Mississippi Department of Transportation State Study No. 214

Final Report

MDOT Implementation Plan for Global Positioning Systems (GPS) Technology in Planning, Design, and Construction Delivery.

Research Conducted by The University of Southern Mississippi, School of Construction

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6. Abstract

Global Positioning System (GPS) technology offers advantages to transportation agencies in the planning, design and construction stages of project delivery. This research study will develop a guide for Mississippi Department of Transportation (MDOT) implementation of GPS technology, both internally and externally, assisting the agency in the areas of construction specifications, quality control, business policies and procedures, and cost budgeting. This study will result in the delivery of a report that includes recommendations for specification language regarding contractor use of GPS for automated machine grading and the sharing of MDOT electronic data. This report will include a suggested plan for implementation of GPS technology in the MDOT corresponding functional areas. Workshops will be delivered with the participation of MDOT personnel and construction company representatives centered on the GPS Guidance Specification and Implementation Plan to facilitate their adoption.

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Summary of Research Conducted

Mississippi Department of Transportation State Study No. 214 consisted of the creation of a Draft Special Provision for contractor use of Automated Machine Guidance (utilizing Global Positioning Systems, GPS, as the machine positioning technology) on construction projects. The draft specification was developed by facilitation of the project investigators under the guidance of the agency's Technology Advisory Committee (TAC) and with significant feedback from the industrial stakeholders in the Mississippi Department of Transportation (MDOT) construction programs. Figure 1 displays the major tasks involved in the research project with general inputs and outputs from each function. The Roman Numerals in the task boxes represent corresponding sections of this Final Report.

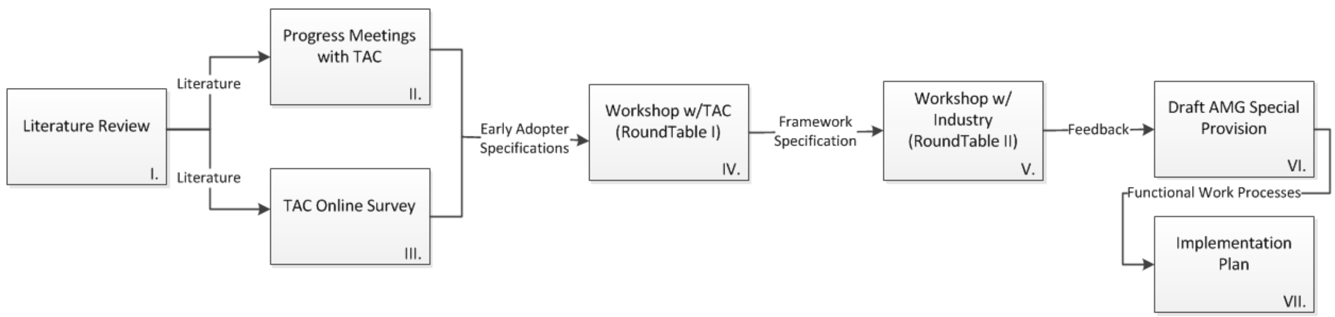

Figure 1: Major Tasks and Work Flow of MDOT State Study No. 214.

I. Literature Review

A review of literature pertaining to Automated Machine Guidance (AMG) was conducted through internet and online database searches. At the onset of the project, in 2008, much of the applicable information was contained in presentation materials which agencies and contractors developed for conferences and meetings. Attendance at the Transportation Research Board (TRB) Annual Conferences resulted in identification of the national community of stakeholders and organizations interested in and concerned about AMG. Some of the agency AMG specifications utilized in the Round Tables (workshops) were not published or available through the internet, and contacts made at TRB resulted in the discovery of their existence. Agency AMG specifications utilized were as follows (see Appendix A):

- California: Non Standard Special Provision Draft for a Project.
  District 11, San Diego
- Colorado: Pilot Project Special Provision.
  Revision Of Section 625 - Survey Control Of Grading By GPS Or RTS Methods.
- Iowa: Developmental Specifications For Global Positioning System Machine Control Grading, September 18, 2007.
  Section 01103, Standard Specification Series 2001
- New York: Changes to Standard Specifications

Section 105-10, Survey and Stakeout
Section 625, Survey Operations, ROW Markers, and Permanent Survey Markers
Section 625-3, Construction Details

- Wisconsin: Specification for 2008 Pilot Project
  Section 650.3.3 Subgrade
  Section 650.4 Measurement

II. Progress Meetings with TAC

Progress and Planning meetings with the MDOT State Study No. 214 TAC took place on the following dates:

November 17, 2008	MDOT Headquarters, Jackson, MS
February 20, 2009	MDOT Headquarters, Jackson, MS
March 6, 2009	MDOT Headquarters, Jackson, MS
June 5, 2009	MDOT Headquarters, Jackson, MS
August 12, 2009	MDOT Headquarters, Jackson, MS
March 25, 2010	MDOT Headquarters, Jackson, MS

III. TAC Online Survey

The Technical Advisory Committee was surveyed on their opinions regarding various content of the draft special provision language which constituted the basis of discussion for Round Table 1. The survey questions can be viewed in Appendix B.

IV. Workshop with TAC (Round Table 1)

Round Table I: October 15, 2009 Thad Cochran Center, The University of Southern Mississippi

V. Workshop with Industry (Round Table 2)

Round Table II: December 10, 2009 Thad Cochran Center, The University of Southern Mississippi

This event was held to gain feedback from Automated Machine Grading (AMG) stakeholders on a draft Special Provision developed by the project Investigators and Technology Advisory Committee (TAC) in Round Table 1. A total of 53 persons participated in the full day event with representations from MDOT, Mississippi construction contractors, construction equipment vendors, and AMG software vendors.

The intention of the roundtable was to invite feedback from MDOT contract stakeholders interested in utilizing AMG technology on construction projects. An initial list of AMG agency personnel, construction contractors, construction equipment vendors, and AMG software and hardware vendors was developed. Email invitations were sent to the contacts of the list with a link to a website created for registration of the workshop participants. Two industrial professional associations where contacted to advertise the workshop date and provide a link to the registration website: The Mississippi Roadbuilders Association, and the Mississippi Asphalt Paving Association. Once the participants registered for the workshop, they were sent logistical information regarding attendance at The Thad Cochran Center of The University of Southern Mississippi.

The Investigators created four groups out of the registered attendees. The groups were chosen in an attempt to diversify the roster between stakeholder interests (agency, contractor, and vendor personnel). The intent was to spur discussion of possible competing interests and diverse points of view within each team in regards to the draft specification future Special Provision). Each team at the workshop was given its own space in the room with a set of tables and chairs arranged in a square. Each group was also provided a computer with a standard comment form to record feedback on the specification (fields included 'Issue' and 'Proposed Remedy'). The facilitators (Investigators) displayed and explained the specification to the group section by section. After an overall introduction and explanation of the draft specification by the facilitators, the break-out groups were tasked with discussing each section amongst themselves and recording any issues and proposed remedies concerning that section on the team's comment form. To record the discussion a computer 'scribe' was designated by each group. There were three such break-out sessions corresponding to the sections of the specification. The team 'scribes' then submitted the comment forms to the facilitators via flash drives and the forms were printed on 36inch x 24inch paper and taped to the meeting rooms walls. In the final session of the workshop, a designated spokesperson for each break-out team presented their team's issues and remedies to the group as a whole (with limited but robust discussion). All participants were given ten 'dot stickers' and instructed to vote for the most important issues in their opinion by placing the stickers on the wall paper comment forms.

The results of the workshop session can be seen in Appendix C. A summarization of stakeholder concerns and issues are shown in the following three tables. The facilitators (project investigators) of the workshop categorized the stakeholder feedback into the following subject areas:

Data Format of EED: This tag represents issues pertaining to Electronic Engineered Data (EED) and digital file formats involved with AMG data exchange between agency and contractor. This data includes all types of capital project related engineering data which is used for the defining, developing, designing, documenting, spatially locating, constructing, and historical recording on a MSDOT Capital Project. This includes Documents and

Publications, Geospatial Data, Digital Terrain Models, and Graphics Information.

Sharing Equipment (Rovers):
This tag represents issues pertaining to the sharing of equipment between agency and contractor, typically GPS receivers (rovers) for checking location/position accuracy.

Specification Language:
This tag represents issues pertaining to terminology, word, reference, and phrase usage of the specification language.

Duties-Risks: This tag represents issues pertaining to risks and duties associated with the AMG specification.

QA/QC: This tag represents issues pertaining to quality assurance and quality control in reference to the specification and AMG process in general.

Process Sequence: This tag represents issues pertaining to the sequencing of the stakeholder tasks, duties, and responsibilities associated with the scope of the specification.

Training: This tag represents issues pertaining to training and competencies associated with AMG and the draft specification.

Subject Area	Stakeholder Issues Submitted	
QA/QC	14	31%
Duties-Risks	9	20%
Data Format of EED	6	13%
Specification Language	5	11%
Sharing Equipment (Rovers)	4	9%
Training	4	9%
Process Sequence	3	7%

Table 1: Round Table 2 Issues Submitted by Stakeholder Groups

An 'issue' was a concern identified by groups in the workshop having to do with the draft special provision that was presented or anything specific to the AMG project delivery process. When the groups identified an issue, they were also tasked with identification of a remedy. Issues and remedies proposed by all the workshop groups can be viewed in the appendix. As can be seen in Table 1, quality assurance and quality control (QA/QC) issues had the most submissions, followed by duties of the stakeholders (in the AMG process). These two areas of concern constituted over half of all the stakeholder issues.

Subject Area	Stakeholder Votes Submitted	
QA/QC	152	30%
Data Format of EED	107	21%
Sharing Equipment (Rovers)	91	18%
Process Sequence	65	13%
Duties-Risks	46	9%
Training	30	6%
Specification Language	18	4%

Table 2: Round Table 2 Votes Cast by Issue Subject Area

Table 2 represents the value of concern to the stakeholders in the workshop to the submitted issues and remedies. When the Table 1 data was presented to the entire group, each individual had the same number of votes to express importance of the issue/remedy. As can be seen in the table, the most important concerns where contained in the subject areas of quality assurance/quality control and the use and exchange of Electronic Engineered Data (EED). In this table, these two subject areas of the AMG process constituted approximately half of all the major concerns of stakeholders.

Table 3 expands the stakeholder priorities of Table 2 into detail showing the ten issues garnering the highest number of votes. The issue receiving the most votes was when (sequentially) in the AMG process that MDOT was planning to share EED with contractors (either before or after the bidding stage).

Topic Section	ISSUE	REMEDY	VOTES
Process Sequence	Timing of providing this information. (EED)	Allow at PREBID	42
Duties/Risk Sharing Equipment	Final Inspection—Who verifies the correctness of the model? How do we know if DTM is good? Specify whether contractor must provide MDOT with a Rover on demand or entire project.	MDOT should have its own equipment for checks. Inspection should be done by an independent method.	37
Data Format for EED	MDOT uses Geopak and would need to import DTM into it, or contractor would export to .dgn file. How do we handle version changes of MicroStation/Geopak?	Land XML files seem to work best for contractors, and maybe we shouldn't limit file format to .dgn.	36
Data Format for EED	Section 5. there is a file format available that will combine much of the information or files	Propose that MDOT consider generating a Land XML file and make that information available.	33

	listed in this section		
Sharing Equipment	Contractor shall provide Engineer with equipment to be returned at end.	Contractor to keep equipment and make it available upon request for use. Equipment may have to have operator since many variable systems could be used. Equipment/Operator will keep equipment.	30
Data Format for EED	Upgrade of software that may not be available to Contractor before MDOT has it.	Possibly send out in format that everyone can use like xml, dwg, txt. Non Proprietary Also give COGO, existing cross section, design cross section, subbase cross section.	26
QA/QC Quality Assurance Quality Control	Control and Calibration	In the front end MDOT and the contractor(s) agree on accurate, visible, and accessible benchmarks. There should be a calibration report showing what is out of tolerance, what's good etc. Some contractors feel that DOT should specify secondary controls. There should be a statewide standard for all to follow.	24
QA/QC Quality Assurance Quality Control	What about contractors who do not have AMG expertise? Smaller contractors will not get as much practice, therefore may not gain experience.	Specify test sections at first, then when contractors gain experience, they can use prior experience to show qualifications. There must be checks on regular intervals or phases.	24
QA/QC Quality Assurance Quality Control	Need to require the contractor to perform a test section in order to demonstrate his ability and the system's ability to meet the project requirements	Specify a test section (field trial)	23
Training	Section 3, No. 2 - Experience of automated systems – need experienced personnel on project with previous experience in automated systems.	Consider quantifying related experience and/or formal training in automated machine control.	18

Table 3: Round Table 2 Issues and Remedies Receiving Top Ten Votes

VI. Draft AMG Special Provision

See Appendix D for the final submitted Draft AMG Special Provision. The Round Table 2 stakeholder feedback was presented to the Technical Advisory Committee in the form of an interim report: 'Report of Findings for Stakeholder Round Table 2', dated February 16, 2010. This report was used as the basis for finalizing the draft special provision with the TAC in a meeting held at the Mississippi Department of Transportation in Jackson, MS on March 25, 2010.

VII. Suggested GPS-AMG Guidance Specification Implementation Plan

Based upon the research conducted on this project, the MDOT implementation plan and recommendations for automated machine guidance encompasses five main areas:

A. MDOT Pre-Construction Processes and Capabilities
B. MDOT AMG Procedures with Draft Special Provision
C. Transfer of Electronic Engineered Data (EED)
D. Quality Assurance and Control of AMG Field Operations
E. Barriers to Implementation

This report utilizes the Integrated Definition 0 (IDEF0) flowcharting method as a basis of the work flow process diagrams. In some instances the Control and Mechanism arrows are omitted and the Task/Function boxes will have various text and numerical identifiers. IDEF methodology is a suite or family of methods that is capable of modeling activities, functions, information and processes of an enterprise and its business areas. An example of IDEF0 flowcharting can be seen in Figure 2.

- For IDEF0 diagramming purposes in this study, a function will be defined as primary tasks performed by the functional units or an activity that transforms inputs into outputs.
- Input is defined as information (data) that is required to perform a function.
- A Control is a condition or circumstance that constrains a functional activity (when used).
- A Mechanism is person, machine, or software application that performs a functional activity (when used).
- An output is the product of a Function and possibly the input to a successive function.

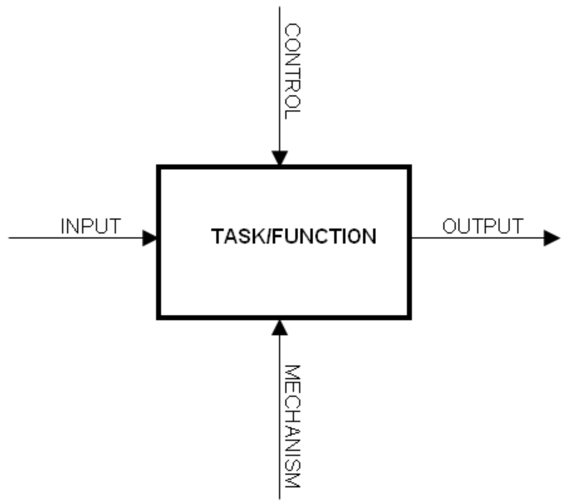

Figure 2: IDEF0 Flowcharting Legend

A. MDOT Pre-Construction Processes and Capabilities

A Digital Terrain Model (DTM) is required for automated machine guidance (AMG) and can be defined as 'a three-dimensional topographic surface, typically consisting of a triangulated irregular network (TIN) connecting spot elevations and vertices of break lines chosen to represent the terrain. An original ground DTM represents the undisturbed ground surface prior to construction. A design DTM represents any of a number of surfaces proposed by a design (e.g., sub grade, base course, finished pavement). An as-built DTM represents any of a number of designed surfaces as they were actually constructed.'(Vonderohe, 2009)

Figure 3 represents the sequential tasks and required inputs and outputs of Electronic Engineered Data for the creation of a project specific DTM.

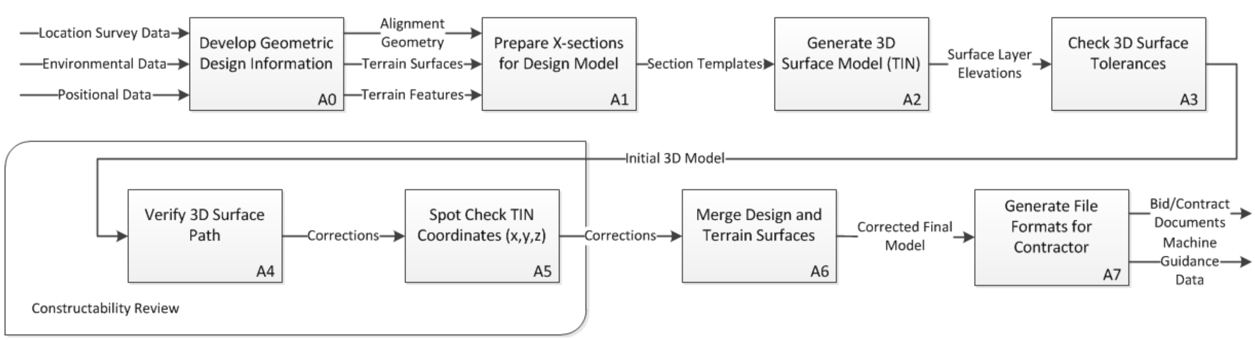

Figure 3: DTM Processes (Mark Taylor, 2010)

The diagram is drawn in the context of a transportation agency, but the process is similar for construction contractors. Contractors which utilize AMG must supply a Triangulated Irregular Network model, or TIN model (see Appendix E), to their machines so that positioning technologies (such as GPS) can orientate the machine end-effector (blade or bucket cutting edges for example) in the model (the model is georeferenced to the physical world). The creation of a TIN model is currently accomplished by one of the following methodologies:

1-The model is created from ‘scratch’, reverse engineering 2-dimensional drawings (paper plans) for creation of the 3-dimensional TIN model (DTM) utilizing specialized software applications.

2-The model is created with EED from the designer. In the case of MDOT, the EED to be shared is listed in the final section of the special provision:

- Project Control - (Microstation DGN file and ASCII file)
- Existing Topographic Data - (Microstation DGN file(s))
- Preliminary Surveyed Ground Surface - (GeoPak TIN) (If available)
- Horizontal and Vertical alignment information - (GeoPak GPK file and/or Microstation DGN file(s))
- 2d Design line work (Edge of Pavement, Shoulder, etc.) - (Microstation DGN file(s))
- Cross sections - (Microstation DGN file(s), GeoPak format)
- Superelevation - (Microstation DGN file(s), GeoPak format)
- Form Grades - (Microstation DGN file(s))
- Design Drainage - (Microstation DGN file(s))

Contractors with experience in AMG spend a considerable amount of time confirming that their DTM is in conformance with the project’s ‘official’ drawings as a best practice. This quality assurance measure holds true for either of the methods stated and is the basis for arguably one of AMG’s greatest benefits to MDOT and the taxpayers of Mississippi—for it is in this quality assurance/conformity assurance that the greatest amount of communication between owner and contractor occur regarding the design intent for the project. This communication acts as a constructability review for both of the parties and is reported to have revealed the identification of design errors and interpretations well in advance of construction field operations, therefore decreasing the occurrence of rework (uncompensated correction of work in place) and change orders or claims (compensated correction of work in place due to design errors).

DTMs utilized by the contractors for enablement of AMG will still require data manipulation and conformance review to the contractual design intent, even when EED is supplied from designers and surveyors (Planning and Design Functions). The level of detail required in a DTM for machine guidance often exceeds that which is required for the project drawings. The DTM used for machine guidance should be considered equivalent to working drawings. Section 105.02 of the *Mississippi Standard Specifications for Road and Bridge Construction*, 2004 Edition, states:

> ‘*The plans will be supplemented by working drawings as necessary to adequately control the work. Working drawings shall be furnished by the Contractor as required for the completion of the work. Except where otherwise specified, working drawings shall be approved by the Engineer but such approval will not relieve the Contractor of any*

> *responsibility. Working drawings shall not be considered as plan changes and any conflicts on working drawings, whether approved or not, shall not supersede the requirements of the original plans and specifications.*'

If the DTMs to be used for machine guidance are treated as working drawings (requiring submittal, review, and acceptance), then determination of the design intent will be verified by the agency. If required, the surveyors and designers can be involved in the review and acceptance. This should be considered a positive opportunity as it initiates the communication process required for constructability review and the avoidance of unintentional results in the field. The MDOT Draft AMG Special Provision includes a disclaimer clause limiting liability for the accuracy of the EED shared with the contractor. Many state agencies are requiring liability waivers to be signed by the contractor before the exchange of EED occurs. MDOT should refer to legal counsel in consideration of such a practice. The Minnesota Department of Transportation utilizes the following disclaimer clause:

> '*Mn/DOT believes the electronic data it will provide is accurate, but does not guarantee it. The documents originally provided with the Contract remain the basis of the Contract, and the electronic data being provided is for informational use only in order to assist the Contractor with the use of machine control. Therefore, if use of this data causes an error, any costs to the Contractor in time or money to make corrections as a result of this error will not be considered extra work*'.(Dillingham, Jensen, & Schulist, 2007)

It is not yet known if accuracy of shared EED equates to the accuracy of the DTM as far as courts or arbiters in the United States are concerned. For example, the shared EED may be accurate as far as design intent, but the DTM utilized for machine control could contain errors. Section 4.B.3 of the special provision clearly states that such a situation is not compensable by MDOT. It may take some period of time before there is legal precedent on issues pertaining to design liability (implied design warranty precedent in D-B-B project delivery). Because of this lack of legal definition by the courts, there is a 'grey area' in relation to the liabilities involved in AMG processes. For these reasons, it is of paramount importance for the DTM which is to be used for AMG be reviewed by the agency and checked for both conformances to the design as well as constructability (Section 3.10 of the MDOT AMG Draft Special Provision).

Some states are legislating that only professionally licensed surveyors or engineers (or those in their 'responsible charge') can create the DTMs to be utilized for machine guidance. In as far as such legislation has the purpose of ensuring conformance and competence, it would appear to the author that the working drawing submittal process is intended to achieve the same result. It is also currently not known if these professionals have the competency or experience to produce DTMs for machine guidance as these are separate skills currently learned through experience and training which is only now emerging in academia and continuing education.

Electronic Engineered Data (EED), in the civil construction domain, will be defined as data required for creation of a Digital Terrain Model, or a three dimensional representation (surface model) of what is intended to be constructed. This data includes all types of capital project related engineering data which is used for the defining, developing, designing, documenting, spatially locating, constructing, and historical recording on MDOT Capital Projects (including Documents and Publications, Geospatial Data, Digital Terrain Models, and Graphics Information).(AGC/DOT Subcommittee on Emerging Technologies, 2008)

A high-level process diagram for automated machine guidance (AMG) is shown in Figure 4, where the process function A1, Design Model Creation represents a three-dimensional, digital design file. In theory and capability (but not in common practice according to our research), process functions A3 and A0 can be connected with input and output lines forming an iterative process of as-built project data utilized for new or retrofit projects and other agency applications such as Geographical Information Systems (GIS).

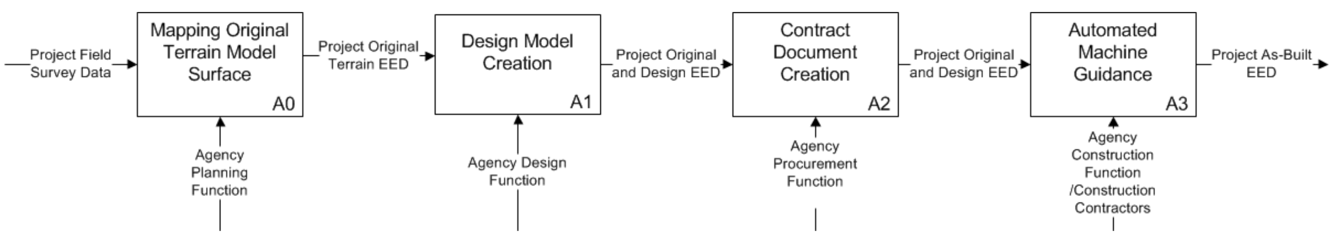

Figure 4: General Automated Machine Guidance Process (Hannon, 2008)

Figure 4 displays Mechanisms consisting of distinct agency functions (as opposed to 'divisions' which vary across different transportation agencies). The Agency Functions (Functional Areas) are defined as follows:

Agency Planning Function: primarily responsible for project initiation and feasibility study as well as collecting data for the design functional area for decision making.

Agency Procurement Function: responsible for advertising and awarding the construction contracts to outside construction contractors, including all documents and processes required by applicable statutory regulations.

Agency Construction Function: responsible for managing the physical construction of the facility in the field, documenting work progress, monitoring project quality and safety, and processing change orders and contractor payment requests.

In regards to MDOT, some of the divisions perform multiple functional processes in construction project delivery and of the District Offices are responsible for multiple functions. For the purposes of this report, the emphasis is on the Planning and Construction Functions, as the

Design Function was removed from consideration of this study by addendum to the scope. Figure 5 represents the MDOT Divisions encompassing the scope of this project.

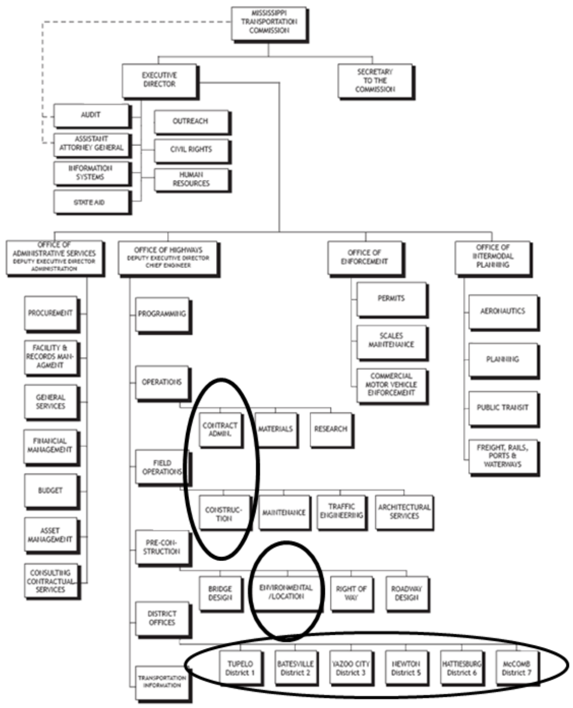

Figure 5: MDOT Divisions

Existing MDOT procedures where documented from investigator interviews of the TAC members both internal and external to the progress meetings listed in Section II. Figure 6 illustrates existing discovered pre-construction work flow processes. Currently, the AMG process for contractors begins after function P3. Digital Terrain Models (DTMs) are created from the paper two dimensional drawings issued for bidding and construction contracts. As the AMG adoption rate by contractors has grown in the last few years, MDOT has shared EED with contractors which request it (in order to develop their own project DTM for machine guidance).

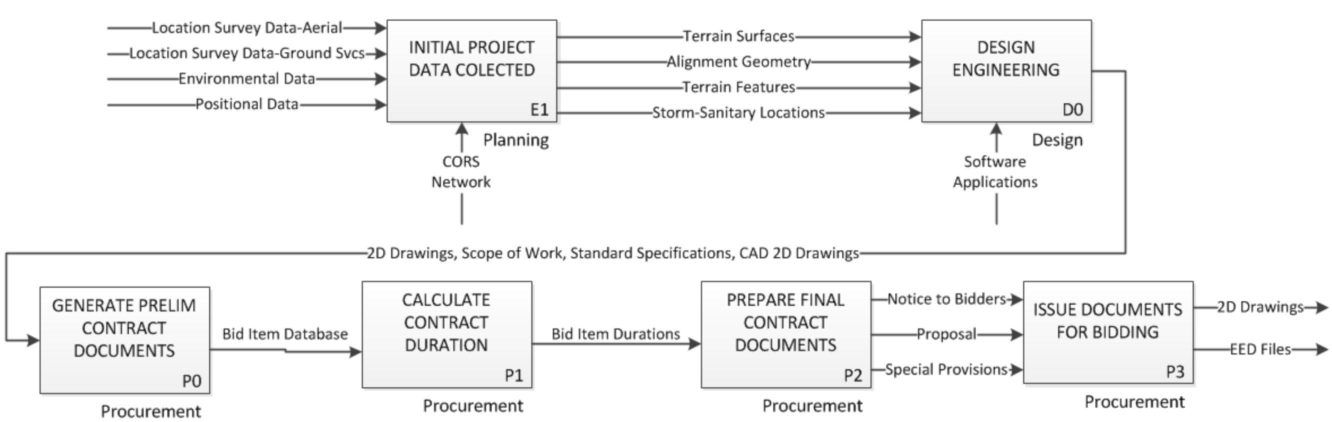

Figure 6: MDOT Existing Pre-Construction Work Flow/Data Flow Processes

B. MDOT AMG Procedures with Draft Special Provision

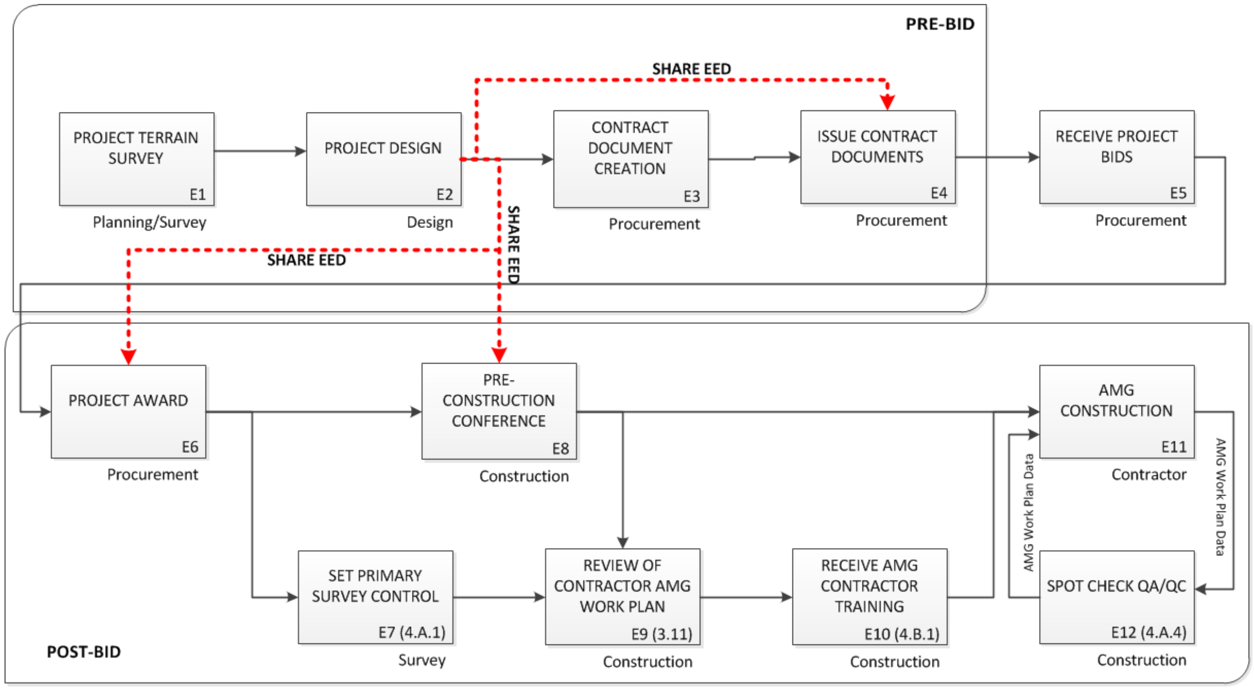

Figure 7: MDOT Work Flow Process Utilizing AMG Special Provision

Figure 7 displays AMG processes contained in the MDOT Draft AMG Special Provision. The process functions or tasks are labeled in the lower left with an alpha-numeric designation by which they are described below. Instead of an IDEF0 mechanism arrow, the Functional Area responsible for the function is listed below the box.

E1-Project Terrain Survey: This task consists of collection and documentation of original ground surface information and data. This data includes location, traffic, environmental, and survey data. The survey data output by this task contains positional data on terrain surfaces and features, alignment geometry utilized for primary survey control and documentation of existing utility/infrastructure locations. The data is collected via aerial (photogrammetric) or ground (Total Station Collectors) MDOT services. The ground services are aided by a statewide network of Continuously Operating reference Stations (CORS) and Real-Time Kinematic Geographical Positioning Systems (RTK GPS). The outputs of this task become the inputs of the Project Design task (E2).

Involved Agency Functional Roles: Surveyor, Engineer
Functional Role Competencies: Surveying (RLS), RTK GPS, photogrammetry, Total Station collectors
MDOT AMG Draft Special Provision Reference: N/A

E2-Project Design: This very broad task encompasses scope determination of the planned project (facility), decision analysis of possible alternatives, and production of construction (contract) plans and working drawings. Currently at MDOT, the design intent from this task output is communicated with the construction contractors via two-dimensional paper plan drawings which are considered the official and original contract documents along with the specifications, for adequately controlling the work.

Involved Agency Functional Roles: Design Engineer
Functional Role Competencies: Engineering (PE)
MDOT AMG Draft Special Provision Reference: N/A

E3-Contract Document Creation: This task involves the creation and assignment of standard, supplemental, and standard specifications to the project scope, generation of bid items and quantities for the Notice to Bidders, proposal, and contract.

Involved Agency Functional Roles: Contract Administrator
Functional Role Competencies: Not directly attributable to AMG
MDOT AMG Draft Special Provision Reference: N/A

E4-Issue Contract Documents: This task involves finalization of scope and preliminary contract documents and bid item durations for issuance to bidders.

Involved Agency Functional Roles: Contract Administrator
Functional Role Competencies: Not directly attributable to AMG
MDOT AMG Draft Special Provision Reference: N/A

E5-Receive Project Bids: : In this task the agency procures a construction contractor by receiving bids (in periodic Bid Lettings) and awarding construction contracts for completion of the work.
Historically included in these bidding documents are 2D plans and working drawings.

Involved Agency Functional Roles: Contract Administrator
Functional Role Competencies: Not directly attributable to AMG
MDOT AMG Draft Special Provision Reference: N/A

E6-Project Award: This task consists of selection of the lowest qualified bidder and executing a construction contract for completion of the work to that bidder.

Involved Agency Functional Roles: Contract Administrator
Functional Role Competencies: Not directly attributable to AMG
MDOT AMG Draft Special Provision Reference: N/A

E7-Set Primary Survey Control: This task refers to the agency provided primary project survey control, (x,y,z) survey referenced to the Mississippi State Plane Coordinate System and typically based upon the National Geodetic Reference System (NGRS). The intent of this task is to provide reference to the contractor so that it can set secondary survey control.

Involved Agency Functional Roles: Surveyor
Functional Role Competencies: Surveying, RTK GPS, Total Station collectors
MDOT AMG Draft Special Provision Reference: Section 4.A.1

E8-Pre-Construction Conference: Pre-Construction conference meetings are a part of the business processes for all MDOT construction projects. Section 108.03.2 of the Mississippi

Standard Specifications for Road and Bridge Construction, 2004 Edition state: ' Prior to commencement of the work, a preconstruction conference shall be held for the purpose of discussing with the Contractor essential matters pertaining to the prosecution and satisfactory completion of the work.' This task is additionally important for projects which will utilize AMG technology as the draft AMG Special Provision requires the Contractor to deliver an Automated Machine Guidance Work Plan at this meeting.

Involved Agency Functional Roles: Project Engineer
Functional Role Competencies: Construction planning and scheduling
MDOT AMG Draft Special Provision Reference: Section 3

E9-Review of Contractor AMG Work Plan: This task may be the most crucial of all elements associated with the special provision and AMG project delivery. The AMG Work Plan is a contractor deliverable to be submitted at the Pre-Construction Conference before kick-off of the project. It is desired, but not stated in the special provision language that the contractor would present and discuss the work plan in the pre-construction meeting. The provision's language requires the agency Engineer to review the submittal for conformance to the special provision, as well as any subsequent changes or alterations to the Contractor's AMG plan or system. Throughout the Round Table workshops, inclusion of this requirement was made in the spirit (intent) of fostering communication between the agency and the contractor regarding expectations and information transfer. The AMG Work Plan must define the following at a minimum:

- Detailed specifications of the AMG system components.
- Information revealing the contractor's personnel that will implement the AMG system and their level of experience and competency.
- The scope and boundaries of the project work which will be affected by the contractor's AMG system.
- Communication and expectation of how secondary survey/stakeout control will be established.
- Quality control calibration procedures and frequency for all equipment in the contractor's AMG system as well as plans for historical documentation (logs) for the life of the project AMG work.
- A schedule describing the methodology and frequency for field verification spot checks and how this information will be communicated to the agency engineer.
- Contingency plan(s) in the event of AMG System failure/outage or out of tolerance performance.
- A schedule defining the methodology and frequency for the contractor to share the DTM(s) with the agency engineer for review, feedback, and communication.

The sharing of the DTM between the stakeholders constitutes a collaborative constructability review of the project work and design intent for the area of the project encapsulated by the model. The literature review has revealed that agencies and contractors are reporting considerable benefits in finding design or stakeout/survey issues prior to commencing the work (thus allowing for mitigation before work stoppage and/or rework is required). If the agency will diligently enforce the elements of the AMG Work Plan, it is anticipated that MDOT will enjoy these benefits as well. The concern is that if the AMG Work Plan were to become just another 'paper submittal' required for the contractor to file with the agency, these benefits will not only not be realized, but there could potentially be more problems and/or issues than if AMG was not utilized at all. The literature also reveals that when the agency engineers become involved with AMG, they begin to realize the benefits of working in 3D while utilizing the contractor's DTM and GPS rover to check grades and calculate pay quantities much more efficiently.

In Round Table II, the contractors were concerned about the period of time that the engineer would be given for review of the work plan. While the special provision is silent on this matter, it would seem equitable to define a reasonable amount of time for turnaround and feedback of this review process in order to avoid delay of AMG-related construction work.

MDOT is also encouraged by this investigator to document the historical successes and failures of the AMG Work Plans submitted and utilized under this special provision. A documented history of implementations should be congregated in one repository, such as a website or 'wiki' board, and periodically reviewed by agency personnel (the Construction Engineer and/or TAC members of this project) so that improvements based upon failure and success can be incorporated into successive versions of the special provision, and possibly at some point the standard specifications.

Involved Agency Functional Roles: Project Engineer
Functional Role Competencies: Knowledge of surveying/stakeout, GPS, QA/QC requirements and tolerances, basic AMG principles (contractor will orient agency personnel to their AMG system via mandated formal training by the contractor in the special provision), use of DTM for constructability review and as-built documentation.
MDOT AMG Draft Special Provision Reference: Section 3

E10-Receive AMG Training: This task involves contractor training of agency personnel specific to each project which involves the AMG special provision. The clause in the provision reads,

> ' *The Contractor shall provide formal training, if requested, on the use of the Automated Machine Guidance Equipment and the Contractor's systems to MDOT project personnel prior to the start of construction activities utilizing AMG. This training is for providing MDOT project personnel with an understanding of the equipment, software, and electronic data being used by the Contractor.*'
>
> In the AMG Work Plan section of the provision (Section 3), the final sentence reads. ' At the conclusion of the Pre-Construction Meeting, the Contractor and MDOT will agree on the quantity and schedule of Contractor-provided training on the utilized AMG system required under 4-B.1.'

The special provision language which was presented to the contractors (and other stakeholders) in the Round Table 2 workshop originally stated that the Contractor would provide the Engineer with equipment (GPS rover) to be returned at the conclusion of the project. It also stipulated that eight hours of formal training would be provided to the agency by the Contractor. As a result of the stakeholder interaction in the workshop (issues and remedies submitted on the topic), it was proposed that the contractor would provide training and equipment upon request by the agency. The MDOT AMG Draft Special Provision is silent on the sharing of a GPS Rover.

Involved Agency Functional Roles: Project Engineer and staff
Functional Role Competencies: Knowledge of surveying/stakeout, GPS, QA/QC requirements and tolerances, basic AMG principles (contractor will orient agency personnel to their AMG system via mandated formal training by the contractor in the special provision), use of DTM for constructability review and as-built documentation.
MDOT AMG Draft Special Provision Reference: Section 4.B.1

<u>E11-AMG Construction</u>: In regards to the actual AMG construction process itself, MDOT has not been restrictive in regards to systems or equipment. In effect the special provision is a performance specification with the exception of some required conventional grade stakes and that the DTM and AMG system not use localized coordinates, but rather the Mississippi State Plane Coordinates.

Involved Agency Functional Roles: Project Engineer and staff
Functional Role Competencies: Contractor will orient agency personnel to their AMG system via mandated formal training by the contractor in the special provision.
MDOT AMG Draft Special Provision Reference: Section 2, Section 4.B.9

<u>E12-AMG QA/QC</u>: This function enables the project engineer to check the accuracy of ' machine control grading results, surveying calculations, records, field procedures, and actual staking' and uses the term 'spot checks as necessary' to ensure compliance with the specifications. The clause gives the agency leeway to make these investigations as randomly 'necessary', while in Section 3.8, in the AMG Work Plan, the contractor is required to include a schedule and frequency of 'field verification checks'.

Involved Agency Functional Roles: District Surveyor, Project Engineer, Project Staff
Functional Role Competencies: Knowledge of surveying/stakeout, GPS, QA/QC requirements and tolerances, basic AMG principles (contractor will orient agency personnel to their AMG system via mandated formal training by the contractor in the special provision), use of DTM for constructability review and as-built documentation.
MDOT AMG Draft Special Provision Reference: Section 4.A.4

C. Transfer of Electronic Engineered Data (EED)

The MDOT AMG Draft Special Provision involves the transfer of Electronic Engineered Data (EED) in one direction, from MDOT to the contractor. The consideration of when EED is to be transferred, either before or after the bidding function, will most likely have an impact on the quality of AMG performed on projects. The special provision is silent as to when in the bidding/contracting processes that the EED will be shared. There are three possible options for the transfer of EED to the contractor. Figure 7: MDOT Work Flow Process Utilizing AMG Special Provision' displays the options with a dotted line and they are as follows:

Option 1: Issue the EED with the Bidding/Contract Documents (Pre-Bid)

Benefit: If the EED is included in the bidding package for the project, it will be used to develop the project cost estimate by at least some of the bidding contractors. In this capacity, the contractor will develop the DTM for estimate quantification purposes. During the estimating process, the contractor will be initiating a constructability review of the project plans and design errors, omissions, or issues may be revealed in either pre-bidding conferences or requests for information/clarification, thus giving MDOT ample time to make corrections or adjustments to the design before the contract is executed. Allowing the contractor estimators, who are the first personnel to reconstruct the design intent in the DTM, to use the EED in the bidding process may also provide the agency with lower bids (as a general rule, the more detailed design information provided to an estimator results in more cost accuracy)(*AACE International Recommended Practice No. 17R-97, COST ESTIMATE CLASSIFICATION SYSTEM*, 2003)

Liability: Any liability may be a legal one in the long term, in which case MDOT could simply alter their practice to Option 2 or 3. Since case law in the United States has not yet caught up with the adoption of AMG technology, it is unknown if transferring EED with the (at the same time as) traditional bidding documents would alter their status as 'official contract documents', and thus imposing liability upon the agency if the EED contains design errors or omissions. For this reason, MDOT should refer to legal counsel and consider a liability waiver be signed by the contractor when receiving EED from the agency, especially during the exchange of bidding documents.

Option 2: Issue the EED when the Contract is Awarded (Post-Bid)

Benefit: This option is preferable to Option 3 in that it gives the contractor time in advance of the pre-construction conference to reverse engineer the official plan documents for the construction of the DTM and bring constructability issues to the agency (while the estimator is planning and assembling the AMG Work Plan submittal for MDOT). This also gives the contractor ample time to identify constructability concerns so that they can be brought to the table at the pre-construction meeting.

Liability: This option does not contain the potential cost benefit to the agency as by this time the contractor's costs are fixed in contractual unit prices (as-bid). There is a potential (future) legal concern as to what constitutes 'contract documents' as in Option 1. A liability waiver should also be considered.

Option 3: Issue the EED at the Project Pre-Construction Conference (Post-Bid)

Benefit: This option is preferable to not sharing EED at all with the contractor.

Liability: Initially providing EED at this point in the process will result in either the contractor already having created a DTM from scratch or the inability to discuss the AMG Work Plan in sufficient detail at the pre-construction meeting because the DTM is not yet created or completed. Issue and communication regarding constructability will be pushed closer to the actual work being performed, thus possibly negating the very benefit of constructability review.

D. Quality Assurance and Control of AMG Field Operations

Quality control and quality assurance components of the special provision are as follows:

MDOT Responsibilities:

- Set Primary Survey Control (Section 4.A.1).
- Field Verification (Spot Checks) of AMG work-in-place (Section 4.A.4).
  This clause enables the project engineer to check the accuracy of ' machine control grading results, surveying calculations, records, field procedures, and actual staking' and uses the term 'spot checks as necessary' to ensure compliance with the specifications. The clause gives the agency leeway to make these investigations as randomly 'necessary', while in Section 3.8, in the AMG Work Plan, the contractor is required to include a schedule and frequency of 'field verification checks'.
- AMG Work Plan (Section 3), see Function E-9 above.
  As previously stated, MDOT should take special care in the review and approval process of this submittal. The submittal constitutes not only a plan for the implementation of a technical construction system of which both the agency and contractor require matching expectations, but also as a mechanism by which both parties can communicate the design intent and constructability issues of the project in advance of the commencement of work.

Contractor Responsibilities:

- Conversion of File Formats (Section 4.B.4)
  MDOT expressly states the data files and formats which it will share with the contractor in the special provision. These files, if used for creation of DTMs for machine control, will require conversion into a proprietary format depending upon the AMG system(s) utilized by the contractor. The most common format is a TIN or grid.(Galbraith, 2009)

Interoperability & File Conversion: File conversion between two software applications utilizing different file formats requires import and export routines (computer code and scripts) creating a data file format that is recognized by each program. When a software program exports data for import into another, it must match the exact data structure and format of the target software application. This is typically accomplished with an American Standard Code for Information Interchange (ASCII) text file or an Extensible Markup Language (XML) file schema. If the structures in these data files do not match exactly, there will be data loss if the export/import is successful. This is not uncommon, as software applications continually experience changes in their coding. Therefore, it is imperative for the user to monitor the data exchange for assurance of 'data quality'. The risks of this interoperability issue compounds when data exchange requirements involve more than two software applications.

- Notice Requirement for Field Verification of Data Accuracy (Section 4.A.2)
  Once EED is shared by MDOT and the contractor converts the data to the AMG system formats, the special provision requires field verification of the accuracy of the converted data. If errors are encountered during field verification, immediate notice to the agency is required. This contractor responsibility is listed under 'MDOT Responsibilities' and should be considered for duplication in Section 4.B.4. The notice requirement is an important component of the communications process required for successful implementation of AMG. The clause in 4.A.2 states, ' *The Contractor shall perform necessary conversion of the files for their selected grade control equipment, field verify the data for accuracy, and immediately report any errors to MDOT.*'
- Secondary Control Points (Section 4.B.5)
  The contractor is required by this special provision to establish secondary control points both inside and outside the project limits as required by the AMG system described in the AMG Work Plan. This information is also a submittal requirement of the AMG Work Plan under Sections 3.4 and 3.3.
  Conventional Grade Stakes (Section 4.B.7)
  Grade stakes are required to be set by the contractor by conventional means, for the use of the project engineer's quality control/assurance purposes. Table 4 displays required stake locations and frequencies where AMG is designated for use:

Stake Location	**Frequency**
Top of finished sub-grade	Mainline @ 2000 ft. intervals
Top of finished base course	Mainline @ 2000 ft. intervals
All hinge points of typical sections	Mainline @ 2000 ft. intervals
Points of tangency (PT)	Critical
Points of curvature (PC)	Critical
Super elevation transition sections	Beginning and end
Middle of curves	Critical
Side Roads	Two locations each side
Ramps	Two locations each side

Each cross slope transition	Beginning and end

Table 4: Conventional Staking Requirements and Frequency

- AMG Work Plan: See Function E-9. A critical aspect of the AMG field operations will be documentation and tracking of design changes in the official plans. A systematic methodology of communication must be established between the contractor and the agency for the incorporation of design changes into the DTMs utilized for machine control. The first paragraph of Section 3 in the special provision states:

  '*Any update or alteration of the Automated Machine Guidance Work Plan in the course of the work shall be approved and submitted to MDOT for determination of conformance with requirements of this special provision*.'

This clause appears to address the documented implementation plan of the AMG system as a whole vs. specific design changes which will be required to the original contract drawings. MDOT should consider adding language in Section 3 which would add an additional requirement to the AMG Work Plan, constituting a documented process for agency design changes to be formally incorporated into the machine control DTM(s).

E. Barriers to Implementation

The Round Table workshops revealed that contractors in Mississippi are adopting AMG technology and that MDOT is making a good faith effort to accommodate their requests and concerns formally via this MDOT AMG Draft Special Provision. Informally, MDOT has been assisting the AMG early-adopter contractors as much as their existing processes allow. During this early-adoption period, the agency had performed some new 'unofficial' processes in order to accommodate and some of these lessons learned have been incorporated into the special provision. Now that new rules and expectations have been defined with the special provision document, consideration can be given to some areas which could potentially hinder the successful implementation of AMG technology in the delivery of Mississippi Department of Transportation construction projects:

- GPS Availability: Automated Machine Guidance can be performed with systems utilizing lasers, sonic systems, and robotic total stations. When the system involves Real Time Kinematic (RTK) Global Positioning Systems (GPS), the project site must be conducive to the reception of GPS satellite signals. Some projects may have terrain or objects which prevent the satellite reception. Additionally, scientists are predicting solar activity and weather by 2013 which may significantly affect the ability to receive signals on earth from GPS satellites.(“Space Weather Enterprise Forum 2010,” 2010) Section 3 of the special provision requires the contractor to define contingency plans in the event of

AMG system failure and this portion of the AMG Work Plan submittal should be taken seriously.

- Failure to Implement AMG Work Plans: The successful implementation of the special provision relies upon the planning information exchanged between the parties via the AMG Work Plan submittal. Failure on the part of either the contractor or the agency to provide the information or collaborate in making improvements and providing feedback to the plan will result in surprises and problems for both sides. The AMG Work Plan is mechanism for defining expectations and methods of quality assurance and control. This submittal document will also define and allow the planning for required training in the contractor's AMG system and equipment for the agency field personnel.

- Lack of Technical Competencies: The utilization of AMG technology requires MDOT personnel poses skills and knowledge in several areas depending upon which AMG functions to which they are involved. MDOT functional roles requires background skills of surveying and layout, knowledge of RTK GPS technology, use of Total Station collectors, knowledge of Mississippi Standard Specifications for Road and Bridge Construction, quality assurance and quality control procedures, knowledge of how to interpret digital terrain models for constructability review and documentation of as-built data. Table 5 lists the special provision AMG functions, functional roles, and required skills and knowledge. The AMG functions refer to Figure 7: MDOT Work Flow Process Utilizing AMG Special Provision.

AMG Function	**Functional Role**	**Required Skills & Knowledge Areas (Credential)**
E-1 Project Terrain Survey	Surveyor, Engineer	Surveying (RLS), RTK GPS, photogrammetry, Total Station collectors
E-2 Project Design	Design Engineer	Professional License (PE)
E7-Set Primary Survey Control	Surveyor	Surveying, RTK GPS, Total Station collectors
E8-Pre-Construction Conference	Project Engineer	Construction planning, scheduling, and administration
E9-Review of Contractor AMG Work Plan	Project Engineer	Knowledge of surveying/stakeout, GPS, QA/QC requirements and tolerances, basic AMG principles (contractor will orient agency personnel to their AMG system via mandated formal training by the contractor in the special provision), use of DTM for constructability review and as-built documentation.
E10-Receive AMG Training	Project Engineer and staff	Knowledge of surveying/stakeout, GPS, QA/QC requirements and tolerances, basic AMG principles (contractor will orient agency personnel to their AMG system via mandated formal training by the contractor in

		the special provision), use of DTM for constructability review and as-built documentation.
E11-AMG Construction	Project Engineer and staff	Contractor will orient agency personnel to their AMG system via mandated formal training by the contractor in the special provision.
E12-AMG QA/QC	District Surveyor, Project Engineer, Project Staff	Knowledge of surveying/stakeout, GPS, QA/QC requirements and tolerances, basic AMG principles (contractor will orient agency personnel to their AMG system via mandated formal training by the contractor in the special provision), use of DTM for constructability review and as-built documentation.

Table 5: Required Skills and Knowledge for AMG

- Legal: Some legal considerations should be recognized as potential future issues which might cause MDOT liability in the future. The investigators have conducted considerable research in an attempt to find documented cases in the United States involving AMG with no success. Although some issues have been reported in published media, the case law is lagging behind the advance of the use of AMG technology. In time we suspect documented cases will emerge. Some of the potential issues identified are as follows:
    - Contract Documents.
      Typically in Design-Bid-Build project delivery, which involves most of MDOT's construction projects, errors or omissions in design are the liability of the owner (MDOT). The contracts are awarded for construction based upon interpretation of the Contract Documents which are defined in the Mississippi Standard Specifications for Road and Bridge Construction, 2004 Edition as ' *All original or official papers relied upon as the basis, proof or support of the contract and shall include those papers stated in the definition of Contract.*' Care should be taken if possible to keep Electronic Engineered Data (EED) from being considered a part of the Contract Documents unless MDOT is willing to accept liability for the accuracy of design contained within. Digital data is subject to manipulation, so unless baseline versions are preserved, errors in EED could be construed as errors in the design intent. The definition of Contract Documents in the 2004 standard specifications refers to paper.
    - Liability Waiver.
      It may be prudent for the agency to require a signed liability waiver from those receiving EED, even though the special provision expressly states that the agency takes no responsibility for accuracy of the data.
    - Registered Professionals.
      Some states are experiencing issues with the professional state license boards regarding who is qualified to create the DTMs for machine guidance. Mississippi could experience similar issues which may hinge on whether the DTM is considered part of the Contract Documents or equated with the status of Working Drawings.

- Design Change Documentation and Implementation.
  Design changes during the course of construction (after contract award), which might not get incorporated into existing DTMs being utilized for machine guidance could potentially cause liability issues. In the case of MDOT, since the paper drawings are considered the official design intent of the Contract Documents, there would seem to be minimal liability exposure. However, the New York State Department of Transportation specifications (Appendix A) issues their EED to contractors through their own controlled (electronic) file management system which documents versions (and baselines).

- Design Change Documentation and Methodology: Section 3 of the special provision states,

  'Any update or alteration of the Automated Machine Guidance Work Plan in the course of the work shall be approved and submitted to MDOT for determination of conformance with requirements of this special provision.'

  This clause encompasses reportage of changes to the Contractor's AMG system to MDOT. The agency needs a mechanism by which design changes can be communicated to the contractor for incorporation into its AMG system. Conventional changes to the design of a project which is already under contract (or has been awarded) typically involve notification and issuance of additional or altered paper drawings. When AMG is utilized, an additional step should be developed and undertaken to assure that the issued changes to the official drawings (paper) are incorporated and updated in any digital terrain models being used by the contractor to implement its machine guidance system. The system must document that the intended changes to the paper plans are updated in the digital drawings guiding the machinery. It is suggested that this methodology be discussed at the pre-construction conference and written into the contractor's AMG Work Plan, and therefore communicated to both parties. Lessons learned regarding methodologies for change management in the DTMs and AMG Work Plans should be documented and communicated to MDOT personnel for process improvement.

Appendix A: Agency Specifications Referenced

California:
San Diego - District 11
Non Standard Special Provision Draft for a project

((FIRST NON STANDARD SPECIAL PROVISION DRAFT DFM 4/23/06))
District 11 Draft NSSP
Revised 10/13/06
Page 1 of 2

Use when project intends to provide electronic information for the Contractor to use for Machine Control Grading. See "Interim Guidelines for Use of Machine Guidance Technology" dated August 8, 2005 for additional guidance.

Machine Control Grading

The Contractor may utilize grading equipment controlled with a Global Positioning System (AUTOMATED) machine control grading system for the grading and construction of the roadway, except for final grading.

The Contractor may use any type of AUTOMATED machine control equipment and system that results in achieving the existing grading requirements. All equipment required to accomplish AUTOMATED machine control grading shall be able to generate end results that meet the Standard Specifications.

If the Contractor chooses to use machine control grading, the Contractor shall furnish a written request for the electronic information within 10 working days after the approval of the contract. The Engineer will have 10 working days to furnish the Contractor with the electronic information. The electronic information (Machine Control Surface Model file) will be provided to the Contractor in ASCII, Land XML and VRS formats.

Attention is directed to "Lines and Grades" of these special provisions. The Engineer will set stakes or marks after notification from the Contractor is received. The Contractor shall provide controls for the machine control grading system.

The Contractor shall perform the necessary conversion of the files for its selected AUTOMATED machine control system. The Contractor shall independently ensure that the electronic information will function in its AUTOMATED machine control system.

The Department does not guarantee that its electronic information is directly compatible with the system proposed by the Contractor. Any manipulation of the electronic information by the Contractor shall be taken at the Contractor's own risk. The Contractor shall meet the same accuracy requirements as conventional grading construction. Grading work shall conform to the requirements in "Earthwork" of these special provisions.

Updated electronic data will be provided when in the opinion of the Engineer, significant changes to the plans affect the final grading surface;, otherwise, grading changes will be addressed through traditional survey staking.

The electronic information provided is available solely for the convenience of the Contractor. It is expressly understood and agreed that the Department assumes no responsibility in respect to the sufficiency or accuracy of the electronic information. Use of the electronic information shall be subject to all of the conditions and limitations set forth in Section 2-1.03, "Examination of Plans, Specifications, Contract, and Site of Work," of the Standard Specifications and these special provisions.

Payment

Full compensation for the use of AUTOMATED machine control grading, including converting the electronic information at any time during construction, shall be considered as included in the contract prices paid for the various items of earthwork involved and no additional compensation will be allowed therefore.

2 – Colorado:
Pilot project special provision: 625Automatedrts - 11.3.2008
REVISION OF SECTION 625
SURVEY CONTROL OF GRADING BY AUTOMATED OR RTS METHODS

Section 625 of the Standard specifications is hereby revised for this project as follows:

Subsection 625.01 shall include the following:

The Contractor may use grading equipment controlled by Global Positioning System (AUTOMATED) machine control grading techniques or Robotic Total Station (RTS) equipment to control the construction of subgrade, subbase, base course and other roadway structure materials and in construction of ditches and other planned excavations and embankment designated on the project.

Subsection 625.02 shall include the following:

When used, equipment required to accomplish AUTOMATED or RTS machine control grading shall be provided by the Contractor and shall be able to generate end results that meet the Contract requirements.

When the Contractor uses automated controlled equipment, the Contractor shall furnish an AUTOMATED Rover or RTS equipment to the Engineer for review of the work. With the equipment, the Contractor shall provide eight hours of formal training on the use of the AUTOMATED or RTS and the Contractor’s systems to CDOT project personnel prior to beginning any grading. This training is for the purpose of providing CDOT project personnel with an understanding of the equipment, software, and electronic data being used by the

Contractor. The AUTOMATED Rover or RTS equipment will be returned to the Contractor upon completion and acceptance of the final as constructed grade report.

The Contractor may use any type of approved AUTOMATED or RTS equipment that achieves the horizontal and vertical tolerances specified in the CDOT Survey Manual.

Add subsection 625.051 immediately following subsection 625.05 as follows:

625.051 Use of AUTOMATED or RTS Equipment in Lieu of Conventional Staking. The plans may indicate areas of the project where CDOT is providing electronic surface models. The Contractor shall convert electronic data provided by CDOT for these areas into the format required by the Contractor's system and equipment at the Contractor's expense. Work performed using AUTOMATED or RTS equipment shall conform to the plan typical sections. The remaining areas shall be constructed with conventional construction survey techniques and stakes unless the Contractor chooses to develop and submit a Digital Terrain Model (DTM) to the Engineer for review. The Contractor shall develop the DTM using the Contract Documents and any CDOT furnished DTM data. Changes in the given electronic data shall not be made unless approved by the Engineer in writing. To use any CDOT furnished DTM data, the Contractor shall release CDOT and its employees from all liability for the accuracy of the data and its conformance to the Contract.

The Contractor shall perform three 500 foot test sections with the selected AUTOMATED or RTS system to demonstrate that the Contractor has the capabilities, knowledge, equipment, and experience to properly operate the system and meet acceptable tolerances. If the Contractor fails to demonstrate this ability, the Contractor shall construct the project using conventional surveying and staking methods.

The Engineer may review the Contractor’s machine control grading results, surveying calculations, records, field procedures, and actual staking at any time. If the Engineer determines the work is not meeting the required horizontal and vertical tolerances, the Contractor shall redo such work to the requirements of the Contract at the Contractor's expense.

The Contractor shall provide stakes at all alignment control points, at every 500 foot stationing, and where required for coordination activities involving environmental agencies and utility companies at the Contractor's expense.

At least one week prior to the Preconstruction conference, the Contractor shall submit to the Engineer, for review, a written AUTOMATED or RTS machine control grading work plan which shall include:

Equipment type
Control software manufacturer
The control software version
Primary survey control to be used along with the locations of the AUTOMATED base stations used for broadcasting differential correction data to the rover units.

Contractor delays due to operating the AUTOMATED or RTS machine control system will not result in adjustment to the bid price or quantity of any construction items or be justification for granting any type of contract extension.

Subsection 625.07 shall include the following:

When AUTOMATED or RTS methods are used for any of the construction surveying, a Professional Land Surveyor (PLS) or Professional Engineer (PE) licensed in Colorado shall be provided by the Contractor to furnish an interim earthwork quantity report to the Engineer prior to 20 percent completion of the planned earthwork in any phase. Prior to beginning work on any subsequent operation the Contractor's PLS or PE shall certify in writing to the Engineer that the final grade is within specified tolerance.

Delete subsection 625.12 and replace with the following:

625.12 Construction surveying will not be measured, but will be paid for on a lump sum basis, regardless of whether conventional surveying, AUTOMATED, RTS, or a combination of these methods is used.

Subsection 625.13 shall include the following:
When AUTOMATED or RTS methods are used for any of the construction surveying, the Contract lump sum price bid shall include full compensation for all such surveying work including but not limited to:
Materials
Equipment
Labor
Office work - preparing the electronic data files for use in the Contactor's machine control grading system, developing or building a DTM to facilitate the AUTOMATED machine control grading system, and all other calculations required to complete the work.
Test section as specified by the Engineer.
Training for CDOT project personnel,
Final as constructed grade report

****
INSTRUCTIONS TO DESIGNERS (delete instructions and symbols from final draft): This is a pilot project special provision that is to be used only on selected projects. Submit proposed pilot projects to the Staff Survey Coordinator for review early in design prior to using this special provision.

Include this special provision on projects on which a digital terrain model (DTM) has been developed for all or part of the work and the Contractor will be allowed to use Global Positioning System (AUTOMATED) machine control grading techniques or Robotic Total Station (RTS) equipment to control construction. The plans should clearly show the areas where a DTM has been developed. List the DTM in the special provision, *Revision of Section 102 – Project Plans and Other Data*, as part of the computer information available.

3- Iowa:

DEVELOPMENTAL SPECIFICATIONS FOR
GLOBAL POSITIONING SYSTEM MACHINE CONTROL GRADING
Effective Date -September 18, 2007

THE STANDARD SPECIFICATIONS, SERIES 2001, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE DEVELOPMENTAL SPECIFICATIONS AND THEY SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

01103.01 GENERAL.

This specification contains requirements for grading construction utilizing Global Positioning System (AUTOMATED) machine control grading techniques and shall be used in conjunction with Section 2526, of the Standard Specifications.

The Contractor may utilize grading equipment controlled with an AUTOMATED machine control system in the construction of the roadway embankment.

The plans indicate the areas of the project where the Contracting Authority ~~IDOT~~ is providing electronic surface models of the roadway embankment construction. The remaining areas may be constructed with conventional construction survey techniques unless the Contractor chooses to build the required surface models to facilitate AUTOMATED machine control grading for those areas at no additional cost to the Contracting Authority.

The Contractor may use any type of AUTOMATED machine control equipment and systems that results in achieving the existing grading requirements. The Contractor shall convert the electronic data provided by the Contracting Authority into the format required by their system.

01103.02 EQUIPMENT.

All equipment required to accomplish AUTOMATED machine control grading shall be provided by the Contractor and shall be able to generate end results that meet the Standard Specifications.

01103.03 CONSTRUCTION.

A. Contracting Authority Responsibilities.

1. The Engineer will set the initial horizontal and vertical control points in the field for the project as indicated in the contract documents.

2. The Engineer will provide the project specific localized coordinate system. The control information utilized in establishing the localized coordinate system, specifically the rotation, scaling, and translation can be obtain from the Engineer upon request.

3. The Contracting Authority will provide the data listed below in an electronic format with the proposal form.

No guarantee is made that the data systems used by the Engineer will be directly compatible with the systems used by the Contractor.

Article 1105.04 of the Standard Specifications shall apply with the additional clarification that information shown on the plans shall govern over the provided electronic data.

This information shall not be considered a representation of actual conditions to be encountered during construction. Furnishing this information does not relieve the Contractor from the responsibility of making an investigation of conditions to be encountered including, but not limited to site visits, and basing the bid on information obtained from these investigations, and the professional interpretations and judgment of the Contractor. The Contractor shall assume the risk of error if the information is used for any purposes for which the information was not intended.

Any assumptions the Contractor makes from this electronic information shall be at their risk. The Contracting Authority will develop and provide electronic data to the Contractor for review as part of the contract documents. The Contractor shall independently ensure that the electronic data will function in their machine control grading system.

The files that are provided were originally created with the computer software applications MicroStation (CADD software) and GEOPAK (civil engineering software). The data files will be provided in the native formats and other software formats as described below. The Contractor shall perform necessary conversion of the files for their selected grade control equipment. The Contracting Authority will furnish the Contractor with the following electronic data files:

a. CAD Files:
GEOPAK TIN files representing the design surfaces.
GEOPAK GPK file containing all horizontal and vertical alignment information.
GEOPAK documentation file describing all of the chains and profiles.
MicroStation primary design file.
MicroStation cross section files.
MicroStation ROW data file.
MicroStation photogrammetry and text files.

b. Machine Control Surface Model Files:
ASCII format.
LandXML format.
Trimble Terramodel format.

Note: TIN files and surface model files of the proposed finish grade include the topsoil placement where required in the plans.

c. Alignment Data Files:
ASCII format.
LandXML format.
Trimble Terramodel format.

4. The Engineer may perform spot checks of the Contractor's machine control grading results, surveying calculations, records, field procedures, and actual staking. If the Engineer determines that the work is not being performed in a manner that will assure accurate results, the Engineer may order the Contractor to redo such work, to the requirements of the contract documents, at no additional cost to the Contracting Authority.

B. Contractor's Responsibilities.

1. The Contractor shall provide the Engineer with a AUTOMATED rover for use during the duration of the contract. At the end of the contract, the AUTOMATED rover unit will be returned to the Contractor. This unit shall have the same capabilities as units utilized by the Contractor. The Contractor shall provide 8 hours of formal training on the Contractor’s AUTOMATED machine control systems to the Engineer.

2. The Contractor shall review and apply the data provided by the Contracting Authority to perform AUTOMATED machine control grading.

3. The Contractor shall bear all costs, including but not limited to the cost of actual reconstruction of work, that may be incurred due to errors in application of AUTOMATED machine control grading techniques. Grade elevation errors and associated quantity adjustments resulting from the Contractor’s activities shall be at no cost to the Contracting Authority.
4. The Contractor shall convert the electronic data provided by the Contracting Authority into a format compatible with their system.

5. The Contractor understands that any manipulation of the electronic data provided by the Contracting Authority shall be taken at their own risk.

6. The Contractor shall check and recalibrate, if necessary, their AUTOMATED machine control system at the beginning of each work day.

7. The Contractor shall meet the same accuracy requirements as conventional grading construction as detailed in the Standard Specifications.

8. The Contractor shall establish secondary control points at appropriate intervals and at locations along the length of the project and outside the project limits and/or where work is performed beyond the project limits as required at intervals not to exceed 1000 feet (300 m). The horizontal position of these points shall be determined by static AUTOMATED sessions or by traverse connection from the original baseline control points. The elevation of these control points shall be established using differential leveling from the project benchmarks, forming closed loops. A copy of all new control point information shall be provided to the Engineer prior to construction activities. The Contractor shall be responsible for all errors resulting from their efforts and shall correct deficiencies to the satisfaction of the Engineer and at no additional cost to the Contracting Authority.

9. The Contractor shall preserve all reference points and monuments that are established by the Engineer within the project limits. If the Contractor fails to preserve these items they shall be

reestablished by the Contractor shall reestablished at no additional cost to the Contracting Authority.

10. The Contractor shall set hubs at the top of the finished subgrade at all hinge points on the cross section at 1000 foot (300 m) intervals on mainline and at least two cross sections on the side roads and ramps. These hubs shall be established using conventional survey methods for use by the Engineer to check the accuracy of the construction.

11. The Contractor shall provide controls points and conventional grade stakes at critical points such as, but not limited to, PC's, PT's, super elevation points, and other critical points required for the construction of drainage and roadway structures.

12. ~~The Contractor shall provide the Engineer with electronic as-built construction data for the final roadway TIN surface models in ASCII format.~~

13. At least one week prior to the preconstruction conference, the Contractor shall submit to the Engineer for review a written machine control grading work plan which shall include the equipment type, control software manufacture and version, and the proposed location of the local AUTOMATED base station used for broadcasting differential correction data to rover units.

01103.04 METHOD OF MEASUREMENT.
The bid item for AUTOMATED Machine Control Grading will be measured and paid for at the lump sum contract price.

01103.05 BASIS OF PAYMENT.
The bid item for AUTOMATED Machine Control Grading will be paid for at the lump sum contract price. This payment shall be full compensation for all work associated with preparing the electronic data files for use in the Contractor's machine control system, the required system check and needed recalibration, training for the Engineer, and all other items described in the Article 01103.03, B ~~Contractors Responsibilities section~~ of this Developmental Specification.

Delays due to satellite reception of signals to operate the AUTOMATED machine control system will not result in adjustment to the "Basis of Payment" for any construction items or be justification for granting contract extensions.

New York:
Changes to Standard Specifications

Make the following changes to the Standard Specifications dated January 2, 2002, and as modified by EI 05-011: **delete** Section 105-10 entirely and **add** the following:

105-10 SURVEY AND STAKEOUT. Prior to the start of construction work, all right of way markers, property line markers and survey control markers located in or adjacent to areas which may be disturbed during construction shall be properly protected and tied to fixed reference points or located from established contract control. Upon completion of the work, all right of way or property line markers or survey markers that have been disturbed by the Contractor, shall be reset under the direction of a Land Surveyor. Field location notes shall be recorded and made available to the Engineer upon request at no additional cost to the State.

All survey control and boundary location work shall be performed in accordance with the Department's *Land Surveying Standards and Procedures Manual* under the direction of a Land Surveyor.

All survey work performed for quality control by the Contractor and for quality assurance by the Department should both utilize: (1) similar levels of measurement precision and methods to perform positional measurements, (2) the same control network from which measurements are made, and (3) the same survey measurement procedures to ensure consistency of results.

Terrain features are measured and positioned by various methods relative to the contract control network established for each contract. The precision with which an instrument or equipment positions a point is related to the quality of the method by which measurements are made, and the ability to duplicate the same measurement. The accuracy of a located point is the closeness of the measured or computed value to a standard or accepted value (actual spatial position on the earth). Positional tolerance is the allowable spatial difference between making measurements by two different methods or by the same method at separate times, all of which have the same level of precision.

Horizontal coordinates and vertical elevations of existing features provided in contract documents are located in the field based on accuracies achievable for each positional point relative to the contract control. Positional accuracies are directly related to the strength of the contract control network closure, the precision of the instruments used to measure to the feature, and how definable the feature is which is being located. Point feature locations represent a single position (for example: property line marker, sign post, utility pole, or fire hydrant) and can be reidentified or verified in the field to within a small variation (high confidence level) from where they were initially positioned. Linear feature locations define the alignment position of that feature. That alignment can be verified to within a specific tolerance depending on the spacing or frequency at which the points were originally measured to define that alignment. Straight or uniformly curved linear features (for example: curbline, edge of roadway, or edge of sidewalk) which can be easily defined in the field should have a relatively small positional variation from their coordinated position when compared to a verified field location. Irregular shaped or not as clearly defined linear features (for example: break lines, ditchlines, treelines, or environmental area perimeters) which are sometimes difficult to define or delineate precisely in the field, could have a larger variation from where they were initially positioned when compared to a field-verified location.

Digital terrain model (DTM) surfaces which are provided in the contract documents are made up of a combination of point and linear features used to produce a DTM surface. The precision of a data collection instrument does not necessarily indicate what positional tolerance should be expected of any feature verified from an existing DTM. The location or elevation of a feature selected from a DTM surface can, at best, be determined by interpolating the horizontal position or elevation between previously positioned points. The verification of any specific elevation on the DTM surface is directly related to: (1) the spacing of collected data used to produce that surface; (2) the uniformity of the surface being measured; (3) the steepness of the slope of that surface; and (4) how obscured the surface is from the measuring technique used to originally locate the surface. Standardized procedures for determining the spacing/frequency of point and linear features (including break lines), are critical to providing consistent results. Department standardized procedures for determining feature locations are described in both the "Land Surveying Standards and Procedures Manual," and the "Specifications for Photogrammetric Stereocompilation."

Any true verification of the positional tolerance of the DTM surface elevation shall require a comparison of the original collected point data with recollected point data which are measured at the same horizontal locations. Field comparisons to interpolated DTM surfaces or recreated surface information (from paper drawings) shall not be used for verification of the positional tolerance of a feature. Comparisons of remeasured point data can only be made with the original collected point data, not to interpolated positions. Measurements for verification of DTM point data shall also be made from the same contract control network, and by instruments capable of an equal or greater precision.

Make the following changes to Volume II of the Standard Specifications dated January 2, 2002:

page 6-117, line 39 through page 6-122, line 11, **delete** entirely and **add** the following:

SECTION 625 - SURVEY OPERATIONS, ROW MARKERS, AND PERMANENT SURVEY MARKERS

625-1 DESCRIPTION

625-1.01 Survey Operations. This work shall consist of providing all necessary surveying to establish, spatially position, measure, navigate to and verify the locations of existing and proposed terrain features and measure quantities of items in accordance with the contract documents or as directed by the Engineer. This work includes but is not limited to the establishment or reestablishment of primary and secondary control, the stakeout of proposed features or the initialization and navigation of automated equipment operations, the location or verification of existing terrain or of constructed features, and the coordination and sharing of engineering data with the Department or other contract stakeholders.

625-1.02 Right of Way Markers. This work shall consist of furnishing, installing and certifying right of way markers at the specific positions described on the right of way appropriation maps, and in accordance with the details shown on the appropriate Standard Sheet.

625-1.03 Permanent Survey Markers. This work shall consist of furnishing, installing, and certifying permanent survey markers in accordance with the details shown on the appropriate Standard Sheet.

625-2 MATERIALS

625-2.01 Survey Operations. None specified

625-2.02 Concrete Right of Way Markers. Concrete right of way markers shall conform to the requirements of §712-05 *Precast Concrete Right-of-Way Markers*, and shall be in accordance with the details shown on the appropriate Standard Sheet.

625-2.03 Steel Pin and Cap Right of Way Markers. Reinforcing steel used for the shank shall conform to ASTM A615, Grade 300 or Grade 420. It shall be epoxy coated for its entire length in accordance with the coating application requirements of §705-14 *Longitudinal Joint Ties* or §709-04 *Epoxy Coated Bar Reinforcement*.

The cap shall be aluminum or a corrosion resistant aluminum alloy. The cap shall weigh a minimum of 50 grams and fasten to the shank by means of threading or force fitting.

A commercial grade silicone sealant shall be used between the cap and the shank. All aluminum or aluminum alloy surfaces to be in contact with cement concrete shall be coated with Zinc Chromate Primer meeting the requirements of §708-04 or an alternate material approved by the Materials Bureau.

Steel Pin and Cap-Type Markers shall be anchored into rock using Concrete Grouting Material meeting the requirements of §701-05.

625-2.04 Permanent Survey Markers. The concrete shall meet the requirements of Class A Concrete in Section 501 *Portland Cement Concrete--General,* except that the requirements for inspection facilities, automated batching controls and recordation do not apply. The batching, mixing and curing methods, and the inspection facilities shall meet the approval of the Department. The Contractor may submit for approval by Director, Materials Bureau~~,~~ a mix at least equivalent to the specified Class A Concrete.

625-3 CONSTRUCTION DETAILS

The following types of Survey Operations shall be completed under the direction of a Land Surveyor. This requirement is directly or indirectly associated with the professional license requirements contained in Article 145 of the NYS Education Law.

1. Establishment or reestablishment of primary or secondary control which shall be used for:

a. Establishing boundaries of new right of way appropriated for this contract.

b. Location of property or highway boundary markers.

c. Tie measurements to, or resetting of control points.

Location or resetting of existing highway and property boundary markers by reference ties to or from contract control to protect their integrity.

Establishment or certification of location of right of way markers and permanent survey markers.

The following types of Survey Operations shall be completed under the direction of either a Land Surveyor or Professional Engineer:

1. Establishment or reestablishment of primary or secondary control which shall be used for:

a. Establishing location for horizontal or vertical roadway alignment.

b. Establishing location for the horizontal or vertical alignment of a structure.

c. Establishing reference station for Global Positioning System (AUTOMATED) control work.

2. Establishing new horizontal or vertical roadway alignment in the field from contract control either by conventional stakeout methods or by use of automated equipment operations.

Contract Control Plan – The Contractor shall develop and submit a Contract Control Plan for all contracts which include the *Contract Pay Item 625.01 Survey Operations*. Contract control includes all primary and secondary horizontal and vertical control which will be used for the construction of the contract. Upon the Contractor's completion of initial survey reconnaissance and control verification, but prior to beginning primary field operations, the Contractor shall submit a Contract Control Plan document (signed and sealed by the Land Surveyor or Professional Engineer who oversees its preparation) for acceptance by the Engineer which includes:

A control network diagram of all existing horizontal and vertical control recovered in the field as contract control.

Include a summary of the calculated closures of the existing control network, and which control has been determined to have been disturbed or out of tolerance from its original positioning.

An explanation of which horizontal and vertical control points will be held for construction purposes (include a NYSPCS coordinate list). If necessary, include all adjustments which may have been made to achieve required closures.

An explanation of what additional horizontal and vertical control (including base stations) was set to accomplish the required stakeout or automated machine operations. Include how the position of these new control points was determined.

Describe the proposed method and technique (technology and quality control) for utilizing the control to establish the existing and/or proposed feature locations and to verify the completed feature location and/or measured quantity.

A listing of the horizontal and vertical datums to be used, the NYS Plane Coordinate System (NYSPCS) zone, and the combined factor to be used to account for the ellipsoidal reduction factor and the grid scale factor.

If the NYS Continuously Operating Reference Stations (CORS) Network was used to establish the initial control for the design of this contract, or if the Contractor proposes to use CORS with any construction operation, the survey reconnaissance and control verification shall include verifying the contract control against at least two NYS CORS Stations, and reporting the accuracy results in the contract control plan.

If the Contractor chooses to use automated machine operations as a method for measuring and controlling excavation, fill, material placement or grading operations, the Contract Control Plan shall include the method by which the automated machine guidance system will initially be site calibrated to both the horizontal and vertical contract control, and shall describe the method and frequency of the calibrations to ensure consistent positional results.

All establishment or reestablishment of contract primary or secondary control shall be done in accordance with the Department's "*Land Surveying Standards and Procedures Manual*."

625-3.01 Survey Operations. All available contract control, alignment or terrain data to be used to establish, position, measure, guide and verify the locations and quantities of existing and proposed features for the contract, will be managed and stored by the Department and shared electronically with the Contractor.

Survey Operations shall utilize: *A. Conventional Survey Stakeout* or *B. Automated Machine Operations*, or a combination of both, for the establishment, positioning, equipment guidance or verification of features. The proposed method shall be approved by the Engineer as part of the Contract Control Plan prior to beginning any field construction operations. Both methods include the same basic requirements that: (1) both parties (Contractor and Department) utilize the same contract control, the same existing terrain data, and the same proposed feature data; (2) both parties utilize the same accuracy and tolerance limits; and (3) both parties utilize equivalent survey verification techniques to ensure that field features are constructed as designed. After completion of the work, the Contractor shall reestablish and retie the contract control points as described in the Department's current "*Land Surveying Standards and Procedures Manual.*"

If an existing Digital Terrain Model (DTM) was developed during design and provided for construction purposes, and possibly updated during construction by supplemental survey, the Department will use that information to develop contract pay item quantities. If a proposed Digital Terrain Model (DTM) was developed during design and provided for construction purposes, or revised during construction due to site changes or redesign, the Department may use that information to develop applicable contract pay item quantities. If the Contractor does not agree with any of the information used, it may verify all or any portion of the existing or proposed DTM, at no additional cost to the State. All exceptions/changes to the supplied existing terrain data shall be brought immediately to the attention of the Engineer, in writing, and terrain data modifications shall be mutually agreed upon prior to beginning construction activities within the area(s) being modified. All existing terrain data supplied by the Department shall be considered as being within acceptable tolerances, except where changes or additions have been approved by the Engineer. Terrain data (DTM) changes will not be accepted by the Department where existing terrain is verified to be within Departmental accepted positional tolerances.

If a proposed Digital Terrain Model (DTM) was not developed, the Department may use line and grade information contained in the contract documents, in conjunction with the original ground survey plus any supplemental survey it collected, to develop contract pay item quantities. If the Contractor does not agree with any of the information used, it may verify all or any portion of the information, at no additional cost to the State.

The Contractor shall establish the center line of bearings for bridge abutments and piers, by setting offset hubs or reference points, so located and protected to ensure they remain undisturbed until such time as they are no longer needed. The Contractor shall mark the location of anchor bolts to be installed, establish the elevation of bearing surfaces and check bearing plates to ensure installation at their proper elevation. Before the erection of structural steel the Contractor shall verify the locations, both vertically and horizontally, of all bearings.

A. Conventional Survey Stakeout. The field location of all features to be constructed shall be established from survey control points which were identified in the Contract Control Plan. Any error, apparent discrepancy or absence in the data shown or required to appropriately accomplish the stakeout survey shall be referred to the Engineer immediately for interpretation when such is observed or required.

The Contractor shall place two offset stakes or references points along the center line at maximum intervals of 20 meters and at such intermediate locations as required to determine location and direction. From computations and measurements made by the Contractor, these stakes shall be clearly and legibly marked with the center line station number, offset and cut or fill from which the establishment of the centerline location and elevation can be determined. If markings become illegible for any reason the markings shall be restored by the Contractor. The Contractor shall locate and place all cut, fill, slope, fine grade, or other stakes and points for the proper progress of the work (maximum station spacing of 20 meters). All control points shall be properly protected and flagged for easy identification.

The Contractor shall be responsible for the accuracy of the work and shall maintain all applicable reference points, stakes, etc. Damaged or destroyed reference points or bench marks made inaccessible by the progress of the construction shall be replaced or transferred by the Contractor. All control points shall be referenced by ties (4 minimum) to specific points on acceptable objects and recorded. Any alterations or revisions in the ties shall be so noted and the information furnished to the Engineer. All stakeout survey work related to highway control shall be referenced to the control line shown in the contract documents. Computations and survey notes necessary to establish the position of the work from control points, shall be made and maintained in a neat, legible and acceptable format by the Contractor. Computations, survey notes and other survey information shall be made available to the Engineer within 3 days from the request. The Engineer may check all or any portion of the stakeout survey work or notes made by the Contractor. Such checking by the Engineer shall not relieve the Contractor of any responsibilities for the accuracy or completeness of the work.

B. Automated Machine Operations. The Contractor may choose an automated method for the establishment, layout, measurement, equipment guidance or verification of work to be constructed. Under this method, all horizontal and vertical control, alignment control, existing terrain data and proposed design data shall be shared/exchanged electronically and kept current between the Contractor and the Engineer. All original active files of electronic contract data shall be maintained and stored by the Department. Prior to beginning field operations, the Contractor and Engineer shall mutually determine acceptable uses of and procedures for the technology being used, and how data can be exchanged for use in stakeout, automated equipment operations, verification and quantity calculations. All engineering data shall be stored and shared in Department standard formats, and shall be derived primarily from the original electronic data provided by the Department.

Automated equipment operations have a high reliance on accurate control networks from which to take measurements, establish positions, and verify locations of features. Therefore, a strong contract control network in the field which is the same or is strongly integrated with the project control used during the design of the contract is essential to the successful use of this technology with the proposed Digital Terrain Model (DTM). Consistent and well designed site calibration for all automated machine operations (as described above under *Contract Control Plan*) are required to ensure the quality of the contract deliverables. The Contract Control Plan is intended to document which horizontal and vertical control will be held for these operations. Continued incorporation of NYS CORS Stations (if included in the initial project control) is essential to maintaining the integrity of positional locations and elevations of features.

The Engineer may perform quality assurance verifications of feature positions and elevations at any time during the contract. Dimensional tolerances shall hold a higher order of importance than positional tolerances, but both may require verification. Quality assurance activities by the Engineer will not relieve the Contractor of any responsibilities for the quality control of the accuracy or completeness of the work.

Verification of the positional locations of features, calculation and creation of supplemental DTM surfaces, and the measurement and calculation of quantities shall be developed through the use of Department standard CADD software. Both the Contractor and the Department shall utilize the following standards: (1) All CADD alignment and land boundary data shall be processed using the Department's standard CADD software. (2) All terrain data collected for the purpose of being used for or merged with Department provided terrain data and/or for the calculation of pay quantities shall be formatted and displayed in accordance with the current "*CADD Standards and Procedure Manual.*" (3) Field data collection and DTM creation shall be in accordance with procedures required in the current "*Land Surveying Standards and Procedures Manual.*" (4) The Department will maintain electronic data files for access by the Contractor using the Department's designated file management system. This will ensure that both parties utilize the same credible data from which to establish locations and measure quantities. The Department will provide all available CADD resource files for use by the Contractor.

The Contractor may choose to introduce an additional new automated method which involves a different technique for positioning features, measuring quantities, or verifying constructed locations. The quality and accuracy of this data produced by this method shall be demonstrated to the Engineer, for acceptance, by a comparison of this method to previously accepted techniques over a mutually agreed upon portion of the work. The new technology shall meet or exceed the quality and accuracy results provided by previously accepted techniques, and the Engineer shall make the final determination as to the acceptability of its use based on the performance, cost savings, and effectiveness of the operation. Previous uses of this same method on other contracts or by other contractors are not acceptable evidence of a technology's viability, due to inherent variations in operator's experience levels, data availability, changing field conditions and differing technologies.

625-3.02 Right of Way Markers. The Contractor shall verify with the Engineer that it has the most current vested Right of Way Acquisition Maps to determine the locations of the proposed right of way markers.

Right of way marker locations shall be determined under the direction of a Land Surveyor from a closed traverse or AUTOMATED network which is included in the contract control plan and in accordance with Federal Geographic Data Committee (FGCC) C2-II, Second-Order, Class II (1 part in 20,000) accuracy, ensuring a local positional accuracy of 20 mm as described in the Department's "*Land Surveying Standards and Procedures Manual.*"

The Contractor shall install right of way markers at the station/offset positions specified on the vested Right of Way Acquisition Maps in accordance with the Standard Sheets to within an absolute positional tolerance of 20 mm.

The Land Surveyor shall certify the as-built location of each installed right of way marker on certification forms provided by the Engineer, including contract information, and control line station and offset (proposed and as-built) to the marker. The record location of all right of way markers shall be recorded to the nearest millimeter and reflect as-built coordinates from a closed traverse or AUTOMATED network which is included in the contract control plan and in accordance with FGCC C2-II, Second-Order, Class II (1 part in 20,000) accuracy.

Prior to placing the cap on a steel pin right of way marker, the cap shall be filled 2/3 full of silicone sealant and then fastened to the bar by threading or by force fit. During the driving operation for the steel pin right of way marker, the lettering on the cap shall be protected by the use of a metal sleeve or cushion block. The marker shall be driven so that the cap is flush with the ground surface.

625-3.03 Permanent Survey Markers. Permanent survey markers shall be installed in accordance with the standard sheet at locations described in the contract documents and approved by the Engineer prior to installation. The sequential numbering required on the permanent survey marker caps shall be coordinated with the Engineer and the Regional Land Surveyor.

The Land Surveyor shall certify the as-built location of each installed permanent survey marker on certification forms provided by the Engineer, including contract information, as-built State Plane Coordinate values, control line and centerline station and offset to the marker, distance and direction to adjacent markers, the elevation of the marker, and a sketch which shows the relative positions to the control line points, four physical ties to the markers, and a north arrow. The record location of all permanent survey markers shall be recorded to the nearest millimeter and reflect as-built coordinates from a closed traverse or AUTOMATED network which is included in the contract control plan and in accordance with FGCC C2-II, Second-Order, Class II (1 part in 20,000) accuracy as described in the Department's "*Land Surveying Standards and Procedures Manual.*"

625-4 METHOD OF MEASUREMENT

625-4.01 Survey Operations. This work will be measured on a lump sum basis.

625-4.02 Right of Way Markers. The quantity to be measured for payment will be the number of right of way markers installed.

625-4.03 Permanent Survey Markers. The quantity to be measured for payment will be the number of permanent survey markers installed.

625-5 BASIS OF PAYMENT

625-5.01 Survey Operations. The price bid shall include the cost of furnishing all labor, materials and equipment necessary to satisfactorily complete the work. Progress payments will be made in proportion to the amount of work completed as determined by the Engineer.

625-5.02 Right of Way Markers. The unit price bid per each shall include the cost of furnishing all labor, materials, and equipment necessary to satisfactorily complete the work. Payment will be made upon the complete and proper installation of the marker, receipt of the certification form by the Engineer, and approval of the certification by the Regional Land Surveyor.

625-5.03 Permanent Survey Markers. The unit price bid per each shall include the cost of furnishing all labor, materials, and equipment necessary to satisfactorily complete the work. Payment will be made upon the complete and proper installation of the marker, receipt of the certification form by the Engineer, and approval of the certification by the Regional Land Surveyor.

Payment will be made under:

Item No.	**Item**	**Pay Unit**
625.01	Survey Operations	Lump Sum
625.03	Concrete Right of Way Markers Type H (High)	Each
625.04	Concrete Right of Way Markers Type L (Low)	Each
625.05	Steel Pin and Cap Right of Way Markers	Each
625.06	Permanent Survey Markers	Each

5- Wisconsin:

Specification for 2008 Pilot Project

Construction Staking Subgrade, Item 650.4500; Construction Staking Supplemental Control, Item 650.9910

Conform to standard spec 650 as modified in this special provision.

Replace standard spec 650.3.3 with the following:

650.3.3 Subgrade

650.3.3.1 General

(1) The contractor may use either global positioning system (AUTOMATED) machine guidance or conventional subgrade staking on designated portions of the contract as follows:

____
____
____
____

Use conventional subgrade staking on the remainder of the contract.

(2) The engineer may require the contractor to revert to conventional subgrade staking methods for all or part of the work at any point during construction if, in the engineer's opinion, the AUTOMATED machine guidance is producing unacceptable results. If the engineer revokes approval to use AUTOMATED machine guidance on all or part of the work for reasons beyond the contractor's control, the department will measure the additional subgrade staking required to successfully complete the work in those areas as specified in 650.4(2) of this special provision.

650.3.3.2 Subgrade Staking

(1) Set construction stakes or marks at intervals of 100 feet, or more frequently, for rural sections and at intervals of 50 feet, or more frequently, for urban sections. Include additional stakes at each cross-section as necessary to match the plan cross-section, achieve the required accuracy, and to support construction operations. Also set and maintain stakes as necessary to establish the horizontal and vertical positions of intersecting road radii, auxiliary lanes, horizontal and vertical curves, and curve transitions. Locate stakes to within 0.25 feet (75 mm) horizontally and establish the grade elevation to within 0.03 feet (10 mm) vertically.

650.3.3.3 AUTOMATED Machine Guidance

650.3.3.3.1 General

(1) No subgrade stakes are required for work approved for AUTOMATED machine guidance.

(2) Coordinate with the engineer throughout the course of construction to ensure that work performed using AUTOMATED machine guidance conforms to the contract tolerances and that the methods employed conform to the contractor's AUTOMATED work plan and accepted industry standards. Address AUTOMATED machine guidance issues at weekly progress meetings.

(3) Provide AUTOMATED rover equipment to department staff as requested to check the work. This equipment is not intended for exclusive use of the department and may be used by the contractor as needed on the project. Provide training for department staff designated to use the AUTOMATED rover. Training shall include but not be limited to hardware, software, and operation of AUTOMATED rover equipment. Provide a copy of the user manual for the supplied rover equipment. Provide routine maintenance of equipment provided for department use. The department is responsible for loss of, or damage (beyond normal wear and tear) to, the rover while in the engineer's possession.

650.3.3.3.2 AUTOMATED Work Plan

(1) Submit a comprehensive written AUTOMATED work plan for department review at least 10 business days before affected grading operations begin. The engineer will review the plan to determine if it conforms to the requirements of this special provision.

(2) Construct the subgrade as the contractor's AUTOMATED work plan provides. Update the plan as necessary during construction of the subgrade.

(3) The AUTOMATED work plan should discuss how AUTOMATED machine guidance technology will be integrated into other technologies employed on the project. Include, but do not limit the contents to, the following:

1. Describe the manufacturer, model, and software version of the AUTOMATED equipment.

2. Provide information on the qualifications of contractor staff. Include formal training and field experience. Designate a single staff person as the primary contact for AUTOMATED technology issues.

3. Describe how project control is to be established. Include a list and map showing control points enveloping the site.

4. Describe site calibration procedures. Include a map of the control points used for site calibration and control points used to check the site calibration. Describe the site calibration and checking frequency as well as how the site calibration and checking information are to be documented.

5. Describe the contractor's quality control procedures. Describe procedures for checking, mechanical calibration, and maintenance of equipment. Include the frequency and type of checks performed to ensure that the constructed subgrade conforms to the contract plans.

650.3.3.3.3 Equipment

(1) Use AUTOMATED machine guidance equipment to meet the requirements of the contract.

(2) Perform periodic sensor calibrations, checks for blade wear, and other routine adjustments as required to ensure that the final subgrade conforms to the contract plans.

650.3.3.3.4 Geometric and Surface Information

650.3.3.3.4.1 Department Responsibilities

(1) The department will provide to the contractor the best available electronic files of survey and design information as described here in 650.3.3.3.4.1 and in CMM 3-1-10. The department incurs no additional liability, beyond that specified in standard spec 105.6 or standard spec 650, by having provided this additional information.

(2) The department will provide data to the contractor that includes the following:

Data Type	Format [1]
Reference Line Data	LandXML
Design Profile Data	LandXML
Proposed Cross Section Data	Land XML or DWG
Existing Surface DTM Data	LandXML DTM or DWG
Existing Topographic Data (excluding utilities)	LandXML
Superelevation Data	LandXML
Graphical Information	DGN or DWG

[1] The department will provide data in whichever listed format the contractor chooses.

(3) The department will provide design surface data in the form of points and break lines derived from the cross sections in the contract in LandXML or DWG format at the contractor's option. The points and break lines will be on the subgrade surface between the subgrade shoulder points, and will be on the finished surface in topsoiled areas. The department provides design surface data for information only, and has no contractual liability for it.

650.3.3.3.4.2 Contractor Responsibilities

(1) Develop and maintain the initial design surface DTM for areas of the project employing AUTOMATED machine guidance consistent with information the department provides. Confirm that the design surface DTM agrees with the contract plans.

(2) Provide design surface DTM information to the department in LandXML or other engineer-approved format.

650.3.3.3.4.3 Managing and Updating Information

(1) The department and contractor will agree on the design surface model before using it for construction. Provide a copy of the resultant design surface DTM to the engineer at least two business days before using that design surface DTM for construction. Use the resulting design surface DTM to ensure that the work conforms to the plans, but the department's approval of the design surface DTM does not superse~~ce~~de the lines, grades, and cross-sections the plans show.

(2) Notify the department of any errors or discrepancies in department-provided information. Provide information regarding errors or discrepancies in the existing surface DTM, identified in the field, to the department in LandXML format if a revision to the contract plans is required. If surveying work, beyond that required under the Construction Staking Slope Stakes bid item, is required to re-define the existing surface the department will pay for costs of that additional surveying as extra work.

(3 The department will determine what revisions may be required. The department will revise the contract plans and existing surface DTM, if necessary, to address errors or discrepancies that the contractor identifies. The department will provide the best available electronic files and other available information related to those contract plan revisions.

(4) Revise the design surface DTM as required to support construction operations and to reflect any contract plan revisions the department makes. Perform checks to confirm that the revised design surface DTM agrees with the contract plan revisions. Provide a copy of the resultant revised design surface DTM to the engineer in LandXML or other engineer-approved format. The department will pay for costs incurred to incorporate contract plan revisions as extra work.

(5) The department will maintain the existing surface DTM by incorporating needed revisions. The department will make the current existing surface DTM available, in LandXML DTM or DWG format, to the contractor throughout construction.

650.3.3.3.5 Site Calibration

(1) Designate a set of control points, including a total of at least 6 horizontal and vertical points or 2 per mile, whichever is greater, for site calibration for the portion of the project employing AUTOMATED machine guidance. Incorporate the department-provided control framework used for the original survey and design.

(2) Calibrate the site by determining the parameters governing the transformation of AUTOMATED information into the project coordinate system. Use the full set of control points, designated under 650.3.3.3.5 (1), for the initial site calibration. Provide the resulting site calibration file to the engineer before beginning subgrade construction operations.

(3) In addition to the site calibration, perform site calibration checks. Perform these checks at individual control points not used in the initial site calibration. At a minimum, check the calibration at the start of each day. Report out-of-tolerance checks to the engineer. The measured position must match the established position at each individual control point within the following tolerances:

- Horizontally to 0.10 feet or less.
- Vertically to 0.05 feet or less.

(4) Provide the previous week's daily calibration check results to the engineer at the weekly progress meeting for monitoring the AUTOMATED work.

(5) The department will use the same calibration file the contractor uses.

650.3.3.3.6 Construction Checks

(1) Conduct calibration checks daily conforming to 650.3.3.3.5 of this special provision and consistent with the contractor's AUTOMATED work plan. Use an AUTOMATED rover to check the subgrade against the plan elevation at 20 or more randomly selected locations per roadway mile. Document all AUTOMATED rover subgrade checks and any auxiliary checks made using other technologies. Provide all documentation to the engineer.

(2) Ensure that at least 4 of any 5 consecutively-tested subgrade points are within 0.10 foot vertically of the plan elevation. Notify the engineer if more than one of any five consecutively-tested subgrade points differs by more than 0.10 feet from the plan elevation.

(3) The department will conduct periodic independent subgrade checks using the contractor supplied AUTOMATED rover or conventional survey methods. When using the AUTOMATED rover, the department will use the same calibration files and other hardware and software settings the contractor uses for subgrade checking. The department will notify the contractor if any individual check differs by more than 0.10 feet from the design.

Replace standard spec 650.3.12 with the following:

650.3.12 Supplemental Control

(1) Set and maintain construction marks as required to support the method of operations consistent with third-order, class I horizontal and third-order vertical accuracy. Check the department-provided horizontal and vertical control information and notify the engineer of any discrepancies. Provide marks to establish and maintain intermediate vertical and horizontal control for reference line alignment, side road alignments, radius points, bench level circuits, and offsetting the horizontal roadway alignment. These marks constitute the field control used to govern and execute the work.

(2) For the portion of the project using AUTOMATED machine guidance, set and maintain supplemental control points sufficient to ensure that there are a minimum of 6 established control points per mile. Ensure that these control points are consistent with third-order, class I horizontal and third-order vertical accuracy. Establish vertical control by differential leveling.

(3) Document and provide to the engineer complete descriptions and reference ties for the control points, alignment points, and benchmarks to allow for quick reestablishment of the plan data at any time during construction and upon project completion. Document additional control on forms described as a part of the contractor staking packet in CMM 3-1-10.

Replace standard spec 650.4 with the following:

650.4 Measurement

(1) The department will measure the Construction Staking bid items for base, concrete pavement, resurfacing reference, and slope stakes by the linear foot acceptably completed, measured along each roadway centerline. The department will not measure construction staking for base underlying concrete pavement.

(2) The department will measure Construction Staking Subgrade by the linear foot of subgrade acceptably completed, measured along each roadway centerline. The department will base measurement on the length of acceptably completed subgrade whether that subgrade was constructed using AUTOMATED machine guidance or using conventional construction staking. The department will include the length of subgrade where AUTOMATED machine guidance is initially employed but subsequently suspended by the engineer for reasons beyond the contractor's control. The department will measure this work twice, once for the suspended AUTOMATED work and once for the conventional subgrade staking required to successfully complete the work. If the department suspends AUTOMATED work for reasons within the contractor's control, the department will measure work in the affected area only once.

(3) The department will measure Construction Staking Curb Gutter and Curb & Gutter by the linear foot acceptably completed, measured along the base of the curb face. The department will measure Construction Staking Concrete Barrier by the linear foot acceptably completed, measured along the base of the barrier. The department will not measure these bid items if abutting concrete pavement.

(4) The department will measure Construction Staking Storm Sewer System as each individual inlet catch basin, manhole, and endwall acceptably completed.

(5) The department will measure Construction Staking Pipe Culverts by each individual pipe culvert staked and acceptably completed.

(6) The department will measure Construction Staking Structure Layout as a single lump sum unit for each structure acceptably completed. The department will measure Construction Staking Electrical Installations as a single lump sum unit for all electrical installations acceptably completed on each project. The department will measure Construction Staking Supplemental Control as a single lump sum unit for all control marks acceptably completed on each contract.

Appendix B: TAC Online Survey Results

This survey was administered to the MDOT State Study No. 214 TAC Committee in July of 2009. The survey was anonymous and administered with an online survey software application. The results we utilized in the August 12, 2009 TAC Quarterly Meeting.

Question 1

In your opinion, which areas should the guidance specification in State Study 214, (MDOT IMPLEMENTATION PLAN FOR GPS TECHNOLOGY IN PLANNING, DESIGN AND CONSTRUCTION DELIVERY), address?

Answer	Response Count	Percentage
GPS Machine Guidance	2	40%
Construction GPS Subgrade Staking	0	0%
Both GPS Machine Guidance and Construction Subgrade Staking	3	60%
Not Sure	0	0%
Other	0	0%

Question 2

Regarding contractor GPS Automated Machine Guidance , how should MDOT specify this technology for construction projects?

Answer	Response Count	Percentage
Mandate for all projects	0	0%
Mandate for specific projects	0	0%
Allow on all projects	4	80%
Allow on specific projects	1	20%
Not sure	0	0%

Question 3

Regarding contractor GPS Subgrade Staking, how should MDOT specify this technology for construction projects?

Answer	Response Count	Percentage
Mandate for all projects	0	0%
Mandate for specific projects	0	0%
Allow on all projects	4	80%
Allow on specific projects	1	20%
Not sure	0	0%

Question 4

A Digital Terrain Model(DTM) is required to perform GPS Machine Guidance and GPS Subgrade Staking. Some of this data is generated by MDOT in the design process. In your opinion, should MDOT share this data with contractors?

Answer	Response Count	Percentage
Yes	1	20%
No	1	20%
Not Sure	1	20%
Other	2	40%

Other Responses:

1-Not at this time maybe at a later date once planning and design process is refined.

2-The existing ground DTM (if available) & XS's (Ex. & Proposed) are already provided to contractors who request CADD files. A design DTM is not currently generated in the Design process.

Question 5

If the contractor is allowed to utilize GPS Automated Machine Grading and/or Subgrade Staking by utilization of its own Digital Terrain Model (DTM), should the contractor share this data with MDOT?

Answer	Response Count	Percentage
Yes	4	80%
No	0	0%
Not Sure	1	20%
Other	0	0%

Question 6

If MDOT allows GPS Automated Machine Grading and Staking technology on projects, how in your opinion should quality control (tolerances) be specified?

Answer	Response Count	Percentage
Via existing Standard Specifications	0	0%
Via additional specifications in Supplemental Special Provisions, Special Provisions, or Interim Specification.	4	80%
Not Sure.	1	20%
Other	0	0%

Question 7

Some agencies with GPS AMG/Staking specifications are requiring contractors to share equipment and even train agency personnel during the course of the project. If MDOT allows GPS Automatic Machine Grading and Staking technology on projects, should a separate Bid Item be included in the Proposal/Contract?

Answer	Response Count	Percentage
Yes	1	20%
No	2	40%
Not Sure	2	40%

Question 8

If MDOT elects to share Digital Design Data (DTM) with contractors in order to efficiently deliver projects and project quality, how should the agency's liability (for errors in the DTM) be limited?

Answer	Response Count	Percentage
Not an issue if there is no sharing.	0	0%
Liability Waiver included as part of the contract documents.	4	80%
Not sure.	1	20%
Other.	0	0%

Question 9.1

Please indicate your opinion regarding potential sections to be included in the GPS Automated Machine Guidance and/or Subgrade Staking Guidance/Interim Specification:

[General Section]

Answer	Response Count	Percentage
Strongly Agree	1	20%
Agree	2	40%
Disagree	0	0%
No Opinion	2	40%

Question 9.2

Please indicate your opinion regarding potential sections to be included in the GPS Automated Machine Guidance and/or Subgrade Staking Guidance/Interim Specification:
[Equipment Section]

Answer	Response Count	Percentage
Strongly Agree	2	40%
Agree	2	40%
Disagree	0	0%
No Opinion	1	20%

Question 9.3

Please indicate your opinion regarding potential sections to be included in the GPS Automated Machine Guidance and/or Subgrade Staking Guidance/Interim Specification:
[Training Section]

Answer	Response Count	Percentage
Strongly Agree	1	20%
Agree	2	40%
Disagree	1	20%
No Opinion	1	20%

Question 9.4

Please indicate your opinion regarding potential sections to be included in the GPS Automated Machine Guidance and/or Subgrade Staking Guidance/Interim Specification:
[Contractor GPS Work Plan Section]

Answer	Response Count	Percentage
Strongly Agree	1	20%
Agree	3	60%
Disagree	0	0%
No Opinion	1	20%

Question 9.5

Please indicate your opinion regarding potential sections to be included in the GPS Automated Machine Guidance and/or Subgrade Staking Guidance/Interim Specification:
[Responsibilities Section-MDOT]

Answer	Response Count	Percentage
Strongly Agree	2	40%
Agree	2	40%
Disagree	0	0%
No Opinion	1	20%

Question 9.6

Please indicate your opinion regarding potential sections to be included in the GPS Automated Machine Guidance and/or Subgrade Staking Guidance/Interim Specification:
[Responsibilities Section-Contractor]

Answer	Response Count	Percentage
Strongly Agree	2	40%
Agree	3	60%
Disagree	0	0%
No Opinion	0	0%

Question 9.7

Please indicate your opinion regarding potential sections to be included in the GPS Automated Machine Guidance and/or Subgrade Staking Guidance/Interim Specification:
[Site Calibration/Survey Control Section]

Answer	Response Count	Percentage
Strongly Agree	2	40%
Agree	2	40%
Disagree	0	0%
No Opinion	1	20%

Question 9.8

Please indicate your opinion regarding potential sections to be included in the GPS Automated Machine Guidance and/or Subgrade Staking Guidance/Interim Specification:
[QA/QC Section]

Answer	Response Count	Percentage
Strongly Agree	1	20%
Agree	2	40%
Disagree	0	0%
No Opinion	2	40%

Question 9.9

Please indicate your opinion regarding potential sections to be included in the GPS Automated Machine Guidance and/or Subgrade Staking Guidance/Interim Specification:
[Data Format Section]

Answer	Response Count	Percentage
Strongly Agree	3	60%
Agree	2	40%
Disagree	0	0%
No Opinion	0	0%

Appendix C: Roundtable II Results

Date of Round Table 2 Workshop: Thursday, December 10, 2009
Facilitated By: John J. Hannon, Tulio Sulbaran
Location: Thad Cochran Center, The University of Southern Mississippi
Number of Attendees: 53 Including Facilitators
Attendee Count by Stakeholder Group

Agency Personnel:	18
Contractors:	15
Heavy Equipment Vendors:	4
Software Vendors:	4
Hardware Vendors:	6

The issues and remedies contributed from the workshop break-out groups were transferred to a word processor from the flash drives. Votes were transferred and tallied from the wall posters to the word processed tables (Appendix H) and then inserted into a spreadsheet for sorting, filtering, and pivot table creation. The issues and remedies were then labeled (grouped) with the following tags:

DATA FORMAT: This tag represents issues pertaining to digital file formats involved with AMG data exchange between agency and contractor.

EQP SHARE: This tag represents issues pertaining to the sharing of equipment between agency and contractor.

LANGUAGE: This tag represents issues pertaining to terminology, word, reference, and phrase usage of the specification language.

DUTIES: This tag represents issues pertaining to risks and duties associated with the AMG specification.

QA/QC: This tag represents issues pertaining to quality assurance and quality control in reference to the specification and AMG process in general.

SEQ: This tag represents issues pertaining to the sequencing of the stakeholder tasks, duties, and responsibilities associated with the scope of the specification.

TRAIN: This tag represents issues pertaining to training and competencies associated with AMG and the draft specification.

Table 6: Summary of Attendee Issues Submitted by AMG Subject Area.

AMG Specification Subject=>	**QA/QC**	**DATA FORMAT**	**EQUIPMENT SHARING**	**PROCESS SEQUENCE**	**DUTIES-RISKS**	**TRAINING**	**LANGUAGE**
Total Attendee Issues Submitted=>	14	6	4	3	9	4	5

Table 7: Summary of Attendee Votes Received by AMG Subject Area.

AMG Specification Subject=>	**QA/QC**	**DATA FORMAT**	**EQUIPMENT SHARING**	**PROCESS SEQUENCE**	**DUTIES-RISKS**	**TRAINING**	**LANGUAGE**
Total Attendee Votes=>	152	107	91	65	46	30	18

Table 8: Summary of Attendee Issues Submitted by Draft Specification Section.

SPECIFICATION SECTION	ISSUES SUBMITTED
Sections 1-3	17
Section 4	18
Section 5	10
Total Attendee Issues=>	45

Table 9: Summary of Attendee Issue Votes Received by Draft Specification Section.

SPECIFICATION SECTION	VOTES RECEIVED
Sections 1-3	159
Section 4	166
Section 5	184
Total Attendee Votes=>	509

Table 10: Issues and Remedies Receiving Top Ten Votes.

Spec Section	ISSUE	REMEDY	VOTES
Section 5	Timing of providing this information.	Allow at PREBID	42
Section 4	Final Inspection—Who verifies the correctness of the model? How do we know if DTM is good? Specify whether contractor must provide MDOT with a Rover on demand or entire project.	MDOT should have ~~their~~its own equipment for checks. Inspection should be done by an independent method.	37

Section 5	MDOT uses Geopak and would need to import DTM into it, or contractor would export to .dgn file. How do we handle version changes of MicroStation/Geopak?	Land XML files seem to work best for contractors, and maybe we shouldn't limit file format to .dgn.	36
Section 5	Section 5. there is a file format available that will combine much of the information or files listed in this section	Propose that MDOT consider generating a Land XML file and make that information available.	33
Section 4	Contractor shall provide Engineer with equipment to be returned at end.	Contractor to keep equipment and make it available upon request for use. Equipment may have to have operator since many variable systems could be used. Equipment/Operator will keep equipment.	30
Section 5	Upgrade of software that may not be available to Contractor before MDOT has it.	Possibly send out in format that everyone can use like xml, dwg, txt. Non Proprietary Also give COGO, existing cross section, design cross section, subbase cross section.	26
Sections 1 - 3	Control and Calibration	In the front end MDOT and the contractor(s) agree on accurate, visible, and accessible benchmarks. There should be a calibration report showing what is out of tolerance, what's good etc. Some contractors feel that DOT should specify secondary controls. There should be a statewide standard for all to follow.	24
Sections 1 - 3	What about contractors who do not have AMG expertise? Smaller contractors will not get as much practice, therefore may not gain experience.	Specify test sections at first, then when contractors gain experience, they can use prior experience to show qualifications. There must be checks on regular intervals or phases.	24
Sections 1 - 3	Need to require the contractor to perform a test section in order to demonstrate his ability and the system's~~s~~ ability to meet the project requirements	Specify a test section (field trial)	23
Sections 1 - 3	Section 3, No. 2 - Experience of automated systems – need experienced personnel on project with previous experience in automated systems.	Consider quantifying related experience and/or formal training in automated machine control.	18

Table 11: Issues, Remedies, and Votes Received by Topic.

ISSUE	REMEDY	DATA FORMAT	EQP SHARE	LANGUAGE	DUTIES	QA/QC	SEQ	TRAIN
Timing of providing this information. (MDOT data sharing).	Allow at PREBID						**42**	
Final Inspection—Who verifies the correctness of the model? How do we know if DTM is good? Specify whether contractor must provide MDOT with a Rover on demand or entire project.	MDOT should have ~~their~~its own equipment for checks. Inspection should be done by an independent method.		**37**					
MDOT uses Geopak and would need to import DTM into it, or contractor would export to .dgn file. How do we handle version changes of MicroStation/Geopak?	Land XML files seem to work best for contractors, and maybe we shouldn't limit file format to .dgn.	**36**						
Section 5. there is a file format available that will combine much of the information or files listed in this section	Propose that MDOT consider generating a Land XML file and make that information available.	**33**						
Contractor shall provide Engineer with equipment to be returned at end.	Contractor to keep equipment and make it available upon request for use. Equipment may have to have operator since many variable systems could be used. Equipment/Operator will keep equipment.		**30**					
Upgrade of software that may not be available to Contractor before MDOT has it.	Possibly send out in format that everyone can use like xml, dwg, txt. Non Proprietary Also give COGO, existing cross section, design cross section, subbase cross section.	**26**						
What about contractors who do not have AMG expertise? Smaller contractors will not get as much practice, therefore may not gain experience.	Specify test sections at first, then when contractors gain experience, they can use prior experience to show qualifications. There must be checks on regular intervals or phases.					**24**		
Control and Calibration	In the front end MDOT and the contractor(s) agree on accurate, visible, and accessible benchmarks. There should be a calibration report showing what is out of tolerance,					**24**		

	what's good etc. Some contractors feel that DOT should specify secondary controls. There should be a statewide standard for all to follow.							
Need to require the contractor to perform a test section in order to demonstrate his ability and the system's ability to meet the project requirements	Specify a test section (field trial)					**23**		
Section 3, No. 2 - Experience of automated systems – need experienced personnel on project with previous experience in automated systems.	Consider quantifying related experience and/or formal training in automated machine control.							**18**
Add suggestion	As directed by Engineer			**16**				
MDOT does not need to take possession of contractor equipment for duration of project	Remove 4.B.1, and add that MDOT will utilize either their equipment, standard methods or a combination of the two to check		**15**					
Time required for review of submittal.	-Evaluate and review time						**14**	
B. Section 7. Accuracies are not addressed per say in the specs.	Use the word tolerances instead of accuracies.					**13**		
"Automated Machine Control grading techniques" needs to be defined	Specify 3D system…i.e. GPS alone does not meet current specs				**13**			
B. Section 10. Superelevation points does not accurately describe the staking location requirement.	Instead of superelevation points, use " beginning and ending of superelevation transition sections"					**13**		
Contractor does not submit a model to MDOT in this spec	Require the contractor to submit their model to MDOT for review, not for approval					**11**		
Certification of staff? Who will be the contact? Operator/Foreman	- A contact person whether operator/foreman should be available to check proper function					**10**		
MDOT will provide design data, if available. How do you know if electronic information is enough to use.	If this information is available, it needs to be PREBID						**9**	
B. Section 1. Causes the contractor to have to buy additional equipment.	Add "make available if needed by the project engineer"		**9**					

Does the survey manual and this specification agree?	Someone needs to verify that the two documents are in agreement				**8**			
8 Hour of training	The training time may need to be varied depending on system and questions.							**8**
First sentence—should it be MDOT's or the contractor's responsibility to produce the DTM?	If contractor is to assume risk, MDOT needs to provide elevations in a more convenient format.				**8**			
Section 3, 1st paragraph – remove "and approved and submitted".	Substitute "submitted and reviewed" by MDOT					**7**		
Secondary control within 30 days may need to be addressed. Wording of HOW needs to be addressed.	- Secondary control is usually established by surveying/construction contractor. The use of HOW should be changed to where it is located and submit for possible use in the Department					**6**		
Frequency of MDOT spot checks of Contractor's machine control grading results, etc. needs to be specified otherwise Contractor can claim if MDOT would have checked more frequently the problem would have been discovered sooner and thus corrected quicker. In the case of disagreement how is it determined who is correct?	Specify frequency of checks and procedure to resolve disputes with data					**6**		
How many control points per job and how should they be spaced?	We may want to include control points in the middle of the curve in addition to transition points. We may want intervals of less than 2000 ft., 1000 ft. may be better. This depends on terrain.					**6**		
How do we handle changes in technology in general, such as when xml gets supplanted or becomes obsolete?	As time passes and this file falls behind move to the next latest and greatest…..File types are in a constant state of change.	**6**						
Section 3.5 & 3.6 are confusing	Separate site calibration 3.5 &					**5**		

	equipment calibration into 3.6. These calibrations will be demonstrated during the test section (field trial) construction							
MDOT needs to provide design data in electronic format on any project that AMC will be allowed	Remove the “if available” from 4.A.3 and only put the spec in projects that the electronic design data is available or designate on a job by job basis that “no CADD files are available”				**5**			
A system that everyone can view	Possibly provide PDF or TIF Format	**5**						
Contractor manipulation of MDOT-provided data	Any manipulation should be communicated to MDOT and documented. This could be included in preconstruction and/or training.				**5**			
The provision of a single on-site staff person will be a challenge for contractors.	Between field experience and certification, this could be addressed.							**4**
MDOT does not need to “approve” the AMC work plan, only acknowledge receipt of it to keep the contractor responsible for the AMC	The engineer shall review the AMC work plan to ensure the required elements are addressed however ultimately it is the contractors responsibility for the performance of the system utilized				**4**			
30 business days is too long to require the work plan	Reduce to 30 calendar days				**3**			
Section 3, no. 4 – control points have not been established at this point	Add “proposed” before control points					**3**		
Section A, No. 1 – last sentence isn’t needed given the discussion of what will be provided in No. 2.	Strike last sentence.			**2**				
Wouldn’t contingency plan just be to revert to standard methods?	Specify that standard methods will be reverted to in the case of failure of the AMC to meet the project requirements					**1**		
Is there a standard format that can be utilized by all hardware or software? Does Microstation need to be converted to	?	**1**						

AutoCAD files?								
Section A, No. 3 – last sentence	Clear up wording			**0**				
B. Section 6. Need to address any needed plan changes to plans that need to be made in conjunction with MDOT.	Add (or move) last sentence under Section 4, A. No. 2.			**0**				
What items should be included in the DTM? Does it include cross drains, pipelines, etc.? This could affect subcontractors.	This can be specified in the contract, and you can make field adjustments.				**0**			
8 hours of training could be too little or too much and also the test section (field trial) can be used to train MDOT as needed	Part can be solved by stating that MDOT can request 8 hours of formal training from the contractor if needed. Mention the training in the test section (field trial) portion of the spec							**0**
The contractor needs to declare his intent to utilize AMC over standard methods	The submittal of the work plan shall include this				**0**			
Section 3, lines 77, 78 – the sentence beginning with "The engineer…" is redundant .	Strike this sentence.			**0**				
	Grand Total of Votes by Topic=>	**107**	**91**	**18**	**46**	**152**	**65**	**30**
		DATA FORMAT	**EQP SHARE**	**LANGUAGE**	**DUTIES**	**QA/QC**	**SEQ**	**TRAIN**

Table 12: Part, Issue, Priority, Topic Tag, Remedy, Votes, and Team by Descending Number of Votes.

Spec Section	ISSUE	Priority	Group	REMEDY	VOTES	TEAM
Section 5	Timing of providing this information.	Not Stated	SEQ	Allow at PREBID	42	RED
Section 4	Final Inspection—Who verifies the correctness of the model? How do we know if DTM is good? Specify whether contractor must provide MDOT with a Rover on demand or entire project.	Not Stated	EQP SHARE	MDOT should have its~~their~~ own equipment for checks. Inspection should be done by an independent method.	37	ORANGE
Section 5	MDOT uses Geopak and would need to import DTM into it, or contractor would export to .dgn file. How do we handle version changes of MicroStation/Geopak?	Not Stated	DATA FORMAT	Land XML files seem to work best for contractors, and maybe we shouldn't limit file format to .dgn.	36	ORANGE
Section 5	Section 5. there is a file format available that will combine much of the information or files listed in this section	Not Stated	DATA FORMAT	Propose that MDOT consider generating a Land XML file and make that information available.	33	YELLOW
Section 4	Contractor shall provide Engineer with equipment to be returned at end.	2	EQP SHARE	Contractor to keep equipment and make it available upon request for use. Equipment may have to have operator since many variable systems could be used. Equipment/Operator will keep equipment.	30	RED
Section 5	Upgrade of software that may not be available to Contractor before MDOT has it.	Not Stated	DATA FORMAT	Possibly send out in format that everyone can use like xml, dwg, txt. Non Proprietary Also give COGO, existing cross section, design cross section, subbase cross section.	26	RED
Sections 1- 3	Control and Calibration	Not Stated	QAQC	In the front end MDOT and the contractor(s) agree on accurate, visible, and accessible benchmarks.	24	ORANGE

				There should be a calibration report showing what is out of tolerance, what's good etc. Some contractors feel that DOT should specify secondary controls. There should be a statewide standard for all to follow.		

Sections 1- 3	What about contractors who do not have AMG expertise? Smaller contractors will not get as much practice, therefore may not gain experience.	Not Stated	QAQC	Specify test sections at first, then when contractors gain experience, they can use prior experience to show qualifications. There must be checks on regular intervals or phases.	24	ORANGE
Sections 1- 3	Need to require the contractor to perform a test section in order to demonstrate his ability and the system'sss ability to meet the project requirements	2	QAQC	Specify a test section (field trial)	23	BLUE
Sections 1- 3	Section 3, No. 2 - Experience of automated systems – need experienced personnel on project with previous experience in automated systems.	1	TRAIN	Consider quantifying related experience and/or formal training in automated machine control.	18	YELLOW
Section 4	Add suggestion	Not Stated	LANGUAGE	As directed by Engineer	16	RED
Section 4	MDOT does not need to take possession of contractor equipment for duration of project	1	EQP SHARE	Remove 4.B.1, and add that MDOT will utilize either their equipment, standard methods or a combination of the two to check	15	BLUE
Sections 1- 3	Time required for review of submittal.	1	SEQ	-Evaluate and review time	14	RED
Sections 1- 3	"Automated Machine Control grading techniques" needs to be defined	4	DUTIES	Specify 3D system…i.e. GPS alone does not meet current specs	13	BLUE
Section 4	B. Section 7. Accuracies are not addressed per say in the specs.	Not Stated	QAQC	Use the word tolerances instead of accuracies.	13	YELLOW
Section 4	B. Section 10. Superelevation points doeses not accurately describe the	Not Stated	QAQC	Instead of superelevation points, use " beginning and ending of	13	YELLOW

	staking location requirement.			superelevation transition sections”		
Section 5	Contractor does not submit a model to MDOT in this spec	2	QAQC	Require the contractor to submit their model to MDOT for review, not for approval	11	BLUE
Sections 1- 3	Certification of staff? Who will be the contact? Operator/Foreman	2	QAQC	- A contact person whether operator/foreman should be available to check proper function	10	RED
Section 4	MDOT will provide design data, if available. How do you know if electronic information is enough to use.	1	SEQ	If this information is available, it needs to be PREBID	9	RED
Section 4	B. Section 1. Causes the contractor to have to buy additional equipment.	Not Stated	EQP SHARE	Add “make available if needed by the project engineer”	9	YELLOW
Section 4	Do~~es~~ the survey manual and this specification agree?	2	DUTIES	Someone needs to verify that the two documents are in agreement	8	BLUE
Section 4	8 Hour of training	3	TRAIN	The training time may need to be varied depending on system and questions.	8	RED
Section 5	First sentence—should it be MDOT’s or the contractor’s responsibility to produce the DTM?	Not Stated	DUTIES	If contractor is to assume risk, MDOT needs to provide elevations in a more convenient format.	8	ORANGE
Sections 1- 3	Section 3, 1st paragraph – remove “and approved and submitted”.	4	QAQC	Substitute “submitted and reviewed” by MDOT	7	YELLOW
Sections 1- 3	Secondary control within 30 days may need to be addressed. Wording of HOW needs to be addressed.	3	QAQC	- Secondary control is usually established by surveying/construction contractor. The use of HOW should be changed to where it is located and submit for possible use in the Department	6	RED
Section 4	Frequency of MDOT spot checks of Contractor’s machine control grading results, etc. needs to be specified otherwise Contractor can claim if MDOT would have checked more	4	QAQC	Specify frequency of checks and procedure to resolve disputes with data	6	BLUE

	frequently the problem would have been discovered sooner and thus corrected quicker. In the case of disagreement how is it determined who is correct?					
Section 4	How many control points per job and how should they be spaced?	Not Stated	QAQC	We may want to include control points in the middle of the curve in addition to transition points. We may want intervals of less than 2000 ft., 1000 ft. may be better. This depends on terrain.	6	ORANG E
Section 5	How do we handle changes in technology in general, such as when xml gets supplanted or becomes obsolete?	Not Stated	DATA FORMAT	As time passes and this file falls behind move to the next latest and greatest…..File types are in a constant state of change.	6	ORANG E
Sections 1- 3	Section 3.5 & 3.6 are confusing	7	QAQC	Separate site calibration 3.5 & equipment calibration into 3.6. These calibrations will be demonstrated during the test section (field trial) construction	5	BLUE
Section 4	MDOT needs to provide design data in electronic format on any project that AMC will be allowed	3	DUTIES	Remove the "if available" from 4.A.3 and only put the spec in projects that the electronic design data is available or designate on a job by job basis that "no CADD files are available"	5	BLUE
Section 4	Contractor manipulation of MDOT-provided data	Not Stated	DUTIES	Any manipulation should be communicated to MDOT and documented. This could be included in preconstruction and/or training.	5	ORANG E
Section 5	A system that everyone can view	Not Stated	DATA FORMAT	Possibly provide PDF or TIF Format	5	RED
Sections 1- 3	MDOT does not need to "approve" the AMC work plan, only acknowledge receipt of it to keep the contractor	1	DUTIES	The engineer shall review the AMC work plan to ensure the required elements are addressed however	4	BLUE

	responsible for the AMC			ultimately it is the contractors responsibility for the performance of the system utilized		
Sections 1- 3	The provision of a single on-site staff person will be a challenge for contractors.	Not Stated	TRAIN	Between field experience and certification, this could be addressed.	4	ORANG E
Sections 1- 3	30 business days is too long to require the work plan	3	DUTIES	Reduce to 30 calendar days	3	BLUE
Sections 1- 3	Section 3, no. 4 – control points have not been established at this point	3	QAQC	Add “proposed” before control points	3	YELLO W
Section 4	Section A, No. 1 – last sentence isn’t needed given the discussion of what will be provided in No. 2.	Not Stated	LANGUAGE	Strike last sentence.	2	YELLO W
Sections 1- 3	Wouldn’t contingency plan just be to revert to standard methods?	6	QAQC	Specify that standard methods will be reverted to in the case of failure of the AMC to meet the project requirements	1	BLUE
Section 4	Is there a standard format that can be utilized by all hardware or software? Does Microstation need to be converted to AutoCAD files?	1	DATA FORMAT	?	1	BLUE
Sections 1- 3	The contractor needs to declare his intent to utilize AMC over standard methods	5	DUTIES	The submittal of the work plan shall include this	0	BLUE
Sections 1- 3	Section 3, lines 77, 78 – the sentence beginning with “The engineer…” is redundant .	2	LANGUAGE	Strike this sentence.	0	YELLO W
Section 4	8 hours of training could be too little or too much and also the test section (field trial) can be used to train MDOT as needed	5	TRAIN	Part can be solved by stating that MDOT can request 8 hours of formal training from the contractor if needed. Mention the training in the test section (field trial) portion of the spec	0	BLUE
Section 4	What items should be included in the DTM? Does it include cross drains, pipelines, etc.? This could affect	Not Stated	DUTIES	This can be specified in the contract, and you can make field adjustments.	0	ORANG E

	subcontractors.					
Section 4	Section A, No. 3 – last sentence	Not Stated	LANGUAGE	Clear up wording	0	YELLOW
Section 4	B. Section 6. Need to address any needed plan changes to plans that need to be made in conjunction with MDOT.	Not Stated	LANGUAGE	Add (or move) last sentence under Section 4, A. No. 2.	0	YELLOW

Table 13: QAQC Grouping of Issues, Remedies, and Votes.

Topic	**Spec Section**	**ISSUE**	**REMEDY**	**VOTES**
QAQC	Sections 1 - 3	Control and Calibration	In the front end MDOT and the contractor(s) agree on accurate, visible, and accessible benchmarks. There should be a calibration report showing what is out of tolerance, what's good etc. Some contractors feel that DOT should specify secondary controls. There should be a statewide standard for all to follow.	24
QAQC	Sections 1 - 3	What about contractors who do not have AMG expertise? Smaller contractors will not get as much practice, therefore may not gain experience.	Specify test sections at first, then when contractors gain experience, they can use prior experience to show qualifications. There must be checks on regular intervals or phases.	24
QAQC	Sections 1 - 3	Need to require the contractor to perform a test section in order to demonstrate his ability and the system'sss ability to meet the project requirements	Specify a test section (field trial)	23
QAQC	Section 4	B. Section 7. Accuracies are not addressed per say in the specs.	Use the word tolerances instead of accuracies.	13
QAQC	Section 4	B. Section 10. Superelevation points does not accurately describe the staking location requirement.	Instead of superelevation points, use " beginning and ending of superelevation transition sections"	13
QAQC	Section 5	Contractor does not submit a model to MDOT in this spec	Require the contractor to submit their model to MDOT for review, not for approval	11

QAQC	Sections 1 - 3	Certification of staff? Who will be the contact? Operator/Foreman	- A contact person whether operator/foreman should be available to check proper function	10
QAQC	Sections 1 - 3	Section 3, 1st paragraph – remove "and approved and submitted".	Substitute "submitted and reviewed" by MDOT	7
QAQC	Sections 1 - 3	Secondary control within 30 days may need to be addressed. Wording of HOW needs to be addressed.	- Secondary control is usually established by surveying/construction contractor. The use of HOW should be changed to where it is located and submit for possible use in the Department	6
QAQC	Section 4	Frequency of MDOT spot checks of Contractor's machine control grading results, etc. needs to be specified otherwise Contractor can claim if MDOT would have checked more frequently the problem would have been discovered sooner and thus corrected quicker. In the case of disagreement how is it determined who is correct?	Specify frequency of checks and procedure to resolve disputes with data	6
QAQC	Section 4	How many control points per job and how should they be spaced?	We may want to include control points in the middle of the curve in addition to transition points. We may want intervals of less than 2000 ft., 1000 ft. may be better. This depends on terrain.	6
QAQC	Sections 1 - 3	Section 3.5 & 3.6 are confusing	Separate site calibration 3.5 & equipment calibration into 3.6. These calibrations will be demonstrated during the test section (field trial) construction	5
QAQC	Sections 1 - 3	Section 3, no. 4 – control points have not been established at this point	Add "proposed" before control points	3
QAQC	Sections 1 - 3	Wouldn't contingency plan just be to revert to standard methods?	Specify that standard methods will be reverted to in the case of failure of the AMC to meet the project requirements	1

Table 14: DATA FORMAT Grouping of Issues, Remedies, and Votes.

Topic	Spec Section	ISSUE	REMEDY	VOTES
DATA FORMAT	Section 5	MDOT uses Geopak and would need to import DTM into it, or contractor would export to .dgn file. How do we handle version changes of MicroStation/Geopak?	Land XML files seem to work best for contractors, and maybe we shouldn't	36

			limit file format to .dgn.	
DATA FORMAT	Section 5	Section 5. there is a file format available that will combine much of the information or files listed in this section	Propose that MDOT consider generating a Land XML file and make that information available.	33
DATA FORMAT	Section 5	Upgrade of software that may not be available to Contractor before MDOT has it.	Possibly send out in format that everyone can use like xml, dwg, txt. Non Proprietary Also give COGO, existing cross section, design cross section, subbase cross section.	26
DATA FORMAT	Section 5	How do we handle changes in technology in general, such as when xml gets supplanted or becomes obsolete?	As time passes and this file falls behind move to the next latest and greatest…..File types are in a constant state of change.	6
DATA FORMAT	Section 5	A system that everyone can view	Possibly provide PDF or TIF Format	5
DATA FORMAT	Section 5	Is there a standard format that can be utilized by all hardware or software? Does Microstation need to be converted to AutoCAD files?	?	1

Table 15: EQP SHARE Grouping of Issues, Remedies, and Votes.

Topic	Spec Section	ISSUE	REMEDY	VOTES
EQP SHARE	Section 4	Final Inspection—Who verifies the correctness of the model? How do we know if DTM is good? Specify whether contractor must provide MDOT with a Rover on	MDOT should have itstheir own equipment for checks. Inspection should be done by an independent method.	37

		demand or entire project.		
EQP SHARE	Section 4	Contractor shall provide Engineer with equipment to be returned at end.	Contractor to keep equipment and make it available upon request for use. Equipment may have to have operator since many variable systems could be used. Equipment/Operator will keep equipment.	30
EQP SHARE	Section 4	MDOT does not need to take possession of contractor equipment for duration of project	Remove 4.B.1, and add that MDOT will utilize either their equipment, standard methods or a combination of the two to check	15
EQP SHARE	Section 4	B. Section 1. Causes the contractor to have to buy additional equipment.	Add “make available if needed by the project engineer”	9

Table 16: SEQ Grouping of Issues, Remedies, and Votes.

Topic	Spec Section	ISSUE	REMEDY	VOTES
SEQ	Section 5	Timing of providing this information.	Allow at PREBID	42
SEQ	Sections 1 -3	Time required for review of submittal.	-Evaluate and review time	14
SEQ	Section 4	MDOT will provide design data, if available. How do you know if electronic information is enough to use.	If this information is available, it needs to be PREBID	9

Table 17: DUTIES Grouping of Issues, Remedies, and Votes.

Topic	Spec Section	ISSUE	REMEDY	VOTES
DUTIES	Sections 1-3	“Automated Machine Control grading techniques” needs to be defined	Specify 3D system…i.e. GPS alone does not meet current specs	13
DUTIES	Section 4	Do~~es~~ the survey manual and this specification agree?	Someone needs to verify that the two documents are in agreement	8
DUTIES	Section 5	First sentence—should it be MDOT’s or the contractor’s responsibility to produce the DTM?	If contractor is to assume risk, MDOT needs to provide elevations in a more convenient format.	8

DUTIE S	Section 4	MDOT needs to provide design data in electronic format on any project that AMC will be allowed	Remove the "if available" from 4.A.3 and only put the spec in projects that the electronic design data is available or designate on a job by job basis that "no CADD files are available"	5
DUTIE S	Section 4	Contractor manipulation of MDOT-provided data	Any manipulation should be communicated to MDOT and documented. This could be included in preconstruction and/or training.	5
DUTIE S	Sections 1-3	MDOT does not need to "approve" the AMC work plan, only acknowledge receipt of it to keep the contractor responsible for the AMC	The engineer shall review the AMC work plan to ensure the required elements are addressed however ultimately it is the contractors responsibility for the performance of the system utilized	4
DUTIE S	Sections 1-3	30 business days is too long to require the work plan	Reduce to 30 calendar days	3
DUTIE S	Sections 1-3	The contractor needs to declare his intent to utilize AMC over standard methods	The submittal of the work plan shall include this	0
DUTIE S	Section 4	What items should be included in the DTM? Does it include cross drains, pipelines, etc.? This could affect subcontractors.	This can be specified in the contract, and you can make field adjustments.	0

Table 18: TRAIN Grouping of Issues, Remedies, and Votes.

Topic	PART	ISSUE	REMEDY	VOTE S
TRAI N	Sections 1-3	Section 3, No. 2 - Experience of automated systems – need experienced personnel on project with previous experience in automated systems.	Consider quantifying related experience and/or formal training in automated machine control.	18
TRAI N	Section 4	8 Hour of training	The training time may need to be varied depending on system and questions.	8
TRAI N	Sections 1-3	The provision of a single on-site staff person will be a challenge for contractors.	Between field experience and certification, this could be addressed.	4

TRAIN	Section 4	8 hours of training could be too little or too much and also the test section (field trial) can be used to train MDOT as needed	Part can be solved by stating that MDOT can request 8 hours of formal training from the contractor if needed. Mention the training in the test section (field trial) portion of the spec	0

Table 19: LANGUAGE Grouping of Issues, Remedies, and Votes.

Topic	PART	ISSUE	REMEDY	VOTES
LANGUAGE	Section 5	Add suggestion	As directed by Engineer	16
LANGUAGE	Section 4	Section A, No. 1 – last sentence isn't needed given the discussion of what will be provided in No. 2.	Strike last sentence.	2
LANGUAGE	Sections 1-3	Section 3, lines 77, 78 – the sentence beginning with "The engineer…" is redundant .	Strike this sentence.	0
LANGUAGE	Section 4	Section A, No. 3 – last sentence	Clear up wording	0
LANGUAGE	Section 4	B. Section 6. Need to address any needed plan changes to plans that need to be made in conjunction with MDOT.	Add (or move) last sentence under Section 4, A. No. 2.	0

Table 20: Workshop Issues Grouped by Issue Type with Votes per Issue

GROUP	VOTES	ISSUES	Votes/Issue
EQP SHARE	91	4	22.75
SEQUENCE	65	3	21.67
DATA FORMAT	107	6	17.83
QAQC	152	14	10.86
TRAIN	30	4	7.50
DUTIES	46	9	5.11
LANGUAGE	18	5	3.60

Appendix D: MDOT AMG Draft Special Provision

Study No. 214

MDOT Implementation Plan for Global Positioning Systems (GPS) Technology
In Planning, Design, and Construction Delivery

DRAFT
MDOT Automated Machine Guidance
Special Provision

Prepared for:

Under the Supervision of:
Lewis, Brad

Prepared by:

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Dr. Tulio Sulbaran – School of Construction

Forward

This document has been prepared as part of the Study No. 214 MDOT Implementation Plan for Global Positioning Systems (GPS) Technology in Planning, Design, and Construction Delivery.

The DRAFT MDOT GPS Guidance Specification contains recommendations for specification language and processes regarding contractor use Automated Machine Guidance and the sharing of MDOT electronic design data.

This DRAFT MDOT Automated Machine Guidance Special Provision was based on (standard, provisions, special pilot, and non- standard) specifications of other states such as: California, Colorado, Iowa, New York and Wisconsin.

This draft special provision document was created by the project investigators under the guidance of the project's Technical Advisory Committee (TAC). We are grateful and appreciative of the committee's assistance, without which this work would not be possible. Members of the TAC are as follows:

Brad Lewis, State Construction Engineer

Keith Boteler, Roadway Design CADD Engineer
Mike Cresap, Assistant Director of Division of Transportation Information
David Foster, Assistant Chief Engineer—Preconstruction
Steve Lyle, Statewide Surveyor
Keith Parker, Programmer Analyst--Information Systems Division
Kevin Rainey, Senior Surveyor, District 5
Cynthia J. Smith, Assistant State Research Engineer
Ken Wallace, Assistant District Engineer—Construction, District 5

DRAFT: Mississippi Department of Transportation
Automated Machine Guidance Special Provision

1- GENERAL.

This special provision contains requirements for utilization of Automated Machine Guidance technologies and systems in accordance with the standard specifications and official contract documents. Automated Machine Guidance (AMG) is defined as the utilization of positioning technologies such as Global Positioning Systems (GPS), Robotic Total Stations, lasers, and sonic systems to automatically guide and adjust construction equipment according to the intended design requirements. The Contractor may use any type of AMG system(s) that result in compliance with the contract documents and applicable Standard Specifications.

2- EQUIPMENT

All equipment required to accomplish Automated Machine Guidance shall be provided by the Contractor. The Contractor may use any type of AMG equipment that achieves compliance with the contract documents and applicable Standard Specifications.

3- AUTOMATED MACHINE GUIDANCE WORK PLAN

The Contractor shall submit a comprehensive written Automated Machine Guidance Work Plan for MDOT review at the Pre-Construction Conference. Submittal of the AMG Work Plan declares the Contractor's intention to utilize AMG instead of conventional methods on the project areas and elements stated in the Work Plan. The engineer shall review the Automated Machine Guidance Work Plan to ensure that the requirements of this special provision are addressed. The Contractor assumes total responsibility for the performance of the system utilized in the Work Plan. Any update or alteration of the Automated Machine Guidance Work Plan in the course of the work shall be approved and submitted to MDOT for determination of conformance with requirements of this special provision.

The Automated Machine Guidance Work Plan shall describe how the automated machine guidance technology will be integrated into other technologies employed on the project. Include, but do not limit the contents to, the following:

1. Describe the manufacturer, model, and software version of the AMG equipment.
2. Provide information on the Contractor’s experience in the use of Automated Machine Guidance system (or Related Technologies) to be used on the project, including formal training and field experience of project staff.
3. Designate a single onsite staff person as the primary contact (and up to one alternate contact person) for Automated Machine Guidance technology issues.

4. Define the project boundaries and scope of work to be accomplished with the AMG system.

5. Describe how project proposed secondary control is to be established. Include a list and map detailing control points enveloping the site.

6. Describe site calibration procedures including but not limited to equipment calibration and the frequency of calibration as well as how the equipment calibration and information will be documented to MDOT and the project Engineer. The documentation should contain a complete record of when and where the tests were performed and the status of each equipment item tested within or out of the ranges of required tolerances.

7. Describe the Contractor's quality control procedures for checking mechanical calibration, and maintenance of equipment. Include the frequency and type of checks to be performed.

8. Describe the method and frequency of field verification checks and the submission schedule of results to the Project Engineer.

9. Describe the Contractor's contingency plan in the event of failure/outage of the AMG system.

10. A schedule for submission of Digital Terrain Models (DTM) intended for use on the project to the Engineer for review, feedback, and communication.

At the conclusion of the Pre-Construction Meeting, the Contractor and MDOT will agree on the quantity and schedule of Contractor-provided training on the utilized AMG system required under 4-B.1.

4- CONSTRUCTION.

A. MDOT Responsibilities.

1. The District Surveyor will set the Primary horizontal and vertical control points in the field for the project as per latest edition of the MDOT Survey Manual. The control points shall be in Mississippi State Plane coordinate system.

2. MDOT will provide an electronic alignment file and primary control file for the project. This file will be based on the appropriate Mississippi State Plane Coordinate Zone either West or East. These files will be created with the computer software applications MicroStation (CADD software) and GEOPAK (civil engineering software). The data files will be provided in the native formats. The Contractor shall perform necessary conversion of the files for their selected grade control equipment, field verify the data for accuracy, and immediately report any errors to MDOT.

3. MDOT will provide design data, if available, in an electronic format to the Contractor. These files will be created with the computer software applications MicroStation

(CADD software) and GEOPAK (civil engineering software). The data files will be provided in the native formats as specified in the Data Format section of this specification. No guarantee is made to the data accuracy or completeness, or that the data systems used by MDOT will be directly compatible with the systems used by the Contractor. Information shown on the paper plans marked with the seal (official plans as advertised) shall govern.

4. The Engineer will perform spot checks as necessary of the Contractor's machine control grading results, surveying calculations, records, field procedures, and actual staking. If the Engineer determines that the work is not being performed in accordance with the Specifications, the Engineer shall order the Contractor to redo such work, to the requirements of the contract documents, at no additional cost to the Department.

B. Contractor's Responsibilities.

1. The Contractor shall provide formal training, if requested, on the use of the Automated Machine Guidance Equipment and the Contractor's systems to MDOT project personnel prior to the start of construction activities utilizing AMG. This training is for providing MDOT project personnel with an understanding of the equipment, software, and electronic data being used by the Contractor.

2. The Contractor shall use the alignment and control data provided by MDOT.

3. The Contractor shall bear all costs, including but not limited to the cost of actual reconstruction work that may be incurred due to errors in application of Automated Machine Guidance techniques or manipulation of MDOT design data in Digital Terrain Models (DTM).

4. The Contractor shall be responsible for converting the information (plans and/or electronic data) provided by MDOT into a format compatible with the Contractor's AMG system.

5. The Contractor shall establish secondary control points at locations along the length of the project and outside the project limits and/or where work is performed beyond the project limits as required by the Automated Machine Guidance system utilized. The Contractor shall establish this secondary control using survey procedures as outlined in the latest edition of the MDOT Survey Manual. A copy of all new control point information shall be provided to the Engineer prior to construction activities. The Contractor shall be responsible for all errors resulting from their efforts and shall correct deficiencies to the satisfaction of the Engineer and at no additional cost to MDOT.

6. The Contractor shall preserve all reference points and monuments that are established by the District Surveyor outside the construction limits. If the Contractor fails to preserve

these items they shall be reestablished by the Contractor to their original quality at no additional cost to MDOT.

7. The Contractor shall set grade stakes at the top of the finished sub-grade and base course at all hinge points on the typical sections at 2000 foot maximum intervals on mainline, critical points such as, but not limited to, PC's, PT's, beginning and ending super elevation transition sections, middle of the curve, and at least two locations on each of the side roads and ramps, and at the beginning and end of each cross slope transition where Automated Machine Guidance is used. These grade stakes shall be established using conventional survey methods for use by the Engineer to check the accuracy of the construction.

8. The Contractor shall meet the same accuracy requirements as detailed in the Mississippi Standard Specifications for Road and Bridge Construction. (The latest edition of this specification as of the execution of the construction contract shall govern). Grade stakes shall be established as per subsection 699 of the Standard Specifications (SECTION 699 - CONSTRUCTION STAKES) for use by the Engineer to check the accuracy of the construction.

9. The contractor shall be responsible for implementing the AMG system using the Mississippi State Plane Coordinate System. No localization methods will be accepted.

5- DATA FORMAT

It is the Contractor's responsibility to produce the Digital Terrain Model(s) and/or 3d line work needed for Automated Machine Guidance. At this time, MDOT does not produce this data in its design process. MDOT does provide CADD files created in the design process to the Contractor. The CADD files provided by MDOT are provided in the native software application formats in which they are created with no conversions, and their use in developing 3D data for machine guidance is at the discretion of the Contractor. The CADD files that may be available are listed below. Cross-Sections are one of the items provided but are not necessarily created at critical design locations. Therefore their use in Digital Terrain Models (DTM) for AMG is limited.

1. Project Control - (Microstation DGN file and ASCII file)

2. Existing Topographic Data - (Microstation DGN file(s))

3. Preliminary Surveyed Ground Surface - (GeoPak TIN) (If available)

4. Horizontal and Vertical alignment information - (GeoPak GPK file and/or Microstation DGN file(s))

5. 2d Design line work (Edge of Pavement, Shoulder, etc.) - (Microstation DGN file(s))

6. Cross sections - (Microstation DGN file(s), GeoPak format)

7. Superelevation - (Microstation DGN file(s), GeoPak format)

8. Form Grades - (Microstation DGN file(s))

9. Design Drainage - (Microstation DGN file(s))

It is expressly understood and agreed that MDOT assumes no responsibility in respect to the sufficiency or accuracy of these CADD files. These files are provided for convenience only and the contract plans are the legal document for constructing the project.

Appendix E: Basic GPS Systems and Equipment Configurations

The following excerpt from the National Cooperative Highway Research Program (NCHRP) Synthesis 372, Emerging Technologies for Construction Delivery, provides an adequate definition of GPS as well and basic equipment configurations required for AMG (Hannon, 2007):

"GPS is a space-based, radio-navigation system that provides worldwide, all-weather, three-dimensional position, velocity, navigation, and time data to both civilian and military users. Potential uses for GPS within the highway community are diverse and range from providing traveler information to mapping (GPS technology can be integrated easily with Geographic Information Systems). GPS can provide a very accurate digital map of the highway infrastructure. The technology operates on the principle of triangulation—if the difference from an observer to three known points can be measured, the position of the observer can be calculated. The system includes at least 24 satellites in orbit 19,320 kilometers (12,000 miles) above the earth and inclined at 55°. These satellites continuously broadcast their position, a timing signal, and other information. By combining the measurements from four different satellites, users with receivers can determine their 3-dimensional position, currently within 4–20 meters (13–66 feet)" (FHWA-HRT-04-071 n.d.).

GPS satellites communicate with ground control stations (base stations) through radio waves which in turn communicate via radio to the end users. The technology utilizes the concept of triangulation from satellite signals to determine a three dimensional (x,y,z coordinate) position on the ground. Triangulation consists of computing the distance from the ground station to at least four different satellites at any given time. The distances to the receiver are determined by measuring the travel time of radio signals from each of the satellites. Atmospheric moisture and distortions of the radio waves in the ionosphere, as well as the satellite's location in the sky influence the accuracy of the measurements which causes an intrinsic maximum error of 45 feet in the raw data. To compensate for the error, Differential GPS (DGPS) systems utilize a correction mechanism by use of a fixed receiver which has known coordinates. Several DGPS systems are currently available:

- Ground stations: These systems combine the ranging signals from the satellites with correction signals from the fixed base station. The location of the DGPS base station is established by collection of GPS signals over a period of time. Thousands of signal readings by the base station are averaged to correct the normal propagation errors to within one millimeter of accuracy.
- Coast Guard Maritime DGPS: A fixed ground receiver (beacon) system that enables real-time differential correction accuracy within one to three meters. The beacons are present around the coastlines of the U.S., Puerto Rico, Alaska, and Hawaii.
- Wide Area Augmentation System (WAAS): A combination of satellites and ground stations which enable real-time differential correction within 3 meters 95% of the time.

- OmniSTAR: A worldwide system of satellites and network control stations which facilitate real-time differential correction of raw data. OmniSTAR provides two accuracy levels of service, both of which must be licensed for access.
- Real-time kinematic GPS (RTK GPS): RTK systems require two or more receivers to be operated simultaneously. Radio waves from a base station receiver transmit corrections to a roving receiver (also receiving signals from the satellites). A computer at the rover receiver processes the readings in real time to produce an immediate determination of its location (Lin 2004).

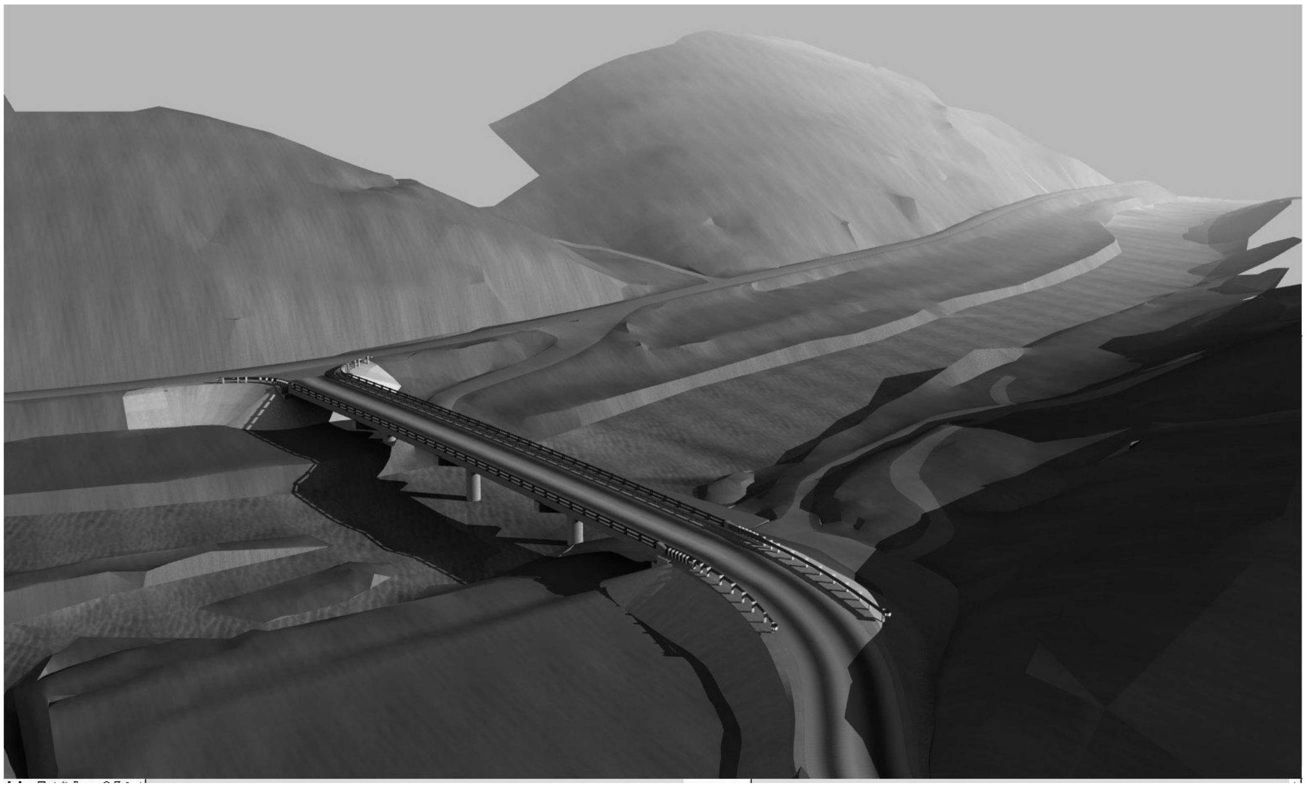
Determination of a computed position is the purpose of GPS. Functionally it is utilized for guidance from one location to another (navigation), monitoring the location and movement of people or assets (tracking), creating maps (mapping/surveying), and bringing precise timing (timing) (Caldas et al. 2004; GPS Integration in Highway Design and Construction: Quality Improvement Opportunities in the Public Sector 2005). Depending upon the application for which GPS is utilized, different combinations of equipment and accuracy are required. Table 3 displays typical grades of accuracy ranges for three intended uses.

GRADES OF ACCURACY IN GPS UTILIZATION

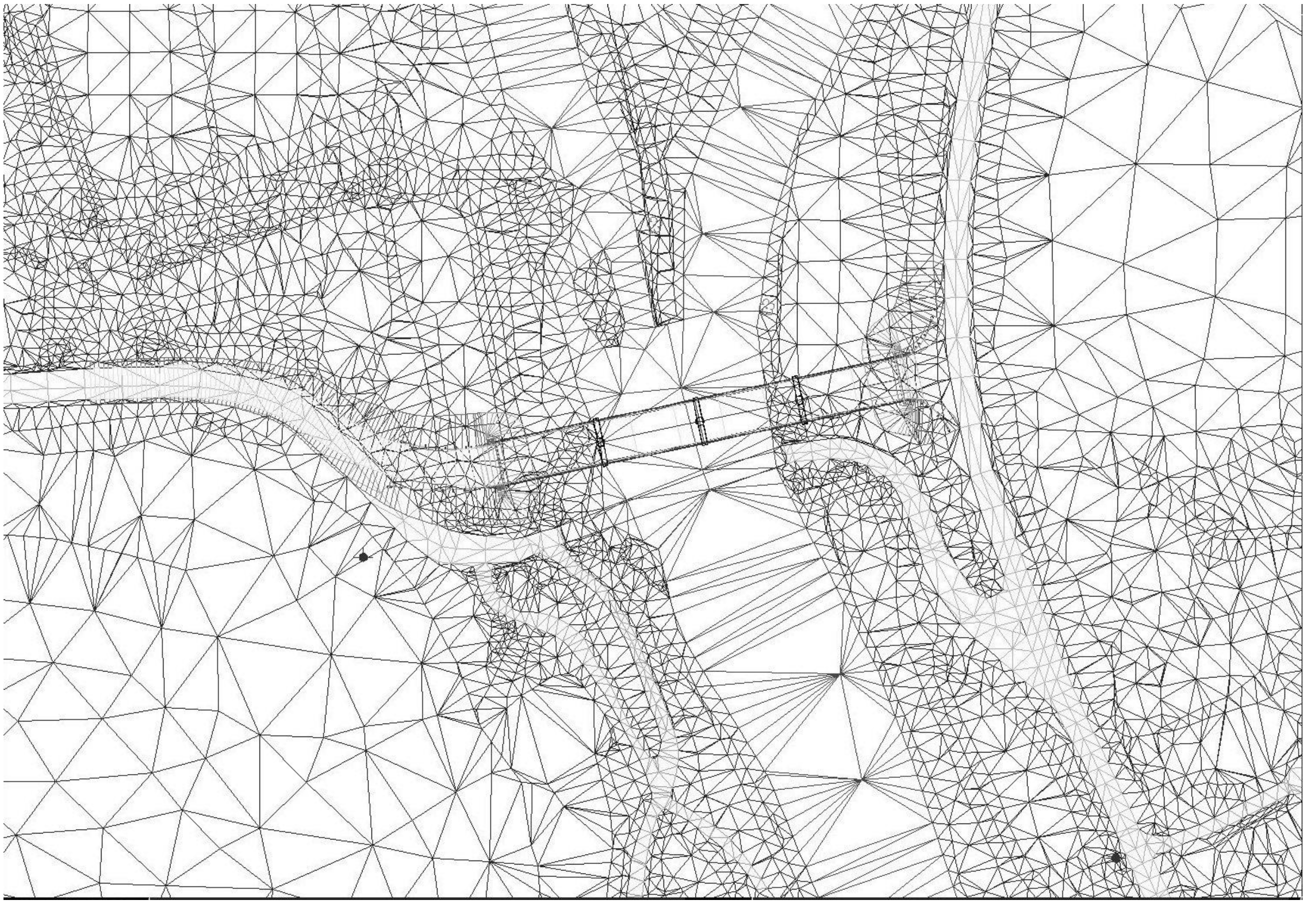
Grade	Accuracy (ft)		Use	Base Station Requirement
	Horizontal	Vertical		
Recreational	15-30	100	Sport/rough location	No
Mapping	3-10	10-30	GIS-type mapping	Yes
Survey	0.03-0.10	0.10-0.15	Land survey/photogrammetry	Yes

GPS usage on transportation projects can manifest itself during both the design and construction stages of delivery. The engineering design phase can apply GPS for surveying of existing topography of the construction project by agencies and consultants. Agency personnel or consultants typically provide survey control and track the quantity of material moved by the contractor (by unit of measure specified) for contractor payment purposes. In the project's planning and programming phases, agency or consultant designers can integrate GPS with geographical information systems (GIS) to provide increased position data accuracy and more efficient (cheaper) data collection(Czerniak 2002). The two primary uses of these technologies early in the project lifecycle are for surveying and mapping.

A requirement for one of the most important applications of GPS technology in the proceeding construction phase, machine guidance, requires the creation, sharing, and utilization of 3 dimensional terrain models. To leverage the advantages of the technology throughout project delivery, the design phase must produce this model. The availability of a 3-dimensional terrain model containing both the existing and design ground contour elevations from existing CAD software design features is preferred. However, most agencies are currently producing traditional 2D drawings or for various reasons, not sharing their 3D designs with contractors. This forces contractors who are implementing GPS technology for machine guidance to produce their own models. A common practice is the production of a Triangular Irregular Network terrain model (TIN) from a 2D design. The TIN consists of elevation points connected to form triangular planes which represent the planes on a terrain surface. **Error! Reference source not found.**The graphical image below displays an image of a 3D design model, while the second image displays a computer screen image of a TIN model.



Computer Display of 3D Terrain Model (Courtesy Bentley Systems, Inc.).



Computer Display of TIN Model (Courtesy Bentley Systems, Inc.).

In the construction phase, the technology can provide efficient methods for tracking materials and determining earthwork quantities by any of the contract stakeholders. Contractors can utilize the technology for machine guidance during excavation and embankment activities.
As stated, one GPS application is the support of earthmoving operations in the delivery of construction projects. These functions include communication between the satellites, base station receivers, the earthmoving equipment (blades and buckets), and the equipment operators as well as quantification of the differences between existing and design ground elevations. Transportation projects typically lend themselves to varying proportions of earthmoving by the contract awardees.

Hardware components required to utilize GPS in survey grade applications are as follows:

1. A GPS receiver and antenna for satellite signal reception.
2. A radio and antenna for GPS signal communication between GPS receivers.
3. A computer for GPS coordinate translation on a rover based upon the known fixed base station coordinates. In tandem with software, the computer functions as an instructional display device for a human end user. Some systems provide an interface to a

construction machine's hydraulic system controls, thereby automating machine direction with reduced need for machine operator control.

Different combinations of these equipment components are assembled into systems dependent upon project conditions and the GPS functionality desired. Large surveying projects in the design stage require high grade receivers and radios be networked to span the large geographical distances which can encapsulate the boundaries of large projects such as highways. A growing network of GPS base stations exist which have been placed by various public agencies and private organizations for the purpose of facilitating mapping and survey grade GPS capabilities. These networks include Continuously Operating Reference Stations (CORS) a network sanctioned by the National Geodetic Survey (NGS). The NGS also established the National Spatial Reference System (NSRS) which is a nationwide coordinate system which specifies latitude, longitude, and elevation through a network of marked control points. Several transportation agencies are actively involved in building out CORS networks within their state boundaries.

For GPS layout applications on construction jobsites, a base station is mounted in a fixed location within 10 km (6 miles) of the jobsite. Rover receivers for networking to the base station are available in multiple forms: Tripod-mounted hardware which combines the components of GPS receiver, radio receiver, and accommodating antennas, receives location data from satellites and correction data from the base station. Mobile pole-mounted receivers carried by field personnel and acting as a second rover can identify location and elevation points on the site's ground surface through communication with the base station and GPS software. Separate computers or controllers can be attached to interpret the data from the receivers. The GPS software applications can reside on handheld computers which then perform operations such as volume computations, staking locations for layout, and grade elevation checks. Rovers can be mounted in the back of pickup trucks and even in backpacks for material tracking applications. These field rovers require batteries for power supply. Currently, lithium ion batteries allow power supply for approximately 10 hours before requiring recharge. The following figures display GPS equipment for use in GPS layout of construction jobsites.

GPS Antennae, Receiver, Hand held Computer on Tripod

GPS Antennae and Computer

(Courtesy McAninch Corporation). **(Courtesy McAninch Corporation).**

GPS Field Computer

(Courtesy McAninch Corporation).

GPS Field Computer and Stylus Input

(Courtesy McAninch Corporation).

For GPS machine guidance, the same hardware components are required in a slightly differing configuration. A fixed base station is required and single or dual receivers (sensors) are mounted on the earthmoving equipment. The configurations are used successfully with excavators, dozers, scrapers, and motor graders. Utilizing design surface elevations from 3D models contained on a computer, the machine mounted GPS receivers guide the equipment blade or bucket to the appropriate levels and angles to produce the desired grade/elevation. This is accomplished either by operator visualization of the onboard computer, whereby the operator engages the appropriate machine controls or automatically through interface controls with the machine's hydraulic system (which engages the blade or bucket position).
The following figures display GPS hardware and software utilized for machine guidance.

Cab Mounted GPS Receiver
(Courtesy McAninch Corporation).

GPS Receiver and Blade Antennae
(Courtesy McAninch Corporation).

Dual GPS Blade Antennae on Dozer
(Courtesy McAninch Corporation).

Dual GPS Antennae on Scraper Pan
(Courtesy McAninch Corporation).

Dual GPS Antennae on Excavator Counterweight
(Courtesy McAninch Corporation).

GPS Antennae Close-up
(Courtesy McAninch Corporation).

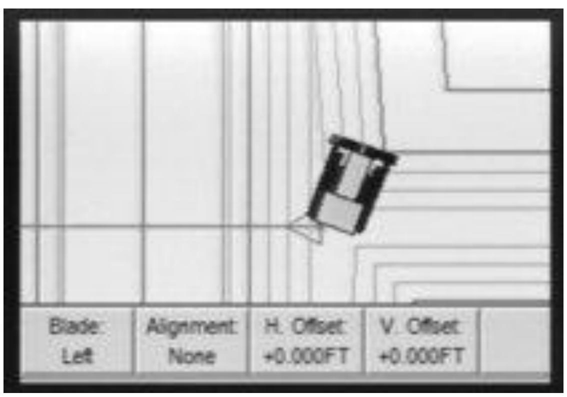
Dual GPS Blade Antennae on Dozer
(Courtesy McAninch Corporation).

Fine Grading with GPS Enabled Dozer
(Courtesy McAninch Corporation).

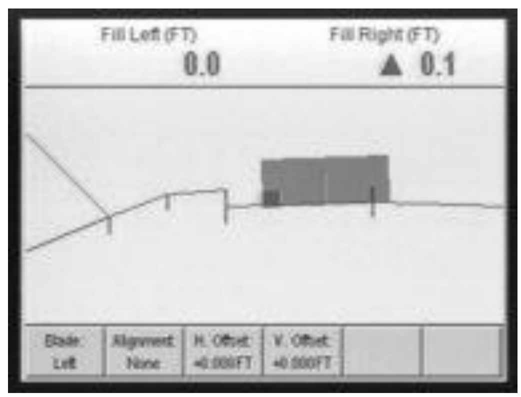
For GPS quantity tracking, base station receiver and any rover receiver can instantly calculate excavation areas, trench volumes, stockpile volumes, etc. without the need to call in a small crew of surveyors to record topographical elevations. A pole mounted receiver, an accompanying handheld computer, and a trained operator are all that is required to obtain accurate length, area, and volume quantities.

The caveat in all GPS scenarios is that a clear line of site from the satellites to the receivers is required. Terrain limitations, tall buildings, and tree cover are detriments to the GPS satellite communication. A new generation of satellites (L2) which will send signals in a different frequency to receivers may alleviate some of these hindrances in the future.

Software requirements include the availability of a 3-dimensional terrain model containing both the existing and design ground contour elevations. Software is also required to control the basic GPS hardware functions of radio signal reception, interpretation, and differentiation. Additional software interprets GPS positioning in relation to the design terrain models and is used for machine operator control and field management for grade checking, spot locations, and quantity differentials. Most GPS software applications provide plan, cross section, and profile views as well as text and text data for the user. The following images display screen shots of plan and profile views observed by construction machine operators and hardware configuration mounts for machine operator viewing. Also displayed is a ruggedized hand held computer for display of GPS information in the field.



Machine Operator Plan Contour View
(Courtesy McAninch Corporation).



Machine Operator Profile View
(Courtesy McAninch Corporation).

Machine Mounted GPS Computer
(Courtesy McAninch Corporation).

Cab Mounted GPS Computer with Light bars
(Courtesy McAninch Corporation).

Machine Mounted GPS Computer
(Courtesy McAninch Corporation).

GPS Rugged Handheld Computer
(Courtesy McAninch Corporation).

Benefits of the Technology

BROAD BENEFITS OF GPS TECHNOLOGY USE

Application	Process Improvement	Resource(s) Saved
Design surveying	Reduces field crews; replaces aerial photogrammetry, reduces facility design-phase duration	Labor count, man-hours, consultants, project duration
Staking	Reduces field crews; reduces iterations; reduces errors	Labor count, man-hours
Machine guidance	Staking iterations, machine operator reliance on physical stakes, physical staking	Labor count, man-hours, project duration, equipment-hours
As-built documentation	Reduces field crews, inspection time	Labor count, man-hours

Benefits compared to conventional surveying technology:

- Design Engineering and Surveying:
  - GPS technology enables faster surveying and mapping for design than conventional methods when line-of-sight conditions allow communications with satellites. Time compression in the design phase shortens the overall project delivery timeline.
  - Many 2-D design anomalies are found and corrected during the creation of required 3-D models.
  - Digital project design plans can provide superior accuracy over conventional 2D drawings:
  - Reduction in errors and omissions: 3D plans provide more complete review for constructability prior to construction start.
  - Utilizing GPS technology for surveying and layout is simply faster than conventional surveying methods.
  - GPS is easily incorporated with GIS mapping.
- Construction Staking:
  - Although some staking is still required, the GPS technology eliminates the need for iterative staking of different project design layers.
- Machine Guidance:
  - Since GPS allows for the most efficient operation of earthwork machinery, less operator time is required for construction, idle time and rework.

- GPS machine guided earthmoving results in greater accuracy and reductions/elimination of finish grading requirements.
  - Allows use of less experienced machine operators.
  - Places design in front of operator(Alsobrooks and Townes 2005).
  - Unlimited machines can be operated from single GPS base station(Alsobrooks and Townes 2005).
  - Line of site not required for instrumentation(Alsobrooks and Townes 2005).
- As-built/QAQC Documentation:
  - Single person can locate and document exact x,y,z positions (labor count of one required) with proper equipment.
  - GPS is easily incorporated with GIS mapping.
- Time savings:
  - Labor resource savings: While required construction of 3D terrain models (TIN: Triangulated Irregular Network) requires more engineering labor upfront in the design process, once digital 3D models are constructed and reviewed for quality, labor savings occur in construction delivery as follows:
  - Equipment resource savings: Earthmoving equipment time is maximized by GPS accuracy when either the machines are equipped with reception antennae, thereby increasing machine precision and accuracy, or simply by field crews which can spot check conventional equipment in real time. Machine idle time can be reduced when there is less waiting for excavation and embankment staking and clarifications. Finish grading iterations are lessened or nullified because of GPS accuracy, therefore resulting in a reduction of machine hours. Equipment utilization of up to 30% can be realized(Alsobrooks and Townes 2005).
  - Construction work process: The earthwork construction tasks are shortened because:
    - Contractors can mobilize to the site and begin work without waiting for surveyors to position grade stakes for the initial lifts.
    - Checking grades and rechecking spot locations immediately versus calling and scheduling a survey crew.
    - Time saved in layout and grade checking can be devoted to machine movement and cycle time efficiency.
    - Reduction in rework: Jobsite grade and location errors are more easily spotted and corrected with GPS technology than with reliance upon 2 dimensional drawings and surveyor's grade stakes.
    - Construction management: Construction field managers can make decisions more quickly and accurately because position and grade information is provided in real time.
    - Contractor and agency labor savings when measuring and documenting (in-situ) as-built quantities and pay-quantity management.
    - Erosion control can be implemented as construction sequences(Alsobrooks and Townes 2005).
    - Construction can proceed during any 24 hour shift in most weather(Alsobrooks and Townes 2005).

Owners encouraging GPS-based construction see a huge potential for speed, quality and cost

improvements, and they ultimately are in the driver's seat for its adoption. "With the motoring
public asking the departments of transportation to deliver projects quicker, this is certainly a step in the right direction," says George Ryan, a project implementation engineer for Illinois DOT.
It appears that more owners are writing GPS into project specifications. "Our goal is to have 100% of our jobs machine-controlled" in the next two years, says Lou Barrett, who heads MNDOT's computer engineering team. Those who are less ambitious are at least starting to address GPS in project manuals, should contractors choose to use it (Hampton 2005).

Bret Alsobrooks of Jones Brothers Construction has observed the following benefits of GPS technology usage by agencies and contractors(Alsobrooks and Townes 2005):

QUANTIFIED GPS RESOURCE SAVINGS

GPS Application	Replacing	Quantified Savings
Grade checking	Manual method	Up to 66% time savings
Reduction or elimination of stakes	Conventional staking	Up to 85% time savings
Improved material yields/select fills/undercutting	Overruns using manual methods	3% to 6% by volume
Un-interrupted earth moving production-all weather-continuous shifts (including night work)	Day shifts, non-precipitous weather	30% to 50% time savings
RTK, robotics stakeout	Traditional survey stakeout	More than 100% in speed and 66% in staffing (labor count)

The investment in high technology surveying equipment has helped Caltrans dramatically reduce design and construction support costs over the last 30 plus years. Between Fiscal Year 1971-1972 and Fiscal Year 2004-2005, the number of persons onboard (POB) in field surveys decreased from 898 to 509. Over the same period, the percentage of field surveys POB to Capital Outlay Support (COS) workload dropped from 14.4% to 5.5%.
Over the last decade, Caltrans has spent about $10 million (average $1 million per year) on high technology survey equipment, including GPS and robotic total stations. Over that same period, the percentage of field surveys staff to COS workload has dropped from about 7.5% to 5.5%, or .2% per year. The increased productivity has allowed Surveys to free up staff and resources to begin to eliminate the historical monumentation backlog and other project close-out work. High technology has also enhanced safety for Surveys staff and the traveling public. The ability to perform surveying operations away from traffic has reduced the number of lane closures. (Gene Mallette correspondence 05/25/06).

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