Industrial Technologies Program

Investigation of a Combined GPS and Inertial Measurement Unit Positioning System for Mining Equipment

Inertially-Aided CAES Hydraulic Shovels and Blasthole Drills to Increase GPS Signal in Open-Pit Mines thereby Improving Mine Productivity

Caterpillar's Computer Aided Earthmoving System (CAES) is a tool that integrates planning and design operations to reduce costs. CAES uses on-board computers, software, Global Positioning System (GPS), and data radios and receivers to replace the manpower-and time-intensive processes associated with conventional surveying. The on-board system displays the mine plan, showing the operator where the machine is relative to the design area, what the current surface is, and where the final design surface is to be. Specifically with loading machines, material maps are displayed which show the location of ore bodies that greatly impact the ore grade quality. CAES identifies material types and tracks operator progress for greater efficiency and control of mine operations. This information is also transmitted back to the engineering office for analysis and documentation. The office software provides the ability to create customized reports on productivity data, cycle times, volume and material type. The result is improved communications, greater production accuracy, and higher energy savings.

The accuracy of CAES is compromised when there is insufficient satellite visibility, known as satellite shading. This visibility problem occurs when machines operate closer to pit walls or deeper in the mine, limiting the strength of the GPS signal. Satellite outages can be lengthy, and insufficient visibility can last up to six hours a day. In order for all mining tasks to benefit from CAES's current capabilities, CAES must compensate for satellite shading that leads to GPS signal loss.

Caterpillar Inc. and Applanix Corporation are developing a combined GPS/Inertial Measurement Unit (IMU) positioning system to achieve comparable accuracy during satellite shading. The current Applanix systems, that combine GPS and IMU, use linear acceleration and angular rate measurements from the inertial sensors with position and velocity measurements from GPS to compute a highly accurate solution. Caterpillar's approach, however, will be to combine the GPS and inertial sensors by estimating the errors in the IMU. This will limit the position and velocity error growth while navigating through extended GPS shading. Caterpillar's approach is self-contained on the machine and does not require any infrastructure to be placed in the mine.

All of the components in this project are widely accepted since they are currently being used in a variety of applications. Applanix's core technology in the Positioning and Orientation System has found uses in multiple areas, from marine to aircraft. Meanwhile, Caterpillar's CAES is being used to optimize accuracy and energy in existing mining operations. Integrating the two technologies will show significant monetary and energy savings, and because CAES will function the same way as it did prior to the integration, there will be no operator adjustment period for the new system.

Applanix's POS MC

Benefits for Our Industry and Our Nation

- Reduces time used to rework benches by better GPS recovery.
- Reduces material and operation costs by improvement in mining productivity.
- Recovers 15% of signal by GPS/IMU system.
- Reduces energy consumption between 4-36% based on installation of technology in various mines.

Applications in Our Nation's Industry

This system has the potential to enhance the economic competitiveness of the domestic mining industry by eliminating unnecessary economic losses during insufficient satellite visibility. This technology will allow more mining tasks to benefit from CAES's ability. Through the development of this technology there will be immediate advancements in the use of the following equipment: hydraulic shovels, rear dump trucks, front-end loaders, and bulldozers. The coal, copper, iron, and gold mining industries will also have an immediate impact from the testing conducted in these types of mines, and the potential exists for impacting more mining industries.

Project Description

Objective: To develop an integrated positioning system for mining operations that will allow accuracy during satellite shading that was not previously possible, and allow machine autonomy.

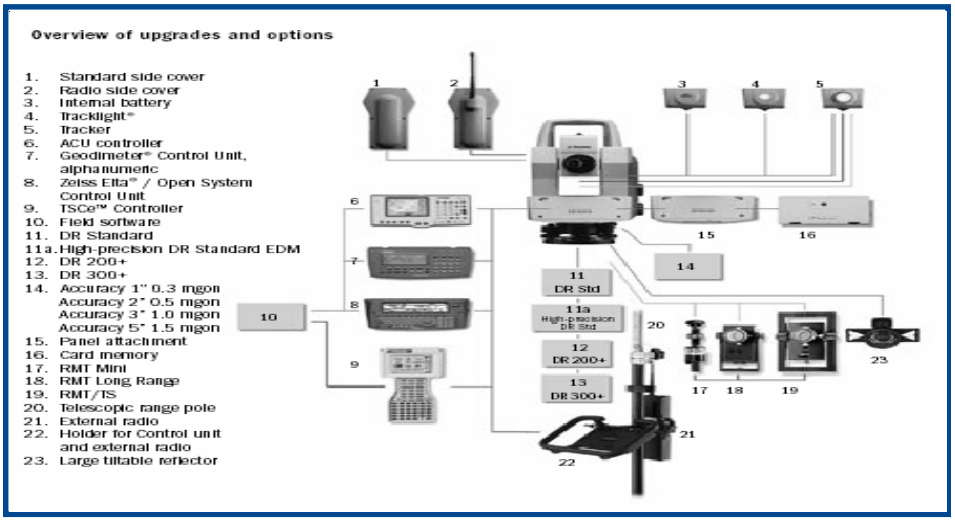
This project will be completed in three phases. The Phase I objective is to successfully test an integrated CAES product on a bulldozer at Caterpillar's proving ground to confirm Applanix's POS MC performance with a Trimble robotic total station. The Phase II objective is to successfully test the new system on a bulldozer in a mine site's rugged environment. A successful test will demonstrate that the system has accurate enough machine position tracking to improve the productivity of a bulldozer during satellite shading. A less expensive IMU will be tested at Caterpillar's proving grounds. Next, it will be installed in a hydraulic shovel and tested at Twin Creeks. The Phase III objective will be to implement the less expensive IMU system for a blasthole drill. Phase III also includes a commercial feasibility study based on cost reduction and energy saving analysis from the data collected from the mine tests on a hydraulic shovel and blasthole drill.

Caterpillar will outfit the hydraulic shovel with a system that can instantaneously switch between Applanix's positioning system (POS MC) and the current GPS system to allow CAES seamless position information. Caterpillar and Applanix will collect data and resolve any problems that occur during testing. They will make adjustments as needed in order to increase position accuracy and reduce energy output.

This project involves the cooperation of Caterpillar, Applanix, and Newmont Mining Corporation. Caterpillar's team will be comprised of Technical Service Division's Systems, Controls and Components Research group, which will manage the program and provide the integration engineering needed to incorporate Applanix's prototype POS MC into the CAES. Applanix's leading contribution to the project is their ability to modify their core technology into products for multiple applications. Caterpillar's joint venture, Caterpillar Trimble Control Technologies (CTCT) will provide product design and GPS expertise, and will ensure that after this research program, the joint venture can continue to work with Applanix to commercialize the prototype system.

Milestones

- Develop method to stream out real-time position data for robotic total station, and use this station to confirm POS MC performance on a shovel at Twin Creeks.
- Test POS MC with a less expensive IMU at Caterpillar Inc. proving grounds, and install new system on shovel.
- Install new GPS/IMU onto the mine site's blasthole drill, establish the data collection method and perform testing and data analysis.
- Perform a commercial feasibility study on the data analysis from the mine testing.



Trimble Robotic Total Station 600

Project Partners

Caterpillar Inc.
Peoria, IL

Applanix
Richmond Hill, ON

Newmont Mining Corporation
Twin Creeks Mine, NV

Trimble Technologies
Chandler, AZ

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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October 2004