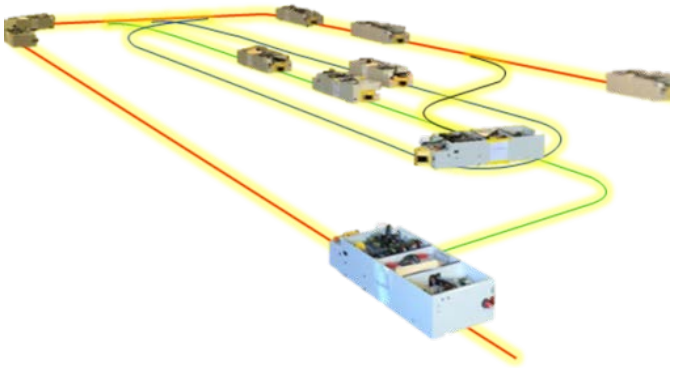
Automatic Guided Vehicle/Guided Cart

'VIRTUAL PATH' AGV/AGC NAVIGATION

AGV/AGC navigation technology selection is the critical factor in achieving a system design that optimizes system performance, reliability, maintenance costs, flexibility and ease of use.

Savant offers unique 'Virtual Path' CAD map navigation on all its automatic guided vehicle and guided cart models.



- Our inertial navigation technology operates <u>without</u> the need of floor tape, saw cut grooves for wire or magnetic rod, structure-mounted reflective targets or any reliance on fixed structure/continuous wall sensing.
- Virtual Path navigation just needs a floor surface and a small, zero-maintenance, floor flush marker. This allows operation, without restriction, in typical facility environments with large open areas.

Savant's internal navigation employs a solid state inertial sensor (also used in smartphones to detect rotation) to determine AGV/AGC heading and positional information as it follows a 'virtual' CAD map of the system path.

Inertial Navigation sensor chip

(similar to one in a smartphone)

Floor-flush magnet

(size of AAA battery)

Savant 'Virtual Path' navigation maintains sub-inch tracking accuracy. The onboard inertial sensor and virtual path are maintenance-free.

Unlike rotational laser navigation sensors, floor tape, vision cameras or natural/contour Lidar navigation controls, Savant's inertial sensor and virtual path are not subject to costly wear-out or damage replacement.

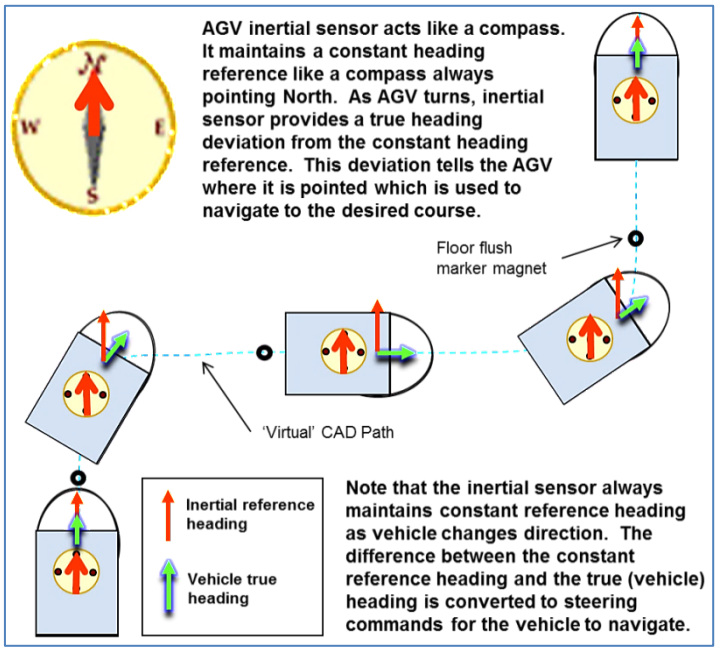
Savant is a full service AGV system supplier. Manufacturing of vehicles & controls, software, system installation and aftermarket support are executed in-house. Our business dates back to 1954 and our staff averages over 20 years' experience in the AGV market.

Benefits of Savant Inertial Navigation

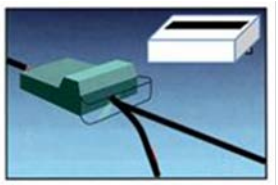
- Reverse travel ready (with option rear safety sensor) for off-aisle load or cart pick/drop
- Non-wire, 'tape & target-free' autonomy
- Inertial sensor has no moving parts to wear. It's not a costly navigation wear item
- Eliminates periodic replacement of rotating laser head at ~$8,000/vehicle.
- Operates on uneven, rough floors, and ramps
- No line of sight/blocked target or tape maintenance issues

Our 4th generation of Virtual Path navigation is standard on all Savant AGVs and AGCs allowing complete intermingling of paths and vehicle types as needed by the user.

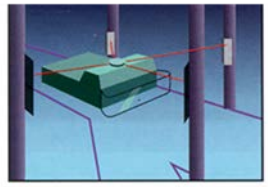
Savant AGV Inertial Navigation Principle



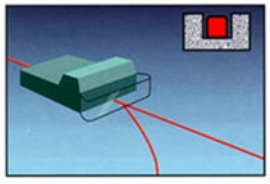
AGV/AGC Navigation Technologies *By Others:*



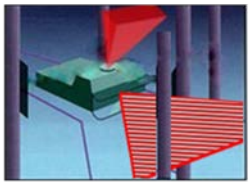
Magnetic or Optical Tape
Drawbacks – damage and repair



Laser Reflective Target
Drawbacks – requires line-of-sight to targets



Saw Cut Groove for Magnetic Bar or Floor Wire
Drawbacks – costly to change



Vision-Camera or Natural-Contour Structure Recognition System
Drawbacks – poor accuracy/requires walls

Automatic Guided Vehicle/Guided Cart

'VIRTUAL PATH' AGV/AGC NAVIGATION

Compared to Laser/Target Inertial Navigation:

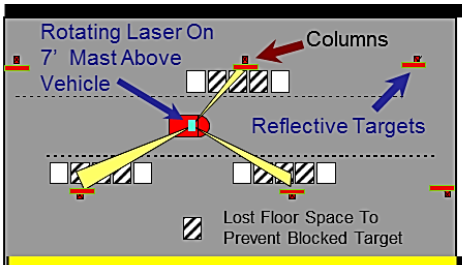
- ***Is Immune to "line of sight" blocked/missed target issues which stop vehicle***
- ***Does Not require installation of additional target mounting posts in large open areas***
- ***Is Not susceptible to damage or sabotage***

Compared to Floor Tape Inertial Navigation:

- ***Eliminates system stoppages because of torn/missing tape spots***
- ***Has No limit to size or complexity of the guide path network***
- ***Does Not use floor code markers (RFID tags, tape, plates) that get damaged***

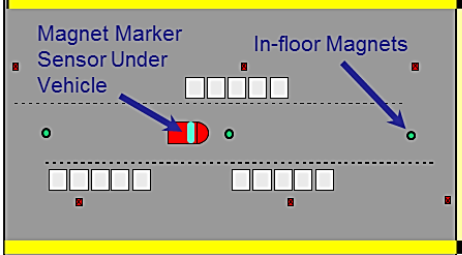
Compared to Vision or Natural/Contour Inertial Navigation:

- ***Is Able to auto-reverse accurately***
- ***Has accuracy required to support automatic load pick and drop***
- ***Offers vastly superior traffic intersection flow efficiency = higher throughput***



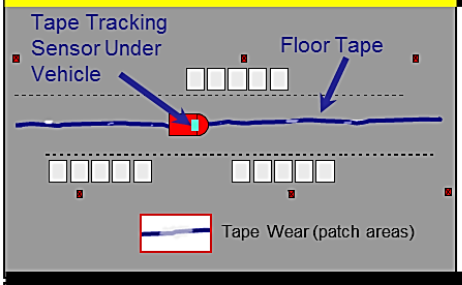
Laser (Target) Navigation

- Targets at fixed elevation estimated ~7' must have clear line of sight
- Target size: ~16" x 6"
- Targets spaced every 20-50 feet, on both sides of path (x2)
- Targets surveyed post installation
- Laser navigation is augmented with distance measuring (wheel encoders)
- Tracking accuracy **±1"**, nominal



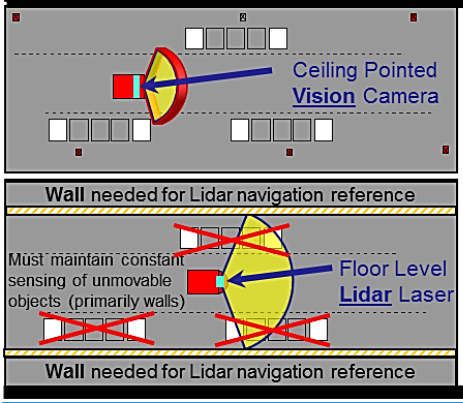
Savant Inertial (Internal) Navigation

- Markers (magnet) flush with floor
- Marker size ~0.75"d x 0.25"l
- Markers spaced one every 25-50 feet along path
- Markers surveyed post installation
- Inertial navigation is augmented with distance measuring (wheel encoders)
- Tracking accuracy **±1"**, nominal



Tape (Magnetic/Optical) Navigation

- Sticky tape affixed to cleaned floor
- Station, branch and action markers (tape, RFID tag, plates) affixed to floor
- Marker size ~ 2" x 3"
- Markers and tape moved with path changes
- Path patched with new tape as needed
- Markers subject to damage
- Tracking accuracy **±1"**, nominal



Natural/Contour Navigation

Vision Camera

- Hi-def scan for ceiling reference structure
- Compares vision data to digitized database

Lidar Laser

- Rotational scans for floor level references
- Compares to cleaned digital database

Common to Both

Highly dependent on reference structures (walls, etc.) for accuracy (open aisles environments are a problem.)
Very sensitive to object movements obscuring line-of-sight to critical reference structures
Susceptible to dust clouding camera or Lidar lens
Requires software engineer to eliminate noise/bad data from navigation scan database
Very crude, inefficient multiple vehicle traffic control
Poor tracking accuracy ±6", typ. does not support required alignment for automatic load transfer or auto-charging
Up to 50% more expensive compared to Inertial-Magnet or Laser-Target

NOTE: SPECIFICATIONS ARE SUBJECT TO CHANGE WITHOUT NOTICE BASED ON PRODUCT IMPROVEMENTS OR TECHNICAL REQUIREMENTS. FORM: 0518NAV

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