An automated storage and retrieval system (ASRS or AS/RS) consists of a variety of computer-controlled methods for automatically placing and retrieving loads from specific storage locations. Automated Storage and Retrieval Systems (AS/RS) are typically used in applications where: there is a very high volume of loads being moved into and out of storage; storage density is important because of space constraints; no value adding content is present in this process; accuracy is critical because of potential expensive damages to the load.

Introduction

AS/RS systems are devices designed for automated storage and retrieval of parts and items in manufacturing, distribution, retail, wholesale and institutions. They focus on bringing "goods to the man" rather than manual walking and searching. Space savings, increased productivity/reduced labor, increased accuracy and reduced inventory levels are some of the primary benefits. Ideal for lean manufacturing, sustainability, six sigma, Kaizen, JIT and other value added methodologies and processes.

Material Handling Institute of America (MHIA), the non-profit trade association for the material handling world, and its members have broken AS/RS into two primary segments. Fixed Aisle and Carousels/Vertical Lift Modules (VLMs). Both sets of technologies provide automated storage and retrieval for parts and items, but use different technologies. Each technology has its unique set of benefits and disadvantages (like everything in the world). Fixed Aisle systems are characteristically larger systems where as Carousels & Vertical Lift Modules are used individually or grouped, but in small to medium sized applications.

Fixed Aisle AS/RS is categorized into three main types: single masted, double masted, and man-aboard. Most are supported on a track and ceiling guided at the top by guide rails or channels to ensure accurate vertical alignment, although some are suspended from the ceiling. The 'shuttles' that make up the system travel between fixed storage shelves to deposit or retrieve a requested load (ranging from a single book in a library system to a several ton pallet of goods in a warehouse system). As well as moving along the ground, the shuttles are able to telescope up to the necessary height to reach the load, and can store or retrieve loads that are several positions deep in the shelving.

Productivity, a measure of efficiency, is a constant goal of all businesses as they seek to enhance their profitability and their relative positions in the marketplace. Productivity improvement is often assisted by new technological developments. The automated factory is a direct by-product of this relationship. It involves the skillful integration of high technology with human resources, which results in dramatic productivity improvements and satisfying employment for members of the manufacturing and distribution workforces. Achieving an automated factory is an evolutionary process wherein the upgrading and improving of components continue to take place as new and more productive technology and components are developed. The equipment and the technologies found in automated factories will vary from application to application, but the common denominator will be the need to produce quality products in a cost efficient and timely manner. The resulting automated factory thereby becomes a unique blend of human effort with advanced technologies.

The automated factory requires the use of numerous key elements such as automated production machines, numerically controlled machining centres, robotics, automatic assembly machines, and the technologies of automated storage/retrieval systems (AS/RS), which include automated storage, automated transportation, automated materials identification and tracking equipment, and real time computer control of inventory. These
elements are all available and in operation today as "islands of automation." The challenge is to "harness the team" and to achieve even greater productivity through integration and elimination of redundant materials, redundant and inefficient material handling, and redundant record keeping systems. AS/RS is the key element for realization of the automated factory because it builds vital bridges between those islands of automation, providing the ability to integrate material handling and control with manufacturing and distribution. Without the application of automated material handling and control, the automated factory simply is not possible.

The place of AS/RS in the automated factory has been assured because AS/RS systems have revolutionized the material handling and material control functions in manufacturing and distribution facilities throughout the world. These systems have broad application and have been effectively adapted to enhance productivity in all areas of the business environment where materials are required to support business objectives. This notes applications of this AS/RS technology, providing an overview of the concepts and applications, which have proven to be successful in a wide range of industries. The information and illustrations have been compiled from actual operating systems as supplied by member companies of the AS/RS Product Section of The Material Handling Industry of America. These real world solutions demonstrate that the automated factory can be realized by utilizing the bridge provided by AS/RS.

To provide a method for accomplishing throughput to and from the AS/RS and the supporting transportation system, stations are provided to precisely position inbound and outbound loads for pickup and delivery by the crane.

In addition, there are three types of AS/RS devices called Vertical Lift Modules (VLMs), Horizontal Carousels and Vertical Carousels. These systems are used either as standalone units or in integrated workstations called pods. These units usually are integrated with various types of pick to light systems and use either a microprocessor controller for basic usage or inventory management software. These systems are ideal for increasing space utilization up to 85%, productivity levels by 2/3, accuracy to 99.9%+ levels and throughput up to 750 lines per hour/per operator.

**Man-aboard AS/RS**

A man-aboard AS/RS offers significant floor space savings. This is due to the fact that the storage system heights are no longer limited by the reach height of the order picker. Shelves or storage cabinets can be stacked as high as floor loading, weight capacity, throughput requirements, and/or ceiling heights will permit. Man-aboard automated storage and retrieval systems are far and away the most expensive picker-to-stock equipment alternative. Aisle-captive storage/retrieval machines reaching heights up to 40 feet cost around $125,000. Hence, there must be enough storage density and/or productivity improvement over cart and tote picking to justify the investment. Also, because vertical travel is slow compared to horizontal travel, typical picking rates in man-aboard operations range between 40 and 250 lines per person-hour. The range is large because there is a wide variety of operating schemes for man-aboard systems. Man-aboard systems are typically appropriate for slow-moving items where space is fairly expensive.

**Vertical Lift Module**
The VLM is a computer controlled automated vertical lift module, storage and retrieval system. Functionally, stock within the VLM remains stationary on front and rear tray locations. On request a movable extractor unit travels vertically between the two columns of trays and pulls the requested tray from its location and brings it to an access point. The operator then picks or replenishes stock and the tray is returned to its home.

VLM system offers variable tray sizes and loads, which could be applied in different industries, logistic, as well as office settings. The VLM systems could be customized to fully utilize the height of the facility, even through multiple floors. With the capability of multiple access openings on different floors, the VLM system is able to provide an innovative storage and retrieval solution. The rapid movement of the extractor as well as the integrated inventory management software can dramatically increase the efficiency of the picking process. Unlike large AS/RS systems, which require a complete overhaul of the warehouse or production line, the Vertical Lift Module are modularized, which can be easily integrated into the existing system, or to be rolled out in gradually over different phases. This is the first model of the same.

**Horizontal Carousels**

A horizontal carousel is a series of bins which rotate on an oval track. Every bin has shelves which are adjustable to .75” and can be configured for a myriad of standard and special applications. An operator simply inputs a bin number, part number or cell location and the carousel will rotate via the shortest path. Multiple horizontal carousels integrated with pick to light technology and inventory management software (a pod of carousels) are used for order fulfillment.

A wave of orders is sent to the pod. A group of orders are selected to create a batch. The operator simply follows the lights and pick round robin from the carousels and place items in a batch station behind them. Each carousel pre-positions and rotates when picked, so it is awaiting for the operator who picks round robin till the batch is complete. When the batch is complete, a new batch is inducted and the process repeated until the wave is complete. Horizontal carousels can save up to 75% of floorspace, increase productivity by 2/3, accuracy levels to 99.9%+ levels and throughput up to 750 lines per hour/operator.

Horizontal carousel systems generally outperform robotic systems which are very vogue right now for a fraction of the cost. Horizontal carousels are the most cost effective AS/RS system available.

**AS/RS layouts**

- **Horizontal Carousels:** Consists of a fixed number of adjacent storage columns or bays that are mechanically linked to an oval track which rotates horizontally, on an overhead or floor mounted drive mechanism. Each column is divided into a fixed number of storage locations or bins. Loads consisting of containers may be inserted and retrieved either manually or by an automatic inserter/extractor mechanism. However, rotation of the carousel, whereby a specific storage location is brought to the picking location, is almost always controlled automatically.

- **Rotary Carousels:** Consists of a fixed number of adjacent storage columns or bays that are mechanically attached to a rotary positioning stage. Each column is divided into a fixed number of storage locations or bins. Loads consisting of containers may
be inserted and retrieved either manually or by an automatic inserter/extractor mechanism. However, rotation of the carousel, whereby a specific storage location is brought to the picking location, is almost always controlled automatically.

- **Vertical Carousels:** Consists of a number of horizontal shelves, trays or bins that are mechanically linked to an oval track which rotates vertically. Because storage is vertical, such systems are popular when conserving floor space. Although automatic insertion and extraction of individual items or loads is possible, it is not as common as it is with horizontal carousel applications.

- **Vertical Lift Modules (VLM):** A storage system that consists of two parallel columns each of which is divided into fixed shelf locations that can hold a single storage module or container. The shelving locations are single deep. A container is inserted, extracted and transported between storage levels and picking locations via an elevator-like device with an automatic shuttle that travels up and down within the space between the storage columns. The storage container is presented to a fixed P/D station by the elevator mechanism.

- **Fixed-Aisle (F/A) Storage Retrieval Systems:** Consists of one or more long, narrow aisles framed on both sides by a steel or extruded aluminum storage rack structure from which loads are automatically stored and retrieved under computer control. The storage/retrieval function in each aisle can be performed a variety of ways. However, the most common way is by a machine that consists of a floor running, traveling structural frame or vertical mast that guides and supports a hoisting carriage on which loads are carried. One or more shuttles or insertion/extraction devices on the hosted carriage manipulate loads into and out of adjacent or opposing storage rack positions. All three machine motions; horizontal (down aisle), vertical and shuttle action are independently and automatically controlled.

These automated storage and mechanized systems eliminate human intervention in performing basic sets of operations that includes:

- Removal of an item from a storage location automatically
- Transferring the above item to a specific processing or interface point
- After receiving an item from a processing or interface point, it is automatically stored at a predetermined location.

Systems vary from relatively simple, manually controlled order-picking machines operating in small storage structures to extremely large, computer-controlled storage/retrieval systems totally integrated into a manufacturing and distribution process. These systems provide users with increased inventory control and tracking, including greater flexibility to accommodate changing business conditions. They can be comprised of modular subsystems that are easily replaced to minimize downtime and extend the service life of the overall system. AS/RS systems also reduce labor costs, lowering necessary workforce requirements, increasing workplace safety, and removing personnel from difficult working conditions (such as cold storage environments). AS/RS systems can produce major savings in inventory storage costs via improved space utilization and storage density - both vertically and horizontally.

Automated storage and retrieval systems do require considerable investments of a company's resources, however. Maintaining a large and highly integrated system requires training and experience. The cost of purchasing and implementing an effective automated storage/retrieval system is significant as well, encompassing everything from the actual purchase price of AS/RS equipment and software to modifying existing facilities or creating new ones. In
addition, experts in the use and maintenance of AS/RS systems note that companies often experience significant ongoing costs for maintenance and updating of various subsystems. Businesses are urged to examine the long-term implications of their choices when they incorporate an automated storage and retrieval system into their operations.

Terminology

The AS/RS industry has its own unique terminology. Because the purchase of such a system for chemical or biological storage may be a once-per-career event for most scientists, it’s not likely they are conversant in all the terms of the trade.

- **Storage Structure:** The rack framework that supports the loads contained in the AS/RS and is used to store inventory items.
- **Storage Racks:** This structural entity comprises storage locations, bays, rows, etc.
- **Storage Space:** The three-dimensional space in the storage racks used to store a single load unit of material.
- **Bay:** The height of the storage rack from floor to the ceiling.
- **Row:** A series of bays placed side by side.
- **Aisle:** The spacing between two rows for the machine operations of AS/RS.
- **Aisle Unit:** Encompasses aisle space and racks adjacent to an aisle.
- **Storage/Retrieval Machine:** Used to move items in and out of inventory. An S/R machine is generally capable of both horizontal and vertical movement. In the case of fixed-aisle storage systems, a rail system along the floor guides the machine along the aisle and a parallel rail at the top of the storage structure is used to maintain its alignment.
- **Storage Modules:** The unit load containers used to hold the inventory items. In the industrial world these include pallets, steel wire baskets and containers, pans and special drawers. In the laboratory environment, these may include vials, plates, bottles, etc. These modules are generally made to a standard base size capable of being stored in the structure and moved by the S/R machines.
- **Pickup and Deposit (P/D) Stations:** Where inventory are transferred into and out of the AS/RS. They are generally located at the end of the aisles to facilitate easy access by the S/R machines from the external material-handling system. The location and number of P/D stations depends upon the origination point of incoming loads and the destination of output loads.
- **Cherry Picking:** The process of the AS/RS accessing any individual unit load container, regardless of location in the storage system and position in access sequence. In the laboratory environment, cherry picking may also involve randomly accessing a given sub-unit within a load container, i.e. a given sample within a multi-sample container, such as a microplate or array of vials.

AS/RS layouts

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**Size of collection, frequency of access, desired turnaround**

Storage collections can range from several thousand to millions of samples. Small collections with a low frequency of demand can be managed manually, but as collection sizes and access frequency increase, AS/RS becomes desirable and then essential to avoid errors. This is especially true if the process involves return of samples to the collection, which is the most error prone operation. Some laboratory focused AS/RS advertise capacity as large as tens of millions of samples, depending on storage format. Systems capable of storing thousands of samples can often fit into a standard laboratory with minor facility modifications. Systems capable of storing 100's of thousands up to millions of samples will generally require significant facility modification, up to and in some cases including the building of a specialized facility for very large collections. AS/RS can be designed to present and retrieve individual samples directly to/from a person if frequency of access is moderate. In cases of high access frequency, an automated front-end to the AS/RS may be necessary. Similarly, the specification for turnaround time from request to receipt of sample will influence the degree of front-end automation and also the degree of multiplexing within the main AS/RS. A requirement for high frequency/high turnaround may necessitate a modular design, where the collection is split among multiple, smaller AS/RS.

**Laboratory AS/RS**
INTEGRATION OF FACTORY PROCESSES

AS/RS is the core

Six major processes exist in most manufacturing facilities with material handling serving as the vital link which enables each one to interface with the others. They are:

- Receiving
- Inspection
- Picking
- Manufacturing
- Assembly
- Shipping

A distribution center typically has similar functions with the exceptions of manufacturing and assembly. An objective, of course, in both manufacturing and distribution is to reduce costly inventories to their lowest possible levels while maintaining an uninterrupted workflow through the six factory processes. A great deal has been done to automate and improve productivity as it pertains to the equipment available to design the product, to produce the parts, to assemble the pieces, to inspect and identify defects in materials and workmanship, to package and protect the materials, to aid in picking and to load and unload shipping vans and rail cars. Those developments not only help to produce materials of high quality workmanship but they greatly increase the quantity of goods produced. The common link to each of these processes is material handling and inventory control. The increased production capability of many of these processes has rendered conventional material handling, storage and inventory control techniques ineffective and incapable of supporting sophisticated modern manufacturing and distribution processes. There is much to be gained by skillfully integrating factory islands of automation into a smooth-running, harmonious system sometimes referred to as the automated factory. AS/RS systems provide that common link and have become the core of the automated factory as a result of these attributes:

1. Space-efficient storage of materials for each function.
2. High-speed input/output of materials to/from storage.
3. High-speed controlled material transportation from process to process.
4. Real-time material identification and tracking capability.
5. Real-time inventory control of all materials in storage or in transit.

Characteristics of the Automated Factory

An automated factory or distribution centre evolves as internal processes and functions are automated to some degree. Automated factories are seldom achieved in one sweeping action. There are five typical and identifiable characteristics common to the automated factory.

I. Data Automation

Conventional methods of manually gathering, recording, checking, correcting and updating data are too slow, costly, and inaccurate and leave out the most important common element of the automated factory: material tracking. Production scheduling, inventory control and material requirements planning, to name a few, rely on the availability of accurate, real time data. In the automated factory, entry equipment and sensing equipment collect data through
keyboard terminals, magnetic wands, scanners, limit switches and other means of material tracking. Paperwork is reduced and data timeliness and reliability are greatly improved. Capturing and transmitting data in real time are vital to the functioning of automated machines and equipment and are essential to timely, informed decision making by management.

2. Networking Controls
Automatic control of equipment is well established in today’s factories. But in the automated factory, equipment must interface with and transmit data directly to other facets of the total operation such as storage and transportation systems as well as with management through a control network. In addition to providing essential information among major stations, an instantaneous communications network also provides an important degree of administrative control and capacity to monitor the entire operation. Such administrative controls, therefore, tie all the functional elements together into a cohesive operational whole.

3. Production Automation
Production automation includes the use of automatic machines that do everything from automated storage and retrieval to welding, die casting, stacking, painting, and inspection. The capability to interface with other automated systems has made these automated production machines an integral part of the automated factory. Flexible machining centres are being serviced by AS/RS systems that can feed machine tools and store the materials between operations.

4. Flexibility
With approximately 75 percent of all manufacturing in the United States now classified in the batch or job shop category, the element of flexibility in the automated factory is most desirable. The ability to make rapid changes in factory processes has become a primary justification for installing automated equipment control systems. Flexibility also extends to the capability of isolating machines when they require service or maintenance, rerouting material flow to avoid disruption of the entire system, and the effective handling of material surges between workstations.

5. Automated Material Handling
The final key element in the automated factory is the automation of the physical handling and control of materials. According to many factory automation experts, it is the most vital characteristic of the automated factory because it is the common interface to all functions and processes. It is also a fruitful area for productivity improvements since most of the time that material is in the plant, it is being handled or stored. From the time material is received until the finished product is shipped, it may be picked up, moved, stored, moved again, worked on and handled dozens of times. Manual, semiautomatic and fully automatic equipment will come into contact with the material. Each piece of handling equipment must interface with other equipment; and at each step, the material must be tracked and controlled accurately in real time.

Today’s AS/RS concepts have become so advanced that they match or exceed sophisticated manufacturing machines and equipment. There are innovative solutions to virtually every material handling requirement and standardization in equipment and installation by system suppliers has helped make AS/RS systems highly cost effective. Integration Planning perspective is the key to many of the benefits of automation. Too narrow a perspective is a common planning flaw and is responsible for many overlooked opportunities to improve
productivity. A broad planning perspective does not require choices between piecemeal automation or massive innovation. Rather it consists of a willingness to examine all facets of the production or distribution process and the interrelationships between those processes before making decisions about changing the process. Automation should be looked upon not only for the efficiencies that might be achieved in any particular process, but also for the chance to eliminate or combine supporting functions. Such opportunities may well provide much greater benefits than process automation by itself. In order to fully understand the magnitude of these possibilities, remember that material handling represents a major portion of the cost of most production and a nearly equal portion of the total floor space. Even more floor space may be taken by floor storage at the point of use or at receiving areas for material not yet logged into the inventory record system. Inefficient material control often results in excess inventory and inventory held at a late stage in the value adding process thus being held at a higher dollar value than that needed to support production. Automation both of the material handling or storage functions and of the associated information system are keys to material control. A broad planning perspective is needed in order to both see these problems and visualize solutions to them. Material control is an objective with many benefits. Among them are the reduction of inventory and the increase of reliability of material available at the point of use. This is a necessary condition for realizing cost savings from process automation. Rates of production and inventory levels may be managed to improve overall plant profitability by minimizing inventory costs without degrading service to customers. Realizing these benefits comes from understanding that a plant is (or ought to be) a closed-loop control system. It is a general rule of closed-loop control systems that the rapidity and accuracy of feedback of information to the controller (i.e. management) define the response of the system to changes in demand. Automation of material handling and storage yields as an important side benefit instantaneous reporting of material status and location - precisely the information feedback needed for efficient control and management of the plant. Implicit in these considerations is a balanced concern both for the productivity of labor and for the productivity of capital. The greatest benefits of the automated factory are not to be realized from mere substitution of machine for muscle. Capital, both fixed and working, can be made to work smarter not harder if a broad perspective is given to the planning process.

**Procedure for Integration**

How a company implements the elements of the automated factory depends on whether it is building a new facility or changing an existing one. Certainly new facilities allow the design form to follow the functions, with single purpose facilities, logically arranged operations and system elements chosen from the latest technology. Existing facilities, however, which are the majority, require carefully phased planning with integration of a few elements at one time so that production can continue. This phased in system is more easily assimilated by both labor and management and assures favorable acceptance and minimal production interruption.

The following may provide the potential automated factory prospect with major guidelines for his planning:

- A completed master plan is essential before changing any of the material handling system elements.
- The system is an integration of independent elements and can be installed as convenience, economics and justification permit.
Product control is fundamental to any system, even the present one. Obtain control as you incorporate elements, and make every successive system element continue this control.

AS/RS provides positive control over stock movement and storage and should be an early system element to capture product control and to provide the common link for future automation elements.

Accurate, timely data is essential if one is to benefit from product control. Real time reporting is necessary for positive inventory control.

Summary
An integrated system is the consolidation of system elements, brought together by the development of reliable interfaces and centralized system control. A top down examination of the entire operation reveals the areas for consolidation, elimination, or expansion as well as a fresh look at the need for present departmental structures. Once the new facility is configured, a careful, step-by-step bottom up development of equipment, interfaces and controls will contribute to a successful and profitable automated facility. The building blocks of the automated factory exist today as reliable, proven equipment. Such subsystems have provided many cost-effective benefits as stand alone solutions to localized problems. Similarly, computerized control of factory data is an established and successful achievement.

AS/RS and RECEIVING
The operational difficulties in many conventional receiving areas are generally well known. Material staging areas often are choked with incoming shipments as they await destination assignments. Material is often handled several times before it is dispatched, increasing the probability of product damage, loss or mis-assignment. Material checkers, expeditors, industrial truck drivers and other personnel make the receiving function labor intensive. Paperwork is shuffled from one point to another, delaying delivery of materials to the point of need. Real-time control of inventory in these conventional receiving areas seems to be impossible to achieve.

In an automated receiving area, material is managed and controlled precisely from the moment it arrives on the dock and sometimes even before its actual arrival. The expanded capacity of the automated system can handle virtually any planned volume, eliminating the need for large staging areas. As material is loaded onto the dock, it is quickly identified to a computer using a keyboard terminal, light pen, magnetic wand or other automatic identification device. The computer, which is linked to other Material Requirements Planning (MRP) data banks, verifies the identification and quantity of the incoming material against material orders. The information control system has the ability to then direct the material to storage, inspection, order picking, manufacturing, assembly, or distribution as appropriate. The computer may direct that a move ticket be printed for attachment to the material at the receiving dock. The material moves rapidly out of the receiving area via an automated transportation system such as a conveyor, in-floor towline, automatic guided vehicle or other means. This systematized process greatly reduces the number of handling operations, the duration of each process and the frequency of handling. Materials destined for storage move to the automated high-rise storage system, which typically occupies less than one-third of the floor space required by conventional floor storage. The system computer has already assigned a storage location by storage aisle and storage rack opening as the material arrives. An S/R
machine picks up the load, stores it in the assigned location, and verifies to the computer that the load has been correctly stored. Precision S/R machines and equipment assure product protection through precise handling while the system protects the material from unauthorized removal by restricting access and through absolute inventory accountability.

Management information systems can determine the need for and size of lot samples to be sent to quality inspection. There is no need, therefore, to retain the entire shipment in the receiving area while awaiting disposition. The material can be sampled, sent to quality control, and the remaining shipment moved directly to storage all in one operation. The material will be quarantined in the computer and cannot be accessed until released by quality control. This not only alleviates congestion in the receiving area, but also assures that materials will not be used until cleared through the inspection process. Real-time inventory control systems assure instant access to information throughout the facility. From machine operator and shop foreman to manufacturing and general management personnel, knowledge of the actual status of all material on hand and where it is located provides an invaluable productivity tool. Equally important, back-up or safety stocks can be significantly reduced. The number of personnel required in a typical receiving area often can be reduced. The resulting decrease in receiving area staff can generate an available labor pool for other areas without necessitating an overall increase in the total number of employees. As a result, safety factors can be improved. Maintenance costs for conventional material handling equipment are reduced. Combine these savings with the reduction in required storage space, reduction in back-up inventory and the annual carrying cost savings for such safety stocks, and the receiving area can become a major contributor to the overall profitability of the company. Most importantly, AS/RS provides real-time inventory control of material from the moment it arrives in the facility.

AS/RS and INSPECTION

One typical difficulty in the materials inspection or quality control process is the erratic schedule for the delivery of materials. In spite of advance planning, it is difficult to balance incoming flow rates. This often results in excessive quantities of materials in the inspection queue, which not only use a lot of valuable floor space, but also expose materials to possible damage or loss. In addition, there is the problem of handling and storing rejected materials until they can be returned to the vendor. Critically needed items are often buried in the inspection staging area and cannot be readily accessed to meet a priority request.

No matter how great the volume may be at the receiving dock, an automated storage/retrieval system can help control the flow of materials so as to avoid overloading any one operation. As the materials arrive, they are entered into the system. The availability of workstations is reviewed automatically and immediate decisions are made and commands issued to direct the material either to an available workstation or into storage. Partial shipments may be sent to a work or inspection station while the remainder of the shipment is directed into storage. This alone can significantly reduce potential congestion by reducing the amount of materials being sent to the inspection station. This eliminates the need for two staging areas and provides real-time control over the flow of materials. Materials awaiting inspection in the AS/RS system can be quarantined in the computer and cannot be accessed until released by inspection. When inspection is ready to check the material, the sample is retrieved, the material checked, and the computer notified that the material is ready for release. If material is found to be unacceptable, it can be held in the AS/RS until shipping is ready to return it to the vendor, at which point the AS/RS system automatically directs it to the shipping dock. Another advantage of using an AS/RS system is its ability to identify and follow priority
items. In its interface with the overall management information system, the AS/RS system can acknowledge such priority designations and insure that those materials are expedited, thereby preventing intolerable time delays or the risk of losing items in an inspection area queue. Since the computer in real time tracks the location of all material, materials can be processed according to actual need and transported to the point of use quickly and accurately.

The automated S/R machines, conveyors, automatic guided vehicles and associated equipment handle, move and store product with a precision unmatched by conventional material handling equipment. Material loss is dramatically reduced because it is stored in secure, high-rise storage and because real time inventory control over all materials discourages unauthorized removals. By integrating AS/RS into the inspection process, use of time is maximized by the efficient flow of materials. There is no longer a need for a large staging area in the inspection department, releasing space for manufacturing or other activities. Productivity is increased because duplicate handling has been eliminated and automated equipment moves and stores the material. The picking activity is labor intensive in the typical factory, whether in support of inspection, fabrication, and assembly or to support shipping in less than unit loads. Getting the right materials to the right place at the right time is the most basic objective of all material handling operations. Every manufacturing and distribution operation strives continuously to achieve that goal, thereby keeping machinery and personnel operating at their peak productivity level for the maximum possible time. Conventional order picking operations normally require large numbers of people to be engaged in repetitive tasks which allow a high margin for error. In addition, close supervision is difficult because the pickers must, of necessity, be scattered throughout the storage areas. In addition to actually picking the order, they must also update inventory records, deliver the order and return for their next assignment. Going to and from the picking areas creates additional unproductive time and encourages haste, which often results in errors.

AS/RS and PICKING

Keeping all the items readily accessible to pickers necessitates storage within a relatively limited reach. Floor space must be utilized for storage rather than manufacturing or other processing operations. Comfortable environmental conditions such as heating/air conditioning and lighting must be maintained for the comfort level of the employee, not of the product. In an AS/RS system, however, between 30 and 40 percent of the floor space usually can be recovered for other operations. And the costly environmental conditions can be revised to achieve significant additional savings. This will greatly increase the utilization of the cube, effect substantial financial savings and increase overall plant productivity. Automated storage/retrieval systems can reduce the time required to pick materials by bringing the material to the picker. An SIR machine can either take the person to the materials for efficient picking or it can direct the S/R machine to retrieve the material from picking stations in front of the storage aisle or via conveyor or transporter to a picking area away from the storage system. The system computer can be designed to direct the picker via a CRT or ticket printer or both to pick the material and send it to a designated area. The number of configurations of picking methods is almost unlimited. Because picking is done at a well-lighted and engineered workstation, picking errors are reduced and picking rates dramatically increased. In some cases, picking rates have been increased from 10 to 15 line items per hour in a conventional operation to 240 per hour. These increased picking rates have sharply reduced manpower requirements, turnover and training costs. Supervision is effective since pickers stay in one place and need not wander through the storage aisles.
When a pick is completed, the picker signals the system computer via his control panel that the task is accomplished. The computer then automatically updates the inventory records in real time, thereby eliminating the human error factor often associated with the completion of paperwork by the picker. It also gives management timely information. The accuracy of inventory records maintained by the system computer can be checked periodically without a physical count of all inventories in the system.

An automatic cycle inventory (AC I) check can be performed by the computer, directing random sample counts, which are compared with the computer records. Real-time inventory control, combined with the speed and accuracy of material picking, contributes directly to the reduction of back-up or "safety" stocks. Management can now place greater reliance on the validity and timeliness of inventory records.

**AS/RS and MANUFACTURING**

Inefficiencies in material handling and control on the manufacturing floor are often the root of productivity problems. Variable path transporters, principally industrial trucks, hand trucks and carts, require the use of up to 40 percent of the floor space for travel and turn-around. To assure that expensive machine tools and equipment have a high operating uptime, additional floor space is used to queue up plenty of materials at each workstation.

In addition, space is used to store materials between manufacturing operations. This work-in-process storage often exceeds the space in which the associated productive work is performed. With materials stacked in workstation queues and work-in-process areas, it is difficult to maintain accurate control, protect material from damage or loss, or determine the real-time status of material, data that is vital to an effective production material control and scheduling system. Automated storage/retrieval systems, long proven effective in warehousing operations, are solving the problems associated with in-process storage, in or near the manufacturing area. In some plants, automated S/R systems directly service manufacturing by providing access to materials through the storage rack openings facing the workstations. Although the S/R machines are captive in the storage aisles, their independent vertical and horizontal motions allow access to any one of a large set of locations on either side of the storage aisle. Thus, the S/R machine behaves like a random path vehicle and can bring materials to work stations as needed. Automated storage/retrieval systems may be located adjacent to the manufacturing area and materials delivered via in-floor tow carts, automatic conveyors or automatic guided vehicles in situations where direct interfacing of AS/RS storage and work stations is not practical. The concentration of storage at or near the processing site does more than save space. It provides a virtually limitless working queue at each process. The storage space may be "partitioned" into any configuration needed, and the partitioning may be changed by changing computer software rather than changing physical facilities or moving machinery. Thus, a production machine is not limited by the queue in front of it, thereby increasing the productivity of the capital equipment while eliminating floor storage of material. Automated S/R systems are central to the success of real-time control of materials in the manufacturing area, when combined with automatic identification systems and with automatic transportation systems, such as automatic conveyors or automatic guided vehicles. In this way material can be tracked and controlled in real time throughout the process. Even without other automatic systems, AS/AS systems can reduce queuing at workstations, eliminate floor storage of work-in-process materials, and increase the effectiveness of production material control and scheduling systems.
AS/RS and ASSEMBLY

Raw material goes through multiple processes prior to becoming part of a finished product. Material stored in its lowest manufacturing state is the least costly as there is a sharp increase in value when labor is added. The sharpest rise generally occurs in the assembly operation. An unplanned shutdown of an assembly line due to slow delivery of materials or parts picked in error is therefore very costly. As a hedge against shutdowns, materials or assemblies are often stored in large quantities near the assembly line, taking up valuable space while increasing the probability of damage or loss. It is here that AS/RS systems provide efficient storage, transportation and real-time control keeping inventories at a minimum and maximizing productivity. In high-speed assembly operations, the material handling function is typically labor intensive. AS/RS can improve the productivity of existing manpower through controlled transportation of materials. Automated horizontal transportation systems also reduce the potential for material damage that occurs through conventional material handling methods. In assembly operations where there are a variety of products or models being produced there are frequent assembly-line changeovers making real-time control provided by AS/RS essential.

Storing parts, materials and assemblies in an automated storage/retrieval system will reduce the amount of material needed at a given time along the assembly line. Production control management can initiate the assembly process with the knowledge that materials are available in the storage system and can be accessed quickly and accurately when needed. There is no need to stockpile materials in excess of day or shift requirements. Materials needed to meet production assembly schedules can be quarantined in the computer. This also prevents excess quantities of materials that may be needed in other areas from being hoarded. Material kept in the AS/RS system is protected from damage or loss, which may occur as it sits for long periods in the assembly area.

AS/RS and SHIPPING

At this stage of the manufacturing process product damage is more costly than at any other time since all the value has been added to the raw materials. Unfortunately, product damage seems to occur more often as it is moved from manufacturing, assembly and packaging into finished goods storage; then out of storage to order build up, onto shipping docks and into trucks or rail cars. In most large finished goods storage warehouses, a third or more of the storage space is lost to aisles for the movement of industrial trucks and people. Areas are often set aside for building up orders. Sometimes, orders cannot be filled on time because inventory records show items to be in storage, yet they cannot be found.

In an AS/RS system, materials and finished products move from the assembly line or manufacturing and, where appropriate, through packaging and automatic palletizing into the shipping/warehouse area where they are identified to the computer. According to shipping schedules, they are sent directly to the shipping dock or to storage via an automated transportation system. The high-density AS/RS system utilizes floor space effectively and maintains accurate inventory control over all items in storage at all times. To fill an order, the computer directs the S/A machines to bring out the items in a predetermined sequence for the efficient loading of trucks or rail cars. The speed and accuracy of an AS/RS system reduce the floor space requirements for staging orders prior to shipment. This single step will help eliminate the practice of accumulating orders ready for shipment on the floor of the warehouse or the shipping dock. The installation of an automated storage/retrieval system in the warehouse/shipping area can improve productivity significantly, reduce damage and improve safety. The resultant manpower reduction and reduction of conventional
transportation equipment also will improve the level of job satisfaction of the personnel in the shipping area.

**JUSTIFICATION**

Automated storage/retrieval systems contribute to the direct reduction of inventory, floor space, man power and material control costs. The reduction in inventory alone is often sufficient to produce a very favourable return on the AS/RS investment. Most companies have techniques for making a justification analysis, but some of the data important to the analysis of an AS/RS is often overlooked. The AS/RS companies that produced this brochure have extensive experience in the data gathering process and would be pleased to assist you in identifying economic analysis data. As you develop the justification of an AS/RS, it is suggested that you consider the following:

- Floor space for storage and material movement.
- Cube utilization.
- Cost of conventional material handling equipment.
- Remote warehousing and transportation costs.
- Manpower, direct and indirect.
- Employee turnover and training costs.
- Number and cost of picking errors.
- Inventory quantities, turns, and safety stocks.
- Inventory carrying costs and taxes.
- Inventory counting and verification.
- Inventory shrinkage.
- Downtime due to material shortage, delays or mis-picking.
- Energy and utility costs.
- Management reports availability, accuracy and timeliness.
- Sales lost due to slow material response.

After making an in-depth analysis of their operation and considering all the direct and indirect benefits of AS/RS as proven in real world applications, most companies conclude a positive justification for AS/RS, both in terms of return on investment and the greater level of control which AS/RS assures.

**AS/RS SUMMARY**

Automated storage/retrieval systems are operating successfully in hundreds of manufacturing and distribution centres around the world, improving productivity and profitability through effective handling, storage, movement and control of a wide variety of materials. The elements of the automated factory are all available and in operation today. But the elements must be integrated effectively to realize the full potential of each element. The key to factory integration is the automation of the material handling and control function. Without this vital link, the automated factory is simply not possible.

The automated factory will not be devoid of humans and their irreplaceable capabilities. By bringing together high technology and human engineering, automated factories will enhance and improve working conditions for people at all levels. Heavy physical demands can be removed from the workplace by precision via automated machines while materials are tracked and controlled in real time with a speed and accuracy no humans can match.
Through an evolutionary process, the automated factory is becoming a reality. The phasing in of automated systems has proven to be a sound process, economically and humanistically. But a master plan is essential before implementing any element. In fact, those who compete in the international marketplace already know their market share has been significantly eroded by those companies implementing these technological advances.