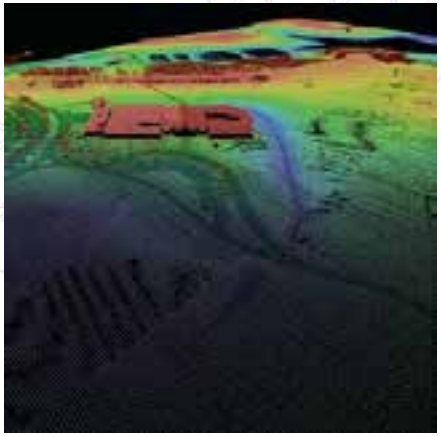
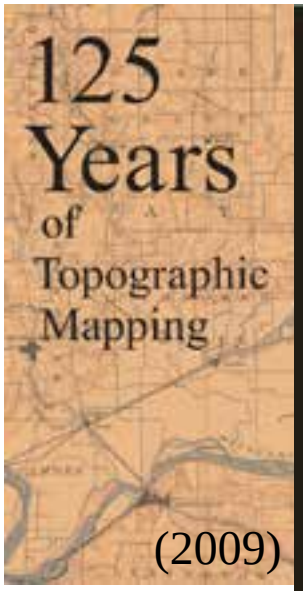
# The 3D Elevation Program: Overview

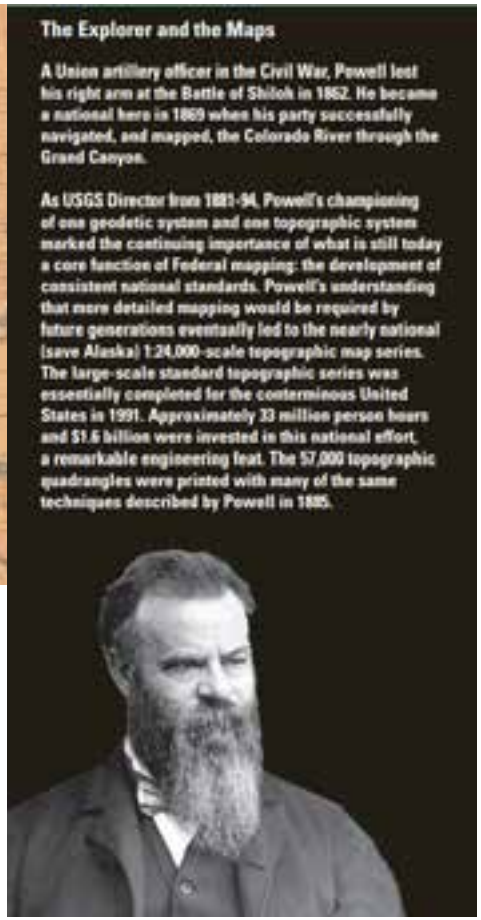


Jason Stoker
USGS National Geospatial Program
ESRI 2015 UC

# A little history

USGS has a long, proud tradition of mapmaking



The Explorer and the Maps

A Union artillery officer in the Civil War, Powell lost his right arm at the Battle of Shiloh in 1862. He became a national hero in 1869 when his party successfully navigated, and mapped, the Colorado River through the Grand Canyon.

As USGS Director from 1881-94, Powell's championing of one geodetic system and one topographic system marked the continuing importance of what is still today a core function of Federal mapping: the development of consistent national standards. Powell's understanding that more detailed mapping would be required by future generations eventually led to the nearly national (save Alaska) 1:24,000-scale topographic map series. The large-scale standard topographic series was essentially completed for the conterminous United States in 1991. Approximately 33 million person hours and $1.6 billion were invested in this national effort, a remarkable engineering feat. The 57,000 topographic quadrangles were printed with many of the same techniques described by Powell in 1885.

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# The changing times

- Mapping the breadth of the Nation in such meticulous detail has been a demanding challenge for USGS mapmakers since 1884.

- For 130 years, this ambitious goal has spurred USGS cartographers to invent new instruments, devise new methods, and apply the most modern technology to improve the accuracy, utility, and efficient production of geographic information.

# The Topographic map

## Art + Science

DESCRIPTION OF THE TOPOGRAPHIC MAP OF THE UNITED STATES.

The United States Geological Survey is making a topographic map of the United States. This work has been in progress since 1882, and about one-fifth of the area of the country, including Alaska, has been mapped. The mapped areas are widely scattered, nearly every State being represented, as shown on the progress map accompanying each annual report of the Director.

This great map is being published in atlas sheets of convenient size, which are bounded by parallels and meridians. The four-cornered division of land corresponding to an atlas sheet is called a *quadrangle* (a word used as specifically as notice is in the surveys of the public lands). The sheets are of approximately the same size; the paper dimensions are 21½ by 18½ inches; the map occupies about 17½ inches of height and 11½ to 13 inches of width, the latter varying with latitude. Three scales, however, are employed. The largest scale is 1:62,500, or very nearly one mile to one inch; i. e., one linear mile on the ground is represented by one linear inch on the map. This scale is used for the thickly settled or industrially important parts of the country. For the greater part of the country an intermediate scale of 1:125,000, or about two miles to one inch, is employed. A third and still smaller scale of 1:250,000, or about four miles to one inch, has been used in the desert regions of the far West. A few special maps on larger scales are made of limited areas in mining districts. The sheets on the largest scale cover 15′ of latitude by 15′ of longitude; those on the intermediate scale, 30′ of latitude by 30′ of longitude; and those on the smallest scale, 1° of latitude by 1° of longitude.

The features shown on this map may, for convenience, be classed in three groups: (1) *water*, including seas, lakes, ponds, rivers and other streams, canals, swamps, etc.; (2) *relief*, including mountains, hills, valleys, cliffs, etc.; (3) *culture*, i. e., the works of man, such as towns, cities, roads, railroads, boundaries, etc. The conventional signs used for most of these features are shown and explained in the marginal columns hereafter.

All water features are shown in *blue*, the smaller streams and canals in full blue lines, and the larger streams, lakes, and the sea by blue water-lining. Certain streams, however, which flow during only a part of the year, their beds being dry at other times, are shown, not by full lines, but by lines of dots. Ponds which are dry during a part of the year are shown by oblique parallel lines. Saltwater marshes are shown by horizontal ruling interspersed with tufts of blue, and fresh-water marshes and swamps by blue tufts with broken horizontal lines.

The land features of the relief, usually represented on maps by shading of some sort, with pen or brush, are here shown by contour lines in *brown*. Each contour passes through those points which have the same altitude. If one follows a contour on the ground one will go neither uphill nor downhill, but on a level.

By the use of contours not only are the shapes of the plains, hills, and mountains shown, but also the elevations. The line of the sea-coast itself is a contour line, the datum or zero of elevation being mean sea-level. The contour line at, say, 20 feet above sea-level is the line that would be the sea-coast if the sea were to rise or the land to sink 20 feet. Such a line runs back up the valleys and forward around the points of hills and spurs. On a gentle slope this contour line is far from the present coast line, while on a steep slope it is near it. Thus a succession of these contour lines far apart on the map indicates a gentle slope; if close together, a steep slope; and if they run together in one line, as if each contour were vertically under the one above it, they indicate a cliff. In many parts of the country are depressions or hollows with no outlets. The contours of course surround these, just as they surround hills. Those small hollows known as sinks are usually indicated by hachures, or short dashes, on the inside of the curve. Certain contours, usually every fifth one, are accompanied by numbers stating elevation above sea-level. Many other heights, instrumentally determined, are also given, the number in each case being placed in close proximity to the point to which it applies.

The works of man are shown in *black*, in which color all lettering also is printed. Boundaries, such as State, county, city, land-grant, reservation, etc., are shown by broken lines of different kinds and weights. Cities are indicated by black blocks, representing the built-up portions, and country houses by small black squares. Roads are shown by fine double lines (full for the better roads, dotted for the inferior ones), trails by single dotted lines, and railroads by full black lines with cross lines. Other cultural features are represented by conventions easily understood.

The sheets composing the topographic atlas are designated by the name of a principal town or of some prominent natural feature within the district, and the names of adjoining published sheets are printed on the margins. The sheets are sold at five cents each when fewer than 100 copies are purchased, but when they are ordered in lots of 100 or more copies, whether of the same sheet or of different sheets, the price is two cents each.

The topographic map is the base on which the facts of geology and the mineral resources of a quadrangle are represented. The topographic and geologic maps of any quadrangle are finally bound together, accompanied by a description of the district, to form a folio of the Geologic Atlas of the United States. The folios are sold at twenty-five cents each, except such as are unusually comprehensive, which are priced accordingly.

Applications for the separate topographic maps or for folios of the Geologic Atlas, accompanied by the cash or by post-office money order (not postage stamps), should be addressed to—

THE DIRECTOR,
*United States Geological Survey,*
*Washington, D. C.*

October, 1897.

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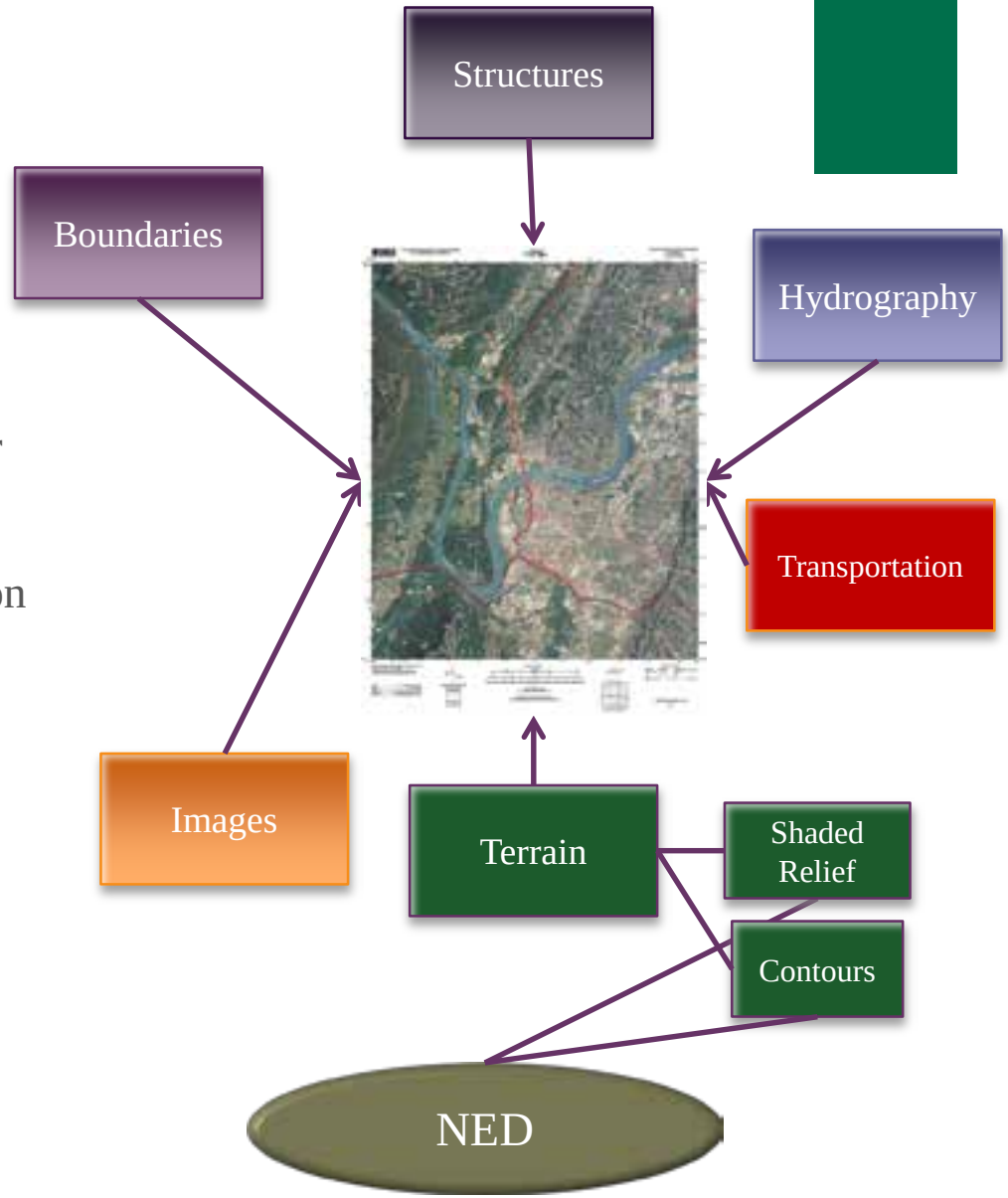
# US Topo

## A new National Map Series

- The project was launched in late 2009, and the term "US Topo" refers specifically to quadrangle topographic maps published in 2009 and later.
- These maps are modeled on the familiar 7.5-minute quadrangle maps of the period 1947-1992, but are mass-produced from national GIS databases on a repeating cycle.
- US Topo maps repackage geographic information system (GIS) data in traditional map form; this benefits non-specialist map users, as well as applications that need traditional maps.



# The National Map

## One of the cornerstones of the U.S. Geological Survey's (USGS) National Geospatial Program

- The National Map is a collaborative effort among the USGS and other Federal, State, and local partners to improve and deliver topographic information for the Nation.
- USTopo is powered by The National Map
- The geographic information available from The National Map includes:
  - orthoimagery (aerial photographs),
  - geographic names
  - hydrography
  - boundaries
  - transportation
  - structures
  - land cover
  - elevation

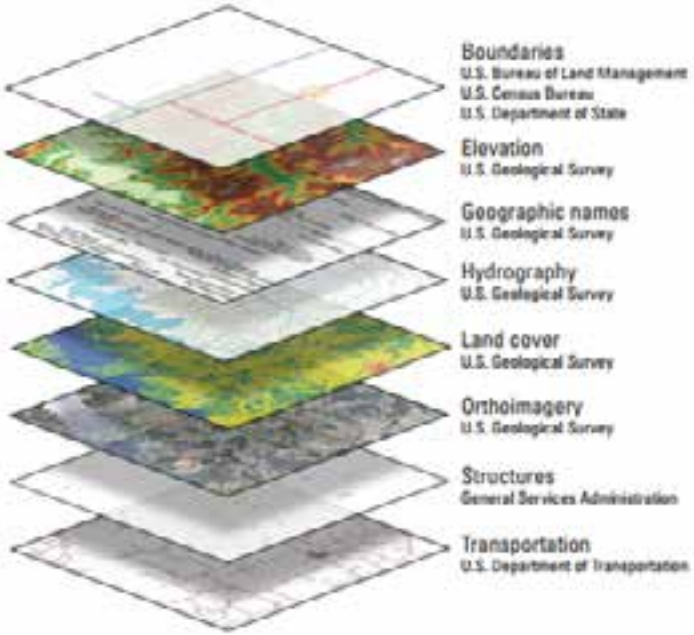



**Figure 1.** Eight base layers of *The National Map* and associated Office of Management and Budget Circular A–16 thematic lead agencies.

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# Elevation Historically

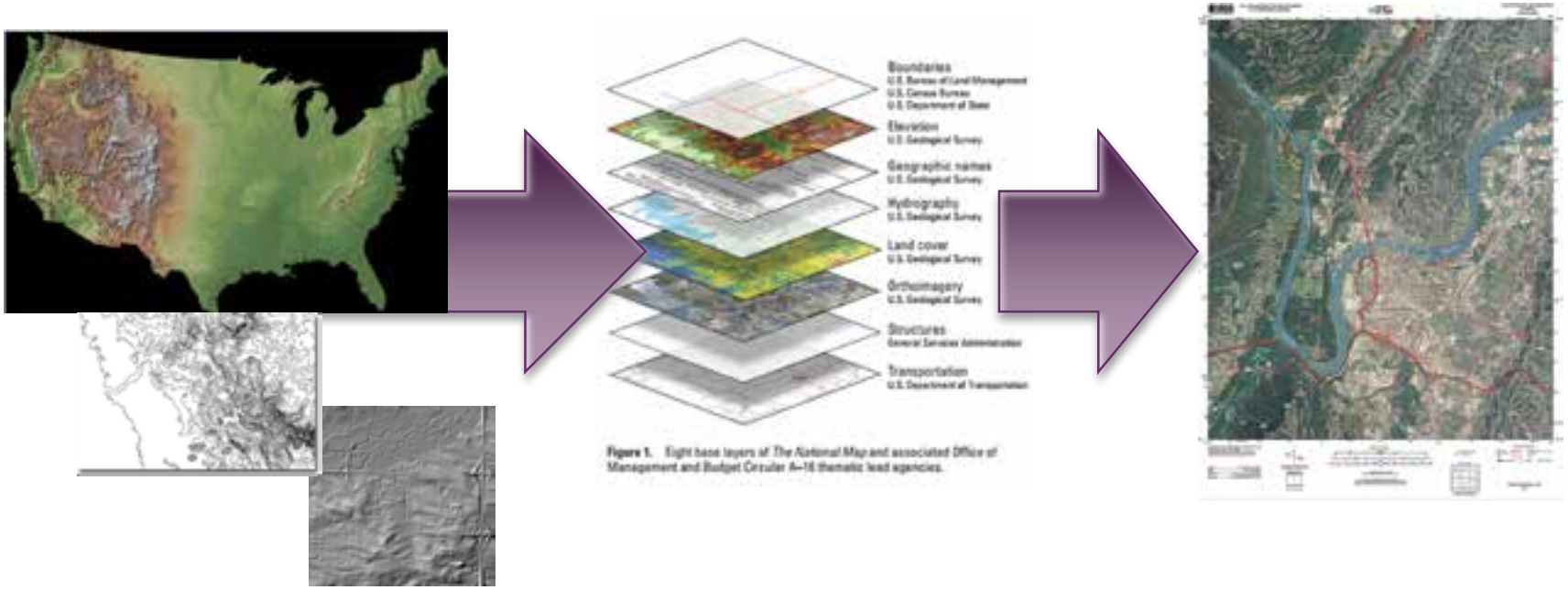
## Powered by the NED

- For 15 years, the National Elevation Dataset (NED) has been the primary elevation data product produced and distributed by the USGS. The NED provides seamless raster bare earth elevation data of the conterminous United States, Alaska, Hawaii, and the island territories. The NED is derived from diverse source data sets that are processed to a specification with a consistent resolution, coordinate system, elevation units, and horizontal and vertical datums.

- The NED served as the elevation layer of The National Map, and provided basic elevation information for earth science studies and mapping applications in the United States.

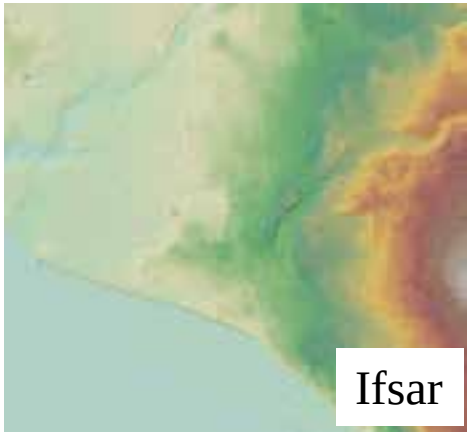
# Tying it all together- Historically

## From NED to derivatives to TNM to USTopo currently

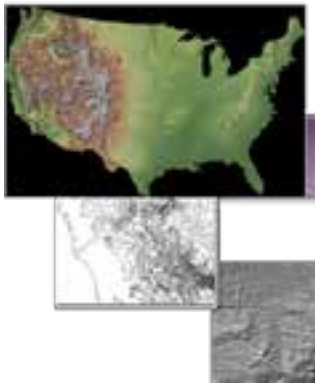


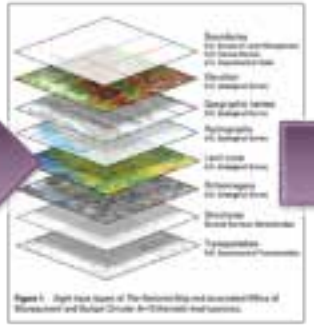
# Bare earth DEMs from Lidar/Ifsar feed our Elevation Historically

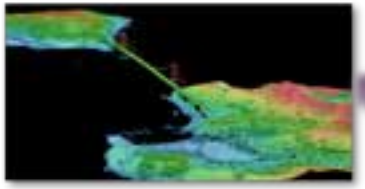
## From Lidar/Ifsar DEMs to NED to derivatives to TNM to USTopo




Bare Earth DEMs





Point Clouds

- CLICK
- Earth Explorer
- TNM

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# Mapping has changed

## Less art, more science

- With the proliferation of lidar and ifsar as our tools to collect elevation data, we are not really mapping anymore- we are now measuring elevation using remote sensing and GPS
- 3-D information from these systems are being used for an incredible amount of applications
  - We are not just measuring bare earth anymore, we are measuring vegetation, buildings, roads, streams, etc. in 3-D
- 3-D information is considered more and more commonplace, and consumer technology is rapidly embracing this trend

# 3-D
## Commonplace in our lives now, and growing








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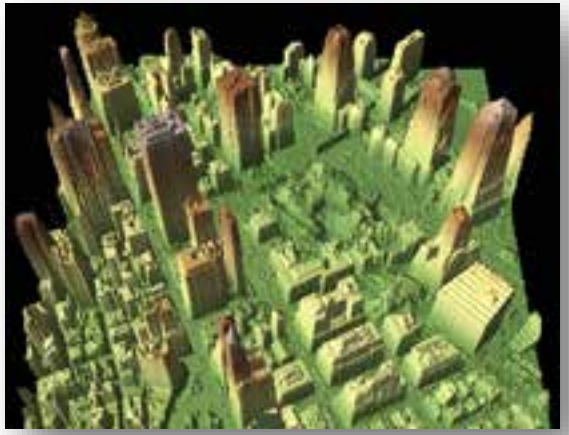
# 3D Elevation Program (3DEP)

**Applies ground-breaking lidar technology to acquire and distribute 3D data**

**Addresses a broad range of critical applications of national significance**



- 3D data include surface elevations and natural and constructed features
- 3DEP increases the quality level of lidar being acquired to enable more accurate understanding, modeling, and prediction
- Goal to acquire national coverage in 8 years

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# What is the 3D Elevation Program?

## 3DEP is a call for community action to…

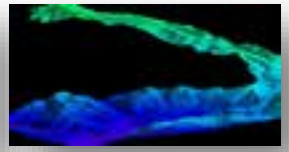
- Address the mission-critical requirements of Federal agencies, states, local governments, tribes, private and not-for profit organizations
- Increase the overall investment in 3D data from about $45 M to $146 M annually to return more than $690 million annually in new benefits
- Leverage collaboration among Federal, states, local and tribal partners to systematically complete national 3D data coverage in 8 years
- Leverage the capability of private industry mapping firms, create jobs
- Achieve a 25% cost efficiency gain by collecting data in larger projects
- Completely refresh national elevation data holdings with new lidar and ifsar elevation data products and services


Natural Resource Conservation


Infrastructure Management


Flood Risk Mitigation


Precision Farming


Land Navigation and Safety


Geologic Resources and Hazards Mitigation

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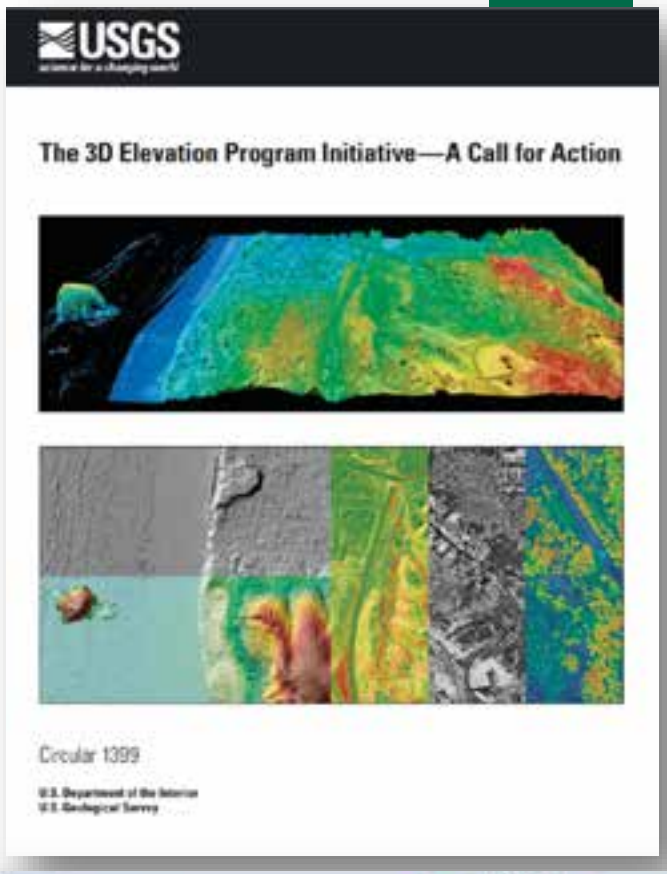
# 3DEP 2012-2015

## READY for a national, 8-year program

### Developed 3DEP infrastructure

- Documented comprehensive requirements and benefits in the National Enhanced Elevation Assessment (NEEA)
- Designed 3DEP based on NEEA and to maximize return on investment
- Developed the NEEA inventory into the annual U.S. Interagency Elevation Inventory in partnership with NOAA and others
- Published plan for action based on extensive stakeholder input
- Issued the first Broad Agency Announcement in 2014, with funding partnerships with FEMA and NRCS





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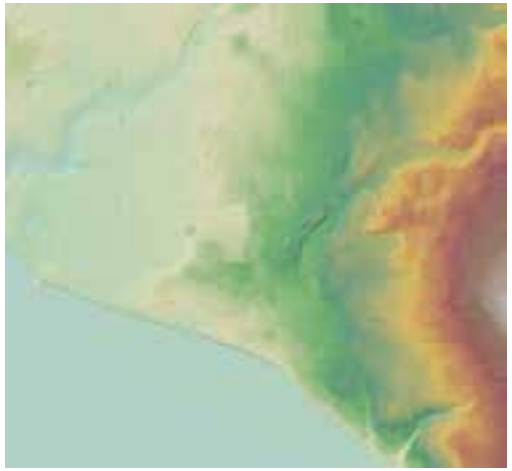
# + 3D Elevation Program

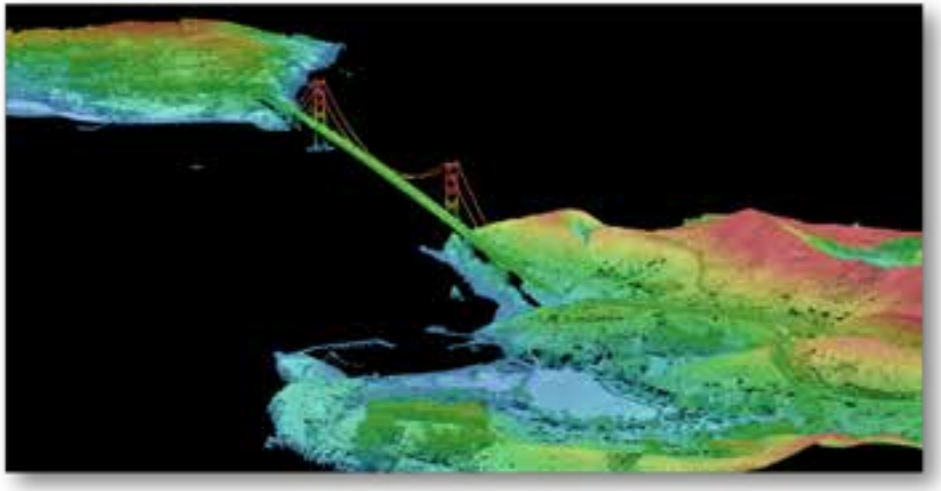
## Quality Levels – A New "Floor"

| Quality Level | Source | Vertical Accuracy RMSEz | Nominal Pulse Spacing (NPS) | Nominal Pulse Density (NPD) | DEM Post Spacing | |
|---|---|---|---|---|---|---|
| **QL1** | Lidar | 10 cm | 0.35 m | 8 points/sq. meter | 0.5 meter | |
| **QL2** | Lidar | 10 cm | 0.7 m | 2 points/sq. meter | 1 meter | Now |
| **QL3** | Lidar | 20 cm | 2.0 m | 0.7 points/sq. meter | 3 meters | Legacy |
| **QL4** | Imagery | 139 cm | N/A | N/A | 5 meters | |
| **QL5** | Ifsar | 185 cm | N/A | N/A | 5 meters | Alaska |

# New products and services being made available in 2015 from The National Map

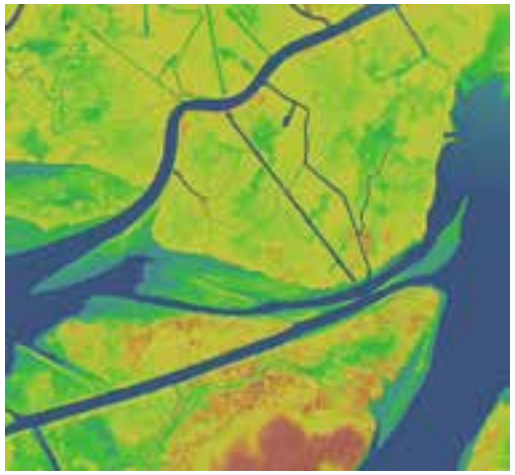


5 meter Alaska DEMs

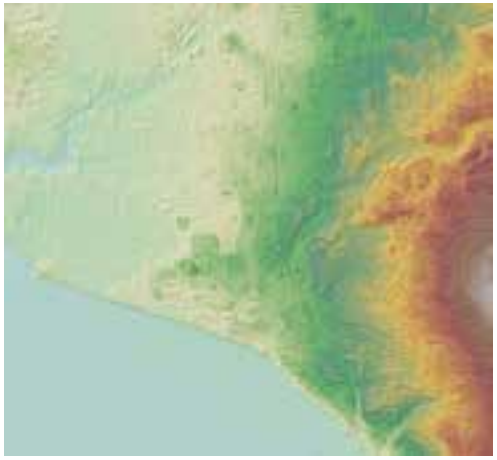


Lidar Point Cloud

Alaska Ifsar ORIs



1 meter DEMs



Alaska Ifsar DSMs

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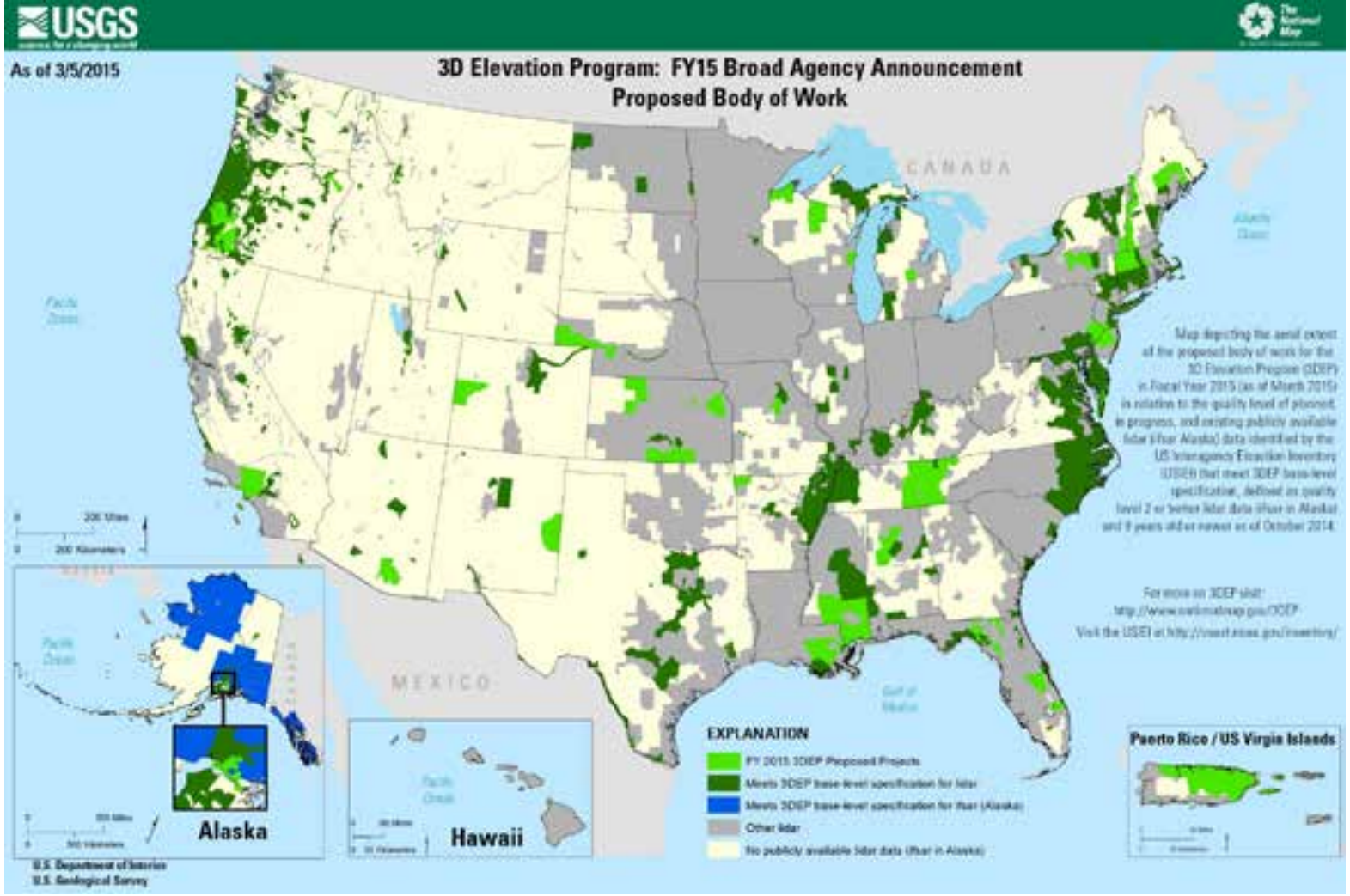
# 3DEP Products and Services

| Product | Planned coverage on release date | Sources | Planned product or service |
|---|---|---|---|
| 1-meter DEM | Partial coverage—U.S. and some territories | Lidar | Tiles (TBD) by download |
| 5-meter DEM | Partial coverage—Alaska | Ifsar | 1-degree×1-degree block by download |
| 1/9 arc-second DEM—Legacy | Partial coverage—U.S. and some territories | Lidar, ifsar, photogrammetry | 15-minute×15-minute block by download |
| 1/3 arc-second DEM | CONUS, HI, some territories, parts of Alaska | Lidar, ifsar, photogrammetry | 1-degree×1-degree block by download |
| 1 arc-second DEM | CONUS, HI, AK, and U.S. territories | Lidar, ifsar, photogrammetry | 1-degree×1-degree block by download |
| 2 arc-second DEM | Alaska | Lidar, ifsar, photogrammetry | 1-degree×1-degree block by download |
| Elevation-point query | CONUS, HI, some territories, AK | 1/3 arc-second DEM, except 1 arc-second DEM in AK | Application service |
| Hillshade | CONUS, HI, some territories, AK | 1/3 arc-second DEM, except 1 arc-second DEM in AK | Viewing service |
| Contours at 5 to 120 feet | CONUS, HI, some territories, AK | 1/3 arc-second DEM, except 1 arc-second DEM in AK | 1-degree×1-degree block by download and viewing service |

# 3DEP Products and Services



| Source data | Planned coverage on release date | Sources | Planned product or service |
|---|---|---|---|
| Lidar full point cloud—Unclassified | Partial coverage—U.S. | Lidar—QL1, QL2, QL3 | Project areas by special request |
| Lidar full point cloud—Classified | Partial coverage—U.S. | Lidar—QL1, QL2, QL3 | Project tiles by download |
| Ifsar digital surface model | Partial coverage—Alaska | Ifsar—QL5 | Project tiles by download |
| Orthorectified ifsar intensity image | Partial coverage—Alaska | Ifsar—QL5 | Project tiles by download |
| Source resolution DEM | Partial coverage—U.S. and some territories | Lidar, ifsar | Project tiles by download |




- 72 pre-proposals submitted, requested funds over $50M, 29 were funded
- Total estimated committed = $9.8M, with a total estimated value of $26.5M (estimates will be refined)
- The $9.8M is comprised of USGS, FEMA and NRCS funds
- Total square miles is estimated at 94,114, with average project size of 3,245 sq mi
- Additional selections may follow with remaining funding as project estimates are refined and FY15 funding is clarified

# 3DEP is Big Data

| Elevation Quality Levels (QL) | Required Point Density Per $m^2$ | Effective Point Density Per $m^2$ | Number of Points for U.S. | LAS 1.4 File Size (Terabytes, Uncompressed) for Entire U.S. |
|---|---|---|---|---|
| Quality Level 1 | 8 | 12 | 111.89 trillion | 39,155.94 |
| Quality Level 2 | 2 | 3 | 27.97 trillion | 9,788.99 |
| Quality Level 3 | 1 | 1.5 | 13.98 trillion | 4,894.49 |
| Quality Level 4 | 0.04 | 0.06 | 559.46 billion | 195.78 |
| Quality Level 5 | 0.04 | 0.06 | 559.46 billion | 195.78 |

Data from Appendix H of
NATIONAL ENHANCED ELEVATION ASSESSMENT FINAL REPORT
*http://www.dewberry.com/services/geospatial/national-enhanced-elevation-assessment*

| Function | Description | Data Type(s) | Potential Data Storage Mechanism | Estimated Data Size (Terabytes, uncompressed) |
|---|---|---|---|---|
| Working Version for Quality Control and Processing | When the LAS data are received from the source, they will need to be accessible for temporary use in quality control and processing. Multiple versions of the source data may be needed during this time. | LAS | Temporary from Secondary or Tertiary Storage Device | 30.08 PB (Assume, on average, two versions of the source data will need to be stored, along with storage space for processing one new derived LAS dataset, for a total of three copies of the LAS data (28.2 PB). Also assume 20% of 9.4 PB of space for derivative products (1.88 PB) |
| Data Archiving | Approved and processed data will need to be archived at each of two offsite locations. Approved source data may also need to be archived. | LAS | Permanent Offline Storage | 22.56-45.12 PB (one copy of LAS data and derivative products archived to two different locations) |
| Data Provisioning | Approved and processed data will need to be stored with availability to the public. This will include processed LAS data and | LAS, other derivative products (contours, breaklines, | Permanent from Secondary or Tertiary Storage Device | 11.28 PB (one copy of finalized LAS data, as well as 20% additional space for derivative products) |
| | may also include other derivative products. | DEMs, TINs, etc.) | | |

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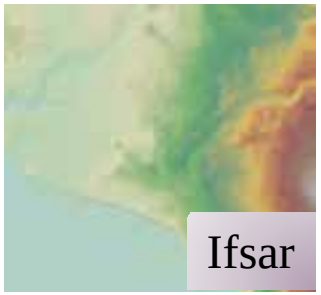
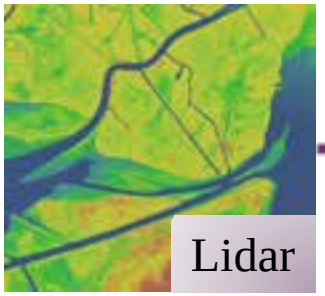
# So what is the 3DEP mindset?

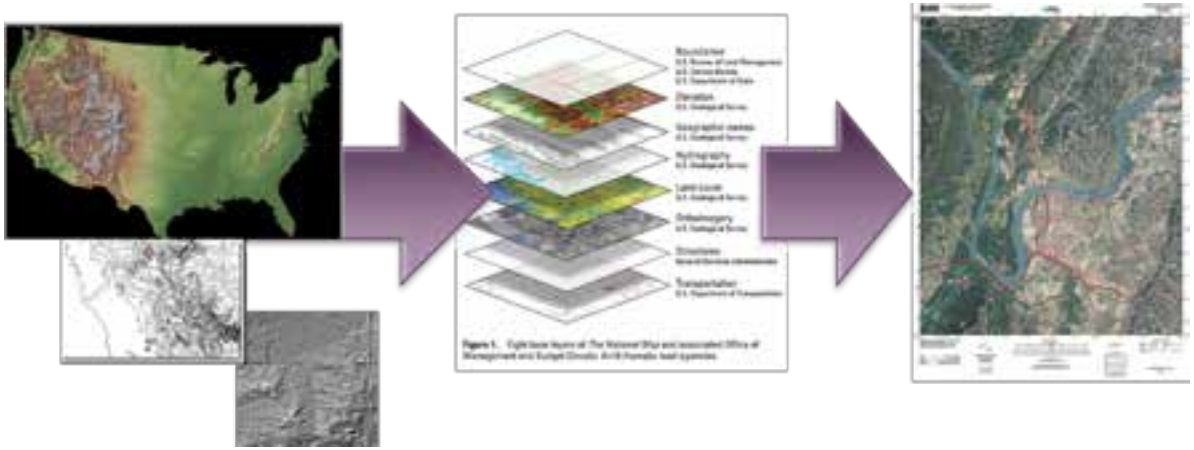
## Need to change how you perceive elevation at USGS

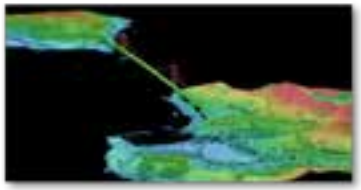
From This:




Bare Earth DEMs





Point Clouds

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# So what is the 3DEP mindset?

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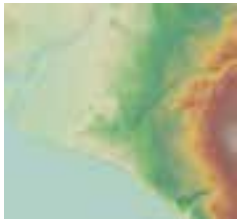

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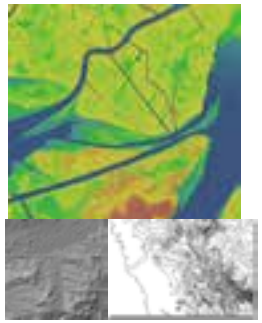
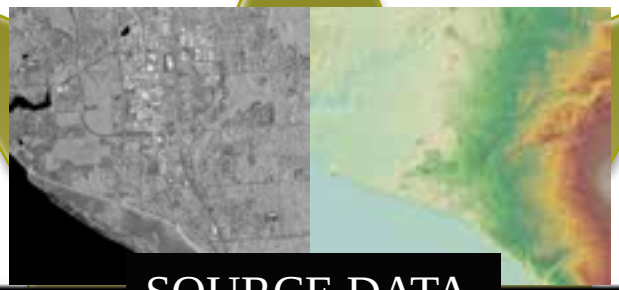
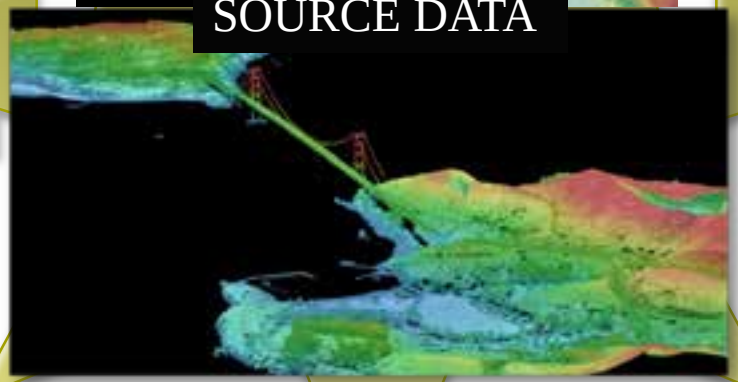
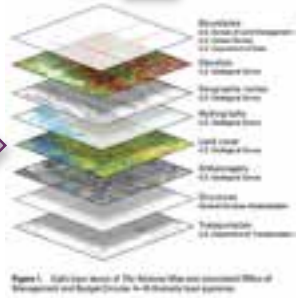


Contours/hillshades





SOURCE DATA



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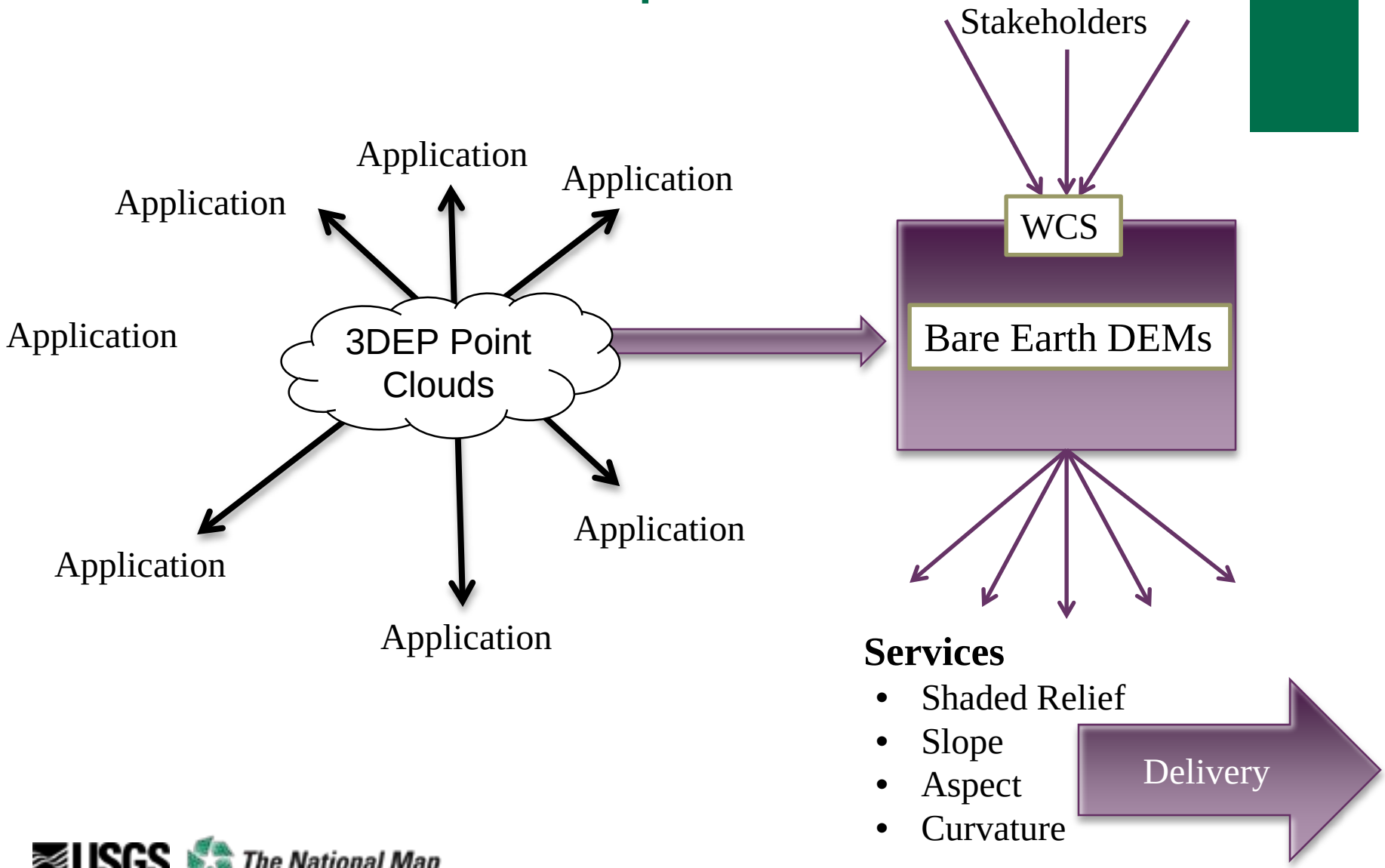
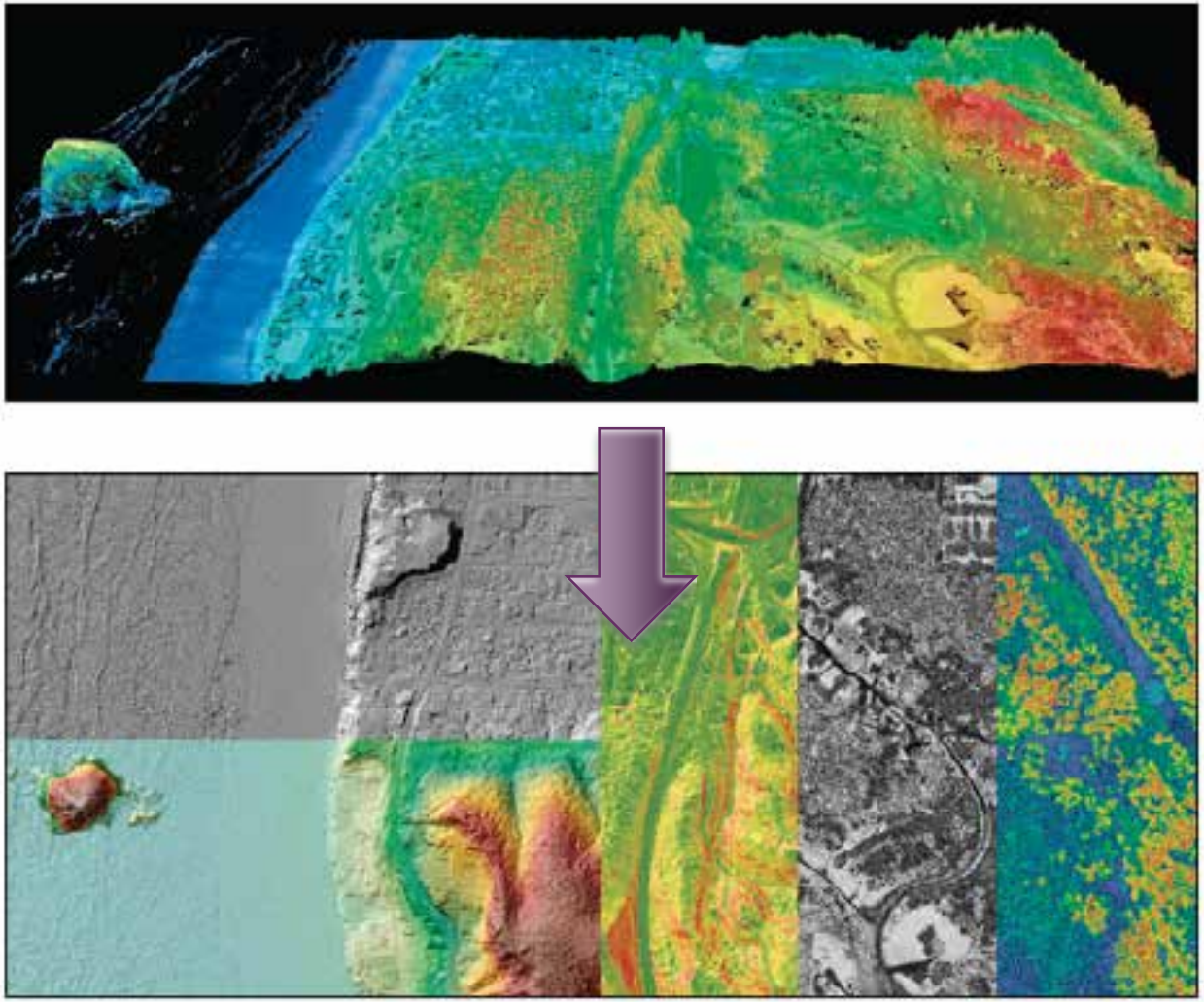
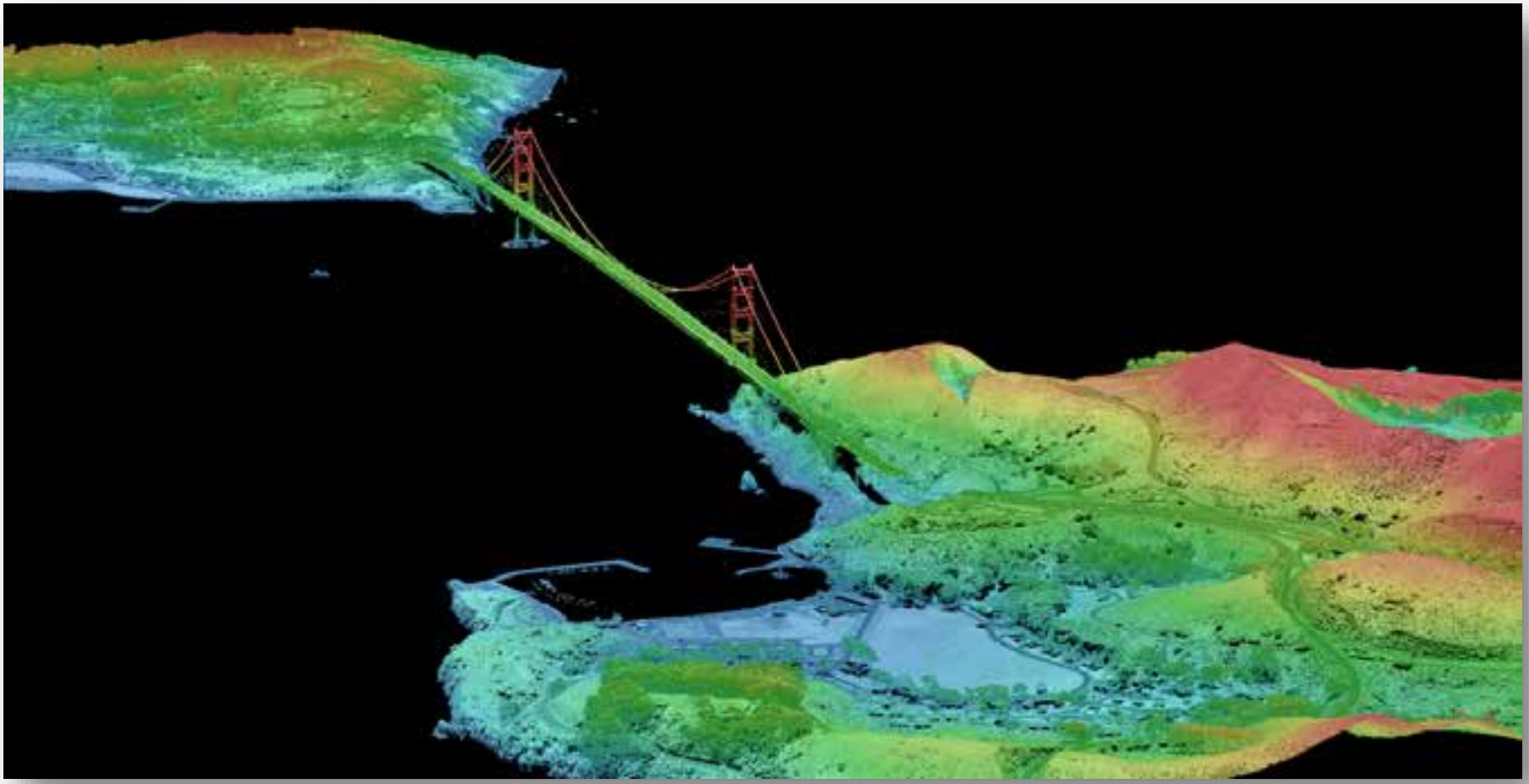
# Services in development



# From point cloud data to information



# Questions?



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