



**FORI AUTOMATION** INC.

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# FORI AUTOMATION

## Automated Guided Vehicles & Carts (AGVs & AGCs)

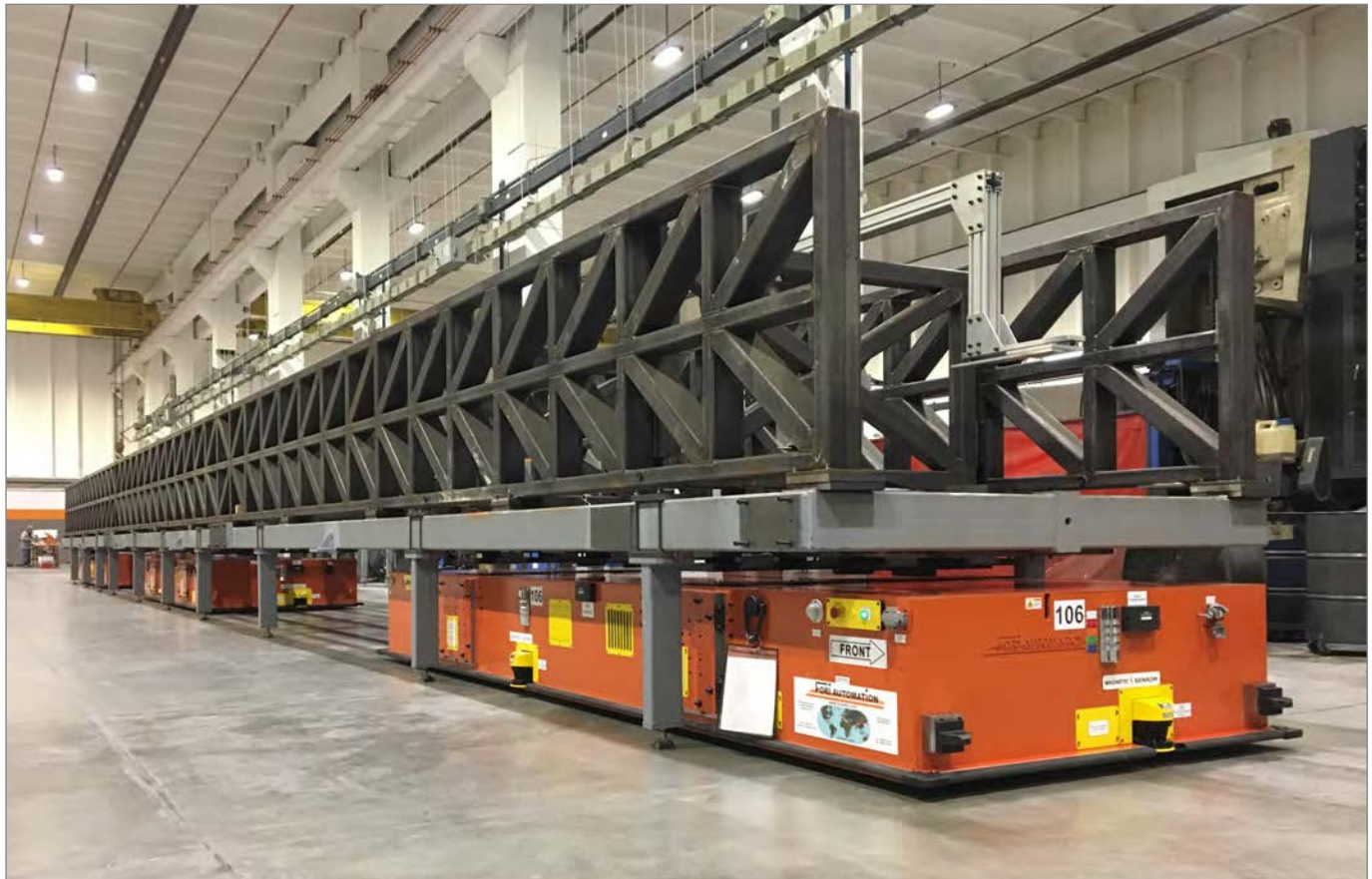
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### GLOBAL HEADQUARTERS

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# Rail Guided Carts for Module Assembly

## Product:

- RGCs

## Guidance Technology:

- Rail guided

## Capacity:

- 1,500 lbs. / 680 kg.

## Safety:

- Safety bumpers
- Fail safe PLC

## Controls:

- Vehicle management system
- Full-auto guidance

## Keys to Success:

- Cost effective, robust design
- Standardized unit, customizable tooling plates for any product
- Opportunity charge system for continuous usage

## Results:

- Increased reliability
- Increased throughput
- Decreased plant infrastructure
- Reduced installation time

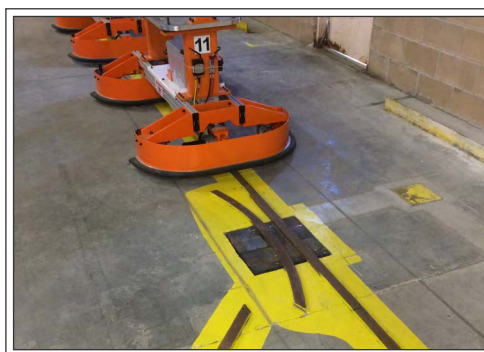
## Solutions:

- Rail guided vehicle
- Standardized control package
- Vehicle management system



Fori has recently developed a Rail Guided Cart (RGC), a cost-effective solution to replace the bulky and expensive conveyance systems that are traditionally used within automotive assembly plants.

The RGCs are a simplistic design which contains one spring loaded drive wheel that tracks an above floor mounted rail. RGCs are a great option when a fixed path will be used and there is a high level of importance placed on reduction of total infrastructure and long term process flexibility. RGCs are modular and can easily be swapped out in the event of an unlikely failure.



The top of the RGCs can be customized to accommodate different sized pallets, trunions and integrated poke yokes.

The RGCs were designed and built based on an open control architecture with a Siemens safety PLC as the vehicle controller. Lead acid batteries are utilized and the opportunity charging option makes for seamless manufacturing solution where the vehicles never have to leave the assembly loop.

The RGCs utilize commercially available components to reduce costs and minimize lead times.



# Automated Guided Carts for Engine Assembly

## Product:

- AGCs

## Guidance Technology:

- Induction wire

## Capacity:

- 2,000 lbs. / 907 kg.

## Safety:

- Safety bumpers
- Fail safe PLC

## Controls:

- Vehicle management system
- Full-auto guidance

## Keys to Success:

- Custom chassis to fit within customers process
- Customizable tooling plates
- Induction system for continuous operation

## Results:

- Robust and reliable system
- System that fits within current skill sets of employees
- Low maintenance system
- Decreased total cost of ownership

## Solutions:

- Automated guided cart
- Standardized control package
- Induction wire for power & guidance



Assembly systems have largely been monument based which include bulky conveyance systems that require large installations and reduce flexibility. Utilizing an induction wire based system for guidance and power provides a more flexible solution and reduced plant infrastructure.

Induction wire allows for an opportunity to reduce the number of vehicles required for the system, this is accomplished based on the continuous power source provided by the induction wire.

Thanks to the induction wire, power can also be supplied from the vehicle to any power tools and equipment that the operators could potentially use for the build process.

Primary focus for the project was to provide a clean, sustainable solution that would provide long term reliability, remove the need for constant battery charging and replacement, as well as ensure a system that would be self sufficient for years to come.



# Automated Guided Carts for Module Assembly

## Product:

- AGCs

## Guidance Technology:

- Magnetic bar / tape

## Capacity:

- 4,000 lbs. / 1,814 kg.

## Safety:

- Safety scanners
- Fail safe PLC

## Controls:

- Siemens open architecture
- Full-auto guidance

## Keys to Success:

- Cost effective design
- Integrated controls system
- Simple operation and setup

## Results:

- Robust and reliable system
- Flexible system
- Cost effective solution

## Solutions:

- Automated guided cart
- Vehicle management system
- Siemens integrated safety
- Magnetic bar guidance



Fori has designed and built a flexible, cost effective solution to replace standard conveyors. Utilizing and Automated Guided Cart (AGC) removes the need for large conveyor installations and retrofits, providing reduced infrastructure and operating costs while increasing flexibility.

As an automation supplier, conveyor systems have been a main stay in the assembly process. Based on customer demand for a more flexible solution, the Fori AGC has been developed to provide increased flexibility and decreased system infrastructure.

The Fori AGC utilizes a magnetic bar or tape for guidance. The magnetic bar increases flexibility and reduces setup time and facility work.

The AGC controller is Siemens Safety PLC based. The AGC is based on a standardized controls architecture, utilizing commercially available components. The results include an open architecture and a reduction in cost and total lead time.



# Automated Guided Carts for Chassis Marriage

## Product:

- AGCs

## Guidance Technology:

- Induction wire

## Capacity:

- 5,000 lbs. / 2,268 kg.

## Safety:

- Safety scanners
- Safety bumpers
- Siemens safety PLC

## Controls:

- Full-auto guidance
- Vehicle management system

## Keys to Success:

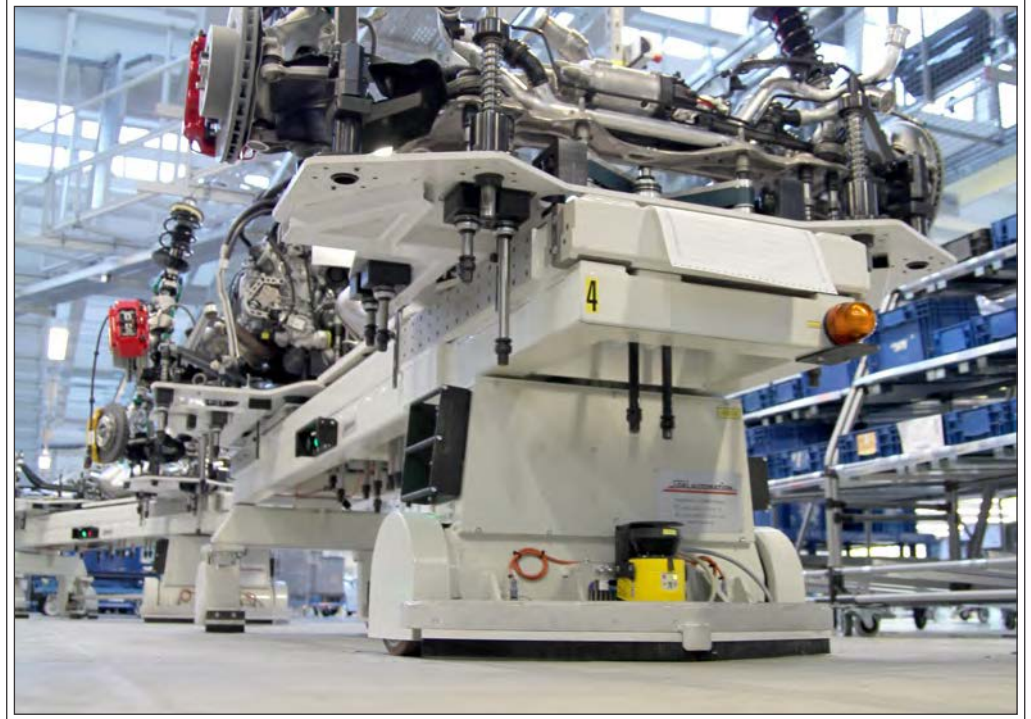
- Custom chassis to fit within customers process
- Customizable tooling plates
- Induction system for operation

## Results:

- Robust and reliable system
- System that fits within current skill sets of employees
- Low maintenance system
- Decreased total cost of ownership

## Solutions:

- Automated guided cart
- Vehicle management system
- Standardized control package
- Induction power & guidance



Automotive chassis marriage has widely been accomplished using Rail Guided Vehicles (RGVs), Fori recently supplied an induction wire based system for power and guidance in order to reduce plant infrastructure costs and increase long term flexibility.

The vehicles pictured were a simple design which contained two drive wheels and a slewing ring with linked steering in order to navigate through the assembly and marriage areas. Steering was accomplished with differential steering. The marriage was accomplished through the utilization of infloor servo lift arbors.

Through the integration of the infloor servo lift arbors (pictured below) into the plant versus the vehicle, there was a notable cost per vehicle reduction. Not only was there a cost reduction for the automated carts, but an overall decrease in vehicle complexity.

Utilizing the induction wire for guidance and power allowed Fori to remove the need for batteries and the associated chargers. These long term costs have lowered the total cost of ownership and reduced the amount of carts required for the project.



# Automated Guided Vehicles for Chassis Marriage

## Product:

- AGVs

## Guidance Technology:

- Magnetic bar / tape

## Capacity:

- 8,000 lbs. / 3,629 kg.

## Safety:

- Safety scanners
- Safety bumpers
- Fail safe PLC

## Controls:

- Vehicle management system
- Full-auto guidance

## Keys to Success:

- Custom design for customers preferred process
- Lithium battery for increased vehicle utilization

## Results:

- Robust and reliable system
- Increased process flexibility
- Decreased infrastructure versus rail guided vehicle
- System that fits within current skill sets of employees

## Solutions:

- Automated guided vehicle
- Vehicle management system
- Magnetic bar guidance
- Operator work platforms
- Fori standard chain lifts



Chassis marriage has primarily been a process that has been completed utilizing Rail Guided Vehicles (RGVs). Utilization of RGVs results in additional infrastructure and decreased overall system flexibility.

Fori's main focus for the Chassis Marriage AGVs is to work within the customers existing controls strategy. Utilization of the PLC based system results in an open architecture for our customers and widely preferred.

Utilizing a Safety PLC as the controller for the AGV chassis marriage system eliminates the standard "Black Box" that is used by many of the material handling system providers.

The vehicles utilized magnetic bar guidance, allowing for a high level of accuracy and repeatability, while keeping infrastructure costs low. Lithium Ion batteries were used to power the vehicles. Utilization of Lithium Ion resulted in decreased time spent charging, ultimately increasing vehicle utilization. Additionally, an "off the shelf" drive wheel and lift was used.

The final result was a cost-effective, commercially available solution for the customer.



# Automated Tuggers for Product Delivery

## Product:

- AGVs - Tuggers

## Guidance Technology:

- Magnetic bar
- Inertial with pencil magnets

## Capacity:

- 35,000 lbs. / 15,909 kg.

## Safety:

- Safety scanners
- Safety bumpers
- Fail safe PLC

## Controls:

- Vehicle management system
- Siemens open architecture
- Full-auto guidance

## Keys to Success:

- Chassis and coupler designed around customer process
- Siemens open architecture, that matched customer strategy

## Results:

- Increased safety
- Increased reliability

## Solutions:

- Automated guided vehicle
- Standard drive package
- Inertial guidance



Fori Automation's Tugger AGV is a cost effective material handling solution that increases safety and throughput.

The Tugger AGVs were designed and built to fit within existing plant environments and each plants respective material handling strategy. The Tugger AGVs were commissioned to replace non-value added material handling tasks, many of which are completed by Fork Lifts. The results are a system with a favorable return on investment.

The Tugger AGVs have also resulted in reduced product damage and there have been improvements in overall system safety.

The Fori Tugger AGV is based on the same design as the Dock N' Lock. The only difference is the Tugger does not include the auto-docking feature. The Tugger requires operator interface for hitching the carts.

The Tuggers can be customized based on specific weights, speeds and total throughput.



# Automated Dock N' Locks for Product Delivery

## Product:

- AGVs - Dock N' Lock

## Guidance Technology:

- Magnetic bar
- Inertial with pencil magnets

## Capacity:

- 35,000 lbs. / 15,909 kg.

## Safety:

- Safety scanners
- Safety bumpers
- Fail safe PLC

## Controls:

- Vehicle management system
- Siemens open architecture
- Full-auto guidance

## Keys to Success:

- Chassis and coupler designed around customer process
- Siemens open architecture, that matched customer strategy

## Results:

- Increased safety
- Increased reliability

## Solutions:

- Automated guided vehicle
- Standard drive package
- Inertial guidance



The Fori Dock N' Lock is a unique AGV product line meant to replace fork lifts and other standard methods of product and material transport.

The Dock N' Lock AGVs offer increased automation versus a standard Tugger AGV. Whereas a Tugger AGV requires an operator to hitch the transport cart. A Dock N' Lock automatically backs into the station and actuates a pin that enables automatic docking to the cart or trailer. The docking method utilized for the Dock N' Lock, partnered with a custom companion cart allow the vehicle to be bi-directional.

The Dock N' Locks overall capacity is 35,000 lbs. / 15,909 kg. The total capacity for bi-directional travel is 5,000 lbs. However total capacity can be customized by utilizing different options of off the shelf drive wheel, gearbox and motor combinations.

The Dock N' Locks are currently capable of speeds up to 200 feet / 61 m per minute. A siemens PLC is used for safety and navigation, resulting in an open controls architecture.





# Aerospace AGVs for Component Assembly

## Product:

- AGVs

## Guidance Technology:

- Magnetic bar

## Capacity:

- 14,000 lbs. / 6,363 kg.

## Safety:

- Safety scanners
- Safety bumpers
- Siemens safety PLC

## Controls:

- Siemens open architecture
- Vehicle management system
- Full-auto guidance

## Keys to Success:

- Two custom designs
- Continuous moving line, as little as 4" / 10 cm an hour
- Pontoon style AGV for operator work platform

## Results:

- Personnel injuries have been Minimized
- Crane Utilization has been greatly reduced
- Continuously moving line resulted in increased throughput and process control

## Solutions:

- Automated guided vehicle
- Vehicle management system
- Siemens integrated safety
- Magnetic guidance
- Integrated operator lift platforms



Fori was enlisted to design and build two styles of AGVs for the Bombardier C-Series project. These vehicles were customized to work within Bombardier's specific build process.

The AGVs pictured are utilized within the production process for the bombardier C-Series. Project requirements included the AGV needing the ability to move as slowly as 4" / 10 cm. per hour in order to meet production, while still being a moving line.

Each vehicle fit within the tooling footprint, while being multi-purpose for the different tools and product. The vehicle was required to minimize deflection and side loading during tooling transport.

The system was required to coordinate the automated continuous movement among the eighteen vehicles. The vehicles were also required to include integrated operator work platforms and lifts that would aid in the cockpit assembly.



# Aerospace AGVs for F-35 Center Wing Box

## Product:

- AGVs

## Guidance Technology:

- Magnetic bar

## Capacity:

- 16,000 lbs. / 7,257 kg.

## Safety:

- Safety scanners
- Safety bumpers
- Siemens safety PLC

## Controls:

- Siemens open architecture
- Integrated production system
- Vehicle management system
- Full-auto guidance

## Keys to Success:

- Siemens integrated production system
- Increased system safety
- Locking arbors to decrease tool CG

## Results:

- Robust and reliable system
- Safety interlocks to ensure personnel injuries have been minimized
- Crane utilization has been greatly reduced
- System that fit within current skill sets of employees

## Solutions:

- Automated guided vehicle
- Vehicle management system
- Siemens integrated safety
- Magnetic bar guidance



Fori supplied three AGVs for the Lockheed Martin F-35 Lightning II Project. The vehicles were custom designed around a fully integrated lean manufacturing methodology.

Project requirements included improved system safety, uniformity of equipment across Lockheed Martin sites and a fully integrated vehicle management system (VMS). The VMS was required to schedule traffic and ensure process flow. It was important that the system be intuitive enough where the skill set of the current workforce could utilize the AGVs.

The user interface was custom designed for the Lockheed project to ensure the HMI interface and vehicle operation would be accepted by the personnel for operation and maintenance.

The project team also placed a high level of importance on data collection and communication among the flow lines (16) cells. The Fori VMS was required to communicate with the plant production system, other pieces of automated equipment and safety systems.



# Nuclear Material Handling AGV for Refurbishment

## Product:

- AGVs

## Guidance Technology:

- Magnetic bar/tape

## Capacity:

- 18,000 lbs. / 8,165 kg.

## Safety:

- Safety scanners
- Safety bumpers
- Siemens safety PLC

## Controls:

- Siemens open architecture
- Semi-automated guidance

## Keys to Success:

- Chassis that allows the AGV to fit through a 38" / .97 m door
- Halogen free wiring for nuclear environment
- High voltage, small footprint Li-Ion battery

## Results:

- Robust and reliable system
- System that fit within current skill sets of employees
- Decreased infrastructure

## Solutions:

- Automated guided vehicle
- Siemens integrated safety
- Magnetic guidance



Within the recent Nuclear project Fori was required to design and build an AGV that could fit within the current building layout and carry at least one flask, totaling 18,000 lbs. / 8,165 kg.

The most critical design requirement for the AGV pictured was for the overall dimensions to be less than 38" / .97 m in width and 30" / .76 m in height. The requirements were derived from the width and height of an airlocked door that the vehicle needed to travel through. The AGV clearance through the door was less than 10mm on each side.

The plant personnel utilize preprogrammed moves based on different areas in the plant. The preprogrammed moves are initiated by the operator and the "hold to run" option is active during vehicle movement. Doing so increases safety and reduced concerns on potential product damage or accidents.

The vehicles were also required to be intuitive enough where personnel could be trained easily, operators are only able to be within a nuclear work environment for a limited number of hours.



# Automotive AGVs for Component Transfer

## Product:

- AGVs

## Guidance Technology:

- Magnetic bar/tape

## Capacity:

- 25,000 lbs. / 11,340 kg.

## Safety:

- Safety scanners
- Fail safe PLC

## Controls:

- Vehicle management system
- Full-auto guidance

## Keys to Success:

- Improved push / pull mechanism for cart transport
- Low voltage system utilizing commercially available parts
- Opportunity charge system for continuous uptime

## Results:

- Increased reliability
- Increased safety
- Increased throughput

## Solutions:

- Automated guided vehicle
- Standard drive package
- Mag-gyro (inertial) guidance

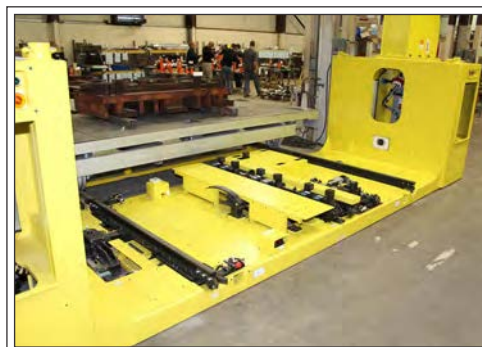


Fori was approached to design and build an AGV that will be used in the manufacturing process of automobile components for the automotive industry.

The vehicles were designed and built to fit within an existing manufacturing process. Once in station, the vehicle interfaced with an existing automated rail system. Each vehicle was outfitted with a three stage push/pull mechanism (middle picture). The push/pull mechanism needed to be capable of pulling a 25,000 lbs. / 11,340 kg. cart off of a rail system and onto the AGV.

Once the loading of the cart was completed, the AGV would transport the cart to the dunnage area, where the cart would be pushed back onto the automated rail. The primary focus for the project was centered around increased safety and reliability.

The previous vehicles were failing frequently, Fori's design was a center around improving reliability of the entire automated vehicle. The flexibility of the guidance solution provided was also an added benefit for the end user.



# Aerospace AGVs for Drill and Fill System

## Product:

- AGVs

## Guidance Technology:

- Magnetic bar

## Capacity:

- 18,000 lbs. / 8,165 kg.

## Safety:

- Safety scanners
- Safety bumpers
- Siemens safety PLC

## Controls:

- Siemens open architecture
- Semi-automated guidance

## Keys to Success:

- Use of inclinometers and servo control for auto-leveling
- Highly accurate and repeatable
- Simple user interface

## Results:

- Personnel injuries have been Minimized
- Crane Utilization has been greatly reduced
- Increased throughput

## Solutions:

- Automated guided vehicle
- Auto-leveling
- Siemens integrated safety
- Magnetic guidance



Fori designed and built two AGVs for a Drill and Fill system that is used within the build process of the Airbus A350 panels at Spirit AeroSystems.

The AGV pictured was a first for the Aerospace industry. The vehicle was required to accurately position within +/- .005" / .12 mm when in station. The frame for the vehicle was designed around a strict .03" / .762 mm frame deflection requirement to ensure the drill machine deflection was minimized during transportation between automation stations.

The final requirement for auto-leveling function included leveling the tooling within .004 degrees, having no more than .005" / .127 mm of deflection after leveling.

Utilizing the Fori AGV to transport the drill machine versus the standard method for this process significantly improved efficiency, reduced manpower requirements and improved cycle time. Most importantly from a health and safety perspective, drill and fill applications have negative implications, the automated system eliminated that concern.



# Aerospace AGVs for Aircraft Wing Assembly

## Product:

- AGVs

## Guidance Technology:

- Magnetic bar
- Inertial with pencil magnets
- Laser contour

## Capacity:

- 12,000 lbs. / 5,454 kg.

## Safety:

- Safety scanners / bumpers
- Siemens safety PLC
- System interlocks

## Controls:

- Siemens open architecture
- Vehicle management system

## Keys to Success:

- Vehicle synchronization
- Highly accurate and repeatable
- Custom designed chassis

## Results:

- Crane utilization has been greatly reduced
- Reduced deflection though synchronized leveling
- Support multiple tooling lengths with (3) AGV synchronization

## Solutions:

- Automated guided vehicle
- Vehicle management system
- Siemens integrated safety
- Synchronization & auto-leveling

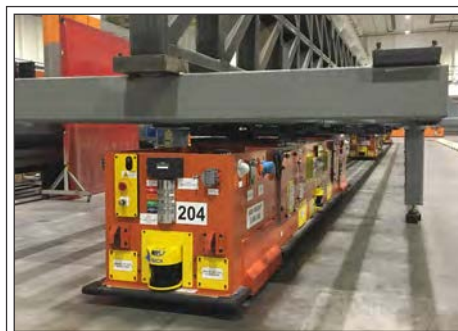


Fori recently supplied (6) Aerospace AGVs for the automated transport of tooling for wing component assembly. The AGVs are required to lift and transport up to 30,000 lbs. when synchronized.

The (6) AGVs were designed in order to support synchronization of up to (3) vehicles. The synchronization included both transporting the tooling, as well as auto-leveling during transport. The AGV is the primary method for transporting the tooling through the assembly process. Traditionally, assembly systems rely heavily on overhead cranes for material handling.

The design intent was to build a vehicle that was modular and interchangeable. The AGV system is required to transport many tools of different lengths and weights. Identification of tooling and drive parameter settings is completed through a vision based system which simplifies the lift and transport functions for the operators.

A Fori vehicle management system has been provided to monitor system I/O, communication between the AGVs, tooling and automated assembly stations. Scheduling of moves also occurs at the Fori VMS.



# Aerospace AGVs for Mobile Robot Transport

## Product:

- AGVs

## Guidance Technology:

- Magnetic bar
- Laser Contour / Camera

## Capacity:

- 40,000 lbs. / 18,181 kg.

## Safety:

- Safety scanners
- Safety bumpers
- Siemens safety PLC

## Controls:

- Siemens open architecture
- Semi-automated guidance

## Keys to Success:

- Highly accurate and repeatable
- Simple user interface
- Custom designed chassis

## Results:

- Improved health & safety
- Reduction in plant monuments
- Increased system flexibility

## Solutions:

- Automated guided vehicle
- Siemens integrated safety
- Magnetic guidance
- Laser contour / camera



Fori recently provided (2) high capacity Aerospace AGVs for the automated transport of a mobile robot for automated drill & fill.

The (2) high capacity AGVs were capable of transporting up to 40,000 lbs. / 18,181 kg. The primary function of the AGV was to transport a mobile robot between each of its respective automation positions.

The AGVs were developed to increase system automation, flexibility and eliminate the traditional monuments that are generally required for automation drilling applications. The design intent was to build a vehicle that was modular and interchangeable. The AGVs were designed to accommodate multiple mobile robots.

The AGV is required to locate within +/- 5mm of an existing aircraft component carrier. The Fori system accomplishes this through the utilization of a combination magnetic bar, natural feature and camera guidance.

Automated movement is handled through the tethered Siemens Mobile Panel. The operators are able to select automation positions on either the Fori HMI or Mobile Robot HMI. Once the position is selected the Fori AGV is responsible for accurately lifting and transporting the Mobile Robots between the automation positions.



# Aerospace AGVs for Vertical Wing Assembly

## Product:

- AGVs

## Guidance Technology:

- Magnetic bar

## Capacity:

- 60,000 lbs. / 27,216 kg.

## Safety:

- Safety scanners
- Safety bumpers
- Siemens safety PLC

## Controls:

- Siemens open architecture
- Semi-automated guidance

## Keys to Success:

- Custom designed chassis
- Highly accurate and repeatable
- Simple user interface
- Locking stanchions for decreased tooling deflection

## Results:

- Robust and reliable system
- Crane utilization has been greatly reduced
- System that fit within current skill sets of employees

## Solutions:

- Automated guided vehicle
- Vehicle management system
- Siemens integrated safety
- Magnetic guidance



A Fori AGV was utilized for a 60' / 18.3 m long wing assembly build process. The vehicle was 40' / 12.2 m long and was the strong-back for the tooling and wing assembly.

The vehicle was designed to minimize deflection. While transporting the FAJ tooling and part, the AGV frame was required to deflect less than 3/16" / 4.76 mm. Fori was also enlisted to design tooling accessories or "TOACS", the blue stanchions pictured (below right) were utilized for setting the tool on while in the assembly stations.

The TOACs included a locking mechanism that lowered the tooling CG and ensured a repeatable pick and drop point. The system started out as a manual operation, transitioning into a semi-automated process.

The vehicle tracks embedded magnetic bar for location within the station. The operator is responsible for adjusting speed for the fore / aft travel. Once in front of station the operator will initiate a preprogrammed move and utilize a "hold to run" operation that will locate the tool within +/- 2mm for drop off in station.





# Nuclear AGVs for Power Plant Refurbishment

## Product:

- AGVs

## Guidance Technology:

- Magnetic bar/tape

## Capacity:

- 68,000 lbs. / 30,844 kg.

## Safety:

- Safety scanners
- Safety bumpers
- Siemens safety PLC

## Controls:

- Siemens open architecture
- Semi-auto guidance

## Keys to Success:

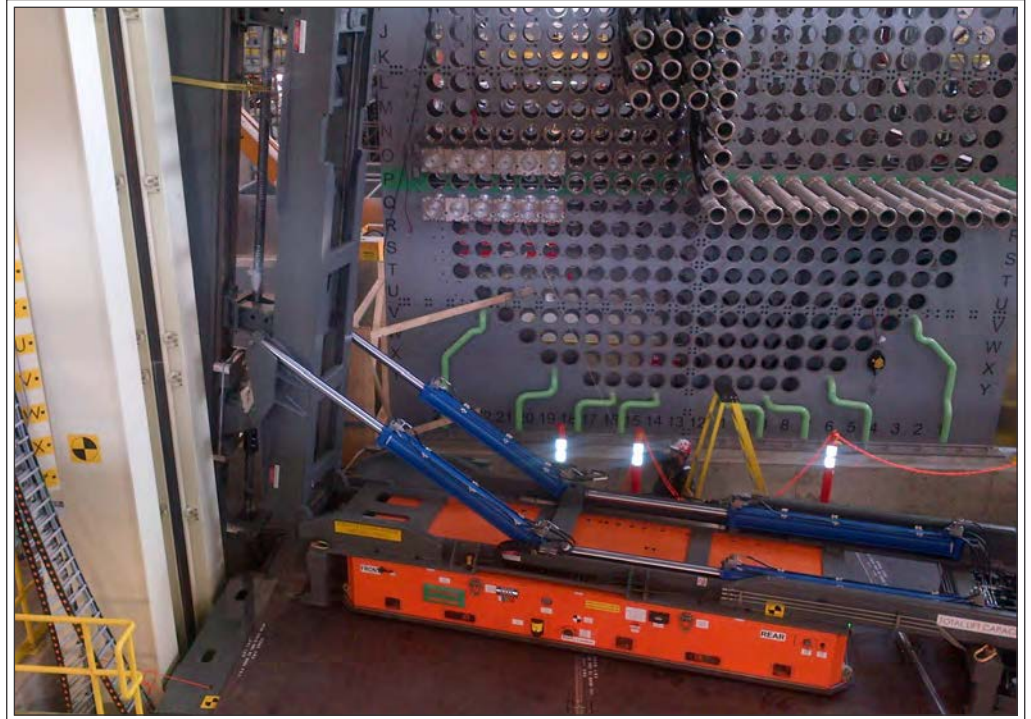
- Rigid platform for reactor tooling and flask transport
- 24/7, 365 days a year operation
- Employee friendly system

## Results:

- Repeatable locating for operator flask loading
- Increased throughput
- Decreased infrastructure

## Solutions:

- Automated guided vehicle
- Siemens integrated safety
- Magnetic guidance

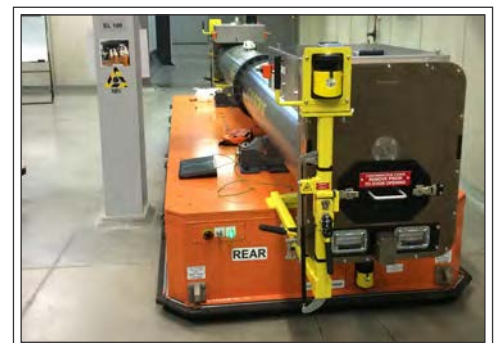


Fori recently designed and built an AGV that is being utilized within a nuclear power plant refurbishment project. The vehicle was required to run 24/7 and be halogen free for the work environment.

The vehicle needed to be highly accurate and have some unique functionality in order to fit within the plan for the power plant refurbishment. Initial concepts included rail and cart system, but through further investigation it was determined that the process would best be completed utilizing an AGV.

The vehicles utilizes magnetic tape guidance in most areas. However, certain moves within the plant have to be accomplished unguided, this was completed through preprogrammed moves relying on the encoders. Fori was able to repeatably achieve +/- 10mm.

The vehicle was designed and built to carry a total of 68,000 lbs. / 30,844 kg. and interface with multiple pieces of tooling. The vehicle needed to accomodate a 24/7 operating time, this was accomplished by using a high voltage Lithium Ion battery and high output charger.



# Aerospace Tugger AGVs for Tooling Transport

## Product:

- AGVs

## Guidance Technology:

- Magnetic bar
- Inertial with pencil magnets
- Laser contour

## Capacity:

- 60,000 lbs. / 27,272 kg.

## Safety:

- Safety scanners / bumpers
- Siemens safety PLC
- System interlocks

## Controls:

- Siemens open architecture
- Vehicle management system

## Keys to Success:

- Vehicle synchronization
- Highly accurate and repeatable
- Custom designed chassis

## Results:

- Crane utilization has been greatly reduced
- Improved system flexibility
- Interchangeable vehicle supports multiple tools

## Solutions:

- Automated guided vehicle
- Vehicle management system
- Siemens integrated safety
- Synchronization



Fori recently supplied (6) high capacity Aerospace Tugger AGVs for the automated transport of tooling supporting automated wing assembly.

The high capacity Tugger AGVs, capable of 120,000 lbs. / 54,545 kg. when paired, have been designed to be fully interchangeable through the utilization of a standardized docking interface. The Tugger AGVs will be the primary method of transporting the tooling and product through the assembly process.

The Tugger AGVs feature auto-docking to the tooling. Auto-docking is accomplished through laser contour and camera based guidance, which accommodates unexpected movement of tooling.

Responsibilities of the AGVs include: automated docking, tooling identification, and transport through the entire assembly process. A Fori vehicle management system has been provided for scheduling of moves and monitoring status of the (6) Tugger AGVs.



# Aerospace AGVs for Aircraft Wing Assembly

## Product:

- AGVs

## Guidance Technology:

- Magnetic bar
- Inertial with pencil magnets
- Laser contour

## Capacity:

- 40,000 lbs. / 18,181 kg.

## Safety:

- Safety scanners / bumpers
- Siemens safety PLC
- System interlocks

## Controls:

- Siemens open architecture
- Vehicle management system

## Keys to Success:

- Vehicle synchronization
- Highly accurate and repeatable
- Custom designed chassis

## Results:

- Crane utilization has been greatly reduced
- Reduced deflection though synchronized leveling
- Support multiple tooling lengths with (3) AGV synchronization

## Solutions:

- Automated guided vehicle
- Vehicle management system
- Siemens integrated safety
- Synchronization & auto-leveling



Fori recently supplied (7) Aerospace AGVs for the automated transport of tooling for wing component assembly. The AGVs are required to lift and transport up to 120,000 lbs. when synchronized.

The (7) AGVs were designed in order to support synchronization of up to (3) vehicles. The synchronization included both transporting the tooling, as well as auto-leveling during transport. The AGV is the primary method for transporting the tooling through the assembly process. Traditionally, assembly systems rely heavily on overhead cranes for material handling.

The design intent was to build a vehicle that was modular and interchangeable. The AGV system is required to transport many tools of different lengths and weights. Identification of tooling and drive parameter settings is completed through a vision based system which simplifies the lift and transport functions for the operators.

A Fori vehicle management system has been provided to monitor system I/O, communication between the AGVs, tooling and automated assembly stations. Scheduling of moves also occurs at the Fori VMS.



# Aerospace AGVs for Component Assembly

## Product:

- AGVs

## Guidance Technology:

- Magnetic bar
- Laser contour

## Capacity:

- 120,000 lbs. / 54,431 kg.

## Safety:

- Safety scanners
- Safety bumpers
- Siemens safety PLC

## Controls:

- Siemens open architecture
- Vehicle management system

## Keys to Success:

- Custom designed chassis
- Custom designed lifts and casters for tooling support and reduced point loading

## Results:

- Crane Utilization has been greatly reduced
- Simplified Autoclave loading results in reduced permanent infrastructure and reduced labor

## Solutions:

- Automated guided vehicle
- Vehicle management system
- Siemens integrated safety
- Magnetic & laser guidance



Fori specializes in design, build and integration of customized vehicles for the Aerospace industry. The AGV pictured was a highly customized vehicle for transporting Aerospace tooling and aircraft components.

Project requirements included the AGV to mimic the tooling footprint, the tool was roughly 30' long and wedge shaped. Total rated capacity for the AGV was 120,000 lbs. One of the most important features was minimizing side loading of tool during lift and transport.

The vehicle utilized dual guidance systems, this requirement was based on the ability to transport tooling in and out of an Autoclave. Previous methods include a large rail system and manual material handling method to locate the tooling within the autoclave.

Previous methods are labor intensive and risk damaging the product. Fori was able to accomplish this feat utilizing automated laser contour and magnetic bar guidance, this method allowed us to locate the tool within +/- 2 mm.



## Fori Standard Components: Lifters

Fori specializes in the design and build of custom lifts, the lifts pictured below were used on previous systems. Fori has the ability to design and build a lift to accommodate any project requirements



**Product:** Servo Tandem Lift  
**Capacity:** 60,000 lbs / 27,215 kg  
**Lift Stroke:** 8 in / 203 mm



**Product:** Chain Lift  
**Capacity:** 4,000 lbs / 1,814 kg  
**Lift Stroke:** 48 in / 1.2 m



**Product:** Servo Lift / Level Arbor  
**Capacity:** 12,500 lbs / 5,670 kg  
**Lift Stroke:** 6 in / 152 mm



**Product:** Servo Lift / Level Arbor  
**Capacity:** 8,000 lbs / 3,629 kg  
**Lift Stroke:** 8 in / 203 mm



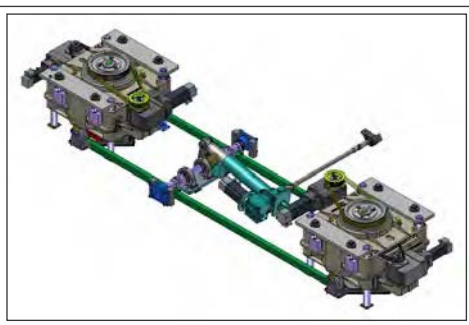
**Product:** Locking Lift Arbor  
**Capacity:** 14,500 lbs / 6,577 kg  
**Lift Stroke:** 8 in / 203 mm



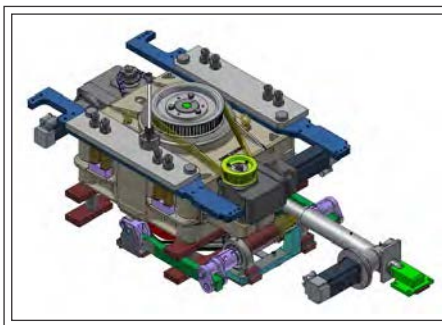
**Product:** Servo Lift / Level Arbor  
**Capacity:** 22,500 lbs / 10,205 kg  
**Lift Stroke:** 4 in / 102 mm

## Fori Standard Components: Drive Steer & Lift

Fori specializes in the design and build of custom drive steers and lifts, the pictures show units used on previous systems. Fori has the ability to design and build a lift to accommodate any project requirements.



**Product:** Dual Drive Steer Lift



**Product:** Single Drive Steer Lift

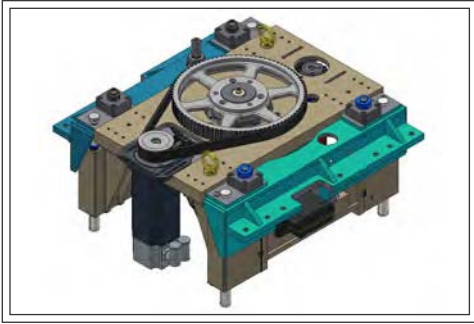


**Product:** Triple Drive Steer Lift

Fori drive steer lifts are used to automatically lift the drive steer when picking up tooling and product. Lifting the drive steer greatly reduces the side to side loading on the tool and allows the AGV to "float" and locate the tool.

# Fori Standard Components: Drive Steer

Fori specializes in the design and build of custom drive steers, the pictures show units used on previous systems. Fori has the ability to design and build a drive steer to accommodate any project requirements.



**Product:** DS-15  
**Capacity:** 15,000 lbs / 6,804 kg  
**Radial Load:** 3,250 lbs / 1,474 kg  
**Speed:** 24 in / 609 mm per second  
**Dimension (L x W x H):**  
 24" x 24" x 16"  
 61 cm x 61 mm x 41 mm



**Product:** DS-25  
**Capacity:** 25,000 lbs / 11,340 kg  
**Radial Load:** 6,000 lbs / 2,722 kg  
**Speed:** 24 in / 609 mm per second  
**Dimension (L x W x H):**  
 44" x 26" x 23"  
 112 cm x 66 cm x 58 mm



**Product:** DS-45  
**Capacity:** 45,000 lbs / 20,041 kg  
**Radial Load:** 9,000 lbs / 4,082 kg  
**Speed:** 48 in / 122 cm per second  
**Dimension (L x W x H):**  
 45" x 30" x 23"  
 114 cm x 76 cm x 58 cm

# Fori Standard Components

Suspended casters, high capacity swivel casters, automated charging stations, battery carts and custom automation equipment



**Product:** Quad Wheel Suspended Caster  
**Capacity:** 19,000 lbs / 8,618 kg



**Product:** Dual Wheel Suspended Caster  
**Capacity:** 13,000 lbs / 5,897 kg



**Product:** Dual Wheel Swivel Caster  
**Capacity:** 13,000 lbs / 5,897 kg



**Product:** Opportunity Charge Contact Pad



**Product:** Battery Carts



**Product:** Custom Automation for AGVs

# Fori Standard Guidance & Power Supplies

The best guidance and power solution will be determined based on each projects design requirements



**Guidance:** Magnetic Bar or Tape

**Description:** Utilizing a continuous magnetic path, Fori is able to achieve accuracy of +/- 0.2 in / 5mm. Magnetic bar is the most cost effective and reliable method.



**Guidance:** Magnetic Gyro (Inertial)

**Description:** Magnetic markers and a gyroscope are used for the Mag Gyro method. Magnetic markers are placed at a predetermined distance and the vehicle will travel utilizing gyroscope feedback and corrections will be made at each magnetic marker.



**Guidance:** Laser Contour

**Description:** Safety laser scanners are used to guide the AGV in areas where magnetic bar placement is not possible. Guidance is completed by measuring the end and outer wall distance from the AGV and using that feedback to locate the AGV within +/- .08 in / 2 mm.



**Power Source:** Lithium Ion

**Description:** LiNMC batteries provide a high energy density and increased life cycle, but are more costly than lead acid options.



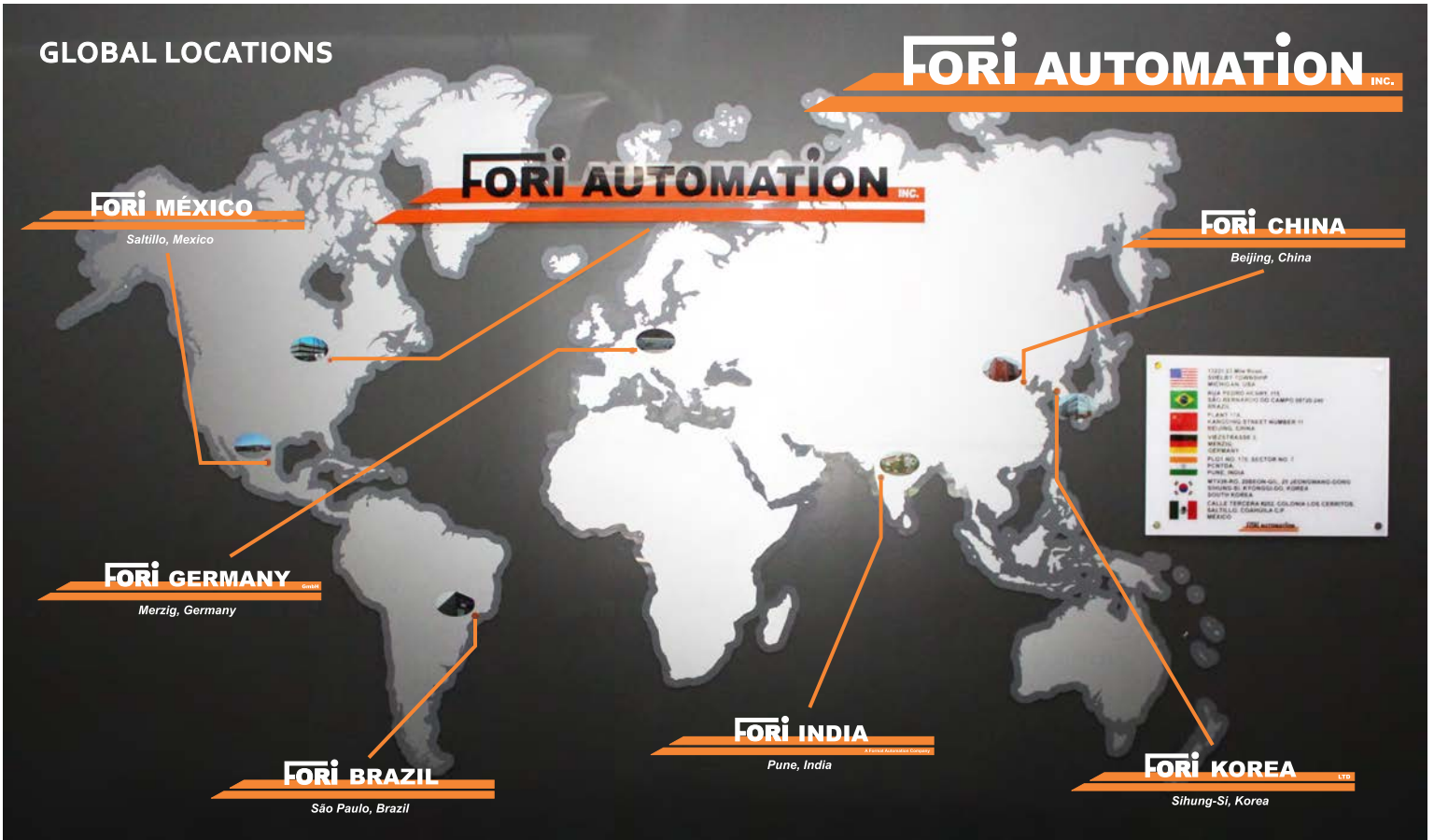
**Power Source:** Lead Acid

**Description:** There are a number of different lead acid options, sealed are the preferred option, larger footprint, reduced cycle life versus LiNMC, but much lower cost.



**Power Source:** Induction Power

**Description:** Induction power allows for non-stop vehicle operation. Completed utilizing an in-floor power and communication cable. Decreased flexibility and increased cost versus battery options.



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