GLOSSARY

Section I
Abbreviations and Acronyms

2D or 2-D…... Two-dimensional

3D or 3-D…... Three-dimensional

3DEP……. 3D Elevation Program

ABGPS…….. Airborne GPS

ABS……Acoustic Backscatter

ACC_r……. Horizontal (radial) accuracy at the 95% confidence level

ACC_z…… Vertical linear accuracy at the 95% confidence level

ACSM ……American Congress on Surveying and Mapping

AGC……... Army Geospatial Center

AGL……Above Ground Level

AINS…….. Aided Inertial Navigation System

ALB……Airborne Lidar Bathymetry

ALH……Airborne Lidar Hydrography

ALS…….Airborne Laser Scanning

ALTM…….Airborne Laser Terrain Mapper (or Mapping)

AM……. Amplitude Modulation

AMT…….. Above Mean Terrain

AOI…… Area of Interest

AOR……...Area of Responsibility

ASCII……. American Standard Code for Information Interchange

ASFPM…….. Association of State Floodplain Managers

ASL…… Above Sea Level

ASP……American Society of Photogrammetry

ASPRS……...American Society for Photogrammetry and Remote Sensing

ATC……...Air Traffic Control

BATS……. Bathymetric and Topographic Survey

BFE…… Base Flood Elevation

BIL……. Band Interleaved by Line (File Format)

BIN…….Binary

BIP……. Band Interleaved by Pixel (File Format)

BMP……...Best Management Practice

BoB…… Bureau of the Budget

BSQ……Band Sequential (File Format)

C^3I…….. Communications, Command, Control, and Intelligence

C/A…… Coarse/Acquisition

CAD…….. Computer-Aided Design

CADD…… Computer-Aided Design and Drafting

CAES……. Computer-Aided Earthmoving System

CCCL…… Coastal Construction Control Line

CCD…….. Charge Coupled Device

CE……. Circular Error

CEP…… Circular Error Probable

CI……Contour Interval

CIR…….Color Infrared

CLICK……Center for Lidar Information, Coordination, and Knowledge

CMAS…….Circular Map Accuracy Standard

CONUS……. Conterminous United States

CORPSCON.. Corps Conversion

CORS…….Continuously Operating Reference Station

COTS……. Commercial Off-the-Shelf

CRS……Coordinate Reference System

CVA…….. Consolidated Vertical Accuracy

DED……... Digital Elevation Data

DEM…….. Digital Elevation Model

DFIRM…….. Digital Flood Insurance Rate Map

DG……. Direct Georeferencing

DGN…….. MicroStation Design (File Format)

DGPS……. Differential GPS

DoD……Department of Defense

DOQ…….. Digital Orthophoto Quadrangle

DOQQ……... Digital Orthophoto Quarter-Quadrangle

DPI…… Dots per Inch

DRG…….. Digital Raster Graphic

DSM…….. Digital Surface Model

DTED…… Digital Terrain Elevation Data

DTM…….. Digital Terrain Model

DVD…….. Digital Video Disk

DWG……. Drawing (AutoCAD File Format)

DXF……Drawing Exchange (File Format)

E00……Export (ArcInfo File Format)

EGM……...Earth Gravitational Model

ENC……....Electronic Nautical Chart

EPA……Environmental Protection Agency

ERDC…….Engineer Research and Development Center

ESRI…….. Environmental Systems Research Institute

FAA……... Federal Aviation Administration

FAR……Federal Acquisition Regulation

FDC……Frequency-to-Distance Conversion

FEMA…… Federal Emergency Management Agency

FGCC…….Federal Geodetic Control Committee

FGCS……. Federal Geodetic Control Subcommittee

FGDC…… Federal Geographic Data Committee

FIRM……. Flood Insurance Rate Map

FM……. Frequency Modulation

FMS……... Flight Management System

FOG……... Fiber Optic Gyro

FOV……... Field of View

FTP…… File Transfer Protocol

FVA……Fundamental Vertical Accuracy

FWD……. Full Waveform Digitizing

FWHM…….. Full Width at Half Maximum

GB……. Gigabyte

GDOP…… Geometric Dilution of Position

GeoTIFF…… Georeferenced Tagged Image File Format

GHz……Gigahertz

GIS…….Geographic Information System

GLONASS….Global Navigation Satellite System

GMT…….. Greenwich Mean Time

GNSS…….Global Navigation Satellite System

GOTS…….Government Off-the-Shelf

GPRA…… Government Performance and Results Act

GPS…… Global Positioning System

GSD……Ground Sample Distance

HARN…… High Accuracy Reference Network

H&H…….. Hydrologic and Hydraulic

ID……... Identification

IFOV……. Instantaneous Field of View

IFSAR…… Interferometric Synthetic Aperture Radar (also InSAR)

IGLD…….. International Great Lakes Datum

IHO…… International Hydrographic Organization

IMG……Image (ERDAS file format)

IMU……Inertial Measurement Unit (also IRU)

INS……. Inertial Navigation System (also INU)

InSAR…… Interferometric Synthetic Aperture Radar (also IFSAR)

INU…… Inertial Navigation Unit (also INS)

ION…… Institute of Navigation

IPP……. Interpulse Period

IR…….. Infrared

IRU…… Inertial Reference Unit (also IMU)

ISO……. International Standards Organization

ITRF…….. International Earth Rotation Service Terrestrial Reference Frame

IV & V……Independent Validation and Verification

JALBTCX…. Joint Airborne Lidar Bathymetry Technical Center of Expertise

JPL……. Jet Propulsion Laboratory

JPSD-PO…… Joint Precision Strike Demonstration Project Office

KAR…….. Kinematic Ambiguity Resolution (also see OTF)

KGPS…… Kinematic GPS

KHz…… Kilohertz

KW…… Kilowatts

L1…….. Level 1 frequency of GPS satellites

L2…….. Level 2 frequency of GPS satellites

L3…….. Level 3 frequency of GPS satellites

L5…….. Level 5 frequency of Block IIF GPS satellites

LAAS……. Local Area Augmentation System

LADAR……. LAser Detection And Ranging

LAG…….. Lowest Adjacent Grade

LAS…… LASer (File Format)

LASER…….. Light Amplification by Stimulated Emission of Radiation

LCD……Liquid Crystal Display

LFE…….Lowest Floor Elevation

LiDAR……... Light Detection And Ranging

LIS……. Land Information System

LMSL…….Local Mean Sea Level

MASER……. Microwave Amplification by Stimulated Emission of Radiation

MB……. Megabytes

MHHW……. Mean Higher High Water

MHW……. Mean High Water

MHz……... Megahertz

MIF/MID….. MapInfo File (format)

MLLW…….. Mean Lower Low Water

MLW……. Mean Low Water

MSE……... Mean of the Squared Errors

MSL…….. Mean Sea Level

MTL…….. Mean Tide Level

NAD 27……. North American Datum of 1927 (horizontal datum)

NAD 83……. North American Datum of 1983 (horizontal datum)

NADCON…. North American Datum Conversion

NAVD 88….. North American Vertical Datum of 1988

NAVSTAR… Navigation Signal Timing and Ranging

NDEP…… National Digital Elevation Program

NDGPS……. Nationwide Differential GPS

NDOP…… National Digital Orthophoto Program

NED…….. National Elevation Dataset

NEOS…… National Earth Orientation Service

NFIP…….. National Flood Insurance Program

NGA…….. National Geospatial-Intelligence Agency

NGP……National Geospatial Program

NGPS……. Nominal Ground Point Spacing

NGS……National Geodetic Survey

NGVD 29….. National Geodetic Vertical Datum of 1929

NIR…… Near Infra-red

NMAS ……National Map Accuracy Standard

NOAA……National Oceanic and Atmospheric Administration

NOS……National Ocean Service

NPD……... Nominal Point Density

NPS…… Nominal Pulse Spacing

NRCS…….Natural Resources Conservation Service

NSDI…….. National Spatial Data Infrastructure

NSGIC……National States Geographic Information Council

NSRS……. National Spatial Reference System

NSSDA……. National Standard for Spatial Data Accuracy

NTDE…… National Tidal Datum Epoch

NTM…….. National Technical Means

NVA…….. Non-Vegetated Vertical Accuracy

NWLON…… National Water Level Observation Network

O&M……. Operations and Maintenance

OC……. Order/Class Code

OCONUS….. Outside the Conterminous United States

OGC…….. Open Geospatial Consortium

OIM……Orthorectified Image Mosaic

OTF……On-the-fly (GPS ambiguity resolution)

OTS……Off-the-shelf

PDOP……. Position Dilution of Position

POD……... Print on Demand

POS…… Position and Orientation System

POS/AV……. Position and Orientation System for Airborne Vehicles

POS/LV……. Position and Orientation System for Land Vehicles

POS/MV…… Position and Orientation System for Marine Vessels

PPM……... Parts Per Million

PPP…… Precise Point Positioning

PRF…… Pulse Repetition Frequency

PRR……Pulse Repetition Rate

PSP…… Pseudo Stereo Pair

QA……. Quality Assurance

QA/QC…….. Quality Assurance/Quality Control

QC……. Quality Control

QL1…… Quality Level 1

QL2…… Quality Level 2

QL3…… Quality Level 3

QL4…… Quality Level 4

QL5…… Quality Level 5

R&D……...Research & Development

RMS…….. Root-Mean-Square

RMSD…… Root-Mean-Square-Difference

$RMSD_z$……. Root-Mean-Square-Difference in Elevation (z)

RMSE…… Root-Mean-Square Error

$RMSE_r$……Radial RMSE (horizontal, as function of $RMSE_x$ and $RMSE_y$)

$RMSE_x$……. RMSE in the x dimension (Easting or longitude)

$RMSE_y$……. RMSE in the y dimension (Northing or latitude)

$RMSE_z$……. RMSE in the z dimension (Elevation)

$RMSE_{xy}$…… RMSE in both the x and y dimensions

$RMSE_{xyz}$…... RMSE in three (x, y, z) dimensions

RTK……... Real Time Kinematic

RTKGPS…… Real Time Kinematic Global Positioning System

SA…….. Selective Availability

SAR……Synthetic Aperture Radar

SDTS……. Spatial Data Transfer Standard

SFHA…… Special Flood Hazard Area

SGM……. Semi-Global Matching

SHOALS…… Scanning Hydrographic Operational Airborne Lidar Survey

SHP…… Shape (ArcView File Format)

SONAR……. Sound Navigation and Ranging

SPCS……. State Plane Coordinate System

SVA……... Supplemental Vertical Accuracy

TDOP……. Time Dilution of Position

TEC……Topographic Engineering Center (U.S. Army)

TEC…… Total Electron Count

TIFF……... Tagged Image File Format

TIN…….Triangulated Irregular Network

TOF…… Time-of-Flight

TPE…… Total Propagated Error

UAS……... Unmanned Aerial System

UAV…….. Unmanned Aerial Vehicle

USACE……. U.S. Army Corps of Engineers

USCG…… U.S. Coast Guard

USFS……. U.S. Forest Service

USGS…… U.S. Geological Survey

UTC…….. Universal Time, Coordinated, the same as Greenwich Mean Time

UTM…….. Universal Transverse Mercator

UV……. Ultraviolet

VERTCON… Vertical Conversion

VHF……... Very High Frequency

VLBI……. Very Long Baseline Interferometry

VMAS……Vertical Map Accuracy Standard

VPF…… Vector Product Format

VRS……Virtual Reference Station

VVA……...Vegetated Vertical Accuracy

WAAS……Wide Area Augmentation System

WGS 84……. World Geodetic System of 1984

XML…….. eXtensible Markup Language

Section II
Definitions

Accelerometer — A device that measures the total specific force with respect to an inertial reference comprising gravity plus acceleration.

Acoustic Wave — See Sound Wave.

Accuracy — The closeness of an estimated value (e.g., measured or computed) to a standard or accepted (true) value of a particular quantity. Not to be confused with precision. Note: With the exception of Continuously Operating Reference Stations (CORS), assumed to be known with zero errors relative to established datums, the true locations of 3-D spatial coordinates of other points are not known, but only estimated. Therefore, the accuracy of other coordinate information is unknown and can only be estimated.

- Absolute Accuracy — A measure that accounts for all systematic and random errors in a data set. Absolute accuracy is stated with respect to a defined datum or reference system. For consistency with the NSSDA, absolute accuracy is normally expressed at the 95 percent confidence level. The absolute vertical accuracy is normally different from the absolute horizontal accuracy.

- $Accuracy_r$ — The NSSDA reporting standard in the horizontal component that equals the radius of a circle of uncertainty, such that the true or theoretical horizontal location of the point falls within that circle 95-percent of the time. $Accuracy_r = 1.7308 \times RMSE_r$.

- $Accuracy_z$ — The NSSDA reporting standard in the vertical component that equals the linear uncertainty value, such that the true or theoretical vertical location of the point falls within that linear uncertainty value 95-percent of the time. $Accuracy_z = 1.9600 \times RMSE_z$.

- Horizontal Accuracy — The horizontal (radial) component of the positional accuracy of a dataset with respect to a horizontal datum, at a specified confidence level. The horizontal accuracy reporting standard ($Accuracy_r$) is defined above.

- Local Accuracy — A value that represents the uncertainty in the coordinates of points with respect to coordinates of other directly connected, adjacent points at the 95% confidence level.

- Network Accuracy — A value that represents the uncertainty in the coordinates of a control point with respect to the geodetic datum at the 95-percent confidence level. For National Spatial Reference System (NSRS) network accuracy classification in the U.S., the datum is considered to be best expressed by the geodetic values at the CORS supported by the National Geodetic Survey (NGS). By this definition, the local and network accuracy values at CORS sites are considered to be infinitesimal, i.e., to approach zero.

- Positional Accuracy — The accuracy at the 95% confidence level of the position of features, including horizontal and vertical positions, with respect to horizontal and vertical datums.

- Relative Accuracy — A measure of variation in point-to-point accuracy in a data set.

- Vertical Accuracy — The measure of the positional accuracy of a dataset with respect to a specified vertical datum, at a specified confidence level or percentile.

Adjustment — A process designed to minimize inconsistencies in measured or computed quantities by applying derived corrections to compensate for random or accidental errors. The most common interpretation is that the sum of the squares of differences between results obtained by measurement and results obtained by calculation shall be a minimum. With this criterion, the method of least squares adjustment is preferred.

Aerial Triangulation (Aerotriangulation) — The process of measuring a number of points on overlapping images and/or ground control points to determine the most probable values of exterior orientation elements of aerial photographs. The output of this process includes ground space coordinates for all points measured on at least two images.

Affine Transformation — Linear transformation plus a translation. Affine transformation can be decomposed into rotational, scale, skew and translation components and for most sensors small errors are well modeled by these terms.

Air Base — The line segment, or length of the line segment, joining two adjacent camera stations when aerial photographs or images are taken.

Airborne GPS — A method for collecting Global Positioning System (GPS) data continuously for an aerial camera, LiDAR or IFSAR sensor so as to: (1) provide Direct Georeferencing of photo centers and/or the origin of individual laser or radar pulses used in mapping, (2) strengthen the positioning accuracy while drastically reducing the number of ground control points necessary on larger mapping projects, and/or (3) enable accurate execution of pre-planned flight lines in automated Flight Management Systems. For example, a geodetic quality GPS receiver records an event marker from the aerial mapping camera, logging the precise time of each exposure station or photo center; this time record is then correlated to the location of GPS ground stations (at known, surveyed locations) which were also recording during the flight.

Aliasing — The difference between the values of constants in a mathematical model and the value the constants would have if the model were improved by adding more terms or denser data.

Altimetry — The science of measuring height or *altitudes* of different objects.

Ambiguity Resolution — Combining the phase data from two or more GPS receivers so that, after eliminating all other significant errors, the unknown number of integer wavelengths can be determined for signals coming from GPS satellites. Redundant L1 and L2 phase observations from two or more receivers, each tracking five or more satellites, provide the information for rapid unambiguous resolution. Once the ambiguities are resolved, the corrected phases for each observed satellite become precise ranges that allow the computation of the baseline vector(s) between the receivers with a typical accuracy of 2-10 centimeters.

Analog Photogrammetry — Stereo photogrammetric procedures that utilize direct viewing of film imagery in analog stereoplotters that optically and/or mechanically replicate, at reduced scale, the physical geometry that existed when stereo photography was acquired. Analog stereoplotters are less accurate than analytical stereoplotters, and they are ill-suited for DEM production.

Analytical Photogrammetry — Stereo photogrammetric procedures that utilize direct viewing of film imagery in analytical stereoplotters that mathematically replicate, at reduced scale, the physical geometry that existed when stereo photography was acquired. Analytical stereoplotters can also mathematically apply camera calibration (interior orientation) parameters, and correct for atmospheric refraction and earth curvature.

Antivignetting Filter — A filter used with wide-angle photography to produce uniform lighting over the whole photograph.

Arc Second (Arc-Second or Second of Arc) — In angular measurements, 1/3600th of a degree. Commonly used in descriptions of geographic coordinate reference systems, for example, the horizontal resolution of the National Elevation Dataset (NED), 1 arc-second, 1/3 arc-second, 1/9 arc-second. For most of the Contiguous United States, 1 arc-second is approximately 30 meters, linear.

Artifacts — An inaccurate observation, effect or result, especially one resulting from the technology used in scientific investigation or from experimental error. In bare-earth elevation models, detectable surface remnants of buildings, trees, towers, telephone poles or other elevated features; also, detectable artificial anomalies that are introduced to a surface model by way of system specific collection or processing techniques, e.g., corn-row effects of profile collection, star and ramp effects from multidirectional contour interpolation, or detectable triangular facets caused when vegetation canopies are weeded from lidar data. Orthophotos and other geospatial datasets also have blemishes referred to as artifacts.

Aspect — The direction which a building or topographic surface faces with respect to points of a compass. The slope direction or steepest downslope across a surface, normally measured clockwise in degrees from due north. The value of each location in an aspect dataset indicates the direction the surface slope faces.

Asymmetry — In satellite photogrammetry, the angle between the bisector of the convergence angle and the projection of the local vertical onto the epipolar plane.

Atmospheric Refraction — The bending of light rays as they pass through the atmosphere.

Attitude — The position of a body defined by the angles between the axes of the coordinate system of the body and the axes of an external coordinate system. In photogrammetry, the attitude is the angular orientation of a camera (roll, pitch, yaw), or of the photograph taken with that camera, with respect to some external reference system. With lidar and IFSAR, the attitude is normally defined as the roll, pitch and heading of the instrument at the instant an active pulse is emitted from the sensor.

Azimuth — Horizontal direction reckoned clockwise from the meridian plane.

Bald Earth — Non-preferred term. See Bare Earth.

Bare Earth — Digital elevation data of the terrain, free from vegetation, buildings and other man-made structures. Elevations of the ground.

Base Flood — A flood that has a one-percent chance of being equaled or exceeded in any given year. Often called the 100-year flood.

Base Flood Elevation (BFE) — An elevation that has a one-percent chance of being equaled or exceeded in any given year by a base flood.

Base-Height Ratio (B:H) — The ratio of the air base (the line segment, or length of the line segment, joining two adjacent camera stations when aerial or satellite images are taken) and the flight height of the stereoscopic pair of images.

Base Map — A map on which information can be placed for comparison or for georeferencing and graphical correlation, including digital orthophotos for horizontal georeferencing and DEMs for vertical georeferencing. A map from which other maps are prepared by adding information; in particular, a planimetric map used in preparing topographic maps.

Base Station — A survey station with known coordinates from which all unknown differentially measured positions are derived.

Basic Control — A survey over the entire extent of a project that establishes monumented points of known horizontal position and elevation.

Bathymetric Chart — A topographic chart of the bed of a body of water. Generally, bathymetric charts show depths by contour lines and gradient tints. Regional bathymetric surveys are conducted to determine the location and orientation of depth contours in water depths and areas where safety of surface navigation is not a major concern. This type of surveying might be accomplished with an interferometric sonar, a vertical beam echo sounder, or a multibeam sonar. Shallow water bathymetry is also determined from airborne lidar bathymetry. Software used for bathymetric surveying is attuned to production of a digital elevation model, or bathymetric surface, from cleaned or smoothed soundings.

Bathymetric Surface — The underwater terrain model.

Bathymetry — The measurement and study of water depths. Traditionally bathymetry has been expressed with contours and hydrography with spot depths. Bathymetry may not meet hydrographic standards, as it may not show all of the bottom characteristics important to the mariner who is navigating. Bathymetric contours depicted on nautical charts may be displaced cartographically to accommodate sounding data which need to be displayed. NOAA's hydrographic depths and bathymetric contours represented on a nautical chart are all related to the national chart datum of MLLW. These depths are expressed as positive numbers below the chart datum. Minus signs are not depicted on nautical charts unless above MLLW, meaning the point is above water when the water level is at MLLW or below.

Bench Mark (Benchmark or BM) — A relatively permanent, natural or artificial, material object bearing a marked point whose elevation above or below an adopted vertical datum is known.

- Permanent Bench Mark — A bench mark as nearly permanent in character as is practicable. The National Spatial Reference System classifies bench marks in terms of their "stability," with *Stability A* being the most stable, and *Stability D* being of questionable stability.

- Temporary Bench Mark — A bench mark established to hold, temporarily, the end of a completed section of a line of levels and to serve as a starting point from which the next section is run. Spikes and screws in poles, bolts on bridges, and chiseled marks on masonry are typically used as temporary bench marks (TBMs).

- Tidal Bench Mark — A bench mark whose elevation has been determined with respect to mean sea level at a nearby tide gauge. The tidal bench mark is used as reference for that tide gauge.

Bias — A systematic error inherent in measurements due to some deficiency in the measurement process or subsequent processing.

Bisector Elevation (BIE) — In satellite photogrammetry, the elevation of the bisector of the convergence angle.

Blunder — An error of major proportion, normally identified and removed during interactive editing. A mistake resulting from carelessness or negligence.

Boresight — Calibration of a sensor system equipped with GPS and an inertial measurement unit (IMU) to determine the accurate position and orientation (roll, pitch, heading) of active sensor pulses (IFSAR, lidar, sonar) or the optical axis of a film camera or a digital imaging system.

Breakline — A linear feature that describes a change in the smoothness or continuity of a surface. The two most common forms of breaklines are as follows:

- A *soft breakline* ensures that known z-values along a linear feature are maintained (e.g., elevations along a pipeline, road centerline or drainage ditch), and ensures that linear features and polygon edges are maintained in a TIN surface model, by enforcing the breaklines as TIN edges. They are generally synonymous with 3-D breaklines because they are depicted with series of x/y/z coordinates. Somewhat rounded ridges or the trough of a drain may be collected using soft breaklines.

- A *hard breakline* defines interruptions in surface smoothness, e.g., to define streams, shorelines, dams, ridges, building footprints, and other locations with abrupt surface changes. Although some hard breaklines are 3-D breaklines, they are often depicted as 2-D breaklines because features such as shorelines and building footprints are normally depicted with series of x/y coordinates only, often digitized from digital orthophotos that include no elevation data.

Bridge — A structure carrying a road, path, railroad, or canal across a river, ravine, road, railroad, or other obstacle. In mapping, a bridge is distinguished from a roadway over a culvert in that a bridge is a man-made elevated deck with no earth or soil on top.

C-Factor — An empirical measure of the inherent contouring accuracy of a photogrammetric plotter and its operator.

Cadastral — Pertaining to extent, value, and ownership of land. Cadastral maps show property corners and property lines.

Calibration — The process of identifying and correcting for systematic errors in hardware, software, or procedures. Determining the systematic errors in a measuring device by comparing its measurements with the markings or measurements of a device which is considered correct. Airborne sensors can be calibrated geometrically and/or radiometrically.

- Camera Calibration — The geometric calibration of a conventional film mapping camera includes the determination of the following quantities: (a) the calibrated focal length, (b) the location of the principal point with respect to the fiducial marks, (c) the location of the point of symmetry, (d) the distortion effective in the focal plane of the camera and referred to the particular calibrated focal length, (e) the resolution of the lens system, (f) the degree of flatness of the focal plane, (g) the opening and closing cycle of the shutter as a function of time, and (h) the locations of fiducial marks — all of which help to ensure that μm measurements made on aerial film will translate correctly into accurate ground coordinates via photogrammetric calculations. Depending on camera design, digital cameras have different forms of geometric calibration and also include radiometric calibration, e.g., spectral response of CCD sensors over the spectral range of the sensor, and determination of the pixel-to-pixel uniformity.

- Lidar System Calibration — (1) Instrument Calibration: Factory calibration includes both radiometric and geometric calibration unique to each manufacturer's hardware, and tuned to meet the performance specifications for the model being calibrated; instrument calibration can only be assessed and corrected by the factory. (2) Data Calibration: The "lever-arm" calibration determines the sensor-to-GPS-antenna offset vector (lever arm) components relative to the antenna phase center; the offset vector components are re-determined each time the sensor or aircraft GPS antenna is moved or repositioned in any way. Because normal aircraft operations can induce slight variations in component mounting, field calibration is normally performed for each project, or even daily, to determine corrections to the roll, pitch, and scale calibration parameters.

Camera, Metric — A camera constructed so that its photographic/image characteristics remain stable, i.e., camera calibration parameters do not change over time. Metric cameras must be consistently spatially accurate; they are essential for most photogrammetric projects and are much more expensive than non-metric cameras.

Camera Axis — A line through the camera lens rear nodal point, perpendicular to the film plane of CCD.

Camera Station — The point in space where the forward node of the camera lens was located at the instant the photographic exposure was made.

Cartesian Coordinates — Coordinate values of two types:

- 2-D Cartesian Coordinates — A pair of numbers (x/y coordinates) that locate a point by its distance from two intersecting, normally perpendicular lines in the same plane. Each distance is measured along a parallel to the other line. UTM and State Plane coordinates are examples of 2-D Cartesian coordinates.
- 3-D Cartesian Coordinates — A triad of numbers (x/y/z coordinates) that locate a point by its distance from three fixed planes that intersect one another at right angles. However, except for unique applications, 3-D Cartesian coordinates with z-coordinates are rarely used. Instead, z-values are more popularly understood as heights or elevations above a curved surface defined by the vertical datum, ellipsoid, or geoid. Thus, when 3-D coordinates are mentioned, the term normally pertains to x/y coordinates and z-values.

Cartography — The science and art of making maps and charts. It is customary to distinguish between maps in general and maps used for navigation; the latter are generally called *charts*.

C-factor and Assumed C-factor — Contouring factor that shows the ratio of the flight height to the smallest contour interval that a photogrammetric system, including the photogrammetric system operator, can consistently map to specification accuracy. Used normally with an analog film camera with 6-inch focal lens and 9-in by 9-in film format, the C-factor = flight height of aerial photography divided by contour interval. A higher C-factor is often assumed for a more-experienced photogrammetrist.

Charts — Maps used for nautical or aeronautical navigation.

Check Point (Checkpoint) — One of the surveyed points used to estimate the positional accuracy of the data set against an independent source of greater accuracy.

Classification (of lidar) — The classification of lidar point cloud returns in accordance with a classification scheme to identify the type of target from which each lidar return is reflected. The process allows future differentiations between bare-earth terrain points, water, noise, vegetation, buildings, other manmade features and objects of interest.

Cleanness — A subjective term to describe the degree to which artifacts have been removed from a DEM or TIN.

Collimation — The process of bringing the optical elements of an optical system into proper relation with each other. Adjusting the fiducial marks in a camera so that they locate the principal point.

Color Separation — The process of preparing a separate drawing, engraving, or negative for each color required in the printing production of a map or chart.

Compilation — The production of a new or revised map or chart, or portions thereof, from existing maps, aerial photographs, field surveys, new data and other sources. The process is called *stereocompilation* if stereoscopic plotting instruments (stereo plotters) are used.

Confidence Level — The percentage of points within a data set that are estimated to meet the stated accuracy; e.g., accuracy reported at the 95% confidence level means that 95% of the positions in the data set are expected to have an error with respect to true ground position that are equal to or smaller than the reported accuracy value.

Consolidated Vertical Accuracy (CVA) — A term used by the NDEP guidelines for vertical accuracy at the 95th percentile in all land cover categories combined.
Contours — Lines of equal elevation on a surface. An imaginary line on the ground, all points of which are at the same elevation above or below a specified reference surface (vertical datum).

Contour Interval — The difference in elevation (z-values) between two adjacent contours.

Contrast — The difference between the densities of the lightest and darkest areas of a photograph.

Control — The coordinates of a control station. The geometric data associated with a collection of control stations, such as coordinates, distances, angles, or directions between control stations. The data associated with a set of control stations and used as the basis for detailed surveys. *Fundamental control* is synonymous with *geodetic control* and is generally not photo-identifiable on aerial imagery. *Supplemental control* for photogrammetric mapping projects must be photo-identifiable point features on aerial imagery so that surveyed points on the ground can be positively correlated with their images on the aerial photographs.

Control Network — Geodetic control together with the measured or adjusted values of the distances, angles, directions, or heights used in determining the coordinates of the control.

Control Point — Stationary point with accurately surveyed horizontal (x/y), vertical (z), or horizontal and vertical (x/y/z) coordinates. When used for aerotriangulation, control points are either chosen as photo-identifiable points or are “paneled” prior to flying.

Control Station — A point on the ground whose horizontal or vertical location is used as a basis for obtaining the location of other points.

Control Tide Stations — Primary water level stations, located with open ocean exposure or within the mouth of a bay or estuary, that have operated for 19 or more years, are expected to continue to operate in the future, and are used to obtain a continuous record of the water levels in a locality. They are sited to provide datum control for national applications.

Convergence — In satellite photogrammetry, the angle in the epipolar plane between the two rays from the ground point to the perspective centers.

Coordinates — A set of N numbers designating the location of a point in N-dimensional space. Horizontal coordinates are 2-dimensional coordinates, normally expressed as x/y coordinates, Eastings and Northings, or Longitude and Latitude (geographic coordinates). A vertical coordinate may be 1-dimensional, i.e., the vertical distance of a point above or below a reference surface (vertical datum) such as the elevation of a bench mark without known x/y coordinates. However, most vertical coordinates are specified as 3-dimensional coordinates, i.e., x/y coordinates and z-values.

Correlation — The extent to which one randomly varying quantity can be expressed as a function of another, or to which both quantities can be expressed as function of a third, nonrandom quantity. See also Image Correlation. With IFSAR, interferometric correlation is a measure of the similarity of the signal received at the two antennae.

Cover — In mapping, vegetation or other land cover over the terrain.

Crab — The condition caused by failure to orient the camera with respect to the track of the airplane, often caused by windy conditions. In vertical photography, crab is indicated by the edges of the images not being parallel to the ground track of the aircraft.

Culture — Features constructed by man under, on, or above the ground that are delineated on a map, e.g., airfield runways, railroads, roads, trails, buildings, bridges, towers, canals, culverts and sewer systems.

Culvert — A tunnel carrying a stream or open drain under a road or railroad, typically constructed of formed concrete or corrugated metal and surrounded on all sides, top and bottom, by earth or soil.

Data Format — The specific arrangement of data in a file, including records, data types, and data labels. For example, floating point numbers as x/y pairs with one set per record.

Data Model — The conceptual view of what information is to be represented. For example, the surface of the earth can be represented as a grid of posts of varying heights (i.e., raster data model), or as lines of equal elevation (i.e., vector data model).

Data Void — In lidar, a gap in the point cloud coverage, caused by surface non-reflectance of the lidar pulse, instrument or processing anomalies or failure, obstruction of the lidar pulse, or improper collection flight planning or execution. Any area greater than or equal to 4 times the Nominal Pulse Spacing (NPS) squared, measured using first-returns only, is considered by USGS to be a data void. See *holiday*.

Datum (plural Datums) — In surveying, a reference system for computing or correlating the results of surveys, to include the origin of coordinates that serves as a zero point in computing x-, y- and z-coordinates. A set of constants that define a geographic coordinate system or height system used for mapping/modeling the size and shape of the Earth and/or its gravity field.

- Diurnal Tide Level (DTL) — A tidal datum which is the average of Mean Higher High Water and Mean Lower Low Water.

- Geodetic Datum — A set of constants specifying the coordinate system used for geodetic control, i.e., for calculating coordinates of points on the Earth. At least eight constants are needed to form a complete datum: three to specify the location of the origin of the coordinate system, three to specify the orientation of the coordinate system, and two to specify the dimensions of the reference ellipsoid. (Before geocentric geodetic datums became possible, it was customary to define a geodetic datum by five quantities: the latitude and longitude of an initial datum point, the azimuth of a line from this datum point, and the two parameters of a reference ellipsoid. In addition, specification of the components of the deflection of the vertical at the initial point, or the condition that the minor axis of the ellipsoid be parallel to the Earth's axis of rotation provided two more quantities. The datum was still not complete because the origin of the coordinate system remained free to shift in one dimension. This meaning does not conform to modern usage.)

- Horizontal Datum — A geodetic datum specifying the coordinate system in which horizontal control points are located. The North American Datum of 1983 (NAD 83) is the official horizontal datum in the U.S.

- Hydrographic Datum — A datum for depths (soundings), depth contours, and elevations of foreshore and offshore features. Also called *chart datum*.

- Local Datum — A datum defining a coordinate system that is used only over a region of very limited extent.

- Low Water Datum — An approximation to mean low water that has been adopted as a standard tidal datum for a specific region although it may differ slightly from a later determination.

- Lower Low Water Datum — An approximation to mean lower low water adopted as a tidal datum for a limited area and retained for an indefinite period. It is used primarily for river and harbor engineering, e.g., Columbia River lower low water datum.

- Mean Higher High Water (MHHW) — A tidal datum computed as the arithmetic mean of the higher high water heights of the tide observed over a specific 19-year Metonic cycle denoted as the NTDE. Only the higher high water of each pair of high waters of a tidal day is included in the mean. For stations with shorter series, a comparison of simultaneous observations is made with a primary control tide station in order to derive the equivalent of the 19-year value.

- Mean High Water (MHW) — A tidal datum computed as the arithmetic mean of the high water heights observed over a specific 19-year Metonic cycle. For stations with shorter series, a comparison of simultaneous observations is made with a primary control tide station in order to derive the equivalent of the 19-year value.

- Mean Lower Low Water (MLLW) — A tidal datum computed as the arithmetic mean of the lower low water heights of the tide observed over a specific 19-year Metonic cycle. Only the lower low water of each pair of low waters of a tidal day is included in the mean. For stations with shorter series, a comparison of simultaneous observations is made with a primary control tide station in order to derive the equivalent of the 19-year value. MLLW is the chart datum used in the U.S.

- Mean Low Water (MLW) — A tidal datum computed as the arithmetic mean of the low water heights observed over a specific 19-year Metonic cycle. For stations with shorter series, a comparison of simultaneous observations is made with a primary control tide station in order to derive the equivalent of the 19-year value.

- Mean Sea Level (MSL) — A tidal datum computed as the arithmetic mean of hourly heights observed over a specific 19-year Metonic cycle. Shorter series are specified in the name, e.g., monthly mean sea level or yearly mean sea level.

- Mean Tide Level (MTL) — A tidal datum which is the average of Mean High Water and Mean Low Water.

- Sea Level Datum — An equipotential surface passing through a specified point at mean sea level which is used as a reference for elevations.

- Tidal Datum — A surface with a designed elevation from which heights or depths are reckoned, defined by a certain phase of the tide. A tidal datum is local, usually valid only for a restricted area about the tide gauge used in defining the datum.

- Vertical Datum — A set of constants defining a height (elevation) system. It is defined by a set of constants, a coordinate system, and points that have been consistently determined by observations, corrections, and computations. The North American Vertical Datum of 1988 (NAVD 88) is the official vertical datum in the U.S.

Decorrelation (IFSAR) — A measure of the dissimilarity of the signal received at the two antennae caused by geometry, thermal noise and other factors.

Deflection of the Vertical — The angle between the direction of gravity, defining astronomical latitude and longitude, and the normal to the reference ellipsoid defining geodetic latitude and longitude.

Diapositive — A positive photograph on a transparent medium. A positive film transparency as opposed to a positive paper print which is not transparent.

Differential Leveling — Survey procedures used to measure the elevation differences between two or more points, to extend vertical control, and to monitor the stability of water level measurement gauges. The quality of leveling is a function of the procedures used, the sensitivity of the leveling instruments, the precision and accuracy of the leveling rod, the attention given by surveyors, and the refinement of the computations.

Digital Correlation — Image correlation performed automatically through the use of digital imagery and digital (softcopy) photogrammetry. DEMs produced through automatic digital correlation are normally edited manually, especially when bare-earth DTMs or contours are required instead of DSMs.

Digital Elevation Model (DEM) — See three different definitions below:

- A popular acronym, as in the title of this book, used as a generic term for digital topographic and/or bathymetric data in all its various forms. Unless specifically referenced as a Digital Surface Model (DSM), the generic DEM normally implies x/y coordinates and z-values of the bare-earth terrain, void of vegetation and manmade features.
- As used by the U.S. Geological Survey (USGS), a DEM is the digital cartographic representation of the elevation of the land at regularly spaced intervals in x and y directions, using z-values referenced to a common vertical datum. As described in Chapter 4 of this manual, there are several different standard USGS DEMs archived in the National Elevation Dataset (NED) based on 1-arc-second, 1/3-arc-second, and 1/9-arc-second grid spacing.
- As typically used in the U.S. and elsewhere, a DEM has bare-earth z-values at regularly spaced intervals in x and y, where Δx and Δy are normally measured in feet or meters in even units; however, grid spacing, datum, coordinate systems, data formats, and other characteristics may vary widely.

Digital Line Graph (DLG) — Geospatial data, digitized as node, line and area features, using hundreds of different attribute codes to define basic cartographic data categories such as hypsography (contours), hydrography, transportation, manmade features, vegetation, boundaries, survey control, etc.

Digital Orthophoto — A digital photograph prepared from a perspective photograph by digitally removing displacements of points caused by tilt, relief, and perspective. A “true digital orthophoto” is defined as one in which the sides of vertical features are not visible, as though looking straight down on each natural and man-made feature from infinity; this feature is especially desired in urban areas with skyscrapers and tall buildings, the sides of which are normally photographed with aerial photography.

Digital Photogrammetry — See Softcopy Photogrammetry.

Digital Surface Model (DSM) — Similar to DEMs or DTMs, except that they depict the elevations of the top surfaces of buildings, trees, towers, and other features elevated above the bare earth. DSMs are especially relevant for telecommunications management, air safety, forest management, and 3-D modeling and simulation.

Digital Terrain Elevation Data (DTED) — A uniform matrix of terrain elevation values produced by the National Geospatial-Intelligence Agency (NGA). It provides basic quantitative data for military systems that require terrain elevation, slope, and gross surface roughness information. Data density depends on the level produced.

- DTED0 post spacing is 30 arc seconds (approximately 1,000 meters), corresponding to small-scale hardcopy products.
- DTED1 post spacing is three arc seconds (approximately 100 meters), corresponding to medium-scale hardcopy products.
- DTED2 post spacing is one arc second (approximately 30 meters), corresponding to large-scale hardcopy products.
- DTED3 post spacing is one-third arc second (approximately 10 meters)
- Specifications for high-resolution DTED levels 4 (3 m) and 5 (1 m) have also been developed.

Digital Terrain Model (DTM) — See two different definitions below:

- In some countries, DTMs are synonymous with DEMs, representing the bare-earth terrain with z-values uniformly spaced in x and y directions.
- As used herein, DTMs may be similar to DEMs, but they may also incorporate the elevation of significant topographic features on the land. DTMs are comprised of mass points and breaklines that are irregularly spaced to better characterize the true shape of the bare-earth terrain. The net result of DTMs is that the distinctive terrain features are more clearly defined and precisely located, and contours generated from DTMs more closely approximate the real shape of the terrain. Such DTMs are normally more expensive and time consuming to produce

than uniformly spaced DEMs because breaklines are less suitable for automated collection, but the DTM may be technically superior to standard DEMs for many applications.

Diode — Specialized electronic equipment with two electrodes that conduct one energy (electric) and convert to another form (light).

Direct Georeferencing — The direct measurement of Exterior Orientation parameters, i.e., position (x/y/z coordinates) and attitude (roll/pitch/heading) at the instant an aerial photograph or digital image is taken, to aid or replace aerial triangulation. The term is also applicable to the position and orientation of airborne lidar or IFSAR sensors.

Direction of Gravity — The direction, toward the Earth's center, indicated by a plumb line. Gravity is a force and therefore has both magnitude and direction. The direction of gravity is independent of any coordinate system, but its components may be described with respect to two mutually perpendicular planes through the local normal, one being that of the local meridian. Both components are given in terms of the *deflection of the vertical* from those planes.

Discrete Return Lidar — Lidar system or data in which the significant peaks in the waveform are captured and stored. Each peak represents a return from a different target, discernible in either vertical or horizontal domains. Most modern lidar systems are capable of capturing three to five discrete returns from each emitted laser pulse. See *full waveform lidar*.

Displacement — Any shift in the position of an image on a photograph due to tilt during photography or scale changes in the imagery, normally caused by changing elevations (relief) of the area photographed. *Relief displacement* is an essential characteristic of vertical aerial photography that causes high terrain points to appear farther from the center of the photograph and low points to appear closer to the center of the photograph, than would the map positions of such points if looking straight down on every feature.

Distortion — A lens aberration that causes a difference between the position of any part of the image and its theoretically correct position.

Diurnal High Water Inequality (DHQ) — The difference between Mean Higher High Water and Mean High Water.

Diurnal Low Water Inequality (DLQ) — The difference between Mean Low Water and Mean Lower Low Water.

Dual Frequency — A high performance GPS receiver for precision applications that tracks the L1 C/A pseudoranges and carrier phase, and either tracks L2 pseudoranges and carrier phase or

computes derived L2 pseudoranges and carrier phase using the known cross correlation between the L1 and L2 code modulations.

Drainage-Enforced — See Hydro-Enforced.

Drape — The superimposition of 2-D features over a 3-D surface, normally for viewing of all features in 3-D perspective, for 3-D fly-throughs or walk-throughs in virtual reality. Also a method for conflating values, typically elevation, from a surface to 2-D features to create 3-D features.

Easting — In a plane coordinate system, the coordinate in a general east-west direction, increasing to the east. The grid coordinate of a point eastward (positive) or westward (negative) from a reference meridian. The grid coordinate eastward (positive) or westward (negative) from the central (zero) meridian (the line of zero eastings or the y-axis) on a gridded map. The central meridian is frequently replaced by another called the false meridian, sufficiently far to the west of the central meridian so that all eastings on the map are then positive with respect to the false meridian. A *false easting* is the constant value added to all eastings so that only positive values of easting are recorded.

Echogram — The graphic record produced by an echo sounder and showing, as a function of time, the strength of the echo signal and the time taken for the echo to return.

Echo Sounder — An instrument for determining the depth of water by measuring the time of travel of a sound pulse from the surface of a body of water to the bottom and back. An echo sounder consist of an oscillator for generating pulses, a hydrophone for detecting the echo, a clock for timing the pulses, and a recorder for converting the time of travel to a depth and plotting that depth on a continuous chart.

Echo Sounding — Determining the distance from the surface of water to the bottom by measuring the time interval required for sound waves to go from a sound generator to the bottom and back again. The principal source of error in echo sounding is uncorrected refraction; another source is schools of fish that reflect sound back before it reaches the bottom.

Effective Vertical Spacing — The vertical point spacing minus the vertical footprint diameter.

Electromagnetic Spectrum — The complete range of wavelengths of electromagnetic radiation, beginning with the longest radio waves and extending through visible light all the way to the extremely short gamma rays.

Elevation — The distance measured upward along a plumb line between a point and the geoid. The elevation of a point is normally the same as its orthometric height, defined as "H" in the equation: H = h – N, where h = ellipsoid height and N = geoid height.

Elevation Certificate — A form on which the lowest floor elevation, lowest adjacent grade, and highest adjacent grade of a building are certified relative to the base flood elevation for the location of the building. Other descriptive information is also provided to help identify the flood risk to the building surveyed.

Elevation Derivatives — Products derived from 3-D source data. With lidar, the point cloud data are the source from which all derivative products are produced, including Digital Surface Models (DSMs), Digital Terrain Models (DTMs), gridded Digital Elevation Models (DEMs), contour lines, hillshades, slope and aspect maps, height-above-ground maps, intensity imagery, cross sections, etc. Elevation derivatives should always begin from the same certified source, if possible, to ensure consistent results.

Elevation Post — The vertical component of a DEM lattice mesh point, having height above the vertical datum equal to the z-value of its mesh point.

Elevation Post Spacing — The constant sampling interval in x and y directions of a DEM lattice or grid. The horizontal resolution of a DEM.

Ellipsoid — A closed surface whose planar sections are either ellipses or circles. The Earth's ellipsoid is a biaxial ellipsoid of revolution, defined by an ellipse with major axis "a" and its minor axis "b," obtained by rotating the ellipse about its minor (shorter) axis.

Ellipsoid Height — See Height.

End Lap — See Forward Overlap

Ensonify — See Insonify.

Ephemeris — A tabulation of the locations and related data for a celestial body, including Earth-orbiting satellites, for given epochs (dates) at uniform intervals of time.

- Broadcast Ephemeris — The ephemeris broadcast from a satellite, from which Earth-fixed satellite positions can be computed.
- Precise Ephemeris — The ephemeris of a satellite computed by adjustment of observations obtained from a worldwide tracking network in order to obtain maximum accuracy.

Epipolar Plane — In satellite photogrammetry, the plane formed by the two rays from the ground point to the perspective centers.

Epoch — A particular instant of time from which an event or a series of events is calculated. A starting point in time to which events are referred.

Equator, Geodetic — The circle of the reference ellipsoid midway between its poles of rotation. The geodetic Equator is the line on which geodetic latitude is 0° and from which geodetic latitudes are reckoned, north and south, to 90° at either pole.

Equipotential Surface — A surface with the same gravity potential at every point. An equipotential surface is also referred to as a level surface. The force of gravity is everywhere perpendicular to this surface. The surface of a body of still water is an equipotential surface.

Error — The difference between the observed value of a quantity and the theoretical or defined value of that quantity. In the computation of root-mean-square errors (RMSE), x-, y- and z-errors are the differences in x- or y-coordinates or z-values between a sample dataset and a dataset of higher accuracy for the same sample points.

- Random Error — An error, produced by irregular causes whose effects upon individual observations are governed by no known law that connects them with circumstances and so cannot be corrected by use of standardized adjustments.
- Mean Error — The average error in a set of values, obtained by adding all errors (in x, y or z) together and then dividing by the total number of errors for that dimension.
- Systematic Error — An error whose algebraic sign and, to some extent, magnitude bears a fixed relation to some condition or set of conditions. Systematic errors follow some fixed pattern and are often introduced by data collection procedures or processing.

Euler Angle — One of a sequence of three angles (rotations) specifying the orientation of one (three-dimensional) coordinate system with respect to another, in which the first and third rotations are about the same axis, and the second is about a different axis. For example, let the system whose axes are x, y, z be rotated into the system with axis X, Y, Z. A sequence of Euler angles is given by a rotation about z yielding x’, y’, z; then a rotation about x’ yielding x’, y”, Z; finally a rotation about Z, yielding X, Y, Z. Used with inertial measurement units (IMUs).

Exterior Orientation — The position and attitude of an acquisition sensor with respect to a ground coordinate system. The six parameters that define the position (x/y/z coordinates) and attitude (roll, pitch and heading) of a remote sensing system, relative to a ground coordinate reference frame, at the instant that a pulse is emitted from an active sensor (e.g., IFSAR, lidar or sonar) or an image is acquired by a passive sensor (e.g., exposure station of an aerial photograph). With digital imaging systems, the exposure station differs with each image line; therefore, the exterior orientation elements vary over time and are often modeled as a non-linear function requiring some measure of time tied to the image lines, ABGPS and IMU data. Also see Direct Georeferencing.

Fathom — A measure of water depth equal to exactly 6 feet.

Feathering — Adjusting the relative weighting of the different data sets over a specified distance to smoothly transition from one data set or combination of data sets to another.

Feature Separation — The process of preparing a separate drawing, engraving, or negative for selected types of data in the preparation of a map or chart. When using offset printing for mass production of large numbers of multi-color maps or charts, all feature separates to be printed in the same color are merged into a single color separate for each color to be printed. When different features are separated in a Geographic Information System (GIS), the separated features are normally referred to as "layers."

Fiducial Marks — Reference marks formed on photography by marks held in a fixed relationship to the camera lens. The intersection of the lines connecting opposite fiducial marks usually defines the *principal point* of the photograph.

Field of View — The angular extent of the portion of object space surveyed by an aerial camera or lidar sensor, measured in degrees. To avoid confusion, a typical airborne lidar sensor with a field of view of 30 degrees is commonly depicted as ±15 degrees on either side of nadir.

First Return — The first significant measurable portion of a return lidar pulse.

Flight Altitude — The vertical distance of the aircraft above mean sea level.

Flight Height — The vertical distance from average terrain elevation to the point from which aerial photography or other remote sensing data are collected.

Flight Line — The planned path of a single pass of the collection aircraft over the target area, designating the path along which the aircraft is to fly when acquiring aerial data. Often used incorrectly to refer to the data resulting from a flight line of collection.

Flight Line Overlap — Percent of redundant coverage in adjoining flight lines to ensure there are no data gaps between the usable portions of lidar swaths. Collections in high relief terrain are expected to require greater overlap so as to avoid data voids.

Flight Plan — All factors related to aircraft and aerial sensor operation contributing to producing suitable data. A flight plan includes flight altitude, flight lines, and additional information, e.g., preplanned camera stations for each frame image to be acquired.

Flood Insurance Rate Map (FIRM) — An official map of a community on which FEMA has delineated both the special flood hazard areas and the risk premium zones applicable to the community.

Flood Mitigation — Activities that lessen the potential for future flood damages.

Floodplain — The low lying area along a river, stream, or coast that is subject to flooding. Any land area susceptible to being inundated by water from any source.

Floodway — The channel and portion of the adjoining area required to discharge the base flood without increasing flood heights more than one foot.

Fly-Through — A terrain visualization technique, used in computer simulations, in which the 3-D perspective view of the terrain continuously changes relative to the location of the viewer who appears to be moving as though flying over the terrain in an aircraft. The terrain models used for fly-throughs may be overlaid with digital imagery, simulated clouds or smoke, or added or enhanced virtual features to depict landmarks or objects of unique importance to a specific fly-through.

Focal Length — The distance between the rear node of a lens (or the vertex of a mirror) and the point at which the image of an infinitely distant object comes into critical focus.

Footprint — Different definitions in geospatial community, depending on usage:

- Footprint (General Usage) — The beam size or surface area measured by a single beam from an active sensor such as IFSAR, lidar or sonar.
- Lidar Horizontal Footprint — The area illuminated by a laser beam on the face of a horizontal surface, typically based on the full width at half maximum (FWHM) points of the beam, or alternative criteria such as 1/e or $1/e^2$ of the maximum irradiance or amplitude. These different definitions are used because a lidar beam diverges/spreads, does not have a constant spatial energy distribution, and decays similar to a Gaussian distribution away from the center of a beam.
- Lidar Vertical Footprint — The area illuminated by a laser pulse (beam) on the face of a vertical surface, based on the FWHM points of the beam. This term is only used when the lidar sensor is tilted into a forward-looking position so that consecutive scan lines “walk up” a vertical surface.
- Building Footprint — The outline of a building, normally as viewed orthogonally from above.

Foreshortening — IFSAR relief displacement towards the direction of the radar, opposite to that of optical imagery where relief displacement is away from the direction of the camera.

Forward Overlap — Overlap of any two successive photographs in the direction of the flight line. Also called End Lap.

Full Waveform Lidar — Lidar system or data in which the entire reflection of the laser pulse is fully digitized, captured, and stored. Discrete return point clouds can be extracted from the waveform data during post processing. See *discrete return lidar*.

Full Width at Half Maximum (FWHM) — A measure of the extent of a function, given by the difference between the two extreme values of the independent variable at which the dependent variable is equal to half of its maximum value, commonly used to define the duration of pulse waveforms. For example, the duration of a laser pulse (pulse width) from a lidar sensor is usually defined as the time during which the laser output pulse power remains continuously above half its maximum value.

Fundamental Vertical Accuracy (FVA) — The term used by the NDEP guidelines for vertical accuracy at the 95% confidence level in open terrain only where errors should approximate a normal error distribution. It is obtained utilizing standard tests for RMSE, where FVA = $Accuracy_z = RMSE_z \times 1.9600$.

Geocentric — Referred to the center of the Earth. The exact meaning of "center" must usually be inferred from the context. The following kinds of center are in common use: (a) the center of an ellipsoid representing the Earth's shape or figure, as in "geocentric longitude"; (b) the Earth's center of mass, as in "geocentric orbit"; (c) the point at which the Earth's axis of rotation intersects the plane of the celestial Equator.

Geodesy — The science that determines the size and shape of the Earth, locates positions on the Earth, and determines the Earth's gravity field. Geodesy also includes the large-scale extended surveys for determining positions and elevations of points, in which the size and shape of the Earth must be taken into account.

Geodetic Coordinates — The position of a point described by latitude, longitude, and height above the ellipsoid.

Geodetic Survey — A survey that takes into account the size and shape of the Earth, as distinguished from a plane survey in which the surface of the Earth is considered a plane.

Geographic Information System (GIS) — A system of spatially referenced information, including computer programs that acquire, store, manipulate, analyze, and display spatial data.

Geoid — An equipotential surface coinciding with mean sea level for the oceans and extended in land areas so the surface is always perpendicular to the direction of gravity. The geoid undulates up and down with local variations in the mass and density of the Earth.

Geoid Height — See Height.

Geodetic Height — See Height.

Geomorphology — The study of the physical features of the Earth, the arrangement and form of the Earth's crust and of the relation between the physical features and geological structures beneath.

Geop — A geopotential surface that approximates the Earth's potentials of gravitation. The geoid is a specific geop, selected to pass through the average sea surface for the Earth.

Geopotential Number — The geopotential number (C) of a bench mark is the difference in potential measured from the reference geopotential surface to the equipotential surface passing through the survey mark. It is the amount of work required to raise a unit mass of 1 kg against gravity through the orthometric height to the mark. Geopotential differences are differences in potential which indicate hydraulic head, i.e., the direction water flows.

Geospatial Data — Information that identifies the geographic location and characteristics of natural or constructed features and boundaries of earth. This information may be derived from, among other things, remote sensing, mapping, and surveying technologies. *Geospatial data* is generally considered to be synonymous with *spatial data*; however, the former is always associated with geographic or cartesian coordinates linked to a horizontal or vertical datum, whereas the latter (e.g., generic architectural house plans) may include dimensions and other spatial data not linked to any physical location.

Global Positioning System (GPS) — A system of satellites combined with receivers on the Earth that determine the latitude and longitude of any particular receiver through triangulation. The distance of the receiver to three of the satellites is ascertained by measuring the time-delay of a predetermined radio signal. Errors in timing can be corrected by checking the signals against the signal from a fourth satellite. When used for navigation and general mapping, current systems can autonomously locate a GPS receiver with an accuracy of several meters. When used for surveying, differential GPS techniques can locate a GPS receiver with centimeter-level accuracy by applying corrections from base station control points surveyed simultaneously with roving GPS receivers at unknown locations – both receiving the same GPS signals.

Graticule — A network of parallels and meridians on a map or chart.

Gravity — The force which is the resultant of gravitation, the force exerted by the mass of the Earth, and the centrifugal force, caused by the rotation of the Earth. The acceleration is a function of the body's location but is independent of the mass, shape, size, or other properties of the body. The term gravity is used for both the force and the acceleration and for both the vector and its magnitude. Thus the word may have any one of several different meanings. At the

Equator and close to the surface, the acceleration of gravity (g) is approximately 978.03 cm/s^2; at the poles, it is approximately 983.22 cm/s^2. The quantity "1 cm/s^2" is called the *gal*.

Great Diurnal Range (Gt) — The difference between Mean Higher High Water and Mean Lower Low Water.

Grid — For general mapping, a grid is a network of uniformly spaced parallel straight lines intersecting at right angles; when superimposed on a map, it usually carries the name of the projection used for the map or chart, e.g., State Plane Coordinate System grid or a UTM grid. For elevation datasets, however, a grid is a rectangular array of cells, each of which stores an elevation value for the centroid of the cell, that forms the basic structure of the most common and uniformly-spaced DEMs. The resolution of the grid (the width and height of the cells) determines the precision of the grid representation.

Grid Post — See *Elevation Post*.

Ground Sample Distance (GSD) — The linear dimension of a sample pixel's footprint on the ground. GSD is normally used when referring to the collection GSD of the raw image, assuming near-vertical imagery. The actual GSD of each pixel is not uniform throughout the raw image and varies significantly with terrain height and other factors. GSD is normally computed using the calibrated camera focal length and camera height above average horizontal terrain.

Ground Truth — Verification of a situation, without errors introduced by sensors or human perception and judgment.

Gyro — A device that measures angular rate or angle increments with respect to an inertial reference.

Hardcopy Photogrammetry — Stereo photogrammetric procedures that utilize direct viewing of film imagery in analog or analytical stereoplotters.

Heading — The azimuth of the longitudinal axis of a vehicle; the "straight-ahead" direction. True heading is the vehicle azimuth with respect to true North; magnetic heading is the azimuth with respect to the magnetic North pole.

Height — The distance, measured along a perpendicular, between a point and a reference surface, e.g., the height of an airplane above the ground surface. The distance, measured upwards along a plumb line (line of force), between a point and a reference surface of constant geopotential. *Elevation* is preferred if the reference surface is the geoid. Height systems are called by different names depending on the geopotential number (C) and gravity (G) selected. When G is computed using the Helmert height reduction formula, which is what was used in

NAVD 88, the heights are called Helmert orthometric heights. When G is computed using the International formula for normal gravity, the heights are called normal orthometric heights. When G is equal to normal gravity at 45 degrees latitude, the heights are called normal dynamic heights, which is what was used in IGLD 85.

- Dynamic Height — The value, assigned to a point, determined by dividing the geopotential number for that point by the value of gravity on the reference ellipsoid at 45° latitude, as calculated from a standard gravity formula. Dynamic heights are geopotential numbers scaled by a constant, using normal gravity at 45 degrees latitude equal to 980.6199 gals. Points that have the same geopotential number will have the same dynamic height. The primary users of dynamic heights use the heights for measuring water-level heights and/or height differences on large bodies of water, i.e., the Great Lakes, because they are interested in knowing the hydraulic head.

- Ellipsoid Height — The height above or below the reference ellipsoid, i.e., the distance between a point on the Earth's surface and the ellipsoidal surface, as measured along the normal (perpendicular) to the ellipsoid at the point and taken positive upward from the ellipsoid. Defined as "h" in the equation: h = H + N. Same as ellipsoidal height and geodetic height.

- Geoid Height — The difference between an ellipsoid height and an orthometric height. Defined as "N" in the equation: N = h — H. Same as geoidal height.

- Helmert Orthometric Height — An approximate value H_N^H found for the elevation of a point P_N by dividing the *geopotential number* W_N at that point by an approximation (g_N^H) to the average value of gravity along the vertical between P_N and the geoid. The value g_N^H is calculated from the measured value g_N of gravity at P_N and two forms of gravity corrections, i.e., the Bouguer and free-air gravity corrections. The difference between adjusted Helmert orthometric heights is computed using geopotential differences based on observed gravity.

- Orthometric Height (Elevation) — The height above the geoid as measured along the plumbline between the geoid and a point on the Earth's surface, taken positive upward from the geoid. Defined as "H" in the equation: H = h - N. The difference between adjusted orthometric heights is computed using a normal gravity formula. The orthometric height (H) and the geopotential number (C) are related through the following equation: C = G x H, where G is the gravity value estimated for a particular system.

Hillshade — A function used to create an illuminated representation of the surface, using a hypothetical light source, to enhance terrain visualization effects.

Histogram — A graphic representation of a frequency or relative frequency distribution consisting of vertical rectangles whose widths correspond to a defined range of frequencies and whose heights correspond to the number of frequencies occurring within the range.

Holiday — An area of missing coverage, caused by missing or unresolvable data, data edits, or incorrectly positioned flightlines, normally identified for further investigation or re-flying. An unintentionally unsurveyed part of a region that was to have been completely surveyed. See *Data Void.*

Horizontal Accuracy — Positional accuracy of a dataset with respect to a horizontal datum. According to the NSSDA, horizontal (radial) accuracy at the 95% confidence level is defined as "$Accuracy_r$."

Horizontal Error — Magnitude of the displacement of a feature's recorded horizontal position in a dataset from its true or more accurate position, as measured radially according to the NMAS and NSSDA standards, or as measured separately, for x and y, according to NSSDA and ASPRS standards. Horizontal errors comprise the errors that are squared in the computation of horizontal root-mean-square errors (RMSEs), whether $RMSE_x$, $RMSE_y$, or $RMSE_r$. Note: $RMSE_r$ = square root of [$RMSE_x^2 + RMSE_y^2$].

Horizontal Post Spacing — The ground distance interval between grid posts in a uniformly gridded data model. It is important to note that features of a size equal to, or even greater than the post spacing, may not be detected or explicitly represented in a gridded model. For gridded elevation data, the horizontal post spacing may be referenced as the cell size, the grid spacing, the posting interval, or the ground sample distance.

Hydraulic Modeling — The use of digital elevation data, rainfall runoff data from hydrologic models, surface roughness data, and information on hydraulic structures (e.g., bridges, culverts, dams, weirs, sewers) to predict flood levels and manage water resources. Hydraulic models are based on computations involving liquids under pressure, and there are many other definitions of hydraulic modeling that have nothing to do with terrain elevations, e.g., modeling of hydraulic lines in aircraft and automobiles.

Hydrographic Survey — A survey conducted to determine the configuration of the bottom of water bodies and to identify and locate all features, natural and man-made, that may affect navigation. Hydrographic surveys are conducted for the purpose of safety of navigation and require very accurate bathymetry and the detection of all hazards to surface navigation like wrecks and obstructions. This type of surveying is most often conducted with a multibeam sonar and/or a sweep sonar, which might be augmented with towed side scan sonar to ensure full coverage of the seabed. Hydrographic surveys may include the delineation of the submerged contours of channels, banks and shoals, and the collection of bottom specimens and samples of water. Also included are consideration of tides and currents, and information on temperature and salinity of the water and their effects on the accurate measurement of depths by echo sounding.

Hydrography — That branch of applied science which deals with the measurement and description of the physical features of the navigable portion of the Earth's surface and adjoining coastal areas, with special reference to their use for the purpose of navigation. Hydrography also includes the collection of other oceanography, geodesy and geologic data (e.g., bottom classification) in conjunction with the depth data, and it may be used for other coastal engineering purposes (e.g., maintenance dredging, construction) in addition to nautical charting.

Hydrologic Modeling — The computer modeling of rainfall and the effects of land cover, soil conditions, and terrain slope to estimate rainfall runoff in streams and lakes. Digital elevation data are used as part of hydrologic modeling.

Hydrologically-Conditioned (Hydro-Conditioned) — Processing of a DEM or TIN so that the flow of water is continuous across the entire terrain surface, including the removal of all spurious sinks or pits. The only sinks that are retained are the real ones on the landscape. Whereas "hydrologically-enforced" is relevant to drainage features that are generally mapped, "hydrologically-conditioned" is relevant to the entire land surface and is done so that water flow is continuous across the surface, whether that flow is in a stream channel or not. The purpose for continuous flow is so that relationships/links among basins/catchments can be known for large areas.

Hydrologically-Enforced (Hydro-Enforced) — Processing of mapped water bodies so that lakes and reservoirs are level and so that streams flow downhill. For example, a DEM, TIN or topographic contour dataset with elevations removed from the tops of selected drainage structures (bridges and culverts) so as to depict the terrain under those structures. Hydro-enforcement enables hydrologic and hydraulic (H&H) models to depict water flowing under these structures, rather than appearing in the computer model to be dammed by them because of road deck elevations higher than the water levels. Hydro-enforced TINs also utilize breaklines along shorelines and stream centerlines, for example, where these breaklines form the edges of TIN triangles along the alignment of drainage features. Shore breaklines for streams would be monotonic 3-D breaklines with elevations that decrease as the stream flows downstream; however, shore breaklines for lakes or reservoirs would have the same elevation for the entire shoreline if the water surface is known or assumed to be level throughout.

Hydrologically-Flattened (Hydro-Flattened) — Processing of a DEM or TIN so that mapped water bodies, rivers, reservoirs, and other cartographically polygonal water surfaces are flat and, where appropriate, level from bank-to-bank. Additionally, surfaces of rivers and long reservoirs demonstrate a gradient change in elevation along their length, consistent with their natural behavior and the surrounding topography. In traditional photogrammetrically-compiled mapping, this process is accomplished automatically through the inclusion of measured breaklines in the DTM. However, because lidar does not inherently include breaklines, a DEM or TIN derived solely from lidar points will depict water surfaces with unsightly and unnatural artifacts or

triangulation. The process of hydro-flattening typically involves the addition of breaklines along the banks of specified water bodies, rivers, ponds, and streams which establish elevations for the water surfaces that are consistent with the surrounding topography, and produce aesthetically acceptable water surfaces in the final derived DEM of TIN. Unlike hydro-conditioning and hydro-enforcement, hydro-flattening is not driven by any hydrologic and hydraulic (H&H) modeling requirements, but solely by cartographic mapping needs.

Hydrology — The scientific study of the waters of the Earth, especially with relation to the effects of precipitation and evaporation upon the occurrence and character of water in streams, lakes, and on or below the land surfaces.

Hypsography — The description of elevations or heights of land surfaces with reference to a specified surface (usually the geoid). The configuration of land or underwater surfaces with respect to a horizontal and vertical datum. Hypsography includes topographic and bathymetric contours, spot heights, mass points, breaklines, and all forms of generic DEM data, except DSMs that depict surfaces above the ground.

Image Correlation — Directly comparing hardcopy or softcopy images, or patches of pixels on conjugate digital images, or indirectly comparing information derived from the stereo images, to determine that points on stereo images (viewed from different perspectives) represent the same points on the imaged surface. Automated image correlation is a computerized technique to match the similarities of pixels in one digital image with comparable pixels in its digital stereo image in order to automate or semi-automate photogrammetric compilation. Automated image correlation provides an efficient method for generating DEMs photogrammetrically, but automated correlation normally results in DSMs instead of DEMs because such correlation generates elevations of rooftops, treetops and other surface features as imaged on the stereo photographs.

Image Resolution — The size of the smallest feature that can be resolved or interpreted in an image. Often confused with ground sample distance (GSD). With digital imagery, the GSD is the size of the ground footprint of a pixel and is reported as linear units/pixel, such as 1 meter/pixel, 1 foot/pixel, etc. The interpretive image resolution is normally superior to the GSD; for example, it is common to interpret highway paint stripes only 4”-6” wide on digital imagery with a GSD of 1 meter.

Imagery — Visual representation of objects and/or phenomena as sensed or detected by cameras, spectral scanners, radar or photometers. Recordings may be on film or digital media.

Independent Source of Higher Accuracy — Data acquired independently of procedures to generate the dataset that is used to test the positional accuracy of a dataset. The independent source of higher accuracy shall be of the highest accuracy feasible and practicable to evaluate the accuracy of a dataset.

Infrared — The portion of the invisible spectrum consisting of electromagnetic radiation with wavelengths in the range from 750 nanometers to 1 millimeter.

Insonify (Ensonify) — To expose an area, or portion of seabed, to sonar energy. Seabed that has been covered by imaging sonar, provided acceptable backscatter and interpretable sonar data, is said to have been insonified. Ping rates (numbers of output pulses per second) are often referred to as "insonification rates."

Intensity, Lidar — For discrete-return lidar instruments, intensity is the recorded amplitude of the reflected lidar pulse at the moment the reflection is captured as a return by the lidar instrument. Lidar intensity values can be influenced by numerous factors such as the instantaneous setting of the instrument's Automatic Gain Control, angle of incidence, etc. and cannot be equated to a true measure of "energy." In full-waveform systems, the entire reflection is sampled and recorded, and true energy measurements can be made for each return or overall reflection. Intensity values for discrete returns derived from a full-waveform system may or may not be "calibrated" to represent true energy. Lidar intensity data make it possible to map variable textures in the form of a grey-scale image. Intensity return data enables automatic identification and extraction of objects such as buildings and impervious surfaces, and can aid in lidar point classification. In spite of their similar appearance, lidar intensity images differ from traditional panchromatic images in several important ways: (1) Lidar intensity is a measure of the reflection of an active laser energy source, not natural solar energy; (2) lidar intensity images are aggregations of values at point samples; the value of a pixel does not represent the composite value for the area of that pixel; (3) lidar intensity images depict the surface reflectivity within an extremely narrow band of the infra-red spectrum, not the entire visible spectrum as in panchromatic images; (4) lidar intensity images are strongly influenced by the angle of incidence of the laser to the target and are subject to "unnatural" shadowing artifacts; and (5) the values on which lidar intensity images are based may or may not be calibrated to any standard reference. Intensity images usually contain wide variation of values within swaths, between swaths, and between lifts; for these reasons, interpretation and analysis of lidar intensity images must be performed with unusually high care and skill.

Interferometer — An instrument that measures differences between the phases of two different electromagnetic signals originating from a common source, but which have traversed different paths The phase differences are measured by combining the two signals. The amplitude of the combined signal is a function of the phase difference between the two signals. The phenomenon of fluctuations in the amplitude of the combined signals in response to phase changes in the input signals if sometimes referred to as interference.

Interferometric Synthetic Aperture Radar (IFSAR) — An airborne or spaceborne interferometer radar system, flown aboard rotary or fixed wing aircraft or space-based platform, that is used to acquire 3-dimensional coordinates of terrain and terrain features that are both manmade and

naturally occurring. IFSAR systems form synthetic aperture images of terrain surfaces from two spatially separated antennae over an imaged swath that may be located to the left, right or both sides of the imaging platform.

Interior Orientation — Definition of the elements of the image and how they relate to the optical system used to acquire them, e.g., the camera's focal length, location of the "principal point" on the image, and any known distortions induced by the optics and film.

Interpolation — As used in this manual, interpolation is the estimation of z-values at a point with x/y coordinates, based on the known z-values of surrounding points. There are many different forms of interpolation:

- ANUDEM — A variation of spline interpolation optimized for the creation of hydrologically correct (hydro-enforced) terrain models.
- Inverse Distance Weighted Interpolation — A method for interpolating the elevations of new points by using a linearly weighted combination of values from nearby points, where the weight is a function of inverse distance.
- Kriging — A method for interpolating the elevations of new points by using geostatistical techniques that weight the surrounding measured values to derive a prediction for each location. However, the weights are based not only on the distance between the measured points and the prediction location but also on the strength of the overall correlation among the measured points. With kriging, the data are used to define the spatial correlation model to determine the weights for neighboring samples that are used to fit a surface to the points.
- Natural Neighbor Interpolation — A method for interpolating the elevations of new points by using an area based weighting scheme to interpolate heights.
- Spline — A method for interpolating the elevations of new points by using a mathematical formula to create a surface that minimizes the overall surface curvatures, resulting in a smooth surface that passes through the input points.

Intervisibility — The identification of all points that are visible from a designated input point. Generally synonymous with "viewshed" and "line-of-sight."

Kalman Filter — A recursive minimum variance estimation technique that uses statistical models to weight each new measurement relative to past information and estimate quantities of interest having statistical characteristics. It can be thought of as a recursive least squares adjustment.

Kriging — See Interpolation.

Kurtosis — The measure of relative “peakedness” or flatness of a distribution compared with a normally distributed data set. Positive kurtosis indicates a relatively peaked distribution near the mean while negative kurtosis indicates a flat distribution near the mean.

L1 — Level 1 frequency of 1575.42 MHz, one of the radio frequencies transmitted by GPS satellites. This frequency carries the C/A code, P-code, and the navigation message.

L2 — Level 2 frequency of 1227.6 MHz, one of the radio frequencies transmitted by GPS satellites. This frequency carries only the P-code.

L3 — Level 3 frequency of 1381.04 MHz of GPS satellites.

L5 — Level 5 frequency of 1176.45 MHz, an additional frequency used on new “Block IIF” satellites, intended for civilian applications in air traffic control.

LAS File Format — A public file format for the interchange of 3-D point cloud data between data users. Although LAS is an abbreviation for LASer, and this file format was developed primarily for exchange of lidar point cloud data, this format supports the exchange of any 3-D x/y/z tuplet. The LAS file format is a binary file format that maintains information specific to the lidar nature of the data while not being overly complex. It is an alternative to proprietary systems or a generic ASCII file interchange system used by many companies. The problem with proprietary systems is obvious in that data cannot be easily taken from one system to another. There are two major problems with the ASCII file interchange. The first problem is performance because the reading and interpretation of ASCII elevation data can be very slow and the file size can be extremely large, even for small amounts of data. The second problem is that all information specific to the lidar data is lost.

Last Return — The last significant measurable portion of a return lidar pulse.

Latitude — The angular distance, in degrees, minutes and seconds, of a point north or south of the equator.

Latitude, Geodetic — The angle that the normal to the ellipsoid at a point makes with the equatorial plane (the geodetic Equator) of the ellipsoid. Geodetic latitudes depend on the chosen geodetic datum, which determines the orientation and dimensions at the ellipsoid.

Lattice — A 3-D surface representation method created by a rectangular array of points spaced at a constant sampling interval in x and y directions relative to a common origin. A lattice differs from a grid in that it represents the value of the surface only at the lattice “mesh points” or “elevation posts” of the lattice, rather than the elevation of the cell area surrounding the centroid of a grid cell.

Layover — A limiting case of foreshortening where points arranged with increasing ground coordinates appear reversed in the radar imagery, precluding the determination of elevation in layover regions. Geometrically this happens when the slope of the terrain is greater than the angle the incident radiation makes with respect to vertical.

Lead Line — A long chain or line with a lead weight attached at one end. The line is used to measure water depths (usually up to 10 fathoms) by survey parties not equipped with electronic depth-measuring equipment. It also can be used to check such electronic equipment.

Least Squares Adjustment — An adjustment satisfying the condition that the sum of the squares of the differences between the given and changed quantities be a minimum.

Leveling — The process of finding differences of elevation.

- Differential Leveling — Determining the difference in elevation between two points by the sum of incremental vertical displacements of a graduated leveling rod.
- Spirit Leveling — Leveling with a leveling instrument that depends on a spirit level for making its line of sight horizontal. A spirit level uses a closed glass container filled with a fluid with free space so that a bubble of air rises to the top to indicate when the instrument is level.
- Trigonometric Leveling — Determining differences of elevation by observing vertical angles between points. Either the horizontal distance between the points must be known or the straight-line distance must be measured.

Lens Distortion — Lens aberration shifting the position of images off the camera axis causing objects at different angular distances from the axis to undergo different magnifications.

Leveling — A surveying operation in which elevations of objects and points are determined relative to a specified vertical datum.

Lever Arm — A relative position vector of one sensor with respect to another in a direct georeferencing system. For example, with aerial mapping cameras, there are lever arms between the inertial center of the IMU and the phase center of the GPS antenna, each with respect to the camera perspective center within the lens of the camera. Lidar sensors also have similar lever arm vectors.

Lidar — An instrument that measures distance to a reflecting object by emitting timed pulses of light and measuring the time difference between the emission of a laser pulse and the reception of the pulse's reflection(s). The measured time interval for each reflection is converted to distance, which when combined with position and attitude information from Global Positioning System (GPS), Inertial Measurement Unit (IMU), and the instrument itself, allows the derivation of the 3-D coordinates of the reflecting target's location.

Lift — A single take-off/landing cycle of a collection platform (fixed or rotary wing) within an aerial data acquisition project.

Line-of-Sight — See Intervisibility.

Local Accuracy — See Accuracy.

Longitude — The angular distance, in degrees, minutes and seconds, of a point east or west of the Greenwich meridian.

Longitude, Geodetic — The angle between the plane of the local geodetic meridian and the plane of an arbitrarily chosen, geodetic meridian, normally the prime meridian in Greenwich, England. A geodetic longitude may be measured by the angle, at one of the poles of the ellipsoid, between the local and geodetic meridian, or by the arc of the ellipsoid's Equator intercepted by these meridians. In recording a geodetic location, it is essential that the geodetic datum on which it is based also be stated.

Lunation — The interval of time between two successive conjunctions (new moons) or oppositions (full moons) of the Moon. A lunar month.

Map — A representation, usually on a plane surface and at an established scale, of the physical features (natural, artificial, or both) or a part or the whole of the Earth's surface. Features are normally identified by means of signs and symbols, and geographical orientation is indicated.

- Engineering Map — A map showing information that is essential for planning an engineering project or development and for estimating its cost. It usually is a large-scale map of a small area or of a route. It may be entirely the product of an engineering survey, or reliable information may be collected from various sources for the purpose, and assembled on a base map.
- Flood Control Map — A map designed for studying and planning flood control projects in areas subject to flooding.
- Hypsographic Map — A map showing relief with elevations referred to a geodetic vertical datum.
- Land Cover Map — A map showing different types of vegetation and manmade impermeable surfaces.
- Land Use Map — A map showing the various purposes for which parcels of land are being used.
- Line Map — A map composed of lines as distinguished from photographic imagery maps.

- Orthophoto Map — A map produced by assembling orthophotographs at a specified uniform scale in a map format.
- Planimetric Map — A map that shows only the horizontal positions of the features represented; distinguished from a topographic map by the omission of relief in measurable form. The features usually shown on a planimetric map include rivers, lakes, and seas; mountains, valleys, and plains; forests and prairies; cities, farms, transportation routes, and public utility facilities; and political and private boundary lines. A planimetric map intended for special use may present only those features essential to the purpose to be served.
- Thematic Map — A map designed to provide information on a single topic, e.g., geology, rainfall, population.
- Topographic Map — A map showing the horizontal and vertical locations of natural and manmade features. It is distinguished from a planimetric map by the presence of numbered contour lines or comparable symbols to indicate elevations of mountains, valleys, and plains; in the case of hydrographic charts, symbols and numbers are used to show depths in bodies of water.

Map Manuscript — The original drawing of a map as compiled or constructed from ground surveys, photogrammetry, etc.

Map Projection — A function relating 3-D coordinates of points on a curved surface (usually an ellipsoid or sphere) to 2-D coordinates of points on a plane map. An orderly system of lines projected onto a plane surface from a curved or spherical surface, to include the mathematical concept of such a system. For maps of the Earth, a projection consists of a graticule of lines representing parallels of latitude and meridians of longitude or a grid.

Map Series — A family of maps conforming generally to the same specifications and designed to cover an area or a country in a systematic pattern.

Mark — A dot, the intersection of a pair of crossed lines, or any other physical point corresponding to a point in a survey. It is the physical point to which distances, elevations, heights or other coordinates refer.

Mass Points — Irregularly spaced points, each with x/y location coordinates and z-value, typically (but not always) used to form a TIN. When generated manually, mass points are ideally chosen to depict the most significant variations in the slope or aspect of TIN triangles. However, when generated automatically, e.g., by lidar or IFSAR scanners, mass point spacing and pattern depend upon the characteristics of the technologies used to acquire the data.

Mean (Arithmetic Mean) — The average of all numbers in a dataset.

Mean Range — The difference between Mean High Water and Mean Low Water.

Mean Sea Level — The average location of the interface between ocean and atmosphere, over a period of time sufficiently long so that all random and periodic variations of short duration average to zero. The U.S. National Ocean Service has set 19 years as the period suitable for measurement of mean sea level at tide gauges.

Median — The value in a dataset at which there are as many larger numbers as there are smaller numbers.

Meridian — A plane curve on the surface of the Earth passing through the axis of rotation and any given point on the Earth's surface. All points on a given meridian have the same longitude. A north-south line from which differences of longitude and azimuths are reckoned. At the International Meridian Conference held in Washington D.C. in 1884, the adoption of the Greenwich Meridian as the *prime meridian* for the Earth was approved by the representatives of 22 governments, including the U.S.

Mesh Points — The regularly spaced points in a lattice. Mesh points are located at a constant interval in x and y directions relative to a common origin, and contain the z-values for the surface at each location. Often referred to as elevation posts or grid posts in USGS DEMs and other regularly spaced elevation data sets.

Metadata —Any information that is descriptive or supportive of a geospatial dataset. This would include formally structured and formatted metadata files, for example, eXtensible Markup Language (XML)-formatted Federal Geographic Data Committee (FGDC) metadata; collection, processing, Quality Assurance/Quality Control (QA/QC) reports; and other supporting data, e.g., survey points, shapefiles.

Metonic Cycle — A period of 6940 days (approximately 19 years) devised by the Athenian astronomer Meton (c. 450 B.C.) for obtaining a period in which new and full moon would recur on the same day of the year.

Micron — One-millionth of a meter. One micrometer.

Mode — The value at which the greatest number of values is concentrated in a dataset. In a histogram, the mode is the value or range of values which has the highest abscissa value at the peak of the histogram.

Model — The copy of a physical object such as the Earth, normally at reduced scale.

- Mathematical Model — The mathematical reconstruction of a physical object such as the Earth, normally for computer display and analyses.

- Photogrammetric Model — The visual or optical image produced by optically combining light transmitted through a stereoscopic pair of photographs or digital images. A stereoscopic model is not a material object but an image or pair of images that give the same visual effect as would a material model.

Monotonic ─ A mathematical sequence in which successive numbers consistently increase or decrease but do not oscillate in relative value. DEMs or other models of watercourses are monotonic when water surface elevations consistently decrease in the downstream direction.

Monument (Surveying) — A permanent physical structure marking the location of a survey point. Common types of monuments are inscribed metal tablets set in concrete posts, solid rock, or parts of buildings; distinctive stone posts; and metal rods driven in the ground.

Morphology — The form and structure of a surface. In TINs, the morphology of a surface is defined by mass points and breaklines used to build the TIN. Breaklines are very significant in defining surface morphology. In lattices, the morphology of a surface cannot be directly represented in the model by linear features (e.g., breaklines) and must be implied from the mesh point z-values.

Mosaic — An assembly of vertical aerial images and/or DEMs to form a continuous representation of the terrain with a common datum, map projection and data format.

Mosaicking — The process whereby multiple images and/or DEMs are merged into a single, continuous image and/or DEM to create a mosaic.

Multipath – Reflected signals that traverse different longer paths than the direct line-of-sight signal before arriving at the receiving device.

Multipath Error — Errors in GPS positioning caused by signals reflected off of fixed surfaces or refracted by foliage, both causing signals with multiple path lengths to impinge on the GPS antenna.

Nadir — The point or line directly beneath the collection platform, corrected for attitude variations.

National Elevation Dataset (NED) — A single, nationwide seamless elevation database with product areas defined by the customers, available in several product format options. It includes the “best available” data that meet a common standard. It is one of the framework data themes within The National Map. Standard datasets have 1-arc-second, 1/3-arc-second, and 1/9-arc-second post spacing and typically comprise the best available, multi-resolution dataset.

National Standard for Spatial Data Accuracy (NSSDA) — A document published by the U.S. Federal Geographic Data Committee (FGDC) that implements a statistical and testing methodology for estimating the positional accuracy of points on maps, and in digital geospatial data, with respect to georeferenced ground positions of higher accuracy. It is not truly a "standard," in the sense of the National Map Accuracy Standard or the ASPRS Accuracy Standard for Digital Geospatial Data, because the NSSDA does not define threshold accuracy values.

National Tidal Datum Epoch (NTDE) — A specific 19-year period (closest full year to the 18.6-year nodal cycle of the moon) used to average out local meteorological effects on sea level and to compute tidal datums.

Natural Neighbor Interpolation — See Interpolation.

Nautical Chart — A chart specifically designed to meet the requirements of marine navigation, showing depths of water, nature of bottom, elevations, configuration and characteristics of coast, dangers, and aids to navigation.

Neap Tide — A tide that occurs approximately midway between the times of the new and full moon. The neap tidal range is usually 10 to 30 percent less than the mean tidal range.

Network Accuracy — See Accuracy

No Bottom At — Historically, depths apparently deeper than the maximum length of a lead line. Now, used to describe areas that have been "cleared" of hazards to an assumed lidar extinction depth, or areas that may be surveyed by sonar without fear of danger to the vessel.

Nodal Point — One of two intangible points in a camera lens that have the characteristic that any ray of light directed to the front nodal point will exit parallel to itself through the rear nodal point.

Nodes — The beginning and ending location of a vector or arc, topologically linked to all vectors or arcs that meet at the node. When specifically applied to elevation data, nodes represent the corner points of each triangle in a TIN. A triangle node is topologically linked to all triangles that meet at that node.

Nominal Pulse Spacing (NPS) — A common measure of the density of a lidar dataset, it is the typical or average lateral distance between points in a lidar dataset, most often expressed in meters. It is often and most simply calculated as the square root of the average area per point. This value is predicted in mission planning and empirically calculated from the collected data.

In high-density collections (<1 meter NPS), this may be directly expressed as Points Per Square Meter (ppsm). PPSM = $1/NPS^2$.

Non-Vegetated Vertical Accuracy (NVA) — The vertical accuracy at the 95% confidence level in non-vegetated open terrain, where errors should approximate a normal distribution. As explained in ASPRS 2014, the NVA is determined with well-distributed static checkpoints located in both open terrain (bare soil, rock, sand and short grass) and urban terrain (concrete and asphalt surfaces).

Normal — A straight line perpendicular to a surface or to another line. Also, the condition of being perpendicular to a surface or line. In geodesy, a *normal* is a straight line perpendicular to the surface of a particular ellipsoid.

Northing — In a plane coordinate system, the coordinate in a general north-south direction, increasing to the north. A linear distance, in the coordinate system of a map grid, northwards from the east-west line through the origin or false origin. A *false northing* is a value assigned the east-west line through the origin on a map grid to avoid the inconvenience of negative northings at some points.

Oblique Photograph — A photograph taken with the camera axis intentionally directed between vertical and horizontal.

Orientation — The rotation or set of rotations needed to make the axes of one rectangular Cartesian coordinate system parallel to the axes of another.

Origin of Coordinates — The point in a system of coordinates that serves as a zero point in computing the system's elements or in prescribing its use.

Orthometric Height — See Height.

Orthophotograph (Orthophoto) — A photograph prepared from a perspective photograph by removing scale differences and image displacements caused by tilt, relief, and perspective.

Orthophoto DEMs — Digital Elevation Models used to correct relief displacement in the production of digital orthophotos.

Orthophotomap — An orthophotograph to which has been added a grid, contour lines, names, and/or other information characteristic of a map but missing on the orthophotography.

Orthophotomosaic — An assembly of orthophotographs forming a uniform-scale photo mosaic.

Outlier — An error larger than justified by a dataset of errors having a normal distribution, often assumed to be errors larger than three times the standard deviation, i.e., "3-sigma" which is equivalent to the 99.75% confidence level for a normal distribution.

Overlap — Any portion of a swath that is also covered by any portion of any other swath. The amount by which one photograph or swath overlaps another, customarily expressed as a percentage. The overlap between aerial photographs in the same flight line is called *forward overlap* or *end lap*, and the overlap between photographs in adjacent parallel flight lines is called *side lap*.

Panchromatic — Black-and-white imagery that is sensitive to all colors of the visible spectrum.

Panel Points — Ground control points used for aerotriangulation and designed to present clearly visible points that can be accurately measured on aerial photographs. They may be removable plastic or wooden panels, for example, or painted over the reference point, normally as “X”, “V” or “T” symbols, and surveyed at the center of the intersecting lines of these symbols. The symbols are sized to be accurately measured based on the image scale.

Parallax — Small changes in the direction from sensor to object as the sensor or object moves. The apparent displacement of the position of an object with respect to a reference system, because of a shift in the location of the observer. Because photogrammetry is based on the imaging of the terrain from two different perspectives, parallax is essential for determining 3-D measurements from stereo imagery.

Parallel — A line which has the same latitude at every point.

Pass Point — A point whose horizontal and/or vertical position is determined from photographs/images by photogrammetric methods and is intended for use as a control point in the relative orientation of adjoining photographs/images in the same flight line. An image point that appears in the overlap area of photos in the same strip of aerial photography are said to “pass” control from one photograph to the next in a single flight line. Pass points often fall within the triple-overlap areas when the aerial photography has a forward overlap of at least 60%, meaning that some points on the ground appear on three consecutive aerial photographs, adding strength to the aerotriangulation process. With softcopy photogrammetry, pass points are commonly identified through automated image correlation.

P-Code — Precision Code (or Private Code) in relationship with the usage of GPS for military applications. It has a 10.23 MHz rate, a period of 7 days and is the principal navigation ranging code.

Peak — A point around which all slopes are negative.

Percentile — A measure used in statistics indicating the value below which a given percentage of observations (absolute values of errors) in a group of observations fall. For example, the 95th percentile is the value (or score) below which 95 percent of the observations may be found, with 5 percent above this value. Although Microsoft Excel and other software packages use slightly different formulas to compute percentiles, most methods yield similar results, particularly with large sample sizes.

Photogrammetry — The art, science and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring, and interpreting photographic images and patterns of electromagnetic radiant energy and other phenomena.

Photography — Photographic film, exposed and processed.

Photo Index — An assembly of photographs in their proper relative positions, generally annotated and copied at a reduced scale.

Photomap — A photographic map made by adding marginal information, descriptive data, and a reference system to a photograph or assembly of photographs.

Pit — A point around which all slopes are positive.

Pitch — The angular deviation from the horizontal of a craft about the horizontal axis normal to its direction of movement. The pitch is positive if it causes the craft's front end to rise. In photogrammetry, the term is applied to a rotation of the camera, or of the coordinate system of the photograph, about either the y-axis of the photograph's coordinate system or about the y-axis of the ground coordinate system.

Pixel — A two-dimensional raster cell, normally used for computer display of imagery or coded feature data.

Pixel Resolution or Pixel Size — The ground size of a pixel in a digital orthoimagery product, after all rectifications and resampling procedures.

Plane Survey — A survey that treats the surface of the Earth as though it were a plane.

Planimetrics — Data about non topographic features on the Earth's surface that are represented only by their horizontal position and having no indication of relief or contours.

Platen — The flat surface of an aerial camera against which the film is pressed while exposure is made.

Plumb Line — A line perpendicular to all equipotential surfaces of the Earth's gravity field that intersect with it. It is a line of force in the Earth's gravity field and thus is curved rather than straight.

Point Classification — The assignment of a target identity classification to a particular lidar point or group of points.

Point Family — The complete set of multiple returns reflected from a single lidar pulse.

Point Cloud — A large set of 3-D points, typically from a lidar collection. As a basic geographic information system (GIS) data type, a point cloud is differentiated from a typical point dataset in several key ways: (1) Point clouds are almost always 3-D, though some consider them 4-D (x/y/z/i) because they typically also include intensity values for each point; (2) Point clouds have an order of magnitude more features than point datasets; and (3) Individual point features in point clouds do not typically possess individually meaningful attributes; the information value in a point cloud is derived from the relations among large numbers of features.

Position — The location of a point on the surface of the Earth, expressed in terms of one of several coordinate systems. Examples are geographic position (latitude, longitude and altitude), UTM northing, easting and height, or State Plane northing, easting and height.

Positional Dilution of Precision (PDOP) — An indicator of a GPS receiver's positional accuracy that can be derived from the geometry of the visible GPS satellites in relation to the GPS receiver. The approximate 3-D positional accuracy is approximated by the product of PDOP and the statistical pseudorange errors.

Positional Error — The difference between data set coordinate values and coordinate values from an independent source of higher accuracy for identical points.

Postprocessing — In lidar, postprocessing refers to the processing steps applied to lidar data point clouds. This includes point classification, feature extraction (for example, building footprints, hydrographic features, and others); tiling; and generation of Digital Terrain Models (DTMs), Digital Surface Models (DSMs), intensity images, hillshades, slope maps and other derivative products. For comparison, see preprocessing.

Precision (repeatability) — The closeness with which measurements agree with each other, even though they may all contain a systematic bias. With geospatial data, standard deviation (σ) is a common measure of precision whereas root-mean-square-error (RMSE) is a common measure of accuracy. Precision is also exemplified by the number of decimal places to which a computation is carried and a result stated.

Preprocessing — In lidar, preprocessing of data most commonly refers to those steps employed in converting the collected Global Positioning System (GPS), Inertial Measurement Unit (IMU), instrument, and ranging information into an interpretable x/y/z point cloud. This includes generation of trajectory information, calibration of the dataset, and controlling the dataset to known ground references.

Primary Control — Survey stations surrounding a local network used to tie the local network to the National Spatial Reference System (NSRS).

Principal Point — The intersection of the optical axis of the camera with the image and origin of an image coordinate system. Film cameras use imprinted "fiducial points" at the corners and sides of each image that define the orientation of the image coordinate system and a context for locating the principal point. Lens distortion is generally modeled as being both radial and tangential to the principal point.

Profile — The side view of a cross section of a terrain surface. In USGS DEMs, profiles are the basic building blocks of an elevation grid and are defined as one-dimensional arrays, i.e., arrays of n columns by 1 row, where n is the length of the profile.

Profilometer — A device to measure the vertical profiles of surfaces on earth.

Projection — A function relating points on one surface to points on another surface so that for every point on the first surface corresponds exactly to one point on the second surface. A map projection is a special case in requiring that one of the surfaces be a spheroid or ellipsoid and the other be a developable surface (normally a plane or a cylinder or cone that can be "cut" and flattened into a plane).

Pseudorange — A GPS receiver's computed pseudorange to each satellite is its estimate of the time of signal propagation from the satellite to the GPS antenna multiplied by the speed of light. The computed pseudoranges comprise the true ranges between the satellites and the GPS antenna plus several pseudorange errors, the most dominant being the receiver clock error.

Puddle — One or more DEM grid cells totally surrounded by cells of higher elevation.

Pulse Duration — Time, measured in nanoseconds, during which the optical power of a laser pulse is at Full Width at Half Maximum (FWHM).

Pulse Energy — The total energy content of a laser pulse measured in micro joules (μJ).

Pulse Repetition Frequency (PRF) — The number of emitted light pulses per second; also known as Pulse Repetition Rate. For example, a 200 kHz lidar system generates 200,000 pulses of laser energy in one second.

Quadrangle (Quad) — A map or plat of a nearly rectangular area usually bounded by given meridians of longitude and parallels of latitude. Quad map dimensions are not necessarily the same in both directions.

Quality Assurance (QA) — Steps taken: (1) to ensure the government receives the quality products it pays for and/or (2) to ensure an organization's Quality Program works effectively.

Quality Control (QC) — Steps taken by data producers to ensure delivery of products that satisfy standards, guidelines and specifications identified in the Scope of Work. These steps typically include production flow charts with built-in procedures to ensure quality at each step of the work flow, in-process quality reviews, and/or final quality inspections prior to delivery of products to a client.

Quality Level (QL) — Quality of digital elevation data, defined in the National Enhanced Elevation Assessment (NEEA) and USGS's 3D Elevation Program (3DEP), based on $RMSE_z$ and nominal point density (NPD) parameters for elevation datasets.

Quality Program — Quality control procedures for specific products as well as overall Quality Plans that typically mandate an organization's communication procedures, document and data control procedures, quality audit procedures, and training programs necessary for delivery of quality products and services.

Radar — An instrument for determining the distance and direction to an object by measuring the time needed for radio signals to travel from the instrument to the object and back, and by measuring the angle through which the instrument's antenna has traveled.

Radar, Synthetic-Aperture — A radar containing a moving or scanning antenna; the signals received are combined to produce a signal equivalent to that which would have been received by a larger, stationary antenna.

Random Error — See Error.

Range (IFSAR) — The distance in a direction perpendicular to the flight path (cross path direction) imaging the terrain below. Range or cross track resolution is achieved by finely gating the received echo in time.

Rangefinder — A device which uses laser energy for determining the distance from the device to an object.

Real Time Kinematic (RTK) — A method of utilizing carrier phase differential GPS with on-the-fly ambiguity resolution transmitted from a base station with known coordinates to a rover receiver via a radio link. This technique will compute a position in real time, relative to the base station within an accuracy of a few centimeters.

Rectification — The process of producing, from a tilted or oblique photograph, a photograph from which displacement caused by tilt has been removed. Ortho-rectification, in addition to correction of tilt displacement, also corrects for perspective and relief displacement.

Relative Accuracy — See Accuracy.
Relief — Topography. The deviation of a surface, or portions thereof, from some surface such as a reference ellipsoid.

Relief Displacement — The displacement of an image, outward from the center of an aerial photograph, caused by the elevation (relief) of features above an established base elevation.

Resolution — The smallest unit a sensor can detect or the smallest unit an orthoimage depicts. The degree of fineness to which a measurement can be made. In the context of gridded elevation data, resolution is synonymous with the horizontal post spacing; resolution is sometimes used to state the number of points in x and y directions in a gridded DEM, e.g., 1201 x 1201 points in a USGS one-degree DEM.

Roll — The angular deviation from the horizontal of a craft about its longitudinal axis, i.e., its direction of movement. The roll is positive if it causes the craft's left wing to rise. In photogrammetry, the angular deviation of an aerial camera or coordinate system of a photograph about either the photograph's x-axis or about the x-axis of the ground coordinate system. In satellite photogrammetry, the roll is the angle between the epipolar plane and the local vertical.

Root Mean Square Error (RMSE) — As used in this manual, RMSE is used to quantify the horizontal and/or vertical accuracy of geospatial measurements. The square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points. The vertical RMSE, for example, is calculated as $RMSE_z = \sqrt{\frac{\sum_{I=1}^{n}\left(z_{data\ I} - z_{check\ I}\right)^2}{n}}$
where:

$z_{data\ I}$ is the elevation (z-coordinate) of the Ith check point in the dataset

$z_{check\ I}$ is the elevation (z-coordinate) of the Ith check point in the independent source of higher accuracy

n is the number of check points tested

I is an integer ranging from 1 to n

Scan Angle — See Field of View

Scale — The ratio of the size of the image or representation of an object on a photograph or map to its true size. Scale may be expressed as a representative fraction (e.g., 1/1200) or ratio (e.g., 1:1200), or it may be expressed as the number of feet to an inch (e.g., 100-scale). Because $1/2000^{th}$ of something is smaller than $1/1200^{th}$ of something, a 1:2000-scale map is considered to be a smaller scale map than a 1:1200-scale map.

Scale Factor —A number by which a distance obtained from a map by computation or measurement is multiplied to obtain the actual distance on the ground. The reciprocal of the ratio used to specify scale on a map. For example, if the scale of a map is given as 1:50:000 or 1/50,000, the scale factor is 50,000.

Scan Period — The period of time, measured in nanoseconds, taken by a scanner to complete a scan pattern and return to its starting point.

Scan Rate — The number of times per second a scanning device samples its field of view, measured in Hz.

Sea Level — In general, the reference elevation of the surface of the sea from which elevations are measured. This term is used as a curtailed form of “mean sea level.”

Secchi Depth — An intuitive water clarity measure that is the depth at which a standard black and white disc, deployed over the side of a boat, is no longer visible to the human eye.

Secondary Tide Stations — Water level stations, located within the mouth of a bay or estuary, that have operated for more than 1 year but less than 19 years, and have a planned finite lifetime. When reduced by comparison with simultaneous observations at a suitable control tide station, they provide accurate control in bays and estuaries where localized tidal effects are not realized at the nearest control station. They also provide data for the reduction of soundings in connection with hydrographic surveys.

Selective Availability (S/A) — An intentional error imposed by the U.S. Department of Defense to limit the highest achievable autonomous (non-differential) GPS positioning accuracy to authorized military users. This was done by intentionally degrading the quality of the broadcast transmitted parameters in the C/A signal that are required to compute each satellite position and clock corrections. S/A limited the achievable autonomous positioning accuracy to 100 meters

horizontal and 150 meters vertical. S/A was turned off on May 2, 2000 and, as a result, the autonomous positioning accuracy improved to 8 meters horizontal and 15 meters vertical.

Semi-Global Matching (SGM) — A stereo photogrammetric method that can be implemented efficiently on different computation hardware and uses automated image correlation (pixel matching) to support various applications to include production of gridded DSMs.

Shadow — A dark area in a radar image where the radar beam cannot reach a portion of the terrain being imaged because it is occulted by other parts of the terrain or other objects in the scene. Shadowed regions have no useful interferometric signal and consequently no elevation values can be determined.

Shoreface — The narrow zone, seaward or lakeward from the shoreline at low water, that is permanently covered by water and over which the sands and gravel actively move with the action of the waves.

Shoreline — The boundary line between a body of water and the land, in particular, the boundary line between the water and the line marking the extent of *high water* or *mean high water*.

Sidelap — The overlap between adjoining swaths of lidar data or adjoining strips of aerial photography.

Signal-to-Noise Ratio — The quantitative ratio between the part of an event that is considered *signal* to the part that is considered *noise*.

Single Frequency — A GPS receiver that tracks only the C/A pseudoranges and carrier phases on the L1 carrier from each satellite.

Skew — A measure of symmetry or asymmetry within a data set. Symmetric data will have skewness towards zero.

Slope — The measure of change in elevation over distance, expressed either in degrees or as a percent. For example, a rise of 4 meters over a distance of 100 meters describes a 2.3° or 4% slope. The maximum rate of change in elevation, either from cell to cell in a gridded surface or of a triangle in a TIN. Every triangle in a TIN has a slope value; the lower the slope value, the flatter the terrain; the higher the slope value, the steeper the terrain.

Softcopy Photogrammetry — Stereo photogrammetric procedures that utilize digital imagery in digital stereo photogrammetric workstations (DSPWs) — also called softcopy workstations — that have significant advantages compared with analytical stereoplotters. These advantages include: automatic digital image correlation, efficient production of DEMs and digital

orthophotos, and superimposition of all types of geospatial data over digital imagery. For DEM generation, superimposition means that all elevation mass points, breaklines and contours can be reviewed in stereo against the actual ground form, and old 3-D data can be superimposed on new stereo models to see where DEMs, breaklines or contours need to be revised.

Sonar — An apparatus that detects the presence of, or determines the distance or direction of, an object underwater by receiving and interpreting sound from the object. The term is applied principally to an apparatus that itself generates the sound; the object then reflects or scatters the sound back to the apparatus.

Sounding — A measurement of depth in water — usually a measurement of the distance of the bottom below the boat or ship from which the measurement is taken. The usual method is to transmit a sonic pulse downwards and to measure the time required for the pulse to travel to the bottom and back. Since the path of the pulse is considerably bent by refraction and the pulse itself also penetrates some distance into the bottom, both factors must be accounted for in depth calculations. In shallow water, alternative techniques are used, to include airborne lidar bathymetry or weighted graduated plumb lines.

Sound Wave — Normally used interchangeably with “acoustic wave” for frequencies within the range of human hearing (sound) plus ultrasonic and sub-sonic frequencies that are respectively above and below the range of human hearing. Acoustic waves are based on vibrations of the actual material of the medium and are manifested as periodic variations of pressure in the medium.

Spatial Distribution — In lidar, the regularity or consistency of the point density within the collection. The theoretical ideal spatial distribution for a lidar collection is a perfect regular lattice of points with equal spacing on X and Y axes. Various factors prevent this ideal from being achieved, including the following: (1) instrument design (e.g., oscillating mirrors); (2) difference between along-track and cross-track point spacing; (3) in-flight attitude variations (roll, pitch, and yaw); and (4) variations in topography.

Special Flood Hazard Area (SFHA) — The land area in the floodplain within a community subject to a 1 percent or greater change of flooding in any given year.

Spot Elevations — Elevation points collected at identifiable points, to leave behind a record of points that can be checked, or at local maxima or minima not represented by contour lines. Spot elevations are most typically collected for hill tops, dam spillway elevations, tops of selected bridge decks and road intersections, and bottoms of volcano craters and local sink holes. Also called spot heights.

Spring Tide — A tide that occurs at the time of the new and full moon when tides have their greatest amplitude. The times when highest and lowest waters are recorded.

Standard (1) — An agreed-upon procedure within a particular industry or profession, that is to be followed in producing a particular product or result.

Standard (2) — A number, or set of numbers, established within an industry, a science, or a technology, setting limits on precision or accuracy with which operations, measurements, or products are to be made.

Standard Deviation — A measure of spread or dispersion of a sample of errors around the sample mean error. It is a measure of precision, rather than accuracy; the standard deviation does not account for uncorrected systematic errors.

State Plane Coordinate System — One of the plane rectangular coordinate systems, one for each State in the U.S., established by the U.S. Coast and Geodetic Survey in 1933 for use in defining locations of geodetic stations in terms of plane-rectangular Cartesian coordinates. Each State is mapped by a conformal map projection in one or more zones, over each of which is placed a rectangular grid. Zones of limited east-west extent and indefinite north-south extent are mapped by a *Transverse Mercator* map projection; zones of limited north-south extent and indefinite east-west extent are mapped by the *Lambert Conformal Conic* map projection with two standard parallels. Zone One of Alaska is on the *Oblique Mercator* map projection. The use of the projections assures that, for zones having a width of 250km, the greatest departure from exact scale (scale error) is 1 part in 10,000.

Stereo Comparator — A photogrammetric instrument that permits stereoscopic viewing of two photographs and measurement of the coordinates of corresponding points, the coordinates of one point and the stereoscopic parallax of its conjugate point on the other image.

Stereo Compilation — Drafting of a map or chart manuscript from stereo aerial photographs and geodetic control data by means of photogrammetric procedures.

Stereo Model — The surface area of elevation and feature models visible in 3-D by viewing the overlapping areas of stereo imagery in an analog, analytical or softcopy stereoplotter.

Stereoscopic — Pertaining to the use of binocular vision for observation of a pair of overlapping photographs or other perspective views, giving the impression of depth.

Stereoscopic Image — A three-dimensional impression given by viewing one of a pair of overlapping pictures of an object with the left eye and the other with the right eye, either simultaneously or in rapid succession.

Strip — A set of overlapping photographs that can be arranged in sequence so that, except for the last photograph, part of the object space shown in one photograph is also shown in the succeeding photograph. A set of overlapping photographs obtained sequentially from a moving aircraft or satellite.

Striping — A DEM anomaly caused by photogrammetric profiling where the floating mark is allowed to pass either above the ground or below the ground on a profiling pass.

Subsidence — The loss of land surface elevation due to removal of subsurface support.

Superimposition — See Softcopy Photogrammetry.

Supplemental Control — Surveys between primary control points to establish additional points necessary to control detailed mapping in a local network.

Supplemental Vertical Accuracy (SVA) — The term used by the NDEP guidelines for vertical accuracy at the 95th percentile in each separate land cover category where vertical errors may not follow a normal error distribution, as in vegetated/forested terrain.

Surface — A 3-D geographic feature represented by computer models built from uniformly- or irregularly-spaced points with x/y coordinates and z-values.
Swath — The data resulting from a single flightline of lidar collection.

Systematic Error — See Error

Target — A contrasting pattern placed around a surveyed point on the ground to facilitate locating and measuring the image of the point in a photograph or image.

Target Value — A desired value as opposed to a mandatory value. For example, the specified Supplemental Vertical Accuracy (SVA) of lidar data is typically a target value for each individual land cover category; the SVA target value does not need to be satisfied for every individual land cover category so long as the specified Consolidated Vertical Accuracy (CVA) is satisfied for all land cover categories combined.

Tenderloin — The central portion of a lidar swath that, when combined with adjacent swath tenderloins, forms a complete, single, non-overlapping, gap-free coverage.

Terrain — An ESRI *terrain* is a multi-resolution, TIN-based surface that must reside in an ESRI Geodatabase feature dataset and is built from feature classes stored within the same feature dataset. It is a dataset that creates a continuous surface by connecting a set a vertices or xyz points which become the nodes of the underlying triangles. The edges between nodes are

interpolated and build the triangular faces which create the continuous surface. Because terrains are TIN-based, terrains identify and build the same topological data structure between adjoining triangles as TINs. Terrain pyramid levels are defined for each terrain dataset, and each pyramid level is a different resolution associated with specified map scale ranges and relative accuracy that shows a different amount of surface detail. Once a terrain is built, these pyramid levels can be viewed on-the-fly in order to quickly visualize data at multiple resolutions. Terrains are different from TINs in that they are capable of storing much greater amounts of information. Terrain datasets can be used to produce TINs and gridded DEMs. While ESRI terrain datasets have become more common and prevalent within the geospatial industry, other software may have their own versions of terrain surfaces. Often these surfaces are created through a TIN-based structure, but will not have associated multi-resolution pyramid levels and may not be compatible with geodatabase storage.

Terrain Visualization — Viewing the terrain in 3-dimensions, normally from differing perspectives.

The National Map — A seamless, continuously maintained set of public domain geographic base information, in digital form, that replaces the USGS (hardcopy) topographic map program. It includes orthoimagery, elevation, geographic names, hydrography, boundaries, transportation, structures, and land cover framework data themes. It is accessible via the Web, as products and services, and as downloadable data. It serves as a foundation for integrating, sharing, and using other geospatial data easily and consistently. It is part of the National Geospatial Program (NGP).

Three Dimensional (3-D) — Having horizontal (x/y) coordinates plus elevations (z-values)

Tidal Day — The time of rotation of the Earth with respect to the moon. Its mean value is approximately equal to 24.84 hours.

Tide — The alternating rise and fall of the oceans with respect to the land, produced by differential variations in the gravitational attraction of the moon and sun. There are three types of tides: diurnal, semidiurnal, and mixed. A diurnal tide has one high tide and one low tide per tidal day. A semidiurnal tide has two high tides and two low tides each tidal day. A mixed tide is similar to a semidiurnal tide except that the two high tides and two low tides of each tidal day have marked differences in their heights.

Tie Points — Image points that appear in the sidelap area of photos in overlapping strips of aerial photography, used to “tie” adjoining strips together. When the aerial photography is flown with 60% forward overlap, and when tie points are measured at the top and bottom corners of each image with adjoining strips, tie point images will appear on 4-6 images, adding extra strength to the aerotriangulation process.

Tide Gauge — A device for measuring the rise and fall and the current height of the tide. The simplest form is a graduated staff placed vertically in the water; the height of the water is read visually from markings on the staff. A more common version has a float with pointer attached to the staff; the float is free to move up and down the staff with the tide. Readings may be made visually, or may be recorded on paper or electronically.

Tilt — For vertical aerial photographs or images, the angular deviation of the camera axis from a vertical line.

Tilt Displacement — The displacement of features in an image caused by the roll and pitch of the aircraft at the instant a photograph is taken.

Topography — The 3-D shape of the terrain surface and the identification of specific landforms. Topography is displayed graphically by contour lines, elevation tints and/or shaded relief. Topography is displayed digitally by mass points, breaklines, triangulated irregular networks (TINs), digital elevation models (DEMs), digital terrain models (DTMs) and/or hillshades. Also called *relief*. Topography is normally mapped in terms of elevations above a geodetic datum, whereas bathymetry, the underwater equivalent to topography, is normally mapped in terms of depths below a tidal datum.

Topology — The spatial relationships which exist between adjacent digital objects. The digitization of node, point, line and area features so that computers are able to determine relationships that humans recognize logically when they determine what feature is connected to, adjacent to, or in close proximity to a point, line, area or surface; what feature intersects a line, area or surface; or what features are contained within an area or surface.

Triangulated Irregular Network (TIN) — A vector data structure that partitions geographic space into contiguous, non-overlapping triangles. The TIN data structure is based on irregularly-spaced point, line, and polygon data interpreted as mass points and breaklines and stores the topological relationship between triangles and their adjacent neighbors. In most geographic applications, TINs are based on Delaunay triangulation algorithms in which no point in any given triangle lies within the circumcircle of any other triangle. The TIN model may be preferable to a DEM when it is critical to preserve the precise location of narrow or small surface features, such as levees, ditch or stream centerlines, isolated peaks or pits in the data model.

Triangulation — A method of extending horizontal position of the surface of the Earth by measuring the angles of triangles and the included sides of selected triangles.

Trilateration — A method of surveying wherein the lengths of the triangle sides are measured, usually by electronic methods, and the angles are computed from the measured lengths.

Two Dimensional (2-D) — Having horizontal (x/y) coordinates only, without elevations (z-values)

Uncertainty (of measurement) — A parameter that characterizes the dispersion of measured values, or the range in which the "true" value most likely lies. It can also be defined as an estimate of the limits of the error in a measurement (where "error" is defined as the difference between the theoretically-unknowable "true" value of a parameter and its measured value). Standard uncertainty refers to uncertainty expressed as a standard deviation.

Undulation — A rise and fall with time, e.g., the undulation of the ocean's surface. A rise and fall with distance, e.g., the undulating hills of Oklahoma.

Undulation of the Geoid — The rise and fall of the geoid, sometimes used synonymously with *geoid height*. Used with the geoid separation.

Universal Transverse Mercator (UTM) Coordinate System — A 2-dimensional Cartesian coordinate system used to identify horizontal locations on the Earth independently of vertical positions. The system divides the Earth into 60 zones, each a six-degree band of longitude, that uses a secant transverse Mercator projection in each zone.

Universal Transverse Mercator (UTM) Grid — A military grid system based on the UTM coordinate system, applied to maps of the Earth's surface extending from the equator to 84-degree north and south latitudes.

Vegetated Vertical Accuracy (VVA) — An estimate of the vertical accuracy, based on the 95th percentile, in vegetated terrain where errors do not necessarily approximate a normal distribution. As explained in ASPRS 2014, the VVA is determined with well-distributed static checkpoints located in all vegetated land cover categories combined, including tall weeds and crops, scrub forests, and fully forested areas, as well as other localized vegetation categories such as mangrove or sawgrass.

Vegetation Removal — Classification of reflective surface elevations on vegetation so as to depict the elevation of the bare-earth terrain beneath the vegetation. Lidar mass points on vegetation are not actually removed but classified to a category other than bare earth.

Veronoi (Thiessen) Polygon — A polygon that contains areas which are nearer to the point around which it is constructed than to any other point.

Vertical — The direction in which the force of gravity acts. Whereas the *vertical* is the perpendicular to an equipotential surface of gravity (e.g., the geoid), a *normal* is the perpendicular to a given ellipsoid.

Vertical Accuracy — See Accuracy

Vertical Datum — See Datum

Vertical Error — The displacement of a feature's recorded elevation in a dataset from its true or more accurate elevation.

Vertical Photograph — A photograph (or image) taken with the camera axis directed downward along (or nearly along) a vertical line.

Vertical Point Spacing — The vertical distance between laser points from consecutive scan lines when the lidar sensor is tilted into a forward-looking position and laser points "walk up" the face of vertical objects.

Viewshed — See Intervisibility

Void — Portions of a digital elevation dataset where no elevation data are available. In USGS DEMs, each elevation post located within a void area is assigned a discrete false value representing the void. Treatment of void areas should be documented in the metadata file.

Von Gruber Points — Points on aerial photographs located to facilitate relative orientation between overlapping photos in analog and analytical photogrammetry. With 60% forward overlap, nine Von Gruber points per photo (see Figure 4-21) enables tie points and pass points in triple-overlap areas to strengthen the aerial triangulation solution.

Voxel — A three-dimensional "cube" that serves as a counterpart to a traditional pixel, used for three-dimensional visualization of elevation data. A 3-D pixel.

Water — A synonym for tide, in the sense of the elevation of the surface of the hydrosphere at a particular longitude and latitude.

- High Water — The greatest elevation reached by a rising tide
- Higher High Water — The higher of the two high waters occurring on a particular tidal day
- Higher Low Water — The higher of the two low waters occurring on a particular tidal day.
- Low Water — The least elevation reached by a falling tide.
- Lower Low Water — The lower of two low waters of any tidal day.
- Lower High Water — The lower of two high waters of any tidal day.

- Mean High Water (MHW) — The average elevation of all high waters recorded at a particular point or station over a considerable period of time, usually 19 years.
- Mean Higher High Water (MHHW) — The arithmetic average of the elevations of the higher high waters of a mixed tide over a specific 19-year period
- Mean Low Water (MLW) — The average elevation of all low waters recorded at a particular point or station over a considerable period of time, usually 19 years.
- Mean Lower Low Water (MLLW) — The average elevation of all the lower low waters recorded over a 19-year period.
- Mean Water Level — The elevation determined by averaging the elevations of the surface of water at equal intervals of time (usually hourly) over a considerable period of time.

Waveform Lidar — See *Full Waveform Lidar*.

Weight — A factor by which a quantity is multiplied to increase or decrease the effect of that quantity on the results of an adjustment.

Well-Defined Point — (1) A photo-identifiable point, used in horizontal accuracy testing, that represents a feature for which the horizontal position is known to a high degree of accuracy and position with respect to the geodetic datum. (2) As defined in the National Map Accuracy Standard, well-defined points are those that are easily visible or recoverable on the ground and plottable on the scale of a map within $1/100^{th}$ inch.

Wellhead Protection Area — The surface and subsurface area surrounding a water well, or well field, supplying a public water system, through which contaminants are reasonably likely to move toward and reach such water well or well field.

Withheld — Within the LAS file specification, a single bit flag indicating that the associated lidar point is geometrically anomalous or unreliable and should be ignored for all normal processes. Withheld points are retained because of their value in specialized analysis. Withheld points typically are identified and tagged during preprocessing or through the use of automatic classification routines. Examples of points typically tagged as withheld include: (1) spatial outliers in either the horizontal or vertical domains, and (2) geometrically unreliable points near the edge of a swath.

World Geodetic System (WGS) — A set of quantities, developed by the U.S. Department of Defense, for determining geometric and physical geodetic relationships on a global scale, based on a geocentric origin and a reference ellipsoid.

X-coordinate — The distance along the x-axis from the origin of a 2-D or 3-D Cartesian coordinate system. An x-coordinate is the first half (the easting) of UTM coordinates or the Easting of State Plane coordinates.

Yaw — The variation, or amount of variation, of the longitudinal axis of a craft from the direction in which the craft is moving, i.e., the difference between the direction in which a craft is pointed and the direction in which it is moving (when typically altered by winds).
Y-coordinate — The distance along the y-axis from the origin of a 2-D or 3-D Cartesian coordinate system. A y-coordinate is the second half (the northing) of UTM coordinates or the Northing of State Plane coordinates.

Z-coordinate — The distance along the z-axis from the origin of a 3-D Cartesian coordinate system. Note, this is not the same as the elevation or height above the vertical datum.

Z-units — The units of measure used for the z-values in a geographic dataset.

Z-values — The elevations of the 3-D surface above the vertical datum at designated x/y locations.

Section III
Formula Notations

a……. Semi-major axis of the Earth's ellipsoid

b…… Semi-minor axis of the Earth's ellipsoid

B…… Air base between consecutive exposure stations in a strip of aerial photographs or digital images

f……. Camera focal length

f……. Flattening of the Earth's ellipsoid where $f = (a – b)/a$

h…… Ellipsoid height, the height above or below the reference ellipsoid, as measured along the normal (perpendicular) to the ellipsoid at the point and taken positive upward from the ellipsoid

i……. Integer value

H…… Orthometric height, the height above the geoid as measured along the plumbline between the geoid and a point on the Earth's surface, taken positive upward from the geoid; commonly called the "elevation"

N…… Geoid height, the difference between an ellipsoid height and an orthometric height (N = h – H) of a point on the Earth's surface.

n…… Number of integers in a series, often used in formulas where i varies from 1 to n.

o……. Focal point of camera lens

r……. Radial component of a measurement, such as the radial distance from the principal point to an image point, the radial component of an RMSE calculation (RMSEr), or NSSDA radial accuracy at the 95% confidence level ($Accuracy_r$).

S…… Photo or map scale

S…… Sample standard deviation

W…….. The ground distance between adjacent flight lines

$\bar{x}$ …… Sample mean error for x-coordinates

x,y……. Photocoordinates

x_0,y_0……Principal point photocoordinates

x_p,y_p…….. Photocoordinates of point p on an image (point P on the ground)

X_P,Y_P……. Ground coordinates of point P

x/y/z…….. 3-D coordinates in the air, obtained directly from airborne GPS or indirectly from aerial triangulation, normally used to identify the 3-D position of the focal point of a camera at the instant an aerial photo or image is taken, or the instant when a LiDAR or IFSAR pulse is emitted; these coordinates provide half of the six exterior orientation parameters used for mapping by photogrammetry, lidargrammetry or radargrammetry. See also ω,φ,κ.

X…… The distance along the X-axis from the origin of a 2-D or 3-D Cartesian coordinate system. An X-coordinate is the first half (the Easting) of UTM or State Plane Coordinates

Y…… The distance along the Y-axis from the origin of a 2-D or 3-D Cartesian coordinate system. A Y-coordinate is the second half (the Northing) of UTM or State Plane Coordinates

$\bar{y}$ …… Sample mean error for y-coordinates

Z…… The distance along the Z-axis from the origin of a 3-D Cartesian coordinate system. Note, this is not the same as the elevation or height above the vertical datum.

$\bar{z}$ …….. Sample mean error for z-coordinates

Z-values……. The elevations of the 3-D surface above the vertical datum at designated X/Y locations

σ…… Standard deviation

μ…… Mean error or bias

ω,φ,κ……. System defining angular orientation in space, also called the roll, pitch and yaw of an aircraft or sensor, in which ω (roll) is the rotation about the x-axis (the direction of flight), φ (pitch) is the rotation about the y-axis, and κ (yaw) is the rotation about the vertical z-axis. These three angles are obtained directly from Inertial Measurement Unit (IMU) measurements or indirectly from aerial triangulation to identify the angular orientation of a sensor at the instant an aerial photo or image is taken, or the instant when a LiDAR or IFSAR pulse is emitted; these angles provide half of the six exterior orientation parameters used for mapping by photogrammetry, lidargrammetry or radargrammetry. See also x,y,z.

γ_1…….. Sample skewness

γ_2…….. Sample kurtosis

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