Quantum Spatial, Inc. • 45180 Business Ct, Suite 800, Dulles, VA 20166 • Phone: 800-558-6707 • www.quantumspatial.com

March 16th, 2018

City of Nashua, through CDM Smith
ATTN: Jayson Brennen
brennenjd@cdmsmith.com

RE: RFP for Photogrammetric Mapping Project

Dear Mr. Brennen:

Quantum Spatial is pleased to provide this response to the City of Nashua (the City) for the Photogrammetric Mapping contract. As one of the largest and most experienced geospatial solution firms in North America, Quantum Spatial offers the City the extensive resources, knowledge base, and experience needed for successful execution of any task issued under this program. Quantum Spatial has completed thousands of acquisition and mapping projects throughout the world including Massachusetts. Quantum Spatial is a leading orthoimagery provider in the US, providing similar services to other state agencies such as Virginia, Vermont, Connecticut, and Maine. We also work with many federal agencies like USDA, USGS, USACE, and NAVFAC; local coalitions which includes Marlborough, MA Peterborough and Hudson, NH; and various private clients including those in the utility and energy sectors.

Quantum Spatial has a full understanding of the required workflow and production of the deliverables outlined in the RFQ. It is our intention to collect all required digital orthoimagery and planimetric features in accordance with the RFP as written. Assisting Quantum Spatial in this effort will be Keystone Aerial Surveys, a trusted data acquisition partner providing acquisition resources and Bryant Associates to provide professional land survey services.

Quantum Spatial is and has been operating on a sound financial basis since 1969. Quantum Spatial is financially secure with over $90 million in annual revenue in 2015 and 2014. As further testimony to our company's financial stability and sustained growth, Quantum Spatial (formerly Aerometric, Photo Science and Watershed Sciences) was ranked 83rd in the top engineering companies on Inc. Magazine's 5000 list, an exclusive ranking of the nation's fastest growing private companies. Quantum Spatial agrees to incorporate both the RFP and this proposal into the form of contract included within the RFP documents. Quantum Spatial will commence with aerial photography as stated in a Notice to Proceed.

Drew Meren, GISP will serve as Quantum Spatial' principal point of contact for this response. Drew will be the Account Manager for Quantum Spatial to the County and will support the partnership needs during the project lifecycle. Drew can be reached directly at 703-471-4510 x239 or via email at dmeren@quantumspatial.com.

As Vice President, I am authorized to sign on behalf of the firm and bind Quantum Spatial to the statements, services, and prices made in this proposal. Please see the Appendix of this response for a copy of my authorization to sign on behalf of Quantum Spatial, in lieu of the corporate seal and signature and the Certificate of Vote Form. I would like to thank you for the opportunity to present our qualifications. We are committed to the successful execution of this contract and please do not hesitate to contact us if we can provide additional information.

Sincerely,

Robert Vander Meer
Vice President, State & Local

1. Technical Proposal – Scope of Services, Schedule of Milestones, & Deliverables

Quantum Spatial's technical approach is based on years of experience of working on complex photogrammetric mapping projects and partner relations. Our coordination using Keystone Aerial Surveys for flying and capturing aerial imagery using the Vexcel UltraCam Eagle and Bryant Engineers providing new photoID ground control points, where appropriate, is vital in setting up this source data in order to produce the digital orthoimages and planimetric with topographic mapping. During the anticipated 6 month project, the Quantum Spatial team will work together to ensure delivery schedules are met. At all times during the lifecycle of this project accuracy, quality, and communication is vital to a successful, on-time delivery to the City.

As the City will notice, our technical approach follows a set process of events for this project. Aerial acquisition, along with ground control support, will be captured during the Spring of 2018 during peak sun angle, leaf-off conditions followed by ground control capture in the weeks following. Upon inspection and acceptance of this data, image processing (AT, orthorectification, and color balancing) starts at relatively the same time as the planimetric capture. Before full scale production takes place, Quantum Spatial advises a pilot delivery area of orthoimages and planimetric data be set up with the City.

1.1. Imagery Acquisition Plan

1.1.1. Aerial Sensor Overview

Quantum Spatial's team member, Keystone Aerial Surveys (Keystone), will operate the UltraCam Eagle (Eagle) to collect aerial imagery for the City. Our team owns and operates turbine (Conquest and Commanders) and twin-piston aircraft capable of flying the Eagle sensors. Being located at the Philadelphia Airport, Keystone has the closest operations to the City region.

The Eagle is a frame sensor that collects full multi-spectral imagery (red, green, blue, and near-infrared) simultaneously. The Eagle frame capture represents one of the largest capture footprints of any sensor in the industry.

Acquisition blocks are then planned for areas that can be flown at constant altitude and that maximize the length of planned survey lines. Ground control point locations are distributed to ensure all flight blocks are consistently tested to meet or exceed American Society of Photogrammetry and Remote Sensing (ASPRS) Class 1 standards at 1″=100′ scale mapping. Weather conditions are reviewed on a daily basis by the Quantum Spatial acquisition management team to determine acceptable flight windows.

1.1.2. Flight Plan Overview

Quality assurance of mapping deliverables starts with a well-defined flight plan. Quantum Spatial takes special care in designing an optimal flight pattern for each sensor that will achieve maximum coverage and efficiency during suitable weather conditions. The flight plan includes all planned exposure locations, flying heights, forward and side overlaps, and also assures that all acquisition missions are conducted safely. It will also incorporate contingencies, such as flight in or near controlled airspace and assigned areas for turns and standby; so that all project operations are conducted safely. The flight plan will be finalized upon project initiation.

We will be flying the City from a NE/SW direction, as shown in the flight plan figure below, to allow for full City coverage. At a flying height of ~4,000 ft, the Eagle sensor has no problems capturing the 4 inch 4 band imagery. It is anticipated that there will be 7 flight lines for a total exposure count of 192 images. The total area coverage is 21 mi^2 to capture the 200 ft buffer, and water.

1.1.3. Image Acquisition

> **Quality Control – Image Acquisition**
>
> Collected image data is field validated for cloud requirements ensuring timely collection of any needed re-flights.

The Quantum Spatial team begins image acquisition with monitoring weather conditions to identify daily opportunities for acquisition. Numerous data sources are utilized in identifying daily acquisition opportunities, including Meteorological Terminal Air Report (METAR) and Terminal Area Forecast (TAF) reports from local airports; cloud cover, temperature, and dew point forecasts from the National Oceanic and Atmospheric Administration (NOAA); and both visible and infrared imagery from NOAA's Geostationary Operational Environmental Satellites (GOES). These data sources are used to determine whether conditions are favorable for imagery collection.

Flight plans are filed with the Federal Aviation Administration (FAA) Air Traffic Control (ATC) center responsible for the airspace over the planned collection area. Crews will obtain the time window corresponding to the required minimum 45-degree sun angle from the U.S. Naval Observatory's Sun Altitude/Azimuth tables. Acquisition missions are launched to ensure the aircrew can be "online" for the first line of the day within five minutes of the sun angle window opening.

Quantum Spatial aircrews ground test the sensor before each mission. The ground test involves booting the sensor control system, recording GNSS/IMU data, initializing the gyro-stabilized mount, and recording image data from the sensor head. These ground tests ensure proper cabling and function of the control, navigation, imaging, and data storage subsystems. Once ground tests are completed, crews launch the image acquisition mission. The pilot performs an in-air initialization of the navigation system, by flying a figure eight pattern, before beginning collection of the first line. After each line is acquired, the pilot makes the turn onto the next line in a teardrop pattern. These flight patterns ensure both left and right turns are made between flight lines, which is critical for collection of the accurate IMU data required for the sensor.

Contiguous survey lines are collected whenever possible. If intermittent or sparse cloud cover is encountered, the full survey line is collected, and any required re-flights are planned and acquired as soon as possible. When substantial cloud cover (defined as more than 30% of the survey line being obscured) is encountered, the line will be aborted and the next clear line identified for acquisition. Imagery will be acquired until weather prevents further acquisition, the sun angle window closes, or the aircraft requires re-fueling. Multiple acquisition missions are performed per day, as needed, whenever weather conditions permit.

Forward and Side Overlap

Quantum Spatial's planned forward overlap is 60% and planned side lap is 30% for base flight plan with some variance due to terrain within the areas of interest. Special consideration for extreme building lean and shadows have been addressed in our proposed base flight plan as requested in this RFP.

Once acquisition is completed for the day, aircrews remove the solid state storage units from the sensor and download the data collected. The data is downloaded and back-ups of each download are stored in the field, and the original downloads are shipped to Quantum Spatial's production facility. Digital flight logs are generated documenting acquisition conditions, sensor parameters and settings, and lines collected and their start/stop times. An initial QC is performed by the crew to identify areas of cloud/cloud shadow that require re-flight. Quantum Spatial's QA/QC methods for flight operations are founded on strict adherence to our ISO-compliant procedures and the strategic design of QC tasks along the workflow path. Any issues that are identified in the field will be re-flown on the next flight, usually before data is received at the home office.

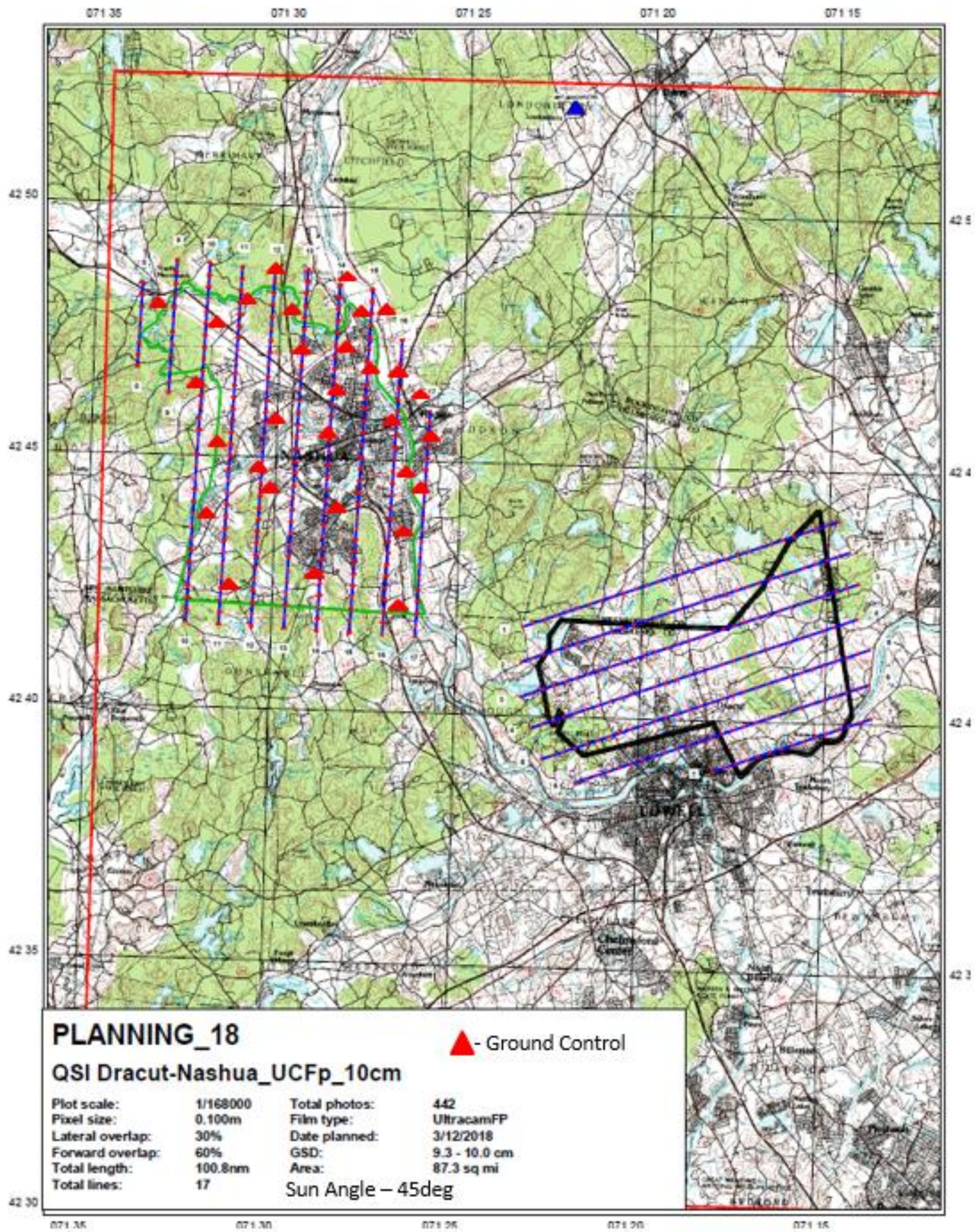

Figure: Proposed Flight Line with a combined mission with Dracut, MA.

1.2. Image Processing

Quality Control – Image Processing

Initial image processing and acquisition inspection confirm compliance with environmental condition requirements and proper sensor function during the acquisition mission.

The image processing chain is designed to make efficient use of data storage resources while preserving the vast amount of image information collected with a direct digital sensor like the Eagle. The CCD array in the sensor heads have broad dynamic ranges, permitting substantial detail to be collected in highlights and in shadowed areas. The analog to digital converter has a 14-bit dynamic range, and 16-bit workflow providing additional bits of “headroom” to prevent clipping of highlights and shadows when the system calculates pixel values from the raw exposure. Once the image data arrives at the production facility, the initial processing steps are handled according to sensor type. The process begins with the imagery being downloaded from the Eagle storage unit onto our networks. Once the imagery is on the network storage location, a checksum is performed to confirm data consistency before processing to “Level 2.” Level 2 is started using custom distributed processing software overtop of the manufacturer’s processing software. Meanwhile, overview images are visually checked for misfires, clouds, alignment, etc. This process is completed with both the manufacturer’s software and in-house developed quality control and management software.

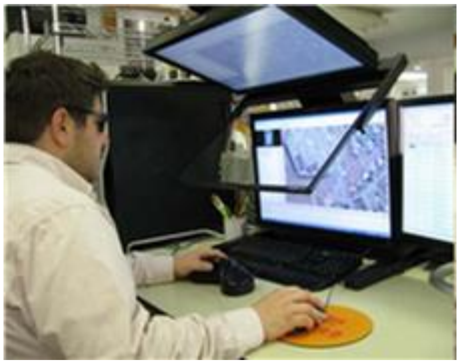

Figure 1: Image inspection

After the imagery is processed to Level 2, software is utilized to simultaneously view the PAN and RGB to confirm processing and perform another quality control check. The Level 2 imagery will then be processed to Level 3 using Quantum Spatial’s distributed system. All Level 3 imagery will be dodged appropriately to match the image quality and tonal balancing of flight lines acquired on different days. During this step, transition of source data is transferred to our global delivery center to perform the photogrammetric compilation stages.

The Quantum Spatial team has implemented a “proprietary methodology” for color balancing frame imagery. This solution achieves the balancing of the individual channels for the PAN and RGB. Look Up Tables (LUT) are utilized to establish a mathematical set of values that transform the input image into a desirable output balance. This process adjusts the gamma, color, contrast, and brightness levels. Emphasis is made during this process to reduce obscurity due to deep shadows to the degree possible while still achieving an overall acceptable image balance with respect to gamma, color, contrast, and brightness levels. Target LUTs are developed and then used for the basis of this process and applied to the image database. Visual inspection checks for potential image anomalies, clouds, smoke, haze, and frame overlap adherence.

1.2.1. Aerotriangulation

The Quantum Spatial team utilizes a combination of direct geopositioning from GNSS/IMU navigation systems and block bundle adjustment to arrive at an aerotriangulation (AT) solution. Kinematic GNSS surveying techniques, along with precise point positioning (PPP) processing techniques, are used to derive coordinates representing the position of the sensor at a frequency of 2Hz along the flight trajectory. The GNSS observations are reduced to final position coordinates utilizing the TerraPOS PPP software, operating in the software’s kinematic processing modality. The processed GNSS positions are combined with the IMU observations, collected at a frequency of 200Hz, using the Leica Inertial Position & Attitude System (IPAS) software. IPAS uses Kalman filtering techniques to obtain the best estimate of the sensor’s trajectory, taking into account the measured offsets (lever arms) between the navigation subsystem reference points (GNSS, IMU) and the sensor’s reference point. Precise timing data collected during image acquisition allows interpolation of the sensor exterior orientation (EO) from the trajectory at the time of each scan line exposure. The final trajectory and exposure timing data provide the direct geopositioning data in Quantum Spatial's AT workflow.

The Quantum Spatial team will use Intergraph's ISAT systems for softcopy aerotriangulation and pass-point selection techniques. Quantum Spatial will select points to adequately support the stereo neat models. These points will be used to tie individual models together along a flight strip. Flight tie points will be established every model to tie adjacent flight lines together. An automatic image correlation technique will be utilized to perform final point sub-pixel measurement. Each point receives a unique point number, "keying" each point to an individual digital frame and frame location. Additionally, each block will be successively coupled together with the selection of tie pass points along their respective borders with adjoining blocks. The block tie points will also be included in the bundle adjustment. Quantum Spatial's point numbering sequence is a QC process, designed to prevent incorrect control point duplication within the blocks. The output ISAT production system generates point coordinates in both the refined coordinate system and raster system (rows and columns). The first is used in performing the aerotriangulation reductions while the second may be used to "post PUG" the measured points for later use in QC procedures. Quantum Spatial's general methodology is to validate all photogrammetric measurements prior to the addition of ground control.

Ground Control Points (GCPs) are introduced to the processing block for validation of the solution. Photogrammetric technicians manually measure the photo-identifiable ground control points in the imagery and compute residuals between the surveyed coordinates of the GCPs and block solution coordinates of the GCPs. Once the block solution meets RMSE requirements, it is moved into the orthorectification phase.

1.2.2. Orthorectification

The orthorectification process begins upon acceptance of imagery through Data Checker and the creation of the exterior orientation data. Utilizing Intergraph's Image Station Photogrammetric Manager (ISPM) application, project parameters are assembled. OrthoPro is then utilized to spatially overlay information extracted from ISPM data. OrthoPro then creates the rectified images, generates seam lines, and mosaics the rectified images into larger blocks. Working in larger seam-matched blocks has been proven to yield greater efficiency in the post-ortho quality review process. Key steps in the orthoimage generation process include:

- Defining project parameters (coordinate system, units and file format)
- Ingest of production block project wide surfaces (elevation data)
- Utilization of exterior orientation (EO) files
- Orthorectification
- Automated/manual seam line placement, mosaicking, and final color balancing
- Horizontal accuracy acceptance

The Quantum Spatial Eagle approach orthorectifies every image frame acquired during the photo missions but typically uses approximately 80–90% of the rectified image frames in the mosaicking process. This methodology maximizes production cost efficiency, while maintaining accurate orthoimages to the highest of visual quality standards. Quantum Spatial's QC process validates the fit of the orthoimages during this production phase. The rectification process employs a cubic convolution resampling method, which sharpens the edges of linear features by sampling 16 of the closest pixels and performs a weighted adjustment; whereas alternatively, nearest neighbor resampling tends to result in jagged linear features, while bilinear resampling creates "fuzzy" linear features.

1.2.3. Color Correction

An important aspect of any visual interpretation of color balance and associated color correction is proper calibration of the image viewing system. This is achieved through the use of International Color Consortium (ICC) profiles. Quantum Spatial uses specialized software and hardware, to calibrate the image viewing system of computers used for image processing. Calibrations are established to achieve a Gamma 2.0 curve at a color temperature of 6500K.

Quality Control – Color Correction & Mosaicking

All color corrections calculated using automated processes are validated through visual inspection before they are applied.

Quantum Spatial implements color correction of the atmospherically corrected images, for storage and viewing as 8-bits per channel GeoTIFF images, in the final processing step before individual tile are clipped from the mosaic. Images generated from the ortho processing block are loaded into Trimble Inpho OrthoVista to perform the color correction, which allows visual as well as numerical inspection of calculated color corrections in real-time, before the corrections are actually applied to the images. The histogram stretch generally reflects a natural logarithm function; this is necessary to accommodate the way in which the human eye perceives light. Once the histogram stretch has been defined and applied, a simple linear scaling may be performed to arrive at the final 8-bit per channel format.

Once color corrections are finalized for a mosaic product, groups of tiles are generated using the OrthoVista mosaicking module. Image quality metrics for luminosity histogram clipping, luminosity histogram contrast, and luminosity histogram brightness are calculated for each tile. Adjustments are applied using Adobe Photoshop software, and are designed to maintain the relative relationship between RGB triplet values achieved in OrthoVista. No corrections are applied to the near-infrared image channel.

CIR Orthoimages

The Quantum Spatial team will be acquiring this project with all 4-bands on at no additional cost to the City. If the City wishes to receive a CIR orthoimage dataset a final step is implemented where the 4-band imagery is displayed in a false-color infrared representation and reviewed for expected color response in vegetation. The histogram stretch for the near-infrared channel is adjusted as necessary to ensure sufficient differentiation of unique plant species within the sample. The histogram stretch files, seamlines, and tile extents are added to the OrthoVista project definition. The mosaicking module loads the images, seamline definition files, and histogram stretch files into the computer’s RAM, then outputs a color-corrected, 8-bit per channel GeoTIFF image.

1.2.4. Ground Control

Surveying Methods

The Quantum Spatial team believes 31 new photo-identifiable (PhotoID) ground control points are required to support validation of the horizontal accuracy. The Quantum Spatial team uses both real-time correction network (RTCN) and static GNSS surveying techniques to derive coordinates of ground control points. RTCN techniques are implemented in all locations with sufficient network coverage to permit efficient ground control collection. Static techniques are implemented in remote areas where RTCN coverage is not available, ensuring that accurate ground control can be extended anywhere it is needed within the project area.

Control Accuracies

The location, density, distribution, and quality of control needed to support a desired final accuracy is dependent on many factors. Some of these factors include the resolution of the acquired imagery, the final accuracy resolution and desired accuracy standard, terrain, land cover, and the geographic extent of the project area. The control plan will be developed to meet or exceed $ASPRS_{XY}$ = 1ft.

The quality of inputs such as airborne GPS and IMU data also impact the final ground control requirements. Quantum Spatial will establish a custom control layout and plan based on final deliverables defined in the contract award. This plan will be shared for discussion at the project kickoff meeting. The Quantum Spatial team has experience meeting and exceeding accuracy requirements specified by all levels of government agencies and commercial vendors.

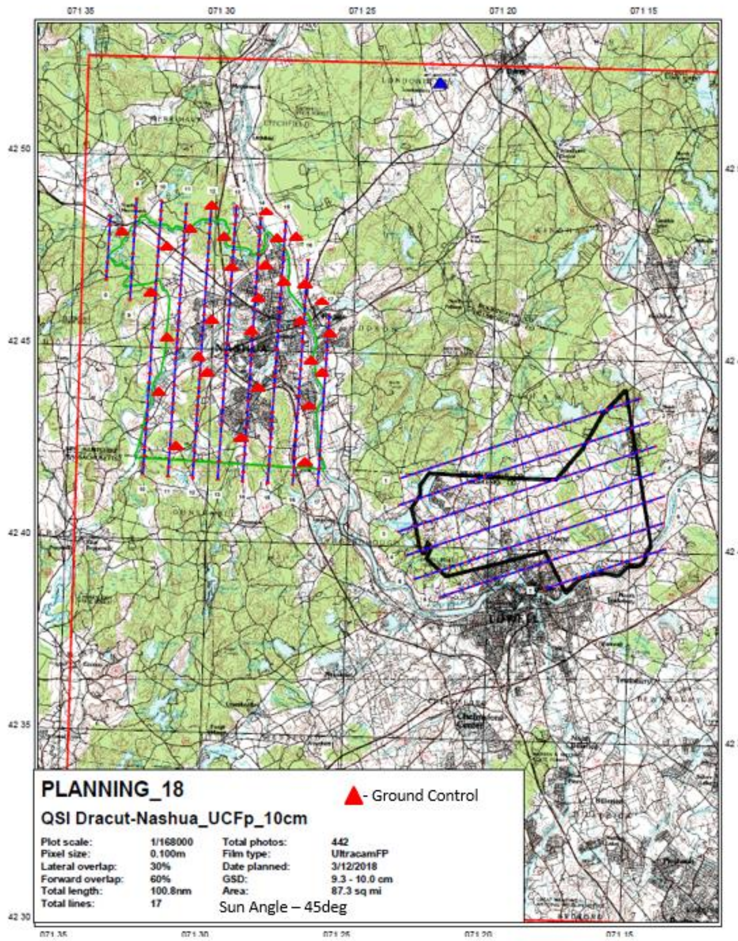

Figure 2: Proposed ground control layout

Quantum Spatial shall approximate and propose the appropriate number of combined ground control points collected between photo-identifiable points and panels to specifically support ASPRS Class 1 standards at 1"=100' scale mapping for the City to review. The specific coordinates will be determined based on local access in the field by our field crews along with the consideration of our flight plans layout.

We will provide a final photogrammetric report detailing the inputs, methods, and outputs from all phases of the project covering any new efforts, including mission planning, ground control survey, image acquisition, and accuracy of final deliverables.

1.3. Planimetric Mapping

Compilation Workflow

Quantum Spatial has experience delineating and classifying a wide variety of planimetric and topographic features from aerial imagery. Our staff of are proficient at feature extraction processing utilizing both monoscopic (heads-up) and stereoscopic (softcopy photogrammetry) methodologies. Quantum Spatial has expertise in planimetric feature extraction, impervious surface analysis, wetlands delineation, land use/land cover interpretation, benthic habitat mapping, and hydrologic analysis to support the National Hydrologic Dataset.

Kick-off

An initial work order production meeting is conducted for the purpose of scope of work confirmation, source imagery review, and detailed discussion of the CADD standards and/or photo-interpretation strategies Quantum Spatial will implement for map production. Related issues include resource allocation strategies, scheduling, budgets and sub consultant coordination.

Set-up Mapping Data and Computing Environment

A standardized data storage environment will be established to mitigate production interruptions that could adversely affect project scheduling. Each Analyst workstation is equipped with high performance NVIDA video cards, 6 GB of RAM, and dual 3.07 GHz processors. Mapping will be performed primarily using the DAT/EM Summit Evolution 7.3 digital stereo plotter software module in conjunction with MicroStation v8i (SELECT series 3) CAD software, however, Esri ArcGIS 10.2.2, AutoCAD 2017, and Global Mapper 17 mapping software are also available and compatible with DAT/EM.

Data Preparation

All source imagery, relevant reference, and ancillary data are pre-assembled and organized to minimize potential task order startup delays. Aerial triangulation will be performed using the Intergraph ImageStation Automatic Triangulation (ISAT) software module and imported into the DAT/EM Summit Evolution Software. Project limits and/or model limits will be generated, if not provided by the client, and all files are checked to insure proper projection, zone, datum, and unit information.

Planimetric Mapping

Quantum Spatial Analysts are able to interpret, capture, and attribute planimetric features stereoscopically using softcopy photogrammetric techniques. Planimetric features are physical features, both natural and cultural, that are independent of elevation, but must be horizontally accurate. These features include transportation surfaces (roads, drives, parking, shoulder, sidewalk, etc.), barriers, drainage, land use/land cover, miscellaneous objects, traffic control devices (traffic lights, signs, etc.), structures, utilities, and vegetation (trees, bushes, etc.). During a planimetric project like this, the same steps are used as a standard full planimetric process but our Spatial Analysts are focused on the changes they see within each stereo image. The Quantum Spatial team will view every stereo image within this project.

Quantum Spatial Analysts are also experienced applying automated and semi-automated feature extraction techniques using the Intergraph ImageStation Automatic Elevations (ISAE) software module to augment the manual softcopy process. This software allows generation of DTM surface data through an auto-correlated Digital Elevation Model (DEM) that can be edited and supplemented with hard breaklines compiled from the imagery.

During the planimetric capture, our internal QA/QC procedures allow for our Project Manager and production team to ensure the maintenance and development of Federal Geographic Data Committee (FGDC) compliant geospatial metadata. When all delivery areas are accepted, this metadata will be supplied as part of the final deliverable.

Delivery

Quantum Spatial is proposing a pilot and four delivery blocks during this project. During all stages of the production period, precise topological integrity and edgematching standards for planimetric data production will be completed. Our internal QC performed by our Certified Photogrammetrist will ensure these standards. We will meet the ASPRS Class 1 accuracy standards the City has on its current dataset at ASPRS Class 1 horizontal accuracy to be 1.0 ft GSD and vertical accuracy be 1/3rd the contour interval for well-defined points, or 0.67 ft (100 scale = 2 ft CI).
A final set of files, and metadata, will be created that will be delivered to the client on media specified in the project scope. Quantum Spatial proposes to deliver final data and map products to the client that are consistent with the standards, protocols, and conventions of the client CAD Standards. For our survey and photogrammetry projects,

Quantum Spatial has extensive experience with all AutoCAD formats (.dgn, .dwg, and .dxf) and ArcGIS formats (shapefile and geodatabase - personal, file, and enterprise).

1.4. Schedule

Milestone Schedule	Start	End
Nashua, NH Project 2018	**3/30/18**	**9/30/18**
Fully Executed Contract	3/30/18	3/30/18
Project Management	3/30/18	9/30/18
Project Kick-off Meeting	3/30/18	3/30/18
Weekly project status reporting (data acquisition & production)	3/30/18	9/30/18
Aerial Imagery Collection	4/01/18	4/30/18
Pre-flight planning	4/01/18	4/15/18
Acquire imagery	4/15/18	4/16/18
Reflights as necessary	4/16/18	4/30/18
Process raw imagery (PPS & virtual review)	4/20/18	4/22/18
Process ABGPS/IMU solutions	4/20/18	4/22/18
Perform initial radiometric adjustments	4/22/18	4/25/18
Geodetic Control Survey	4/01/18	4/30/18
Prepare control plan (new and existing if applicable)	4/01/18	4/01/18
PhotoID control positions (post aerial acquisition)	4/18/18	4/30/18
QA/QC and prepare final survey report	5/03/18	5/04/18
Submit survey report	5/07/18	5/07/18
Aerotriangulation (AT)	4/25/18	5/14/18
DEM Processing	4/25/18	5/30/18
Pilot Data Delivery	5/01/18	6/02/18
Initial pilot delivery to City	5/01/18	5/01/18
City comments	5/12/18	5/12/18
Pilot Delivery to City	5/24/18	5/24/18
Pilot acceptance	6/02/18	6/02/18
Delivery Area 1 – Area defined during kick-off	6/23/18	7/21/18
Initial delivery to City	6/23/18	6/23/18
City comments	7/05/18	7/05/18
Delivery to City	7/14/18	7/14/18
Acceptance	7/21/18	7/21/18
Delivery Area 2 – Area defined during kick-off	8/04/18	9/01/18
Initial delivery to City	8/04/18	8/04/18
City comments	8/16/18	8/16/18
Delivery to City	8/25/18	8/25/18
Acceptance	9/01/18	9/01/18
Full Delivery	9/08/18	9/08/18
City comments	9/21/18	9/21/18
Data Delivery & Acceptance	9/30/18	9/30/18

2. Related Experience – References

Digital Orthoimagery, Topography & Planimetric Updates

During the Spring of 2017, Quantum Spatial was selected by the Town of Hudson, NH for their Aerial Flyover project. Quantum Spatial was tasked to acquire new aerial photography at 4 inch 4-Band (Color and CIR). Along with ground control surveying new 4 inch Color and CIR digital orthoimages were created. At the same time, planimetric update mapping included an impervious layer to support the Towns' stormwater efforts.

The project area is just over 32 mi^2 and encompassed the entire Town of Hudson. The Planimetric map data was photogrammetrically updated from the new digital stereo photography. Mapping was collected at 1"=100' scale using standard photogrammetric methods with Quantum Spatial software product line DAT/EM Summit Evolution.

Client Agency
Town of Hudson

Elvis Dhima
603-886-6008
edhima@hudsonnh.gov

Project Location
Hudson, New Hampshire
Period of Performance
4/2017-9/2017
Key Professional Services
- Aerial photography
- 3D planimetric mapping
- Orthoimagery

City of Marlborough, MA Mapping - Digital Orthoimagery, Topography & Planimetrics

During the Spring of 2017, Quantum Spatial (QSI) was selected by the City of Marlborough, MA for their RFP for City-Wide Planimetric Mapping Services. QSI was tasked to acquire new aerial photography at 3 inch 4-Band (Color and CIR). Along with ground control surveying new 3 inch Color and CIR digital orthoimages were created. At the same time, new planimetric mapping, and 1 foot contours were produced and delivered.

The project area is just over 22 mi^2 and encompassed the entire City of Marlborough. Planimetric map data was photogrammetrically updated from the new digital stereo photography. Mapping was collected at 1"=40' scale for features that were determined by or interpreted from the photography using standard photogrammetric methods with QSI software product line DAT/EM Summit Evolution.

Contracting Agency
City of Marlborough
Nat Bowen, GISP
nbowen@marlborough-ma.gov

Project Location
Massachusetts

Period of Performance
2/27/2017 - 10/27/2017

Key Professional Services
- Photogrammetry
- Surveying
- Aerial data acquisition
- Data processing
- Mapping/GIS services

Town of Peterborough Mapping -Digital Orthoimagery, Topography & Planimetric updates

During the Spring of 2017, Quantum Spatial (QSI) was selected by the Town of Peterborough, NH for their RFP for Aerial Flyover. QSI was tasked to acquire new aerial photography at 6 inch 4-Band (Color and CIR) and LiDAR at 3 points per square meter. Along with ground control surveying new 6 inch Color and CIR digital orthoimages were created along with a LIDAR derived Bare-Earth DEM. At the same time, planimetric update mapping, and 2 foot contours were produced and delivered. A Digital Surface Model (DSM) was also provided.

The project area is just over 38 mi^2 and encompassed the entire Town of Peterborough. The Town elected to further enhance the LiDAR point cloud to include classified points for vegetation and buildings. The Planimetric map data was photogrammetrically updated from the new digital stereo photography. Mapping was collected at 1"=100' scale using standard photogrammetric methods with QSI software product line DAT/EM Summit Evolution.

Contracting Agency
Town of Peterborough
Fash Farashahi
fash@peterboroughnh.gov

Project Location
New Hampshire

Period of Performance
4/06/2017 - 9/30/2017

Key Professional Services
- Photogrammetry
- Surveying
- Aerial data acquisition
- LiDAR data acquisition
- Data processing
- Mapping/GIS services

3. Project Team & Qualifications – Staffing Plan

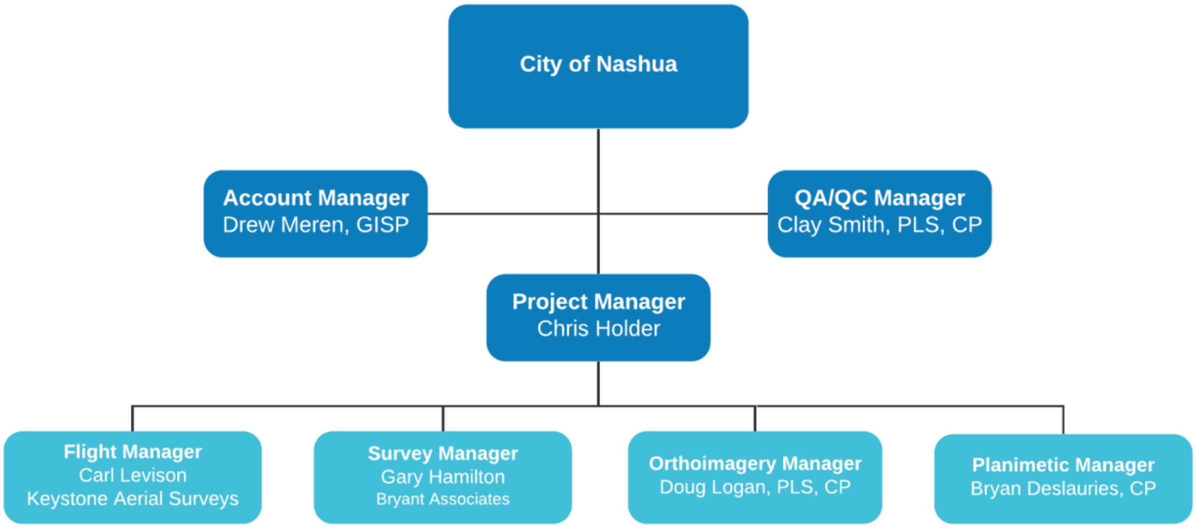

Figure 3: Organizational chart of key personnel

Drew Meren – Account Manager

Drew is responsible for business development efforts as it relates to geospatial state and local government programs and Architectural/Engineering firms along the eastern United States. Drew also participates in identifying new growth markets to provide Quantum Spatial services to. Prior to joining Quantum Spatial, Drew held account management and project lead roles supporting photogrammetric mapping and geospatial data production and analysis. During which, he was primarily responsible for managing existing client relationships, providing estimates for budgeting and proposals, expand relationships with partners, and monitoring project work engagements. Drew has a BS in Geography from Towson University and is a GISCI Certified GIS Professional. Drew joined Quantum Spatial in 2016 with 16 years of experience.

Chris Holder – Project Manager

As a project manager, Chris develops and manages work breakdown structures; prioritizes business and technical requirements; manages resource allocations and timelines; documents and manages risk; specializes in team development; and works with geographically diverse staff. Before becoming a Project Manager, Chris served as a Senior Stereoplotter Operator for the firm's digital Stereocompilation Department. He offers 18 years of experience relating to photogrammetry and mapping. During his career, Chris has guided and coordinated work disciplines to meet the individual specifications of each project. Chris has an MA in Administrative Leadership from University of Louisville and a BA in Geography from University of Kentucky. Chris has been with Quantum Spatial for 18 years.

Clay Smith, PLS, CP – QA/QC Manager

Clay has 38 years of experience providing quality geospatial services with Quantum Spatial. He is an ASPRS Certified Photogrammetrist and a professional land surveyor licensed in North Carolina, South Carolina, and Virginia. For this program, Clay will be responsible for the implementation of Quantum Spatial's Quality Management System by establishing a Quality Policy and Objectives, conducting management review, ensuring the availability of resources, and communicating the importance of meeting client requirements. Clay has expertise in surveying (all types), bathymetry, aerial imagery, GPS and LiDAR data collection and processing, orthoimage generation, DEM/DTM development, AT, compilation, CAD, GIS, and metadata documentation. Clay is active in the American Society for Photogrammetry and Remote Sensing (ASPRS).

Carl Levison – Flight Manager

Carl joined Keystone Aerial Surveys as a Survey Pilot in 2006. Carl is a highly-experienced aerial survey pilot. Lead projects include designing, developing, and maintaining the company's virtual flight board project management/flight dispatch system and air traffic control coordination/mapping software. He is one of Keystone's most experienced aerial survey pilots and is a qualified and experienced flight instructor, operating Cessna 206, 210, 310, 320, 421, 441; Piper Aztec; and Navajo aircraft. He has experience conducting survey flights in numerous operational environments including over mountainous terrain, open ocean, and within congested or highly-restricted airspace. His education includes BSc in Atmospheric Science from the University of Illinois, Flight training from Private Pilot to Multi-Engine Instrument Instructor at the University of Illinois Institute of Aviation, and MSc in Meteorology from the University of Oklahoma.

Gary Hamilton, PLS – Bryant Associates

As Director of Survey for Bryant Associates, Gary is responsible for overseeing the daily operations of the surveying department in their Boston, MA location. Gary is a **Professional Land Survey registered in Massachusetts (No. 33596)**, New York, and Rhode Island. He has nearly 40 years of experience and has worked with almost every public agency within the City of Boston and Massachusetts including: Boston Parks and Recreation Department (BPRD), Boston Water and Sewer Commission (BWSC), Department of Conservation and Recreation (DCR), Massachusetts Bay Transportation Authority (MBTA), Massachusetts Port Authority (Massport), and Massachusetts Water Resources Authority (MWRA). Gary has an AAS in Survey, Forest Technician from Paul Smith's College and has also completed training and coursework for performing aeronautical surveys in accordance with FAA Advisory Circulars 150/5300- 16, 17 and 18; Mean High Water Surveying; Legal Perspectives on Land Surveying Issues III; and Tides and Water Levels for Survey and Mapping. Gary is affiliated with Society of American Military Engineers (SAME) and Massachusetts Association of Land Surveyors and Civil Engineers (MALSCE). Gary was responsible for the oversight of many photo control projects throughout New England including many projects in Massachusetts. Gary has been with Bryant Associates for 24 years.

Doug Logan, PLS, CP – Orthoimagery Manager

With 34 years of experience and 26 years with Quantum Spatial, Doug leads the orthoimagery mapping production at our Lexington, KY facility. He is involved in all digital orthoimagery production; project planning, supervision, and quality control for Intergraph, Arc/Info, and AutoCAD workstation processing. Doug performs digital data collection, editing, and file conversion for MicroStation and AutoCAD. He currently edits and processes data to client specifications, including DTMs. Doug's experienced in the successful delivery of user compatible digital data in a wide variety of formats for military, state and federal government, utility, and private/industrial clients. As an ASPRS Certified Photogrammetrist, Doug is a member of the American Congress on Surveying and Mapping, the American Society for Photogrammetry and Remote Sensing, and the Kentucky Association of Professional Surveyors. Doug has an AS in Electrical Engineering from Lexington Technical Institute.

Bryan Deslauriers, CP – Planimetric Manager

As a Certified Photogrammetrist, Bryan is well versed in national mapping policies and guidance standards. He serves as the supervisor for Quantum Spatial' digital stereo compilation department. Bryan is responsible for monitoring stereoplotter model sets for absolute resolution of the project control, quality control of the digital collection of map features, and the digital collection of elevation data used for the generation of Digital Terrain Modeling (DTM) and contour mapping. Bryan is knowledgeable in the use of Microstation, ArcGIS, SOCET SET, and SoftPlotter feature extraction systems. He is an active member of the American Society for Photogrammetry and Remote Sensing and the Florida Surveying and Mapping Society. Bryan has 11 years of experience with Quantum Spatial and has a BS in Earth Science from Frostburg State University.

4. Price Proposal

City of Nashua, New Hampshire
Base Proposal – Plan, Topo (2ft), 4-inch Ortho
Price Proposal

Price include services as specified in RFP.
Task numbers are coordinated with RFP scope items

Option 1 – New Planimetric Mapping, Topographic Mapping (2ft) and 4-inch Orthos

4.1	Flight and Aerial Photography	$4,589.00
4.2	Ground Control, FAAT	$11,106.00
4.3	Planimetric Mapping	$148,674.00
4.4	Topographic Mapping	$11,726.00
4.5	Color Digital Orthophotography	$2,687.00
4.6	Infrared Digital Orthophotography	$1,075.00
Project Total Cost:		**$179,858.00**

Comments: None

Name of firm: Quantum Spatial, Inc.

Authorized Signature: ____________________
Printed Name: Robert Vander Meer
Date: 3/16/2018

City of Nashua, New Hampshire
Base Proposal – Plan, Topo (1ft), 2-inch Ortho
Price Proposal

Price include services as specified in RFP.
Task numbers are coordinated with RFP scope items

Option 2 – New Planimetric Mapping, Topographic Mapping (1ft) and 2-inch Orthos

4.1	Flight and Aerial Photography	$15,185.00
4.2	Ground Control, FAAT	$16,240.00
4.3	Planimetric Mapping	$205,631.00
4.4	Topographic Mapping	$14,449.00
4.5	Color Digital Orthophotography	$5,751.00
4.6	Infrared Digital Orthophotography	$2,151.00
Project Total Cost:		**$259,406.00**

Comments: None

Name of firm: Quantum Spatial, Inc.

Authorized Signature: ____________________
Printed Name: Robert Vander Meer
Date: 3/16/2018