CHAPTER 9

Contracting and Cost Estimating

9-1. Contracting Considerations. This chapter is designed to equip government personnel to better estimate "relative" (not absolute) costs associated with procuring professional mapping services. This chapter will help Contracting Officers and technical personnel associated with contracting to better estimate how the scope, schedule, and technical merits of a project can affect the relative cost of professional services. This chapter will not help determine the actual costs associated with procuring professional mapping services. Instead, it will help readers understand which factors should be considered when drafting a solicitation and how those factors affect the associated cost, schedule, and complexity of the procurement.

a. Project Scope. Before writing a Request for Proposal (RFP), performing market research, or initiating a solicitation for professional mapping services or data, it is important that one understands the scope of the needs, the stakeholders, and what type of solicitation is required. How best to procure and the eventual cost of the needed services is highly dependent on the scope of the project. Important questions to consider include the following:

(1) Identification of Stakeholders. Have the stakeholders (the individuals, organizations or groups that will bear the cost, use or benefit by the procured mapping services) been identified?

(2) Stakeholder Needs. Have the needs of the stakeholders been systematically identified and addressed? How will their needs affect scope, schedule, and costs?

(3) Downstream Users. Have potential users (or benefactors) of the mapping data been identified? Do their needs or use of the data affect the project scope?

(4) Team Size. Will the solicitation require a single contractor or a large team of contractors and/or subcontractors? The project can be an order of magnitude more complex to administer if multiple firms (or teams) are needed.

(5) Capacity of Service Providers. Is the capacity of the profession sufficient to meet the needs in the required timeframe? Some projects' scope, timeframe, or specifications may be unachievable using available providers. Consider changing the scope or timeframe of the project.

(6) Technology. Have the stakeholders been identified and do they understand the relevant technology and options needed for the required professional mapping services and data? Do they have the computer capacity to handle the very large volumes of digital data from modern digital geospatial data sets?

(7) Costs. Do stakeholders understand the relative effect on costs for each specification described? Have alternative solutions been discussed that meet their objectives?

b. Solicitation Type. How professional mapping services or data are solicited is often mandated by law. When a specific method is not mandated, there are several methods available. The method used can have a significant bearing on the outcome of the project and quality or timeliness of the services and data rendered. Common sense, good judgment, and verification of qualifications are prerequisites to a successful procurement.

(1) Request For Proposals (RFP). An RFP is an invitation for offerors, often through a bidding process, to submit a proposal on a specific commodity or service. RFPs often dictate the structure and format of the offeror's response. They are a price-based solicitation meaning that the offerors bidding on the project must include pricing information with the proposal.

(a) An RFP can very clearly describe the specifications of a project: budget, benchmarks, expected outcomes, standards, etc. Offeror proposals provide a basis for choosing among seeming equals. But are they equals? Are they equally qualified to perform the services and deliver the data as requested and when requested? Is one offeror's proposed methods superior or more likely to produce the required deliverables than another's very different methods? When procuring professional services, using RFPs may not always be the appropriate tool.

(b) Professional services are not commodities. They are designed and prescribed to fit the specific needs of the stakeholders. They are often unique and tailored to a specific scenario. They cannot be purchased at a hardware store or off-the-shelf. Additionally, the taxpayer and other stakeholders need some measure of confidence that the mapping services or data were produced and delivered by qualified professionals not just by anyone that won a bidding contest.

(c) The major drawback to this approach when procuring professional services is that the stakeholders have been unable to leverage the expertise of the professionals in the firms so the project design is optimal and designed to deliver maximal value to the stakeholders using the wisest mix of technology and methodology. Instead, the RFP may dictate exactly what deliverables were needed and when. The bidders often propose very different methods to meet those specifications. This then leaves the review board (often populated with few members qualified to assess the technical or practical merits of a proposal) in the position of deciding which method has maximal value and makes the most sense except by comparing price which is often an unreliable indication of competence or quality.

(d) Using price bidding procedures, the low bidder wins regardless of their "fitness" or qualifications for delivering the professional services. The entity procuring professional services often does not have the expertise required to adequately define the scope and operational methods to accomplish project objectives. This can lead to misunderstandings and

misinformation about the project scope and expectations and ultimately to deliverables that may not meet the needs of the stakeholders.

(2) Qualification-Based Selection (QBS). Selecting qualified geospatial professionals is a key ingredient to a successful project. The project design will determine the costs, financial and functional feasibility and the operation and maintenance costs during the life of the project. QBS is an objective, flexible, and fair process to select professional engineers, land surveyors, and geospatial practitioners based on the professionals' experience and credentials. Only after qualified firms have been identified and selected is "pricing" negotiated. The pricing is often negotiated after consultation with the firm about the application of best practices to meet the needs of the stakeholders. The cost of services plays no role in the initial selection of qualified firms.

(a) All fifty states impose strict education and registration or licensing requirements for surveying professionals, and many include mapping in such licensing laws. The high standards established by organizations for their members exemplify the professional nature of their work. These standards are designed to protect the public health and safety during and after contract performance. Some states even prohibit licensed professionals from engaging in competitive bidding.

(b) The Brooks Act (Public Law 92-582), passed in 1972, rejected the idea of price competition for architectural and engineering services and enacted the federal Brooks A-E Act. Surveying and mapping activities are included in the definition of A-E services defined by the Brooks Act. The FAR Act [(FAR) 48 CFR 36.601-4(a)(4)] specifically includes surveying and mapping activities as services subject to section 36.601 of this act and must be procured using QBS. Since that time, many states have implemented similar legislation commonly referred to as "mini-Brooks Acts."

(c) QBS protects those procuring professional services by ensuring that only the most qualified firms can be awarded the project. It minimizes the probability (although does not guarantee) that unqualified or poor performing professionals perform the contracted services. All bidders' qualifications are assessed independent of price, and unqualified or under-qualified firms are discovered and eliminated before contract award.

(d) For a more thorough explanation of the QBS process, see section 8-3 below, and the Council on Federal Procurement of Architectural and Engineering Services (COFPAES) site at http://www.cofpaes.org/QBS_Resources.php.

(3) Procurements Using A Mix of Price and Qualifications. When QBS is not the legislated procedure for procuring professional services, solicitation procedures can be used that balance the tension between price and quality. Often this process may use an RFP but request that

pricing be submitted in a separate sealed envelope. Then the RFP review board selects one or more proposals based on their references, experience, and quality of the proposal, and the aptness of the methods. Only after this decision on the firms most qualified to perform the services are the price quotations of the qualified firms reviewed and a selection made. The major drawback to this approach is similar to that of the RFP process. When the insight and skill of geospatial professionals are not used to design an approach to the problem that best matches the need of the stakeholders, the qualifications of the firm, and the merits of existing technology, the safety of the public and value to the taxpayer can be compromised. Because public safety and taxpayer value are generally important considerations, the best procurement process is one that maximizes the probability that the most qualified firms are selected and that the best quality services are rendered.

c. Licensing Data. Licensed data are data not wholly owned or controlled by the licensee. All or part of the ownership and control of how the data are used resides with the licensor. The licensor grants the licensee certain rights and privileges for using the data. Frequently, the data may not be resold or used by entities other than those listed on the license.

(1) License terms are many and varied. Some of the more common or most discussed include the Creative Commons license, the Open StreetMap license, and Open Data Commons (ODC) Open Database License (ODbL). There are a number of legitimate reasons why data procured using public monies should or should not be available without cost to the public which are fascinating but beyond the scope of this discussion.

(2) Once the data for a geospatial project are procured, will the data be licensed or wholly owned by you? If owned by you, how will you control its distribution? Will you require some type of payment for costs associated with requests for the duplication of the data? Will you allow others to make derivatives from the data? Can others obtain copies and resell it?

(3) If licensed, the data can often be procured at less expense because the licensor is able to sell or lease the data to multiple parties. Conversely, there are added costs associated with managing the license that should be carefully considered. Licensed data often includes flexible terms such that any government agency (and related agencies and contract personnel) is allowed unrestricted internal use of the data. If licensed, how will access to the data be guaranteed if the licensor is purchased, sold, or goes out of business? Who will need access to this data? How will the data need to be used: streamed, downloaded, processed? What uses of the licensed data are allowed? Can the data be resold by me or others? Are other agents for our organization (e.g., subcontractors or associates) allowed to use the licensed data? These and many other questions should be answered before agreeing to purchase licensed data.

d. Bid Bond. A bid bond (or surety bond) is a financial guarantee ("insurance" issued as part of a bidding process) to the project owner, to guarantee that the winning bidder will

undertake the contract under the terms at which they bid. The bid bond protects the purchaser against financial loss if the bidder withdraws its bid or does not, within the time required, enter into a formal contract. Bid bonds are an unnecessary expense if the professional services are procured using QBS and other methods that ensure only firms with demonstrated qualifications and performance are contracted. If QBS or similar contracting procedures are not used, then bid bonds may bring a measure of confidence that the services will be rendered but not without added cost. A bid bond does nothing to ensure that the services procured will be from quality professionals.

e. Paper or Digital Submissions. Will the project proposal and qualifications materials be required as bound paper or digital submissions? Procurements are often released that require multiple bound paper copies even when digital copies would be less expensive and facilitate more rapid dissemination among contracting officers and other staff. Requiring hard copy submittals may be convenient for some, but is often more costly and cumbersome.

9-2. Cost Estimation Considerations. Most of the common technical cost estimation factors associated with geospatial procurements are described in this section. Associated with each one is a rating system that is designed to inform the reader as to how important each factor is to relative cost, schedule, and the complexity of the procurement being considered. Contracting and technical factors in Table 9-1 are all relative ratings and are meant as a general guide to help the reader focus on those factors that could have the most impact on a project. That said, any single factor could have the opposite effect on the cost, schedule or complexity for a particular project than what is described here if the context of the procurement is unusual. It is important that each factor be considered as part of a whole procurement and that the ratings are meant only as a general guide, not an absolute estimate of importance.

a. Deliverables. When procuring professional mapping services, it is important to enlist the technical expertise of those professionals most knowledgeable about those services. These are usually experts working with the firms that will be competing for the procurement. It behooves the contracting officer to engage these experts to the maximum extent possible to help define deliverables using the best technology and best practices so the value and utility of the procured services are maximized.

(1) Technology changes rapidly. Recent advances in technology may make one type of deliverable or method of delivery more expensive or less important than one in common use previously. Some qualified firms may have procured new equipment or discovered superior methodologies that the contracting officer could not be aware of. Therefore, it is important that contracting officers consult with qualified firms and discuss the fundamental needs of the end users and exploit the professionals' expertise to define the deliverables and methodology used to create and deliver them.

Table 9-1. Contracting & Technical Factors that Impact Cost, Schedule and Complexity of Mapping Projects

Contracting Factors	**Cost**	**Schedule**	**Complexity**	**Importance**
Project Scope	■ ■ ■ ■ ■	■ ■ ■ ■ ■	■ ■ ■ ■ ■	15 of 15
Solicitation Type	■	■ ■ ■	■ ■ ■	7 of 15
Licensing Data	■ ■	■	■ ■	5 of 15
Bid Bond	■ ■ ■	■	■ ■	6 of 15
Paper / Digital Submissions	■ ■	■	■	4 of 15
Technical Factors	**Cost**	**Schedule**	**Complexity**	**Importance**
Accuracy Requirements	■ ■ ■ ■ ■	■ ■ ■ ■	■ ■ ■	12 of 15
Map Scale	■ ■	■	■	4 of 15
Satellite Image Acquisition	■ ■ ■ ■	■ ■ ■	■ ■ ■ ■	11 of 15
Aerial Image Acquisition	■ ■ ■ ■ ■	■ ■ ■ ■ ■	■ ■ ■ ■ ■	15 of 15
Aircraft	■ ■ ■	■ ■ ■	■ ■	8 of 15
Mobilization / Timeframe	■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	13 of 15
Image Resolution	■ ■ ■ ■ ■	■ ■ ■	■ ■ ■	11 of 15
Image Bands / Bit Depth	■ ■ ■	■	■ ■ ■	7 of 15
Camera System Type	■ ■ ■	■ ■	■ ■ ■	9 of 15
Topography / Climate	■ ■ ■ ■	■ ■ ■	■ ■ ■	10 of 15
Topographic Mapping	■ ■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	13 of 15
Topographic Deliverables	■ ■ ■ ■ ■	■ ■ ■	■ ■ ■	11 of 15
LiDAR	■ ■ ■ ■ ■	■ ■ ■ ■	■ ■ ■ ■	13 of 15
Planimetric Mapping	■ ■ ■ ■ ■	■ ■ ■ ■ ■	■ ■ ■ ■ ■	15 of 15
Ground Control	■ ■ ■	■ ■ ■	■ ■ ■	9 of 15
QA/QC	■ ■ ■	■ ■ ■	■ ■ ■	9 of 15
Deliverable Methods	■ ■	■	■	4 of 15

(2) If deliverables are defined in the solicitation without this expertise, it may likely create unwelcome tension with “best value.” If professional services are procured as “lowest price,” this can often deflate the utility of the final product to the end user, at best, and at worst create public hazards.

(3) At times, it can be advantageous to allow contractors to propose additional deliverables (or different formats) if that would improve the final product or enhance production efficiencies. Contracting officers should also be cognizant of the fact that deliverables cost money, and if unnecessary reports or other deliverables are required, it takes funds away from the actual intent of the project. This cautionary note does not pertain to good metadata which is always important.

(4) The discussion below lists many of the most important factors that should be considered with a specific type of deliverable in a mapping project. The importance of each to the scope, cost, schedule and complexity of the project is also indicated. Because end-user needs and technology are in constant flux, this cannot be an exhaustive list. But given the state of

technology and business today, the factors listed below, if understood and carefully considered with geospatial professionals, should contribute to a more successful procurement.

b. Map Accuracy Standards. Map accuracy is generally the primary driver of costs in geospatial projects. Few other factors affect the cost and complexity of geospatial solicitations more than positional accuracy specifications. Buyers often inadequately define these important measures, especially since transition from standards defined for printed maps (with specified scale and contour interval) to digital geospatial products (with scales and contour intervals that can be changed by the click of a mouse without ever changing the positional accuracy of the digital data). Chapter 3 of this manual is devoted to explaining the transition from the traditional National Map Accuracy Standards (published in 1947) and the ASPRS Standards for Large-Scale Maps (published in 1990), both defined for printed maps with specified scale and contour interval, to the latest ASPRS Positional Accuracy Standards for Digital Geospatial Data explained in Tables 3-2 and 3-3 (Orthoimagery Horizontal Accuracy Standards), Tables 3-4 and 3-5 (Planimetric Data Horizontal Accuracy Standards), and Table 3-6 (Elevation Data Vertical Accuracy Standards).

(1) Map users often use geospatial data without understanding its accuracy specifications or intended use. When map accuracy standards are not clearly specified for procurement, it may be difficult or impossible to compare approaches and costs between contractors. As mentioned in the discussion of Ground Sample Distances (GSD) below, accuracy can be achieved (or not achieved) using a wide array of equipment configurations, flight parameters, and post-processing techniques. Any lack of specificity for map accuracy standards may result in sub-standard services and will make it virtually impossible to compare different proposals and project approaches.

(2) It is important that the solicitation state that a Certified Photogrammetrist on staff is a requirement for all firms. These professionals receive national certification from the American Society for Photogrammetry and Remote Sensing (ASPRS) every five years. This professional credential increases the likelihood that the professional has a thorough understanding of positional accuracy specifications, photogrammetric principles and techniques, and mapping project design.

(3) Spatial accuracy is expensive. Therefore, it is important to identify the potential users' positional accuracy "needs" not "wants." There will normally be tension between the "needed" accuracy and the budget. By balancing spatial accuracy needs with budget realities, the best value can be provided to the geospatial users. A professional geospatial service provider can help users identify the best value using current geospatial technology. As a rule of thumb, higher costs are justified for higher horizontal accuracy when mapping small features like fire hydrants and other utility features including pipelines, but lower accuracy products are much less expensive and are well suited for land use planning, orthophotography, and environmental

modeling, for example. Higher costs are justified for higher vertical accuracy under many scenarios, but especially when it is important to know which direction the water will flow over land areas that are essentially flat. Sponsored by the National Digital Elevation Program (NDEP), a major study was completed in 2012 that included the most comprehensive benefit/cost analysis ever performed for any layer of The National Map. The final report of the National Enhanced Elevation Assessment (NEEA) is available on-line (http://www.dewberry.com/Consultants/GeospatialMapping/FinalReport-NationalEnhancedElevationAssessment) to review the hundreds of Business Use requirements for elevation data of different quality levels from LiDAR, photogrammetry and IFSAR.

(4) The solicitation should also address how map accuracy is assessed, whether "tested" or "produced to meet" a specified accuracy threshold.

(a) A geospatial product can be "tested" by the professional that creates it or independently tested by a third party. Additional testing, however, is more expensive with costs largely dependent on the number and distribution of what are known as QA/QC check points that can be expensive to survey, even if surveying the minimum of 20 broadly-distributed check points recommended by the NSSDA or ASPRS, with each check point costing hundreds of dollars. For vertical accuracy testing of LiDAR data, for example, it is common to survey a minimum of 20 QA/QC check points in each of three or more major land cover categories, as specified by USGS, FEMA and ASPRS, for example. Table 3-7 in Chapter 3 provides the recommended number of check points based on area. In all cases, however, common economic sense must prevail, and the number of check points is normally reduced for smaller mapping projects so that the cost of positional accuracy testing does not exceed 15-20% of the total project costs.

(b) Organizations procuring geospatial services are often not qualified to measure and certify positional accuracy. However, they may be able to withhold sufficient ground control from the contractor and use it to verify that their accuracy assessment is reliable. Qualified independent contractors are often used to provide unbiased accuracy assessments. Although this is generally the more costly alternative, it will provide the highest level of certainty about the "tested" accuracy. With horizontal positional accuracy testing consistent with the USACE standards in Chapter 3, the metadata should report accuracy at the 95% confidence level as: "Tested __ (meters, feet) horizontal accuracy at 95% confidence level." With vertical positional accuracy testing consistent with the USACE standards in Chapter 3, the metadata should report: (1) "Tested __ (meters, feet) Non-vegetated Vertical Accuracy (NVA) at 95% confidence level" and (2) "Tested __ (meters, feet) Vegetated Vertical Accuracy (VVA) at 95th percentile."

(c) Also documented in the metadata, the ASPRS specifies that the "produced to meet" statement below should be reported when the guidelines for testing by an independent source of higher accuracy cannot be followed and an alternative means is used to evaluate accuracy. Report accuracy at the 95% confidence level for data produced according to procedures that have

been demonstrated to produce data with particular horizontal and vertical accuracy values as: "Produced to meet __ (meters, feet) horizontal accuracy at 95% confidence level" and/or "Produced to meet __ (meters, feet) vertical accuracy at 95% confidence level." This less expensive method for reporting positional accuracy is most appropriate for topographic mapping data produced from traditional photogrammetric procedures, including aerial triangulation, that have been used for decades and least appropriate for LiDAR mapping data where the vertical accuracy is largely dependent on the density of the vegetation above the bare-earth terrain.

c. Map Scale. Today, in the digital age where map scale can be changed simply by hitting a zoom button, a geospatial deliverable's positional accuracy is no longer directly related to the scale of a map as it was when all mapping was based on analog techniques. Modern digital mapping techniques minimize the loss of accuracy throughout the entire map production cycle. For this reason, map scale is of much less importance than ground sample distance (GSD) or pixel resolution.

(1) Every deliverable mapping product has some level of accuracy (at any scale) for which the horizontal and/or vertical accuracy should be documented in the metadata as described in section 8-2b (4) above.

(2) Mapping is usually classified as either "large-scale" or "small-scale." These terms are frequently confused but easily remembered if one knows that the "largest" possible scale is 1:1 (actual scale). Therefore, when map scale is expressed as a unit-less fraction like 1/2400 (where 1 unit on the map equals 2400 units on the ground) or 1/500, the fraction closest to 1.0 is a "larger" scale. In this case, $1/500^{th}$ of something is larger than $1/2400^{th}$ of something. "Large-scale" mapping (generally agreed to be 1/2400 and larger fractions) shows more detail and requires flying at lower altitudes. "Small scale" mapping (generally agreed to be 1/4800 and smaller fractions) is acquired at higher altitudes and show less detail. Note that different terminologies may be used to denote map scales, e.g., 1/2400 is the same as 1:2400 and both are the same as 1" = 200', commonly called "200-scale mapping."

(3) Large-scale mapping is generally possible when flying close to the earth. Small-scale mapping is achieved by flying further above the earth. Measurements of the earth are more accurate as the distance between it and the remote sensing equipment is shortened. With modern, digital sensors, solicitation materials should rarely, if ever, dictate to the service provider the altitude from which remote sensing operations should be performed. Instead, the solicitation should define the required positional accuracy and deliverables; then the professional service provider can prescribe the methods needed to produce those deliverables to a defined quality standard.

d. Image Acquisition. Whether imagery is acquired from satellites, fixed or rotary-wing aircraft, there are many different factors that impact the cost, schedule and complexity of image

acquisition. Satellite imagery may or may not be more cost effectively or timely than airborne imagery for a given project. It is important to understand the capabilities and limitations inherent in both satellite and airborne imagery for a given project and choose the image source that will provide the best value to the project and not compromise technical specifications or schedule.

(1) Satellite Image Acquisition. Satellite imagery is available with a dizzying array of technical specifications. They can be an important component of a project or, if used inappropriately, could produce undesirable results. How to determine whether satellite imagery is optimal for use as a base map or supplemental imagery source for a project involves a number of considerations explained in Chapter 5, to include the various satellites and acquisition/delivery options, including: image resolution, spatial accuracy, off-nadir angle / elevation angle, sun elevation, cloud cover, spectral information, projection, re-sampling method, collection capacity, and delivery method.

(a) Today, most satellite data are licensed and restrictions on use are common. They may or may not be less expensive than acquiring imagery using airborne platforms or purchasing imagery from other sources. Satellites have resolutions that vary from 40 cm to dozens of meters. The imaging satellites listed in Chapter 6 only include high- to medium-resolution satellites most commonly applicable to requirements of the U.S. Army Corps of Engineers.

(b) Satellite imagery typically has a panchromatic band and multispectral bands (typically red, green and blue bands in the visible portion of the electromagnetic spectrum, plus near-infrared in the invisible portion) or many (dozens to hundreds) hyperspectral bands from the ultraviolet to the thermal infrared portions of the spectrum. All meet some defined positional accuracy standards but these can vary depending on the number and quality of ground control points used. Satellite image positional accuracies are generally much poorer than accuracies from aerial imagery, and satellite imagery is often expressed in terms of relative accuracy rather than absolute accuracy; for example, if using satellite imagery to determine the number of acres of water or forested areas, the acreage is the important statistic – not the absolute positional accuracy of those acres.

(c) Most satellite constellations are configured to photograph sections of the earth every few days. Some satellite sensors can be “tasked,” that is, the satellite operator can send commands to the sensor and tell it to “look there and image the earth.” This is expensive but can at times be extremely beneficial to a project especially if airborne collection is not an option due to time constraints or geographic location. To image a section of the earth at a specific time in the growing season or immediately after a natural disaster, or on a clear day, can be quite beneficial. It is important to determine if satellite imagery can be used to meet project specifications and understand the cost implications associated with the acquisition and production of deliverables from the imagery. Normally, imagery in archives can be acquired less expensively than imagery yet to be acquired.

(d) Some satellite imagery is available in both stereo and as orthophotos, using combinations of panchromatic, color, multispectral and hyperspectral bands. Any 3D feature extraction of X, Y and Z coordinates must be done from stereo satellite imagery which is normally more expensive than satellite orthophotography.

(2) Airborne Image Acquisition. Although best practices, when writing performance based Statements of Work, generally do not include dictating how the data are obtained, and instead allow the contractors to describe those practices "best" suited to the specifications, it is useful to have a general understanding of how different technical specifications can affect costs. Equipped with this information, the Contracting Officer can better understand what is possible within the budget and schedule realities. Aerial acquisition is a major cost driver for many geospatial projects. The execution of this task is often confined to very narrow windows of opportunity by weather and vegetative conditions. They are often further impacted by equipment failures and other acquisition projects the contractor must complete in the same window. There is always a risk of the acquisition not being completed because of these factors. How can this risk be mitigated? How much of this risk should the contractor assume versus the buyer? The contractor has high incentives to complete the acquisition because payments are often tied to its completion, and further mapping derivatives are seldom possible without it. There are strategies that Contracting Officers can employ to mitigate the risk that the acquisition will not be completed:

(a) First, the contract could allow for imagery collected to lower specifications (later in the season, with more cloud cover, with more standing water, etc.) at a lower cost.

(b) Second, when the specifications are written, ensure the maximum possible time is allowed for acquisition. If spring leaf-off acquisition is required, don't unnecessarily constrain the acquisition period by insisting that grass turn green before acquisition can occur unless this is absolutely necessary. Sometimes specifications require "no snow cover" and photography cannot be acquired even if there are a few piles of snow in parking lots. If these piles will not degrade the usability of the imagery for its intended uses, then these specifications are too restrictive.

(c) Third, ensure the contract negotiations are completed well before acquisition is possible. This will ensure all the stakeholders have sufficient time to prepare for the project, e.g., order materials, schedule aircraft maintenance, and deliberately re-prioritize their acquisition schedule to accomplish the project. Contractors are seldom able to organizationally accommodate a project until it has changed from a possible contract to a signed contract.

(d) Fourth, incentives can be paid to the contractor so they give the project priority over other acquisition projects on their schedules.

(e) Fifth, large projects that may require a great portion of the contractor's acquisition resources will tolerate fewer interruptions due to weather, equipment malfunctions, or the like. Therefore, consider breaking the acquisition into smaller projects and require more resources from that contractor or additional subcontractors with more equipment committed to the project. This will increase the likelihood that the acquisition will be completed successfully.

(3) Airborne Aircraft. Many factors impact the cost of aerial data acquisition.

(a) All aircraft manufactured have a service ceiling (maximum altitude above which the aircraft is not rated to fly). Flying above 18,000' requires more specialized equipment and approvals from government regulators. Airspace above 18,000' is called "Class A" airspace and is controlled by the FAA Air Traffic Control (ATC) and requires approved flight plans before these areas can be entered. Aircraft flying over 29,000' must be equipped with reduced vertical separation minimum (RVSM) equipment. Projects that require remote sensing above 18,000' may cost significantly more or be prone to higher costs associated with more complicated access to airspace. If there are ways to accommodate project objectives without requiring acquisition at these altitudes, the project may be less costly and less complex. Aircraft are rated to operate only within certain altitude ranges. Aircraft rated for operation above 27,500' above ground level can normally operate at lower altitude but at higher costs than other aircraft. Aircraft rated for operation below 27,500' cannot be used above this altitude without special modifications. Even if modified, they would often be more costly to operate than others rated for high altitudes.

(b) High speed aircraft can be advantageous to enable acquisition over shorter periods of time or in narrow windows of opportunity. Aircraft designed to fly lower often fly at lower speeds but are less costly to operate at those altitudes than high speed aircraft rated for higher altitudes.

(c) Unmanned aerial vehicles (UAV) and Unmanned Aerial Systems (UAS) are now in common use by the military, government agencies and educational institutions with special authorizations. UASs are currently not allowed for commercial use in the U.S. Many government agencies like the Forest Service and Department of Homeland Security now regularly use UASs for aerial data acquisition. UASs will be increasingly used for commercial applications in the near future. New applications for this technology will become important to future geospatial procurements. Many professional services delivered today using manned vehicles may be better served using commercial UASs when this is permitted by the FAA.

(d) Military Operating Areas (MOS) refer to airspace over sensitive military areas. These are often the most tightly controlled areas of airspace and can cause considerable delays, and therefore increased costs, of acquisition. These are generally the most problematic areas to operate commercial aircraft.

(e) Mapping of national parks and wildlife refuges can be delayed if there is need to establish ground survey control or acquire imagery from low altitudes that disturb wildlife or nesting birds, for example. It is common to require several months to obtain the necessary permits. Similarly, other acquisition authorizations in unrestricted airspace can be difficult to receive because of temporary flight restrictions like Presidential visits in the area, or elevated terror alerts. Sometimes considerable delays are caused by the inexperience or personality of the FAA personnel working the airspace a particular day. These complications are often unplanned and unknowable and may incur considerable costs and delays to a project. In some sensitive areas, FBI agents or park service rangers must physically accompany the pilot and sensor operator performing the aerial data acquisition.

(f) A "true orthophoto" is an orthophoto with geometric corrections applied to position the buildings and other features in their exact geographic locations. Often, buildings and other objects appear to "lean" when they are not directly under the camera. The two adverse effects of this are that the roof of the building is portrayed in an erroneous location, and ground-level imagery (usually on two sides of a building) is blocked by the feature. The true orthophoto process corrects these effects by moving the pixels corresponding to the feature surfaces to their proper position and filling any voids with pixels from other images. Projects that require "true orthophotos," or otherwise limit building lean, will cost more to meet project specifications. To minimize building lean, it is common to fly higher using a narrow-angle lens, and to acquire imagery with higher forward overlap between images (e.g., 80% instead of 60%) and higher sidelap between flightlines (e.g., 60% instead of 30%) so that orthophotos can be produced from the "sweet spots" of images when the views are nearly straight down. Obviously, increasing the forward overlap and sidelap increases the number of flight lines flown and images acquired which in turn increases the cost of an orthophoto project.

(4) Mobilization / Timeframe. Many factors impact the acquisition firm's ability to mobilize and acquire the aerial data in the allowable timeframe:

(a) The calendar days and daylight hours that remote-sensed data can be acquired is dependent on a number of factors. The size of this acquisition window of opportunity can have a major impact on acquisition costs. If the time the imagery can be acquired is limited to one week in the spring or to only a few hours each morning for a period of two months, then acquisition costs will be much higher than with more flexible acquisition windows. Understanding the remote sensing equipment, the project scope, the intended use of the deliverables, and what factors may limit when an area can be remotely sensed, is critical.

(b) The major factors to consider include "leaf on" or "leaf off, i.e., whether vegetation has foliage or not and how much shading of the ground or features on the ground is permissible. How the imagery will be used will determine which factors are most important. If used for

mapping the surface of the earth (e.g., feature extraction or DEM/DTM collection), then a clear view of the earth's surface may be imperative and "leaf off" will be a requirement. However, if the project is for vegetative classification, for example, then it may be important that acquisition be performed during a predetermined period of the growing season with foliage fully expressed. "Leaf on" or "leaf off" is chiefly a consideration only in temperate parts of the world where deciduous trees can lose their leaves. In these regions, there are generally two seasons – spring and fall – when vegetation is leafless or has minimal foliage. Otherwise, in applications that require foliage, then it is important to acquire imagery when the growth state of the target vegetative species is most advantageous.

(c) Shading of the ground or important features on the ground is impossible to avoid except in areas devoid of all vegetation. Even during seasons of leaf-less canopies, those parts of the vegetative canopy (grass, trees, shrubs) that are erect obscure incident light and cause shadows and darkening of anything under them. Areas of high relief are often perpetually shaded. The impact of these shadows to the project depends again on the project scope and the needed deliverables. If the surface of the earth or features under vegetative canopies must be accurately mapped, then less shadow will be required. It is not uncommon for project specifications to allow that the earth's surface under forest canopies be modeled with less accuracy than other non-forested areas. In these cases, heavy foliage may not be a deterrent to the project.

(d) Shadows are also caused by clouds. Most acquisition specifications include some requirement similar to "acquisition must happen with less than 10% cloud cover." Again, because of newer digital sensors, the effect of shadows caused by clouds obscuring features is less important for many applications, and more shadows caused by foliage, solar radiation, or clouds can be tolerated. A higher tolerance for shadows means a larger acquisition window. A project with a larger acquisition window may be considerably less expensive and have a significantly higher chance of being completed. Unnecessary restrictive acquisition windows are budget busters and make projects more difficult to complete.

(e) Other factors that may constrain the acquisition window are environmental or climatic factors that obscure the ground, e.g., tidal levels, river levels, snow cover and standing water. Normally, no snow cover is allowed. However, will snow cover in ditches or remnants of snow piles in parking lots be allowed? If a heavy rain occurs during the acquisition window and there is standing water in agricultural or urban areas, will this negatively impact image quality or the accuracy of project deliverables? Is so, then they should not be allowed. But waiting until the last snow crystal melts and every puddle dries up from the project area may cause project costs, schedule and complexity to increase dramatically. Seriously consider how these environmental factors affect the project and do not overly constrain the acquisition window.

(5) Image Resolution. Sometimes a pretty picture is all that users are after; but at other times, these images must also be positionally accurate or specific features on the ground must be

clearly visible and interpreted. A key quality component of digital camera systems is spatial resolution. The pixel size limits the spatial resolution attainable. In practice, the nominal resolution of a sensor system is seldom achieved due to blur and noise caused by a variety of factors like optical path quality, electronics, the CCD (charge-coupled device), forward motion compensation, camera mount, camera port glass (if any), flight altitude, flight velocity, exposure, sun angle, air turbulence, visibility, and post-processing of the data. Some cameras allow higher-resolution panchromatic images to "pan-sharpen" lower-resolution multi-spectral images. All of these factors can have important effects on the quality of imagery acquired for a project. For these reasons it is important that each camera system used on a mapping project have a recent field and factory calibration to ensure the system is operating optimally.

(a) One of the key considerations for any imagery acquisition project is ground sample distance (GSD). This statistic describes the size of one raw image pixel on the ground in meters or feet. Three primary factors affect this: distance from earth (flight height), focal length of the lens assembly, and CCD size. In simple terms, the further away from a target the camera is positioned, the larger the GSD (lower resolution). A CCD with 9 micron pixel size will produce imagery with a larger GSD than a CCD manufactured with 6.5 micron pixels (assuming the same lens is used). Focal length also affects GSD by changing how much ground area is projected onto the CCD surface.

(b) Whereas the GSD is the same as the raw image pixel size, the GSD is different from the pixel size of final digital orthophotos produced from such imagery. Normally the GSD is ≤ the pixel size of the final digital orthophotos. However, when imagery is acquired with heavy forward overlap (e.g., 80%) and heavy sidelap (e.g., 60%), all camera manufacturers agree that "super resolution" enables the GSD to be slightly larger than the orthophoto pixel size, e.g., as when each 3" orthophoto pixel is produced from six to ten different images, each with 4" GSD.

(c) In practice, the GSD for a given camera and lens is determined by flight height. Some camera systems allow lenses to be changed so focal length can be adjusted and change GSD at a given altitude. Large-format digital cameras today can produce 1m GSD imagery at flight heights above ground of approximately 10,000 feet.

(d) Higher resolution (small GSD) imagery is more expensive and generally most preferred in many applications. But as GSD gets smaller the costs of acquisition get larger. Project planners must determine the GSD (resolution) needed to meet project objectives. However, as desirable as high resolution is to a project, image interpretation (or the resolving power) can be adversely affected. "Resolving power" is described as a measure of lines per millimeter that can be distinguished. The more lines per mm that can be discerned, the better the resolving power. Imagine a camera capable of imaging the earth's surface from 10,000' above ground and producing 1m GSD imagery using a 10 micron pixel CCD array. If this camera was put into space and the CCD was upgraded to an amazing 1 micron pixel, the imagery could have the

same GSD (1m) as if flying at 10,000'. However, the image from space with identical GSD using a higher resolution CCD is much further away from the fire hydrant and it cannot be discerned. So the GSD of each image is identical but the resolving power (the ability to discern features) of each is quite different. For many projects where photo interpretation is important and positional accuracy requirements are high, the resolving power of the camera system must be considered.

(e) In this age of digital camera systems, there is no longer any reliable correlation between flight altitude and positional accuracy. Pixel sizes of a CCD, focal lengths of lenses, and flight height can all be changed to produce similar GSDs. A high-resolution orthophoto does not have an implicit positional accuracy simply because of its high resolution (small GSD). Additionally, high resolution does not guarantee that small features can be discerned. To ensure that remote sensed data will be dependable and consistent and that positional accuracy, GSD, and resolving power can be defined reliably, it is generally recommended that only "metric" cameras be used.

(f) The importance of accuracy will vary based on the intended use of the deliverables. Specific accuracy requirements should be defined. In many cases actual accuracy should be tested after the deliverables are received. Increased accuracy generally means increased cost. Therefore, it is important to not over-engineer the project requiring excessive accuracy and waste project budget dollars for higher accuracy that is not needed. In summary, the positional accuracy of remote sensed data is dependent on a large number of interrelated factors, and professionals that understand photogrammetry, equipment, and production procedures should be consulted when designing a project. This is ultimately the reason why Tables 3-2 and 3-3 in Chapter 3 show multiple accuracy classes for orthophotos with the same pixel sizes.

(6) Image Bands / Bit Depth. Digital cameras sense and record electro-magnetic energy. Satellite and aerial cameras typically image in the visible light and infrared parts of the electro-magnetic spectrum. Other sensors can image well beyond this slim slice of the electro-magnetic spectrum. Sensors that record red, green and blue (full color) plus infrared are referred to as multi-spectral. These are commonly used on projects that require land classification. The infrared bands are used to differentiate vegetation and even paved areas. Sensors that record more than four bands are generally referred to as hyper-spectral and are used for a variety of specialized needs.

(a) Most remote sensing projects today require only full color imagery (red, green, blue). However, many digital camera systems are designed to capture both full color, panchromatic (black and white) and near infrared (NIR) bands. It costs virtually nothing extra to collect these additional bands. However, requiring additional bands of imagery as deliverables may incur higher fees because additional image processing is required.

(b) Bit depth quantifies how many unique colors are available in an image (or image sensor) color palette in terms of the number of 0's and 1's, or "bits," which are used to specify each color. This does not mean that the image necessarily uses all of these colors, but that it can instead specify colors with that level of precision. For a grayscale image, the bit depth quantifies how many unique shades of gray are available. Images with higher bit depths can encode more shades or colors because there are more combinations of 0's and 1's available. Equipment manufacturers often use the term "bit depth" in confusing ways. The bit depth for each primary color is termed the "bits per channel." The "bits per pixel" (bpp) refers to the sum of the bits in all three color channels and represents the total colors available at each pixel. Confusion arises frequently with color images because it may be unclear whether a posted number refers to the bits per pixel or bits per channel. Using "bpp" as a suffix helps distinguish these two terms. For image processing, bits per pixel is the important consideration, and today's digital camera systems routinely acquire imagery with 10 to 12 bit depth and store it in 16-bit files.

(c) Printers and computer monitors are unable to display more than 8 bits per pixel so we are unable to perceive the extra 2-4 bits of color captured with today's digital camera systems. However, these extra bits are important for a number of reasons because they can be "seen" by algorithms that read and process the imagery. One application that benefits tremendously from the higher bit-depth of this imagery is "image correlation." This is the computer process that matches a small patch of pixels in one image with the same area in other images. In an 8-bit image, for example, shaded areas are black, i.e., the pixel value is 0 and no detail can be discerned in these areas. However, in a 12-bit image, there are many more shades of gray in the shadow areas, meaning features are much more likely to be discerned in these areas. This enables much more accurate correlation of DEMs produced from such imagery, and more accurate automated generation of pass points and tie points used in the aerial triangulation, when using automated image correlation.

(7) Camera System Type. Cameras rarely acquire imagery today independent of an array of associated equipment. Today, the quality of remote sensed data is determined by the camera or LiDAR "system." Each component of a camera system (e.g., aircraft, airborne GPS, inertial measurement unit, cables, computer system, antenna, forward motion compensation, operational personnel training), can have a major impact on the quality of information produced. It is important to access the entire camera system and not only the camera.

(a) Camera systems are further defined as "metric" (calibrated) or "non-metric" (not calibrated). Metric cameras enable geometrically accurate reconstruction of the scene. They will deliver accurate, stable, and repeatable results when operated appropriately. The stability, accuracy and repeatability of a non-metric camera by definition is unknown. Most geospatial projects are best served using metric camera systems operated by qualified personnel. Film camera systems were, for the most part, very uniform and could be calibrated by a single USGS lab dedicated to this task. These systems were generally calibrated once every three years.

(b) Today's digital camera systems are comprised of many components and there are many different unique camera systems generally characterized as "frame-based" or "pushbroom" sensors. Frame-based cameras take a series of "frames" of photography that resemble a digital aerial photograph from a traditional aerial film camera; for example, a frame-based camera may acquire individual image "frames" that are each 11,500 by 7,500 pixels. Pushbroom sensors are similar to scanners and take single continuous exposures over a long distance and produce "strips" of imagery instead of frames; for example, each scan line in the strip may be 1-pixel along-track and 12,000 pixels cross-track.

(c) There are significant pros and cons with each camera type that the stakeholders should understand. Because there are many diverse digital camera systems today (and the number and diversity continues to increase) the USGS no longer performs digital camera calibrations. Instead, calibrations are performed periodically by the operator and camera manufacturer. The general expectation is that a digital camera system be calibrated once each 1-2 years by the manufacturer. Field calibrations may be performed by the operator as often as each project.

(d) Project specifications should request that camera calibrations be current. These should be reviewed carefully. The old adage that beauty is only skin deep aptly applies to remote sensed imagery. Making pretty pictures is the easiest part of remote sensing and the easiest thing to sell. Making pictures accurate and useful for the intended purposes is by far much more challenging.

(e) Film camera systems are still in use today and provide very good imagery. Many project specifications can easily be met using film systems. Projects should not exclude film cameras just because they use older technology. Some projects may be more affordable hiring a contractor using film cameras than others using digital cameras. This will become increasingly more difficult as the film cameras and photogrammetric scanners age and film is more difficult to obtain.

(f) Digital camera systems are generally cheaper to operate than film and produce imagery with greater bit depth and superior image quality. This can accentuate color and positional accuracy. But digital camera systems are generally much more complex, extremely expensive, and require a higher level or expertise to operate. One is not assured of superior imagery simply because it was acquired with a digital sensor. The operation of the sensor and post-processing of the imagery is probably more important to the final quality and accuracy of the imagery than whether it was acquired with a film or digital sensor.

(g) Forward motion compensation is a feature of many camera systems that reduces image blur caused by rapid movement. Satellites and aircraft move across the earth at high speeds. The closer an object is to the sensor at a given speed the more pronounced will be image blur. A camera system equipped with forward motion compensation will dramatically reduce this blur

and allow greater accuracy and resolving power. Forward motion compensation used to be a common requirement for photogrammetric projects. However, because of superior optics and electronics of modern digital systems, forward motion compensation is not as important and is no longer a required necessity to ensure imagery that will meet project specifications. (Pushbroom sensors require no forward motion compensation, for example.) Image blur increases at a given speed with increased exposure time. Better optics and electronics in digital camera systems enable shorter exposure times and less image blur.

e. Effects of Topography and Climate. The topography of geographic features can impact remote sensing costs and complexity. Mountainous terrain is more difficult and expensive to sense with LiDAR or photography than flat terrain. It requires more planning, more flight lines, may require more sophisticated and powerful aircraft, and may have far more limiting weather than other types of geography. Very flat areas may be easy to acquire, but mapping them accurately is often much more difficult because of the lack of elevation change. Flat areas in the tropics may be easy to fly across, but atmospheric conditions (clouds, rain) are often severely limiting to remote sensing operations. Heavy urban areas may be difficult to image because of heavy smog that peaks during the optimal acquisition times. These factors and their effects on costs must carefully be considered when planning project specifications.

f. Topographic Mapping (3-D). Topographic mapping is an important component of many mapping projects. Some type of elevation data or 3-D surface model is needed for production of digital orthophotos, for example. Will the best available model be used or will a new model be created from the stereo imagery or from LiDAR? If “best available” is used, will this be supplied by the client or obtained from a public or other source? If newly created, will it be auto-correlated from stereo imagery, manually digitized, or collected using LiDAR? These are all important considerations and have significant impact on cost, schedule and complexity of the project.

(1) Public sources of elevation models make excellent choices for some projects because they are inexpensive and help reduce the overall cost of the project. The quality and positional accuracy, though often well-described, may not be sufficient for the project. It is important to verify whether they are of sufficient quality and accuracy to meet project specifications or require the contractor to verify their quality and accuracy.

(2) Client-supplied elevation models may be another option. If the solicitation will require the contractor to use an existing elevation model previously compiled on a prior project, was the positional accuracy of that data tested? How old (or current) are the data? What proportion of the data will need revisions? Can areas needing updating be described for the contractor? If the contractor finds the data less accurate than assumed, how will he/she be compensated to bring that data up to specification? If the project specifications require a defined positional accuracy,

then answers to these questions are important to the contractor and have direct bearing on the cost and, perhaps, the schedule of the project.

(3) Creating an elevation model can be one of the most expensive components of mapping. Therefore, if an elevation model from a previous project is available it may reduce the costs significantly. However, if the provided elevation model is of unknown or untested positional accuracy, and the project requires the contractor to meet positional map accuracy specifications, then the elevation model has less value to the contractor because he/she is unable to assume it meets the accuracy specifications of this project and will have to carefully test and document the elevation model's accuracy. This adds to the cost of the project. If the elevation model is accurate but dated, which areas and how much area will need to be updated to meet the accuracy requirements?

(4) Sometimes an existing elevation model is not available and a new model must be created from stereo imagery acquired for the project. Will this new model be derived from the stereo models using auto-correlation? Will it be breakline-enhanced? Will LiDAR be used to collect the elevation model?

(5) An auto-correlated elevation model is one where elevation measurements are made automatically from stereo imagery on a grid with pre-defined grid spacing. Most computer systems today perform these operations very rapidly. However, many points are inaccurately positioned on undesirable objects because of poor automated correlation. Therefore, it is important to determine whether auto-correlated elevation models (or products derived from them, like contours) are edited or systematically tested to ensure they meet positional accuracy specifications. Semi-Global Matching (SGM) is the modern term for auto-correlated DEMs.

(6) Sometimes an auto-correlated digital elevation model (DEM) cannot support required positional accuracy requirements and will need to be enhanced with breaklines. Highly accurate breaklines can only be photogrammetrically compiled from imagery acquired as stereo models. In these cases, it may be more economical to procure LiDAR services.

(7) What is the required point spacing needed to achieve accurate flood plain mapping? Are breaklines needed with the DEM to achieve the accuracy specifications? Will "soft" or "hard" breaklines be needed? Will contours be aesthetically pleasing or topographically accurate? Will contours be labeled? How does the user know if LiDAR, IFSAR or stereo imagery is needed to create a surface model sufficient to meet user needs? These are all important questions that must be addressed in the procurement process and can have a major impact on the project cost. Consultation with a professional services provider before the solicitation is drafted is highly advised so these questions are answered responsibly and the stakeholders understand their impact on price and schedule.

g. Topographic Mapping Deliverables. For much of the 20th century, topographic mapping was equated with contour mapping of the bare-earth terrain, free of trees and man-made structures above the ground. Many contour lines were mapped in forested areas even though the photogrammetric compiler could not see the bare-earth terrain in stereo beneath the forest canopy. Although such contour lines were supposed to be depicted as dashed contours, many contours were depicted with solid lines and gave the false impression that contours were more accurate than they were. Today, digital elevation data are provided in many forms, to include individual elevation mass points, 2-D or 3-D breaklines, bare-earth Digital Terrain Models (DTMs) consisting of irregularly-spaced mass points and breaklines, bare-earth Digital Elevation Models (DEMs) that are regularly-spaced, Digital Surface Models (DSMs) of top reflective surfaces (e.g., tree tops and roof tops), contours produced from DTMs, LiDAR point clouds that include multiple return elevations from each laser pulse, and derivative products produced from these products, such as hillshades, slope, aspect and/or curvature maps. All of these topographic products are explained in detail in the latest edition of "Digital Elevation Model Technologies and Applications: The DEM Users Manual," published by the American Society for Photogrammetry and Remote Sensing (ASPRS 2001 and ASPRS 2007).

(1) Digital Terrain Models (DTMs) / Digital Elevation Models (DEMs). The vertical accuracy of a DTM is correlated with the density of measurements made of the bare-earth when penetrating through vegetation or when mapping the ground in non-vegetated areas. With LiDAR, for example, the nominal pulse spacing may be very small so that the average point density is 8 points per square meter. In extremely dense vegetation, however, it is possible that none of the 8 pulses for some 1 m^2 areas actually reach the ground. The density of vegetation to be penetrated is the primary reason why Table 3-6 in Chapter 3 suggests different accuracy classes for different LiDAR point densities. The vertical accuracy of a gridded DEM may be poorer than the vertical accuracy of a DTM with irregularly-spaced mass points and breaklines because the DEM tends to smooth over the small undulations in the surrounding mass points and breaklines. With DEMs of larger post spacing (5 meters, for example), the DEM may not detect an abrupt change in elevation, e.g., a creek bank or ditch, that will not be modeled. This is the primary reason why breaklines may be needed.

(2) Breaklines. Breaklines are linear features, or the boundaries of areal features, which represent important natural or artificial discontinuities in slope contained in the landscape. 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 maintain in a Triangulated Irregular Network (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. 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. The accuracy of a DTM is greatly enhanced using breaklines. Although the cost of modeling a surface using a DTM is often higher, a DTM with breaklines can be a much more useful model of the terrain surface. The nominal pulse spacing of a LiDAR dataset can be significantly larger with the addition of breaklines and still meet the same positional accuracies, or, alternatively, the higher densification of LiDAR point cloud data may reduce the need for expensive breaklines.

(3) Digital Surface Models (DSMs). A DSM maps the top reflective surface of trees, bushes, buildings, towers and other man-made features, as well as the top surface of grass fields, paved surfaces, and ice-capped mountaintops, for example. DSMs are produced from photogrammetric auto-correlation, or from LiDAR first returns or IFSAR. DSMs are much less expensive to produce than DTMs. The report of the National Enhanced Elevation Assessment (USGS, 2012) documents many business uses for DSMs in addition to the traditional bare-earth DTMs or DEMs.

(4) Contours. Whereas DTMs and DSMs are used for computer depiction of hillshades, slope or aspect maps for example are for computer analyses such as hydrologic and hydraulic modeling or inter-visibility analyses, and contours are for human interpretation of the topography. Contours today are normally generated from DTMs and are rarely photo-grammetrically compiled from stereo imagery or lidargrammetry. Depending on the DTM (with or without breaklines), the generated contours may be quite accurate but commonly do not look cartographically pleasing. Decisions must be made based upon how the information will be used on whether the contours are smoothed and labeled to produce cartographically pleasing contours or whether to leave the contours unsmoothed and irregular. This is especially true as pertains to contours that cross roads or streams where users have an expectation of how contours should be depicted.

(5) LiDAR Deliverables. Chapter 6 explains many factors that impact the cost, schedule and complexity of LiDAR projects. In addition to the factors listed in sections 3-2d and 3-2e above that impact the cost of aerial image acquisition, LiDAR costs are also directly related to four other factors: (1) nominal pulse spacing (NPS) or point density (points per m^2), (2) vertical accuracy, (3) the level of LAS classification required, and (4) post processing needed to produce various deliverables, including whether or not the DTM is hydro-flattened (as required by USGS), hydro-enforced (as required by those performing hydrologic and hydraulic modeling), or hydro-conditioned (as required by those who model the flow of water across land areas). Some projects also require other derivative products such as hillshades, slope or aspect maps, for example. Furthermore, so many organizations have developed their own computer algorithms for generating specialized products (e.g., NRCS' LiDAR Enhanced Soil Surveys) that LiDAR raw point cloud data (all returns, all collected points, fully calibrated and adjusted to ground, by swath) and/or classified point cloud data (fully compliant with LAS v1.2, v1.3 or v1.4) are a

standard deliverable for all projects that comply with USGS' Lidar Base Specifications, Version 1.0 (Heidemann, 2012), or Version 1.1 (Heidemann, 2014) – see Appendix F.

h. Planimetric Mapping (2-D). Planimetric mapping is the 2-dimensional mapping of natural and man-made features like roads, buildings, fence lines, manholes, etc. Planimetric features are mapped with points, lines, polygons or symbols. The majority of planimetric mapping is still performed manually and is therefore quite labor intensive. Understanding the true needs of the potential user base for project deliverables is important so unneeded features are not specified and the project budget is not exceeded.

(1) There are many technical factors that contribute to the quality and costs of planimetric mapping. These may be important to define in the project specifications. For example, streams may be consistently digitized upstream or downstream, and features that form "networks" (like roads and streams) must be physically connected to other features in the network. If not, further analyses of the data may not be possible or severely limited. Project costs can be reduced considerably if planimetric features are delivered with dangling endpoints and crossing features. However, the value of these datasets for many GIS and CAD applications are severely impacted. Topological data structure (which costs more) is important for many planimetric mapping projects. Topology is 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.

(2) Some planimetric features are digitized in 2-D, such as the shoreline of lakes that can be digitized directly from digital orthophotos and, if also part of a DTM, assigned one elevation value for the entire shoreline so that the lake's surface will be flat. With photogrammetry or lidargrammetry, some features are digitized in 3-D so that the 2-D (x/y) coordinates are usable in a planimetric map while the 3-D (x/y/z) coordinates are usable in a topographic map or DTM/DEM.

(3) Because planimetric mapping can be very labor intensive to digitize, it may make sense to use existing planimetric data to augment deliverables for the current project. This can save considerable expense if the mapping meets similar quality and positional accuracies of the current solicitation. However, if too dissimilar, they may actually increase the project costs because they introduce too many errors and inaccuracies. If existing planimetric data are used, project specifications concerning positional accuracy of the plan data should be defined. Additionally, will the planimetric data need to be updated? If so, allow costs for this and decide if information can be provided to the professional that identifies the areas that need updating. If this is not available, then expect costs to increase because all planimetric data will have to be verified to be consistent with the photography or LiDAR. In many cases the existing planimetric

data will not have been collected by the same professionals that are updating it. They may discover quality problems with the data. If so, how will discrepancies be handled? If the positional accuracy of the planimetric data was not field tested, then who will be responsible to fix and pay for inaccuracies discovered?

(4) The number and density of planimetric features specified have a significant impact on cost and schedule. Digitizing all roads in a rural area will take a fraction of the time than those in an urban area. Buildings in an older part of a community may have roof lines that are closer together and more difficult to discern from imagery than ranch style homes in the suburbs. When collecting buildings, is it important that decks be included as part of the "house" feature or as a separate "deck" feature, or not at all? Are sidewalks required? If so, what about sidewalks on private property? Should different types of road surfaces (concrete, gravel, blacktop) be attributed for the roads as they are collected? Should the shoulders of paved roads be symbolized? Should unpaved road shoulders be digitized? Should fire hydrants, manhole covers, utility poles be digitized? All of these questions and many more need to be carefully considered before a solicitation is released. It is important to include geospatial professionals in these discussions so the needs (not wants) of the user community are closely aligned with the procured services and are possible within the project budget.

i. Ground Control. Ground control forms the basis for any mapping or geospatial project and shows the true relationship of features or objects to each other in terms of distance, angle, area, etc. Ground control is the anchor point, the determining factor in stating the positional accuracy with which a given geospatial dataset matches the location at which the dataset occurs in the world. Ground control allows the establishment of absolute accuracy of geospatial data referenced to horizontal and vertical datums (normally NAD83 and NAVD88). QA/QC checkpoints, surveyed relative to ground control, are necessary for USACE accuracy testing and reporting described in Chapter 3 of this manual.

(1) Ground control for photogrammetric mapping projects is either paneled as an aerial target or collected as a photo-identifiable point. Paneling a point allows aerial mapping contractors to put control exactly where they want it, but it requires leaving a target, usually painted or identified with plastic strips, to identify where the control point is located and to make it visible to aerial sensors. This has both pros and cons. With plastic, it can be disturbed or destroyed by a farmer's cow or by high winds. So panel maintenance becomes necessary to ensure the panels are in place and visible when the aerial photography occurs. This can become expensive and require coordination between the ground survey and aerial survey crews. If a single critical control point is obscured or destroyed and cannot be seen in the aerial photography, re-flights may have to occur. Further, the control targets cannot be removed until after the acquired data has been verified as usable. Removing the targets requires a revisit to the property. This adds another cost to the project.

(2) Photo-identifiable points offer the benefit of being permanent or semi-permanent features in the area of interest clearly visible to the remote sensing equipment, without requiring a panel. Quality, photo-identifiable control is easy in urban areas, but in more remote areas it can become more difficult to find a suitable point feature that has enough contrast, permanency and visibility to act as a stable control point over time.

(3) The source of ground control is important and has direct bearing on the confidence one can place in the accuracy of the base mapping. The value of the very expensive topographic and planimetric mapping and orthoimagery acquired can be significantly compromised without good ground control. Extreme care and expert advice is needed to ensure adequate control is used for the project. Whatever the source, the ground control must have a "defined, measured" accuracy, collected to a defined set of standards. Geospatial professionals know the required number and placement of ground control points and the survey procedures necessary to achieve the required horizontal and/or vertical accuracy of geospatial products.

(4) The costs of surveyed ground control can be impacted by a number of factors that need to be considered in the solicitation. Is access to the property possible with or without permission of the land owner? Are the locations of the points accessible or remote? Can they be surveyed safely or will they require special precautions to protect the surveyors? Can the points be accessed using ground vehicles or will they require other modes of transport?

(5) Ground control should be obtained using trained GPS technicians and professional surveyors. Many states require professional surveyors to perform this work. For most projects, an ASPRS Certified Photogrammetrist is qualified to design a project using photo-identifiable control. Professional surveyors are generally needed to measure ground control after the mapping professionals have determined the number and placement of the control points needed to meet the mapping accuracy specifications. Because manual labor is involved, costs can be quite high. However, they often comprise only a small proportion of the overall project costs and are foundational to the validity and usefulness of all the information built on top of it and used by design engineers or GIS analysts for multiple applications.

(6) National Geodetic Survey (NGS) datasheets, available free on the web, document 2-D and 3-D control points in the National Spatial Reference System (NSRS). The coordinates and "to-reach" instructions are available for many thousands of previously-surveyed horizontal control points and vertical benchmarks throughout the U.S., but these points are rarely photo-identifiable and would need to be paneled in order to be visible from aerial photography. For LiDAR projects, however, NGS control points do not necessarily need to be photo-identifiable. Lastly, existing commercial control may be available and can be licensed. Some agencies balk at the idea of non-ownership, but when viewed as a commodity, licensed control data (in effect "pre-used") can be more cost-effective than acquiring new survey control needed for the project.

j. Quality Assurance / Quality Control (QA/QC). Quality control (QC) is a process employed to ensure a certain level of quality in a product. Quality assurance (QA) is the process of verifying or determining whether products meet or exceed customer expectations. Every contractor performs some level of QC for a mapping project. It is prudent to understand what QC measures the contractor will employ to ensure deliverables meet quality expectations. QA is generally performed by the buyer and can be done in-house or contracted to a 3rd party. What is checked and what QC methods are employed by geospatial contractors to ensure consistent quality and repeatability? How much and what methods of QC are needed by contractors and what degree of QA is required by the government? How much QA/QC can be afforded? Should independent contractors be used to certify the quality of deliverables? What measures of quality are important? When choosing a 3rd party QA/QC contractor, those with intimate knowledge of and experience with ASPRS accuracy standards are best qualified to ensure that government requirements are satisfied.

(1) Normally, government contracts include a Scope of Work (SOW) that specifies required criteria for data collection, data processing, data accuracy and deliverables. In some cases, the SOW requirements refer to specifications from the Federal Geographic Data Committee (FGDC), USGS, or ASPRS for example. Geospatial contractors routinely have in-house QC procedures that verify that all such SOW requirements are satisfied, to include such common criteria as media, media label, file organization, file names, file formats, pixel definition, georeferencing, projection, horizontal and vertical datums, units, tiling scheme, tile coverage, and metadata.

(2) The qualitative assessment of orthoimagery tends to be more subjective than the quantitative accuracy assessment which is objective. Many organizations provide detailed Acceptance/Rejection criteria for image qualitative factors such as color consistency, image appearance, image artifacts, smears, wavy features, mosaic seamlines, building lean, and shadows, for example, but qualitative assessments still tend to be subjective. For this reason, sample orthophotos or pilot projects are recommended to establish “up front” what is acceptable and unacceptable to the client.

(3) Acceptance/Rejection criteria are especially important for planimetric data. Each of the numerous types of features to be collected (e.g., various water features, water structures, vegetation features, paved and unpaved surfaces, road features, street hardware, utilities, airport and railroad features, buildings and other structures, barriers, landmarks, construction sites, quarries, mines, etc.) require Acceptance/Rejection criteria agreed to by the government and the contractor performing the planimetric mapping.

(4) Acceptance/Rejection criteria are also recommended for elevation datasets, especially breaklines and contours for which aesthetics may be important.

(5) In all cases, the geospatial contractor is responsible for in-house QA to ensure that SOW requirements are fully satisfied. When portions of the work are subcontracted, the prime contractor is responsible for QA/QC to ensure the subcontractor delivers acceptable data to the prime contractor.

(6) The government is responsible for quality assurance (QA) to ensure that it receives what it paid for, that SOW requirements are satisfied, and that the data will be usable for its intended purpose. When the government has sufficient qualified in-house staff available to perform its own QA, the government normally performs the necessary steps and then notifies the contractor of any rework if necessary. Some government agencies hire a specialty firm to perform independent 3rd party QA/QC of geospatial data produced by others to both ensure that government reviews are completed professionally and in a timely manner, and to ensure that intense cost competition, rushed schedules and automated procedures do not lead to geospatial products being untested and unseen by human eyes prior to delivery. Independent QA/QC includes thorough and systematic reviews, to detailed Acceptance/Rejection Criteria, of data produced by other firms with no contractual relationship to the QA/QC firm; such reviews typically take many minutes per tile to open and review visually. Independent QA/QC does not include in-house QC checks by data producers or a prime contractor's automated review of data produced by their subcontractors, taking mere seconds per tile, that often fail to detect the kinds of errors detectable by visual reviews. Visual reviews almost always detect errors that are undetectable by automated reviews.

(7) It is very important that QA/QC procedures and costs be considered while the solicitation is drafted so the project budget accurately reflects these associated costs. The costs of QA typically range from 15% to 20% of the project budget.

k. Deliverable Methods. Geospatial projects continue to grow in size. The total area being mapped or modeled, and the volume of data produced and delivered, continues to grow to unprecedented levels. Delivery of this information is an important consideration for many projects. Several factors should be considered:

(1) Is a physical digital copy of the deliverables needed? Should the data be delivered on a DVD, external hard drive, or tape (used by some organizations for archival purposes)? If hard drives are used, will they be USB 2.0 or SATA interfaces?

(2) Can the data be delivered to the government via file transfer protocol (FTP)? This can save shipping costs, but it can entail a lengthy process to download the data if file sizes are very large.

(3) It may be advantageous to have data delivered as a cloud web service. The advantages to this include avoiding the high cost of infrastructure and personnel to maintain infrastructure

that is needed to host large volumes of geospatial data internally. Once outsourced, the users may work as usual but the high costs of infrastructure have been outsourced and become a low fixed cost to the organizations. If "cloud services" are procured for delivery of project data, project specifications should be clearly established. How will each type of data be provided? Are these services portable to other cloud providers? Are these services scalable? Are the web services compatible with the browsers and desktop GIS software that will be used by the user community? Are potential data ownership and licensing issues clarified? Where are the data physically located? Are the on-boarding (loading data into the web service) and off-boarding (pulling data off the web service) processes and deliverable types clearly defined? Are the data from the cloud provider secure? Who is responsible for what if the service fails? Are the billing methods for using the service compatible with your organization's needs?

l. Collaboration with Others. Both the National Digital Orthophoto Program (NDOP) and the National Digital Elevation Program (NDEP) have goals to: enhance data sharing among Federal, State and local agencies, the private sector, and academia; minimize redundant data production; leverage resources to satisfy multiple requirements; develop flexible standards common to all users; and assure availability and accuracy of "best available" data. As a member of NDOP and NDEP, the U.S. Army Corps of Engineers supports these goals for numerous reasons: (1) By pooling resources of Federal, State and local agencies to develop data needed by multiple users, limited agency funding will be maximized. In addition, establishing common standards and guidelines will maximize the utility of the data and promote the sharing of data among agencies and organizations. It is also in the general public's interest to make the most accurate, up-to-date data readily accessible to all who need it. Moreover, sharing these data and eliminating redundancy in data collection and development by government agencies will save tax dollars. The establishment of common, yet flexible standards is a critical factor in supporting the remote sensing industry. Whenever geospatial data produced for USACE can also satisfy requirements of USGS and FEMA, for example, everybody benefits from such collaboration.

m. Cost Estimation Templates. A cost estimation template for an example task order for aerial photography, digital orthophotography and planimetric feature collection is in Appendix G; a cost estimation template used for an example task order for LiDAR and digital orthophotography is in Appendix H; and a cost estimation template used for an example task order for a hyperspectral image acquisition and feature delineation is in Appendix I.

9-3. Qualifications-Based Selection (QBS) for Professional Mapping Services.

a. Background. Traditionally, government procurement procedures properly have emphasized awarding contracts to the lowest bidder, or using price as a dominant factor. For many goods which governments purchase, e.g., paper, office equipment, desks, even construction services, this process serves the government and the taxpayer well. Specifications can be written, products can be inspected and tested, and safeguards can be built in to assure

saving money. Sometimes, however, agencies mistakenly assume professional mapping services fall into this category. Unfortunately, the assumption ignores the increase in costs to administer the preparation of detailed scopes of work and bid specifications, evaluation of numerous bids, and to remedy serious consequences of unprofessional surveying and mapping. Quality, therefore, should always be the primary focus in the competition for surveying and mapping procurements. Only after high quality performance is ensured should the focus turn to the contract price.

(1) All states have standards for licensing of surveying and mapping professionals. State licensing standards and government procurement regulations for professional services should be designed to protect the public health and safety during and after contract performance. For these reasons, some state licensing boards prohibit licensed professionals under their jurisdiction from engaging in competitive bidding to secure work.

(2) If inaccurate, a map could cloud land titles or jeopardize subsequent construction designs, planning activities or program management that must rely on accurate mapping data. Just as a poorly designed dam can burst, subjecting the government to huge claims, so too can a poorly planned or executed map unleash a flood of problems, creating an impediment to the expeditious completion of a government project, causing substantial loss of time and money, and jeopardizing the public safety. Like a well-made dam, a high quality map will stand the test of time and ensure that the government can proceed with its design, construction or resource planning project based on complete and precise groundwork.

(3) In addition to the direct cost of the contract, the government must be concerned about such consequent indirect costs as physical destruction of property or clouded claims that could result from poor quality workmanship.

b. Negotiated Contracts. The government should negotiate contracts for professional mapping services independent of other professional design or construction services to ensure that specialized mapping skills and technologies are evaluated properly and not overlooked. In this manner, the government will benefit from direct control of both the quality of the services and the map's development. The use of negotiated procedures directs the focus of procurement activity where it should be – on the quality of the mapping services specifically suited to a given contract. All competitors must submit their qualifications to the procuring agency; the agency assesses the relative expertise of the competing firms; and the one most qualified firm is selected for the particular procurement. Such procedures produce a more cost effective survey or mapping produce than can be achieved under price bidding or best value procedures. Several reasons for this are as follows:

(1) Negotiated procedures afford built-in protection, because either the selection process eliminates unqualified firms, or the negotiations reveal a firm's comparative lack of expertise. In

either case, the problem is discovered before the contract is awarded, not after the job is done. Under price bidding procedures, however, the low bidder wins, regardless of the marginal capabilities it may have demonstrated previously.

(2) The extreme difficulty of defining adequately, in advance of negotiations, the quantity and quality of the mapping and photogrammetric services to be secured is likely to lead to misunderstanding as to the scope of the services to be rendered and the expectations of the government concerning the services and the desired project. The negotiating process allows the government to work as a team with qualified professionals to refine the government's contract requirements and develop more tailored, economical mapping. Thus, in the pre-contract stage, the agency benefits from the professional's years of experience and demonstrated competence.

(3) The government saves substantial administrative costs of preparing detailed specifications that would be required under price bidding procedures to avoid widely varying interpretations by competing bidders. The government also saves significant personnel costs if it can employ a few specialists to review qualifications, negotiate contracts and specialists to review qualifications, negotiate contracts and monitor or inspect performance – rather than maintain the large staff needed to process numerous bids received on each procurement and evaluate the qualifications of each of those bidders, as well as execute and monitor contract performance.

(4) Negotiated procedures ultimately result in more efficient, economical procurements for the competing professional firms as well as the government, because of the very nature of surveying and mapping. Because only the top ranked firms need to prepare boundary analyses and detailed estimates on the work, other competitors are free to pursue other contract opportunities without wasting money on a contract they will not be awarded.

c. Government Benefits. The government benefits from the professional photogrammetrists' fiduciary obligation to their client in the following ways:

(1) Emphasis on the quality of the work establishes a relationship of cooperation and trust, whereas price competition pits honest professionals against competitors who are willing to cut corners or deliver substandard services to bid low. When the low bid is the primary selection criterion, the interests of unscrupulous or inexperienced contractors are advanced over the interests of the public. The low bid map often is inaccurate or incomplete because the government will pay far more, or contract with another to complete the project begun by the low bidder who went bankrupt trying to meet an unreasonably low contract price. Rather than an adversarial relationship, which is promoted in competitive bidding procedures, the mapping professional should negotiate their fees and work as a team.

(2) The government must be mindful of the indirect or hidden costs, such as legal fees, court expenses and insurance claims that it can incur when boundary, trespass and other property disputes are caused by outdated or erroneous maps. By negotiating contracts with private mapping professionals, the government can save in-house costs and increase mapping outputs significantly.

(3) Historically, more firms compete, and thus the government gets a better service as a fairer price, when QBS is used. Government inspection or quality control of a mapping project to monitor contract compliance is much more difficult than inspection of manufactured products or other professional services. The map's geographic scope is often immense, and the only effective way the government can check for accuracy is to retrace the entire map. Even a trained eye cannot find a map's critical flaws that could threaten the public's safety and its pocketbook in future years. Unlike materials, a map cannot be adequately sampled before and thoroughly tested after production. The client or owner is totally dependent upon the integrity of the mapping professional – even at his/her mercy – for even a bad map can look good. It often takes months or years before errors and problems are discovered.

d. Technical Considerations. There are many technical considerations that impact the cost of a surveying and mapping project and the care taken to "do things right":

(1) Maps are tied to existing control points on the ground, the location and condition of which are uncertain until a survey is performed. Legal descriptions of boundaries may or may not indicate physical monuments. These physical monuments may or may not still exist on the ground. If they do exist, they may or may not be the original monuments, and they may or may not fit other physical evidence in the area. One cannot price the unknown.

(2) Mapping is usually dependent on other existing surveys and recorded documents. The evaluation of such surveys or documents is a matter of judgment which cannot be made until the professional has researched the project, both in the field and in the repository of deeds. The professional surveyor may find that as the result of his/her new work, the existing survey may have to be rerun to achieve the accuracy required by the client, even though the records of the existing survey indicated otherwise beforehand. The surveyor may find deeds or other documents that will affect the interpretation of the client's land description. These conditions may not be known, nor even suspected, until the survey is substantially started.

(3) Mapping is weather dependent. Cloud cover, storms, excessive hot or cold weather, floods, rain, snow, wind and other inclement conditions can delay or prolong an aerial photography and mapping project for indefinite periods of time. Precise leveling is extremely sensitive to the vagaries of weather. For ground surveys, fog affects sighting lengths, and wind affects instrumentation and measurements. For aerial surveys, clouds and fog prevent the acquisition of aerial imagery and LiDAR, and excessive winds affect the ability to maintain

acceptable aircraft roll and crab needed to get the correct sidelap between adjoining flight lines. Delays cost money. The decision to stop or delay the operation should be based on a determination that the quality of the result will suffer, rather than on a profit-loss motive.

(4) The accuracy of a map depends upon the manner and the conditions under which the work is performed and by methods which have been demonstrated to meet certain accuracy specifications. A map or survey could close within specified tolerances, but the work could be unacceptable because of the methods used.

e. Low Bid Contracts. By requesting bids, a client assumes the responsibility for defining the scope of the services required and, thus, does not take advantage of the knowledge and background of qualified professionals engaged in providing such services:

(1) All too few administrators and even engineers are knowledgeable in mapping, and their inadequacy in this regard is apparent in their requests for bids. The knowledgeable person is aware of the indeterminate nature of mapping. The reputable professional, if he (or she) is to bid, must either attempt to anticipate the many possible problems, determine which problems he feels will occur, and bid accordingly, or bid so high that he can include every possible condition (in which case he undoubtedly will not be the successful bidder). If an honest attempt is made and unforeseen conditions occur, the mapper faces the decision to adhere to the specifications, thereby producing an inferior product (which he cannot ethically do) or perform the work to the best of his ability, thereby operating at a loss. Either way, the client/taxpayer is the ultimate loser.

(2) Numerous cases can be cited to prove that the lowest bid does not necessarily result in the lowest overall cost. The old cry, “Bid as low as you dare, but make your money on the extras,” is inevitable and the resulting relationship between the government client and the surveyor or mapper, caused by change orders, assumes an arms-length status which is not conducive to the completion of professional assignments and effectively eliminates any exercise of professional judgment on the part of the surveyor or mapper.

f. Summary. A broad coalition of design-related organizations support qualifications-based selection procedures for surveying and mapping services:

(1) The Federal competence and qualifications-based selection law was codified in 1972 to protect the interest of taxpayers. It is Federal law because over the life of a project, the engineering and related design services account for less than one-half of one percent of total costs. Yet these important services play a major role in determine the other 99.5 percent of the project’s “life cycle costs,” such as construction, operations and maintenance. In addition to surveying and mapping, the same is true of the associated geographic information system (GIS) projects.

(2) The Federal Acquisition Regulation (FAR) requires that Architect-Engineer (A-E) contractor performance information be collected (FAR Part 42) and used in source selection evaluations (FAR Part 15). In October 2004, the Department of Defense (DoD) Business Transformation Agency (BTA) was established to manage DoD's e-business enterprise solutions, including the Contractor Performance Assessment Reporting System (CPARS). On October 1, 2009, management of CPARS transitioned from BTA to the Defense Logistics Agency (DLA). The Architect-Engineer Contract Administration Support System (ACASS), a sub-module of CPARS, establishes procedures for the collection and use of Past Performance Information (PPI) for A-E contracts. ACASS-generated PPI is one of the tools used to communicate contractor strengths and weaknesses to source selection officials and Contracting Officers. ACASS collects contractor performance information and passes it to the Federal Past Performance Information Retrieval System (PPIRS) where it can be retrieved by Federal Government Agencies including the DoD.

(3) The QBS process has been so successful at the Federal level that it is recommended by the American Bar Association in its model procurement code for State and local governments. The ABA model code specifically includes surveying and mapping. More than half the States have enacted their own competence and qualifications-based selection laws for architecture, engineering, surveying and mapping services. Others use it as a standard procedure. No state has a specific law requiring bidding of these services.

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