3D GPS Earthmoving Equipment Controls

Dwayne McAninch, chairman and CEO of McAninch Corp, Iowa's largest earthmoving contractor is not your typical contractor. He is responsible for the successful marriage of Trimble Navigation Ltd.'s surveying/GPS technology and Caterpillar Inc.'s earthmoving equipment nearly a decade ago. McAninch facilitated testing, development and refinement of prototypes on his own equipment, set out on a campaign to educate the construction industry on the benefits of GPS-based digital earthmoving and shared his own performance data to demonstrate significant productivity and safety improvements.

McAninch adopted GPS in 1999 when Trimble Navigation introduced the dual-antenna Site Vision system that employs guidance and machine control. McAninch was the first earthmoving contractor to employ Trimble Site Vision GPS receivers on his equipment and currently has almost seventy receivers on scrapers, trucks, excavators, graders and dozers.

For decades, equipment operators took their instructions from stakes in the ground that had to be moved and reset as the work unfolded. Grade stakes will soon be obsolete, thanks to 28 Global Positioning Satellites that send radio signals to earth. Onboard GPS receivers allow scrapers, dozers, and graders to plot accurate courses with little or no reference to in-ground markers. Light bars mounted in the operator's field of vision signal proper blade angle as the machine moves, while a video display shows the proper cut or fill on the job site. Equipment operators work with a computer screen inside their cabin and know where their blades are within a fraction of an inch. The immediate benefits are speed and extreme accuracy. Productivity is improved by at least 30% with higher quality results. Grade tolerances are between 0.1 and 0.01 feet.

With GPS, supervisors and foremen no longer have to reset stakes, instead, they can concentrate on monitoring the work, haul routes and cycle times. At the end of the day they drive their GPS-equipped pickups and send progress data to the home office so that estimators can check actual progress and productivity against the original schedule. Real-time information allows for more effective monitoring of the job, detailed and accurate management of individual pieces of equipment and more precise cost analysis. Earthmoving operations are safer because less time is spent on the job and less people are involved. In short, all earthmoving tasks and management functions are improved by GPS and this more than offsets the cost of the technology.

The technology has been used on several projects in the United States and in Australia. For the future, McAninch has expressed interest in seeing GPS used for "intelligent" soil compaction and streamlining digital data between designer/consultant, contractor and operator.

Engineering News Record selected McAninch as recipient of the 2005 Award of Excellence in their April 6th, 2006 issue. According to the magazine, "the pioneering and persevering work of J. Dwayne McAninch is set to revolutionize design and construction in the field." The 69-year-old McAninch has spent years perfecting and advocating the use of global positioning system technology in his industry, bringing earthmoving into the digital age.

The innovation nominated here for the Nova Award is 3D-based earthmoving equipment controls for construction, from invention to implementation. Obvious prime movers were Caterpillar and Trimble who together developed the first GPS system for a bull dozer. However, that dozer's instruments were not well fitted to construction. McAninch was the third prime mover, for construction, because he brought to Caterpillar and Trimble the need for more accurate and practical controls for construction equipment and worked with them using his own construction equipment fleet to develop the tools construction needed. Therefore, primarily responsible for the innovation are Caterpillar, Trimble, and McAninch.

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Transformation.
McAninch converts plan (left) into a digital model (center) so it can grade the finished product (right).


AccuGrade®
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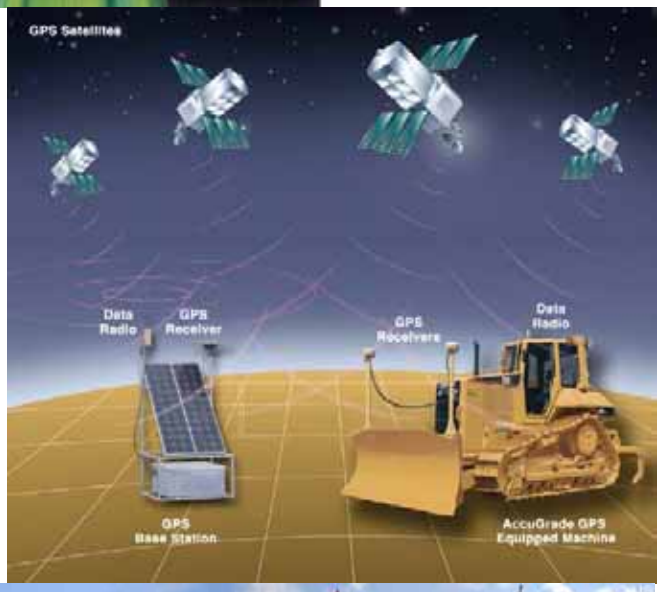
GPS Satellites
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GPS Receiver
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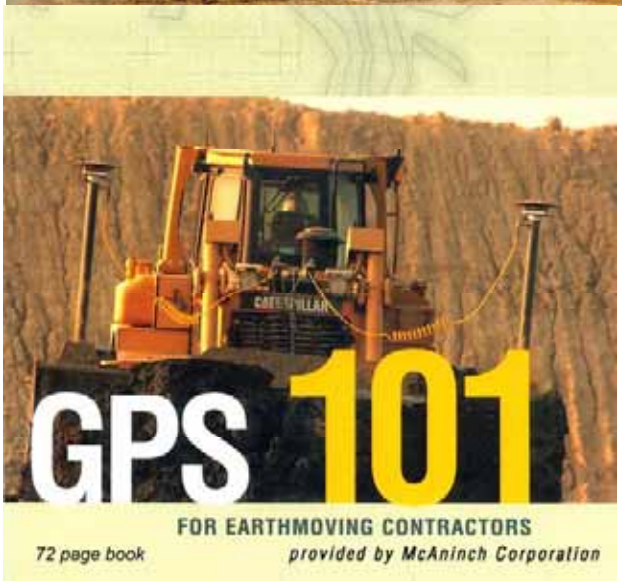
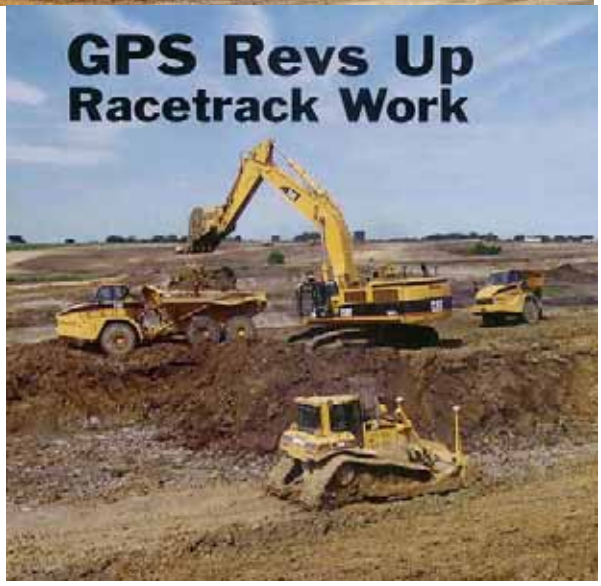
Trimble
Productivity


GPS 101
FOR EARTHMOVING CONTRACTORS
72 page book
provided by McAninch Corporation


GPS Revs Up
Racetrack Work

INVESTIGATOR'S SUMMARY[1]

Nomination 2006-30
Investigator: Charles R. Glagola, P.E.[2]

3-D GPS EARTHMOVING EQUIPMENT

The Innovation

The innovation is a 3-dimentional grade control system that eliminates conventional survey staking requirements though application of Global Positioning System (GPS) technology and sophisticated control systems. On-board GPS receivers allow scrapers, dozers, and graders to plot accurate courses with little or no reference to in-ground markers. Light bars mounted in the operator's field of vision signal proper blade angle as the machine moves, while a video display shows the proper cut or fill on the job site. Equipment operators work with a computer screen inside their cabin and know where their blades are within a fraction of an inch. The immediate benefits are speed and extreme accuracy. Productivity is improved by at least 30% with higher quality results grade tolerances are between 0.1 and 0.01 feet.

On a traditional earthmoving site, there can be thousands of survey stakes required to guide the heavy equipment through cut and fill operations, fine grading, and compaction efforts. This process of establishing and reestablishing grading control is a critical path element that can make or break a project. The process is slow, labor-intensive, and exposes surveyors to potentially hazardous working environments. With the development of 3-D GPS earthmoving technology, the drawbacks of the traditional survey staking process are not only eliminated, but there are significant savings in time, accuracy, machine productivity, equipment usage reductions, etc. as a result. Application of this innovation can result in as much as 30% savings in schedule as well as increasing project safety.

This technological advancement has many other applications for heavy equipment operations and produces many advantages in productivity and safety beyond that of the

[1] October 3, 2006
[2] Associate Professor of Civil Engineering, University of Florida.

savings derived from replacing conventional survey control of sites. One of the main advantages is that the operator works within the cab of the equipment with a completely updated plan from which decisions can be made based on accurate and current project status rather than on intuition and experience.

Application of the Innovation

Although there are many current and countless future uses for this innovation in construction, the 3-D GPS control system has been successfully used on a range of applications including:

- Bulk earthmoving such as land reclamation projects, dam and reservoir construction, new infrastructure projects, landfills, and waste disposal sites
- Find grading applications including new road construction and road widening, airport construction including runways and tarmacs
- Fine grading operations for concrete pours and slab placement
- Commercial site preparation requiring high accuracy
- Mining and tunneling operations
- Residential site preparation and subdivision construction
- Single house pads or entire neighborhood with infrastructure
- Marine construction applications such as dredging using GPS for positioning, or near-shore applications such as seawalls or channel construction with excavators.

One of the prime participants in the evolution of this innovation in earthmoving operations is McAninch Corporation of Des Moines, Iowa. McAninch has been so successful in its application of this technology that the company's founder and CEO, Dwayne McAninch, was named the Award of Excellence Winner by *Engineering News Record* for his contributions, using 3-D GPS, to the advancement of the industry.

On a very large earthmoving project at the Iowa Speedway, McAninch employed the 3-D GPS for general excavation and will also employ it for the installation of over 40,000 feet of various kinds and sizes of pipe necessary for site drainage and utilities. In the general earthmoving operations, a CAT 385 excavator and CAT D9L/369 scraper significantly improved efficiency and productivity. As well as individual machine improvement, McAninch discovered that one of the real savings was in significantly reducing wait time supporting equipment since four or five trucks depended on the efficiency of the excavator. Whenever the excavator worked efficiently the truck utilization also become more efficient.

A few of the earthmoving projects that have been or are being constructed using this technology are:

- a $40.4 million dollar roadbuilding project in North Carolina,
- $7 Million earthmoving contract in conjunction with development of the Iowa Speedway in Newton, Iowa,
- Powder River Basin (PRB) where 35% of the nation's coal is mined
- Cortez Gold Mines in Nevada
- Jack Nichlaus-designed Bear Mountain Golf Course in Victoria, British Columbia
- Greg Norman-designed Cliffs Over Maple Bay, Vancouver Island, British Columbia

In earthmoving operations related to the mining industry, real-time GPS position monitoring of mining equipment is becoming more and more commonplace. Digital mining plans can now be used onboard properly equipped earthmoving equipment and excavation status is available in real-time via high bandwidth data radio systems. These systems provide a closely integrated link between operations and planning. Use of GPS at an open copper mine has resulted in system payback of slightly over one year. As ramps, benches, reclaim contours, etc. are constructed at the open pit, the earthmoving equipment used in the operations displays desired slopes and elevations from digital plans on board. "Superimposing and up-to-date topographic map display derived from real-time on-board GPS triangulation, permits the operator to determine how much cut or fill is required. This "virtually surveyed" topo map is continuously updated and recorded as the tractor moves about thus providing accurate cut and fill indications everywhere, regardless of visibility conditions and availability or proximity of physical survey marks.

A test of the 3-GPS in dozer operations at a large open cut coal mining operation over a three week period where dozers were used in benching for dragline pads resulted in production increase of 30% greater than that from conventionally survey-supported machines. These "incredible results" were realized under very difficult earthmoving conditions. The ground was very soft, slopes were steep, and machines were constantly moving about. The distance from top of highwall to toe of dragline pad was significant and difficult to cover adequately with conventional survey marks. Thanks to continuous virtual survey marks (the 3-D GPS system) engineers were able to utilize a more complex plan at the top of the highwall which minimized material handling requirements. Over a one year period, the amount of material ordinarily "rehandled" was reduced by 2,000,000 cubic yards resulting in a $500,000 cost savings just in this one part of the operation.

Landfill operations have also benefited from this innovation. Compactors and loaders are typically used in landfill operations and with the 3-GPS technology, these operations are streamlined. A plan for

machine operations is developed on a computer and these plans are input into the GPS equipment on the compactor. As compactors make a pass over an area, the GPS system records this in color on a screen displaying the operations plan. As new loads of refuse are brought in these changes in the physical character of the fill are also noted on the system in the control building and transmitted real-time to the compactor where the plan is automatically updated. The operator knows which areas have been adequately compacted and which are in need of further passes. Using this innovation, a test run at a Midwest landfill showed a 14% increase in compaction from 1150 lb/cubic yard to almost 1400 lb/cubic yard. This resulted in a $1,500/day in airspace savings thus increasing the life of the landfill. Because the operator knows instantly what areas have been adequately prepared and which areas are in need of attention has drastically reduced the "over-working" of areas of the fill. The decrease in the amount of rework in landfill operations has been reported as high as 90%.

Background of the Innovation

The innovation was brought to its current state of development and application through the combined efforts of a high-tech products development company, Trimble 3-D Products, the heavy equipment giant Caterpillar Corporation, and McAninch Corporation an Iowa earthmoving contractor. While these three companies represent different operations and strategic interests in the industry, they discovered that these interests could be better served by working together for a common vision which has resulted in a system that is state of the art in earthmoving technology today.

The first GPS (NAVSTAR) satellite was launched in 1974, primarily for defense applications. By the late 1980s, researchers in non-military establishments, like Caterpillar and Trimble Navigation, were experimenting with commercial applications of GPS. In the early 1990s Caterpillar researchers demonstrated that GPS could deliver accuracies at the centimeter level by employing a local reference station. The "GPS Controlled Earthmoving Machines" invention at Caterpillar was documented in 1943 with the filing of US Patent 5,850,341. This patent described the combination of real-time, hi-accuracy GPS positioning, on-board computing, and on-board digital site plans to guide and control earthmoving machines. Within Caterpillar it was recognized that this innovation could potentially control blades on earthmoving machines much more efficiently and accurately than machine operators working from paper plans and survey stakes.

Like Caterpillar, Trimble Navigation was also experimenting with GPS at this time and in 1998 they introduced the 3D construction grade control system as one of the most revolutionary changes in earthworks machinery controls. Trimble has continued to develop innovations in equipment and software for grade control systems with the introduction of GCS21 in 1997, BladePro 3D in 1998, SiteVision SPS Grade Control System in 1999, and now the GCS900 in 2005. Today, Charles L. Schaidle of CAT and Mark Nichols of Trimble lead the combined Caterpillar and Trimble team.

In 1999, Dwayne McAninch, the largest earthmoving contractor in Iowa, began innovating his earthmoving operations by being the first earthmoving contractor to employ the Trimble Site Vision system that employs guidance and machine control. Today McAninch has almost seventy receives on scrapers, trucks, excavators, graders and dozers.

Responsibility for the Innovation

Although GPS technology presented significant possibilities and was making significant advances through the 1990s, it wasn't until the three innovators joined forces and Caterpillar, Trimble, and McAninch Corporation embarked on the next phase of this technology revolution by actually controlling the blade of earthmoving machines in construction applications. Leading McAninch Corporation's involvement was a team led by Dewayne McAninch and included Tim Tometich, Pat Ruelle and Don Taylor. Caterpillar was led by Charles L. Schaidle and Trimble was led by Mark Nichols.

The technical innovation was a joint development of Caterpillar and Trimble. Making this technology work however, required to combining of the technical expertise of CAT and Trimble as well as the operational expertise of McAninch. This brought the correct combination together that has resulted in the remarkable product that is changing the face of the earthmoving industry today.

Opinions of Persons Contacted

Arthur Taylor, Trimble 3D Products – Trimble started out in the mining industry providing GPS solutions to their earthmoving operations. Later, we found out the Caterpillar was working on similar applications and rather than compete with different products we got with the people at CAT and formed a joint venture so as to combine the knowledge, experience, and expertise of our people and the people at CAT. As the products developed, we became aware of Dewayne McAninch, an earthmoving contractor in Iowa, who had a lot of innovative ideas and was eager to apply our technologies to his

operations. McAnninch was our first earthmoving contractor to utilize our control systems on his equipment and has been instrumental in contributing operational needs and requirements in the refinement and development of new products. The support from Caterpillar was essential and when McAninch joined the effort, all thing seemed to come in to place.

Charles L. Schaidler, Caterpillar Corporation – We started looking into the possibilities of GPS application after studying what the military was doing with the first GPS systems that were developed around the NAVSTAR satellite (the first) and other satellites that were subsequently launched. We began to develop prototypes in the late 1980s and soon realized that we weren't the only people interested in this new technology. One of the other companies experimenting with GPS was Trimble Navigation. Trimble was looking into controls that could be used to enhance earthmoving operations by controlling the equipment. We joined with Trimble in 1994, to develop systems for our Caterpillar earthmoving equipment. Working with Trimble we developed a number of equipment control systems but the real breakthrough came when we joined forces with McAninch. This marriage of CAT, Trimble, and McAninch has been significant in bringing together just the right combination of expertise that has resulted in the development of equipment control systems that are making significant impacts on the industry.

Tom Holtz – McAninch Corporation – McAninch has always been an innovative company thanks to the leadership of Dwayne McAninch. This is a competitive business and by being at the cutting edge of technology, we feel, combined with our service focused culture, gives us a significant advantage in the market. Implementing the Trimble system back in 1999 and then joining forces with Caterpillar and Trimble to help in the development of new and improved systems has been very beneficial for all of us. We're pleased with the results we've achieved from using the GPS control systems and feel that there are still significant opportunities for further development and improvement and we feel that we are going to be a part of that with this relationship that's been built and has worked so successfully.

Investigator's Comments

Being an old earthmover myself, I was very excited to be assigned to this award nominee. As a young man, I worked on a survey crew with the C&O Railway Co. building lines to coal mines in West Virginia and Eastern Kentucky. With a brushhook and an old bubble level we'd go up and down those mountains staking for earthmoving (blasting) operations and then once again for pay quantities. To think of how this GPS technology would have helped!

What I'm illustrating is a contrast between what we had to work with only a few years ago and what is now available. This 3-D GPS innovation has just started to revolutionize the earthmoving industry; the possibilities that lie ahead are mind-boggling and, based on my investigation, I would suspect that the innovators nominated here will be at the forefront of the breakthroughs. It always takes visionaries to make revolutions and I

believe that this innovation is truly a revolution as I have come to realize that the participants are truly visionaries.

SELECTED INTERVIEW SUMMARIES

(See opinions of persons contacted above)

SUPPORTING EXHIBITS

1. Grandia, Curt, *Embracing New Technology*, *GPS Offers Improvements in Safety, Accuracy, Efficiency, Midwest Contractor*, January 10, 2005

2. Schaidle, C.L., *Earthmoving in the Information Age*, Society for Mining, Metallurgy, and Exploration, Inc., Preprint Number 94-48.

3. United States Patent, Patent Number 5,850,341, Dec. 15, 1998.

4. Chadwick, John, *New Technology at Cortez*, MINING Magazine, February 2000

5. Hampton, Tudor, *Award of Excellence*, Engineering News Record, April 10, 2006.

6. Grandia, Curt, *GPS Revs Up Racetrack Work*, Midwest Contractor, August 8, 2005

7. Kral, Steve, *Caterpillar's MineStar Helps Black Thunder Coal Mine Maximize Production*, MINING Engineering, November 2001

8. Greene, Dennis, *Benefits of GPS Position Monitoring for Earthwork Equipment*, Society for Mining, Metallurgy, and Exploration, Inc., March 1998.

9. Fisher, Christina, *Staking the Grade with GPS*, Dixie Contractor, May 1, 2006.

10. Grandia, Curt, *GPS Expands Contractor's Capabilities*, Midwest Contractor, August 14, 2006.

11. Kalousdian, Aram, *GPS Used on I-69*, Michigan Contractor & Builder, August 5, 2006.

12. Sitek, Greg, *Equipment and Electronic Integration*, Construction Digest, August 14, 2006.