

Manufacturing Apparatus and Manufacturing Line comprising the Manufacturing Apparatus

Field

5 The present invention relates to a manufacturing apparatus for handling a designated process in manufacturing and a manufacturing line comprising a plurality of the manufacturing apparatus, in particular, the manufacturing apparatus comprises modules for easy assembly.

Background

10 Highly Automated and customized manufacturing lines have been traditionally used for mass production of products throughout the world for many decades. Multinational companies have been using low wage countries such as China, India, and Thailand to mass produce their goods with semi-automated or manual manufacturing or production lines. However, increasing wages in these countries has made this approach less attractive and increased the demand for fully automated manufacturing lines.

15 Traditional automated production lines come with limited flexibility in high volume production. These lines are often not easily scalable due to its rigid line design that is meant for mass production. This limited flexibility also makes such lines unsuitable for "low volume - high mix" manufacturing needs.

20 As product complexity increases, automated manufacturing line gets more complex and investment cost goes up. Almost all automated manufacturing lines are custom built and as such the lead time for designing and building such line systems are significantly longer and affects the time to market.

25 With an ever demanding market push to reduce time to market and shorter life span of many modern products, huge initial investments put into manufacturing are inevitably increasing product cost. Moreover, little or no re-usable features render the entire line to be unsuitable for new products when an existing product goes "End Of Line" resulting in significant wastage of investment.

30 With the current market trend, product life cycles are much shorter and consumers prefer customised features in their products that may not be feasible in highly customised, automated lines. Thus, making the return on investment for capital equipment very unattractive for such low volume, high mix product manufacturing.

Scalability is another problem associated with highly automated production lines. Should there be a need for an incremental capacity increase, it will be very difficult to, if not impossible, to achieve such increase without significant re-design to the existing line resulting in prolonged down time and increased investment cost.

35 Traditional manufacturing rely heavily on a centralised control system to control the integrated modules with passive product transportation pallets without any connectivity. This approach restricts product transportation and data traceability in the line. Moreover, this also heavily occupies network resources.

40 Maintainability is another key issue of highly automated lines. The entire production line needs to be stopped to troubleshoot a module and such stoppage causes significant down time and loss of production to the entire line.

To manage shorter product life cycle, current efforts are directed at operations control such as just-in-time or "Kanban" manufacturing philosophy which control materials availability and enable more efficient management of raw materials and end products.

45 For certain manufacturing processes, tooling change within the machine can be done to allow the same machine to process multiple types of products. However, that is only limited to product change within the same form factor product family undergoing the same process. Some of this changeover requires hours of conversion time.

50 Due to the nature of the automated line with dedicated design, significant re-wiring and tubing are required for multi-product capability. Therefore, current machine designs do not offer much re-usability and flexibility.

Currently "Low volume - High mix" manufacturing requirements are often achieved through Manual or semi-automated lines with significant labour involvement.

55 There are some current efforts to address the aforementioned problems. For example, an existing ETUAN MPC (Multi-Purpose Cell) Series manufacturing system (<http://www.etuan.com.sg/product/Multipurpose.html>) designed with a common platform that allows the system to be configured for few applications including:

- Dispensing
- Conformal coating
- 60 • De-paneling

- Odd-shaped pick and place/ labelling/ inspection
- Screw fastening etc.

The ETUAN MPC manufacturing system can be configured up to three applications, for example, "dispensing", "pick and place" and "inspection" in a single system. However, product transportation
 5 utilises existing technology, which is not scalable and inflexible, and data traceability in the line is limited or does not exist.

Furthermore, the ETUAN MPC manufacturing system offers limited processing capability and does not offer scalability, re-usability, decentralised control, traceability and flexibility.

10 Summary

The invention is defined in the independent claims. Some of the optional features of the invention are defined in the dependent claims.

According to an aspect of an example of the present disclosure, there is provided a
 15 manufacturing apparatus for handling a designated process in manufacturing, the manufacturing apparatus comprising: a detachable process module to handle the designated process; and a detachable rail module comprising a plurality of rail segments, the detachable rail module being attachable to a corresponding detachable rail module of an adjacent manufacturing apparatus to form a rail, the rail being configured for one or more carts to travel thereon for transporting items between the manufacturing apparatus and the adjacent manufacturing apparatus, wherein a processor for
 20 executing one or more applications for controlling devices is connected to the manufacturing apparatus or the detachable process module, wherein a first rail segment of the plurality of rail segments comprises a first track and a second track configurable to connect with a third track and a fourth track respectively of a second rail segment, wherein each of the tracks is for the one or more carts to travel on, and the processor is configured to control the first track to move and connect with
 25 the fourth track of the second rail segment.

According to another aspect of an example of the present disclosure, there is provided a manufacturing line comprising a plurality of the manufacturing apparatus placed adjacent to one another, wherein the plurality of the manufacturing apparatus is placed adjacent to one another in series in at least two rows, wherein an inter-row rail segment is attachable to the detachable rail
 30 module of a manufacturing apparatus at an end of one row and is attachable to the detachable rail module of another manufacturing apparatus at an end of another row to enable the one or more carts to travel to any manufacturing apparatus residing in the at least two rows.

Brief Description of Drawings

35 Embodiments of the invention will be better understood and readily apparent to one skilled in the art from the following written description, by way of example only and in conjunction with the drawings, in which:

Figure 1 shows a cutaway perspective view of an example manufacturing apparatus of the present disclosure.

40 Figure 2 shows a perspective view of a plurality of the manufacturing apparatus in a manufacturing line of the present disclosure.

Figure 3 shows a perspective view of a manufacturing base of the manufacturing apparatus.

Figure 4 shows a perspective view of the manufacturing apparatus with a detachable rail module detached and with panels opened and a pivotable platform pivoted outwards.

45 Figure 5 shows a cutaway side view of the manufacturing apparatus.

Figure 6 shows a close up perspective view of a lower half of a base of the manufacturing apparatus.

Figure 7 illustrates operation of a sliding surface for facilitating mounting of a detachable process module of the manufacturing apparatus.

50 Figure 8 illustrates Automatic Tool Changer connectors residing in the base of the manufacturing apparatus and the detachable process module that are to be connected to one another.

Figure 9 shows the mounting of the detachable process module into a designated space in the manufacturing apparatus.

Figure 10 shows various views of the detachable process module.

Figure 11 shows examples of various types of the detachable process module.

55 Figure 12 shows a top perspective view of a picker device.

Figure 13 shows a close up perspective view of the picker device.

Figure 14 shows a side breakaway view of the picker device.

Figure 15 shows a perspective view of the detachable rail module with panels removed to reveal tracks.

60 Figure 16 shows a top view of the detachable rail module with panels removed to reveal tracks.

Figure 17 shows a front view of the detachable rail module with panels removed to reveal tracks.

Figure 18 shows a perspective view of a cart.

Figure 19 shows a breakaway perspective view of the cart.

Figure 20 shows a jig detached from the cart.

5 Figure 20A illustrates how a cart can manoeuvre corners on a track.

Figures 21 to 30 illustrate picture frame by picture frame movement of a cart between two of the manufacturing apparatus in a manufacturing line.

Figure 31 illustrates a detachable process module taken out of a manufacturing apparatus in a manufacturing line for maintenance but a rail formed by a plurality of connected detachable rail modules operates as normal.

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Figure 32 is a flowchart indicating an operation process of the manufacturing apparatus.

Figure 33 shows a perspective view of a plurality of the manufacturing apparatus in a manufacturing line of the present disclosure linked via an inter-row rail segment.

Figure 34 shows use of the manufacturing apparatus in a traditional manufacturing line layout.

15 Figure 35 illustrates a detachable process module taken out of a manufacturing apparatus in a manufacturing line and placed in a centralized maintenance module for maintenance.

Figure 36 shows possible locations for placement of electronic tag readers in an example manufacturing line.

20 Detailed Description

An example of the present disclosure is an agile manufacturing cell-based or module-based manufacturing apparatus designed to meet the needs for highly flexible and scalable automated production lines. The manufacturing concept of a manufacturing line comprising more than one of the manufacturing apparatus involves highly flexible and re-usable manufacturing cells or modules (each manufacturing apparatus is a cell or module), wherein each cell or module is capable of

25 accommodating various dockable process modules, versatile product handling robotics and/or intelligent transport mechanism with full Internet Of Things (IOT) capability. Each manufacturing apparatus comprises a detachable and changeable processing module configured for handling a specific manufacturing process and a detachable and changeable end effector configured for mounting on a robotic arm or a mechanical arm that is designed for handling the specific manufacturing process.

With ever reducing Time-to-Market and product lifetime, agile manufacturing cells or modules that are capable of manufacturing multi products with Rapid Change Over (RCO) concept and re-usable hardware provides a unique manufacturing platform. The manufacturing line comprising more than one of the manufacturing apparatus has a scalable design to make it suitable for "Farm" based manufacturing plant that allows non-sequential placement of processing modules and ad-hoc, incremental scalability without any tedious re-programming and re-arrangement. Multi product (manufacturing) capability makes the manufacturing line comprising more than one of the manufacturing apparatus ideal for Low volume-High mix product manufacturing requirements on the one hand and high volume mass production on the other hand. The cells or modules of the manufacturing line are designed based on distributed intelligence concept with full IOT capability. This allows module level intelligence that enables 'batch size one' capability. The cells or modules of the manufacturing line together with an IOT cart for transporting products in the manufacturing line and associated control systems enable end to end data traceability by horizontal and vertical integration of networked machine with cyber physical connectivity. The design of the cells or modules offers unique capability to be re-used for new products to be manufactured with change of only the processing module and the end effector. The design also provides scalability for incremental capacity increase without any manufacturing line re-design. Each manufacturing apparatus has a detachable base and modular architecture. Detachable bases of multiple standard sizes can be made available to allow a significant portion of the manufacturing apparatus to be mass produced resulting in reduced lead time and cost. The system architecture of each manufacturing apparatus also allows for offline centralised maintenance and troubleshooting to reduce unplanned downtime and abrupt stoppage of entire production or manufacturing line. The processing module of each manufacturing apparatus can be un-docked and transported to a maintenance workshop for repair and troubleshooting while the rest of the manufacturing line comprising other manufacturing apparatuses functions as normal.

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Figure 1 illustrates a cutaway figure of an example of the manufacturing apparatus 100 as described above. Several covers of the base 102 (may also be known as chassis or casing) of the manufacturing apparatus 100 have been removed in Figure 1 to provide a better view of the features of the manufacturing apparatus 100. Covered up views of the manufacturing apparatus 100 is illustrated in Figure 2. Generally, the manufacturing apparatus 100 for handling a designated process

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in manufacturing comprises a detachable process module 104 for attaching components to handle the designated process, and a detachable rail module 108 comprising a plurality of rail segments 110.

There is present a processor 112 or control unit for executing one or more (software) applications for controlling devices (For instance, a picker device 106) connected to the manufacturing apparatus 100 or the detachable process module 104. The processor 112 may be a programmable logic controller and/or an integrated circuit comprising cache memory, read only memory, random access memory, and the necessary system bus to enable it for receiving data inputs, data processing and for data outputs. In the present example, the processor 112 is attachable to and detachable from the manufacturing apparatus 100 or the detachable process module 104 and is specifically located on top of the manufacturing apparatus 100 in the present example. The manufacturing apparatus 100 further comprises a detachable rail module 108. The detachable rail module 108 comprises a plurality of rail segments 114, more specifically, 3 rail segments 130, 132 and 134 and a shuttle rail segment 124 in the present example. The picker device 106, which may be a robotic arm for picking items in the designated process, is mounted to the base 102 of the manufacturing apparatus 100.

Beside the processor 112 is a Hipa filter that can be installed for clean room usage of the manufacturing apparatus 100.

For example, the base 102 may house a Programmable Logic Controller, Loader Robot servo drive systems to run the picker device 106, Solenoid Valves, Safety Circuit and Input/Output (I/O) required for control of the detachable process module 104.

The base 102 of the manufacturing apparatus 100 can also, for example, be made available in three sizes namely Small, Medium and Large with the following dimensions and configurations.

Small – Size 1200 x 1200 x 1800 mm with 70 Input/Output (I/O) points and 12 Solenoid Valves

Medium – Size 1400 x 1200 x 1800mm with 120 I/O points and 20 Solenoids Valves

Large – Size 1600 x 1400 x 2000mm with 180 I/O points and 20 Solenoids Valves

The standardised design of the base 102 mentioned above allows the base 102 to be mass produced to reduce cost and lead time.

Each of the 3 rail segments (also known as "module shuttles") 130, 132 and 134 comprises at least a pair of tracks 116, 118 and 120 respectively. In addition, a track 122 is located beneath the pairs of tracks 116, 118 and 120 respectively. The pairs of tracks 116 and 120 may be known individually as horizontal shuttle. The shuttle rail segment 124 also comprises at least a pair of tracks 110, one being an upper track and the other being a lower track. The pair of tracks 110 may be known as vertical shuttle. Each one of the pairs of tracks 116, 118, 120, and 110 is for one or more carts, in this case, a cart 126 to travel on. The shuttle rail segment 124 is configured to move the pair of tracks 110 in a direction orthogonal to a direction of travel of the one or more carts on the tracks. More specifically, the pair of tracks 110 is said to be a vertical shuttle configured to move vertically upwards and downwards. The shuttle rail segment 124 acts as a traffic junction for moving the one or more carts travelling on one track to travel on another track if a track ahead is obstructed for the one or more carts to move forward.

Specifically, the manufacturing apparatus 100 can be said to be configured such that a first rail segment (e.g. 130, 132, 134, 124) of the plurality of rail segments 114 comprises a first track and a second track configurable to connect with a third track and a fourth track respectively of a second rail segment, wherein each of the tracks is for the one or more carts to travel on, and the processor 112 is configured to control the first track to move and connect with the fourth track of the second rail segment. These features cover four scenarios below, which are illustrated by Figure 1.

Scenario 1:

The first rail segment refers to the rail segment 130. The first track may be one of the pair of tracks 116 and the second track may be the other one of the pair of tracks 116. In Figure 1, the second track is horizontally adjacent to the first track. Since the pair of tracks 118 is adjacent to the pair of tracks 116, the third track is in this case one of the pair of tracks 118 and the fourth track is the other one of the pair of tracks 118.

Scenario 2:

The first rail segment refers to the rail segment 132. The first track may be one of the pair of tracks 118 and the second track may be the other one of the pair of tracks 118. In Figure 1, the second track is horizontally adjacent to the first track. As the pair of tracks 118 are disposed in the middle of the pair of tracks 116 and 120, the third track is in this case one of the pair of tracks 116 or 120 and the fourth track is the other one of the pair of tracks 116 or 120. The pair of tracks 118 may be fixed in its location and is optionally moveable.

Scenario 3:

The first rail segment refers to the rail segment 134. The first track may be one of the pair of tracks 120 and the second track may be the other one of the pair of tracks 120. In Figure 1, the second track is horizontally adjacent to the first track. Since the pair of tracks 120 are adjacent to the pair of tracks 118, the third track is in this case one of the pair of tracks 118 and the fourth track is the other one of the pair of tracks 118.

In the present example, for Scenarios 1 to 3, the first track and the second track are mounted at a fixed distance from each other and are moveable together when the first track is moved to connect with the fourth track. The direction of movement of the first track and the second track is horizontally towards a location for carrying out the designated process in the base 102 of the manufacturing apparatus 100. For example, when the first track (i.e. one of the two tracks 118 in Figure 1) is moved and connected with the fourth track (i.e. one of the two tracks 116 or 120), one or more carts, in this example, the cart 126 on the second track, is moved to a location where the one or more carts are docked in the manufacturing apparatus 100 for carrying out the designated manufacturing process. Typically, after one or more carts are docked, products transported on the one or more carts can be loaded or unloaded through the help of the picker device 106. In Figure 1, the cart 126 located on the second track is docked in a location accessible by the picker device 106. The processor 112 is configured for updating that the one or more carts, in this case, the cart 126, is docked in a location in the manufacturing apparatus 100 in a table stored in a memory of a server. Such table is accessible by any device requiring information on current location of the one or more carts, in this case, the cart 126, that is docked in the location in the manufacturing apparatus 100.

Scenario 4:

The first rail segment refers to the shuttle rail segment 124. In Figure 1, the first track is vertically adjacent to the second track. With reference to Figure 1, the first track is the lower one of the pair of tracks 110 of the shuttle rail segment 124 and the second track is the upper one of the two tracks 110 of the shuttle rail segment 124. Since the two tracks 110 of the shuttle rail segment 124 are adjacent to the pair of tracks 120, the fourth track is in this case an upper one of the pair of tracks 120 connected with the first track but the third track is the track 122 located beneath and running along the pairs of tracks 116, 118 and 120 respectively. For a cart to pass from the fourth track to the first track and vice versa, the shuttle rail segment 124 has to be moved vertically upwards such that the second track is disconnected from the third track.

In scenario 4, the aforementioned second rail segment may be a rail segment of an adjacent manufacturing apparatus. In this case, the fourth track may be an upper one of pair of tracks of the second rail segment (not shown in Figure 1) and the third track may be a lower one of the pair of tracks of the second rail segment (not shown in Figure 1). If the first track is connected to the fourth track, the fourth track has another cart thereon obstructing the cart on the first track to move to the fourth track and the third track has no cart obstructing passage, the processor 112 is controllable to move the first track to connect with the third track so that the cart on the first track can move to the third track. Likewise, when the first track is connected to the third track, the first track has one or more carts thereon, the third track has one or more carts thereon obstructing the one or more carts on the first track to move to the third track, and the fourth track has no cart thereon and obstructing passage, the processor 112 is controllable to move the first track to connect with the fourth track so that the one or more carts on the first track can travel on the fourth track.

Specifically, the manufacturing apparatus 100 of Figure 1 has the following modules.

A dockable or detachable process module 104, which is a module that is specifically designed for a product or process that can be easily interchanged in the base 102 without any additional wiring or tubing other than Automatic Tool Changer connectors 606.

A picker device 106, which is a versatile robotic pick and place that can handle multiple end effectors that can be quickly changed.

A detachable rail module 108 that is a monorail based transport system with shuttles, which is low cost and highly efficient, and comprises module level shuttles for traffic control and for facilitating module connectivity.

A cart 126 implemented based on the concept of Internet Of Things (IOT), which is an intelligent cart system that is capable of traffic control, data traceability and module communication. For convenience, the reference numeral 126 is used to label more than one carts in the present disclosure.

A processor 112, which is a smart manufacturing control system that allows scalability and multi product capability with simple recipe based operation (a recipe refers to specific procedures and operations required in a particular manufacturing process) and configurations without any re-programming of Programmable Logic Controller or Control system. The processor 112 can communicate either wirelessly (Wi-Fi and the like) or through wired means (Cabled Ethernet) with a

central server (not shown) controlling the entire manufacturing line comprising the manufacturing apparatus 100.

The synergy of the various components of the manufacturing apparatus 100 provides a complete end-to-end product traceability and production monitoring system that is capable of providing module and component level information tracking for production monitoring, process control and maintenance.

Figure 2 illustrates the manufacturing line 200 as described above. The manufacturing line 200 comprises a plurality of the manufacturing apparatus 100 (with casing or chassis 102 covered up by panels or safety fences).

The detachable rail module 108 of one manufacturing apparatus 100 is attachable to a corresponding detachable rail module 108 of an adjacent manufacturing apparatus 100 to form a rail 204, the rail 204 being configured for one or more carts 126 to travel thereon for transporting items between the manufacturing apparatus 100 and the adjacent manufacturing apparatus 100. In the present example, the rail 204 is specifically made up of the pair of a plurality of the two tracks 110 connected together, one track located vertically above the other track. In the centre of the manufacturing line 200, one detachable rail module 202 is deliberately wheeled out of its rightful position where it forms the rail 204 with the adjacent detachable rail modules 108. Each detachable rail module 108 or 202 has wheels to facilitate movement of the detachable rail module 108 or 202. In the present example, the rail 204 has two levels comprising an upper track and a lower track for the one or more carts 126 to travel.

With reference to Figure 33, a plurality of the manufacturing apparatuses 100 in a manufacturing line can be placed adjacent to one another in series in at least two rows. Figure 2 only illustrates the manufacturing line 200 having only one row. However, Figure 33 shows a manufacturing line 3300 with 4 rows 3304, 3306, 3308 and 3310, wherein each row has 4 manufacturing apparatuses 100. In the case of more than one row, an inter-row rail segment 3302 can be attached to the detachable rail module 3314 of a manufacturing apparatus 100 at an end of one row 3304 and is attachable to the detachable rail module 3316 of another manufacturing apparatus 100 at an end of another row 3306 to enable the one or more carts to travel to any manufacturing apparatus 100 residing in the at least two rows. The inter-row rail segment 3302 is like a highway track with two levels comprising an upper track and a lower track for the one or more carts 126 to travel. Advantageously, one or more manufacturing apparatuses 100 can be added to the end of the manufacturing line 200 to increase manufacturing capacity. Advantageously, the layout of the manufacturing line 3300 saves more space compared to traditional manufacturing line layouts as the manufacturing apparatuses 100 in each row are placed adjacent to one another and the inter-row rail segment 3302 connects up numerous rows. For illustration, each of the manufacturing apparatus 100 in the manufacturing line 3300 is mounted with a user control panel 3312 that is connected to the processor 112 of the manufacturing apparatus 100. The user control panel 3312 comprises a screen (may be a touchscreen) for user viewing and buttons for users to make settings.

Figure 3 shows the base 102 of the manufacturing apparatus 100 in Figures 1 and 2 with a front panel 302, left side panels 304, and right side panels 306 opened. The front panel 302, left side panels 304, and right side panels 306 are located in an upper half of the manufacturing apparatus 100 but beneath the top of the manufacturing apparatus 100 where the processor 112 is located. The base 102 is a re-usable machine base and the processor 112 operates as an integrated control system for controlling the processes of the designated manufacturing process. A lower half of the base 102 has space for housing the detachable process module 104.

Figure 4 shows the manufacturing apparatus 100 illustrated by Figures 1 to 3 with the front panel 302, left side panels 304, and right side panels 306 opened and the detachable process module 104 being mounted to the base 102 of the manufacturing apparatus 100. The picker device 106 is mounted to hang from a pivotable platform 402 mounted to the upper half of the base 102. The pivotable platform 402 is located below the processor 112 and is pivotable about the base 102. A rear view of the detachable rail module 108 is shown in Figure 4. The respective two tracks 116, 118, and 120 of the respective rail segments 130, 132 and 134, and the two tracks 110 of the shuttle rail segment 124 are shown. The track 122 running beneath the two tracks 116, 118, and 120 are shown as well. The two tracks 118 in Figure 4 are shown as moved to a location deemed as docked in the manufacturing apparatus 100 like the case of the two tracks 118 in Figure 1. In Figure 4, the processor 112 is actually placed in a rear portion of the manufacturing apparatus 100 unlike the example in Figure 1 and the Hipa filter 136 is at the same location. Furthermore, Figure 4 shows a detachable frame for joining the detachable rail module 108 to the manufacturing base 102.

Figure 5 shows a cutaway side view of the manufacturing apparatus 100. The manufacturing base 102, the picker device 106, processor 112 and detachable rail module 108 are shown amongst

other components. Right side panels (that is, 306 in Figure 3) of the manufacturing base 102 are deliberately removed to reveal the picker device 106.

Figure 6 shows a close up view of the lower half of the base 102 of the manufacturing apparatus 100. The lower half of the base 102 comprises a designated space 600 for the detachable process module 104 to be slotted into the manufacturing apparatus 100. The manufacturing apparatus comprises a sliding surface 604 configured for receiving the detachable process module 104 and for facilitating the slotting of the detachable process module 104 into the designated space 600 in the manufacturing apparatus 100. The sliding surface 604 comprises a plurality of rollers 608 configured to enable sliding of the detachable process module 104 over the sliding surface 604 upon activation of the plurality of rollers 604 to facilitate mounting of the detachable process module 104 to the base 102 and to disable sliding of the detachable process module 104 over the plurality of rollers 608 upon deactivation of the plurality of rollers 608 when the detachable process module 104 is pushed into position in the manufacturing base 102.

The detachable process module 104 has one or more locating pins (710, 902, 908 and 910 in Figure 9) for aligning the detachable process module 104 for slotting into the designated space 600 in the manufacturing apparatus 100. The locating pins (710, 902, 908 and 910 in Figure 9) are slotted into datum slots 610 and 612 in Figure 6 disposed in a rear portion located furthest away from where the detachable process module 104 enters to slot into the designated space 600 of the manufacturing base 102. The datum slots 610 and 612 act as guides for the assembly of the detachable process module 104 to ensure the X (horizontal) and Y (vertical) position of the detachable process module 104 is maintained during docking. Each of the datum slots 610 and 612 is a semi-circular docking locator residing on a rear end of the base 102. The manufacturing base 102 comprises a lock 602 for locking the detachable process module 104 in position in the manufacturing apparatus 100. The manufacturing apparatus 100 comprises at least one first Automatic Tool Changer (ATC) connector 606 for connecting with at least one corresponding second ATC connector (not shown in Figure 6) of the detachable process module 104. Each of the first automatic tool changer 606 and the second automatic tool changer comprises one or more connections for enabling use of electrical, pneumatic and/or vacuum devices attached to the detachable process module in the designated process.

Figure 7 shows a cutaway side view of the base 102 of the manufacturing apparatus 100 to illustrate the operation of the sliding surface 604 of Figure 6 in more detail. Specifically, the sliding surface 604 is a ball riser unit with a plurality of slots 708 containing the plurality of rollers 608 in the form of ball bearings 608. Each of the plurality of slots 708 comprises a slot opening 712. The slot openings 712 are sized such that the ball bearings 608 will not be pushed out of the slot openings 712 when air is channelled to push the ball bearings 608.

Figure 7 shows two drawings 700 and 702. The drawing 700 illustrates the ball bearings 608 when they have risen to enable easy sliding in or out of the detachable process module 104 into the designated space 600 in Figure 6. The ball bearings 608 can rise by channelling air to push each ball bearing 608 upwards to the slot openings 712. The detachable process module 104 comprises a side skirt 704 that can rest and slide over the ball bearings 608 during the assembly of the detachable process module 104 to the base 102. The side skirt 704 is part of a base plate (1016 in Figure 10) of the detachable process module 104. Alignment of the detachable process module 104 is achieved by aligning the locating pin 710 to the datum slot 610. The side skirt 704 sits on the lock 602, which is an anti-back lock, when the detachable process module 104 is sliding in or out of the base 102. The anti-back lock 302 is configured such that the side skirt 704 of the detachable process module 104 rises to rest on an apex 714 of the lock 302 when the ball bearings 608 are pushed to the slot openings 712 to facilitate sliding of the detachable process module 104. As long as the side skirt 704 rests on the apex 714, the lock 302 is not in locking state.

The drawing 702 illustrates the ball bearings 608 retracting into their respective slots 708 when no air is channelled to push them to the slot openings 712 as the detachable process module 104 is sitting in position. The locating pin 710 of the detachable process module 104 is slotted into the datum slot 610 in drawing 702. The lock 302 is configured such that the apex 714 is located at an end towards a rear side of the manufacturing apparatus where the datum slot 610 is disposed. The lock 302 is shaped such that the side skirt 704 of the detachable process module 104 will fall to rest on the sliding surface 604 as shown in drawing 702 once air is no longer channelled to the ball bearings 608 and the side skirt 704 has went beyond the apex 714. The lock 302 is fixed and made pivotable in a slot 716.

Advantageously, the detachable process module 104, which can be a heavy object, can be easily mounted to the base 102 with just one operator once the detachable process module 104 is placed in contact with the sliding surface 604. The detachable process module 104 may be first raised to the level or height of the sliding surface 604 using a jack lifter with wheels so as to position the side

skirt 704 of the detachable process module 104 over the lock 302 first, followed by over the sliding surface 604. Accordingly, repeatable accurate detachable process module docking can be achieved.

Figure 8 illustrates the at least one first Automatic Tool Changer (ATC) connector 606 residing in the base 102 of the manufacturing apparatus 100 that is for connecting or engaging to the at least one second Automatic Tool Changer connector 802 of the detachable process module that are to be connected to one another. The at least first ATC connector 606 and the at least one second ATC connector 802 are connected once the detachable process module 104 is slotted into the manufacturing apparatus 100. Advantageously, no other wiring or tubing is required for electrical and/or pneumatic connections other than these at least one Automatic Tool Changer connector 606 and 802. The use of ATC connectors 606 and 802 ensures Rapid Change Over (RCO), which is a concept of fast changeover of the detachable processing module 104 with minimum wiring or tubing change. Specifically, the ATC connectors 606 and 802 are used to link all electrical (both control and Power) supply, Pneumatic and Vacuum supply to the detachable process module 104, as required.

Figure 9 shows the mounting of the detachable process module 104 of the earlier Figures into the designated space 600 in Figure 6 of the base 102 of the manufacturing apparatus 100. Figure 9 shows that the detachable process module 104 can have four locating pins 902, 908, 910, and including 710, which is illustrated in Figure 7. In the case of Figure 9, the locating pins 710 and 902 are to be aligned and slotted into respective datum slots 610 and 612 in the base 102. The other locating pins 908 and 910 are present because depending on how components are placed in the detachable process module 104 and the position of the Automatic Tool Changer connectors 802, it may be possible to turn the detachable process module 104 around for slotting into the designated space 600 with the locating pins 908 and 910 being aligned and slotted into the respective datum slots 610 and 612.

Figure 10 shows various views of the detachable process module 104 in Figure 4, in particular, a perspective view 1000, a top view 1002 and a front view 1004. The Automatic Tool Changer (ATC) connectors 802 can be seen in Figure 10. The ATC connectors 802 are to be attached to the ATC connectors 606 of the detachable process module 104 to provide all electrical, pneumatic and/or vacuum connectivity.

At a top of the detachable process module 104 is a base plate 1016. In a center of the detachable process module is a rotary index table 1006 (the index table 1006 can rotate) that can be replaced with tables having different devices for different types of manufacturing process. On the present table 1006 shown in Figure 10, there are two product specific fixtures 1010 and 1012 (also called jigs). The rotary index table 1006 helps to optimise the manufacturing process cycle by allowing loading and unloading of one or more products on one fixture, for instance, fixture 1010, while another product or products are being processed on the other fixture 1012.

Opposite to the ATC connectors 802 is a power track 1008 for energizing or charging a power source or supply of the cart 126 of Figure 1 when the cart 126 is docked with the detachable process module 104 and in contact with the power track 1008. This ensures that the power source of the cart 126, which may be a portable battery, is charged as long as the cart 126 is docked.

In a lower half of the detachable process module 104, there is a cabinet for housing process specific control modules or system 1014 for operating the components on the table 1006 or mounted to the detachable process module 104. The specific control modules or system 1014 may comprise a processor and memory for controlling the process to be handled by the detachable process module 104. The processor may be a programmable logic controller and/or an integrated circuit comprising cache memory, read only memory, random access memory and the necessary system bus to enable it for receiving data inputs, data processing and for data outputs. The processor may also be a process module specific controller for operating the detachable process module 104 as a servo drive unit, a laser control unit, a leak test control unit etc. The cabinet also contains remote Input/Output (I/O) connections connected to the processor 112 of Figure 1 through the ATC connectors 606 and 802.

Each detachable process module 104 is also issued an identifier to provide module identification and to facilitate automatic program selection required for a manufacturing process through a Programmable Logic Controller that may be mounted to the detachable process module 104 or the base 102.

Figure 11 shows examples of various types of the detachable process module 104 that can be mounted to the base 102 of the manufacturing apparatus 100 of the earlier Figures including (non-exhaustively) manufacturing tools and devices such as a leak tester, a laser measurement tool, a dispensing tool, a vision system tool and the like.

The detachable process module 104 can be a custom made module to accommodate various products and/or processes that is required to be carried out. For example, the detachable process

module 104 can be an X-Y-Z Laser measurement tool or a Dispensing module with a multiple axes dispensing mechanism or a sub assembly module for one or more components to be assembled on a base product. The detachable process module 104 is one of the only two physical items required to be changed over in the manufacturing apparatus 100 in the case of a manufacturing product change.

The other item being the end effector (1200 in Figure 12) of the picker device 106 of Figure 1.

Holding and biasing fixtures, processing tools and module specific controls may be placed within the detachable process module 104. For example, an X-Y-Z Laser measurement module will have a laser controller, X-Y-Z servo controller etc. hosted within the detachable process module 104. This design allows multi-product capability by detaching an entire detachable process module 104 along with all its control and attaching a totally new detachable process module 104.

Figure 12 shows a top perspective view of an example of the picker device 106 of Figure 1. The picker device 106 is for picking or placing items on the one or more carts 126 of earlier Figures and the picker device 106 comprises a clip-on mounting 1202 (also known as quick release coupling) for attaching one or more application specific end effector 1200 through a clipping action without requiring further fastening. The picker device 106 is driven by a two axes (Y axis 1210 and Z axis 1208) drive motor 1204 and has a rotary actuator for rotating the end effector 1200 about a vertical W axis 1208 (coincides with the Z axis 1208). Y-axis movements are in a direction along the Y axis 1210 and are made by the picker device 106 to move from one configuration to an extended configuration based on needs of the predetermined manufacturing process. Z axis movements are up and down movements along the Z axis 1208. W axis movement in the present disclosure is defined as rotating movements about the W axis 1208 (coincides with the Z axis 1208).

Figure 13 shows a close up perspective view of the picker device 106 shown in Figure 12. Figure 14 shows a side breakaway view of the picker device 106 shown in Figures 12 and 13. The end effector 1200 for picking and/or placing of a manufacturing process can be removed and replaced by another end effector 1400 that has another picking and/or placing function for the same or another manufacturing process. The end effector 1200 can be easily interchanged at the clip-on mounting 1202 or quick release coupling.

With reference to Figures 12, 13 and 14, the picker device 106 is a custom made 3 axes robot with the Y axis 1210, the Z axis 1208 and the W axis 1208 capable of fast product transfer using the suitable end effector 1200 that is changeable. With the picker device 106, for example, a complete cycle of pick and place with a distance 400mm and a height of 70mm can be completed in 3 seconds. The end effector 1200 is fitted on with two picking fingers 1302 and 1304 that are 180 degrees apart to simultaneously pick and place products or articles at the detachable process module 104. In the present example, the robot servo axes of the picker device 106 are fully controlled by a Programmable Logic Controller (PLC) and the pick and place path and position of the picker device 106 can be changed by teaching through Human Machine Interface (HMI).

Figure 15 shows a perspective view of the detachable rail module 108 of Figure 1 with panels deliberately removed to reveal the track 122, the rail segments 130, 132, 134 and 124 and the respective pairs of tracks 116, 118, 120, and 110. The detachable rail module 108 has a swing open structure 1518 that can be lifted like a bonnet of a car to reveal the tracks 116, 118, and 120, which would be covered by panels in normal circumstances. Figure 16 shows a top view of the detachable rail module 108 with panels deliberately removed to reveal the same rail segments 130, 132, 134 and 124 and tracks 122, 116, 118, 120, and 110. Additionally, Figure 16 shows arrows indicating possible horizontal directions of movements of each of the pairs of tracks 116, 118 and 120 to move a cart (not shown in Figure 16) residing thereon into or out of a docking area in the manufacturing apparatus 100 of Figure 1. Figure 17 shows a front view of the detachable rail module 108 with panels deliberately removed to reveal the same rail segments 130, 132, 134 and 124, the tracks 122 and 110, and outer tracks 1504, 1508, 1512. Additionally, Figure 17 shows arrows indicating possible vertical directions of movements of the pair of tracks 110, which acts as a traffic junction to move a cart (not shown in Figure 17) residing thereon to travel from one track to an adjacent track if a track ahead is obstructed for passage.

With reference to Figures 15 to 17, more specifically, the pair of tracks 116 comprises an inner track 1502 and the outer track 1504 that are coupled and moveable together and may be known as horizontal shuttle. The pair of tracks 118 comprises an inner track 1506 and the outer track 1508 that are coupled and may be optionally moveable together, and if they may move together, they are known as horizontal shuttle. In the present example, the pair of tracks 118 is fixed in position with the inner track 1506 always adjacent to a docking area for a cart (e.g. 126 of Figure 1) to dock in the detachable process module 104. The pair of tracks 120 comprises an inner track 1510 and the outer track 1512 that are coupled and moveable together and may be known as horizontal shuttle. The pair of tracks 110 comprises an upper track 1514 and a lower track 1516 that are coupled and moveable

together. The track 122 is a single piece of track running beneath all the inner tracks 1502, 1506, and 1510 and the outer tracks 1504, 1508, and 1512.

All the inner tracks 1502, 1506 and 1510 will be placed further into the manufacturing base 102 of Figure 1 and the respective outer tracks 1504, 1508, and 1512 are placed further outside of the manufacturing base 102. The inner tracks 1502, 1506, and 1510 when moved into the manufacturing base 102 would be deemed to be docked in position for a manufacturing process of the detachable process module 104 of Figure 1 to take place.

Figure 18 shows a perspective view of the fully assembled cart 126 of Figure 1 with a bottom half 1802 covered. There are two collision sensors 1804 and 1806 mounted in front and rear positions of the cart 126 for detecting collision with another cart in the front and rear of the cart 126 respectively.

Figure 19 shows a breakaway perspective view of the cart 126 with covers in the bottom half 1802 of the cart 126 deliberately removed to reveal rollers 1904 of the cart 126 that enables the cart 126 to move on the tracks (e.g. each of the tracks 116, 118, 120, 110, and 122 in earlier Figures). There are also rollers 1914 and 1916, which are electrical conductors, contactable to the power track 1008 of Figure 1000 for charging a portable power source or supply (i.e. battery) 1902 when the cart 126 is docked with the detachable process module of Figure 10. The power source 1902 and a cart jig top 1906 (also called "jig" or "product container") are deliberately shown as disconnected from the cart 126 to reveal an on-board controller or processor 1908 controlling the operations of the cart 126. A container 1910 comprising the rollers 1914 and 1916 also comprises an electronic tag reader, for example, a Radio Frequency Identification (RFID) reader, required for tracking location of the cart 126 when it is in a manufacturing line.

Figure 20 shows a perspective view of the cart 126 with the cart jig top 1906 broken away from the cart 126 and again with covers in the bottom half 1802 of the cart 126 deliberately removed to reveal the rollers 1904. The main objective of Figure 20 is to show that the jig top 1906 is interchangeable to suit any manufacturing process requirements.

Figure 20A has two carts 2004 and 2006 (126 in other figures) illustrating how each cart 2004 and 2006 can be configured to manoeuvre corners on a track or rail.

With reference to Figures 18 to 20, and 20A, the one or more carts, for instance, the cart 126 of Figure 1, described in the present disclosure can be known as a smart cart due to the following features.

The cart 126 operates based on a Distributed Intelligence concept that is the cart 126 has its own on-board controller or processor 1908 with memory, and Wi-Fi connectivity or equivalent wireless data communication connectivity to communicate and navigate through, for instance, the manufacturing line 200 of Figure 2. The on-board controller 1908 is responsible for cart movement and control, and navigation of the cart to reach specific destinations, for instance, to reach and dock in specific detachable process modules 104 of specific manufacturing apparatus 100 in the manufacturing line 200. The on-board controller 1908 may be a programmable logic controller and/or an integrated circuit comprising cache memory, read only memory, random access memory and the necessary system bus to enable it for receiving data inputs, data processing and for data outputs.

The cart 126 can be battery (chargeable power supply) operated and is movable on each track of the guided monorail tracks 116, 118, 120, 110, and 122 described with reference to Figures 15 to 17.

With reference to Figure 20A, each of the two carts 2004 and 2006 (each can be the cart 126 in the other figures) comprises two built-in pivot links 2002 at two opposing ends of each cart 2004 or 2006. Only one of the two pivot links 2002 of each cart 2004 and 2006 is shown in Figure 20A. Such pivot links 2002 facilitate the cart 2004 and 2006 to manoeuvre corners on a track or rail with no impact to products carried in the cart jig top 1906. Each of the two pivot links 2002 are located in a central portion of a front end and a rear end respectively of each of the carts 2004 and 2006 respectively. Each pivot link 2002 connects a movable end block 2008 of the cart 2004 and 2006 to the rest of the cart 2004 and 2006. The movable end block 2008 contains wheels or rollers 1904 for moving the cart 2004 and 2006 along the track or rail. The movable end block 2008 is rotatable or pivotable about a center axis 2010 of the pivot link 2002 of the cart 2004 and 2006 to enable the cart 2004 and 2006 to manoeuvre a corner on the track or rail.

With reference to Figures 18 to 20, the cart jig top 1906 is easily interchangeable to accommodate holding of multiple products with RFID tags. The cart 126 may be driven by a Direct Current Stepper Motor 2002 that allows accurate positioning within a distance of 0.1mm on a track. This motor 2002 also allows the cart 126 to travel in both directions of a track to facilitate transportation of products. This is helpful in the case of non-sequentially arranged manufacturing apparatuses 100 of Figure 1 in a manufacturing line (e.g. 200 of Figure 2) because the cart 126 can be configured or programmed to move around the manufacturing apparatuses 100. Unlike the

conventional way where each manufacturing process has to be arranged in sequence such Process 1, Process 2, Process 3 and perhaps Process 2 again, with the help of such smart carts 126 and the detachable rail module 108, which can direct traffic of carts, the manufacturing apparatuses 100, for example, for the same Processes 1, 2, 3 and 2 again need not be arranged adjacent to one another in that order. The smart cart 126 allows a product or products carried thereon to be transported to any desired location in the manufacturing line (e.g. 200 of Figure 2) based on a preconfigured recipe or procedure/process. Each cart, including the cart 126, used in the manufacturing line is remotely connected to a central Smart Manufacturing Control System operated by, for instance, a central server (not shown in the Figures), for cart traffic control and navigation.

During operation, in a first step, a loading station (e.g. a manufacturing apparatus 100) loads a product or products to the cart 126 on its jig top 1906 and the station updates the cart 126 with product details such as product type and serial numbers of the products. Upon receiving the product or products, in a second step, the cart 126 connects via Wi-Fi to the central server to download a recipe, which comprises a preconfigured procedure/process the cart 126 needs to follow. The cart 126 stores the recipe into its memory. Based on the recipe and current location of the cart 126, the cart 126 generates a routing table (such as Table 1 below) to the one or more destinations the cart 126 has to visit and the cart 126 navigates to each of the detachable process modules 104 responsible for certain manufacturing process or processes in the manufacturing line (e.g. 200 in Figure 2) accordingly. As such, the cart 126 receives wirelessly from the central server information on one or more manufacturing apparatus 100 to dock at in sequence that are situated along a rail (e.g. 204 of Figure 2) formed by a plurality of manufacturing apparatuses in a manufacturing line.

Each cart (also given the reference numeral 126 for convenience) used in the manufacturing line is fitted with an electronic tag reader, for example, an RFID tag reader. An RFID tag is fitted to the jig top 1906 of the cart 126. It is appreciated that other forms of tagging using Near Field Communication (NFC) tags, barcodes, etc. can be used as well. The RFID tag reader is used to track location of the cart's location in the manufacturing line. The RFID tag allows the base 102 of each manufacturing apparatus 100 to identify the jig top 1906 to prevent a jig carrying a wrong product. The RFID tag may be configured to indicate the type of product the jig top 1906 carries.

Electronic Tags, for example, RFID tags, may be fixed on upper and lower levels of the monorail tracks, for instance, any one of the upper tracks 1502, 1504, 1506, 1508, 1510, 1512 and 1514 of Figure 15, and any one of the lower tracks 122 and 1516 of Figure 15, for tracking location of each cart 126. Each cart 126 is dynamically controlled based on a cart identifier (may be an RFID tag) labelled on the cart 126 and the recipe details received from the central server.

Figure 36 shows possible locations for placement of electronic tags, for example RFID tags, in an example manufacturing line 3600 comprising two manufacturing apparatus 100. Figure 36 also shows two close-up views 3610 and 3612 of the electronic tags. Specifically, one of the manufacturing apparatuses 100 comprises one or more electronic tags, in this case, two electronic tags 3602 and 3604. The other manufacturing apparatus 100 comprises two electronic tags 3606 and 3608 as well. These electronic tags 3602, 3604, 3606 and 3608 are configured to be read by an electronic tag reader mounted to each of the one or more carts 126 so as to track location of the one or more carts 126 in the manufacturing line 3600. To enable cart location tracking on upper and lower levels 3614 and 3616 of the monorail tracks (e.g. upper tracks 1502, 1504, 1506, 1508, 1510, 1512 and 1514 of Figure 15, and lower tracks 122 and 1516 of Figure 15), one electronic tag 3602 or 3606 of each manufacturing apparatus 100 is located closer to the lower level 3616 and another electronic tag 3604 or 3608 of each manufacturing apparatus 100 is located closer to the upper level 3614.

An example of the information of the aforementioned recipe to navigate the cart 126 is represented by table 1 below.

Table 1

Recipe				
Step	Station ID	Process Module	Track level	Cart Direction
1	2	10	2	0
2	1	20	1	1
3	2	30	2	0
4	3	40	2	0
5	1	50	2	0

In table 1, "Step" refers to each step in the manufacturing process. The "Station Identifier (ID)" refers to a number issued to each manufacturing apparatus 100 in the manufacturing line to go to at

each step. The "process module" number refers to a number issued to each detachable process module 104 of the respective manufacturing apparatus 100 to be docked by the cart 126. The "track level" indicates the upper tracks, which can be any one of the tracks 1502, 1504, 1506, 1508, 1510, 1512 and 1514 of Figure 15, and the lower tracks, which can be any one of the tracks 122 and 1516 of Figure 15. If the track level indicates "1", the cart 126 is to travel on the upper tracks and if the track level indicates "2", the cart 126 is to travel on the lower tracks. If a switch from upper track to lower track or lower track to upper track is required, this can be accomplished through the shuttle rail segment 124 of the detachable rail module 108. The "cart direction" refers to direction of travel of the cart 126 on the tracks. "0" indicates one direction and "1" indicates a reverse direction of that of "0".

Upon reaching each manufacturing apparatus 100 in the manufacturing line, the cart 126 communicates with the detachable process module 104 of the manufacturing apparatus 100 through one or more status tables to indicate whether to dock at the manufacturing apparatus 100 for a manufacturing process to be carried out on the product or products carried by the cart 126. The status table helps the manufacturing apparatus 100 to instruct the cart 126 to make fine movements required for precise docking and placement for the designated manufacturing process. When the cart 126 reaches the manufacturing apparatus 100, an RFID tag reader mounted outside of the manufacturing apparatus 100 on the tracks of the detachable rail module 108 confirms the cart identifier in the form of an RFID tag through the processor 112 mounted on the base 102 and dock the cart 126 to the detachable process module 104 through help of the horizontal shuttles (116, 118 or 120 of Figures 15 to 17) of the respective detachable rail module 108. The necessary Input/Output (I/O) for communication with the cart 126 and processor 112 are mapped or initialised such that the cart 126 is in condition for communicating with the processor 112 to conduct the required manufacturing process at the detachable process module 104 docked by the cart 126. This I/O mapping or initialisation process may include downloading and uploading of instruction tables containing physical memory addresses of a list of commands for carrying out corresponding actions. Thereafter, the processor 112 can command the cart 126 to move through the locations in the detachable process module 104 for loading and unloading by controlling the horizontal shuttles (116, 118 or 120 of Figures 15 to 17).

The cart 126 may also store in its memory information in the following table 2, table 3 and table 4. Table 2 indicates location and direction information of the cart 126. Table 3 indicates track level of the cart 126 and table 4 indicates docking status of the cart 126 when the cart 126 docks with a detachable process module 104.

Table 2

Location and Direction	
HeartBeat	1
Previous Station	3
Current Station	1
Next Station	2
Direction	0
Track Level	1
Traffic busy to move	0
Cart Collision feedback	0
Task completed	2

In table 2, "Heartbeat" refers to a constant communication exchange between the cart 126 and the central server. The on-board controller of the cart 126 and the central server exchange wirelessly a specific data Input/Output (I/O) bit in a pre-defined frequency to indicate constant communication. Absence of this bit on either side that is the on-board controller and the central server would denote a failure in communication. "Previous Station" refers to a previous station (i.e. manufacturing apparatus 100) docked by the cart 126. "Current Station" refers to a current station (i.e. manufacturing apparatus 100) docked by the cart 126. "Next Station" refers to the next station to be docked by the cart 126. "Direction" refers to current direction of travel by the cart 126, which in this case is a direction indicated by "0" ("1" would indicate reverse direction). "Track level" refers to current track level the cart 126 is travelling on. "Traffic busy to move" is an indication whether both upper tracks and lower tracks ahead have carts obstructing passage of the cart 126, wherein "0" indicates at least one of the upper or lower track is available for passage. "Cart Collision feedback" refers to whether the cart 126 has detected an obstruction along the way in its direction of travel and stopped. When the obstruction is cleared, the cart 126 moves forward in its direction of travel. "Task

completed" refers to number of predetermined tasks completed by the cart 126. Information in table 2 may be communicated to the manufacturing apparatuses 100, the detachable process module 104 and/or the central server periodically.

Table 3

Track Level Changing	
Station ID	5
Lifter Up	1
Lifter Down	0
Lifter Position OK	1
Cart Datum Position ok	1

In table 3, Track level Changing refers to a list of parameters pertaining to traffic control and positioning of the cart 126. "Station Identifier (ID)" refers to the station ID at which the cart 126 is located. "Lifter Up" refers to, for instance, the vertical shuttle 110 of Figure 1 of the shuttle rail segment 124 moving upwards (in the case of "1" or not moving upwards in the case of "0") such that the lower track 1516 of Figure 15 connects with an upper track 1510 or 1512 of Figure 15, or an upper track of an adjacent detachable rail module 108. "Lifter Down" refers to, for instance, the vertical shuttle 110 of Figure 1 of the shuttle rail segment 124 moving downwards (in the case of "1" or not moving upwards in the case of "0") such that the upper track 1514 of Figure 15 connects with an upper track 1510 or 1512 of Figure 15, or an upper track of an adjacent detachable rail module 108. "Lifter Position OK" with a value of "1" indicates that the Lifter is in position and a value of "0" indicates that the Lifter is not in position. "Cart Datum Position ok" indicates whether the cart 126 is docked properly in position or not ("1" means docked properly and "0" means not docked properly).

Table 4

Request to Enter and Exit in Process Module	
Process Module status	1
Cart request to enter	1
Process module Entry Pass	1
Shuttle carry IN Datum Position	0
Cart Position 1-Call	1
Cart Position 2-Call	0
Cart Position 3-Call	0
Cart Position 4-Call	0
Cart Position 5-Call	0
Shuttle carry OUT Datum Position	0
Process Module Task Complete	0

In table 4, "Process Module status" indicates a status of the detachable process module 104. This status is defined according to the process of the detachable process module 104. "Cart request to enter" refers to whether the cart 126 has made a request to enter or dock with the detachable process module 104 ("1" for request made and "0" for no request made). "Process module Entry Pass" refers to whether the detachable process module 104 allows entry or docking with the cart 126 ("1" to allow and "0" to disallow). "Shuttle carry IN Datum Position" refers to whether the horizontal shuttle (e.g. 116 or 120 of Figure 15) is in position for carrying the cart to dock with the detachable process module 104 ("1" for in position and "0" for not in position). Each of "Cart Position 1-Call" to "Cart Position 5-Call" refers to which predetermined positions 1 to 5 the cart is at in a particular instance ("1" at that position and "0" when not at that position). "Shuttle carry OUT Datum Position" refers to whether the horizontal shuttle (e.g. 116 or 120 of Figure 15) is in position for carrying the cart out of the detachable process module 104 ("1" for in position and "0" for not in position). "Process Module Task Complete" indicates whether the manufacturing process of the detachable process module 104 is complete ("1" for complete and "0" for not complete).

With reference to Figures 15 to 17, each detachable process module 104 may comprise in a memory of its control module or system (e.g. 1014 of Figure 10) predefined manufacturing process information such as those in the following table 5 for controlling the horizontal shuttles 116, 118 or 120 of Figures 15 to 17 of the detachable rail module 108, the cart 126 docked with the detachable

process module 104 and the picker device 106 to carry out a designated manufacturing process. Hence, in the case of change in processes in the detachable process module 104 or change in hardware, software wise, only a table like Table 5 needs to be re-configured or re-programmed.

Table 5

Step	Process
Step 1	Shuttle Carry In Extend
Step 2	Cart moves to Position 1
Step 3	Shuttle Carry In Retract
Step 4	Picker Picks Product 1 from Cart
Step 5	Cart moves to Position 2
Step 6	Picker Places Product 1 in Index table
Step 7	Index table rotates 180 degree
Step 8	Picker Picks Product 2 from Cart
Step 9	Picker Places Product 2 in Index table
Step 10	Index table rotates 0 degree
Step 11	Picker Picks Product 1 from Index table
Step 12	Index table rotates 180 degree
Step 13	Picker Places Product 1 in Cart
Step 14	Cart moves to Position 3
Step 15	Picker Picks Product 2 from Index table
Step 16	Picker Places Product 2 in Cart
Step 17	Cart moves to Position 4
Step 18	Cart will verify the next station
Step 19	Shuttle Carry Out retract after verifying
Step 20	Cart moves to next station
Step 21	Shuttle Carry Out retract

In table 5, Step 1 "Shuttle Carry In Extend" refers to the horizontal shuttle 116 (or 120 in the case the cart is travelling in a reverse direction), extending to move a cart 126 residing on the inner track 1502 towards the detachable process module 104. Step 2 "Cart move to Position 1" refers to the cart 126 moving towards another track 1508 adjacent to horizontal shuttle 116. The track 1508 has previously moved towards the detachable process module 104. Step 3 "Shuttle Carry In Extend" refers to the horizontal shuttle 116 moving back to connect with the outer track 1508. Step 4 "Picker Picks Product 1 from Cart" refers to the picker device 106 picking a product 1 from the cart 126. Step 5 "Cart moves to Position 2" refers to the cart 126 moving to a position 2 to facilitate picking up of a product 2 later. Step 6 "Picker Places Product 1 in Index table" refers to the picker device 106 placing the product 1 in a rotary index table (e.g. 1006 in Figure 10). Step 7 "Index table rotates 180 degree" refers to the index table rotating 180 degrees. Step 8 "Picker Picks Product 2 from Cart" refers to the picker device 106 picking up another product 2 from the cart 126. Step 9 "Picker Places Product 2 in Index table" refers to the picker device 106 placing the product 2 in the index table. Step 10 "Index table rotates 0 degree" indicates that the index table does not rotate. A manufacturing process may be performed on the product 1 and the product 2 on the index table. Step 11 "Picker Picks Product 1 from Index table" refers to the picker device 106 picking up the product 1 from the index table and step 11 is carried out after the manufacturing process is conducted. Step 12 "Index table rotates 180 degree" refers to the index table rotating 180 degrees. Step 13 "Picker Places Product 1 in Cart" refers to the picker device 106 placing the processed product 1 back in the cart 126. Step 14 "Cart moves to Position 3" refers to moving the cart to a position 3 to facilitate placing of the product 2 onto the cart 126. Step 15 "Picker Picks Product 2 from Index table" refers to the picker device 106 picking up product 2 from the index table. Step 16 "Picker Places Product 2 in Cart" refers to the picker 106 placing the product 2 onto the cart 126. Step 17 "Cart moves to Position 4" refers to the cart moving to a position 4, which is on the track 1510 of the horizontal shuttle 120, for moving the cart 126 out of the detachable process module 104. Step 18 "Cart will verify the next station" refers to the cart 126 checking which is the next station (i.e. another manufacturing apparatus 100) to go. Step 19 "Shuttle

Carry Out retract after verifying" refers to the horizontal shuttle 120 moving the track 1510 carrying the cart 126 to connect with the adjacent track 1514 or 1516 after the cart confirms which is the next station to go. Step 20 "Cart moves to next station" refers to the cart 126 moving on to the next station. Step 21 "Shuttle Carry Out retract" refers to the horizontal shuttle 120 retracting back to connect the track 1512 with the adjacent tracks 1508, and 1514 or 1516.

Advantageously, the central Smart Manufacturing Control System operated by the central server (not shown in the Figures) can make use of information in the Tables above to control the cart 126 and manufacturing process. With reference to Figure 36, RFID tag readers mounted to each cart 126 may be configured for data communication via wired or wireless means with the central server. These RFID tag readers are used for communicating with RFID tags (e.g. 3302 and 3304 or 3306 and 3308 of Figure 36) placed at specific locations along the tracks (for instance, at the positions in Figure 36) for tracking location of the cart 126. Through the RFID tag reader and tags along the tracks, each cart 126 can track or monitor its location for determining direction of travel and its next movement based on the recipe (e.g. Table 1 information) downloaded to the cart 126 and information on traffic conditions (e.g. Table 2 information) available to the cart 126. In addition, the central server can also track the cart's location.

Figures 21 to 30 illustrate picture frame by picture frame sequential movement of the cart 126 between two manufacturing apparatuses 2102 and 2104 in a manufacturing line (e.g. 200 of Figure 2) and shows how the vertical shuttle 110 operates to an obstructed track ahead. The cart 126 as received a recipe to dock with a detachable process module 104 of the manufacturing apparatus 2102 for processing. Each of the two manufacturing apparatuses 2102 and 2104 is similar to the manufacturing apparatus 100 described earlier except that the respective picker devices and detachable process modules may be different to provide different manufacturing processes. Some reference numerals in previous Figures are re-used for the same components in Figures 21 to 30.

The cart 126 travels on a monorail transport system having the rail 204 formed by placing adjacent detachable rail modules 108 together. The monorail tracks 116, 118, 120, 110 and 122 allow easy connections between the manufacturing apparatuses 100 and allow smooth cart traffic on them. The tracks may be made of extruded aluminium profile with features for cart transportation and guidance.

In the present example, each detachable rail module 108 mounted to the base 102 is fitted with pneumatically operated, two horizontal shuttles 116 and 120 and one vertical shuttle 110. The pair of tracks 118 may be fixed in position and need not move, and it may optionally be configured as a horizontal shuttle like the horizontal shuttles 116 and 120. The vertical shuttle 110 has a pair of tracks 1514 and 1516. If the track 1506 of the pair of tracks 118 of a current manufacturing apparatus 100 is holding a cart that is docked with the detachable process module 104, the other track 1508 is connected with the tracks 1502 or 1504 and the tracks 1510 or 1512, the lower track 122 is still available for other carts not to be docked with the detachable process module 104 to pass by the current manufacturing apparatus 100.

In the present example, beginning with Figure 21, the cart 126 is moving along a track 2106 of a manufacturing apparatus (not shown) adjacent to the manufacturing apparatus 2102. The track 2106 is coupled to a track 1504 of a horizontal shuttle 116. The horizontal shuttle 116 comprises the inner track 1504 and the outer track 1506. The horizontal shuttle 116 is part of a rail segment of a detachable rail module 108 of the manufacturing apparatus 2102. The track 1504 is an inner track closer to a detachable process module 104 of the manufacturing apparatus 2102. The tracks 1504 and 1506 are configured to be moveable together.

Figure 22 shows that the cart 126 has arrived at the horizontal shuttle 116, specifically, the cart 126 has arrived at the track 1504. By default, the horizontal shuttle 116 should be in a configuration as shown in Figure 1, which allows any cart moving in to go onto the inner track 1504 instead of the outer track 1506. This is so that the horizontal shuttle 116 can extend and bring the cart on the inner track 1504 to dock with the detachable process module 104.

Figure 23 shows that the cart 126 is carried into the base 102 or more specifically towards the detachable process module 104 by the horizontal shuttle 116. The horizontal shuttle 116 is said to be carrying in the cart 126 by extending itself (Step 1 of Table 5). Arrival sensors (not shown; may be infrared sensors) at the position of the cart 126 in Figure 23 provide feedback to a processor 112 coupled to the base 102 of the manufacturing apparatus 2102 about the cart's 126 arrival. The processor 112 only communicates with one or more carts that is currently docked and commands the docked cart 126 to move to its loading home position. That is, the docked cart 126 carried by the horizontal shuttle 116 is commanded to move to an adjacent track 1508. The adjacent track 1508 is one of a pair of tracks 118 comprising the inner track 1508 and an outer track 1510. In the present example, the pair of tracks 118 is fixed in position in the detachable rail module 108 and is not

moveable like the horizontal shuttle 116. In the present example, the processor 112 communicates with the one or more carts via Wi-Fi once each cart is docked in position in the detachable process module 104. Once docked, the docked cart's movement is controlled by the detachable process module 104. A processor or controller of the detachable process module 104 can command the docked cart to move a required distance in each step required in the designated manufacturing process programmed to be performed by the detachable process module 104.

After the command to move to the loading home position (also called position 1) is issued (Step 2 of Table 5), with reference to Figure 24, a cart stepper motor (not shown) residing in the cart 126 is triggered to move in forward direction towards the track 1508 and to accurately position the cart 126 at the loading home position. Thereafter, home position sensors (not shown) at the loading home position confirms the cart's 126 arrival. The horizontal shuttle 116 may then retract to its original configuration shown in Figure 21 (Step 3 of Table 5). However, in the present example, the horizontal shuttle 116 is not shown to retract. Next, the processor 112 controls a picker device 106 of the manufacturing apparatus 2102 to pick a product or products from a jig top 1906 of the cart 126 at position 1 (Step 4 of Table 5) and transfer the product or products to a jig 1010 on an index table 1006 of the detachable process module 104 (Step 6 of Table 5). Simultaneously, the processor 112 controls the cart 126 to move to a second position (position 2) based on the product type and recipe of the cart 126 (Step 5 of Table 5). Depending on the predetermined process information, steps such as Steps 7 to 16 of Table 5 may be carried out until all products on the cart 126 are unloaded for processing and, depending on the process, the product or products may be loaded back on the cart 126. After loading of the cart 126 is completed, a second cart (not shown) may be allowed to move in to track 1504 like what cart 126 did and thereafter dock in position 1 through movement of the horizontal shuttle 116 for processing at the detachable process module 104.

With reference to Figures 24 and 25, after the cart 126 that has completed the processing at the detachable process module 104, the processor 112 commands the cart 126 to move to an adjacent track 1510 of a horizontal shuttle 120, which has been extended towards the detachable process module 104 for the cart 126 to move onto the track 1510. The horizontal shuttle 120 comprises the inner track 1510 and an outer track 1512. The horizontal shuttle 120 is part of a rail segment of the detachable rail module 108 of the manufacturing apparatus 2102. When the cart 126 is on the track 1510, the cart 126 verifies the next station (i.e. which manufacturing apparatus in the manufacturing line) to go to by checking a recipe table such as table 1 stored in a memory of the cart 126 (Step 18 of Table 5).

The horizontal shuttle 120 retracts as shown in Figure 26 after the cart 126 verified the next station to go to (Step 19 of Table 5). After the horizontal shuttle 120 retracts, the track 1510 carrying the cart 126 connects with an adjacent track 1516 of a vertical shuttle 110. The vertical shuttle 110 comprises an upper track 1514 and the lower track 1516. The vertical shuttle 110 acts as a traffic junction to move the cart 126 from an upper level track to a lower level track and vice versa depending on whether a track ahead in the upper level or the lower level is obstructed by another cart. If the tracks on both levels are obstructed, the cart 126 will wait for one of the obstructed tracks to clear up before moving forward. The vertical shuttle 110 may always be in a default position of extending the lower track 1516 to connect with upper tracks such as the track 1510 and the upper track 1514 is disconnected from any adjacent track. This is so that the vertical shuttle 110 may immediately retract the cart 126 that has moved onto the lower track 1516 to travel on a lower level track 2622 of an adjacent detachable rail module 2608.

Figure 27 shows the cart 126 moving onto the lower track 1516 of the vertical shuttle 110 to get to the next station (Step 20 of Table 5). At a later stage not shown in Figures 21 to 30, the horizontal shuttle 120 will retract to its original default configuration as shown in Figure 25, where the inner track 1510 is moved towards the detachable process module 104 (Step 21 of Table 5).

With reference to Figure 28, according to the recipe stored in the memory of the cart 126, the cart 126 does not have to dock at the manufacturing apparatus 2104. Furthermore, as there are no obstructions in upper level tracks 2802 ahead in the direction of travel of the cart 126, the vertical shuttle 110 does not have to retract to move the cart 126 to the lower level track 2622 of the detachable rail module 2608. Hence, the cart 126 is shown to travel smoothly on the upper level tracks 2802.

Figure 29 shows that the cart 126 has reached a lower track 2916 of a vertical shuttle 2910 of the detachable rail module 2608 of the manufacturing apparatus 2104. The vertical shuttle 2910 has the same design as the vertical shuttle 110 and comprises an upper track 2914 and the lower track 2916. At the vertical shuttle 2910, it is detected that there is a cart in an upper level track (not shown) of another manufacturing apparatus (not shown) ahead of the cart 126 in the direction of travel of the cart 126. Furthermore, it is detected that there is no obstruction in a lower level track (not shown) of

the manufacturing apparatus (not shown) ahead of the cart 126. Hence, the vertical shuttle 2910 retracts to move downwards.

Figure 30 shows that the vertical shuttle 2910 has retracted and moved downwards so that the lower level track 2916 connects with the unobstructed lower level track (not shown) of the manufacturing apparatus (not shown) ahead of the cart 126 to allow the cart 126 to move forward.

Figure 31 illustrates an advantage of a manufacturing line 3100 made up of a plurality of the manufacturing apparatus 100 as described earlier. A detachable process module 104 is taken out of a manufacturing apparatus 100 in the center of the manufacturing line 3100 for maintenance and/or troubleshooting but a rail 204 formed by a plurality of connected detachable rail modules 3102, 108, and 3104 still operates as normal. This is possible due to the traffic control capabilities of the vertical shuttles 3106, 110 and 3108 of the plurality of manufacturing apparatuses in the manufacturing line 3100. At the workshop, the detachable process module 104 can also advantageously be docked to the manufacturing base 102 of Figure 3 to facilitate repair and/or maintenance.

Figure 35 shows another example of a manufacturing line 3500 made up of a plurality of the manufacturing apparatus 100 as described earlier. A detachable process module 104 (not shown as it is covered up by panels of a manufacturing apparatus 3502) is taken out of a manufacturing apparatus 100 in the center of the manufacturing line 3500 for maintenance and/or troubleshooting by installing the detachable process module 104 into the manufacturing apparatus 3502, which operates as a centralised maintenance module.

Furthermore, unlike conventional manufacturing line design, a manufacturing line formed by a plurality of the manufacturing apparatus 100 adopts a "Farming" concept that provides flexibility and space saving layout. Each of the plurality of manufacturing apparatus 100 is like an individual module or cell. The manufacturing line of the present disclosure eliminates the need to follow a rigid manufacturing line conventional layout where there is no flexibility to add on an additional process module should the need arises to increase manufacturing capacity. Rigid manufacturing line conventional layout design comprises custom made machines that are usually permanently fixed into position and comprises fixed components made only for predetermined manufacturing processes.

In contrast, in the case of the manufacturing line 200 of Figure 2, 3100 of Figure 31, or 3300 of Figure 33 described earlier, for example, if a product has to undergo processes 1, 2 and 3. The detachable process modules 104 responsible for the processes 1, 2 and 3 of each manufacturing apparatuses 100 in the manufacturing line 200 or 3300 need not be positioned in sequence. This is possible due to features such as the smart cart 126 described with reference to Figures 18 to 20 and tables 1 to 4, the docking features using horizontal shuttles 116 and 120 as described earlier, traffic control features of the vertical shuttle 110 as described earlier etc. A new manufacturing apparatus 100 can be added in series after an adjacent manufacturing apparatus 100 in the manufacturing line 200 of Figure 2, 3100 or 3300 if there is a need to expand the capacity of a manufacturing process.

Unlike a conventional automated manufacturing line, the manufacturing line of the present disclosure needs not be shut down for maintenance or when one of the manufacturing apparatuses is faulty. An offline manufacturing base (for example 3502 of Figure 35) (without the detachable process module or detachable rail module) of the manufacturing apparatus can be used for periodic maintenance and/or diagnostic purposes to reduce unplanned line downtime. This is possible as all detachable process modules are configured to be interchangeably connected to any manufacturing base.

With reference to Figure 34, it should be appreciated that the manufacturing apparatus 100 of Figure 1 can also be deployed in a manufacturing line 3400 with a layout similar to a "traditional manufacturing line" if it is preferred. Figure 34 illustrates a perspective view 3404 showing a plurality of manufacturing apparatus 100 and a top view 3402 showing the plurality of manufacturing apparatus 100. Several rail segments 3406 of odd lengths and shapes are provided to join up with the detachable rail modules 108 of the manufacturing apparatuses 100 to form a rail of the manufacturing line 3400. However, different from the traditional manufacturing line, each manufacturing apparatus 100 can be changed and reconfigured easily to handle different products or different manufacturing processes. Such "traditional manufacturing line" layout is less preferred compared to the manufacturing line layout shown in, for example, Figures 2, 31 and 33, as it takes up more space.

Figure 32 is a flowchart indicating an operation process of the manufacturing apparatus 100 as described with reference to earlier figures in an example manufacturing line comprising a plurality of the manufacturing apparatus 100. Reference is made to reference numerals of components previously described in earlier figures.

In a step 3202, an empty cart is docked in a manufacturing apparatus 100 responsible for loading a product or products onto the cart through a picker device (e.g. 106 of earlier Figures) mounted to manufacturing apparatus 100.

A check is conducted at a step 3204 to check product presence in the cart and whether the product type matches with what the jig top of the cart is configured to carry. Such check may be conducted by inspection/monitoring equipment (may include, for example, RFID tag readers and tags, cameras, infrared sensors, laser sensors etc.) mounted to the manufacturing apparatus 100. It is noted that a cart with one or more product jigs for holding products need not be fully loaded with products in all locations of the one or more product jigs. "Product presence" check refers to a check on whether a product or products are loaded or present in each product jig. In one example, an electronic tag, which may be an RFID tag, may be mounted on a jig plate of a cart for holding products. This RFID tag may be read by an RFID tag reader mounted to the manufacturing base (e.g. 102 of earlier Figures) to confirm the validity of the product residing on the jig based on the predetermined manufacturing recipe (i.e. check whether the product is of the correct type for the designated manufacturing process).

If the product type does not match and no product is present, an alarm is triggered to inform an operator to check the cart at a step 3222.

If the product type matches and the product or products are present, a central server controlling all the manufacturing apparatus 100 in the manufacturing line will upload a predetermined recipe 3230 (e.g. Table 1) to the cart and the cart will update one of its cart status table 3324 stored in its memory (e.g. Table 2) based on the recipe.

Based on the recipe and in first in first out (FIFO) manner, each cart in the example manufacturing line travels to the respective manufacturing apparatus for processing at a step 3208. For example, in a first step, a cart is instructed to go to a station (manufacturing apparatus) with identifier (ID) 2 mounted with a detachable process module with ID of 10, to travel on a track level 2 (which could be upper or lower level tracks) and in a cart direction defined as 0. Depending on traffic conditions, the cart may be required to change track level as it is travelling in the rail of the manufacturing line. In this case, a track level changing table 3226 (e.g. Table 3) stored in the memory of the cart may be updated for traffic control and instruction purposes.

In a step 3210, before the cart moves off to the destination station with ID 2, the cart verifies track traffic conditions updated in table information 3228 (e.g. Table 4) for requesting to enter to dock or to exit a detachable process module. After verification, the cart moves to its destination station, which in this example is the station with ID 2. If the traffic conditions verified are not satisfied for the cart to move off, the cart waits and takes no action until the traffic conditions are fine for it to move off. The table information 3228 is continuously updated by the central server. The table information 3228 provides latest status of traffic conditions on each track of each manufacturing apparatus 100. The cart may take an alternative route to the destination station based on the updates to the table information 3228.

In a step 3212, the cart reaches the destination station with ID 2 and requests to dock in the detachable process module of the station. If there are no existing carts being processed by the detachable process module, the detachable process module accepts the request and the cart is moved towards the detachable process module via a horizontal shuttle (for carrying the cart in). Acceptance by the detachable process module is communicated via, for instance, the cart status table 4.

In a step 3214, the detachable process module performs processes based on a process recipe table (e.g. Table 5) stored in a memory of a processor controlling processes of the detachable process module.

After the detachable process module finishes the processes in the process recipe table, a check is done to see whether all tasks (steps) in the recipe table 3230 of the cart are completed at a step 3216.

If not all tasks are completed, the cart goes back to step 3208. That is, the cart moves off to the next station indicated in the recipe. If all tasks are completed, the cart moves to an area for product loading/unloading, which is step 3202.

Examples of the present disclosure may have the following features.

A manufacturing apparatus (e.g. 100 in Figure 1) for handling a designated process in manufacturing, the manufacturing apparatus comprising: a detachable process module (e.g. 108 in Figure 1) to handle the designated process; and a detachable rail module comprising a plurality of rail segments (e.g. 130, 132, and 134 in Figure 1), the detachable rail module being attachable to a corresponding detachable rail module of an adjacent manufacturing apparatus to form a rail (e.g. 204 in Figure 2), the rail being configured for one or more carts (e.g. 126 in Figure 1) to travel thereon for transporting items between the manufacturing apparatus and the adjacent manufacturing apparatus, wherein a processor (e.g. 112 in Figure 1) for executing one or more applications for controlling devices is connected to the manufacturing apparatus or the detachable process module, wherein a

first rail segment of the plurality of rail segments comprises a first track and a second track configurable to connect with a third track and a fourth track respectively of a second rail segment, wherein each of the tracks is for the one or more carts to travel on, and the processor is configured to control the first track to move and connect with the fourth track of the second rail segment.

When the first track is moved and connected with the fourth track, one or more carts on the first track may be moved to a location where the one or more carts are docked in the manufacturing apparatus for carrying out the designated process.

The first track and the second track may be mounted at a fixed distance from each other and may be moveable together when the first track is moved to connect with the fourth track.

The processor may be configured for updating that the one or more carts is docked in the location in the manufacturing apparatus in a table stored in a memory of a server, wherein the table is accessible by any device requiring information on current location of the one or more carts that is docked in the location in the manufacturing apparatus.

The second rail segment may be a rail segment of the adjacent manufacturing apparatus.

When the first track is connected to the third track, the first track has one or more carts thereon, the third track has one or more carts thereon obstructing the one or more carts on the first track to move to the third track, and the fourth track has no cart thereon, the processor may control the first track to connect with the fourth track so that the one or more carts on the first track can travel on the fourth track.

Each cart of the one or more carts may comprise a processor (e.g. 1902 in Figure 19) configured for communicating with the processor attachable to the manufacturing apparatus or the detachable process module for adjusting movement of the one or more carts so as to position the respective cart precisely for carrying out the designated process.

The detachable process module may be configured for slotting into a designated space in the manufacturing apparatus and the manufacturing apparatus comprises a sliding surface (e.g. 608 in Figure 6) configured for receiving the detachable process module and for facilitating the slotting of the detachable process module into the designated space in the manufacturing apparatus.

The detachable process module may comprise one or more locating pins (e.g. 610 and 612 in Figure 6) for aligning the detachable process module for slotting into the designated space in the manufacturing apparatus.

The sliding surface may comprise a plurality of rollers (e.g. 604 in Figure 6) configured to enable sliding of the detachable process module over the sliding surface upon activation of the plurality of rollers and to disable sliding of the detachable process module over the plurality of rollers upon deactivation of the plurality of rollers.

The manufacturing apparatus may comprise a lock (e.g. 602 in Figure 6) for locking the detachable process module in position in the manufacturing apparatus.

The manufacturing apparatus may comprise a first automatic tool changer connector (e.g. 606 in Figure 6) and the detachable process module comprises a second automatic tool changer connector (e.g. 802 in Figure 8) for connecting to the first automatic tool change connector, wherein each of the first automatic tool changer and the second automatic tool changer comprises one or more connections for enabling use of electrical, pneumatic and/or vacuum devices attached to the detachable process module in the designated process.

The first automatic tool changer and the second automatic tool changer may be connected once the detachable process module is slotted into the manufacturing apparatus and the manufacturing apparatus requires no further connection for enabling use of electrical, pneumatic and/or vacuum devices attached to the detachable process module in the designated process.

The manufacturing apparatus or the detachable process module may be configured for mounting a picker device (e.g. 106 in Figure 1) for picking or placing items on the one or more carts and the picker device comprises a clip-on mounting for attaching one or more application specific end effector through a clipping action without requiring further fastening.

Each of the one or more carts may comprise a processor (e.g. 1902 in Figure 19) configured to receive wirelessly from a server (e.g. the central server described previously) information on one or more manufacturing apparatus situated along the rail to dock at in sequence.

Each of the one or more carts may comprise a chargeable power supply.

The chargeable power supply may be charged when the respective cart is docked at a manufacturing apparatus situated along the rail.

Each of the one or more carts may comprise an electronic tag reader (e.g. the electronic tag reader residing in 1910 of Figure 19) for reading one or more electronic tags (e.g. 3602, 3604, 3606 and 3608 of Figure 36) tagged along the rail (e.g. 204 of Figure 2, and 3614 and 3616 of Figure 36) for tracking location of the one or more carts.

The manufacturing apparatus may comprise one or more electronic tag readers (may be located in the detachable process module) for wirelessly reading one or more electronic tags tagged to a product container (e.g. jig 1906 in Figure 19) in each cart of the one or more carts for checking product type carried by the respective cart (e.g. step 3204 in Figure 32).

One of the one or more carts (e.g. 2004 and 2006 of Figure 20A, and 126 of Figures 18 to 20) may comprise a movable end block (e.g. 2008 of Figure 20A) with rollers (e.g. 1904 in Figures 19 to 20A) for moving the cart on the rail, and the movable end block is pivotable about the cart to facilitate the cart to manoeuvre a corner on the rail.

A manufacturing line (e.g. 200 in Figure 2) comprising a plurality of the manufacturing apparatus placed adjacent to one another, wherein the plurality of the manufacturing apparatus is placed adjacent to one another in series in at least two rows, wherein a rail segment is attachable to the detachable rail module of a manufacturing apparatus at an end of one row and is attachable to the detachable rail module of another manufacturing apparatus at an end of another row to enable the one or more carts to travel to any manufacturing apparatus residing in the at least two rows.

Furthermore, the manufacturing apparatus 100 as described previously utilizes a smart manufacturing control system comprising one or more of the following features.

- Personal Computer based program interfaces.
- Multiple Programmable Logic Controllers (i.e. the processor 112) with each mounted at each manufacturing base 102.
- Cart control interfaces for horizontal integration.
- External server systems for vertical integration.
- Ability to provide dynamic cart to base interface based on cart location.
- Ability to provide real time location information to carts based on RFID reading locations throughout the manufacturing line.
- Provides seamless control of autonomous cart traffic in the entire manufacturing line.
- Use of status tables (e.g. Tables 1 to 5) to provide status information to all modules, manufacturing bases and carts.
- Enables one to one communication between cart and a manufacturing base when the cart is in a vicinity or docked with the base.
- Dynamic program interface allowing multiple product handling without any re-programming during a product change.
- Provides Operator Interface to allow setting of recipe and manufacturing apparatus configurations. This feature provides scalability during the addition of manufacturing apparatuses and carts without any re-programming of a Programmable Logic Controller or a Personal Computer.

Many modifications and other examples can be made to the Manufacturing Apparatus and Manufacturing Line comprising the Manufacturing Apparatus described herein by those skilled in the art having the understanding of the above described disclosure together with the drawings. Therefore, it is to be understood that the Manufacturing Apparatus and Manufacturing Line comprising the Manufacturing Apparatus is not to be limited to the above description contained herein only, and that possible modifications are to be included in the claims.

Claims

1. A manufacturing apparatus for handling a designated process in manufacturing, the manufacturing apparatus comprising:
 - a detachable process module to handle the designated process; and
 - a detachable rail module comprising a plurality of rail segments, the detachable rail module being attachable to a corresponding detachable rail module of an adjacent manufacturing apparatus to form a rail, the rail being configured for one or more carts to travel thereon for transporting items between the manufacturing apparatus and the adjacent manufacturing apparatus,
 wherein a processor for executing one or more applications for controlling devices is connected to the manufacturing apparatus or the detachable process module,
 wherein a first rail segment of the plurality of rail segments comprises a first track and a second track configurable to connect with a third track and a fourth track respectively of a second rail segment to enable the one or more carts to travel between the first track and the third track or between the second track and the fourth track, and the processor is configured to control the first track to disconnect from the third track and connect with the fourth track of the second rail segment to enable the one or more carts to travel between the first track and the fourth track.
2. The manufacturing apparatus as claimed in claim 1, wherein the first track and the second track are mounted at a fixed distance from each other and are moveable together when the first track is moved to connect with the fourth track, wherein when the first track is moved and connected with the fourth track, one or more carts on the second track are moved to a location where the one or more carts are docked in the manufacturing apparatus for carrying out the designated process.
3. The manufacturing apparatus as claimed in any one of the preceding claims, wherein the processor is configured for
 - updating that the one or more carts is docked in a location in the manufacturing apparatus in a table stored in a memory of a server,
 - wherein the table is accessible by any device requiring information on current location of the one or more carts that is docked in the location in the manufacturing apparatus.
4. The manufacturing apparatus as claimed in any one of the preceding claims, wherein the second rail segment is a rail segment of the adjacent manufacturing apparatus.
5. The manufacturing apparatus as claimed in any one of the preceding claims, wherein when the first track is connected to the third track, the first track has one or more carts thereon, the third track has one or more carts thereon obstructing the one or more carts on the first track to move to the third track, and the fourth track has no cart thereon, the processor controls the first track to connect with the fourth track so that the one or more carts on the first track can travel on the fourth track.
6. The manufacturing apparatus as claimed in any one of the preceding claims, wherein each cart of the one or more carts is configured for communicating with the processor attachable to the manufacturing apparatus or the detachable process module for adjusting movement of the one or more carts so as to position the respective cart precisely for carrying out the designated process.
7. The manufacturing apparatus as claimed in any one of the preceding claims, wherein the detachable process module is configured for slotting into a designated space in the manufacturing apparatus and the manufacturing apparatus comprises a sliding surface configured for receiving the detachable process module and for facilitating the slotting of the detachable process module into the designated space in the manufacturing apparatus.
8. The manufacturing apparatus as claimed in claim 7, wherein the sliding surface comprises a plurality of rollers configured to enable sliding of the detachable process module over the sliding surface upon activation of the plurality of rollers and to disable sliding of the detachable process module over the plurality of rollers upon deactivation of the plurality of rollers.
9. The manufacturing apparatus as claimed in any one of the preceding claims, wherein the detachable process module comprises one or more locating pins for aligning the detachable process module for slotting into a designated space in the manufacturing apparatus.

10. The manufacturing apparatus as claimed in any one of the preceding claims, wherein the manufacturing apparatus comprises a lock for locking the detachable process module in position in the manufacturing apparatus.

11. The manufacturing apparatus as claimed in any one of the preceding claims, wherein the manufacturing apparatus comprises a first automatic tool changer connector and the detachable process module comprises a second automatic tool changer connector for connecting to the first automatic tool change connector, wherein each of the first automatic tool changer and the second automatic tool changer comprises one or more connections for enabling use of electrical, pneumatic and/or vacuum devices attached to the detachable process module in the designated process.

12. The manufacturing apparatus as claimed in claim 11, wherein the first automatic tool changer and the second automatic tool changer are connected once the detachable process module is slotted into the manufacturing apparatus and the manufacturing apparatus requires no further connection for enabling use of electrical, pneumatic and/or vacuum devices attached to the detachable process module in the designated process.

13. The manufacturing apparatus as claimed in any one of the preceding claims, wherein the manufacturing apparatus or the detachable process module is configured for mounting a picker device for picking or placing items on the one or more carts and the picker device comprises a clip-on mounting for attaching one or more application specific end effector through a clipping action without requiring further fastening.

14. The manufacturing apparatus as claimed in any one of the preceding claims, wherein each of the one or more carts is configured to receive wirelessly from a server information on one or more manufacturing apparatus situated along the rail to dock at in sequence.

15. The manufacturing apparatus as claimed in any one of the preceding claims, wherein each of the one or more carts comprises a chargeable power supply.

16. The manufacturing apparatus as claimed in claim 15, wherein the chargeable power supply is charged when the respective cart is docked at a manufacturing apparatus situated along the rail.

17. The manufacturing apparatus as claimed in any one of the preceding claims, wherein each of the one or more carts comprises an electronic tag reader for reading one or more electronic tags tagged along the rail for tracking location of the one or more carts.

18. The manufacturing apparatus as claimed in any one of the preceding claims, wherein the manufacturing apparatus comprises one or more electronic tag readers for wirelessly reading one or more electronic tags tagged to a product container in each cart of the one or more carts for checking product type carried by the respective cart.

19. The manufacturing apparatus as claimed in any one of the preceding claims, wherein one of the one or more carts comprises a movable end block with rollers for moving the cart on the rail, and the movable end block is pivotable about the cart to facilitate the cart to manoeuvre a corner on the rail.

20. The manufacturing apparatus as claimed in any one of the preceding claims, wherein more than one of the rail are formed when the detachable rail module is attached to a corresponding detachable rail module of an adjacent manufacturing apparatus, and one of the rails being an upper level rail and another one of the rails being a lower level rail.

21. The manufacturing apparatus as claimed in claim 20, wherein a memory table residing in a memory of each cart is used to determine movement of each cart between a track in the upper level rail and a track in the lower level rail for cart traffic control.

22. The manufacturing apparatus as claimed in any one of the preceding claims, wherein a memory table downloaded to each cart is used to determine which manufacturing apparatus each cart

goes to for processing, which track the cart travels on, and which direction of travel of the cart on the track.

23. The manufacturing apparatus as claimed in any one of the preceding claims, wherein a memory table residing in a memory of each cart is used to determine cart location and direction of travel of the cart, and said memory table includes an indicator of detection of an obstruction along the direction of travel of the cart causing the cart to stop travelling.

24. The manufacturing apparatus as claimed in any one of the preceding claims, wherein a memory table residing in a memory of each cart is used to request docking at each detachable process module for processing, or request exit from each detachable process module, wherein each docking or exiting cart is shuttled in or out together with a track on which the cart resides according to the docking or exiting request.

25. The manufacturing apparatus as claimed in any one of the preceding claims, wherein the detachable process module comprises a memory table for controlling the handling of the designated process, wherein the memory table is re-configurable or re-programmable to change the designated process being handled.

26. A manufacturing line comprising a plurality of the manufacturing apparatus as claimed in any one of the preceding claims placed adjacent to one another, wherein the plurality of the manufacturing apparatus is placed adjacent to one another in series in at least two rows, wherein an inter-row rail segment is attachable to the detachable rail module of a manufacturing apparatus at an end of one row and is attachable to the detachable rail module of another manufacturing apparatus at an end of another row to enable the one or more carts to travel to any manufacturing apparatus residing in the at least two rows.

27. The manufacturing line as claimed in claim 26, wherein the plurality of manufacturing apparatuses handles manufacturing processes that have to be handled sequentially but the plurality of manufacturing apparatuses is physically arranged in a non-sequential manner in the manufacturing line.