Alameda-Contra Costa Transit District

STAFF REPORT

TO: Planning Committee
AC Transit Board of Directors

FROM: David J. Armijo, General Manager

SUBJECT: California PATH Vehicle Automation & Assistance Study

ACTION ITEM

RECOMMENDED ACTION(S):

Consider authorizing the General Manager to enter into an agreement with the University of California to participate in a study of magnetically guided buses led by California PATH, and the Federal Transit Administration’s Vehicle Automation and Assistance (VAA) program.

EXECUTIVE SUMMARY:

The FTA Joint Office for Intelligent Transportation Systems and Caltrans Office of Research and Innovation have established a program to investigate various technologies aimed at assisting drivers in lane keeping and precision docking. These offices have engaged UC Berkeley’s “California PATH” researchers to develop the technologies.

AC Transit, along with Lane County Transit District (Oregon), is participating in a field test of promising technologies. AC Transit’s participation so far has been focused on developing a customer focus group and survey strategy, coordinating the delivery of buses to the PATH researchers and preparation of the operations and operator training elements of the study. The upcoming phase of the investigation involves evaluating a magnetic guideway technology using magnetic embedded in the roadway along with detection, steering assistance equipment and Differential Global Positioning System (DGPS) equipment on the coach. This approach has been successfully tested at the California PATH proving grounds in Richmond and is now ready for real world testing and evaluation.

Once engaged, the PATH system will keep the coach on track +/- 1 centimeter without driver input at the wheel. This feature promises to increase safety and speed through narrow passages like toll plazas and enable precise positioning of the coach at Bus Rapid Transit (BRT) stations.

At all times, the driver manually controls the speed of the vehicle and can assume full control of the coach by simply turning the steering wheel or manually turning the system off.

If awarded, the contract would require AC Transit to:

- Provide two MCI coaches to California PATH, one at a time, for modification;
- Train coach operators to operate the system;
• Dispatch the coaches in revenue service; and

• Collect and report data on the operation of the system, operators' and public perception of the system.

• The District and Lane County Transit District (LTD), in Eugene Oregon, are participating agencies in a Field Operations Test of an automated guidance system for public transit buses. Participation by both agencies demonstrates the transit industry’s interest in the technology.

• The study is sponsored by Federal Transit Administration's Joint Office for Intelligent Transportation Systems and Caltrans' Office of Research and Innovation. The study is led by California PATH, a research arm of UC Berkeley.

• The program, called Vehicle Automation and Assistance, focuses on technology to assist bus operators and improve safety through "lane keeping" and precision docking. The test will use two AC Transit coaches operating in revenue service on the M Line. The system employs magnets embedded in the roadway that are read by on-board detectors and computers which accurately position the bus in its travel lane.

• The technology will be evaluated for its ability to improve vehicle speed, reduce accidents and vehicle damage. Operators will be queried about its effectiveness, ease of use and effect on their stress levels. A separate customer focus group and survey will also be conducted to assess public satisfaction and acceptance.

**BUDGETARY/FISCAL IMPACT:**

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<td>Labor</td>
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The District does make a financial contribution. However, that contribution consists of the staff time required to assist the researchers. UC Berkeley has funds to pay the District up to $20,000 for expenses incurred such as travel or overtime. The dedication of District Staff time and staff time at LTD is an in-kind contribution. To FTA, this demonstrates the transit industry’s interest in the technology. Staff time is required to train operators, conduct public outreach and publicity and to provide data to the independent evaluator. Staff will perform tasks intermittently for the 10 months the project is underway. Below is an estimate of the amount of staff effort involved to complete the study.
BACKGROUND/RATIONALE:

Program Overview. The District and Lane County Transit District, in Eugene Oregon, are participating agencies in a Field Operations Test of an automated guidance system for public transit buses. The VAA Field Operations Test began in September 2009 following a successful grant application by California PATH.

FTA is supporting this research to create technologies that close the performance gap between buses and light rail. The lane keeping and precision docking functions are particularly viewed as key components of future BRT systems and promise the following key benefits:

- Reduced right-of-way requirements and lower costs due to the ability to use narrower bus lanes
- Precision docking and level boarding providing better access for those with limited mobility
- Safer overall operations, reduced accidents and fewer on-board falls
- Smoother ride quality
- Shorter dwell times to reduce operating cost and increase ridership
- Improved bus operator health outcomes such as lower stress levels and reduced incidence of musculoskeletal problems

The study will evaluate the automated guidance technology under a variety of real world conditions. The District portion of the test will focus on High Occupancy Vehicle lane and toll plaza applications. By contrast, the LTD portion of the test will focus on low speed urban Bus Rapid Transit applications. Attachment 1 is an overview presented to the Bus Rapid Transit Policy Steering Committee and Attachment 2 is the most current study schedule.

Study Sponsors. The study is sponsored by Federal Transit Administration’s Joint Office for Intelligent Transportation Systems and Caltrans’ Office of Research and Innovation.

Description of Technology & Field Operations Test. The overall program, called Vehicle Automation and Assistance, focuses on technology to assist bus operators and improve safety through “lane keeping” and precision docking.

The first phase of this study was conducted in 2008. PATH operated a university-owned bus outfitted with the technology on East 14th in San Leandro. This test produced +/- 1 centimeter (0.4 inch) accuracy over hundreds of bus runs. Attachment 3 is a UC Berkeley press release on the test.

In 2009, PATH received an additional FTA grant to test the technology in revenue service and develop prototypes that could be manufactured by US companies and deployed on a variety of buses. To develop a product ready for manufacture, PATH has engaged local businesses such as Richmond’s ContainerTrac and Bob McGee’s Machining Company in Berkeley.

The system employs magnets embedded in the roadway that are read by on-board detectors and computers which accurately position the bus in its travel lane. These inputs control a steering actuator, a small electric motor which steers the bus. The system has two separate
computer controllers for redundancy and improved safety and performance. Photographs of the equipment are shown in Attachment 1.

The AC Transit effort will use two MCI coaches operating in revenue service. The District portion of the study will take place on the M Line that traverses the Hayward-San Mateo Bridge. In cooperation with Caltrans District 4 (SF Bay Area), PATH has installed magnets in the High Occupancy Vehicle (HOV) Lane of State Route 92 from Hesperian through the toll plaza, a distance of three miles. The system will operate at bus speeds ranging from 65 miles per hour in the HOV lane to very low speeds through the toll plaza. Negotiating the toll plaza is a challenge for operators, with only six inches clearance on either side of the mirrors. Operators currently slow down to a near stop to safely pass through the plaza. The system is intended to provide precise vehicle control through this very constricted space, potentially enabling operators to travel smoothly and consistently at the posted speed of 5 mph without stopping.

PATH has completed the installation of the equipment on the two MCI coaches. In late August, PATH will finish the calibration and software updates for the equipment and conduct closed-course testing. The District and PATH will next conduct road tests without passengers. Operators will be trained in September or October and the vehicles placed in revenue service shortly thereafter. All eight M line operators will be trained in use of the system for each sign-up. Only trained operators may use the system. If an untrained operator (e.g. from the extraboard) is assigned to a particular run, the system will be disabled for that run. Maintenance of the equipment will be the responsibility of PATH. The maintenance of the vehicles remains the responsibility of the District. Operators will retain responsibility for safe operation of the coach. Consequently, they will have the option of disabling the system at their discretion. In addition, the system permits the operator to disable the system in an emergency by simply taking control of the steering wheel or turning the system off.

The test will last six months and include comparisons of performance on runs with the system turned on and turned off. The study will be completed in September 2013.

**Evaluation Plan.** The technology will be evaluated for its ability to improve vehicle speed, reduce accidents and incidents of vehicle damage. The system itself will measure its accuracy and record any technical problems. The system will also collect data on speed and smoothness of travel. Operators will be queried monthly about its effectiveness, ease of use and its effect on their perception of stress level using the system verses not using it. District records of vehicle damage before and during the study will be provided to the independent evaluator. A separate customer focus group and survey will also be conducted to assess public satisfaction and acceptance. Vehicles will be clearly identified as being outfitted with the technology to assist in the customer survey. Attachment 4 is a sample decal for placement on test buses. The District-specific program is called MAGS, short for magnetic guidance.

The independent evaluation is being led by the Center for Urban Transportation Research/National Bus Rapid Transit Institute at the University of South Florida.
### Staffing Plan

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<tr>
<th>Name</th>
<th>Position</th>
<th>Hours</th>
<th>Total Staff Time</th>
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<tr>
<td>Jim Cunradi</td>
<td>Study Coordinator</td>
<td>12 hrs x 10 months</td>
<td>120 hours</td>
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<tr>
<td>Karen Lynch</td>
<td>Customer Outreach &amp; Passenger Survey</td>
<td>8 hrs x 10 months</td>
<td>80 hours</td>
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<tr>
<td>Tony Divito –</td>
<td>Operator Liaison &amp; Maintenance Data Collection</td>
<td>8 hrs x 7 months</td>
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<tr>
<td>Joe Tating</td>
<td>Operator Training &amp; Training Development</td>
<td>Operator training (70 hrs) + program development (12 hrs)</td>
<td>84 hours</td>
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<tr>
<td>Stuart Hoffman</td>
<td>Technical Services/Coordination &amp; Bus Delivery</td>
<td>4 hrs x 10 months</td>
<td>40 hours</td>
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<tr>
<td>Christopher Beach</td>
<td>Operations Management</td>
<td>4 hrs x 10 months</td>
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<tr>
<td>Bus Operators</td>
<td>Classroom &amp; Track Training</td>
<td>8 operators x 5 hrs x 3 signups</td>
<td>120 hours</td>
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<td>Bus Operators</td>
<td>On-the-Road Training</td>
<td>8 operators x 3 hrs x 3 signups</td>
<td>72 hours</td>
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<td><strong>Total staff time</strong></td>
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<td><strong>612 hours (0.29 FTE)</strong></td>
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**ADVANTAGES/DISADVANTAGES:**

May reduce damage caused by collisions at the bridge toll plaza for the duration of the test. Participation demonstrates the District’s leadership in technological innovation. Success of the technology will benefit the US transit industry by giving buses more rail-like performance. For the District and the entire transit industry, the technology can provide the advantage of precision maneuvering and docking along with increased safety in traffic and a smoother ride for passengers. The technology promises to improve bus rapid transit operations by permitting reliable docking at BRT stations, increasing speeds through reduced dwell times and increased safety for passengers boarding at the platform.

Finally, a successful test may position the District for receipt of funds for a future FTA-funded demonstration project for BRT or bus yard applications (e.g. washing and fueling). Staff time for District needs and study needs may be in conflict. Accommodations will need to be made by all partners. It is understood by both PATH and FTA that the District’s needs will remain paramount in the allocation of staff time.
ALTERNATIVE ACTIONS:

Decline to participate in the program. This would delay development of promising technologies that have the potential to increase the District’s speed through toll plazas and improve the safety and precision of docking at BRT stations.

PRIOR RELEVANT BOARD ACTIONS/POLICIES:

None.

ATTACHMENTS:

1. Presentation to Executive Staff (2010)
2. Schedule
3. PATH Press Release
4. Sample MAGS Decal

Department Head Approval: Dennis W Butler, Chief Planning and Development Officer

Reviewed by: Vincent C. Ewing, General Counsel
Dennis W Butler, Chief Planning and Development Officer
James Pachan, Chief Operating Officer
Lewis Clinton, Chief Financial Officer

Prepared by: Jim Cunradi, Manager of Special Projects
Vehicle Assist & Automation Test Program

Report to Executive Staff
September 14, 2010

What is the Federal Vehicle Assist & Automation program?

- VAA is technology that automates or assists the operator in the steering, docking, acceleration and deceleration of the bus

- Pilot program to demonstrate the benefits of vehicle assist and automation (VAA) applications for full-size public transit buses
Why are we interested vehicle assist & automation?

- Improved vehicular safety in traffic
- Reduced maintenance costs & vehicle damage
- Better ride quality and improved passenger cabin safety
- Improved fuel economy
- For BRT may permit narrower dedicated bus lanes and lower long-term pavement cost
- Aids level boarding and creates narrow horizontal gap at boarding platform to comply with ADA
- May reduce operator stress and fatigue
- Bus yard & transit terminal applications?

The Research Team

- California-Oregon Vehicle Assist & Automation (VAA) Team
  - USDOT Federal Transit Administration and Research and Innovation Administration
  - Caltrans
  - AC Transit
  - Lane Transit District - LTD (Eugene-Springfield)
  - Partners for Advanced Transit and Highways (PATH)
  - Local Bay Area Industrial partners
    - ContainerTrac
    - Integrated Motion Inc.
    - Bob McGee's Machine Co.
The California-Oregon VAA Project

■ 2003 – Automated Bus demonstration
  ■ Three-bus platoon with fully automated functions

■ 2005 – Intelligent Transportation Systems World Congress, San Francisco
  ■ Demonstration of Lane Assist and Precision Docking Systems

California-Oregon VAA Project (cont.)

2008 – Field Tests and Demonstration
East 14th Street, San Leandro

■ First real world test
  ■ urban setting, uneven street crowns, potholes and obstacles, mixed with city traffic
  ■ Test demonstrated system’s accuracy and reliability
  ■ 1/4 inch tolerance
  ■ Lessons learned will benefit future development and future deployment
  ■ Demonstrated strong inter-agency partnerships
  ■ Positive response from transit agencies
  ■ AC Transit as supporting partner
Current Research Activities

- 2009-2011 Revenue Service Test
  - Sponsored by the Federal Transit Administration’s Intelligent Transportation Systems Joint Program Office

- California/Oregon team selects magnetic guidance as the primary technology
  - Other technologies will also be evaluated for accuracy

- Project Goals
  - Demonstrate the technical merits and feasibility of VAA technology in revenue service
  - Assess benefits and costs
  - Evaluate attitudes of transit agencies, passengers and bus operators

- Budget
  - $1.9 million in federal funds (FTA) + $500k California funds (Caltrans)

- AC Transit Role
  - Active partnership & cooperation

Research Project Purpose

- Address deployment issues
- Assess benefits and costs in revenue-service operations
- Document public perceptions

- Study a full range of VAA applications
  - Highway (ACT) and urban BRT application (LTD)
    - Precision docking and guidance
    - Very low speeds to highway speeds (65 mph)
    - Varying degrees of operator assistance
VAA Project Description

- LTD, Eugene Oregon
  - 2.5 miles of single/double dedicated ROW
  - One 60ft New Flyer BRT bus
  - Functions to be tested:
    - Lane guidance for on dedicated BRT lane
    - Precision docking

- AC Transit
  - A 3 mile section of HOV lane, on the California State Route 92 freeway from Hesperian Blvd. to the Hayward-San Mateo Bridge toll plaza
  - Two MCI motor coaches
  - Functions to be tested:
    - Lane guidance on HOV lane
    - Guidance through toll plaza

Research Project Schedule

- Major Activities
  - March 2010 – System Design
  - April 2010 – Component Development
  - August 2010 – District kickoff meeting
  - September 2010 – Bus Component Integration into LTD bus
  - September 2010 – Richmond Field Station Track Preparation
  - November 2010 – Software Development and Integration
  - March 2011 – Begin AC Transit Performance test and Evaluation
  - September 2011 – Complete Operational Test and Data Collection

- Independent evaluation to be conducted by Center for Urban Transportation Research (CUTR) – University of South Florida
The Technology

- PATH System
  - Magnetic markers in pavement + sensors on the bus + Differential GPS + Inertial Navigation Systems + hardware & computers to steer bus
  - Redundancy to ensure performance & safety

Magnets in Pavement + Sensors, Hardware & Computers on Bus

- 1 x 4 inch magnets are placed in the roadway pavement every 3 feet
- Magnets are minimally subject to interference
  - Missing magnets
  - Unwanted magnets
- Not compatible with heavily damaged asphalt
- Installation costs of $10-20k per lane mile
- No maintenance needed after installation
Hardware: Sensors on the Bus

Hardware: Steering Actuator
Hardware: Computer Processors

Hardware: GPS/INS System
Line M: Route Selection Factors

- Highway speeds combined with physical constraints
- Large over-the-road coach
- Yard close to TEC
- Tech-savvy riders for ease of surveying
- Operates on portions of California State Highway system
- Limited vehicle and driver pool for quality control and ease of implementation by the District

AC Transit’s VAA Study Interests

- Better speeds
- Improved safety
- Reduced vehicle damage & lower maintenance costs
- Improved fuel economy
- Improved customer satisfaction
- Improved productivity
- Reduced operator stress & fatigue
AC Transit Role & Tasks

Routine Duties
- Provide vehicles
- Schedule buses and operators
- Perform regular maintenance (PATH maintains system)
- Operate buses & serve our customers

New Duties
- Train our operators to use the system
- Provide currently available or collect new data for researchers
- Survey operators
- Survey bus riders via email
- Publicize the program via email, press, decals
- Support PATH researchers in the little things

Research Project Next Steps
- Bench testing of equipment (complete)
- Install equipment on LTD bus
- Test on closed track at Richmond Field Station
- Transplant equipment onto AC Transit bus
- Test on the closed track
- Test on Line M and TEC without passengers
- Test on Line M with passengers
- Provide data & conduct surveys
- Complete evaluation
### Attachment 2: VAA Demo Test Schedule (Modified 06/25/2012)

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<td>LTD bus installation</td>
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<td>LTD track installation (repair - if required)</td>
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Data analysis and final report
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Researchers showcase automated bus that uses magnets to steer through city streets

By Sarah Yang, Media Relations | 05 September 2008

BERKELEY – The thought of a bus moving along city streets while its driver has both hands off the wheel is alarming. But a special bus introduced today (Friday, Sept. 5), steered not by a driver, but by a magnetic guidance system developed by engineers at the University of California, Berkeley, performed with remarkable precision.

The 60-foot research bus was demonstrated along a one-mile stretch of E. 14th Street in San Leandro that was embedded with a series of magnets. Special sensors and processors on board the bus detected the magnets in the pavement and controlled the steering based upon the information it received. The driver maintained control of braking and acceleration, but the steering was completely automated, allowing the bus to pull into stops to within a lateral accuracy of 1 centimeter, or about the width of an adult pinky finger.

Researchers say such precision docking would help shave precious seconds off of the time to load and unload passengers at each stop, adding up to a significant increase in reliability and efficiency over the course of an entire bus route. For example, precision docking could potentially negate the need to deploy wheelchair ramps and make passenger queuing more efficient.

Moreover, the ability to more precisely control the movement of the bus reduces the width of the lane required for travel from 12 feet - the current standard - to 10 feet, researchers say.

The California Department of Transportation (Caltrans) has provided $320,000 to fund this Automated Bus Guidance System demonstration project, conducted by the California Partners for Advanced Transit and Highways (PATH) program based at UC Berkeley.

"Today's demonstration marks a significant step in taking the technology off of the test track at UC Berkeley's Richmond Field Station towards deployment onto real city streets," said Wei-Bin Zhang, PATH transit research program leader at UC Berkeley. "We have seen increasing interest among transit agencies in this technology because of its potential to bring the efficiency of public bus service to a level approaching that of light rail systems, but at a much lower overall cost."

California PATH researchers have been studying magnetic guidance systems as a means of controlling vehicle movement for nearly 20 years with significant funding from Caltrans and the U.S. Department of Transportation. They have showcased how the technology can control a platoon of passenger cars speeding along high occupancy vehicle (HOV) lanes in Southern California, as well as industrial vehicles such as snowplows and tractor trailers in Northern California and Arizona. Today's test run
along E. 14th Street marks the first application of magnetic guidance technology for use in transit buses on a public road.

"It is our mission to improve mobility across California, and maximizing transportation system performance and accessibility through this technology helps us to achieve our mission," said Larry Orcutt, chief of the Caltrans Division of Research and Innovation. "The rising cost of fuel has created greater interest in public transit. This technology could convince more people to get out of their cars and onto buses, and as a result, reduce congestion."

In the system demonstrated today, sensors mounted under the bus measured the magnetic fields created from the roadway magnets, which were placed beneath the pavement surface 1 meter apart along the center of the lane. The information was translated into the bus's lateral and longitudinal position by an on-board computer, which then directed the vehicle to move accordingly. For a vehicle traveling 60 miles per hour, data from 27 meters (88 feet) of roadway can be read and processed in 1 second.

Zhang added that the system is robust enough to withstand a wide range of operating conditions, including rain or snow, a significant improvement to other vehicle guidance systems based upon optics. Researchers also pointed out that magnetic guidance technology allows for a bus to safely follow closely behind another. Extra vehicles, much like extra cars on light rail trains, could thus be added during peak commute times.

In the E. 14th Street demonstration, the magnetic guidance system was only used to control the steering for the bus, but on test tracks it has been used for full vehicle control - including braking and accelerating - creating a true "auto-pilot" system for the bus. At any time, the driver can resume manual control of the bus.

Potential applications for the system include automating bus passage through narrow tollbooths and vehicle routing in bus maintenance yards. The system could be integrated into traditional bus routes, as shown on E. 14th Street, or used as part of more advanced bus rapid transit (BRT) systems that could include a dedicated traffic lane. Many cities throughout the world, including 20 in the United States, have deployed some form of BRT, although only a few include dedicated bus-only lanes.

Today's demonstration included a special industry presentation attended by dozens of representatives from California transit agencies interested in whether PATH's magnetic guidance technology might fit with their own BRT plans.

On some routes in the Bay Area, AC Transit currently operates a version of bus rapid transit that includes electronic signs informing riders of when to expect the next bus. However, the transit agency is currently in the midst of preparing an Environmental Impact Report for a proposed BRT project that could include bus-only lanes along an 18-mile stretch from downtown Berkeley near the UC Berkeley campus south to San Leandro's Bay Fair BART station.

"AC Transit is a leader promoting advanced technologies for transit buses. As such, we are continually investigating new technologies to improve the performance, safety and comfort of buses," said Chris Peeples, president of AC Transit's board of directors. "The magnetic guidance system developed at UC Berkeley can both improve safety and provide a smoother ride for our passengers. The system has the potential to make bus rapid transit routes - particularly those that involve bus-only lanes - as efficient as light
rail lines, which in turn will make buses more effective in getting people out of their cars."

AC Transit puts the cost of its BRT proposal at $273 million, while a comparable light rail system would cost around $2 billion. Zhang said that adding the magnetic guidance technology to AC Transit's proposed BRT project would help it run more like a light rail system for an additional $5 million. The Valley Transportation Agency has also compared the costs of BRT and light rail systems for its planned Santa Clara Alum Rock Transit Improvement Project. The estimated cost for BRT came in at $128 million, compared with $393 million for light rail.

AC Transit is joining Caltrans and the U.S. Department of Transportation in funding the next stage of the Automated Bus Guidance System project as it becomes part of the federal Vehicle Assist and Automation Program. The project will expand to AC Transit routes along Interstate 880 and the San Mateo Bridge, and to a dedicated BRT route in Eugene, Ore.

"Ultimately, it's up to the community to decide which transit option is best for its members," said Zhang. "Our job is to develop the technology that can help improve whatever form of transportation is used."
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MAGS
MAGNETIC GUIDANCE SYSTEM
AC Transit PATH Caltrans FTA RITA

Magnetic Guidance System Technology Installed on this Bus
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