation values. If data will be stored as received, then processing will need to occur to account for the differences in ellipsoids and geoid models used.
7. Medium priority – Evaluate data as-a-service solutions for 3D elevation data. The emerging Geospatial Platform and cloud services capabilities offer opportunities for customers to acquire data services rather than building many one off solutions. Policy issues with respect to cost recovery (who pays) will be addressed as part of this research topic.
8. Medium priority - Determine user requirements for seamless one meter DEMs and other lidar point cloud derived products for user-defined areas of interests that cross (acquisition) project boundaries. If required, determine the availability of geoprocessing tools and data management capabilities for rendering such products efficiently.
9. Medium priority - Standard products development - The standard suite of 3DEP products derived from lidar point clouds will be identified from the ongoing user requirements assessments. Some products, such as hillshades, slope, and aspect can be readily produced using commercial software and require research only to make them operational in a national context. Others may require research and development. This is expected to be an ongoing research need as the program changes over time.
10. Long term research priority - Explore High Performance Computing (HPC) and Cyber GIS to support lidar and 3DEP processing; investigate big data approaches with lidar and 3DEP and integration with other USGS science data. Advances in HPC, including parallel processing, grid computing, and cloud-based computational solutions may provide an opportunity to handle the complex computations and massive volumes of data from 3DEP.

DRAFT

11. Long term research priority – Evaluate spatiotemporal data models that support the x, y, and z coordinates available from 3DEP data and also supports integration with legacy datasets of hydrography, transportation, and other topographic data. This longer term research objective, while broader, relates to the elevation and hydrography integration objective.
12. Long term research priority - Identify relations between map scale and geomorphological characteristics of cartographic features to automate hydrographic and elevation feature extraction and generalization. This research objective applies to other feature types found in *The National Map* as well.
13. Long term research priority - Develop methods, tools, processes, and systems to support use of lidar and other elevation products in USGS science programs. The impacts of 3DEP data resolution on current scientific models are unknown.

Acknowledgements

The 3-D Elevation Program initiative is the product of thousands of hours of tireless work by many individuals both within the USGS and among our partner Federal, State and professional organizations. Larry Sugarbaker is the primary author. Contributions have been made by David Brostuen, Eric Constance, Michael Domaratz, Hans Karl Heidemann, Allyson Jason, Vicki Lukas, James Mauck, David Saghy and Jason Stoker. Dave Maune, of Dewberry Inc. was instrumental in conducting the original NEEA study. He has often characterized the study as a great example of the private sector and government working in partnership. Working together in partnership has been the theme of the entire program and it is with a sense of optimism that the author puts forth this plan. As of this writing, the program initiative has received far reaching support from the States, many private sector companies and organizations to include the National Digital Elevation Program committee and the member agencies, the National States Geographic Information Council, the National Geospatial Advisory Committee, the Management Association for Private Photogrammetric Surveyors and others.

References

Dewberry, 2011, Final Report of the National Enhanced Elevation Assessment: Fairfax, Va., Dewberry, 84 p. plus appendixes (revised 2012), available at http://www.dewberry.com/Consultants/GeospatialMapping/FinalReport-NationalEnhancedElevationAssessment.

Executive Office of the President, Office of Management and Budget, 2010, OMB Circular A-16 Supplemental Guidance (November 10, 2010) 33pp.

GAO-13-94, 2012, Geospatial Information: OMB and Agencies Need to Make Coordination a Priority to Reduce Duplication, GAO Report to the Committee on Homeland Security and Governmental Affairs, U.S. Senate, 56 p.

Heidemann, H.K., 2012. Lidar base specification version 1.0, U.S. Geological Survey Techniques and Methods, book 11, chap. B4, 63 p., URL: http://pubs.usgs.gov/tm/11b4/ (last date accessed: 4 June 2013).

DRAFT

Appendix A: Source Elevation Data and Product Definitions

Elevation Source Data

Source data are the raw data from which elevation models and their derivatives are created.

Enhanced Spatial Metadata

As most airborne lidar and ifsar datasets are collected and organized by flight line and lift, the metadata will document spatial data by project and by lift. As a result, the project metadata records and preserves information for the entire collection and is a good summary of the project. Providing metadata per flight line would be valuable because errors in the data could be identified and corrected more easily, thus giving the consumer a better idea of the nature of the data and how it behaved in the collection.

For data delivered in orthometric heights, ensure that the metadata includes the geoid model used to convert from ellipsoid heights to orthometric heights. This allows all data to be re-adjusted to newly adopted geoid models by converting orthometric heights back to the ellipsoid, and then to the refined orthometric heights (using the formula: $H2 = H1 + N1 – N2$) where H1 is the old orthometric height, H2 is the new orthometric height, N1 is the old geoid height, and N2 is the new geoid height, for all points.)

Lidar Full Point Cloud

A lidar point cloud is a collection of x, y, z coordinates of the locations, in 3-dimensional space, at which first, last, and significant intermediate laser returns from each emitted pulse were reflected back to the sensor. These returns may reflect from towers, bridges or other elevated structures, rooftops, tree branches and leaves, and the earth surface.

Fully calibrated and controlled lidar point cloud data are delivered in two formats:

- In swaths, unclassified
- In tiles, classified

Lidar Full Waveform

Lidar full waveform data records the entire backscattered signal of each emitted pulse, rather than discrete first, intermediate and last pulses from traditional laser scanners.

Breaklines

Breaklines are linear features that describe a change in the smoothness or continuity of a surface. They can be either 2-D breaklines with x/y coordinates only or 3-D breaklines with x/y coordinates plus z-values representing elevations above a defined vertical datum. In most all cases, breaklines are 3D (PolylineZ); 2D breaklines are usually an interim product intended to have elevation values conflated to the vertices during later processing. The USGS requires delivery of breaklines only if used for hydro-flattening.

Orthorectified Ifsar Intensity Images

The radar reflectance intensity of various earth surface materials. Orthorectified ifsar images are standard deliverables of the Alaska ifsar acquisition projects.

Elevation Models

There are a variety of digital models used to depict the earth's surface: the bare earth (minus vegetation and structures); the surface with vegetation and structures; uniformly gridded or irregular; and hydrologically-enforced, flattened, or neither. Each differs but can share similar qualities. The following are elevation models under consideration for a 3DEP product offering. The current standard NED product is a hydro-flattened DEM.

DEM Resolution	Edge matched or seamless	Potential Coverage	3DEP Source	Format
Source resolution	No	CONUS, HI, AK, Territories	Lidar or Ifsar	ArcGrid and .img
1 meter	No	CONUS, HI, AK, Territories	Lidar or Ifsar	ArcGrid and .img
3 meters	No	CONUS, HI, AK, Territories	Lidar	ArcGrid and .img
5 meters	No	AK	Ifsar	ArcGrid and .img
1/3 arc-second (~10 meters)	Yes	CONUS, HI, AK, Territories	Lidar and Ifsar	ArcGrid and .img
1 arc-second (~30 meters)	Yes	CONUS, HI, AK, Territories	Lidar and Ifsar	ArcGrid and .img
2 arc-second (~60 meters)	Yes	AK	Lidar and Ifsar	ArcGrid and .img

Digital Elevation Model – No Hydro Treatment

A grid of bare-earth elevations (z-values) at regularly spaced intervals with no hydro flattening or enforcement.

Digital Elevation Model (DEM) – Hydro Flattened

A grid of bare-earth elevations (z-values) at regularly spaced intervals where ponds and lakes are leveled and streams and rivers are modified for continuous downhill flow. Bridge decks are typically removed, while roads over culverts remain in the surface model. Hydro flattened DEMs are used for general topographic mapping and contour generation.

Digital Elevation Model (DEM) – Hydro Enforced

A grid of bare-earth elevations (z-values) at regularly spaced intervals where ponds and lakes are leveled and streams and rivers are modified for continuous downhill flow. Bridge decks are removed, and roads are cut to allow the surface to depict the actual flow of water beneath the road. Hydro enforced DEMs are used for many forms of hydrographic and hydraulic modeling.

Digital Elevation Model (DEM) – Hydro Conditioned

A grid of bare-earth elevations (z-values) at regularly spaced intervals where ponds and lakes are leveled and streams and rivers are modified for continuous downhill flow. Bridge decks are removed, and roads are cut to allow the surface to depict the actual flow of water beneath the road. In addition, all spurious surface pits and depressions are removed (filled), allowing continuous water flow across the entire surface. Hydro conditioned DEMs are used for many forms of hydrographic and hydraulic modeling.

Digital Surface Model (DSM)

A grid of bare-earth elevations (z-values) at regularly spaced intervals. A DSM is a raster elevation model of the top reflective surface that may include buildings, trees, towers and other features elevated above the earth as well as the bare earth surface in open terrain. The first returns in the lidar point cloud and returns of x-band ifsar yield the DSM.

Digital Terrain Model (DTM)

The DTM is a representation of a bare-earth surface that can include irregularly spaced mass points and breaklines. The bare-earth points and breaklines as specified in the USGS Lidar Specification (Heidemann, 2012) comprise a DTM. Although both map the bare-earth terrain, the major difference between a DEM and DTM is that the DEM has a uniform grid, but the DTM can include irregularly spaced mass points and breaklines.

Derivatives
Number of Returns/Density A raster-based count of the number of returned laser signals within a pixel area.
Orthorectified Lidar Intensity Images This is the strength of the signal reflection from the target(s) back to the lidar instrument represented as a gray-scale raster image. Intensity images are useful because they are inherently georeferenced, which allows for photogrammetric-like stereo compilation of breaklines and other features. Currently there is no standardized method for calibrating or normalizing an intensity image, which means the same type of object may reflect at a different intensity based on a wide range of factors including flying height, beam divergence, scan angle, etc.
Hillshade Hillshades are 2-D gray-scale or color-ramp images that simulate a 3-dimensional visualization of the terrain. They may be generated using variable view angles and sun angles in order to maximize visual interpretability of the terrain. Hillshades are an alternative to contours for human visualization of 3-D topographic surfaces, however they do not provide any actual elevation information. Hillshades are typically derived from bare-earth DEMs or TINs, but could also be produced from DSMs in order to visualize the terrain with elevated features such as vegetation and man-made structures.
Contours Contours represent lines of equal elevation on the earth's surface. The USGS presently produces and distributes contours at elevation intervals appropriate for terrain depiction at 1:24,000-scale and select smaller scales. Future services could allow contours to be generated at user-specified intervals for viewing and download.
Cross-section/Profile A profile is a side view of a cross section of a surface or point cloud. A cross section of a surface has zero depth. A cross section of a point cloud has a user defined depth.
Height Above Ground The elevation difference between the highest detected point in a cell and the ground elevation for that cell. This is simply a raster calculation where a DEM elevation is subtracted from the DSM elevation. The derived resolution is a function of the pixel size of the DEM and DSM data. This calculation provides the height of features above the ground. Tree/canopy heights and building footprints/heights can easily be extracted from this derivative.
Slope Slope is the measure of change in elevation over distance, expressed either in degrees or as a percent, from either a TIN or from a raster. Slope maps may be derived as raster datasets from DEMs.
Curvature Curvature is a form of elevation derivative that defines the shape of the terrain surface for analysis of surface flow pathways and soil wetness, for example. There are nine basic curvature types that are combined for many types of curvature analyses, e.g., plan form curvature, profile curvature, and tangential curvature.
Aspect Aspect is the direction, normally measured clockwise in degrees from north, of the steepest down-slope across a surface. Aspect datasets are typically derived in raster from DEMs.
Flow Direction A flow direction grid consists of a flow direction value for each DEM point that identifies which neighboring point has the lowest elevation.
Flow Accumulation A flow accumulation grid consists of an integer value, derived at each DEM point, which represents the number of "upstream" DEM points whose flow path passes through it. High accumulation values indicate points in a stream, whereas low values represent areas of overland flow.

Acronyms

3DEP	3D Elevation Program
ARRA	American Reinvestment and Recovery Act
ASPRS	American Society for Photogrammetry and Remote Sensing
CLICK	Center for Lidar Information, Coordination, and Knowledge
CoNED	Coastal National Elevation Dataset
CONUS	conterminous United States
CORS	Continuously Operating Reference Stations
DEM	Digital Elevation Model
DSM	Digital Surface Models
DTED	Digital Terrain Elevation Data
DTM	Digital Terrain Model
FA	functional activity
FACA	Federal Advisory Committee Act
FGDC	Federal Geographic Data Committee
GAO	U.S. Government Accountability Office
GB	gigabyte
GPS	Global Positioning System
GPSC	Geospatial Products and Services Contract
GSD	Ground Sample Distance
HARN	High Accuracy Reference Network
HPC	High Performance Computing
IDIQ	Indefinite Delivery, Indefinite Quantity
ifsar	interferometric synthetic aperture radar
IMU	Inertial Measurement Unit
IWG-OCM	Inter-agency Working Group on Ocean and Coastal Mapping
K-12	kindergarten to twelfth grade
lidar	light detection and ranging
MAPPS	Management Association for Private Photogrammetric Surveyors
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NCMS	National Coastal Mapping Strategy
NDEP	National Digital Elevation Program
NED	National Elevation Dataset
NEEA	National Enhanced Elevation Assessment
NGAC	National Geospatial Advisory Council
NGP	National Geospatial Program
NGS	National Geodetic Survey
NHD	National Hydrography Dataset
NPS	Nominal Pulse Spacing
NSRS	National Spatial Reference System
NSGIC	National States Geographic Information Council
QA/QC	Quality Assurance/Quality Control
QBS	Qualifications Based Selection
QL	Quality Level
OMB	U.S. Office of Management and Budget
RMSD	Root Mean Square Difference
RMSE	Root Mean Square Error
TBD	To Be Determined
TIN	Triangulated Irregular Network
TNM	The National Map

DRAFT

USGS	U.S. Geological Survey
USIEI	United States Interagency Elevation Inventory
UTM	Universal Transverse Mercator
VMAS	Vertical Map Accuracy Standards

DRAFT

Contact information:
Larry Sugarbaker, Senior Advisor
National Geospatial Program, USGS
Phone: 703 648 5741
Email: lsugarbaker@usgs.gov

DRAFT Version 0.91 released on June 7, 2013
Reviewer comments received on August 20, 2013
DRAFT Version 1.0 released on November 27, 2013.
Reviewer comments due not later than February 12, 2014
Pre-publication copy target release date – March 12, 2014
Final publication (USGS circular) – Spring 2014