Storage and Retrieval Machine with Elevated Track Opens New Applications in Warehouse Technology and Material Supply

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Abstract An innovative Storage and Retrieval (S/R-) machine can drive around obstacles like conveyor lines or escape routes in the upper and lower part of a warehouses shelf. This innovative S/R machine can also drive around a second S/R machine in its warehouses aisle, so that one or two of these machines can operate independently in one aisle. These improvements open new applications in warehouse planning, management and production:

- The dimensions of the warehouse (height, length width) can be easier adjusted to the existing building development and building regulations.
- The handling capacity can be upgraded aisle by aisle, which allows to scale the handling capacity to the increasing demand.
- The warehouse can be integrated in the manufacturing or assembly area and integrates in house transport into storage.

These improvements enhance storage capacity, save space and expand handling capacity, thus saving investment and cost compared to conventional warehouse technology.

Warehousing and the Design Concept of the Innovative Storage and Retrieval Machine

The best warehouse is no warehouse. This rule of lean management and lean process design is almost impossible to realize in real life material supply. Warehouses are still needed

- to level out batch supply and continuous consumption,
- to secure supply,

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- to guarantee supply,
- to enable economies of scale in centralized manufacturing and decentralized consumption by worldwide customers.

But warehouses need investment in warehouse technology, space and inventory and they generate operation cost for handling and warehouse administration. In standard warehouses like a storage for palletized goods the palettes are handled, stored and retrieved by

- high bay fork trucks with driver or by
- automated Storage and Retrieval Machines (S/R-Machines) that are guided by tracks on the floor and on top of the shelf.

The S/R machines are faster and automated but they are less flexible in use than fork trucks. In almost any case an S/R machine is configured to a specific warehouse location.

The number of S/R-machines determine the handling capacity of the warehouse system, measured in double cycles per hour (= numbers of storage and retrieval operations per hour). As only one S/R machine can be operated in an aisle of the warehouse, the desired handling capacity determines the minimum number of aisles and in consequence the width of the warehouses layout.

In any case the warehouse is like an impermeable block that does not allow crossway traffic. Therefore, the warehouse is located in a separate building or at the border area of a production building. This is to avoid fixed points and obstacles in future changes of the layout.

An innovative S/R machine changes these rules and additionally allows a better use of space in a warehouse facility: The innovative S/R-machine is guided by an upper and a lower track, which is fixed on the storage rack (Fig. 1). A telescopic mast is used to access the bottom and top areas of the shelf. A conventional load handling device on the telescopic mast stores and retrieves the load units from the shelves on both sides of the aisle.

Improved Space Utilization

The telescopic mast of the innovative S/R machine allows driving around obstacles in the aisle or in the shelves (Fig. 2). Such obstacles can be conveyor lines on the floor or on higher level, they can be traverses of the building, pipe lines for ventilation or power supply. In conventional warehouses these high obstacles would limit the accessible height of the S/R machine on the full length of the aisle, but not only at the point of installation like for the innovative S/R machine. This function improves the space utilization of the warehouse building. Compared to conventional warehouses the alternative warehouse saves investment in floor space and building volume.

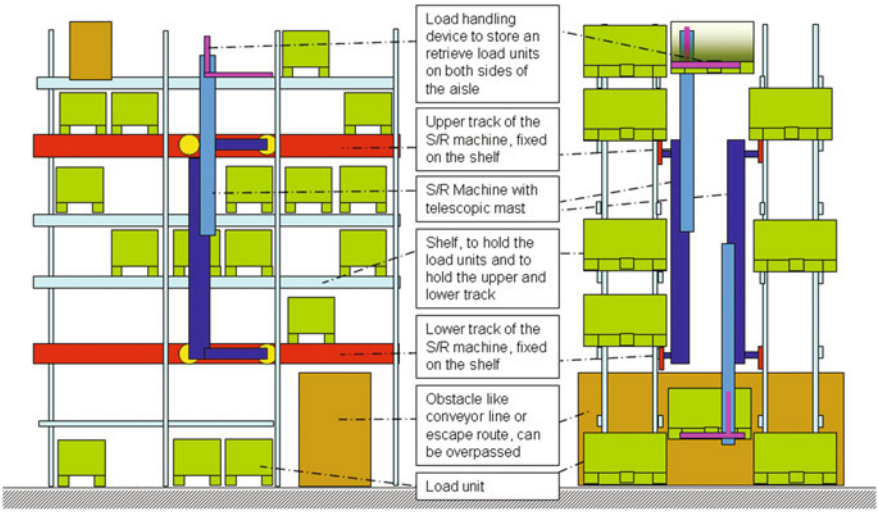

Fig. 1 Sketch of the innovative S/R machine with elevated tracks

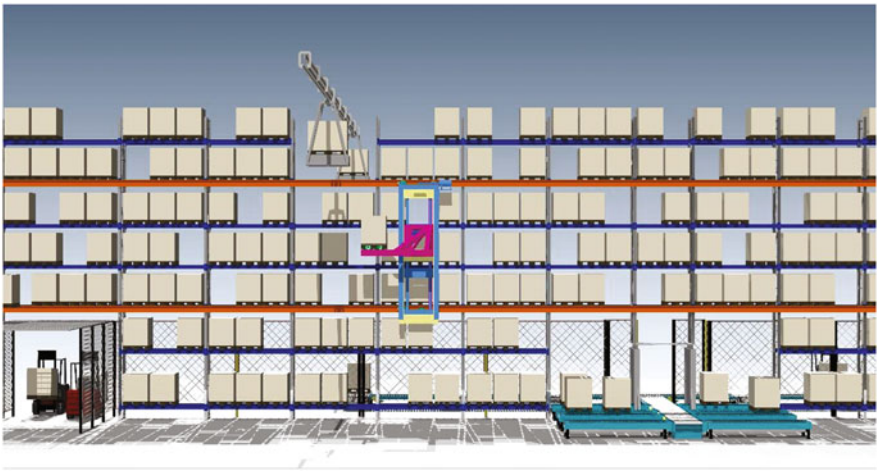

Fig. 2 The innovative S/R machine (center) can drive around obstacles in a warehouses shelf like an aisle for escape route and material transport (bottom left), an overhead conveyor (top center) or the cross conveyor to connect the marshalling area with the storage area (bottom right)

Benefits of the Design Concept in Warehousing

Flexibility in Warehouse Design and Warehouse Upgrade

The obstacle to drive around can also be a dynamic obstacle, in the aisle of a warehouse: Another S/R machine can be passed if one S/R machine has lowered its

load handling device, while the other S/R machine in the same aisle lifts its load handling device (see Fig. 1). Two S/R machines in one aisle run on tracks fixed on the racks on both sides of the aisle, one on the left shelf, the other on the right shelf. As the two S/R machines can operate in one aisle independently, except when the pass, the handling capacity in one aisle can be almost doubled.

In warehouse planning, the room (length × width × height) determines together with the width of the aisle the storage capacity measured in number of bin locations. The width of the aisle is wider for fork trucks and smaller for S/R machines. The number of fork trucks or S/R machines determines the handling capacity measured in double cycles per hour (= number of storage and retrieval operations per hour). As in conventional warehouses only one or less S/R machines or fork trucks can operate in one aisle, the number of aisles determines the maximum handling capacity. So in conventional warehouses handling capacity can only be enlarged by adding aisles which can conflict with the footprint of the space available.

The innovative S/R machine enlarges flexibility in warehouse planning. As S/R machines can operate independently in one aisle, the handling capacity is no longer connected with the number of aisles. Consequently, it is much easier to adjust the warehouses dimensions to the footprint of the available space. The number of aisles can be designed to the space available, no longer to the handling capacity needed. In the fictive example shown in Fig. 3, the same storage capacity and handling capacity could be attained with six aisles or three aisles, if two S/R machines can work in one aisle independently.

If an upgrade of handling capacity is needed after years of operation, the handling capacity can be even enlarged after start of operation. The additional S/R

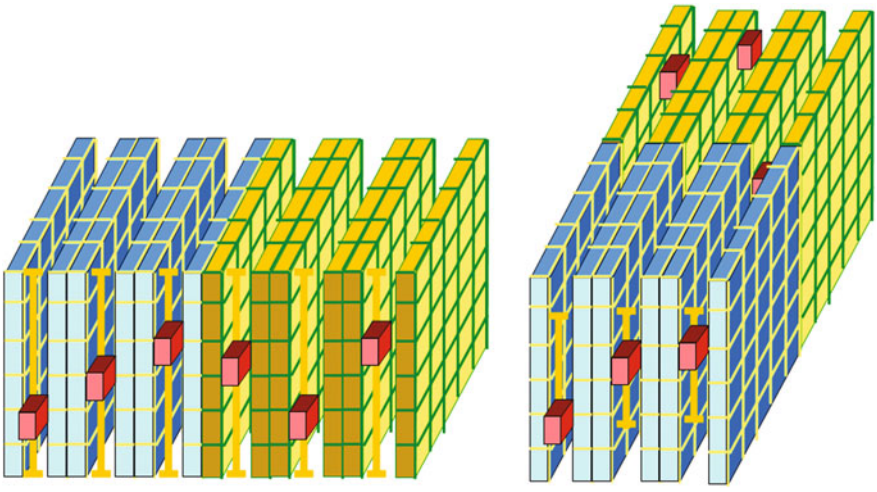

Fig. 3 Two innovative S/R machines can operate in one warehouses aisle independently, thus enhancing flexibility in warehouse

machines can be added aisle by aisle and the handling capacity can be scaled. In contrast adding handling capacity to an existing conventional warehouse means greater measures on the warehouse building.

High Handling Capacity

The function to drive around obstacles opens a further opportunity for high handling capacity, which is needed for intensive order picking (see Koether 2014) or any other high turnover rate. In a conventional warehouse the cross conveyor that connects the aisles of the warehouse to the marshalling area is installed at the front of the warehouses racks. The innovative S/R machine can jump over conveyors like the cross conveyor. So this conveyor can be placed in the middle of the racks (Fig. 4), with two effects:

1. The average distance from the cross conveyor to the shelf space is shorter, allowing shorter driving time and speeding up the S/R machine's handling operations.
2. The warehouse can be divided in two virtual blocks on the right and left side of the cross conveyor. In every aisle now up to four S/R machines can operate independently, two on each side.

Again this feature can scale the number of S/R machines operating in one aisle from one to four S/R machines and the number of S/R machine in a specific aisle can be chosen independently from other aisles.

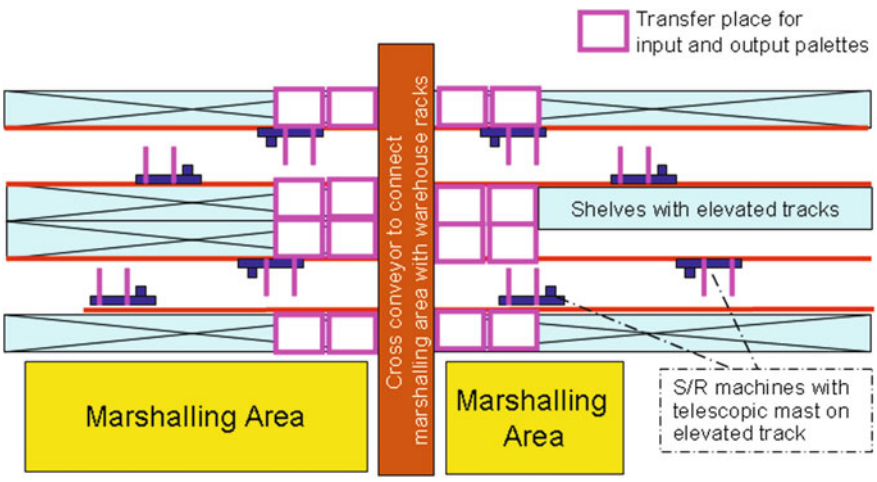

Fig. 4 With the central cross conveyor in every aisle 2 S/R machines can operate left of the conveyor and 2 S/R machines right of the conveyor independently

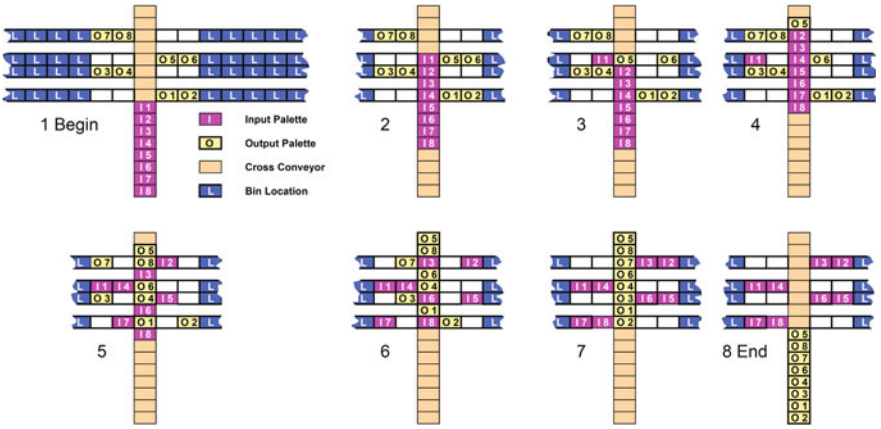

Fig. 5 Supply and collections of palettes on the central cross conveyor

The highest handling capacity is achieved by four S/R machines in one aisle, which are connected to the marshalling area by a central cross conveyor. To avoid bottlenecks in the supply of goods to store (input palettes) and the collection of stored items (output palettes) a synchronized handling process of the cross conveyor was developed (see Fig. 5).

In the marshalling area the input palettes are placed on the cross conveyor (1 Begin) and then driven halfway into the shelf area (2). Input palette I1 is pushed on the empty transfer place to the left, while simultaneously output palette O5 is loaded on the cross conveyor from the right (3). In the next step the palettes on the cross conveyor move forward and at the same time palettes I1 and O6 move one position to the left (4). In the 5th step input palettes I2, I4, I5 and I7 are pushed to the transfer places on the left and right side of the cross conveyor und the output palettes O1, O4, O6 and O8 are loaded on the cross conveyor, so that in step 5 8 palettes are moved simultaneously. The row of input and output palettes on the cross conveyor is moved by one position. At the same time output palettes O2, O3 and O7 approach the cross conveyor and input palettes I2, I5 and I7 leave the transfer places next to the cross conveyor (6). Then similar to step 5 6 palettes are loaded and unloaded simultaneously: I3, I6 and I8 are pushed from the conveyor to the respective transfer places while O2, O3 and O7 are loaded on the cross conveyor. Only output palettes are now sitting on the cross conveyor (7). They are moved in one chain to the marshalling area (8 End).

Save Investment for Floor Space and Building

The feature of multiple S/R machines operation in one aisle allows saving floor space for warehouses with high turnover rate, because the number of aisles can be

determined by the storage spaces needed, not by the handling capacity. In addition, the handling capacity of existing warehouses can be enlarged without building measures.

The aspect of floor space which is needed per aisle to achieve the handling capacity is even greater for manually operated warehouses with fork trucks. As fork trucks offer less handling capacity per device than S/R machines, even more aisles would be needed for a certain handling capacity. In addition, the aisle width for fork truck operation must be larger which consumes even more floor space and building volume. The investment for floor space and for the building can be saved. These savings allow paying off the larger investment for the innovative S/R machine compared to conventional ones or compared to fork trucks.

New Opportunities in Material Supply

Figure 6 shows an exemplary modular layout of an assembly line with warehouse in a 15 m × 15 m raster of pillars. The warehouse that guarantees a secure supply is located adjacent to the manufacturing or assembly area.

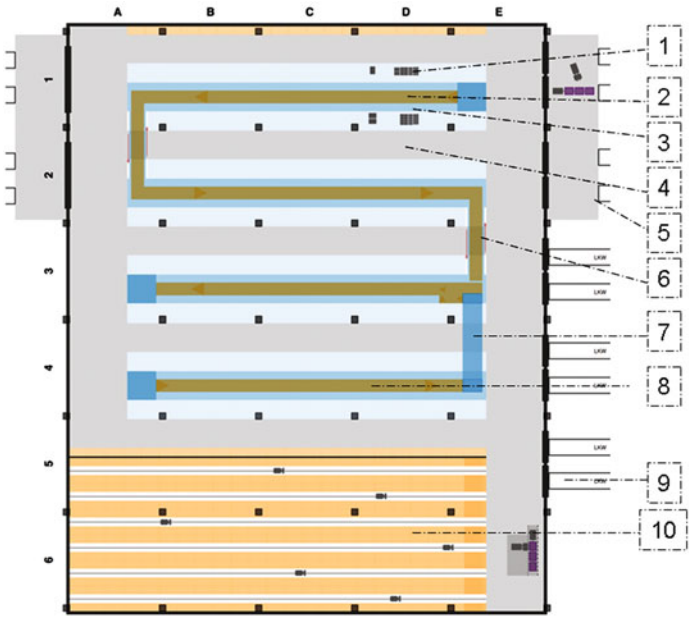

Fig. 6 Layout of assembly with adjacent warehouse (exemplary sketch). Legend: 1 Material supply zone, 2 assembly line, 3 working area 4 drive way for internal transport and for escape route, 5 loading docks, 6 floor transfer of assembly line, 7 overhead transfer of assembly line, 8 preassembly line, 9 loading docks for just in time (JIT) supply, 10 conventional warehouse for assembly material

Table 1 Process for material supply and return of empty containers

Conventional process, separate warehouse	Lean process, integrated warehouse with innovative S/R machine
Receive purchased item form outside supplier or prefabricated item from in house cost center	Receive purchased item form outside supplier or prefabricated item from in house cost center
Place item in warehouse	Place item in warehouse
Demand of manufacturing or assembly	Demand of manufacturing or assembly
Retrieve item from warehouse	Move item in the warehouse from bin position to point of consumption by innovative S/R machine
Ship item with internal transportation (fork truck or tugger train) to manufacturing or assembly	
Place item at point of consumption (machine, workplace, assembly station)	
Remove empty container and return it to staging area	Remove empty container by innovative S/R machine and place in storage bin until return to supplier
Return empty container from staging area to supplier	

A typical supply process in production is shown in the left column of Table 1.

Conventional warehouses are set apart from assembly or manufacturing area for two reasons: It is hard to move a warehouse with racks and inventory when the layout is changed. And warehouses are like blocks that cannot be penetrated crossways e.g. by escape routes that have to be clear all the time.

The innovative S/R machine can get over obstacles on the floor, it can get over escape routes. This characteristic allows using these S/R machines in manufacturing and assembly areas with people operating machines or assembling work pieces. Consequently, the shelves for warehousing and the innovative S/R machines can be located in the manufacturing or assembly area, which give two opportunities for cost saving:

1. Simplify the supply process (Table 1, compare left and right column)
2. Save space for aisles and save investment for floor space and building.

Figure 7 illustrates an exemplary sketch of an assembly's layout with integrated warehouse. The assembly line with working area and material supply zone is similar to the conventional layout (Fig. 6). So is the infrastructure with loading docks and handling area next to assembly line and warehouse area. The warehouse area which is separate from the assembly in Fig. 6 is integrated in the assembly lines in Fig. 7. Two integrated warehouse aisles with four shelves fill a space that used to be a driveway for internal transportation and for emergency exits. The emergency exists are specific escape routes (15), crossways to the shelves in the integrated layout (Fig. 7).

As the assembly of every part number is assigned to a specific station of the assembly line, it is dedicated where the part number has to be stored in the upper or lower aisle of the warehouse block. The S/R machine can retrieve the part's

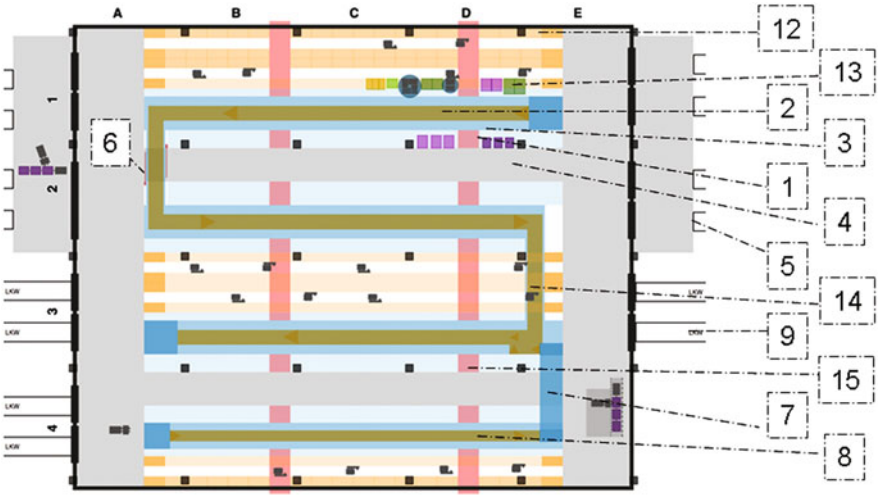

Fig. 7 Layout of assembly with integrated warehouse (exemplary sketch). Legend: 1 Material supply zone, 2 assembly line, 3 working area 4 drive way for internal transport and for escape route, 5 loading docks, 6 floor transfer of assembly line, 7 overhead transfer of assembly line, 8 preassembly line, 9 loading docks for just in time (JIT) supply, 12 integrated warehouse for assembly material, 13 material supply zone, material placed by innovative S/R machine, 14 floor transfer of assembly line over passed by innovative S/R machine, 15 escape route crossing shelves

container from shelves of either side of the aisle and relocate it to the material zone of the assembly line.

Every second driveway still exists to connect the escape routes (15) with the drive ways (4) and to enable conventional transportation for all material that is not stored in the warehouse sections with innovative S/R machine. Such parts can be packed in oversized or special containers, they can be sequenced or preassembled items or they can be parts that are delivered Just In Time (JIT) form outside or inside suppliers. So every workplace and every section of the assembly line has access to the driveway.

As two innovative S/R machines can operate independently in one aisle one machine can handle palettes, the other one small part containers. Thus it is possible to supply palletized material and small parts directly from the warehouse without intermediate handling.

The warehouse sections in the integrated layout (Fig. 7) are part of the assembly layout structure. This structure typically can be reused for modernized, upgraded and new products. To match the layout and the number of assembly stations with the planned volume the layouts in Figs. 6 and 7 are configured by modular elements of area. These modules can be copied and inserted (see Fig. 8). To enlarge the length of the assembly lines, the elements of vertical area module in column B and C can be copied, multiplied and pasted like column BCa, BCb, BCc and so on. To insert more assembly lines the elements of horizontal area module between the

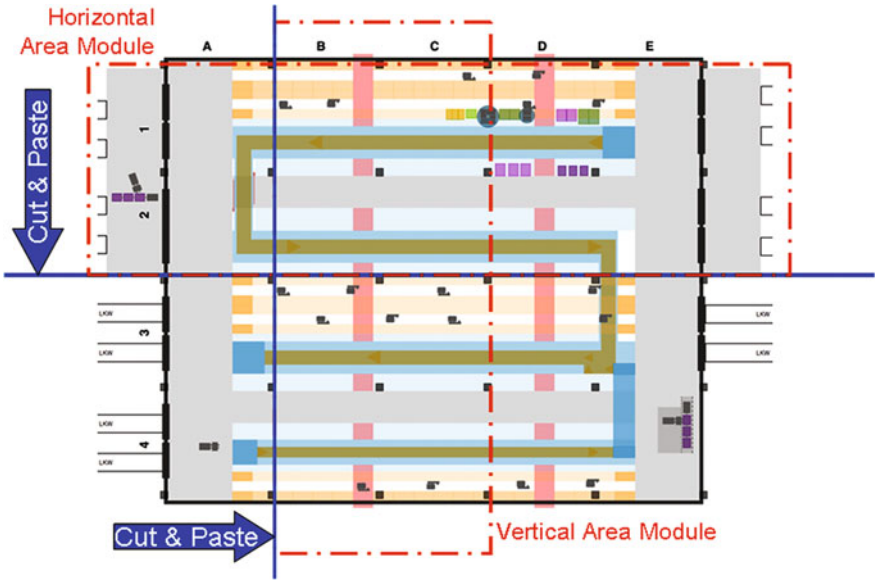

Fig. 8 Modular design of layout with integrated warehouse

pillars in row 1 and 2 can be copied. The sequence of the assembly hall naves from top to bottom would then be: 1,2, 1,2, 1,2, .. 3, 4.

A short glance at Figs. 6 and 7 already shows that the assembly line with integrated warehouse demands less floor space than the conventional layout with separated assembly and warehouse zones. Less floor space means less investment for land and for the building. Furthermore, the simplified and automated process (Table 1), saves time and handling cost.

Conclusion

The innovative S/R machine described is applied for a patent. Together with an industrial partner a detailed design and control concept will be developed in the near future.

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