LOCATION TECHNOLOGIES FOR APPAREL ASSEMBLY

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Results of the survey suggest that location technologies for apparel manufacturing must be capable of placing a part or a seam to within 1/32 of an inch in a time of approximately 10 seconds at a cost of less than $500.

A review is also given of state-of-the-art vision systems. These systems have the necessary accuracy and precision for apparel manufacturing applications and could conceivably meet the targeted time and cost constraints in the near future. (Cont.- Reverse)

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Two applications for currently available location technologies--part location and edge following-- are discussed and will be the subject of future work.

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APPAREL ADVANCED MANUFACTURING TECHNOLOGY DEMONSTRATION

SHORT TERM RESEARCH AND DEVELOPMENT TASK

LOCATION TECHNOLOGIES FOR APPAREL ASSEMBLY

Wayne C. Tincher, Douglas M. Moore and Wayne Daley

I. INTRODUCTION

The apparel industry since its inception has relied primarily on the visual and tactile skills of human operators for sensing the location and the registration of parts during sewing. The ability and versatility of human operators in these tasks has been impossible to duplicate with machine vision systems at reasonable cost. Much of the development work in registration of cut parts and in locating and guiding parts in joining operations has been directed to systems and techniques that aid rather than replace the operator in these tasks.

Simple photoelectric devices have been introduced by many manufacturers to sense the location of parts. Most of these devices are used simply to determine if a part is present and to initiate or terminate a sewing cycle. In some automated sewing systems photoelectric sensors are used to assure that various phases of the cycle have been completed before allowing the operation to continue.

Several more sophisticated uses of vision systems have been introduced recently into apparel manufacturing. The video camera is used to determine part location in several of the machines developed as part of the Textile and Clothing Technology Corporation ($[TC]^2$) research program and a number of systems have been introduced using fiber optic systems to determine placement and to guide parts through a sewing operation. The cost of these more advanced systems has been a major barrier to their widespread use in apparel work stations.

Within the past few years very significant advances have been made in machine vision systems. The lower cost of computing power, improvements in sensor technology, and the development of firmware specifically for analysis of vision data are major developments that have impacted speed, cost and capabilities of these systems. The current work was undertaken to define the requirements for location technologies in the sewn products industry as a precursor to development of applications of these new advances in vision technology in apparel manufacturing, particularly in production of military garments.

The research program was divided into several related tasks. First, requirements for part location and orientation, speed, accuracy, etc. in manufacture of garments in accordance with military specifications were determined. Second, methods currently used in locating and orienting parts in apparel production were reviewed and correlated. Third, a review of currently available vision technologies applicable to the manufacture of apparel were reviewed and evaluated. Finally, recommendations for systems that appear to be promising in locating,orienting and guiding parts in apparel assembly are presented.

II. REQUIREMENTS FOR LOCATION TECHNOLOGIES IN APPAREL MANUFACTURING

A. Military Garment Manufacturing Specifications--Accuracy

Two military garments were selected for initial studies--Trouser, Men's Dress, Wool and Polyester/Wool (Mil-T-43957C[GL]) and Shirt, Man's, Long Sleeve, Polyester/Cotton, Army Green 415, Durable Press (Mil-S-44039B[GL]). These two garments were expected to provide a good cross-section of typical apparel assembly operations for defining location technology requirements.

Specifications for the two selected garments given above were obtained from the Defense Personnel Support Center (DPSC). The specifications were carefully reviewed to determine the tolerances permitted for placement of seams and for location of parts in each of these two garments. The detailed results of this analysis are given in Appendix A.

A summary of the results of the analysis of the specifications for military trousers and shirts is given in Table 1. The tolerances for seam and part location shown in the table indicate

TABLE 1

Frequency of Specific Tolerances in Specifications for Military Trousers and Shirts

Tolerance(in.)	Trousers	Shirts
1/64	0	1
1/32	14	19
1/16	14	16
1/8	10	13
3/16	2	3
1/4	3	2
3/8	1	0

that a location system that could accurately position a part or a seam within 1/32 of an inch (.0313 inches) would be able to handle the vast majority of the operations required in apparel assembly. This would demand a vision system that has a minimum resolution of 1 in 64 (i.e. 64 pixels per inch or 4096 pixels per square inch). This is not a particularly stringent requirement for modern vision systems.

Three shirts (Shirt, Man's, L.S., AG-415) and three pairs of trousers (Trousers, Men's, Poly/Wool Trop. Green-2241) were obtained from DPSC Sample Section to determine if seam and part placement were generally within the specification tolerances. It was clear from examination of these garments that considerable variation existed in the manufacture. The shirts had not been produced on automated equipment as evidenced by the decorative stitching (top stitching or single needle stitching) on various parts of the shirts. For example, specifications call for edge stitching the shirt pocket flaps 1/4 inches from the edge (0.25 inches). Measurements on 6 flaps gave average values of 0.22, 0.22, 0.22, 0.22, 0.22, and 0.24. Variations within a given pocket ranged from 0.21 to 0.25. Similar results were obtained from other measurements.

The trousers were produced by at least two different manufacturers. It was evident that one of the manufacturers was employing automated equipment in several of the assembly operations that gave much more regular placement of seams and parts. Although the majority of measurements were within specifications on all the pants, the improved uniformity of seam placement was obvious in the pants produced on automated equipment.

The survey of shirts and pants suggested that manufacturers are quite capable with existing equipment to produce military shirts and trousers within the published specifications. The application of location technologies would therefore have to be justified on bases other than the need to meet specifications. Automated systems do lead to improved appearance and to greater consistency in garment manufacturing.

B. Part Sizes

A second important consideration in assessing location technologies for automated assembly systems is the sizes of parts that must be accommodated in apparel assembly. Survey of the military shirts and trousers suggests that parts typically range in size from approximately 1 inch by 6 inches (e.g. shoulder loops) to 16 inches by 48 inches (e.g. trouser front and rear panels). Clearly, locating and registering the larger parts will be difficult for current location technologies. For example, a resolution requirement of 64 pixels per inch over 48 inches would require a total of 3072 pixels. Dealing with such large parts will require either determining location in selected regions (e.g.

locating a corner or edge), control of the part over limited distances (e.g. edge guiding with control of a section of the panel at any given time) or use of multiple sensors to cover the entire part. The particular application of location technologies will determine which of these approaches will be best for the application.

C. Time Constraints

In the course of visitations with apparel manufacturers, data was collected to determine the current times for workers to locate, orient, and register parts in apparel operations. These times will be important benchmarks in evaluating the speeds that will be required for location technologies to be competitive in apparel manufacturing. Since most companies consider these times to be confidential, only a summary of the data from a number of sources will be presented.

Table 2 gives time ranges for specific location and registration operations in apparel assembly. Times for complex operations are usually obtained by summing times for the individual steps. All data in Table 2 are from a minimum of 3 sources. It

TABLE 2

TIME RANGES FOR SPECIFIC LOCATION AND REGISTRATION OPERATIONS IN APPAREL ASSEMBLY

Operation	Time Range (min)
Locate part to needle	0.016-0.025
Pick 2 parts, Align	0.064-0.075
Pick part, Locate to needle	0.034-0.037
Pick 2 parts, Align, Locate to needle	0.087-0.117

that the time constraints on part location, registration, and placement systems will be of the order of 10 seconds or less for such systems to be competitive with existing manufacturing methods.

III. METHODS CURRENTLY USED TO LOCATE AND ORIENT PARTS

In order to determine the nature and extent of the use of location technologies in both production and prototype apparel manufacturing equipment, project team members visited a variety of manufacturing facilities, demonstration centers, and trade shows. Equipment was studied at these locations to gather information regarding the function, usefulness, and accuracy of the location devices utilized. Observations were conducted at the following locations:

Technology Demonstration Centers:
- AMTC - Georgia Tech, Atlanta GA
- AMTC - Fashion Institute of Technology, New York NY
- AMTC - Clemson University, Clemson SC
- $(TC)^2$ - Raleigh, NC

Military Garment Manufacturers:
- DPSC - Philadelphia PA
- Martin Manufacturing - Martin TN
- Tennessee Apparel - Tullahoma TN

Civilian Manufacturers:
- Arrow Shirts - Cedartown GA
- Oxford Industries - Monroe GA
- Tokyo Style - Tokyo, Japan

Apparel Equipment Manufacturers:
- Ark, Inc. - Shelbyville TN
- Jet Sew, Inc. - Barneveld NY
- Juki - Ohtawara, Japan

Trade Shows:
- Bobbin Show - Atlanta GA
- JIAM '90 - Tokyo, Japan

Detailed data collected during the plant visits are given in Appendix B. A detailed report on the equipment shown at the JIAM Exhibition is given in Appendix C. Data from the appendices are summarized below.

A wide variety of location devices were observed to be in use at the various facilities. The most common location device by far is the machine operator, or more specifically the operator's hands and eyes. In the majority of cases, the operator determines the placement of parts or seams through the manual alignment of parts and the placement of parts to the sewing needle. In some instances, the operator is totally unaided and relies on experience and visual approximation to locate parts and stitching. This technique is most commonly observed where the dimensional tolerances are large and a high degree of accuracy is not required. More common, however, is the use of some type of aid to assist the operator in the placement task.

It was observed that location technologies in use tend to fall into one of three general categories. Of these, the first two are essentially aids to the machine operator, and are of a relatively passive nature. The third category of devices includes the more advanced, automatic devices that generally require only rough initial location by the operator. The three general categories are:

1) Tactile Aids: Mechanical edge guides and stops, folders, and special presser feet that provide some tactile feedback to the operator indicating that the fabric is in the correct location.

2) Visual Aids: Devices that operate in conjunction with the operators vision, such as fabric notches and drill holes, alignment marks on machine tables, chalk marks, and crosshair projectors.

3) Advanced Systems: Active devices that function without operator assistance and that are used to locate and position fabrics and activate machine cycles.

The three technology categories are discussed in more detail below.

A. Tactile Aids

The simplest of the location devices in this category is the *edge guide* -- a fixed mechanical stop or fence located at a specified distance from, and to the side of, the sewing needle. The fabric edge is held against the guide as the fabric is drawn through the sewing machine and results in the stitch being placed at a constant distance from the edge of the fabric, as long as the operator holds the fabric in contact with the edge guide. This device allows reasonable placement accuracy with minimal operator skill, but requires virtually constant attention from the operator. Edge guides are commonly used for long straight seams, such as pant leg inseams and joining of shirt backs to fronts. A simple edge guide is shown schematically in Figure 1.

Closely resembling edge guides, mechanical *stops* are more commonly used for initial positioning of a garment part relative to the sewing needle, and are most often found on automatic sewing equipment. The major difference is that the fabric is continuously moving past the edge guide, but is static with respect to the stop. Stops may be used singly or in pairs, when it is desired to locate the part in two dimensions. Common applications include collar and sleeve button hole/sew machines and automatic pocket setters.

For more complex seaming operations, specially designed *folders* facilitate the alignment and lapping of two or more plies as they are fed into the needle for joining. Folders greatly simplify the task of forming complex seams, but still require a high degree of operator skill. A common example of a folder

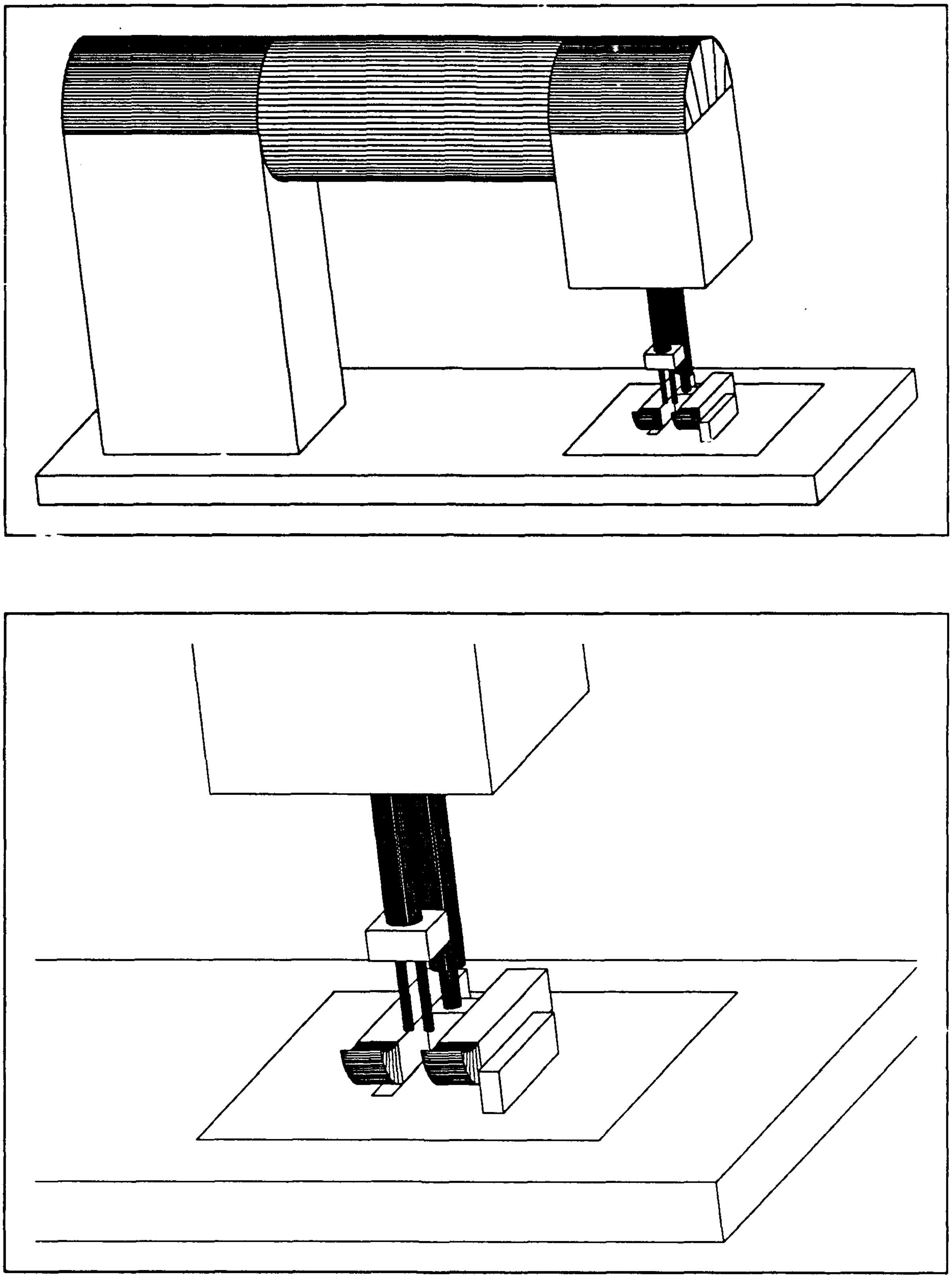


Figure 1. Sewing Machine with Attached Edge Guide

application is the double interlocked felled seam employed in the pant leg closing on most jeans. A few very complex folders were noted that provided simultaneous alignment of as many as four separate components, such as was used to form a complex pants waistband in a single operation. A simple folder is shown schematically in Figure 2.

Probably one of the most sophisticated of the mechanical location devices observed was the "Zyppy" sewing machine attachment shown in Figure 3. This device will attach to a wide range of sewing machines and will align the cut edges of two parts to be joined and place the fabrics so the seam joining them will be the correct distance from the edge. The unit has two directed air jets, one on the lower surface of the top plate and one on the upper surface of the bottom plate. The top and bottom plates are separated by a low friction metal plate. One fabric is placed between the top and center plates and the other fabric is placed between the center and bottom plates. The directed air jets move both fabrics until they strike a mechanical barrier (the three metal rods coming through the top plate in Figure 3). This aligns the edges of the two cut parts with each other, and the position of the mechanical barrier relative to the machine needle determines the distance of the seam from the edges of the two parts being joined. As the seam is sewn, the device continues to automatically align the two fabrics. The use of this device minimizes the degree of operator skill necessary, because the operator simply ensures that the two pieces of fabric are roughly aligned.

A final mechanical-type device in common usage is the *compensating presser foot*. This foot is split longitudinally at the center, with one side of the foot spring-mounted so that it can ride at a different height than the other side, allowing it to follow a previously sewn seam where one side of the seam is thicker than the other. The thicker side of the component is butted against the fixed side of the presser foot. This foot is particularly well-suited for top-stitching where the top stitch is sewn very close to the edge of the fold (usually about 1/16").

B. Visual Aids

Notches and drill holes in fabric are one type of visual aid that was frequently observed. These aids are put into the component parts of the garments at the time that they are cut. Notches are most often used to align two pieces of fabric longitudinally along the edge, whereas drill holes are more likely to be used to locate the position of a set-on piece, such as a pocket, that is not located at the edge of a panel.

Pieces of colored tape are often applied to the table of the sewing machine as a visual aid to the operator. These tape marks are used to facilitate the initial positioning of a panel, so that

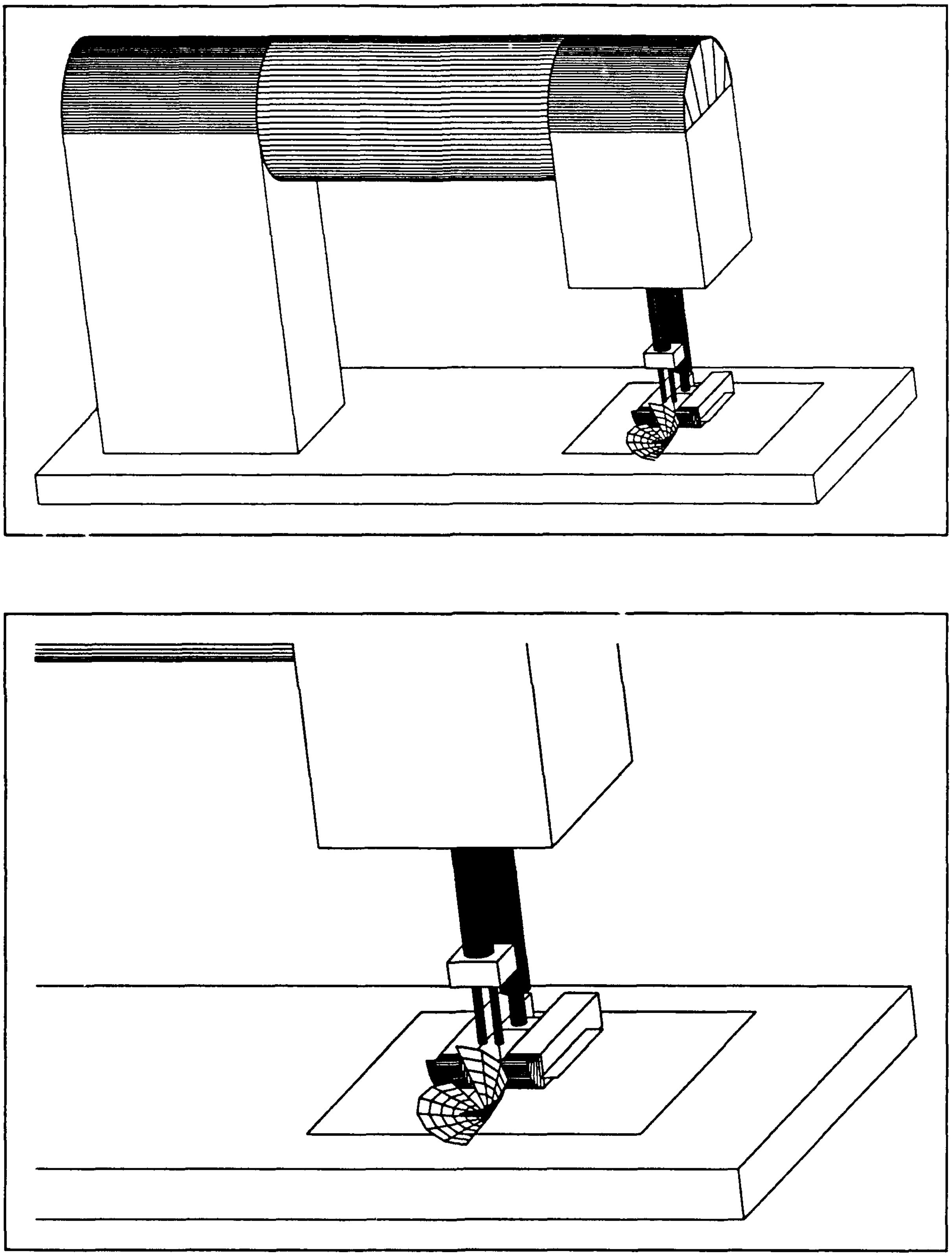


Figure 2. Sewing Machine with Attached Folder

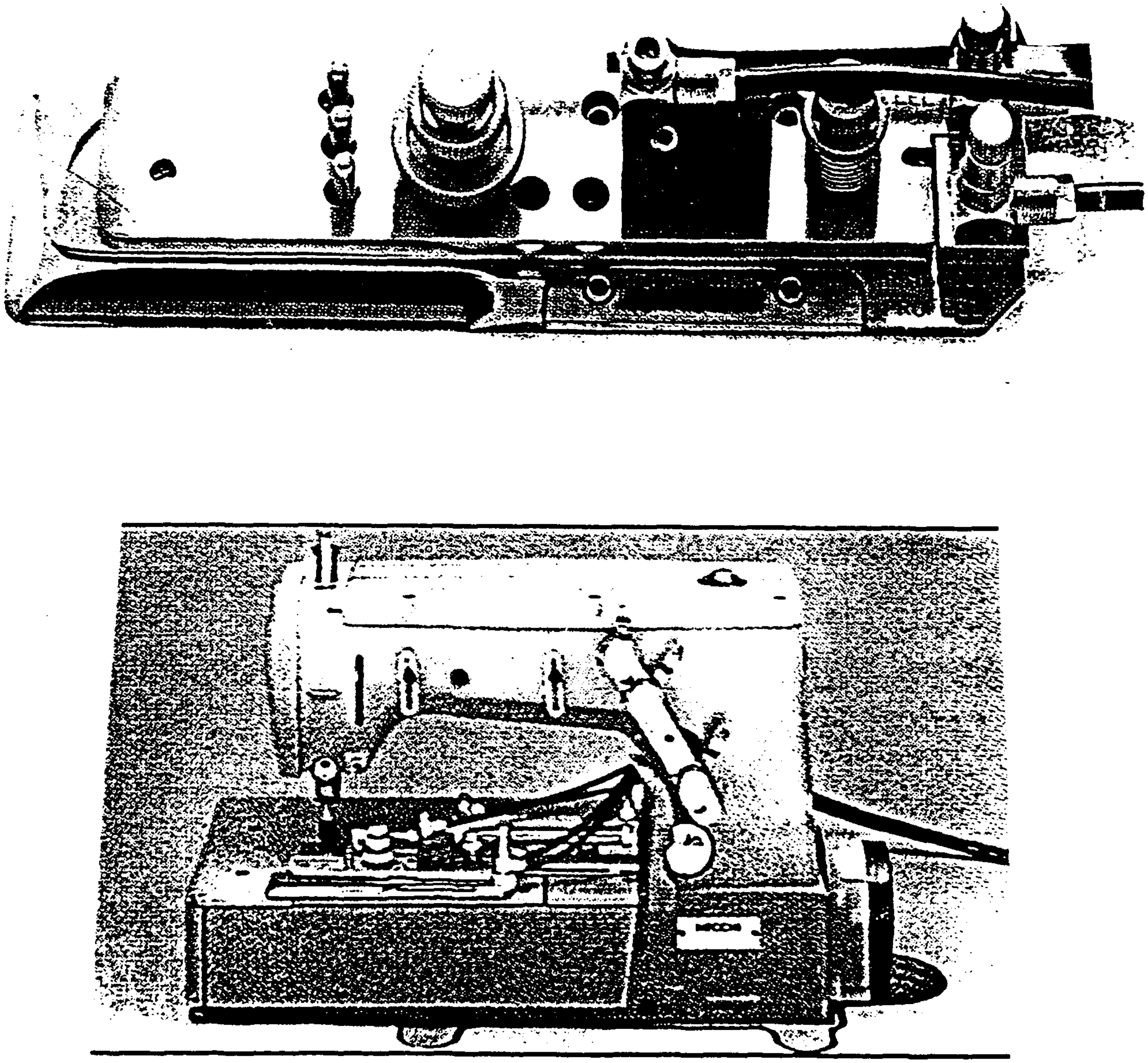


Figure 3. Zyppy Sewing Machine Attachment

the sewing needle will start in the proper location, or in a manner similar to an edge guide, where the fabric edge is held in alignment with the tape mark as the fabric is drawn through the machine.

Chalk marking of component parts is commonly utilized for locating items such as seams and buttonholes. Cardboard templates are often used for location of the chalk marks.

Crosshair projectors were observed at several locations. These devices project a cross of light onto the fabric at the table level, providing a point location at the intersection of the two crosshairs. These devices are particularly suited to initial location of components relative to the sewing needle where the major point of reference is in the center of the component rather than at the edge (such as a buttonhole). A crosshair projector is shown in Figure 4.

C. Advanced Location Systems

The simplest of the advanced systems are the electronic photocells. These devices find numerous applications in automatic and semi-automated equipment, and are most frequently employed in some form of edge-sensing capacity. Photocells are generally one of three types: 1) through-beam, with a separate light source and receiver, 2) retro-reflective, with the light source and receiver packaged together in one unit, and a piece of reflective tape applied to the machine table or similar location, and 3) ambient light sensing, where the photocell detects the level of incoming ambient light. In all cases, the presence of fabric is detected when the fabric interrupts the light beam or obscures the photocell from ambient light.

The signal from a simple photocell control is binary. In other words, the signal is either "on" or "off", indicating either the presence or absence of fabric. This signal can be used in a number of ways, the most common being starting and stopping the sewing head or other device. When used with programmable machines, the photocell can determine when the edge of the fabric being sewn is a certain distance from the needle; the machine will then sew a pre-programmed number of stitches, stopping the seam at a fixed distance from the edge of the fabric. This may be necessary for two reasons. First, it is difficult physically to locate the photocell in close proximity to the sewing needle. Second, some time must be allowed for the sewing machine to decelerate so as not to overrun the edge of the fabric. This application allows a manually-fed machine to be operated at maximum speed all the way to the end of the seam. The operator is not required to anticipate the end of the seam and slow down the machine as it approaches.

Some relatively effective edge-following fabric feed systems

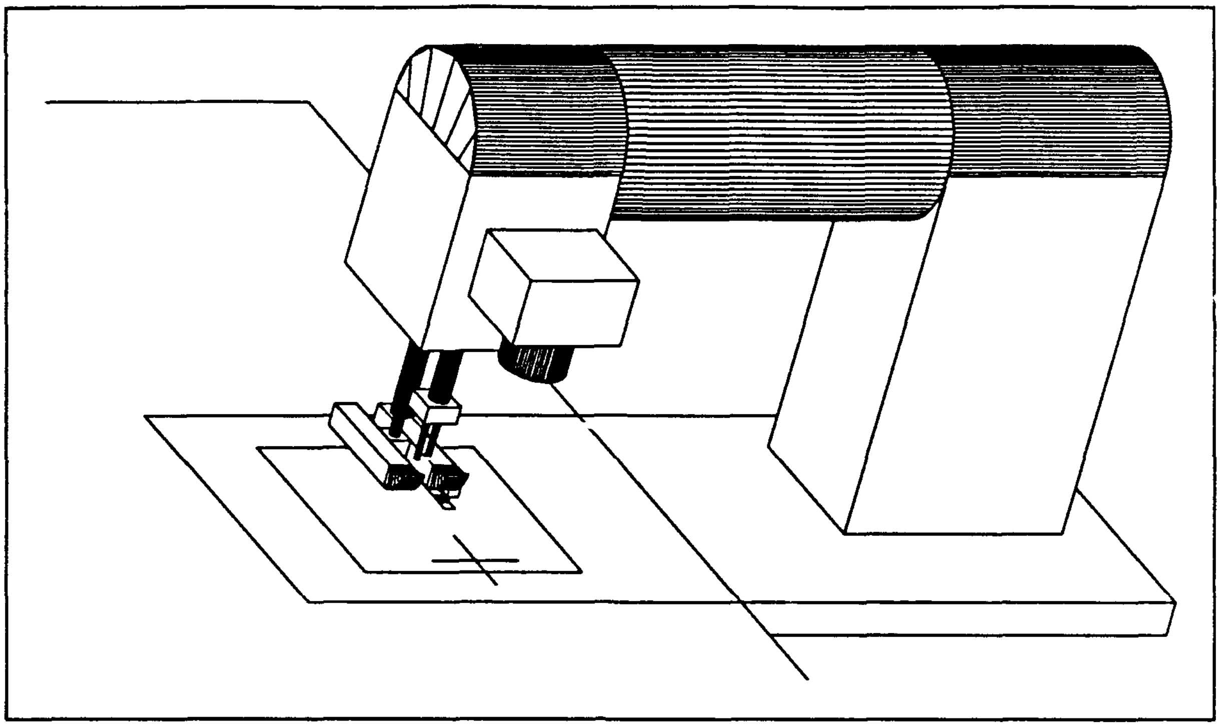


Figure 4. Sewing Machine with Crosshair Location Light

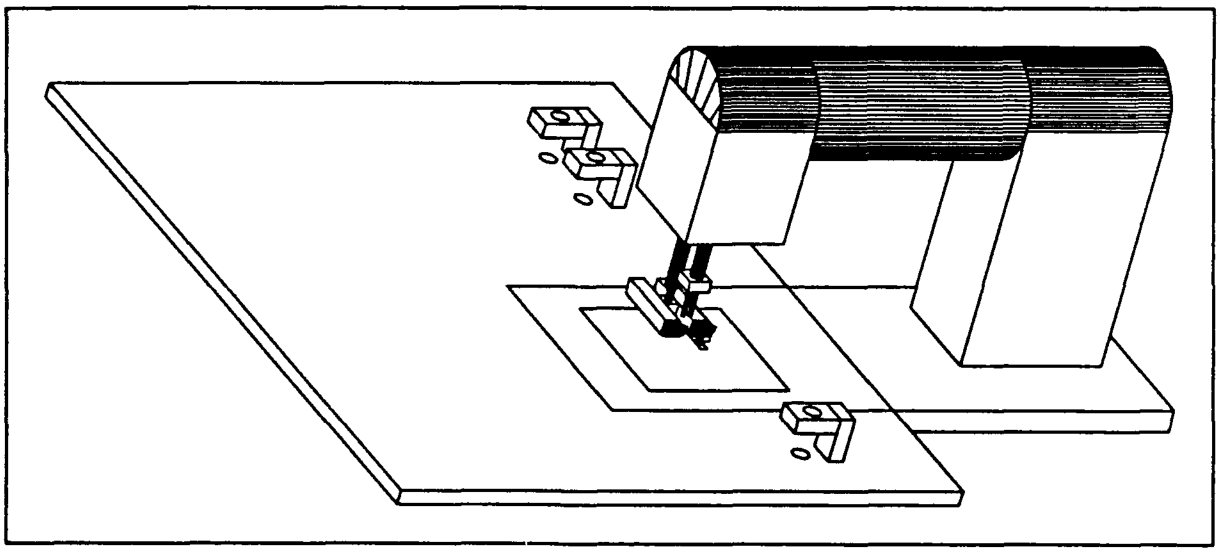


Figure 5. Sewing Machine with Photocell Part Detection

have been developed using photocell control. A variety of automatic sergers were seen that utilize photocells to guide the fabric into the needle by raising and lowering a pinch point that causes the fabric to be pulled into or away from the needle. This process is not highly accurate, however, and it is therefore necessary for the machine to trim excess fabric from the seam. A two-ply edge following device under development at Porter Sewing Machine Company was observed which is actually two identical edge trackers, one for each ply. The two plies are separated by a metal part that holds two sets of 10 each LEDs for the two edge trackers. Each edge tracker has 10 photocell detectors opposite the 10 LEDs. A stepper motor is used to control the direction of two undriven wheels that guide the fabric. This application is unique in that it uses a photocell array instead of a single photocell, attempting to keep half of the photocells covered. This approach provides a stepped output signal as the fabric edge moves off-center. It is not a true proportional analog signal, however, and control is less than optimum.

Photocells are used extensively in virtually all of the more automated equipment observed, including both production and prototype machines under development at Ark, Inc. and Jet Sew. A common application is for edge alignment, such as the case of picking a shirt front from a stack of cut parts and transporting it to a moving conveyor. Two or more photocells located at various points along the length of the panel are utilized to detect the edge of the fabric and stop the motion of the panel at that point, providing initial alignment of the edge of the panel (in one dimension only) before it is fed to the sewing head. Additional photocells are typically used to detect the arrival of the panel at the sewing head and to start the sewing operation or activate some other part of the process. An application of this type is indicated schematically in Figure 5.

A very interesting two-dimensional positioning system was seen on the prototype knitwear (sweatpants) machine under development by Jet Sew. This machine has the ability to align the corners of the top and bottom panels of the sweatpants prior to joining. This location task is accomplished by two photocells at each corner. The material is gradually moved in two directions until the corresponding photocell "sees" the edge, thus locating the corner in two dimensions. A similar control strategy is used by the pocket machine developed by Ark, Inc. One of the major limitations of photocells for location is their lack of flexibility to accommodate a variety of shapes and sizes. The photocells must be physically relocated to adjust the machine to a different style.

A specialized application of photocells are those that utilize fiber optic cables for remote location of the light source and receptor. This approach allows these components to be located in a much more confined space than would normally be possible with a single-component device. An interesting application of this technology was seen in the full fell seamer demonstrated by $(TC)^2$ at the Bobbin show in September. The remote components are actually imbedded within the complex folder used to guide the fabric to the sewing needle. A toothed wheel is directed by the photocell to ensure that the material is properly inserted into the folder. A second application of fiber optic cable technology was seen in a prototype Juki 2-dimensional machine developed under the MITI project. This machine is capable of independent control of top and bottom fabric feed and position. Two fiber optic cables are used to independently detect the edges of two parts being joined.

The use of video camera vision systems in apparel manufacturing equipment to-date has been limited to prototype equipment. A number of systems were seen on MITI developed equipment. An automated spreading machine uses a camera to determine the alignment of plaid fabrics and to automatically adjust the fabric to ensure proper cutting. Cameras are also used on the automatic fabric defect detection unit incorporated prior to the automatic spreading machine. At $(TC)^2$'s research and development center, a Singer-developed trouser machine was seen that uses two computerized camera vision systems to locate trouser fronts and backs for joining by two digitally controlled sewing heads. The vision system utilizes conventional video cameras located approximately 13 feet above the machine table to define the outline of the parts, which are then transported to the sewing head for the joining operation. The vision system provides 512 x 512 lines of spatial resolution. This unit is still far from production use and has several remaining problems to be solved.

$(TC)^2$ research personnel noted that the vision system is limited to a silhouette view only and cannot see detail inside of the outline of the fabric. There is some loss of positioning accuracy as the fabric moves from the measurement table to the sewing head, and these errors are cumulative as the fabric moves further down the machine. The physical size, including height, of the unit is prohibitive, as would probably be the cost of a production model. The unit is also relatively slow, although current computing technology could probably improve this aspect significantly.

IV. CURRENTLY AVAILABLE LOCATION TECHNOLOGIES

In order to automate the process of apparel assembly, there are many tasks that require visual guidance. Most of these have been identified and discussed in the preceding sections. This section will discuss some of the options and techniques available to provide this visual information which could be used for machine control.

A. Background and Terminology

Most of the sensors used for obtaining visual information today are based on solid state technology. Some of the various devices as well as the terminology used when referring to solid state sensors are described below. Solid state photodetectors, are devices that are responsive to electromagnetic radiation in the visible, infrared, and/or ultraviolet spectral regions. A brief description of the device types and the technologies and their operating principles follow:

1. Device Types:

Photodiode: A diode responsive to radiant energy and characterized by linearity between the input radiation and the output current. It has faster switching speeds than the phototransistor. Photodiode matrix sensors are in general sensitive and have more uniform and better spectral response as well as a higher quantum efficiency.

Phototransistor: A transistor (bipolar or field-effect) that is intended to be responsive to radiant energy.

Charge-Coupled Device (CCD): A charge-transfer device that stores charge in potential wells and transfers this charge almost completely as a packet by translating the position of the potential wells. This is related to a charge coupled image sensor which is a charge coupled device in which an optical image is converted into packets of charge that can be transferred as the electrical analog of the image. These devices can further be broken down into two types: interline and frame transfer CCDs. With interline transfer there is some dead space on the sensor as the photo-sites are non-contiguous. With frame transfer CCDs the photosites are contiguous and provide more accuracy in measurement applications.

Charge Injected Device (CID): Performance as good as CCDs, whole image area photosensitive, resistant to blooming. CIDs can also be non-destructively sampled.

Metal-oxide Semiconductor (MOS): Suffer from low sensitivity and random and fixed pattern noise. Also, has a tendency to exhibit lag due to incomplete charge transfer.

Charge Prime Device (CPD): A hybrid MOS/CCD sensor. A attempt to overcome the noise limitations of MOS sensors and also to increase the dynamic range.

Time Delayed Integration Sensor (TDI): A line scan sensor that displays high sensitivity and is capable of operating at very low light levels.

2. Performance Definitions:

Quantum Efficiency (of a photosensitive device): The fractional number of effective electron-hole pairs produced within the device for each incident photon. For devices that internally amplify or multiply the electron hole pairs, such as phototransistors or avalanche photodiodes, the effect of gain is to be excluded from quantum efficiency.

Quantum Efficiency, External (of a photo emitter): The number of photons radiated for each electron flowing into the radiant source.

Saturation Exposure: The exposure (light intensity * integration time) level that produces a saturation output charge (unit energy/unit area).

In the early 1970's, the lack of proper devices in the field of optical sensors initiated a desire to examine the potential application of solid state devices CCD's (Charge Coupled Devices) and CID's (Charge Injected Devices) for implementing solid state image sensors with high resolution capability and good uniformity.

The CCD sensor was developed in 1969, at Bell Labs, while searching for an electrical analog to magnetic bubble memory. The CID devices were developed by General Electric. These sensors have since been used in a variety of configurations (line, matrix and circular arrays) for a variety of imaging tasks.

B. Commercial Solid State Sensors

There are several manufacturers of solid state image sensors, these include:

EG&G Reticon
Fairchild Weston
Dalsa
Kodak
Sony
Hitachi
Centronic

Phillips
Hamamatsu
Texas Instruments

C. Line/Linear Array Sensors

Line or linear array sensors consist of a single line or column of sensor elements. These are made in resolutions that go typically from 128 to 2048 elements. Traditional imaging using these devices therefore requires relative motion between the material being imaged and the sensor.

The typical sensor elements in line sensors consists of photodetectors (silicon photodiodes) that can be obtained as single elements of varying sizes to linear arrays as well as CCD sensors. Minimum separation for the CCD sensors are on the order of 20 - 30 micrometers while it is about 1.0 mm for photodetectors allowing the CCD to provide much higher resolution and accuracy than the photodiode devices.

CCD sensors are typically more sensitive and come in packages that have built in circuits for providing video type output from the sensor sites. This makes for easier interfacing to computer equipment. Photodetectors can also be bought in packages that have built in interface electronics.

CCD array prices can vary based on the number of sensor elements, the sensitivity of the sensors, as well as the functionality provided by a particular package. Table 3 lists some available sensors along with prices and performance information.

One line sensor of note, is made by Dalsa and is capable of operating at fairly low light levels. It uses a technique called TDI (Time Delayed Integration) allowing for shorter integration times and tries to capitalize on the relative motion requirement for using line sensors. It provides increased sensitivity based on the number of stages in the sensor. A 32 stage sensor can improve performance by 32 times while a 128 stage sensor is capable of a 100 fold increase when compared to a single stage. The requirements for proper operation of the sensor is very close coupling between the motion of the material being imaged and the sensor.

D. Area/Matrix Sensors

These sensors are constructed using the same technologies as line (linear array) sensors except that the detector elements are arranged in a matrix. This then enables the acquisition of a

TABLE 3

IMAGING SENSOR SPECIFICATIONS								
Manuf.	Type	Model	No. Pix.	Size (mm)	Tech No.	Sensiti. (mj/cm2)	ScanRate (MHz)	Price ($)
Fairchild/Weston	Linear	CCD 111-ADC	256	9.9	CCD	0.5	10	47
Fairchild/Weston	Linear	CCD 111-BBC	256	9.9	CCD	0.5	10	120
Fairchild/Weston	Linear	CCD123	1728	27.43	CCD	0.31	2	80
Fairchild/Weston	Linear	CCD134	1024	20.7	CCD	0.33	20	165
Fairchild/Weston	Linear	CCD143A	2048	32.77	CCD	0.67	20	145
Fairchild/Weston	Linear	CCD145	2048	32.77	CCD	0.27	5	285
Fairchild/Weston	Linear	CCD151	3456	32.77	CCD	0.36	5	215
Fairchild/Weston	Linear	CCD153A	512	20.7	CCD	0.67	20	N/A
Fairchild/Weston	Linear	CCD181	2592	32.77	CCD	0.3	20	250
EG&G	Linear	RL0256D	256	3.33	CCP	0.47	20	80
EG&G	Linear	RL0152D	512	6.66	CCP	0.47	20	125
EG&G	Linear	RL1024D	1024	13.31	CCP	0.47	20	195
EG&G	Linear	RL2048D	2048	26.62	CCP	0.47	20	220
EG&G	Linear	RL1282D	256	4.61	CCPD	0.45	15	300
EG&G	Linear	RL1284D	512	9.22	CCPD	0.45	15	800
EG&G	Linear	RL1288D	1024	18.43	CCPD	0.45	15	150 0
EG&G	Linear	RL0128G	128	3.2	CCD	1.8	15	60
EG&G	Linear	RL0256G	256	6.4	CCD	1.8	15	100
EG&G	Linear	RL0512G	512	12.8	CCD	1.8	15	180
EG&G	Linear	RL1024G	1024	25.6	CCD	1.8	15	360
EG&G	Linear	FL1024H	1024	15.37	CCD	3	15	375
EG&G	Linear	RL1728H	1728	25.92	CCD	3	15	735
EG&G	Linear	RL2048H	2048	30.71	CCD	3	15	730
EG&G	Array	RA0128NAQ-020	128*128	5.994*5.994	CCPD	?	10	125 0
EG&G	Array	RA0128NAQ-020	128*128	5.994*5.994	CCPD	?	10	100 0
EG&G	Circular	R00064NG	64	2mm Diameter	CCPD	34 pA/uWatt /cm^2	2.5	195
Texas Instruments	Linear	TC102-1	128	0.93	CCD	0.005	10	32
Texas Instruments	Linear	TC103	2048	24.95	CCD	0.005	10	82
Texas Instruments	Linear	EC104	3456	36.67	CCD	0.004	8	108
Texas Instruments	Linear	TC106-1	2592	24.95	CCD	0.004	8	69
Texas Instruments	Linear	TC210	192*165	2.64*2.64	CCD	0.004	7.16	732

traditional looking image from one scan of the sensor array. These are the sensors that are employed in most video camera type applications.

E. Vision Systems

Figure 6 shows the diagram of a general vision system. The major components of the system are a camera, a frame grabber, and a computer. The function of the camera is to acquire the image. The frame grabber then generates a digitized version of the image from the analog signal provided by the camera. This digital representation is then processed by the computer to extract information concerning the scene.

The system described above, is that of a camera with a matrix sensor; similar systems are constructed using linear sensors and are called line scan systems. The overall principle of operation is the same as a system with a matrix array except that to obtain a traditional image with a line scan system, there needs to be relative motion between the camera and the object being imaged.

Processing on the digitized data from these systems are conducted using a combination of hardware and software. Data processing in software basically consists of computer programs to manipulate the data, while hardware processing would be implemented using specialized chips such as math co-processors or DSPs (Digital Signal Processors). Special hardware processors are utilized whenever processing speed is of the essence.

F. Specific Systems

The IRI SVP-512 vision system typifies the functionality provided by most commercially available vision systems. This system is capable of accepting up to eight camera inputs and provides many of the standard machine vision algorithms implemented in both hardware and software.

This functionality is also available in other packages some of them personal computer based. The series of PC based boards from Matrox and Imaging Technologies are examples of these systems.

A recent introduction is the Maxvideo 20 board from Datacube which provides the functionality of 20 of their previous boards implementing many vision functions in hardware.

Line scan systems of similar functionality are also available, an example is a system from Digital Design. Various PC based implementations are now becoming available with systems from companies such as Data Translation, Epix, and Imaging Technology.

The typical cost of the above systems including cameras, is in the $10,000 to $20,000 range.

A lower cost alternative that is applicable to apparel manufacturing functions is a system designed at Georgia Tech. This system is able to achieve its reduced cost by taking a different approach to that described in Figure 6. Instead of generating an analog signal which is then digitized, the microprocessor reads the information from the CCD image sensor directly and then carries out its operations on this data. This approach simplifies the overall design and makes for a more cost effective system. An additional benefit, is that for operations that require accurate measurements, the direct pixel position information is obtained, eliminating the analog stage; this increases the accuracy and repeatability of position information obtained from the camera. The projected cost for this system is $1000 to $1500. This system is currently bein, marketed by Dickerson Vision Technologies , Inc. This design could also be modified to obtain a low cost line scan system.

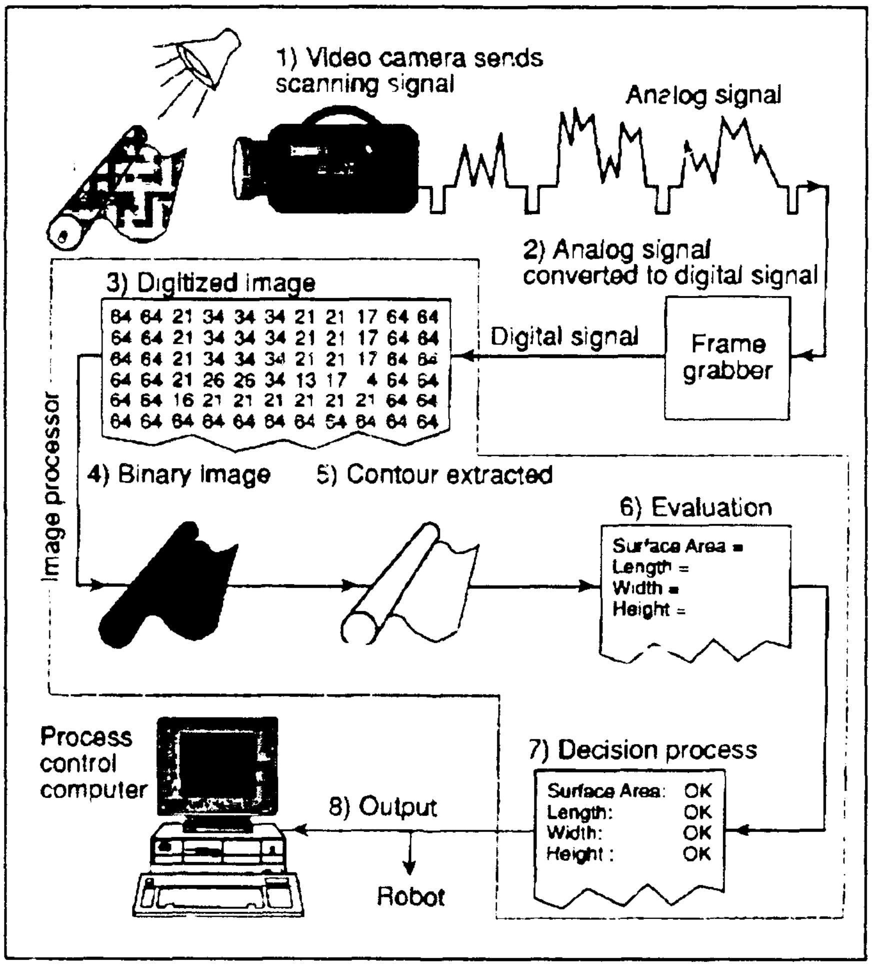
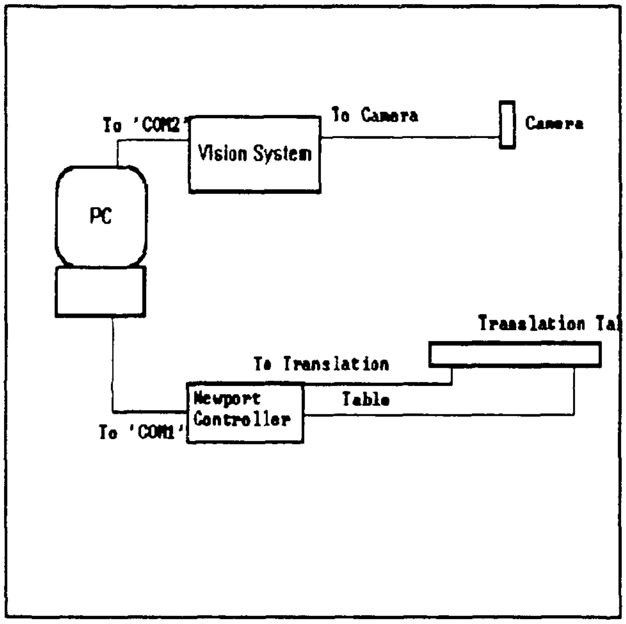


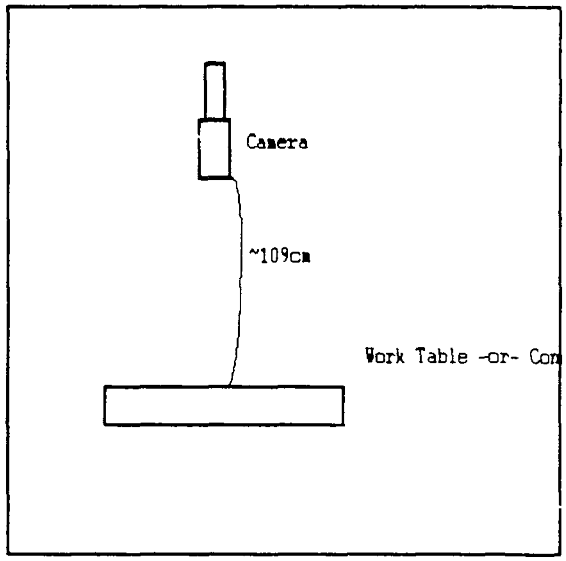
Figure 6. Vision System Operation

G. Vision System Accuracy Tests

In order to determine how accurate commercially available visions are in determining location, tests were conducted on an IRI SVP-512 vision system and an AdeptVision system used for robot guidance. A performance test procedure developed by the Automated Vision Systems Association, AVA, (American National Standards Institute, "For Automated Systems--Performance Test--Measurement of Relative Position of Target Features in Two-Dimensional Space", ASNI/AVAA15.05/1-1989) was conducted on each system using lenses with varying focal lengths. What follows is a summary of how the tests were conducted and the results. Details of the test procedure are given in Appendix D.



System Setup



Camera Setup.

1. Equipment

The equipment used to perform the Vision Systems performance test is as follows:

1. A Newport Model 855C controller with 2 linear actuators (accurate to .0001 mm).

2. An IBM PC compatible.

3. Adept system with AdeptVision XGS option and a PULNIX TM-540 camera with various lenses.

4. SVP512 Vision System Camera. (Both systems had a resolution of 512 x 512 with 8 bit gray scales.

2. Test Procedure

The techniques for conducting the accuracy tests are described in the Appendix. The tests performed are called the "SINGLE-POINT STEADY RATE" and the "SINGLE-POINT CYCLE TIME" and were as specified by the AVA and provides the same information as far as determining positional accuracy. The data from the accuracy tests are presented in Table 4. Accuracy denotes the confidence in making a measurement anywhere in the camera's field of view while repeatability denotes the confidence in measuring an object at a particular point repeatedly.

TABLE 4

RESULTS OF VISION SYSTEM ACCURACY TEST

System: AdeptVision XGS Package
Field of Measure: 100mm x 100mm

Lens Focal Length	Accuracy mm (in)	Repeatability mm (in)
25 mm	1.65 (0.065)	0.55 (0.022)
50 mm	0.76 (0.030)	0.20 (0.008)
Telephoto at 30mm	0.90 (0.035)	0.33 (0.013)

System: SVP512 Vision System
Field of Measure: 100mm x 100mm

Lens Focal Length	Accuracy mm (in)	Repeatabilituy mm (in)
50mm	0.30 (0.012)	0.02 (0.001)

3. Test Results

It should be remembered that the accuracy numbers are a function of the system configuration (lighting, optics etc.) but are representative of what would probably be obtained in practice. This test also locates a part in x-y space, and does not denote the accuracy for say locating an edge, which could be much higher, as subpixel interpolation techniques could then be used. In apparel applications, the typical accuracy required is on the order of 1/32nd of an inch (0.03 inches). The above data shows that in about a 4x4 in (10x10 cm) area these accuracies can be achieved with current vision technology.

H. Fiber Optic Sensors

With the advent of fiber optic conductors, systems that integrate fiber optic cables and photoelectric sensors are now available. Photoelectric sensors are basically photo transistors and photo diodes with the needed electronic circuitry to make them operable. Optical fibers can then be used to guide light to and from these sensors. The advantages of these integrated units are: operable in tight sensing locations, inherent noise immunity, vibration, and shock resistance. It is also relatively easy to design custom sensors for position sensing. Fiber optic assemblies can be made as small as hypodermic needles. Their main function is to detect the presence or absence of objects.

I. Apparel Applications

While traditional vision systems have fallen in cost and increased performance in the past few years, the prices are still above what some manufacturers are willing to invest. This is particularly true in high volume low profit margin operations, such as the apparel industry.

Advances in the development of optical sensors are impressive, however, and the approach taken by Dickerson Vision Technologies whereby low cost systems are developed by directly interfacing computers to their sensors could be a viable solution for the apparel industry. Typical applications would be in part location and guidance. An adaptation of the Dickerson Vision Technologies (DVT) concept could produce both line and area systems in $500 to $700 range with the required functionality, for some of the tasks outlined in the previous sections. This could then lead to the implementation of automated machinery with built-in part location and seam tracking capabilities.

Possible systems that should be evaluated would include a low cost position location system that could be used to locate and register parts.This could be obtained by modifying the hardware and software in the DVT camera to provide these outputs. This system could then be used to provide feedback for part location. Another potentially useful development would be a system that provides feedback control for edge guidance. This could be implemented using one or two line sensors, integrated with a microprocessor system, to sense edge position and then provide control signals to maintain a desired path.

V. LOCATION TECHNOLOGIES FOR NEXT GENERATION APPAREL ASSEMBLY EQUIPMENT

Based on the surveys of existing apparel industry requirements, the state-of-the-art in location technologies, and currently available vision systems, two applications have been identified for application of advanced location technologies in apparel production. First, in many apparel joining processes it is necessary to locate a point on the cut part as a reference for part folding or as a starting point for sewing. An excellent example of this type of operation is determination of the location of the corners in the $(TC)^2$-Jet Sew sweat pant machine. Two photocells are located at the points where the two edges extending from a corner on the cut part will be located when the corner is at the proper location. The part is first moved until one of the photocells is obstructed and is then moved perpendicular to the original direction until the second photocell is obstructed. This process is repeated on the second corner prior to folding the sweat suit panel. The sequential movement required by this process is quite time consuming and the fixed positions of the photocells limits the versatility of the location system. This would appear to be an excellent application for a simple low-cost area camera system similar to the device marketed by Dickerson Vision Technologies, Inc. Although this location device currently sells for approximately $1,000, it is expected that a price in the range of $500 might be possible in volume production. A $500 price is in the range that can be considered for location technologies by manufacturers of apparel production equipment.

A second area of interest for location technologies is the large number of assembly processes that employ some method of edge following. Examples are numerous--part serging, trouser side-seaming, etc. These types of operations should benefit by use of location technologies based on line or linear array sensors. Two such sensors could be employed to sense the edge of a part and provide signals to a suitable device controlling the position of a part being sewn. One application could be as the sensing device for coupling to the Porter Sewing Machine Company Automated Side-Seamer. This machine has a relatively low resolution diode array system that provides very limited control of the parts being joined. For example, it will follow edges that are straight or slightly curved but it cannot follow even moderate radii of curvature. An improved location system and some redesign of the part control mechanism could greatly improve the versatility and broaden the applicability of the Porter Side-Seamer. A modification of the Dickerson approach especially adapted for a linear array detector would be developed for this application.

Discussions have been held with $(TC)^2$ and Jet Sew relative to working with Georgia Tech on an improved vision system for the sweat pant machine. Both have expressed interest in a possible joint project. Close ties have also been established with Russell Corporation, the principal site for utilization of the sweat pant machine, and they would probably be willing to cooperate in such a project. Porter Sewing Machine and Tennessee Apparel Corporation are good candidates for working jointly on an improved automated side-seamer for military dress trousers. One or both of these two potential applications for improved location technologies in apparel assembly will be the subject of future proposals to DLA as implementation efforts following the current project.

APPENDICES

Appendix A-1	Tolerances Specified for Military Men's Shirts
Appendix A-2	Tolerances specified for Military Men's Trousers
Appendix B-1	Survey of Location Technologies at Southern Tech AAMTDC
Appendix B-2	Survey of Location Technologies at FIT AAMTDC
Appendix B-3	Survey of Location Technologies at Clemson AAMTDC
Appendix B-4	Survey of Location Technologies at $(TC)^2$
Appendix B-5	Survey of Location Technologies at DPSC Factory
Appendix B-6	Survey of Location Technologies at Martin Manufacturing
Appendix B-7	Survey of Location Technologies at Tennessee Apparel
Appendix B-8	Survey of location Technologies at Arrow Shirt
Appendix B-9	Survey of Location Technologies at Oxford Industries
Appendix B-10	Survey of Location Technologies at Arc., Inc.
Appendix B-11	Survey of Location Technologies at Jet Sew
Appendix C-1	Travel Report JIAM Exhibition '90
Appendix C-2	Survey of Location Technologies at Bobbin '90
Appendix D	Determination of the Repeatability and Accuracy of current Vision Systems

Appendix A-1
Tolerances Specified for Military Men's Shirts

No.	Manufacturing Operation	Tolerance (inch)
1.	Cutting	
	a. Cut shirts accordance with patterns	
	b. Cut component parts	
	c. Cut the interlinings	
	d. cut pocket and flap	5/32 ± 1/32 larger on three sides
2.	Replacement of defective components	
3.	Component marking	
	a. Mark all components of the shirt	
	b. Use of ink pad numbering machine	
	c. methods should be avoided	
4.	Labeling	
	a. Center size marking on top collar stand	1/4 off center tolerance
	The bottom of the marking	3/8 ± 1/8 from the seam joining
	b.Position the instruction label	
	The bottom of the label	1-1/2 ± 1/2 from the hemmed bottom
	The side of the label	2-5/8 ± 3/8 from the front folded edge
	c. Stitch the identification label	
	d. Position the yellow combination label	
5.	Make cuffs	
	Finished appearance	
	Width of cuff	2-7/8 ± 1/8
	a. Position interlining and stitch	9/32 ± 1/32 from folded edge
	b. Join the plies of the cuff	
	Turn, single stitch	7/32 ± 1/32 from edge
	Edge stitching	1/2 ± 1/8 from top edge
	c. Make horizontal buttonhole	1/4 inch off center tolerance
	The inside cut edge of it	1/2 ± 1/8 from front edge
	d.Press cuffs	

No.	Manufacturing Operation	Tolerance (inch)
6.	Make collar	
	a. Unslotted collar stay holder construction	
	(1) Position fusible interlining to top collar	1/16 from top and side edges and fuse
	(2) Position stay holder	
	(3) Stitching the stay holder to undercollar with	two rows of stitching 15/32 ± 1/32 apart
	(4) Insert collar stay tapered end	1/16 inch from the top edge
	b. Unslotted collar stay ultrasonically fused construction	
	(1) Position fusible interlining to top collar	1/16 inch from top and side edge and fuse
	(2) Position collar stays	
	(3) Ultrasonically fuse the collar stays to the undercollar	
	c. Slotted collar stay stitched construction	
	(1) Position fusible interlining to top collar	1/16 inch from top side edges and fuse
	(2) Position collar stays tapered end	1/16 from the top edge stitching
	(3) Stitch collar stays to the undercollar	1-3/8 ± 1/8 long tack
	d. Stitch collar and undercollar	
	e. Work out edges and points	
	f. edge stitch top and side	7/32 ± 1/32 from collar edge
7.	Make collarstand and attach collar	
	a. Fold back the bottom edge of the undercollar stand Stitch	7/32 ± 1/32 3/32 ± 1/32
	b. Superimpose interlining and top collarstand and stitch	3/32 ± 1/32
	c. Place collar between the top and undercollar stand, stitch Raise stitch	7/32 ± 1/32 from edge 5/64 ± 1/64 from turned edge
	d. Press collar and collarstand	

No.	Manufacturing Operation	Tolerance (inch)
8.	Make shoulder loops	
	Finished appearance Width	 1-15/16 ± 1/16 at the armhole seam 1-7/16 ± 1/16 at the pointed end
	a. Stitch the three plies of the should loop and interlining	
	b. Turn loop, edge stitch	7/32 ± 1/32 from edge
	c. Make a horizontal buttonhole in the center of each loop inside cut edge of the buttonhole	1/8 inch off center tolerance 7/16 ± 1/16 from point of loop
	d. Press shoulder loops	
9.	Make pocket flaps	
	a. Position the pocket flaps Turn, edge stitch	 7/32 ± 1/32 from side and bottom edges
	b. Make one vertical buttonhole Lower inside cut edge	1/8 off -center tolerance 7/16 ± 1/16 from bottom edge of flap
	c. Press pocket flaps	
10.	Hem breast pocket Fold under top edge of pocket raw edge turned Stitch Hem width	 under 1/4 1/16 from the folded edge 1-3/8 ± 1/8
	-or-	
	Overedge stitch top raw edge of pocket and turn top of pocket Hem width	 1-5/8 ± 1/8
11.	Make fronts	
12.	Make and set pen pocket	
	a. Fold under top edge Mark with the raw edge turned Stitch Finished hem width	 under 1/4 1/16 from the folded edge 1 ± 1/8

No.	Manufacturing Operation	Tolerance
12.	Make and set pen pocket (cont'd)	
	-or- Overedge stitch top raw and turn top of pocket, Hem width	1-1/4 ± 1/8
	b. Turn in the side edges Finished width	3/8 2-1/4 ± 1/8
	c. Vertical stitching at the center	± 1/8 from top to bottom of pocket
13.	Attach pockets and flaps	
	Finished appearance Pocket depth finished width	 5-7/8 ± 3/16 4 -1/2 ± 3/16 for size 13 through 14-1/2 5 ± 3/16 for size 15 through 16-1/2 5-1/2 ± 3/16 for size 17 through 18
	a. Stitch pockets on fronts Continuing stitching	3/32 ± 1/32 from edge 5/16 ± 1/16 across top of pockets 9/16 ± 1/16 down to the first stitching
	b. Press fronts	
	c. Position and stitch flap Raise stitch Finished top folded flap edge	5/32 ± 1/32 from raw edge 7/32 ± 1/32 from turned edge 3/4 ± 1/8
	Attach yoke	
	Finished appearance a. Position back of shirt	
	b. Press back and yoke	
	Make sleeve openings	
	Finished appearance Sleeve opening shall measure	 5-1/2 ± 1/2 long exclusive of cuff
	a. Turn, insert the edges of sleeve opening Width of binding	1/4 ± 1/16 into binding and seam 5/8 ± 1/8
	b. Turn, Stitch through binding and sleevc -or-	3/16 ± 1/16
	Turn sleeve, stitch through binding	

No.	Manufacturing Operation	Tolerance (inch)
16.	Join shoulder seams	
	Position fronts, stitch	
17.	Set shoulder loops	
	Position shoulder loop Point of loop	 1/4 ± 1/8 back of shoulder seam 3/8 ± 1/8 from collar
	front edge of loop at armhole opening Stitch	1 ± 1/8 forward of shoulder seam 5/32 ± 1/32 from raw edge of opening
18.	Set sleeves	
19.	Join side and underarm seams	
	Seams	1/4 tolerance
20.	Join collar to shirt	
	Finished appearance Collar ends uneven in length Stitching down collarstand	 1/8 1/8 on or off the opposite stand
	a. Fold front facings of shirt	
	b. Turn in the top collar stand Stitch	 3/32 ± 1/32 from turned edge
	-or-	
	Stitch top collarstand and interlining to inside of shirt	
	c. Stitch down the under collarstand	3/32 ± 1/32 from turned edge
21.	Hem shirt bottom	
	Hem width	7/32 ± 1/32
22.	Join cuffs to sleeves	
	a. Seam on the underside	
	b. Stitch cuff and interlining to the bottom of sleeve	on the outside 3/32 ± 1/32 from edge
	-or- Finish attachment as a. and b. above Backtack another line of stitching	

No.	Manufacturing Operation	Tolerance (inch)
23.	Make buttonholes	
	a. Make six vertical buttonholes Position	 3/4 ± 1/16 in from front edge
	b. Make one horizontal buttonhole in center of collar Front inside cut edge of buttonhole	 3/4 ± 1/16 inch from front edge of shirt
24.	Clean shirts	
25.	Pressing	
26.	Sew on buttons	
	Finished appearance	± 1/16 in collarstand, front of shirt, shoulder loops, flaps and cuffs.
	Collar ends shall open	9/16 ± 3/16 when buttoned
	a. Sew one button on right end of Collar stand	
	b. Sew six buttons on right shirt front	3/4 ± 1/16 from the front edge
	c. Sew one button on inside of each Cuff	9/16 ± 1/16 from edge
	d. Sew one cotton on each shoulder seam	
	e. Sew one button on each breast pocket	
27.	Touch-up pressing and buttoning shirt	

Appendix A-2
Tolerances Specified for Military Men's Trousers

No	Manufacturing Operation	Tolerance (inch)
1.	Cut trousers	
	a. Spread the material	
	b. Cut trousers	
	c. Measurements of the direction lines	not more than 1 inch from the warp direction
	d. Cut all parts	
	e. Trousers should be cut from the same materials.	
	f. Cut the stripping buttonhole tabs	
	g. Selvage	
2.	Cut linings and interlinings	
	a. Cut the right fly	
	b. Cut left fly	
	c. Cut crotch lining pieces	
	d. Cut the waistband linings and interlinings	
	e. Cut waistband stabilizer	
	f. Cut rubberized waistband material	
	g. waistband materials	
3.	Cut pockets	
4.	Marking	
5.	Replacement of damaged parts	
6.	Overedge stitching	
	a. Overedge the seam allowance of foreparts	
	b. The folded crotch lining	
	c.Overedge the seam allowance of backparts	

No.	Manufacturing Operation	Tolerance (inch)
6.	Overedge Stitching. (cont'd)	
	d. Overedge the left end of the waist-band	
7.	Make stripping for buttonhole tab and belt loops.	
	a. Fold stripping -or- b. Fold stripping -or- c. Fold stripping	not less than 1/16 from edge 11/32 ± 1/32 wide
8.	Make hip pocket buttonhole tab.	
	a. Cut stripping	1-1/4 ± 1/8 long
	b. Place bartacks	5/8 ± /16 from the first tack 7/16 ± 1/16 long
9.	Make fly tab (applicable if separate tab piece is used)	
	a. Stitch the two fly pieces	3/32 ± 1/32 from edge
	b. Make buttonhole	11/16 ± 1/16 form edge
10.	Make flies	
	a. Stitch back edge of fastener tape to left fly	Scoops 3/8 ± 1/8 above the fly notch 9/16 ± 1/16 from edge at top 5/16 ± 1 /16 from edge at bottom
	b.Stitch the fastener tape to right fly	3/8 ± 1/8 above the fly notch
	c. Seam the fly lining -or-	9/16 ± 3/16 from the top raw edge 1 ± 1/4 from top of fly
	d. seam lining to the front edge of right	1 ±1/4 from top to fly
	e. Make flies	
11.	Seam darts in back (all classes)	
	a. Fold the back	3/8 inch from cut edges at the top
	b. Press darts	

No	Manufacturing Operation	Tolerance(inch)
12.	Make hip pockets and attach labels Finished appearance	$6 \pm 1/4$ deep 5-1/4 $\pm$ 1/8 long
	a. Position the identification and label.	
	b. Turn in bearer and seam	
	c. Position cord facing	
	d. Cut opening	$3/32 \pm 1/32$ cord edge
	e. Turn in raw edges of cord facing	
	f. Fold pocketing.	
	g. Smooth out pocketing and single stitch	$11/32 \pm 1/32$ from edge
	h. Form facing on the upper edge, insert buttonhole tab at center	$5/32 \pm 1/32$ cord of the facing 1/4 inch off center tolerance
	i. Tack ends of pocket opening -or-	$5/16 \pm 1/16$ through cord
	j. Double piped pocket machine -and-	
	k. Raise stitch the joining seam	
13.	Make side pockets.	
14.	Attach side pockets.	
	Finished appearance	6-1/8 $\pm$ 3/8 between tacks
	a. Seam side pocket to front	$7/32 \pm 1/32$ from edge
	b. Fold pocket seam raw edges	
	c. Tack ends of the opening to the bearer	$5/16 \pm 1/16$ inch tack opening tolerance 1/2 inch
15.	Sew on flies.	
	a. Sew on right fly	
	b. Sew on left fly	$3/32 \pm 1/32$ back of folded edge

No.	Manufacturing Operation	Tolerance (inch)
16.	Join outseams.	
	a. Join outseams	
	b. Press outseam open	
17.	Finish side pockets	5/16 ± 1/16 from edge
18.	Ornamentation	
	Finished appearance	1/2 inch apart on each outseam
	a. Position the stripes on foreparts	1/2 or 1 from first stripe stitching 1/16 1/32 from each edge
19.	Attach waistband and set belt loops.	
	Finished appearance front edge of loop position Extra loop for larger sizes	1-1/2 ± 1/8 wide 1/8 inch from side seam 1-1/2 ± 1/4 from right joining seam
	a. Stitch right and left waistbands	
	b. Press waistband seams open	
20.	Make and join waistband lining	
	Finished appearance Waistband stabilizer	not less than 2 wide
	a. Overlap the lining	1/4 on the rubber track 1/8 from each rubber tack 1/16 from edge of lining
	Overlap the lining	1 on the interlining
	Stitch	5/32 ± 1/32 from edge
	Position waistband stabilizer and stitch	1/2 inch from edge
	b. commercial waistband -or-	
	c. The waistband stabilizer	
	d. Turn waistband lining	not deviate from the straight 3/16
	e. Tack the tops of the belt loops	
	f. Turn right end of waistband lining	
	g. Fold waistband lining.	

No.	Manufacturing Operation	Tolerance (inch)
21.	Attach hooks and eyes	
	a. Position the hook on center	1/4 off center tolerance
	b. Position the eye	
22.	Finish right and left flies	
	Finished appearance	
	a. stitching fly lining	
	b. Turn right fly lining and stitch -or-	$3/32 \pm 1/32$ from front edge
	c.Turn right fly lining and stitch	$2/32 \pm 1/32$ from front edge
	d. Stitch fly	
	e. Stitch down left fly	$1\text{-}3/8 \pm 1/8$ from front edge of fly
23.	Join inseams	
	a. Join inseams	1-1/8 at crotch to 3/8 at notch
	b. Press inseams open	
24.	Join seat seams	
	Finished appearance	
	a. Join seat seam, stitching	$3/128 \pm 1/128$ apart
	b. Press crotc h and seat seam open	
25.	Finish waistband and attach size or combination size and identification label	
	a. Top stitch the waistband seam	1/16 below the joining seam
	b. Stitch the size label	1/2 beyond ends of the label
26.	Assemble slide fastener	
27.	Stitch right fly extension	
28.	Attach center back belt loop	
	Finished appearance	

No.	Manufacturing Operation	Tolerance (inch)
28.	Attach center back belt loop (cont'd.)	
	a. Stitch, tack or bartack	3/32 ± 1/32 from folded edge
	b. Turn under bottom and bartack opening of the finished loop	1/4 ± 1/8 below waistband 1-9/16 ± 1/16 between tacks
	c. Finish belt loop attachment folded edge finished belt loops	 1/8 ± 1/16 from top of waist band 1-3/4 ± 1/8 from bartack
	d. Attach center back belt loop	
	Finished appearance	
	Bartack the loop	7/16 ± 1/16 below waistband seam
	e. Position folded edge	1/8 ± 1/16 from top of waistband
	Bartack to trousers	3/32 ± 1/32 from folded edge
	Finished back center belt loop	1-3/4 ± 1/8 from top of loop to the bottom folded edge
29.	Make buttonhole	
	The inside edge of eyelet	11/16 ± 1/16 from point
30.	Mark or gage and sew buttons	
	a. Sew button on the left waistband lining	
	b. Sew button on left hip pocket	
31.	Bartacking	
	Finished appearance	
	at side pocket openings	beyond the outseam 3/32 ± 1/32
	a. Bartack all pockets	
	b. Bartack crotch seam and fly	
	c. Bartack right and left flies	

No.	Manufacturing Operation	Tolerance (inch)
32.	Finish trouser bottoms	
	When ornamental stripes required	3 ± 1/8 long, 2 ±1/8 wide 7/32 ± 1/32 from edge
	1. strips after pinking	
	2.Center a protector strip, stitch	
33.	Cleaning	
	a. trim ends of stitching and loose threads	length 5/32 ± 3/32
	b. Trim ends of center back belt loop	
	c. Remove all spots	
34.	Pressing	
	a. Press and crease the legs	
	b. Permanent creasing	length of the crease not vary by 1-1/2
	c. Press tops of trousers	
	d. Close slide fastener, fasten waist-band and button hip pocket.	

APPENDIX B-1

SURVEY OF LOCATION TECHNOLOGIES AT SOUTHERN TECH AAMTDC

All assembly equipment at the Southern Tech AMTC has been reviewed to identify location technologies used in the various operations. A list of such technologies by workstation is given below:

1. Make Belt Loops--folder acts as mechanical stop to position fabric during belt loop formation.

2,3. Hem Pockets--folder acts as mechanical stop to form hem and position pocket relative to needle.

4. Buttonhole Back Pocket--two guide bars attached to machine bed to assist operator in placing pocket.

5. Make Left Fly--air flotation with mechanical stop to position fly, light emitting diode with optic fiber pickup to photocell, mechanical feelers with microswitches.

6. Make Right Fly--folder acts as mechanical stop to position fabric to both join and topstich fly.

7. Join Flies--guide bar to align fabric parts being joined.

8. Sew Back Darts--panel is notched to indicate position for placement of panel on a guide bar, photocell detects position of guide bar and initiates sewing cycle, clamp holds dart and positions relative to needle, photocell detects end of fabric and initiates trim and take-off cycle.

9. Topstitch Back Darts--two guide bars to help operator position panel.

10. Attach Back Label--tape applied to machine bed indicates position of back panel to the operator, label fits in recessed metal holder which positions label on panel.

11. Attach Back Pockets--drill holes in panel indicates pocket position to operator, template guides panel through sewing pattern.

12. Seatseam--none.

13. Attach Front Pockets--same as Operation #11 above.

14. Attach Left Fly--two mechanical stops on folder to position fly and panel

15. Top Stitch Left Fly--guide bars to position panel, combination clamp and sewing template to guide fabric through sewing pattern, photocell to detect end of fabric and initiate trim and take-off cycle.

16. Join Fronts--mechanical stop to position panels.

17. Match Parts--none.

18. Load UPS--none.

19. Sideseam--folder for both panels with mechanical stop to position both panels for the needle.

20. Inseam--same as operation #19 above.

21. Attach Waistband--folder with mechanical stop to position waistband relative to trousers, tape marker for depth of placement of trousers.

22. Close Band Ends--guide bars to assist operator in placement.

23. Button Hole-Button Sew--mechanical stops to assist operator in positioning trousers for each operation.

24. Belt Loop Attach--encoded shaft motor to control length of loops, operator uses other seams in garment to estimate placement of belt loops.

25. Tack Fly, Sew Label--none.

It is obvious from this list that the principal location device at most workstations is the operator with various simple devices to help the operator position the parts being joined.

APPENDIX B-2

SURVEY OF LOCATION TECHNOLOGIES AT FASHION INSTITUTE OF TECHNOLOGY AAMTDC

During the visit to Fashion Institute of Technology Advanced Apparel Manufacturing Technology Development Center in December, a survey of location technologies utilized on equipment at the center was conducted. Several systems are reviewed below:

Union Special Automatic Serger--This machine automatically serges a variety of cut parts. It employs six photocells to sense the location of the part and assist with guiding the part through the seam path.

Brother Automatic Serging Machine--An on-off photocell controls a grooved wheel with a matching roller to move the part perpendicular to the sewing direction.

Brother Programmable Sewing Machine--Uses a photocell to detect the end of a part being sewn and then sews a predetermined number of stitches to complete the seam. The Singer 591 programmable machine uses a similar system.

Brother SA5310 Dart Maker--Part is held in a clamp which is moved by two stepper motors that can be programmed in the X,Y plane. A similar placement system is employed on the Mitsubishi PLK0804 machine.

Beisler Pocket Welt Machine--This machine uses chalk marks and three cross-hair lights to position the parts for sewing. Limit switches are used to control the width of the pocket opening.

Juki Button Sew Machine--Employs a stepper motor to move the sleeve of a man's suit coat for precise placement of buttons.

APPENDIX B-3

SURVEY OF LOCATION TECHNOLOGIES AT CLEMSON UNIVERSITY AAMTDC

All assembly equipment at the Clemson AAMTDC has been reviewed to identify location technologies used in the various operations. A list of such technologies used in the production of the Short-Sleeve 415 Army Shirt, by machine number, is given below:

1. Reece S-72/Branson:
   Sonic Collar Stay--mechanical stop and tape marker on table for positioning of collar, location of stay determined by travel of placement arm (adjustable), approx. accuracy +/- 1/8".

2. Kannegiesser VH 600:
   Fuse Epaulets, Collars and Flaps--none (human eye).

3. Adler 973-S-204-3:
   Run Collar--mechanical stops for initial part location, programmable machine determines stitch pattern, approx. accuracy +/- 1/16".

4. Singer 591C200G:
   Collar Stand and Loop Cutter--human eye aided by notch in piece.

5. Lunapress CP-323S:
   Trim, Turn and Press--sewn collar aligned over metal template before trimming corner. Mechanical stop for alignment in press.

6. Pfaff 3557:
   Topstitch Collar--mechanical stops on machine table for initial alignment, edge-following guide sews at constant distance from edge, photocell detects end of seam, interrupts stitching, and initiates automatic part rotation around sewing needle.

7. Adler 971-800:
   Run Epaulets and Flaps--human eye assisted by tape mark and mechanical stop used to align two halves, manually loaded into machine against mechanical backstop with side-to-side alignment by human eye. Sewing and trim heads directed by mechanical cam and follower.

8. Cutters Exchange:
   Turn Epaulets and Flaps--none.

9. Brother Exedra 737:
Topstitch Epaulets and Flaps--edge-guiding foot maintains spacing from edge of piece, photocell detects when end of piece is near and stops machine after programmed number of stitches are sewn after detection of edge. Set Flaps--Alignment bar on presser foot for visual alignment of pocket top, edge-guiding foot aligns top of flap, alignment of flap side-to-side strictly visual.

10. Brother LH-4:
Buttonhole Flaps and Epaulets--mechanical plate template guide.

11. Lunapress CP 300:
Crease/Press Pockets--mechanical guides.

12. Reece Series 74:
Serge Pocket Tops/Flaps/Fronts--photocell detects presence of cloth and activates machine.

13. Mitsubishi PLK 0804:
Attach Label--tape guides on machine table for manual positioning of fabric, holding frame positions label, approx. accuracy +/- 1/8".

14. Singer 591D200G:
Set Pencil Pocket--tape guides on machine table used for manual positioning of base fabric, pocket visually aligned with presser foot.

15. Necchi 2531-A:
Set Patch Pockets--tape guides on machine table for manual positioning of base fabric, tape guide used to align center of button in pocket holding frame.

16. Astechnologies 4103:
Buck Press Fronts--notches in fabric indicate ends of crease lines for manual folding.

18. Reece S-26 w/Indexer:
Button Sew Front--mechanical stops for manual positioning of front, location of buttons automatically determined by spacing of holes in indexing tape within machine.

19. Durkopp 741-7 w/Indexer:
Bottonhole Front--

20. Juki MB373 w/Hopper:
Button Sew Pockets--notches in fabric indicate fold point, mechanical stops for manual positioning of fabric on machine.

21. Mitchell S-26 w/ Hopper & Grommet Feeder:
Button Sew Neck--tape marker for manual positioning.

22. Union Special LF611K100MF:
Set Yoke--edges of back and two yoke pieces aligned manually, mated parts guided by edge guide.

23. Union Special LF611K100MK:
Join Shoulders--fabric edges manually aligned, edge guide maintains stitch position.

25. Jet Sew 2627:
Hem Sleeves--sleeve picker drops sleeve on moving tray, optical sensor stops sleeve at proper location before dropping onto conveyor.

27. Brother Exedra 737:
Set Collar--notches in fabric facilitate visual alignment of parts, edge guide on machine table facilitates alignment of fabric through machine.

28. Juki DDL-5550:
Same as No. 27.

29. Singer 591C200G:
Close Collar--stepped presser foot (compensating foot) directs fabric through machine.

30. Durkopp 556:
Buttonhole Neck--tape guides on machine table for manual positioning.

31. Mitsubishi PLK0804:
Baste Epaulet--end of epaulet located by button (see No. 32), and opposite end visually aligned with collar seam.

32. Brother CB3 w/Hopper:
Button Sew Epaulet--positioning light with crosshair projected onto fabric for visual alignment with seams.

33. Wilcox & Gibbs 515-E32:
Set Sleeve--notches in fabric aligned manually before stitching.

34. Wilcox & Gibbs 515-E32:
Side Seam--none (visual, unaided).

35. Singer 469U-141-28L:
Bartack Sleeve--tape guides on machine table for insertion depth, centerline mark on foot aligned with seam.

36. Singer 591 D200GD:

Bottom Hem--folder on foot guides fabric into machine.

Location technologies utilized in the production of the single-needle long-sleeve dress shirt are listed below, according to machine number. Because many of the manufacturing operations utilize the same equipment as for the short-sleeve army shirt, only the unique operations for this shirt are described below.

17. Juki ACF 161 w/Indexer:
Button Sew Front--manual positioning of front along edge guide with end stops, button spacing controlled by stepping motor and optical encoder.

37. Jet Sew 2M-RD 3000 w/3002 Feeder:
Bandcrease--clu picker picks bands and liners, rough alignment on table determined by photocells, moving side stops provide final alignment, bands and liners picked together and dropped into beveled well of same contour as the parts, ensuring exact registration of the two parts before being fused and creased.

38. Necchi UAN-2584-A:
Bandstitch--band aligned by holding template of same contour as band, collar manually aligned by mechanical stops, second band laid on top and assembly clamped and sewn by programmed sewing machine.

40. Juki DLN-5410-6:
Set Collar--raised edge on throat plate guides material.

41. Rimoldi 264-06-ICD-01:
Finish Sleeve--knife guide follows seam, light source below fabric allows visualization of seam beneath.

42. Juki ACF 171 w/Indexer:
Buttonhole Front--Same as No. 17.

43. Pfaff 563:
Set Cuff--mechanical edge guide, compensating foot.

51. Jet Sew 2654-5054:
Line Cuffs--clu picker drops cuffs on moving table, optical sensors stop moving at proper location, dropping cuffs onto continuous strip of liner material.

52. Toyota AD 1023-F15:
Label Sew Yoke--none, strictly visual.

53. Lunapress CP-141:
Buck Press Collar--none.

60. Singer 275E11 & 371U002:
Button and Buttonhole Cuffs--mechanical guides.

61. Durkopp 273:
Run Sleeve Facing--folder on machine serves to guide

fabric.

63. Pfaff 5483:
Yoke, Box Pleat, Locker Loop--notch in back aligns with seam in yoke, folder aligns parts, location and size of box pleat estimated visually.

64. Pfaff 561:
Join Shoulders--folder on machine table plus special design compensating foot.

65. Rimoldi 264:
Set Sleeves--folder on machine table.

66. Adler 272:
Close Sides--folder on machine table.

67. Adler 272:
Topstitch Sides--split foot follows seam.

APPENDIX B-4

SURVEY OF LOCATION TECHNOLOGIES AT TEXTILE AND CLOTHING TECHNOLOGY CORPORATION

Project staff visited the Technology Center and the R&D facilities of the Textile/Clothing Technology Center ($(TC)^2$) in Raleigh N.C. to identify location technologies utilized in both areas. Men's dress pants were being produced for Land's End in the highly automated Technology Center. A description of the technologies in use is given below by operation:

1. Fabric spreading: photocell edge sensing guides the fabric spreading operation to ensure that edges are aligned within 2 mm.

2. Serging: material placed in the automatic serger is initially aligned with the sewing needle. Air jets hold the fabric against an edge guide during sewing. Photocells detect the corner of the garment and initiate rotation of the fabric.

3. Sew band: rectangular perforations in edge control band are aligned with the sewing needle, a folder aligns band roll, edge control, curtain, and band. An edge guide is also used for fabric placement, and a tape marker on the machine table is used to indicate when to interrupt the band roll.

4. Sew labels: mid-point of band is estimated and labels aligned by eye, no aids.

5. Fuse belt loops: groove in machine table locates lining material, edge guides align fabric.

6. Face front pockets: initial alignment of parts by eye, with folder on machine to make fold. Photocell detects end of pocket and stops machine.

7. Bag front pockets: notches in fabric for initial alignment.

8. Face back pockets: edge guide for facing, folder for fabric.

9. Sew zipper: feeder aligns fly lining, machine foot has groove that directs zipper. Edges of fabric and lining initially aligned, with edge spacing gradually increased to 3/8" assisted by tape marker.

10. Cut apart fly: zipper follows groove, edge of zipper manually aligned with cutting blade.

11. Line right fly: edge of curtain aligned with tape mark on table, edges of fabric aligned with edge of foot.

12. Sew darts: fabric folded at notch over metal plate, photocell detects end of fabric.

13. Sew back pocket: initial alignment provided by tape mark on table, edge stop, and crosshair light centered over end of dart.

14. Finish back pocket: eye alignment with foot and sewing needle.

15. Serge left/right fly: none.

16. Bind seatseams and fly: folder holds binding, fabric aligned with binding, photocell cuts binding at end of seam.

17. Set front pockets: edge of foot aligned with edge of fabric.

18. Bar tack pockets: clamp on machine aligned with pocket opening. Eye alignment only on front pockets.

19. Buttonhole back pocket: mechanical depth stop, sewing needle aligned with dart for side-to-side location.

20. Side seam: edge guide for spacing of seam, notches in fabric for lengthwise alignment, "zippy" feeder facilitates alignment during feeding.

21. Attach loops: none.

22. Re-stitch front/back pockets: compensating foot provides 1/8" seam.

23. Attach waistband: notch in waistband aligned with center seam, edges of waistband and pants aligned, edge guide provides spacing, visually monitored by perforations in edge control.

24. Hook and eye: mechanical guide/stop for depth, tape mark on guide for side-to-side alignment.

25. Close corners: none.

26. J-Stitch: notch in zipper aligned with sewing needle, edge of fabric butted against mechanical stop, photocell detects end of fabric.

27. Inseam: "zippy" attachment aids alignment, notches in fabric for lengthwise alignment.

28. Tack crotch: clamp centered over band and middle seam.

29. Buttonsew: button is sewn through button hole.

30. Seat seam: inseams matched for lengthwise alignment, waistband marker set for correct pant size is used to make pencil mark on inside of waistband, final segment of seat seam directed by eye to pencil mark.

31. Blindstitch waistband: guide prong on machine aligned with edge of waistband curtain.

32. Tack loops: centerline mark on clamp centered over belt loop.

33. Hem bottoms: tape mark on machine table set for 1-1/2" hem.

At $(TC)^2$'s research and development center, a variety of prototype machines in various stages of completion were seen. The most interesting in relation to location technologies was the Singer trouser machine. This machine has been under development for over five years, and uses two computerized vision systems to locate trouser fronts and backs for joining by two digitally controlled sewing heads. The vision system utilizes conventional video cameras located approximately 13 feet above the machine table to define the outline of the parts, which are then transported to the sewing head for the joining operation. The vision system provides 512 x 512 lines of spatial resolution. While by far the most advanced form of location technology observed by the project team to-date, the unit is still far from production use and has several remaining problems to be solved.

$(TC)^2$ research personnel noted that the vision system is limited to a silhouette view only and cannot see detail inside of the outline of the fabric. There is some loss of positioning accuracy as the fabric moves from the measurement table to the sewing head, and these errors are cumulative as the fabric moves further down the machine. The physical size, including height, of the unit is prohibitive, as would probably be the cost of a production model. The unit is also relatively slow, although current computing technology could probably improve this aspect significantly.

APPENDIX B-5

SURVEY OF LOCATION TECHNOLOGIES AT DEFENSE PERSONNEL SUPPORT CENTER FACTORY

Assembly equipment used at the Defense Personnel Support Center in Philadelphia has been reviewed to identify location technologies used in the various operations. The review centered on two garments: a poly/cotton men's long sleeve shirt AG 415, and women's poly/wool dress slacks, blue sh. 1608 AF MIL-S. Because production of the slacks was very low, only a few of the operations were being conducted. Production of Navy dress pants was also being conducted in this area, and many of these operations were also observed. The location technologies identified in the manufacture of both types of pants are discussed below by type of technology used.

1. Notches and punch holes: These types of alignment aids are put into the component parts of the garments at the time that they are cut. Notches are used primarily to align two or more pieces before they are joined and for maintaining alignment on long seams such as inseams. Punch holes are used to locate the ending point of darts along the waistband.

2. Chalk marking: Marking component parts with chalk lines is extensively utilized for locating items such as seams and buttonholes. Cardboard templates are used for location of the chalk marks.

3. Tape and pencil lines: Masking tape placed on the machine table is often used as a visual alignment aid. The edge of the tape, or pencil marks on the tape, are typically used as guides for the fabric edge as material is fed into the machine, or for establishing the location of the base component before the attachment of a pocket or label.

4. Edge guides: Many operations utilize an edge guide against which the fabric is held as it is fed into the machine, primarily for the purpose of establishing the spacing of a stitch from the edge of the garment. An interesting edge guide noted in common use at this facility is a retractable guide which pivots out of the way when not needed, allowing a single machine to perform two or more operations without time consuming machine adjustment.

5. Compensating foot: This device is a special presser foot that is split in the center with one side spring-loaded

so that it will track over garment components of two thicknesses. It is typically used in topstitch operations where a stitch is placed approximately 1/16" from the edge of an existing seam. The thicker side of the component is butted against the fixed side of the presser foot.

6. Alignment guides: Several devices were noted that are attached to the sewing machine to provide a reference point for visual alignment without actually contacting the garment as with an edge guide. Examples include a guide, attached to the tape feeder, which follows the pant leg seam when applying a reinforcing tape to the inside of the seam, and a foot-mounted guide which is oriented with the pocket edge in the finish pocket operation.

Location technologies used in the manufacture of the AG 415 dress shirt are described below by operation number.

2.1 Fuse interlining to flaps (non-thermal): adjustable edge guide to maintain stitch spacing from edge of part.

3.0 Join, trim, turn and topstitch flaps: adjustable edge guide to maintain stitch spacing from edge of part.

4.0 Buttonhole flaps: side and edge stops to position panel.

6.0 Fuse interlining to cuff (non-thermal): adjustable edge guide to maintain stitch spacing from edge of part.

7.0 Hem cuff: adjustable edge guide.

8.0 Join, trim, turn and topstitch cuffs: adjustable edge guide for stitch positioning in joining, edge guide built into foot for topstitch follows edge of cuff.

9.0 Press cuffs: none

10.0 Buttonhole cuffs: side and edge stops to position panel.

11.0 Sew buttons to cuff: side and edge stops to position panel.

12.0 Join, trim, turn, and topstitch loops: edge guide for stitch positioning.

13.0 Press shoulder loops: none

14.0 Buttonhole loops: side and edge stops to position panel.

15.0 Overlock top and side edges of pocket: notches in fabric locate fold line of pocket.

16.0 Spray pockets with water: none.

17.0 Crease pocket edges: edge guides on press.

20.0 Fuse interlining to collar: edges of collar and lining are aligned.

21.0 Set collar stay: edge guide plus depth stop for positioning panel.

22.0 Join collar: edge guide for stitch positioning.

23.0 Trim turn and press collar points: collar points placed over pointed holders on automatic machine.

24.0 Topstitch collar: edge guide for stitch positioning.

25.0 Press collar: none

26.0 Trim edge of collar: excess lining trimmed off by following edge of fabric.

27.0 Hem collar stand: none noted.

28.0 Join collar to collarstand and interlining: notches in three parts aligned, line on plate followed for side-to-side alignment.

29.0 Join collar assembly to undercollar stand: Compensating foot follows seam.

30.0 Stay stitch collar stand and interlining: Foot follows previous stitch.

31.0 Bind sleeve opening: Folder forms hemmed edge.

32.0 Bartack bindings: none.

33.0,1 Join yoke to back: notches in fabric align parts, edge guide for stitch positioning.

33.2 Press yoke: none.

35.0,1 Stitch I.D. and instruction label to front: masking tape on machine table locates front of shirt, label placed below sewing needle.

36.0 Press fronts: notches in fabric determine location of crease line.

37.0 Mark for buttonholes, pockets and flaps: pencil marks made on fabric using cardboard templates.

38.0 Buttonhole left front: pencil marks made in 37.0 used to locate first two holes, center-to-center spacing of remaining holes determined by holder over which previous buttonhole is placed. Side-to-side alignment provided by edge stop.

39.0,1 Set pockets and flaps: pockets aligned with pencil marks made in 37.0, compensating foot with edge guide spaces stitch from side of pocket.

40.0 Mark for buttons: notches in fabric used to align two sides of shirt, buttonholes made in 38.0 used for placement of pencil marks on shirt for buttons.

41.0 Sew buttons: pencil marks made in 40.0 used to locate buttons.

42.0,1 Join shoulder seams: edge guide provides stitch spacing.

44.0 Set collar, staystitch neckline: notches in fabric align panels, compensating foot follows fabric edge.

45.0 Set shoulder loops: end of loop aligned with collar.

46.0 Set sleeves: notches in fabric align panels, edge guide provides stitch spacing.

47.0 Close side and sleeve: shoulder seams used to align front and back, edge guide provides stitch spacing.

48.0 Hem bottom: folder (swing-away) forms hemmed edge.

49.0 Mark for shoulder button: button hole used to locate pencil mark in one direction, 1/4" dimension from seam estimated by eye.

50.0 Set shoulder buttons: pencil mark made in 49.0 used to locate button.

50.1 Make button hole and sew collar button: plate on machine table used for panel alignment for button hole; mechanical stop for depth and side-to-side alignment by eye for button.

51.0,1 Turn sleeves and set cuffs: compensating foot and folder on machine plate provide seam allowance.

APPENDIX B-6

SURVEY OF LOCATION TECHNOLOGIES AT MARTIN MANFACTURING

Assembly equipment utilized by Martin Manufacturing has been reviewed to identify location technologies used in the various operations. The company has recently invested in several Adler automatic machines for production of shirt components. The location technologies used in the manufacture of shirts (of all types) at this facility are given below:

1. Run cuffs/collars/epaulets (Adler automatic machine): Two pieces are manually aligned and placed into the machine against a backstop and held in a clamp. The two halves are joined by an automatic sewing head which determines the stitch profile by following a template.

2. Turn and topstitch cuffs: edge guide for stitch spacing from edge.

3. Button-sew cuff: Edge guide and back stop locate panel.

4. Hem bands: Folder on machine.

5. Attach collar stays: Edge stops on table of ultrasonic machine locate panel.

6. Turn & topstitch collar (Adler automatic machine): Turned manually on dies, then inserted against backstop. Photocells initiate sewing and stop-and-turn cycle when collar is rotated around sewing needle at each collar point.

7. Turn & topstitch collar (manual machine): Edge guides determine stitch spacing.

8. Topstitch epaulets: Compensating foot determines stitch spacing.

9. Make pockets: Lining material aligned with notches in pocket fabric, fabric folded at notch. Edge guide determines stitch spacing.

10. Topstitch pocket flaps: Curved edge guide on machine table.

11. Military crease: Fabric folded at notches. Edge guide determines stitch spacing.

12. Button hole epaulets: Edge and back stops locate panel.

13. Hem pockets: Fabric folded at notch. Edge guide for stitch spacing.

14. Button sew pockets: Side and back stops position panel.

15. Sew labels: Eyeball estimate of vertical distance and centering on notch in fabric.

16. Serge fronts: Edge guide on machine.

17. Sew in front plackets: Folder on machine aids alignment.

18. Hem front: Folder on machine forms hem.

19. Set pencil pocket: Drill hole in shirt front locates corner of pocket.

20. Button sew front (automatic machine): Fabric folded at notch and aligned with end stops on clamp. Mechanical stops on the machine determine the spacing of the buttons.

21. Button hole front (automatic machine): Fabric folded at notches, gauge on machine for lengthwise location. Button hole spacing programmed into machine.

22. Button hole/sew sleeve: Edge and back stops locate panel.

23. Close sleeve (automatic machine): sleeves manually loaded onto dies which position fabric.

24. Face sleeve: Folder aligns sleeve and facing.

25. Attach yoke: Edge guide, corners of back and yoke aligned.

26. Join shoulder: Folder aligns two yoke panels and shirt front.

27. Mark collars: Marking fixture makes pencil marks on collars for later joining operation.

28. Attach collar: Pencil marks made above aligned with shoulder seam; compensating foot determines stitch spacing.

29. X-stitch epaulets: Edge of foot aligned with fabric for starting point, location of stitching determined by eye strictly from experience.

30. Set pockets (automatic machine): Tape marks and

mechanical stops on table for location of panel; pocket centered over die around which it is automatically folded.

31. Mark fronts for flaps: Template placed against top of pocket, pencil marks made through holes in templates.

32. Set flaps: Flaps aligned with pencil marks, compensating foot determines stitch spacing.

33. Close collars: Compensating foot follows fabric.

34. Button hole/sew collar band: Back depth stop plus tape marks on table for side-to-side location.

35. Set sleeve: Notches in center of sleeve and yoke aligned, edge guide for stitch spacing.

36. Close sides: Corners and sleeve seams aligned, edge guide determines stitch spacing.

37. Hem sleeves: Modified foot with built-in edge guide.

38. Hem bottoms: Special foot with built-in folder (scroll foot).

APPENDIX B-7

SURVEY OF LOCATION TECHNOLOGIES AT TENNESSEE APPAREL

Assembly equipment utilized by Tennessee Apparel in Tullahoma, Tennessee was reviewed in late November, 1990, to identify location technologies used in the various operations. The location technologies used in the manufacture of men's leisure trousers were studied in detail and are given below:

1. Serge front pocket facing: Swing-out edge guide.

2. Face front Pockets: Edges of two pieces are aligned, stitching directed by eye along serged edge.

3. Stitch elastic to front pockets: Corners of pocket and elastic band aligned with template on machine table.

4. Close front pockets at bottom: Notches in fabric locate fold point, swing-out edge guide directs stitching.

5. Turn front pockets: None.

6. Restitch front pockets at bottom: Compensating foot.

7. Face back pockets: Edge guide directs pocket, folder folds and orients facing.

8. Attach label to back pocket: Backstop and tape mark on table for pocket location, label held by double clamp foot, stitch programmed by mechanical cam.

9. Fuse left fly: Fly pieces laid end-to-end in tray-type guide on top of continuous band of facing.

10. Serge left fly: Edge guide.

11. Attach zipper to left fly: Edge guide for fabric, zipper feeder locates zipper.

12. Cut zipper: Zipper follows groove in machine table.

13. Attach slides and stops: None.

14. Run belt loops: Not observed.

15. Fuse belt loops: Not observed.

16. Run tab loops: Not observed.

17. Backtack and cut loop tab: Loop folded around steel pin. Mechanical stops locate loop for second tack.

18. Fuse bands: Same as step 9.

19. Sew and cut back pocket: Base panel aligned with mechanical edge guide, notch in panel aligned with mark on edge guide. Edge guides on clamp for flap and lining. Stitch length is programmed.

20. Sew facing: Compensating foot maintains 1/16" stitch width.

21. Close and turn top cord: Edge of fabric aligned by eye with edge of foot. Tab located in center of band by eye.

22. Attach label to back: Clamp aligned with edge of pocket and tab, label placed in clamp.

23. Tack back pockets: Eye alignment under clamp and needle.

24. Restitch back pockets: Compensating foot for 1/8" stitch.

25. Backsew back pockets: Pencil mark made through loop, mark aligned under needle.

26. Seatseam: Corners aligned, swing-out edge guide.

27. Pleat fronts: Fabric folded at notch and placed over mechanical finger, inserted to backstop, stitch is programmed.

28. Set & topstitch left fly: Notches in panel aligned, compensating foot for topstitch.

29. J-stitch: Mark on table and back stop for initial positioning, stitch profile programmed, photocell senses edge of fabric and stops machine.

30. Set and topstitch pockets: Edge guiding foot.

31. Backtack front pockets: Two back stops plus edge guide.

32. Stitch pocket to front: Existing stitch followed by eye.

33. Form tab: Fabric folded at notches, tape mark for stitch.

34. Set right fly, join crotch: Edges aligned, edge of fabric aligned with edge of foot by eye.

35. Join crotch: Foot follows edge of zipper.

36. Match for sideseam: None.

37. Sideseam: Swing-away edge guide.

38. Topstitch sideseam: Edge guide built into foot.

39. Inseam: Swing-away edge guide.

40. Serge pant top: Fabric aligned with edge of foot.

41. Tack elastic to back: Marks on table aligned with seams.

42. Turn pant: None.

43. Hem leg bottoms: Swing-away folder turns fabric, edge guide built into foot.

44. Band pant: Double folder forms seam, tape mark on folder.

45. Clip and rip band ends: None.

46. Finish band ends: Follows existing stitch.

47. Stitch elastic: Width of foot matches band.

48. Tack belt loops on: Depth stop and side edge guide (automatic machine).

49. Backtack crotch and fly: Tack placed on top of existing stitch.

50. Buttonhole and buttonsew band: Mechanical depth stops, button aligned with stitch.

APPENDIX B-8

SURVEY OF LOCATION TECHNOLOGIES AT ARROW SHIRT

Assembly equipment utilized by Arrow Shirts has been reviewed to identify location technologies used in the various operations. The company has a relatively high level of automated equipment. Many of the automatic machines have been reviewed in previous reports and a detailed discussion of the location technologies used by these machines is not repeated. The location technologies used in the manufacture of shirts at this facility are given below:

1. Fuse collar: None

2. Run collar: Back and edge stops provide registration of top and bottom plies and stay/stiffeners. Clamp holds parts in registration for programmed stitching and trimming.

3. Turn and press collar: Collar turned over template.

4. Topstitch collar: Edge guide on machine table.

5. Band creasing: Automatic Jet Sew picker aligns band and lining and feeds parts to creaser. See Clemson AAMTDC report (APPENDIX B-3).

6. Band insert: Same as run collar.

7. Attach collar button: Mechanical stop.

8. Button hole collar: Same as attach button.

9. Hem cuffs: A Jet Sew automatic picker places the cuffs on a moving conveyer where the cuff is automatically folded and stitched. See Clemson AAMTDC report (Appendix B-3).

10. Run Cuff: Adler automatic machine. See Clemson AAMTDC report (Appendix B-3).

11. Turn and topstitch cuff: Manually turned over template which locates the cuff as it is fed into and clamped by automatic topstitch machine (Ideal). Stitch profile determined by die and mechanical follower.

12. Fuse cuffs: None.

13. Button hole/sew cuff: Back and edge stops position

panel.

14. Attach sleeve binding: Folder guides binding and sleeve.

15. Bartack (doghouse): Mechanical prong-like dies inserted into sleeve bindings which position sleeve for automatic stitching (Jet Sew automatic machine).

16. Buttonhole sleeve: Tape marks on table and edge guides position panel.

17. Button sew sleeve: Mechanical depth stop and edges of machine table used to align panel.

18. Sew pleats (sleeve): Fabric folded at notches and tacked.

19. Hem sleeves (short) and fronts: Automatic Jet Sew hemmer. See Clemson AAMTDC report (Appendix B-3)

20. Center pleat: Double folder aligns front, liner, and pleat material.

21. Center pleat (automatic): Jet Sew automatic machine, see October report.

22. Button hole fronts: Back stops and end stops for panel location - hole spacing programmed into machine.

23. Hem pocket: Similar to hem cuffs above - Jet Sew automatic machine.

24. Set pocket: Tape marks on table for front panel location, pocket loaded onto template against backstop and centered by eye. Necchi automatic machine programmed for stitch profile.

25. Fuse label: Notches on collar aligned with mechanical stop and center pointer.

26. Join fronts/backs: Corners and edges of fabric aligned, edge guide for stitch spacing.

27. Attach collar: Notches in collar aligned with shoulder seams and notches in back panel. Compensating foot follows edge of collar.

28. Insert sleeves: Gauge on machine table positions fabric as it is fed into machine.

29. Stitch down sleeve: Folder on machine table forms seam.

30. Folder fell (side seam): Folder forms seam.

31. Attach cuffs: Guide on table aligns edge of cuff, 3/8" sleeve insertion estimated by eye, compensating foot follows top edge of cuff.

32. Hem bottom: Special foot with folder built in.

APPENDIX B-9

SURVEY OF LOCATION TECHNOLOGIES AT OXFORD INDUSTRIES

Assembly equipment utilized by Oxford Industries has been reviewed to identify location technologies used in the various operations. The location technologies used in the manufacture of pants at this facility are given below:

1. Cutting: A Gerber cutter is used to ensure accurate dimensions of the cut parts. This is felt to be critical to proper dimensioning in the finished garment.

2. Serging: Six photocells mounted in the machine table direct the fabric feed and signal the control unit when the corner of the garment is reached. This unit will follow an inside curve well but will not follow an outside (convex) curve.

3. Make darts: Notches in the fabric locate the fold points of the dart. Mechanical guides on machine table determine depth of the dart.

4. Pocket Welting: Tape marks on machine table locate pocket, cross-hair light source provides alignment point of back panel (aligned with dart).

5. Upper cord - back pocket: Compensating foot follows fabric.

6. Restitch pocket: Edge guide on table for panel alignment.

7. Close front pockets: Pocket folded in half manually with notches aligned. Photocells direct feed of fabric to automatic sewing machine. Some manual assistance is needed to follow outside (convex) curves.

8. Pleat fronts: Darts provide location point for pleats. Tape mark on table for depth.

9. Attach pockets: Corners and edges aligned manually. Compensating foot follows edge of fabric.

10. Join panels: Edge guide determines stitch location.

11. Restitch front pockets: Edge guide determines stitch location.

12. Rocap band (make band): Edge control, curtain, band roll and band fed through complex folder to double needle machine.

13. Sew band: Edge guide and notches in edge control facilitate positioning of stitch.

14. Sew left fly: J stitch programmed into machine. Fabric placed into machine against back stop.

15. Slide and brad: Pencil mark made on waistband for proper waist size with manual marking apparatus.

16. Seat seam: Starting point at bottom of fly aligned under needle by eye. Stitching follows edge of fabric with no aids - amount of excess fabric beyond stitch is gradually increased - ending point of stitch is determined by pencil mark made in step 15.

17. Attach belt loops: Folder/feeder locates loop, band placed against backstop, lateral locations determined by operator experience.

18. Hem bottoms: No aids provided.

APPENDIX B-10

SURVEY OF LOCATION TECHNOLOGIES AT ARK, INCORPORATED

During the visit to Ark Incorporated, three prototype machines were inspected and technologies used to perform location functions were noted. The *Turn and Divide* machine is designed to separate a stack of cut parts taken directly from the cutting table in a face-to-face arrangement into two stacks of parts all facing up, by inverting every other part and restacking. The use of location technology is minimal in this machine. Proximity sensors are used to determine the location of a moving conveyor and activate the picking and placing functions at the correct point in time. Photocells are used to ensure that a part is placed consecutively in each stack, stopping the machine when an error is detected to avoid miss-stacked parts. Photocells are used also to detect the presence of every other part in a clamp that closes on the part's leading edge so that it can be inverted before being dropped on the stack. The actual location of each part on the stack is determined by the timing of the picking and dropping operations, and the photocells are used only to determine the presence or absence of a part.

Ark's pocket facing machine consists of two standard Beisler pocket facing machines mated with Ark-designed feed systems which feed and orient the pocket into the Beisler machines, rather than having them manually fed by an operator as they were originally designed. The pocket facings are applied to the pocket from magazines, which is a standard feature of the Beisler equipment. The feed systems incorporate X-Y-theta positioning, in which the pocket can be moved in the plane of the table in two dimensions (X and Y), and can also be rotated (theta). Photocells mounted in the table are used to control the movement of the system. In general, the part is moved in the X direction until a single photocell is covered, which stops the movement in that direction. The part is then moved in the Y directicn and rotated if necessary until equal coverage of two photocells, located along the line at which the part is to be placed, is obtained. Once at the proper location, the facing is applied and the parts are clamped and drawn together through the sewing head.

A very similar X-Y-theta location system is used by Ark to feed a standard AMF pocket bagging machine. Once the pocket is bagged (folded in half), it is directed to a Willcox and Gibbs sewing head which utilizes a fairly unique edge following system. This system uses a contact belt that raises and lowers and can drive in either direction to feed more or less material into the sewing head. The belt is piloted by photocells in the machine table ahead of the needle, and is mounted at an angle to the direction of feed.

APPENDIX B-11

SURVEY OF LOCATION TECHNOLOGIES AT JET SEW

The Jet Sew Company plant in Barneveld, New York, was visited in October, 1990, to survey the location technologies used in the variety of highly automated machines produced by this company. Machinery at the plant included the knitwear (sweatpants) machine that was displayed at the $(TC)^2$ booth at the Bobbin show in September. Observation of this machine in operation was not possible due to the fact that it was in the process of being rebuilt as a result of shipping damage during the return trip from the Bobbin show. The primary innovation in location technologies demonstrated by this machine is the use of dual photocells in the X and Y axes to locate the corners of the cut fabric at each of four locations. This machine was described in some detail in the September monthly report and will therefore not be discussed further at this time.

A second prototype machine seen at Jet Sew was a washcloth machine designed to produce finished washcloths from a continuous bolt of woven terry cloth. Location technologies utilized by this machine include mechanical edge guides that align the fabric from side-to-side as it is fed into the machine, and photocells (3) which look through the fabric in order to see the break between cloths where the weave threads are omitted.

Location technologies utilized by the production machinery produced by Jet Sew are discussed below by machine:

Center pleat machine: This machine forms the center pleat in the front of a man's shirt, where the buttonholes are located. A mechanical edge stop is used for initial alignment of the shirt front and center pleat. Photocells are used to detect the edge of the fabric to control the various operations including sewing, cutting the lining material, and off-loading the finished piece. A folder at the feed of the sewing head creates the necessary folds and therefore determines the size of the pleat, seam overlap, etc.

Band crease feeder: This machine is designed to stack the lining and face ply of collar bands in the proper orientation for feeding into the band creaser. Photocells are used to spot the ends of the lining and face ply, while a belt encoder measures the length of each piece and aligns them according to their centerlines. The pieces are then pushed against a fixed edge stop to establish side-to-side location allowing them to be picked and stacked in proper registration.

Band creaser: This machines relies on a tapered die of the shape of the band and lining so that when the pieces are placed by the feeder they will settle into the bottom of the die in exact registration.

Pocket setter: Tape marks are typically placed on the machine table to provide a locating point for the shirt front. The pocket is placed on a die so that the fabric overlaps evenly on three sides while the top of the pocket rests against a mechanical stop. The pocket is folded over the die, determining its shape, and the shirt and pocket are moved together to a programmable sewing machine which is programmed for the proper stitch profile.

Band/collar joiner: This machine relies on mechanical guides and stops for holding the parts in alignment while they are joined. A programmable sewing head is used to provide the proper stitch profile.

APPENDIX C-1

TRAVEL REPORT
JAPAN INTERNATIONAL APPAREL MACHINERY EXHIBITION '90

The Japan International Apparel Machinery (JIAM) Exhibition was held in Tokyo May 23-26, 1990. The express purpose for attending the JIAM Exhibition was to survey location technologies in use in Japan. The trip was made in conjunction with a tour arranged by Juki for Apparel Research Committee members. In addition to the exhibition and seminars on international research on apparel manufacturing, Juki arranged for a tour of a major Japanese apparel manufacturing plant and a tour of Juki's Ohtawara automated sewing machine manufacturing facility for members of the tour group.

TOKYO STYLE

The group arrived in Tokyo on Sunday evening, May 20. The tour of Tokyo Style, a Japanese ladies' wear manufacturer was scheduled for May 21. Tokyo Style's annual sales are approximately $41 million, primarily in high fashion ladies' blouses and jackets. A typical blouse sells for $70 dollars at retail. The plant employs 380 people, predominately young women in their early to mid 20's. Workers are all paid on an hourly basis ($4 per hour initial rate) with an annual bonus based on meeting production goals.

The plant is very committed to quick response. The time from design to start of manufacture was given as 20 days (versus 3 to 4 months in the U.S.). Both a regular production line and a modular production unit were in operation at the plant. The regular line had a throughput time from order to completion of the order of 20 days and the modular line a throughput time of 5 days (order Monday, ship Friday). Total work-in-process inventory was given as 7 days.

Fabric is received at the plant in relatively small rolls of approximately 25-30 yards per roll. The blouse fabric was said to be micro-denier polyester which produces a silk-like final product. The Japanese are probably well ahead of the U.S. fiber manufacturers in this important new area of apparel fabrics. Despite the high cost of this fabric, the plant did not appear to be very efficient in fabric utilization. All fabrics were plaids or highly patterned prints.

Tokyo Style had all modern design, grading and marker making equipment. They had input 10 years of production data into the system to assist in production planning for new garments. the systems appeared to be very similar to units in-use in the U.S.

apparel industry.

Cutting was done on a Gerber S93 cutter. The spreads were very small and only a few plies were being cut at one time. Because of pattern matching requirements, some parts were rough cut on the Gerber and then recut by hand to insure matching. Small pieces of fabric were also being pinned and then cut by hand for small parts in critical matching areas. Both of these procedures were very inefficient in fabric utilization. The same cutting operations were used for both the regular production lines and the modular manufacturing unit.

All parts for a given garment being manufactured in the regular production line were placed on a hanger and input to the unit production system for assembly. The sewing machines in use were relatively new but essentially basis models with few automated features. Machine operators made extensive use of templates and other simple devices to ensure proper placement of folds and seams. The machine operators appeared to be well trained and dedicated.

The modular production system represented a very different approach to flexible manufacturing than is seen in the U.S. The system was developed by Juki and Tokyo Style appears to be a beta test site for Juki. The system consisted of approximately 10 workstations with one worker per station. A unit production system was employed to carry individual garments between workstations. All workers were standing. Each workstation had a number of different sewing machines and a variety of pressing units in the workstation. Most of the workstation had three sewing machines with a few with two. Thus, this represented a very capital intensive modular manufacturing system. The worker would perform a variety of sewing and pressing operations on each garment. Garments of different type and style were intermixed at random in the production system. The modular unit had an output of 350 blouses per day. Ladies jackets were also produced on the modular production unit with a capacity of 35 jackets per day.

No sophisticated location technologies were being used in the Tokyo Style plant. The human eye was the principal resource for positioning parts for folding and sewing. Several devices were commonly used to assist the eye. For example, lasers were being used extensively to give a straight line of light on a plaid fabric to assist the worker in lining up plaids for cutting. In some cases two perpendicular laser beams were being used for pinning plaids prior to cutting. Mechanical barriers were common to ensure proper alignment of fabric for serging and other seaming operations. Almost every workstation had one or more templates to assist in placing folds and/or in ensuring that seams were precisely located. Only a few machine were equipped with simple photo diodes to start and stop machines when the fabric entered or exited the machine. The extensive use of templates was probably the major difference in location technologies in this plant compared to a typical U.S. plant.

JUKI OHTHWARA PLANT

On May 22, the group toured the Juki sewing machine manufacturing plant. This is supposedly the most highly automated sewing machine manufacturing facility in the world. The plant receives castings for machine heads and base plates from another Juki facility. The castings go on two parallel computer controlled machining lines where the rough castings are milled, drilled, tapped, inspected, etc. by computer controlled machines. The two lines merge at the end and the heads and base plates are automatically joined. After the combined heads and base plates are powder coated in an electrostatic spray booth, they enter a second automated assembly line where a variety of bushings and other parts are inserted. This automated assembly system produces only lock stitch machines but it was reported to be capable of producing ten different modifications of this machine. The automated line has a production capacity of one machine every 1.3 minutes. The units then go to a manual assembly line where internal parts and subassemblies are inserted into the machine. Machines are then tested and packed for shipment.

JAPANESE INTERNATIONAL APPAREL MACHINERY EXHIBITION '90

The JIAM exhibition is held every three years with JIAM '90 being the third exhibition. It is not as large as the Bobbin Show but is focussed almost entirely on apparel manufacturing machinery. The exhibit occupied approximately 490,000 square feet with 258 exhibitors. Approximately 100,000 people attended the exhibit, the majority being from Pacific rim countries but with substantial representation from the western hemisphere and Europe. A major attraction of JIAM '90 was the first public exhibition of results of the MITI "large scale" project on "Automated Sewing System". In addition to the exhibition of MITI developments at the show, two major seminars on the MITI project were presented on Saturday, May 26.

This review of the JIAM show will be presented in three parts. Part one will highlight some of the important developments exhibited at the show, part two will discuss general location technologies shown, and part three will discuss the important aspects of the MITI project that were unveiled at the exhibition.

PART 1: HIGHLIGHTS OF THE JIAM '90 EXHIBITION

Space and interest at the show were dominated by the large Japanese machinery manufacturers. The theme of all these Japanese manufacturers was flexible, computer integrated manufacturing. The theme was carried to its highest expression in the Brother exhibit. Brother formed a working relationship with Lectra Systems to demonstrate the most advanced computer integrated manufacturing system that has been achieved in the apparel industry. The system is designed to manufacture single garments in random order similar to a made-to-order facility. A diagram of the computer hardware and software configuration used in this system is shown in Figure 1.

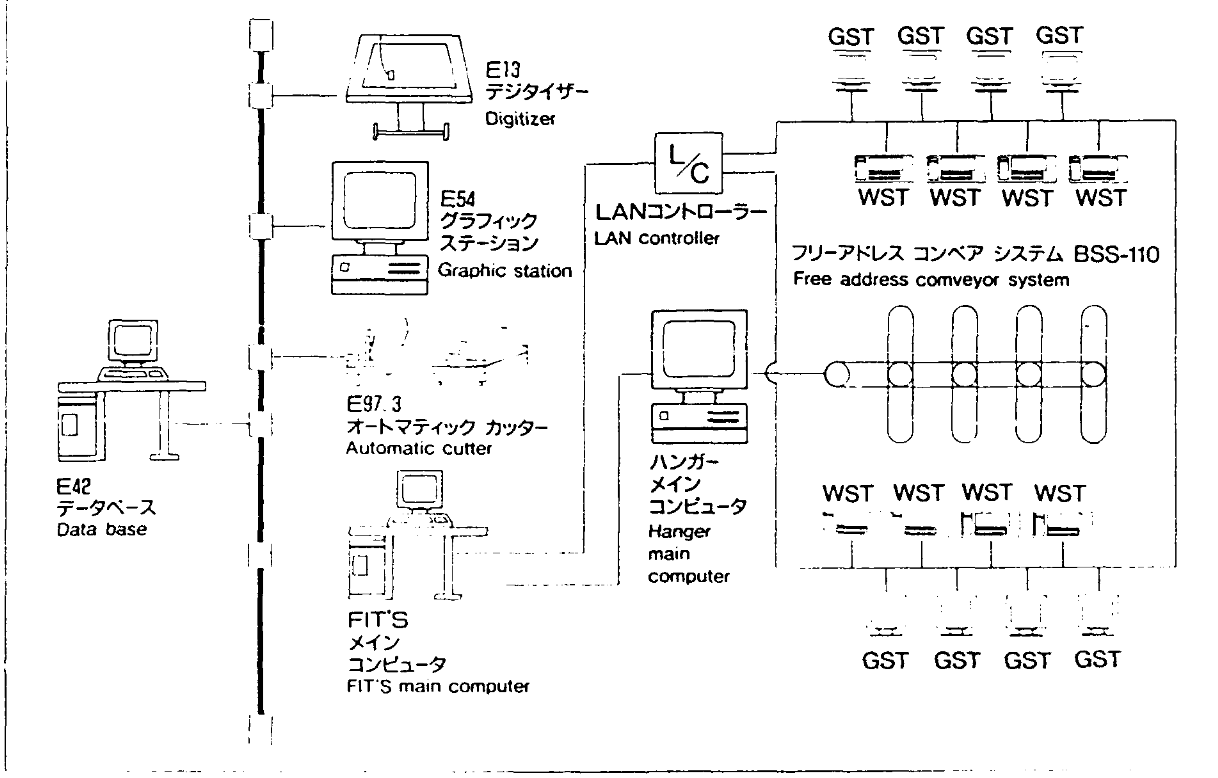
The system has the Lectra design and pattern-making units with information transmitted directly to a single-ply laser cutter. The real innovation is the coupling of the design and pattern system through a local area network to terminals and graphics monitors at each sewing workstation. Each workstation is serviced by a free address conveyor system also in direct communication with the main computer. The workstations are each operated by one worker (standing) who operates up to three sewing machines and other auxiliary equipment (pressing systems etc.). When garment parts arrive at a given workstation, the conveyor computer communicates to the main computer the garment type and the main computer downloads to the programmable sewing machines at the workstation all settings, etc. needed to perform the operations on that garment. In addition, the operator's monitor displays instructions for the operations she is to perform on the garment including a graphical representation of seam placement, fold placement etc. This communication system is an essential part of a manufacturing environment that enables each worker to perform several operations on a mix of garment types arriving in random order at the workstation.

The "Clotho" system demonstrated by Juki represents a second version of the Japanese flexible, quick response manufacturing concept. The Clotho system is illustrated in Figure 2. This system also employs single-ply cutting of individual garments with assembly conducted by three workers standing at work stations with multiple sewing machines. The workstations are serviced by a rotary table in the center of the production module. The Clotho unit is designed to be part of a retail store where made-to-order garments can be produced quickly and efficiently.

In varying degrees of sophistication, all of the major Japanese machinery manufacturers (Brother, Juki, Toyota, Mitsubishi, Yamato) exhibited similar flexible manufacturing systems. Common elements were workstations with several different kinds of sewing machines and auxiliary assembly equipment for each worker, workers performing multiple operations while standing, computer based conveyor systems, single-ply cutting and individual garment assembly and a random intermix of garment types. Modules contained from 3 to 16 workstations (and workers) for complete assembly of garments. Such systems are obviously designed for maximum manufacturing flexibility and the shortest possible production times. Computer integrated manufacturing is an integral part of all of these systems with direct transfer of information from the design stage to manufacturing units. The machines used in the assembly units were generally standard sewing machines with some interesting features to give flexibility. For example, a number of machines had multiple pressor feet that were selectable by either the control computer or the operator. In some cases small folders were attached to one or more of three available

FIGURE 1

トータルアパレルシステムBL-1000のハードウェア構成モデル
BL-1000 System configuration model(hardware)

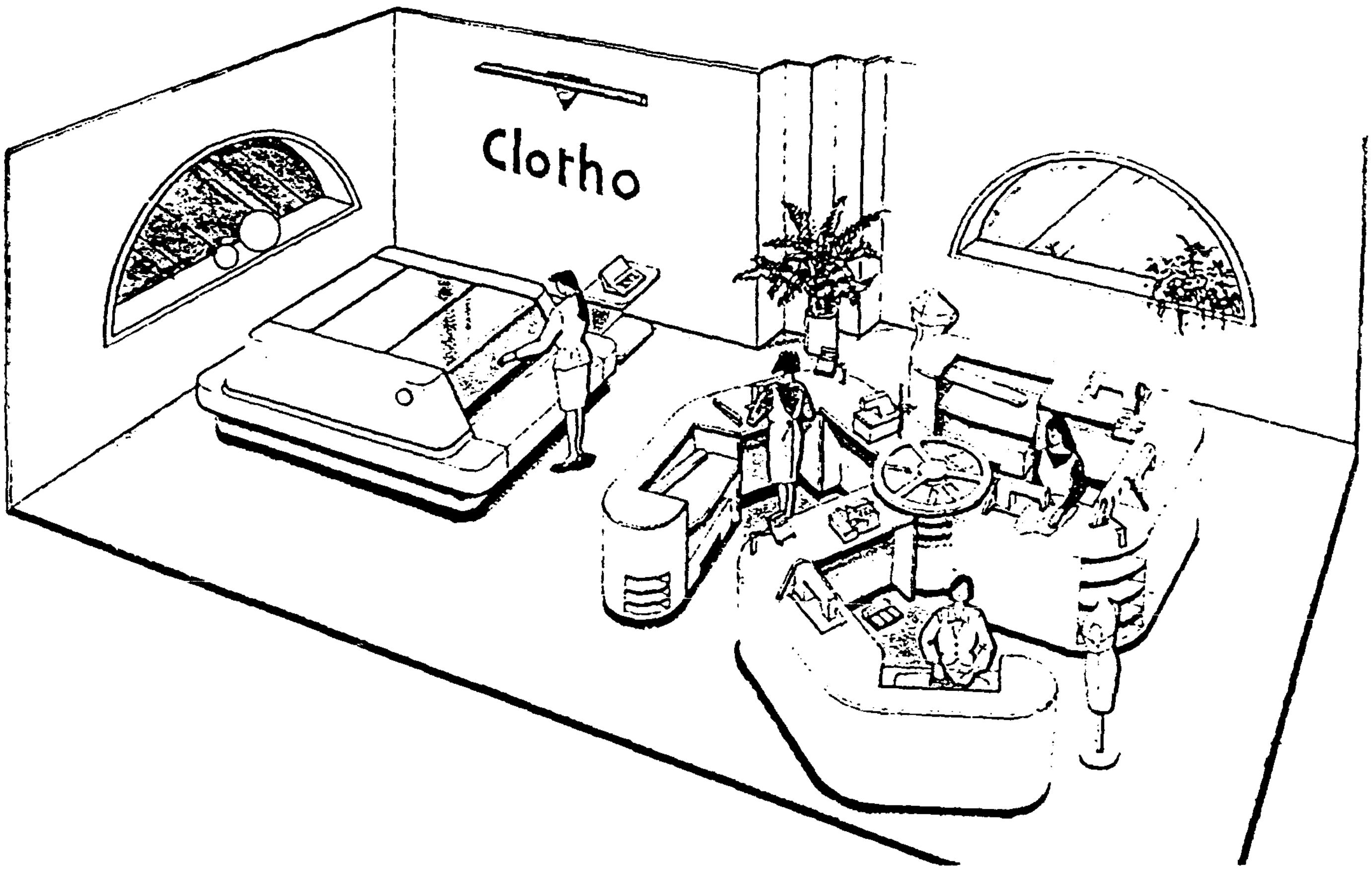


トータルアパレルシステムBL-1000のソフトウェア構成
BL-1000 System configuration(software)

BL-1000

- 管理 Management
  - 受注管理 Order reception management
  - 工程管理 Process management
- 企画 Design
  - スケッチング Sketching
  - パターン作成・修正 Pattern making and modification
  - グレーディング Grading
  - メイドトゥーメジャー Made-to-measure (イージーオーダー用 Easy Order)
  - コスト計算 Cost calculation
- 生産 Production
  - 延反・裁断・制御 Spreading, cutting, control
  - ハンガーコンベア制御 Hanger conveyor control
  - システム対応ミシン制御 Computer-aided sewing machine control
  - 工程分析・編成 Process analysis, organization
  - 作業指示 Work instructions
  - 縫製仕様指示 Process specifications
- 営業 Sales
  - 納期予測 Delivery prediction
  - 生産計画 Production planning

FIGURE 2



● Individual Production Unit for Apparel Products

"Clotho" has been developed in order to respond to the need for the individual production of apparel products, as well as the need for the creation of a comfortable working environment attractive to people working in a garment factory.

"Clotho" is a through-production package system for the individual production of single apparel products starting with the CAD system stage, followed by cuting up to the sewing stage. We will be demonstrating how a single high quality jacket for ladies is manufactured using an FC-1, a newly developed small-sized laser cutter, and a sewing unit called the "spiral unit" attended by three operators.

pressor feet on a given machine. Thus, the operators could perform several tasks on one machine by simply rotating the pressor foot assembly. At the Kansai booth, sewing machines in a "lazy susan" arrangement were demonstrated which allowed a single operator to select any one of four machines for conducting a number of assembly steps.

The Japanese approach to flexible or modular manufacturing has a number of significant differences when compared to the general approach taken by U.S. manufacturers. In most U.S. flexible manufacturing units the worker moves from one machine to another in order to carry out multiple assembly tasks and each worker is trained on a limited number of such tasks. In the Japanese approach each worker is provided with a variety of machines in a workstation and is expected to carry out a very wide range of assembly tasks at that workstation. Extensive capital investment in materials handling systems and information interchange systems is integral to the functioning of these Japanese modular units.

The Japanese concept of the apparel manufacturing facility of the future appears to be based on the utilization of a small number of highly trained workers who are provided with extensively engineered workstations supplied with the machines, equipment, and systems to maximize the productivity of each worker. These systems have a very high capital investment per worker and poor machine efficiency by U.S. standards. It was interesting to note in discussing the Japanese approach with a number of U.S. apparel engineers that they did not believe the Japanese concept was appropriate for American manufacturers. This may be due to the American manufacturing strength in "commodity products" where standard products are produced in large volume for mass markets. Some apparel manufacturers of women's apparel from other countries did state in conversations that they felt the Japanese approach was the direction of the future for that segment of the apparel industry.

PART 2: LOCATION TECHNOLOGIES

Very little new in the use of systems to locate, register, and control parts during the assembly of apparel was demonstrated at JIAM '90 with the exception of the systems developed as part of the MiTI project. The MITI developments will be discussed in Part 3. The lack of new location technologies in the other areas of the show is quite probably due to the directions of Japanese development described above. The flexible workstations demonstrated by the major exhibitors at the show clearly relied on the skilled operators' eyes and hands for location and control of parts during assembly. Any location technologies that were used were all designed as aids to the operator rather than replacements for the operator.

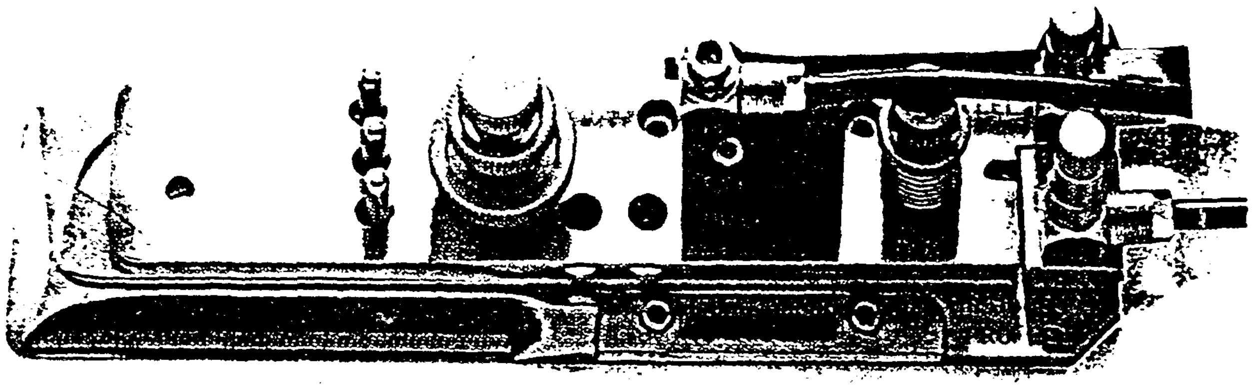
The simplest type of operator aid is the use of markers on the machine bed to show where parts should be located for a given assembly operation. Colored tape and metal tabs are commonly used as vision aids of this type. Other examples would include notches or holes placed in parts during cutting and lights with a crosshair image shining on the machine bed to indicate the correct placement during sewing. Laser light sources (similar to the ones used at Tokyo Style) were also being demonstrated at the N.C.A. Company, Limited exhibit as aids for operators aligning plaid fabrics for cutting.

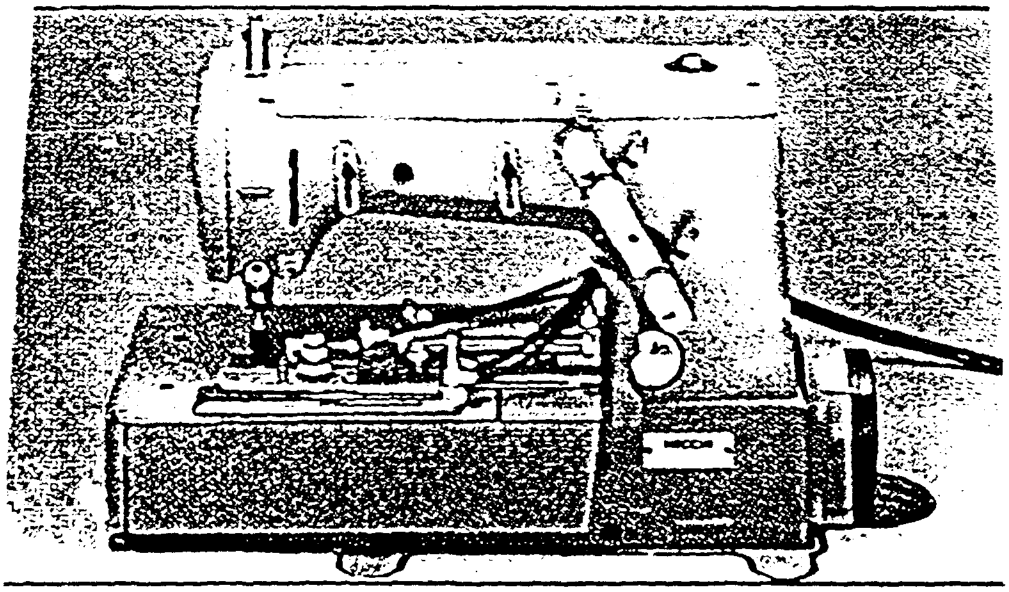
Mechanical restraint systems seemed to be most common as aids for the operator in locating and controlling parts during assembly. The simplest form of this approach is a mechanical stop that the fabric being sewn is placed against for precise location. Rail guiding systems were also displayed which move a carriage carrying the cloth being sewn along a complex curved rail. This allows parts to be sewn with complex seam paths.

Probably one of the most sophisticated of the mechanical placement systems seen at the exhibition is the "Zyppy" sewing machine attachment shown in Figure 3. This unit will attach to a wide range of sewing machines and will align the cut edges of two parts to be joined and place the fabrics so the seam joining them will be the correct distance from the edge. The unit has two directed air jets one on the lower surface of the top plate and one on the upper surface of the bottom plate. The top and bottom plates are separated by a low friction metal plate. One fabric is placed between the top and center plates and the other fabric is placed between the center and bottom plates. The directed air jets move both fabrics until they strike a mechanical barrier (the three metal rods coming through the top plate in Figure 3). This aligns the edges of the two cut parts with each other and the position of the mechanical barrier relative to the machine needle determines the distance of the seam from the edges of the two parts being joined. As the seam is sewn, the device continues to automatically align the two fabrics. A Zyppy unit is installed on one of the machines in the modular manufacturing unit at the AMTC at Southern Tech and will be evaluated as part of the location technologies project.

A few of the machines and systems on display used photoelectric devices to sense the position of cut parts during assembly operations. The devices were generally of the on-off type very similar to ones currently used on a number of automated sewing systems. These devices are essentially on-off type switches that inform the controller whether a light beam is activating the sensor. They are useful in determining when a cut part has interrupted a light beam and can therefore be used to detect the position of a part. For example, when a part is conveyed to or away from the sewing machine, these devices are often used to either turn the machine on or off. They are also used to insure proper alignment of a fabric edge by having two or more sensors at positions at which a fabric edge should be if it is properly

FIGURE 3





aligned.

Most of the innovative work in location technologies has been conducted as part of the MITI project and was shown at exhibits of companies and research centers participating in this project.

PART 3: THE MITI RESEARCH PROJECT

JIAM '90 was chosen by the Japanese as a major showcase for the accomplishments produced by the MITI project. Results of the research and development effort were shown at a number of exhibit booths of companies that participate in the project (Aisen Seiki, Mitsubishi, Juki, Asahi, Matsushita, Brother, Gunze). Exhibit space had also been provided for the universities conducting research on MITI projects (Research Institute for Polymers and Textiles, Industrial Products Research Institute). A list of the equipment and machinery exhibited at JIAM '90 developed as part of the MITI project is listed in Figure 4.

The seminar sessions conducted on Saturday, May 26, by Dr. Shouichi Ishikara, professor at Tokyo Institute of Technology and Chairman of Japan Apparel Industrial Research Association, and Mr. Shigeo Ogawa, Manager of the Technical Department of Technology Research Association of Automated Sewing System, were very thorough and informative. Several of the technical personnel actively involved in the MITI project were also present at the meeting and seemed very open and eager to discuss the results of their work.

The Automated Sewing System project was described by Mr. Kimoshita, Research and Development Officer of the Agency of International Science and Technology, as a "large scale project". This is defined by MITI as a high cost (10-20 billion Yen), long term (7-8 years) and high-risk (cannot be undertaken by industry) project. Eleven such projects are currently being funded by MITI. The Automated Sewing System project began in 1982 and, in final form, had a budget of 10 billion Yen ($68 million) and is scheduled for completion at the end of 1990. Twenty-eight companies participated in the effort (See Table 1) in addition to the two research institutes noted earlier.

The Automated Sewing System project was a continuation of earlier work in Japan on apparel assembly. A development project under Dr. Tatsuya Kawakami was undertaken at the Research Institute for Polymers and Textiles ("Senkoken") between 1967 and 1970 to develop the "Workerless Factory" (System J) for the production of formal shirts. Further work on the handling of sheet-like flexible materials in 1971-1973 and on material handling technology for sewing of parts in 1975-1978 were the forerunners of the Automated Sewing System project.

The objective of the MITI project was to develop the technologies required to demonstrate an automated, flexible apparel

FIGURE 4

Equipment and Machinery to be Exhibited at JIAM '90

Developing Agency (excluding apparel makers)	Developed Technology and/or Equipment	Exhibition Location
Research Institute for Polymers and Textiles	1. Fabric gripping hand 2. Water jet seaming equipment	Automated Sewing Corner
Industrial Products Research Institute	1. Fabric gripping position checking sensor 2. Fabric gripping condition checking sensor 3. Parts shape condition checking sensor 4. Active sensor system	
Aisin Seiki Co., Ltd. (Some of the element technology by Yamato Sewing Machine MFG. Co., Ltd.)	1. High-functional sewing technology (replacement of bobbin, exchange of needle thread, replacement of needle)	At the Corner for the maker developing the equipment in question (Hitachi, Ltd.'s equipment is at Asahi Chemical Industry Co., Ltd.'s Corner.)
Mitsubishi Electric Corporation	1. High-speed laser cutting equipment (the main body)	
JUKI Corporation	1. Automatic sleeve attachment unit 2. Lock stitch sewing machine with automatic feeding of bobbin thread 3. Automated feeding control equipment	
Hitachi, Ltd.	1. Pattern matching system	
Brother Industries, Ltd., Yamato Sewing Machine MFG. Co., Ltd., Matsushita Electric Industrial Co., Ltd., Kayaba Industry Co., Ltd.	1. Multi-functional sewing station 2. Head machine mounted on this equipment 3. Equipment for conveyance between stations for the above equipment	
Gunze Ltd.	1. Sewing thread for automated sewing system 2. Small, light-weight machine for three-dimensional sewing equipment	

Table 1: Composition of the Technology Research Association of Automated Sewing System

Name of Company		
Aisin Seiki Co., Ltd.	Sanyo Shokai Ltd.	Hitachi, Ltd.
Asahi Chemical Industry Co., Ltd.	Daiwa Senko Co., Ltd.	Brother Industries, Ltd.
Asics Corporation	Tsuyakin Kogyo Co., Ltd.	Pegasus Sewing Machine MFG. Co., Ltd.
Kind Wear Co., Ltd.	JUKI Corporation	Matsushita Electric Industrial Co., Ltd.
Kao Corporation	Toyama Goldwin Inc.	Mitsubishi Electric Corporation
Onward Kashiyama Co., Ltd.	Toyo Denki Seizo K.K.	Yamato Sewing Machine MFG. Co., Ltd.
Kayaba Industry Co., Ltd.	Toyobo Co., Ltd.	Renown Inc.
Kimuratan Co., Ltd.	Toray Industries, Inc.	Wacoal Corp.
Ginza Yamagataya Co., Ltd.	Nippon Kayaku Co., Ltd.	Textile Industry Rationalization Agency
Gunze Ltd.	Japan Vilene Co., Ltd.	

Table 2: Outline of Research and Development on Element Technology

Element Technology	Sub-Element Technology	Main Content of R&D
1. Sewing Preparation Processing Technology	(1) Fabric characteristics evaluation technology	Develop an equipment which can measures and evaluate the characteristics of the fabric which are necessary for controlling the processing and handling conditions in relation to the fabric.
	(2) Fabric stabilizing technology	Develop a technology for stabilizing measurement and form of the fabric which have inappropriate physical properties in terms of fabric handling and product quality.
	(3) High-functional pattern formation technology	Develop a technology for forming patterns that are suitable for three-dimensional sewing of clothes.
	(4) Fabric inspection, fabric spreading and cutting technology	Develop a technology which is capable of detecting defects, fabric spreading and cutting, with the speed and precision which is appropriate for the system.
2. Sewing Assembly Technology	(1) Sewing pretreatment technology	Develop pretreatment technology for bending fabrics, temporary joining of pieces, etc., in order to enable sewing assembly to be processed efficiently.
	(2) High-functioinal sewing technology	Develop a three-dimensional sewing system and super sewing unit that are appropriate for automated sewing system, without regard to the existing sewing principle.
	(3) High-function press processing technology	Develop a dummy for three-dimensional press-ironing and high-functional putting on and taking off of the item being processed, in order to automate press processing.
3. Fabric handling technology	(1) Fabric gripping technology	Develop a mechanism that can grip flexible fabrics like a worker.
	(2) High-functional position-determining technology	Develop a technology which can determine the position of a flexible fabric in accordance with the set position with a high level of precision, and a technology which can pile up and combine a number of fabric sheets .
	(3) Flexible fabric conveyance technology	Develop a technology for conveying fabric items being processed between the different work stages reliably.
4. System management and control technology	(1) System integration management technology	Develop a technology for integrating and managing the production line overall including setting of the best production line in response to a change in product variety, etc.
	(2) Testing and trouble detection technology	Develop a technology for testing for defective products for each work stage on the production line, handle the defects, and carry out replacement of the malfunctioning mechanical parts
	(3) Control information imparting equipment	Develop a method for imparting sewing and processing control information to fabrics.
	(4) Information recognition equipment	Develop a technology for recognizing the fabric's shape and surface conditions and a technology which can read swewing processing control information.

assembly plant. The plant was envisioned to require four major subsystems--Sewing Preparation, Flexible Sewing (2D), High-Tech Assembly (3D), and Three-dimensional Flexible Press. The first six years of the project were devoted to development of the elemental technologies required by the plant subsystems. A major review of the progress on the elemental technologies was held in 1988 at which time the decision was made to go forward to design and construction of a demonstration plant. This plant is being constructed at Tsukuba Center, Inc. and will be demonstrated in December, 1990.

The principal R&D efforts for the major subsystems of the demonstration plant during the first six years are listed in Table 2 (It is interesting to compare this list with similar research project lists and with on-going research projects in the U.S.). Each of the sub-element technologies was discussed in Mr. Ogawa's paper and selected comments on several of these technologies are given below:

1.1. Fabric Characteristic Evaluation--The Japanese are making extensive use of fabric physical properties as measured by the Kawabata Evaluation System (KES) in design of system units and in production control systems. Several MITI project machines used KES data in initializing sewing parameters for different fabrics. This was especially true of sewing systems designed to add fullness by differential feeding of fabric during sewing.

1.2. Fabric Stabilizing--The Japanese have developed both permanent and temporary hardening technology for fabrics with inadequate physical properties for automatic handling. The permanent system appears to involve fusing systems using dielectric curing. Less is known about the temporary system, but one speaker did indicate that water soluble polyurethanes were being used in the temporary system. Such an approach would be quite expensive.

1.3. High-Functional Pattern Formation--Patterns that are specifically designed for automated manufacture were developed under this R&D effort. One example mentioned was men's trousers with one piece replacing the typical four leg panels. This seems to be a very important concept for automated manufacturing.

2.1. Sewing Pretreatment--Much of the joining of face fabrics with interlinings is accomplished using adhesives and high frequency induction heating. A novel water-jet fiber entangling system was shown at JIAM '90 to replace basting operations for temporarily joining two fabrics.

2.2. High Functional Sewing--Two types of sewing systems resulted from this work. The jacket sleeve setting machine using the light-weight (2.2 pound) Juki developed lock-stitch machine and a flexible, automated 2-dimensional machine with independent control of the top and bottom fabric feed and position. In many respects this latter machine represents a very significant advance in subassembly production capability. It could join totally different kinds of parts with different, complex sewing paths from information downloaded from the control computer. It could add fullness by differential feeding of the two fabrics being joined. The unit had two fiber optic cables that were used to independently detect the edges of the parts being joined. It was said to use KES data directly to insure high quality in the seam for wide varieties of fabrics. Both of these machines were displayed at the Juki exhibit at the show.

3.1. Fabric Gripping--Very little information in this area was presented in the seminars. Two types of gripping systems were on display at the show. One developed by Research Institute for Polymers and Textiles is a robot arm with a two finger device equipped with a sensitive strain gauge attached to a phosphor bronze plate to determine height of the cut part stack. Pressure is applied to the stack a short distance from the edge to separate the edges and the phosphor bronze finger is inserted between the top and second ply. This device seemed very slow and, according to published data, is never more than 90% reliable. The second gripping device on display was a very clever pick and place unit displayed by Eagle. It used four small pinchers to literally grip the loose fiber ends on the surface of a staple yarn fabric. The positions of the four grippers were adjustable so that both large and small parts could be picked and placed by the same unit.

3.2. High-functional Position-Determining--A number of video camera vision systems were in place on MITI developed equipment. One automated spreading machine used a camera to determine the alignment of plaid fabrics and to automatically adjust the fabric to insure proper cutting. Cameras were also used on the automatic fabric defect detection unit incorporated prior to the automatic spreading machine. Also, approximately 10 photodetectors were arranged around each arm-hole of the 3D sleeve setting machine to insure exact placement of the sleeve prior to sewing. A very interesting area tactile sensor based on technology developed at Stanford University was demonstrated at the Industrial Products Research Institute's booth. At the points within the area where pressure is being applied to the sensor, the resistance changes and this position is determined by x and y direction potentiometers. This device could be used to determine the position of a cut part by the pressure it exerts on the sensor surface.

4.3. Control Information--The Japanese have developed an invisible marking system for labeling of each part for identification. This label can be detected by a reader at each workstation so that sewing and processing information can be downloaded from the central computer for each operation.

Following development of the elemental technologies described above, the Japanese for the past three years have been integrating the various technologies into a demonstration plant. There has been some feeling in U.S. circles that this integration would not be accomplished, but it was clear at the meeting that the Japanese plan to demonstrate the Automated Sewing System plant in December, 1990, at Tsukuba. The plant is less versatile than originally planned (it will make only one garment type). The garment selected for manufacture is ladies blazers and the plant will produce two different designs in three sizes in two woven fabrics (plain and Pattern) and one knit fabric. The plant will have four subunits which are shown schematically in Figures 5 and 6.

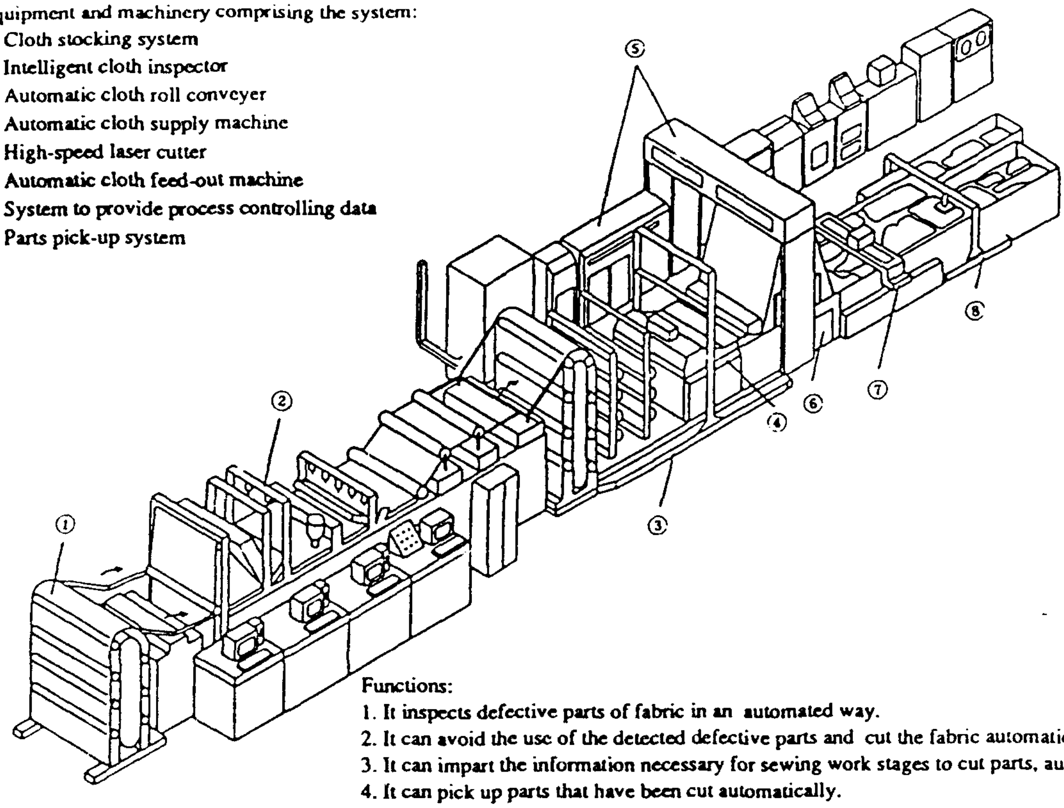
In the first subunit (the Sewing Preparation Subsystem) fabric rolls are selected and the fabric unrolled and run through a fabric inspection system (No. 2 in Figure 5A). This system apparently examines the fabric for both defects and shade and rerolls the fabric. Information about defects is passed to the Automatic Cloth Supply Machine (No. 4 in Figure 5A). Fabric is then spread in a single ply in such a way as to avoid cutting parts with fabric defects. The automatic spreading system shown at the show (see 3.2 above) is used to insure proper alignment of patterned fabrics. Single plies of fabric are cut with a high speed laser cutter (No. 5). Cut parks are given the invisible marking code by unit number 7 in Figure 5A. Parts are now ready to pass to the first assembly subunit.

Most subassembly manufacture will take place in the Parts Sewing Sub-system shown in Figure 5B. The first part of the unit has the part recognition reader and attaches interlinings and probably temporary stiffening (if required) to garment parts. The second half of the unit is described as consisting of multi-functional sewing station for serging, pocket assembly and attachment. These units, according to the description, will make extensive use of vision and other location technologies for part location and pattern matching. The last unit in this sub-system is an automatic inspection station. The units in the Parts Sewing Sub-system were not as clearly described in the seminar as the other sub-systems and components of this sub-system were not clearly defined (if present) at booths in the exhibition hall.

The two automated sewing machines described earlier in 2.2. are the heart of the High-Tech Assembly Sub-system (Units 3 and 6 in Figure 6A). Extensive use of vision systems in the joining module and opening seam press are indicated in the drawing of this sub-system.

FIGURE 5

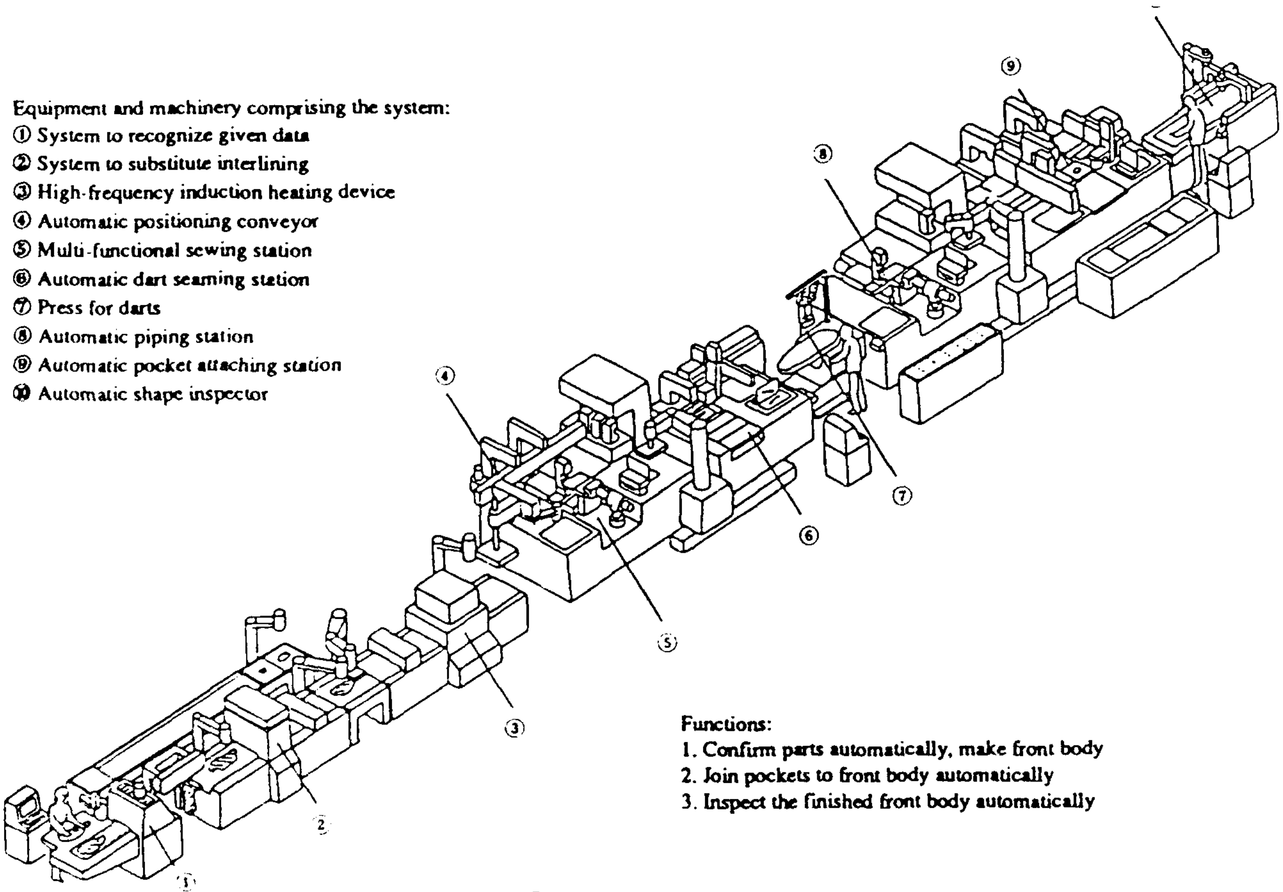
Equipment and machinery comprising the system:
① Cloth stocking system
② Intelligent cloth inspector
③ Automatic cloth roll conveyer
④ Automatic cloth supply machine
⑤ High-speed laser cutter
⑥ Automatic cloth feed-out machine
⑦ System to provide process controlling data
⑧ Parts pick-up system



Functions:
1. It inspects defective parts of fabric in an automated way.
2. It can avoid the use of the detected defective parts and cut the fabric automatically with the use of laser
3. It can impart the information necessary for sewing work stages to cut parts, automatically.
4. It can pick up parts that have been cut automatically.

A **Conceptual Drawing of Sewing Preparation Subsystem**
~~(High-speed laser cutting subsystem)~~

Equipment and machinery comprising the system:
① System to recognize given data
② System to substitute interlining
③ High-frequency induction heating device
④ Automatic positioning conveyor
⑤ Multi-functional sewing station
⑥ Automatic dart seaming station
⑦ Press for darts
⑧ Automatic piping station
⑨ Automatic pocket attaching station
⑩ Automatic shape inspector

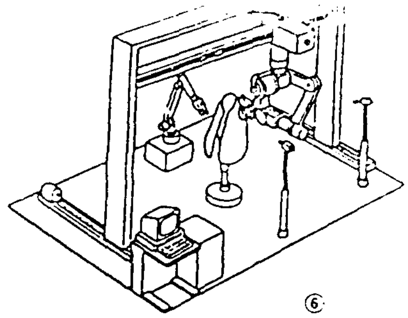


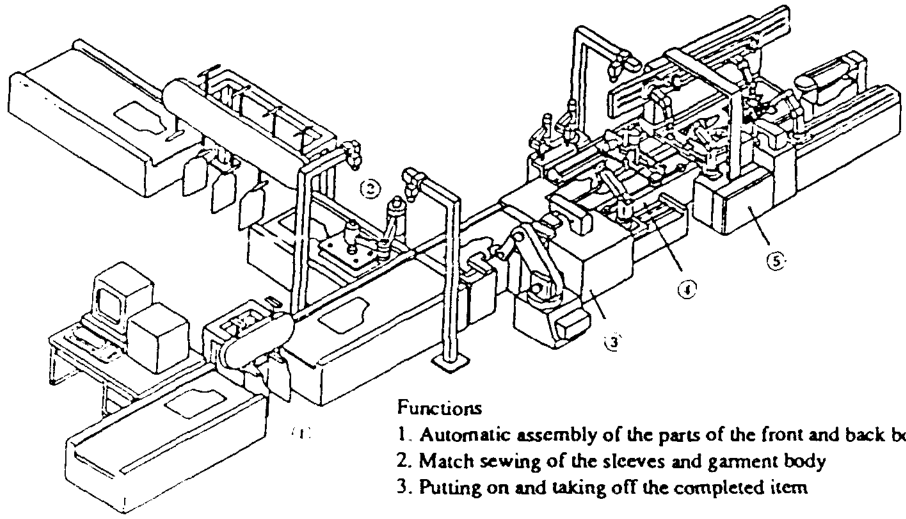
Functions:
1. Confirm parts automatically, make front body
2. Join pockets to front body automatically
3. Inspect the finished front body automatically

B **Conceptual Drawing of Parts Sewing Sub-system**
(Flexible sewing sub-system)

Equipment and machinery comprising the system:
① Turning-out system
② Joining module
③ Automatic closing system
④ Opening seam press
⑤ Multi-handle cooperative controlled assembly system
⑥ Three-dimensional seamer

FIGURE 6

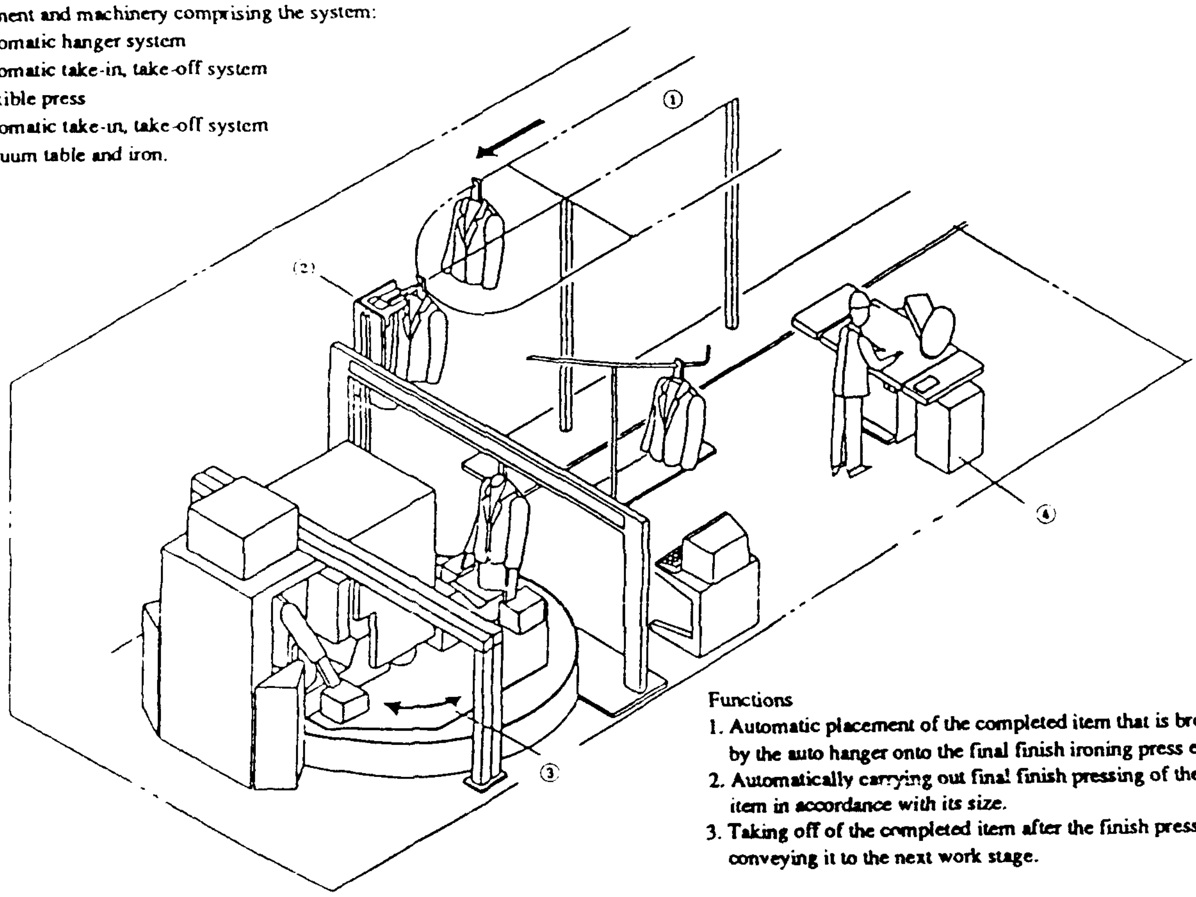




Functions
1. Automatic assembly of the parts of the front and back body that are carried forward.
2. Match sewing of the sleeves and garment body
3. Putting on and taking off the completed item

A Conceptual Drawing of High-Tech Assembly Sub-system

Equipment and machinery comprising the system:
① Automatic hanger system
② Automatic take-in, take-off system
③ Flexible press
④ Automatic take-in, take-off system
⑤ Vacuum table and iron.



Functions
1. Automatic placement of the completed item that is brought forw... by the auto hanger onto the final finish ironing press equipment
2. Automatically carrying out final finish pressing of the completed item in accordance with its size.
3. Taking off of the completed item after the finish pressing and conveying it to the next work stage.

B Conceptual Drawing of the Three-Dimensional Flexible Press System

The last sub-system (Three-Dimensional Flexible Press System) will handle the final pressing and finishing of the garment.

The Seminar program also included presentations by Joe Off of $(TC)^2$ and Hans-Dieter Jahler describing the BRITE project in Europe. The main thrust of Joe Off's paper was the change in thrust of the $(TC)^2$ program toward more education and demonstration and less fumdamental research (now about 30% of the budget). The paper on the BRITE project contained absolutely no information of a technical nature.

APPENDIX C-2

SURVEY OF LOCATION TECHNOLOGIES AT THE BOBBIN SHOW 1990

Research personnel attended the Bobbin Show on September 11-13 to review new location technologies on apparel assembly equipment being exhibited at the show. Most of the location technologies seen at the show have already been reviewed in previous reports on equipment in the DLA centers (See Appendix B). Reviews of these technologies will not be repeated here. Several new concepts were observed at the Show and will be reviewed.

The TC^2 Booth had the greatest concentration of new location systems. One unit of the new sweatsuit pant making machine was on display that used several photoelectric devices to locate parts. A light beam passed diagonally about one inch above the folding table and was wsed to insure that both parts had been picked up by the pick-and-place unit. Photodetectors at the corners of the parts being sewn were used to insure that the parts were placed in the correct position for sewing. These photodetectors (one at each of the two sides of a corner) were directly coupled to the device moving the fabric and when the light beam to both cells was broken the part was in the correct position. Both the top and bottom plies of fabric were positioned in this way prior to sewing.

The semi-automated felling machine also had interesting location devices. In these machines fiber optic bundles were used to transmit light inside the machine folder and to return light to a photodetector. When the fabric in the machine folder failed to interrup the light beam a motor and toothed wheel assembly were activated to feed more fabric into the folder. When the light beam was broken again the motor was cut off thus, keeping the fabric always at the same position in the folder. Control of both the top and bottom fabrics was obtained in the same way. This attachment to a standard felling machine was reported to significantly deskill the felling operation.

A third interesting application of location technologies was exhibited at the Porter Sewing Machine Booth. An optic fiber linear array with 10 photodetectors located over approximately one inch was used to determine the position of a cut part edge. This detection system was directly coupled to a simple mechanical device to move the fabric in or out to keep the edge aligned at the needle. Two identical units were used to separately control the cop and bottom fabrics being sewn together. The attachment was able to correct for two parts that were misaligned by an inch or more with no apparent difficulty.

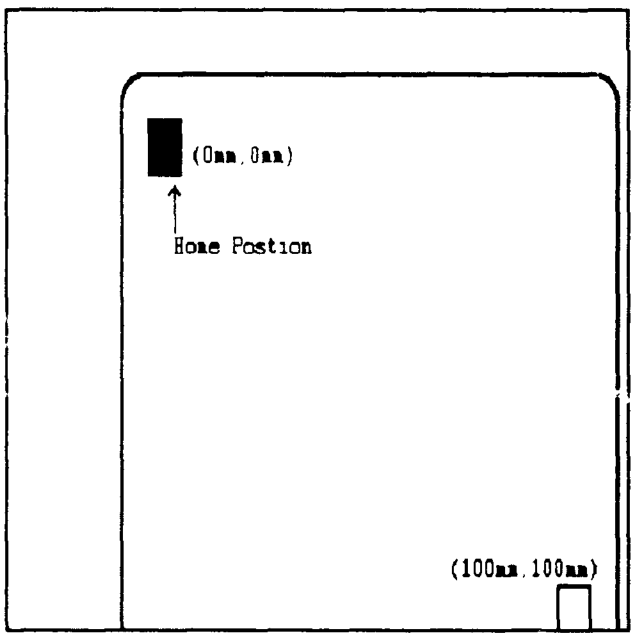
APPENDIX D

DETERMINATION OF THE ACCURACY AND REPEATABILITY OF CURRENT VISION SYSTEMS

Setup

The setup for this performance test involved making the camera perpendicular to the Newport controllers target surface. On the Adept this was done by placing the Newport on the work surface and the camera on a rack that extended over the work area. In the Automation lab, the Newport table was placed on the conveyor and the camera mounted on the vision rack that surrounds the conveyor. Both setups proved to be fairly easy to adjust.

The test required that the Newport translation table be square with the camera, and that the target (in this test a reflective square with dimensions 1cm x 1cm) in it's home position be in the upper left corner of the screen. Each axis should move in an outward direction from this point. For this test, the 'X' axis has been defined to be the horizontal axis and the 'Y' axis the vertical axis.



Translation Table Setup

The setup for this test involves mounting the Newport's two actuators in the correct position and orientation and calibrating the vision system being used. The Newport actuators should be mounted in such a way that when in their fully retracted positions (Home position) the target on the table, which is to be mounted on top of the actuators is in the upper left corner of the screen. The target should be close enough to this corner so that the actuators can fully extend with the target still visible on the screen. **The target should never be partially or fully off of the screen with the actuators in any position.** The actuators should cause the target to move parallel to the X and Y axis. Actuator #1 should move the target parallel to the X axis and actuator #2 the Y axis.

Vision System Calibration

Calibration is different for each vision system. The SVP512 vision system simply requires that the target be moved to particular points that the program will give, while the AdeptVision software is a bit more involved. Each is outlined below.

Calibration for the SVP512 Vision system requires that the target be in home position and then at another position specified by the program. To load the Vision program, boot the PC connected to it and then turn the Vision system on. After both have come on type:

go local	<return>
svp	<return>
do commprog	<return>

where '<return>' denotes pressing ENTER or RETURN. In order to move the target to the position that the program asks, simply connect to the Newport via some type of terminal program and **WITH NO SPACES** type:

A1'x-pos'	<return>
A2'y-pos'	<return>
V1.4	<return>
V2.4	<return>
M0	<return>
W0	<return>
.1	<return>

where 'x-pos' and 'y-pos' are the given X and Y positions respectively. When the line **'lin 0'** appears on the screen, return to the connection with the vision system and the program will take this point any perform all calibrations and state that it is ready to work with the test program.

Calibration with the AdeptVision system requires that calibration program that is supplied with the AdeptVision system be run and a calibration array be made. After calibration of the system, the system needs to be trained to find the target on the translation table.

The V.BACKLIGHT switch needs to be OFF in order to properly train the target. Once both of these tasks have been completed the following needs to be done:

delete a.areacal	<return>
load vision	<return>
ex vision	<return>

The vision program will then prompt that the translation table be in the home position. Once it is signaled that the table is in the home position it will take a reading and state that it is ready to work with the performance program. In order for the Vision system to work with the PC, a serial cable needs to be connected between the PC's 'COM2' serial port and the Adept's USER1 port.

Program Execution

After the calibration is completed, all that is left is the run the performance program. In the directory 'AVA' type **'testa'** and the program will begin execution. The program will ask a few questions about the setup and target and it will also ask which test to perform. The setup that is described above will work with the SINGLE-POINT STEADY RATE and the SINGLE-POINT CYCLE TIME tests. The other two tests require a target sheet and are a lot more complicated to execute. Both the STEADY RATE and CYCLE TIME yield similar results.

What follows is a brief explanation of how the Accuracy and Repeatability mentioned in the report were calculated using the AVA ANSI standard test:

Calculation of Accuracy

Let N designate the number of distinct points measured, M designate the number of times each distinct point is repeatedly measured, and K designate the dimensionality of the point (two in this test). We let Y_{pqmk} designate the measured value of the kth component from the mth repeated measurement of the nth point and μ^{*}_{nk} designate the nominal value of the kth component of the nth point. The nominal value is the location of the point as specified by the test controller to the translating table. The accuracy of the vision system is estimated by $\hat{\sigma}_a$ where $\hat{\sigma}_a$ is calculated as:

$$\hat{\sigma}_a = \{ [\frac{1}{NMK} \sum_{n=1}^{N} \sum_{m=1}^{M} \sum_{k=1}^{K} (Y_{nmk} - \mu^{*}_{nk})^2] \}^{\frac{1}{2}}$$

Calculation of Repeatability

As in the accuracy case, we let N designate the number of distinct points measured, M designate the number of times each distinct point is repeatedly measured, and K designate the dimensionality of the point. We let Y_{nmk} designate the measured value of the kth component from the mth repeated measurement value of the nth point, and we let $\hat{\mu}_{nk}$ be the mean of the M repeated measurements of the kth component of the nth point.

$$\hat{\mu}_{nk} = \frac{1}{M} \sum_{m=1}^{M} Y_{nmk}$$

The repeatability of the vision system is estimated by $\hat{\sigma}_r$ where $\hat{\sigma}_r$ is calculated as:

$$\hat{\sigma}_r = [\frac{1}{NK(M-1)} \sum_{n=1}^{N} \sum_{m=1}^{M} \sum_{k=1}^{K} (Y_{nmk} - \hat{\mu}_{nk})^2]^{\frac{1}{2}}$$

References:

American National Standards Institute, "For Automated Vision Systems-Performance Test-Measurement of Relative Position of Target Features in Two-Dimensional Space," ANSI/AVA15.05/1-1989.