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Delco Systems Operations

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Phase 2 Final Project Report #8 PWB Inspection, Revision A

Final

FROM 1984 TO 1987

1987, 10, 09

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This report describes

Automatic Printed Wiring Board Inspection using Machine Vision Technology.

Captain Curtis Britt

513-258-4263

Approved for public release
Distribution Unlimited

For more information, please contact DTIC at 513-258-4263.
INDUSTRIAL TECHNOLOGY MODERNIZATION

Phase II Final Report
Project 8
PWB Inspection

Prepared for
GENERAL DYNAMICS
Fort Worth, Texas

Contract No. F33657-82-C-2034

Delco Systems Operations
DELCO ELECTRONICS CORPORATION
Goleta, California 93117
INDUSTRIAL TECHNOLOGY MODERNIZATION

PHASE II FINAL REPORT

PROJECT #8

PWB INSPECTION

CONTRACT No. F33657-82-C-2034

January 9, 1987

REV A

prepared for

GENERAL DYNAMICS

Fort Worth, Texas

by

Delco System's Operations

Goleta, California
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A Comparison of Present and Proposed Methods

Present

Printed wire board inspection is presently accomplished using human operators to visually verify circuit trace integrity. In a typical inspection environment (lab benches) and primarily used illuminated magnifiers to inspect for circuit trace shorts, opens, and general workmanship. Inspection times may vary depending on build schedules, but in general takes approximately 30-45 minutes. Circuit card assemblies average 8 layers (PB &) and typically require 100% inspection prior to bonding. Two to three operators are generally employed full time to accomplish this task, during peak periods additional inspectors are used on a temporary basis.

Proposed

The proposed method of printed wire board inspection will utilize automated machine vision technology. The system will capture an image of a PCB and compare it to a preprogrammed database. This not only allows the system to look for shorts and opens, but also to verify circuit trace presence/absence and width. Typical inspection times would be under 5 minutes. It is envisioned that only one or two operators will be required to feed printed wire boards into the system or accomplish required programming.
Statement of Objective

Purpose

The purpose of the PWB Automatic Inspection Machine is to provide visual inspection capability with a 0% defect escape rate. In addition to providing higher yields with defects detected earlier in the fabrication flow, the results of this inspection will be used to help understand, improve and control the processes.

General Requirements

1. The annual production of PWB’s to be screened by the PWB Automatic Inspection Machine is anticipated to be 50,000–100,000 units.

2. The PWB Automatic Inspection Machine must be capable of meeting the mechanical and visual inspection requirements of Delco Electronics Specifications E9-9368 and E8-11663, Electro-Motive Division Specifications 234 and 2350, and MIL-P-35110C.

3. The PWB Automatic Inspection Machine must be capable of inspecting Artwork, Panels and completed PWB’s. (Double Sided, Multi-Layer and Double-Double-Sided PWB’s)

4. The PWB Automatic Inspection Machine must be automated using robotic techniques for all handling of material. This shall include loading items to be inspected and unloading items after inspection.

5. The PWB Automatic Inspection Machine must be capable of inspecting items at a rate of between one and two minutes per side. (Compared to the human inspector who might take 30–45 min per panel)

6. The PWB Automatic Inspection Machine must have an Edit-out capability for areas such as alpha-numeric, which violate the design rules, and therefore must be ignored.

7. The System must have the capability of inspecting panels up to a size of 24” x 24”.

8. The System must be compatible with Plant Host Computer Systems, including VMS/VAX, CAD, MCB and IBM.

9. The System should be Software oriented, Menu driven and operator friendly.

10. Inspection operation should be initiated by inputting the Part Number of the item to be inspected or through use of Bar Codes on the part using a Bar Code reader.

Inspection by Design Rules

The PWB Automatic Inspection Machine shall be capable of the following:

1. Identify the Serial Number of the item to be inspected by use of a Bar Code reader.

2. Taking measurements of individual parameters and storing this data.

3. Identifying defect locations by X-Y coordinates.

4. Identifying defect data to PWB or Panel inspected.
5. Providing a printed output of inspection results.
6. Providing a means of stepping through listed defects, displaying an enlargement of the defect on a TV Monitor
7. Driving an X-Y Plotter Station to be used for Verification/Repair of Repairable Items.

MEASUREMENTS
Measurements to be taken are of the following dimensional magnitude:
1. The minimum Conductor Width to be measured will be 0.003".
2. The minimum Conductor Spacing to be measured will be 0.004".
3. Terminal Areas will be 0.027" x 0.047" Minimum.
4. Annular Rings minimum size will be 0.002" to 0.010".
5. Hole sizes of 0.006" to 0.080". (Some non-plated holes as large as 0.250")

Undercutting of conductors shall not exceed the thickness of the copper clad and the plated copper.

SURFACE TREATMENTS
Inspection must be possible with item surfaces such as those:
1. Treated with oxides.
2. Etch roughened.
3. Tin-Lead plated.
5. Other types of plating material.

FLAW DETECTION
The following types of flaws must be detectable:
1. Cracks and Voids.
2. Open and Short Circuits.
3. Pin Holes.
5. Notches/Mousebits.
6. Spurious Copper.
SYSTEM OUTPUTS

The following outputs must be available as a result of data manipulation:

1. Statistical Analysis using accumulated data.
2. Trend Charts (X Bar & R).
3. Defect Summaries & Trend Reports.
5. Sort of inspected hardware based on types and magnitudes of flaws detected.
6. Payroll information based on quantities of accepted items.

II. Technical Approach Followed

To provide potential suppliers with detailed requirements, a Statement of Work was prepared. The SOW was submitted to each of four suppliers with a Request for Quotation. The Statement of Work is contained herein in its entirety.

STATEMENT OF WORK

1.0 SCOPE

This Statement of Work and associated attachments establish the requirements for procurement of an Automatic Printed Wiring Board Inspection Machine.

2.0 APPLICABLE DOCUMENTS

2.1 General Motors Corporation


2.2 Delco Electronics


Exceptions to this document applicable to this Work Statement are as follows:

Para. 17.1.1 - Shipping instructions to be obtained from Marv Friebert by calling (414) 768-2953.
Para 18.1.1 - The approving authority at Delco Electronics, Milwaukee is the Work Statement originator. All approval prints, final drawings, or reproducibles, requests for deviation and questions concerning this specification shall be addressed to:

Delco Electronics Division
7929 South Howell Avenue
Oak Creek, Wisconsin 53154

ATTENTION: Mr. R. W. Ladd or
Mr. B. F. Sibley
Mail Station 2A13

TELEPHONE: (414) 765-2642

Para 20.2.1 - Delete reference to requirements of Indiana Law (IC 1971, 22-B-1.1 et. seq.)

On page 38 under PROGRAMMABLE CONTROLLERS' delete Modicon


2.4 Attachments to this Statement of Work:

Attachment 1. Requirements for an Automatic Printed Wiring Board Inspection Machine

3.0 ARTICLES AND SERVICES TO BE SUPPLIED BY THE CONTRACTOR

3.1 Equipment

a. Design
b. Fabrication
c. Delivery

3.2 Engineering Data

a. Layout Drawings
b. Final Drawings
c. Specifications
d. Operating & Maintenance Manuals
e. Recommended Spare Parts List
f. Installation Instructions
g. Operating Software

3.3 Progress Information

3.4 Training
3.5 Quality Assurance Provisions
3.6 Warranty
3.7 Installation & Checkout Surveillance
4.0 DESCRIPTION OF ARTICLES & SERVICES

4.1 Equipment

4.1.1 Design - The Subcontractor shall execute all new design and the necessary modification to existing design to meet the requirements of the Attachments to this Statement of Work. Should the Subcontractor have an engineering standard practice on this design which conflicts with this Statement of Work, he may submit this standard provided he states in detail the variance from this Statement of Work in his quotation. If no exceptions are stated in the quotation, Delco Electronics will require the Subcontractor to fulfill all details of this Statement of Work.

4.1.2 Fabrication - The Subcontractor shall fabricate the Automatic Printed Wiring Board Inspection Machine per the requirements of Attachment #1 to this Statement of Work.

4.1.3 Delivery - The Subcontractor shall be responsible for the packaging and safe delivery of the Automatic Printed Wiring Board Inspection Machine to Delco Electronics.

4.1.4 The Subcontractor shall act in an advisory capacity during the installation and checkout of the equipment at Delco Electronics.

4.1.5 Milestone Chart and anticipated machine implementation schedule

a. Release this S.O.W.
b. Vendor Quotation response
c. Delco Technical Review & Vendor selection
d. Release Purchase Order

e. Preliminary Design Review
f. Final Design Review
g. Fabrication and Assembly
h. Preliminary Acceptance @ Vendor facility
i. Installation and checkout @ Delco
j. Final Acceptance @ Delco

4.2 Engineering Data

4.2.1 Drawings outlining the Automatic Printed Wiring Board Inspection Machine showing approximate dimensions, weight, mounting points and requirements for accessibility, operation and maintenance

4.2.2 One reproducible electrical and pneumatic schematic, block diagram, and wiring diagram showing selected components and connector pinout

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4.2.3 Final Drawings - One set of reproducible and one set of non-reproducible drawings of the Automatic Printed Wiring Board Inspection Machine shall include the following information as a minimum:

a. Parts List - including generic part numbers where applicable
b. Electrical, pneumatic and hydraulic schematics
c. Cable and wire list.
d. Modifications made to purchased commercial equipment
e. Assemblies, subassemblies, details & system interface.

All drawings and manuals will be the property of Delco Electronics for Maintenance, Repair and Servicing. Drawings will not be used to duplicate this machine.

4.2.4 Operation and Maintenance Manuals - The Subcontractor shall generate and submit two copies to Delco Electronics of an OPERATION AND MAINTENANCE MANUAL which shall be suitable for use by skilled technical level personnel in the repair, maintenance and the operation of the Automatic Printed Wiring Board Inspection Machine.

The MAINTENANCE MANUAL shall contain sufficient information to permit servicing down to the component level. Standard Maintenance Manuals on unmodified commercially available equipment is adequate.

4.2.5 Spare Parts List - The Subcontractor shall submit one list of recommended spare parts. Quantities listed shall be sufficient to support one piece of equipment for one year.

4.2.6 Installation Instructions - The Subcontractor shall submit installation drawings defining utilities and special installation requirements.

4.3 Training

Training of Technician skill level personnel, for two people at the Contractor's facility, shall be quoted separately at or near the time of acceptance.

4.4 Quality Assurance Provisions

4.4.1 Notification of Readiness for Acceptance - The Subcontractor shall notify Delco Electronics of the readiness of the Automatic Printed Wiring Board Inspection Machine for acceptance. This notification shall be given at least one (1) week before the scheduled acceptance start date. Notice of cancellation or change of an acceptance date shall be given at least three (3) days in advance of any scheduled acceptance date.

4.4.2 Preliminary Acceptance - Preliminary acceptance of the Automatic Printed Wiring Board Inspection Machine shall be accomplished at the Subcontractors facility. A functional demonstration in compliance with the requirements of this Statement of Work shall be conducted in the presence of the authorized Delco Electronics representatives. Acceptance shall be based on both hardware compliance and machine performance.

4.4.3 Final Acceptance - Final acceptance of the Automatic Printed Wiring Board Inspection Machine shall be accomplished at Delco Electronics and shall be based on demonstration of compliance with the requirements of this Statement of Work. A final acceptance shall be conducted in the presence of authorized Delco Electronics representatives. Acceptance shall be based on both hardware compliance and machine performance.

4.4.4 Equipment Verification - The Subcontractor shall maintain technical liaison with Delco Electronics to correct deficiencies and/or to affect improvements in the operation and design of the equipment during the warranty period.
5.0 SUGGESTED METHOD FOR ANSWERING THIS STATEMENT OF WORK

5.1 Indicate either compliance or deviation and alternate specification in response, as required, to all numbers of this Work Statement and Attachments thereto. Follow this same procedure on the G.M. Electrical Standards.

5.2 Provide a breakdown of costs as follows, in answering this Statement of Work:

5.2.1 Non-recurring Costs - Engineering, design, drafting, software, operating manuals, service manuals, first copy equipment verification (liaison) and first copy checkout support.

5.2.2 Recurring Costs - Fabrication and material.

5.2.3 Training - Quote training of Delco personnel as a separate cost item.

6.0 MAILING INSTRUCTIONS

The mailing address for documentation, reports and notices shall be as follows:

Delco Electronics Division
General Motors Corporation
P.O. Box 471
Milwaukee, Wisconsin 53201

ATTENTION: Mr. J Lukowski
Purchasing
Dept 417, M/S 1A09

CC: Mr. R. W. Ladd (2 Copies)
Quality Engineering
Dept 474, M/S 2A13
ATTACHMENT I

AUTOMATIC PRINTED WIRING BOARD INSPECTION CELL

ITM PROJECT 8

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3.0 ACCEPTANCE TESTING

This document outlines the equipment requirements for an Automatic Printed Wiring Board Inspection Machine to be used for the inspection of fabricated Printed Wiring Board layers, artwork, and laminated printed wiring boards.
1.2 DOCUMENTS

The following government standards, specifications, and regulations, issues in effect on the date of this contract, or as otherwise stated herein, shall form a part of this statement of work to the extent specified.

Sound Level Specification
GM Spec SL1.0
Robotic Safety Standards
Section 28
Basic Electrical Standard
ESI
GM Manufacturing Automation Protocol
(Based on Availability)

2.0 DESCRIPTION OF ARTICLES AND SERVICES TO BE FURNISHED

2.1 GENERAL

2.1.1 SYSTEM OBJECTIVES

2.1.1.1 The Automatic Printed Wiring Board Inspection Machine will use automatic vision and robotic systems to visually inspect a PWB Inner Layer for proper line widths and line spacing, pad sizes and annular ring dimensions, as well as providing positive detection of configuration departures such as open and shorted conductors, conductor width and spacing below minimums, locally reduced conductor width, cracks and voids, spurious copper and mousebites.

2.1.1.2 The Automatic Printed Wiring Board Inspection Machine shall be capable of inspecting various types of product including but not necessarily limited to the following:

   a. Artwork – Silver Halide, positive or negative transparencies, Diezo, Glass
   b. Inner Layers – Etched Copper, Photoresist on Copper
   c. PWB’s – Etched Copper, Tin-lead plating, refloved tin-lead

2.1.1.3 The inspection cell shall consist of: 1) an inspection station to be used for the actual inspection of the product; 2) a material handling robotic system to automatically load and unload the inspection machine; 3) a primary computer controller; 4) an off-line manual verification station; 5) a Bar Code label machine to identify defective parts; and 6) a safety system.

2.1.1.4 Part fixtureing requirements shall be semi-dedicated, allowing for common usage between several classes of parts to be inspected. All fixtureing shall be loaded and unloaded using robots. Detailed fixtureing requirements shall be developed during the final systems development.

2.1.1.5 The Inspection Cell System shall provide interface through an entry keyboard which will allow the user to define acceptance criteria for individual part number identification through menu selection of design rules. Acceptance criteria shall have restricted access. The operator of the system shall only have access to hard copy printouts of inspection results, plus the option of statistical quality and process trend information.

2.1.2 INSPECTION CELL SUBSYSTEMS DEFINITION

The Automatic Printed Wiring Board Inspection Machine System shall consist of:

   a. Inspection Station
   b. Material Handling Robotics System
   c. Primary Computer System with keyboard, monitor and printer
   d. Manual Verification Station
   e. Bar Code reader
   f. Safety System
   g. Thermal Printer
2.1.2.1 INSPECTION STATION

2.1.2.1.1 The Inspection Station shall be capable of meeting the mechanical and visual inspection requirements of Delco Electronics Engineering Specifications ES-9368 and ES-1663, as well as meeting the requirements of MIL-P-35110C.

2.1.2.1.2 Printed wiring board flimsies, multilayer panels, and completed boards of all types will be presented to the machine for inspection. In addition, the machine will be utilized for periodic inspection of artwork photo-tools.

2.1.2.2 MATERIAL HANDLING ROBOT(S)

2.1.2.2.1 A material handling robot system shall be designed into the inspection cell to accommodate the transfer of parts from a transport container to the inspection machine, to turn the part over for inspection of the reverse side, and to remove the part to another transport container.

2.1.2.2.2 The material handling system, in concert with the central controller, shall be capable of placing the unloaded parts in different transport containers, determined by the results of the inspection performed. The system should be programmable such that parts with no reported defects can be off-loaded to one location while parts with defects can be off-loaded to a different location.

2.1.2.3 PRIMARY COMPUTER

2.1.2.3.1 The primary computer shall control all of the activities of the overall work cell including the bar code reader, robotics controls, vision system controls, material handlers, servo-mechanical controls and statistical process controls. For this reason, it is necessary that the primary computer runs under a Unix-like, real-time, multi-tasking operating system such as OS/VS or XENIX. The preferred computer for this work cell control is an IBM PC/AT. The preferred programming language for software development within the primary computer is the "C" language. For the purpose of uniformity with other Delco Electronics automated work cells, portability between various CPU's and the general flexibility provided by this language.

2.1.2.3.2 The primary computer system utilized with this inspection cell shall be compatible with and designed to interact with the present plant computer systems (Digital Equipment Corporation VAX or PDP 11/730). The inspection cell must be capable of providing data outputs to the plant system dealing with acceptable and reject hardware quantities on a part number/lot by part number/lot basis.

2.1.2.3.3 The system printer is used for printing out Design Rules, individual piece part inspection results and/or lot results, including Statistical Analysis presentations.

2.1.2.3.4 The dictionary of defect codes defined by Delco Electronics for Quality Trend Reporting shall be incorporated into the primary computer system software.

2.1.2.4 MANUAL VERIFICATION STATION

2.1.2.4.1 The Manual Verification Station shall include an X-Y table which can be driven by the primary computer, downloaded from a VAX central computer system or a disc drive loaded with the defect coordinate data. The operator should be able to view the inspection results by manually stepping through the defects.

2.1.2.4.2 The Manual Verification Station shall be capable of presenting a magnified video image of the detected defect to the operator and will include a 10X microscope to be used for repair activity.

2.1.2.4.3 The Keyboard and monitor shall be linked with software which provides a menu driven, operator friendly type of operation.

2.1.2.4.4 The data storage system must be capable of accepting the results of the activity performed at the Manual Verification Station, i.e., determination that defect was a false alarm, changes in defect classification, rework performed, disposition of product as acceptable or scrap. This data will then be available in periodic inspection reports.
2.1.2.5 BAR CODE READER

2.1.2.5.1 Defective product as determined by the Automatic Printed Wiring Board Inspection Machine must be identified by coding which relates to the stored defect detail information within the system. An Automatic Bar Code Label attachment shall be provided which will apply a sequentially numbered label to any product item which has reported defects. The labels must be removed from the product prior to lamination.

2.1.2.5.2 The Bar Code label will be keyed to a sequential numbering system within the primary computer software system, thereby enabling the operator to recover defect information applicable to a given item.

2.1.2.6 SAFETY SYSTEM

2.1.2.6.1 The inspection cell shall have a safety system that will automatically shut down all operations in areas accessible by operating robots when entered by any person. Alarm annunciators shall be provided to indicate the occurrence of a safety violation. A plexiglass perimeter shield is preferable to a light beam system.

2.1.2.6.2 A flashing indicator light will be on when the system is operating.

2.1.2.7 THERMAL PRINTER

2.1.2.7.1 A thermal printer shall be provided for the purpose of providing a permanent record of observed defects if desired.

2.1.2.7.2 The printer shall be capable of reproducing the image present on the TV Monitor display screen.

2.1.3 SEQUENCE OF OPERATIONS

During the initial development phase it will be acceptable for parts to be manually loaded into fixtures or to the station. A typical sequence of operations is summarized herein.

2.1.3.1 Operator types Part number of lot of parts to be inspected. (This presumes that design rules have already been loaded by Quality Engineering.) The design rules are downloaded into memory from the central database computer but should also reside on disk storage within the inspection machine primary computer system.

2.1.3.2 First part is loaded into machine and inspection sequence is initiated.

2.1.3.3 After the first side of the part has been inspected, the inspection sequence for the second side will be initiated.

2.1.3.4 The physical order of the pieces being inspected must be maintained throughout the two inspection cycles. Bar Code labels must be applied to each piece that is indicated as defective. The label must carry the part number of the part as well as an arbitrary (or real) serial number identification.

2.1.3.5 The defective items will be routed to the Manual Verification/Repair station for final disposition.

2.1.3.6 After inspection is complete, all data shall be transferred from the controller to the primary computer and an inspection report for the lot will be generated. Identifying all discrepancies and providing statistical information pertaining to that lot. The quality data will also be sent to the VAX or PDP 11/730 for further processing.

2.1.4 SYSTEM CYCLE TIME AND THROUGHPUT

The system must be capable of maintaining a throughput time for a standard multi-layer inner layer panel (as used in preliminary tests) of less than one (1) minute per side.
2.1.5 EXPANSION CAPABILITY

2.1.5.1 The inspection system shall be designed to include an expansion capability. This expansion shall be accomplished through the addition of additional inspection machines linked to the same central computer and/or through expansion of the system software.

2.1.5.2 The inspection system shall be capable of receiving operational data from an intranet network and returning measurement data to that network. The electrical standard shall be IEEE-802 token passing bus or as a minimum, RS-232. The protocol shall be the QMAP standard which is based on current ISO, IEEE and NBS standards for local area networks.

2.2 OPERATING SYSTEM SOFTWARE

2.2.1 GENERAL REQUIREMENTS

2.2.1.1 The system software shall include an interactive application system which guides the operator through all of the inspection station functions. The application system shall provide a menu of selectable system functions. Prompting routines which are easily understood shall be used to direct the operator in a step by step manner through the completion of each system function. The routines must include input error detection and provide operator feedback for correction of invalid data entry. The structure of all furnished software shall be modular and written with attention to top down hierarchical design.

2.2.1.2 The operating system shall provide multi-level security codes (passwords) that protect the system from illegal data entry. Access to the system data base (including measurement, sensor configuration, design rule inputs and calibration data) shall require a higher level security code than access to system startup and inspection report functions.

2.2.2 SYSTEM INITIALIZATION

2.2.2.1 The system shall perform diagnostic checks on all computer and processing equipment including CPU boards, memory devices I/O interfaces (discrete, analog and serial ports), power supplies, sensors and peripheral devices (reference section 2.2.7).

2.2.2.2 A prompting routine shall be provided to direct the operator through the initialization process.

2.2.2.3 The system shall be capable of start and stop by simple keyboard input without repeating initialization routines. (This includes both robots and the vision system.)

2.2.3 MEASUREMENT CONFIGURATION

2.2.3.1 Product Configuration data must be stored on a non-volatile memory device that is readily available for alteration and can be loaded directly during system initialization (reference section 2.2.2).

2.2.4 SYSTEM CALIBRATION

2.2.4.1 The manpower and level of technical expertise to perform system calibration must be plant personnel compatible and shall not require assistance. Calibration procedures shall be automatic and must be designed for easy implementation under the limited time constraints associated with production conditions.

2.2.4.2 Set up and system calibration data must be stored on a non-volatile memory device that is readily available for alteration, can be loaded directly during system initialization (reference section 2.2.2) and can be accessed for verification, replacement or recalibration functions.

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2.2.5 MEASUREMENT DATA STORAGE

The measurement data produced by the inspection station must be stored in a database which meets the following system requirements.

2.2.5.1 Part number, lot number and program code shall identify each part inspected. Each of these identifiers shall not exceed a 20 alpha/numeric character limit.

2.2.5.2 Date and time of system operation.

2.2.5.3 Upon completion of an inspection sequence, a data field shall be created that contains all the necessary information for report generation.

2.2.6 INSPECTION REPORTS

2.2.6.1 The generation of inspection reports for each lot of part numbers shall be sufficient to maintain report printing synchronization (real time) with each lot as it exits from the inspection cell. Reports shall also be made available if requested manually.

2.2.6.2 All reports shall be available for output in either the systems console (CRT) or printer.

2.2.6.3 Individual inspection reports shall contain at a minimum:
   a. Program Code
   b. Part Number
   c. Lot number
   d. Date and Time
   e. Inspection results - Defect type, magnitude, x-y location, disposition(Accept/Reject).

2.2.7 SYSTEM DIAGNOSTICS

2.2.7.1 The objective of the system diagnostics shall be to provide the operator with automatic detection and reporting of any hardware failure, down to the board or major component level. The diagnostics should be done both at system power up (System Initialization) and during normal on-line operation or when manually requested.

2.2.7.2 System hardware diagnostics shall be provided for system initialization. The diagnostics shall verify that each major system component is operating properly prior to allowing normal on-line operation. Component failures shall be identified and reported on the system console (CRT) and printer in a fashion that is easily understood without specialized training. Reference section 2.2.2 System Initialization.

2.2.7.3 The operating system shall monitor the on-line operation and detect failure modes for all major hardware components. Component failure shall be identified and reported on the system console (CRT) and printer. Detection of component failure or power loss which may cause inaccurate measurement shall discontinue on-line operation of the sensors, energize the system alarm annunciator and display an appropriate error message on the system console and printer.

2.2.7.4 The system shall provide on-line diagnostics which prevent the storage of invalid measurements.
2.2.8 SYSTEM UTILITIES

The following operating system utilities and features shall be provided to enable Delco Systems Operations personnel to perform troubleshooting and enhancement of the inspection system:

a. File Management
b. Editors
c. Compilers
d. Link/Loaders
e. Task Scheduling
f. Hardware Real Time Clock

2.2.9 OPERATING MODES AND CAPABILITIES

2.2.9.1 The operational sequence presented in section 2.1.3 assumes a part to be 100% inspected for both line widths and spacing as well as the listed types of defects.

2.2.9.2 Manual operator entry of part identifiers as described in section 2.2.6.3.

2.2.9.3 Manual operator prompting of on-line operation to provide the capability of inspecting without input from the inspection cell controller.

2.2.9.4 Capability of manually enabling and disabling inputs and outputs from the system console.

2.3 SYSTEM HARDWARE

2.3.1 GENERAL REQUIREMENTS

2.3.1.1 The system shall conform to Delco Systems electrical specifications and workmanship standards.

2.3.1.2 Readily available (off the shelf) materials and components shall be used wherever possible. Any single source items used in the system shall be clearly identified and a statement of availability supplied.

2.3.1.3 Troubleshooting shall be facilitated by the following considerations:

a. Self-diagnostic that provide fault detection and reporting down to the major component level.
b. Easy access to all mechanical and electrical components.
c. Minimization of unique board proliferation.
d. Attention to modular design.

2.3.1.4 The system console (CRT) and printer must be mounted in enclosures which meet all of the environmental conditions stated in this specification.

2.3.1.5 All enclosures must have an automatic disconnect feature which disengages power when the internal enclosure temperature reaches the manufacturer's specified limit of the device most sensitive to elevated temperature. The power disconnection feature must be designed to provide a controlled power shut-down, which maintains the integrity of the inspection cycle that is in process at the time the power shut-down occurred.

2.3.1.6 On power up and power down conditions, all outputs shall hardware default to a safe off state and remain so until commanded differently from the controlling processor.

2.3.1.7 All DC power supply outputs shall have short circuit, over-voltage protection and adequate filtering.
2.3.1.8 There shall be an additional 120 VAC, 10 amp rated wall duplex receptacle for powering test equipment, etc., fused separately from the main circuit breakers, noise isolated from the computer/processing equipment and mounted inside the main control enclosure.

2.3.1.9 All receptacles, fuses, indicators, modules, circuit boards and test points shall be permanently labeled.

2.3.1.10 All PROM based computer-processors shall have on-line PROM checksum error detection.

2.3.1.11 Provisions shall be made to attach 4 AWG ground strap between all panels and subpanels to earth ground.

2.3.1.12 The main operating system computer must have a hardware real time clock.

2.3.2 ENVIRONMENTAL REQUIREMENTS

2.3.2.1 The inspection system must operate at full accuracy under the environmental conditions of the PWB fabrication department, including the following:

a. Ambient temperature range of 62 Deg F to 90 Deg F.
b. Humidity levels from 30% to 100% (non-condensing)
c. Airborne contaminants such as dust and oils.
d. RFI and EMI electrical noise, both conducted and radiated.

2.3.2.2 Plant power source supplying standard 120 VAC and 220 VAC.

3.0 ACCEPTANCE TESTING

The delivered machine must pass acceptance tests at the purchasers' facility under the terms of the Purchase Order. Items to be used for the tests shall be from the normal production flow and typical of the current system.

The tests to be performed shall consist of comparisons between the results of machine inspection and visual examination of the product by trained personnel who currently perform that task.

Final Acceptance and payment by the contractor shall be dependent upon successful performance of these tests.

III Explanation of Technical Approach Tasks:

a Existing Method/Technical Approach Employed

After review of the many types of vision equipment available on the market, it was determined that four companies had developed equipment that could potentially fulfill the needs of this project. Extensive testing was done in an effort to determine which of the equipments was best suited for this purpose.


Industry/vendor Survey Findings

This matrix has been formulated in order to provide a comparison between four potential suppliers of an Automatic Printed Wiring Board Machine for the Industrial Tech Mod Project #8. The information contained herein is based upon each supplier's responses to Delco Electronics Request for Quotation dated October 29, 1985 and Statement of Work GE-00474-85 approved on 10/28/85.

The comment "Comply" for a specific paragraph or item means only that the potential supplier has so indicated in their response and in no way guarantees that condition exists. In the case of AEI, Inc, the indication of compliance has been entered by the undersigned, based on observed and documented performance of that equipment. This was necessary due to the lack of a detailed response from that corporation as was requested by Delco Electronics.

Point values have been assigned by "weighting" each characteristic in light of its comparative importance. Each of the potential supplier's response is then graded by the degree of their conformance. Totaling the individual grades for each supplier then represents an overall grade for that supplier. This grade becomes a relative indication of each supplier's conformance to Delco's needs and requirements.

The assignment of point values is based on the following definitions:

5 - Maximum importance 4 - Great importance 3 - Basic need 2 - Nice to have 1 - Minimal importance

<table>
<thead>
<tr>
<th>ITEM</th>
<th>HUGHES</th>
<th>ADI</th>
<th>AEI</th>
<th>OPTROTEK</th>
</tr>
</thead>
<tbody>
<tr>
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<td>$440,990.00</td>
<td>Points: <em>4</em></td>
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<td>Price</td>
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<td></td>
<td></td>
<td>$375,000.00</td>
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<tr>
<td>Does not include Bar Code Labeler /Reader</td>
<td>Does not include Bar Code Labeler /Reader or Thermal Printer</td>
<td>Does not include Bar Code Labeler /Reader or Thermal Printer</td>
<td>Points: <em>1</em></td>
<td>Oper Training included. Maintenance personnel training costs extra.</td>
</tr>
<tr>
<td>2. Value: <em>2</em></td>
<td>Points: <em>2</em></td>
<td>Included in base price of machine</td>
<td>Points: <em>2</em></td>
<td>Comply</td>
</tr>
<tr>
<td>Training Costs</td>
<td></td>
<td>Comply</td>
<td>Points: <em>2</em></td>
<td>Comply</td>
</tr>
<tr>
<td>3. Automation and Safety System</td>
<td></td>
<td></td>
<td>Points: <em>0</em></td>
<td>Not Included</td>
</tr>
<tr>
<td>Value: <em>3</em></td>
<td>Points: <em>0</em></td>
<td>Not Included</td>
<td>Points: <em>2</em></td>
<td>Comply</td>
</tr>
<tr>
<td>Material handling Robot System</td>
<td>Accept/罕 automa-</td>
<td></td>
<td>Not Included</td>
<td>Not Included</td>
</tr>
<tr>
<td></td>
<td>tion for load/unload Operator to turn over</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>stacks of boards</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Value: <em>2</em></td>
<td>Points: <em>1</em></td>
<td>Comply</td>
<td>Points: <em>0</em></td>
<td>Not Included</td>
</tr>
<tr>
<td>Separation of inspected hardware</td>
<td>Not Included</td>
<td></td>
<td>Not Included</td>
<td>Not Included</td>
</tr>
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</table>

16
<table>
<thead>
<tr>
<th><strong>Value:</strong></th>
<th><strong>Points:</strong></th>
<th><strong>Value:</strong></th>
<th><strong>Points:</strong></th>
<th><strong>Value:</strong></th>
<th><strong>Points:</strong></th>
<th><strong>Value:</strong></th>
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<td>N/A</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Payment</td>
<td>Within thirty (30) days of date of invoice</td>
<td>50% on completion of preliminary acceptance at Delco</td>
<td>Comply</td>
<td>Ninety Days with purchase of Maintenance Contract</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>warranty</td>
<td>1</td>
<td>1</td>
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<td>1</td>
<td>2</td>
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<tr>
<td>Freight Charges</td>
<td>Delivery is F.O.B. Carlsbad, CA</td>
<td>Delivery is F.O.B. Burlington, Mass</td>
<td>No Response</td>
<td>In substantial compliance</td>
<td></td>
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</tr>
<tr>
<td>Delivery Date</td>
<td>120 days after acceptance of order</td>
<td>20 weeks after acceptance of order</td>
<td>Six (6) months</td>
<td>June 1986</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subcontractor advice</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applicable Documents</td>
<td>Meets most if not all listed GM &amp; Delco Stds. No attempt made to verify compliance</td>
<td>Accepted, except as noted in sect 1.2 &amp; 2.1.1.1 of Attach 1</td>
<td>No Response</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value: 3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Indication of compliance or deviation from SOW requirements</td>
<td>Comply</td>
<td>Comply</td>
<td>Does not Conform to Method requested by B.O.M.</td>
<td>Comply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conformance to Delco Electrical specifications and workmanship standards</td>
<td>See response to SOW para 2.0</td>
<td>System Complies to Industrial Electrical Standards</td>
<td>Under examination. Will advise later.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conformance with: Sound Level Spec Robotic Safety Std Basic Elec Std GM MAPP</td>
<td>See response to SOW, para 2.0</td>
<td>AOI equipment conforms to industry stds for safety, service &amp; maintenance</td>
<td>Being Investigated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Installation Drawings</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
</tr>
<tr>
<td>Value</td>
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<td>Points</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14: Value: 2 Elec &amp; Pneumatic Schematics</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Points: 2 Pneumatic schematics H/A Electricals will be provided</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15: Value: 2 Final Drawings</td>
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<td>2</td>
<td>2</td>
<td>2</td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16: Value: 2 Operation and Maintenance Manuals</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Points: 2</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17: Value: 3 Ability to meet Delco PWB requirements (ES-9369, ES-11648, MIL-P-55110C)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Points: 3 See response to SOM, para 2.0</td>
<td>Comply as per list</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18: Value: 3 Composition of Inspection Cell:</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Points: 4</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspection Station Material Handling Robotics System Primary Computer System with keyboard, monitor and printer</td>
<td>Comply</td>
<td>Not included</td>
<td>Not included</td>
<td>Comply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual Verification Station Bar Code Reader Safety System Thermal Printer</td>
<td>Comply</td>
<td>Not included</td>
<td>Not included</td>
<td>Comply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19: Value: 4 User Interface</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Points: 2 Comply, except Statistical Quality and Trend data not now available</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20: Value: 5 Product types that can be inspected:</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Points: 4</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artwork - Silver Halide positive or negative transparencies, Diazo, Glass</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inner Layers - Etched Copper, Photoresist on Copper</td>
<td>Comply</td>
<td>Comply</td>
<td>Will Conform</td>
<td>Comply</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PWB's - Etched Copper Tin-lead plating refloowed tin-lead Tin-lead plating on certain substrates not easily inspected</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td>Tin-lead plating before reflow cannot be inspected</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value</td>
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<td>Points: 2</td>
<td>Points: 3</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Items to be inspected (Filmsies, M/L Panels, PWB's after Lamination)</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td></td>
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<tbody>
<tr>
<td></td>
<td>Defect Types that can be detected</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
</tr>
<tr>
<td>Line widths</td>
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<td>Line Spacing</td>
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<tr>
<td>Pad sizes</td>
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<td></td>
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<tr>
<td>Annular ring dim</td>
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<td>Opens</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Shorts</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Neckdown</td>
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</tr>
<tr>
<td>Cracks</td>
<td></td>
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</tr>
<tr>
<td>Voids</td>
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<tr>
<td>Spurious Copper</td>
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<tr>
<td>Housebites</td>
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<tbody>
<tr>
<td></td>
<td>Delco QTR Defect Codes shall be incorporated into primary computer software</td>
<td>Hughes defect code will be used. Comparison to Delco will be made and differences resolved</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
</tr>
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<tr>
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<th>Points: 1</th>
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<tbody>
<tr>
<td></td>
<td>Part Fitting</td>
<td>To be developed later.</td>
<td>None Required</td>
<td>To be developed</td>
<td></td>
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<tr>
<th>Value</th>
<th>25</th>
<th>Points: 3</th>
<th>Points: 4</th>
<th>Points: 1</th>
<th>Points: 1</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Primary computer runs under a Unix-like, real-time, multi-tasking operating system such as QNX or XENIX</td>
<td>Primary computer is an SM/11/23 with 512K byte memory.</td>
<td>Comply</td>
<td></td>
<td>Functions are performed. Architecture is different</td>
</tr>
<tr>
<td>The preferred computer for this work cell control is an IBM PC/AT</td>
<td>Operating System is standard Digital RDX-11M System (DEC LSI 11/23 Microprocessor)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The preferred programming language for software development within the primary computer is the &quot;C&quot; language.</td>
<td>Primary computer language is Fortran. System Algorithms written in &quot;C&quot; language.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Programming language is Fortran.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
26. **Value:** 4  
**Points:** 4  
The primary computer system shall be compatible with and designed to interact with the present plant computer systems (Digital Equipment Corporation VAX or PDP 1170).  
The inspection cell must provide data outputs to the plant system about acceptable and rejected hardware.

27. **Value:** 4  
**Points:** 4  
System Printer is used to print Design Rules part/lot insp results and Statistical Analysis presentations.

28. **Value:** 4  
**Points:** 4  
Manual Verification Station X-Y table can be driven by the primary computer system down loaded from a VAX central computer system or a disc drive. Operator may step-view defects.

29. **Value:** 3  
**Points:** 3  
The VFR station shall present a magnified video image of the detected defect and will include a 10X microscope to be used for repair activity.
<table>
<thead>
<tr>
<th>Value</th>
<th>Points</th>
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</thead>
<tbody>
<tr>
<td>30</td>
<td>3</td>
</tr>
<tr>
<td>The Keyboard and monitor shall be linked with software which provides a menu driven, operator friendly type of operation.</td>
<td>Comply</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td>31</td>
<td>2</td>
</tr>
<tr>
<td>The data storage system must be capable of accepting the results of the activity performed at the Manual Verification Station. This data will then be available for inspection reports.</td>
<td>Software must be written.</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td>32</td>
<td>0</td>
</tr>
<tr>
<td>Automatic Bar Code Label attachment</td>
<td>Not Included</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>33</td>
<td>3</td>
</tr>
<tr>
<td>Label will be keyed to primary computer software system</td>
<td>Not Included</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td>34</td>
<td>3</td>
</tr>
<tr>
<td>Bar Code Reader</td>
<td>Not Included. The system generates a tag for the defective board.</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>35</td>
<td>2</td>
</tr>
<tr>
<td>The inspection cell shall have a safety system.</td>
<td>Do not Comply since robots are not used.</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td>36</td>
<td>2</td>
</tr>
<tr>
<td>A flashing indicator light will be on when the system is operating.</td>
<td>Not Included</td>
</tr>
<tr>
<td></td>
<td>0</td>
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</table>

Total: 14
<table>
<thead>
<tr>
<th>Value</th>
<th>Points</th>
<th>Points</th>
<th>Points</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>Comply</td>
<td>Comply</td>
<td>Not Included</td>
<td>Not Included</td>
</tr>
<tr>
<td>A thermal printer shall be provided</td>
<td>3</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
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<th>Points</th>
<th>Points</th>
<th>Points</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>Optional Graphic Output Station reproduces the image present on the graphics monitor</td>
<td>2</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>The printer shall be capable of reproducing the image present on the TV Monitor display screen</td>
<td></td>
<td></td>
<td></td>
<td>TV pictures stored by video recorder and reproduced on monitor</td>
</tr>
</tbody>
</table>

### SEQUENCE OF OPERATIONS

<table>
<thead>
<tr>
<th>Value</th>
<th>Points</th>
<th>Points</th>
<th>Points</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>39</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
</tr>
<tr>
<td>Operator types Part number of lot of parts to be inspected. Design rules are downloaded into memory from the central database computer. Design rules should also reside on disk storage within the inspection machine primary computer system</td>
<td>3</td>
<td></td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value</th>
<th>Points</th>
<th>Points</th>
<th>Points</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>39</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
</tr>
<tr>
<td>First part is loaded into machine and inspection sequence is initiated.</td>
<td>3</td>
<td></td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value</th>
<th>Points</th>
<th>Points</th>
<th>Points</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>39</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
</tr>
<tr>
<td>After the first side of the part has been inspected, the inspection sequence for the second side will be initiated.</td>
<td>1</td>
<td></td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
Value:  4
The physical order of the pieces being inspected must be maintained throughout the two inspection cycles. Bar Code labels must be applied to each defective piece. The label must carry the part number of the part as well as an arbitrary (or real) serial number identification to link the piece to the stored data.

Points:  2
Bar Code labels not used
Comply

Value:  3
The defective items will be routed to the Manual Verification/Repair station for final disposition.

Points:  2
Comply

Value:  4
After inspection is complete, all data shall be transferred from the controller to the primary computer and an inspection report for the lot will be generated, identifying all discrepancies and providing statistical information pertaining to that lot. The quality data will also be sent to the VAX or PDP 11/730 for further processing.

Points:  2
A statistical analysis package is not provided. Data can be extracted and formatted by the user.

Points:  3
After inspection, some data is available. After classification at the V/R station additional statistics are generated.

Points:  4
Statistical info can be generated only after defect verification step and inputting defect data by station operator

Value:  4
The system must be capable of maintaining a throughput time for a standard multi-layer inner layer panel (as used in preliminary tests) of less than one (1) minute per side.

Points:  2
3.0 SF - 1.0 mil
1.0 SF - 0.3 mil

Points:  4
6.0 SF - 1.0 mil
3.0 SF - 0.5 mil
.25-3.0 SF - 3 mil
.84 SF - 0.5 mil

Points:  3
2.5 SF - 1.0 mil

Points:  1
<table>
<thead>
<tr>
<th>Value</th>
<th>Points:</th>
<th>Points:</th>
<th>Points:</th>
<th>Points:</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

The inspection system shall be designed to include an expansion capability. This expansion shall be accomplished through the addition of additional inspection machines linked to the same central computer and/or through expansion of the system software.

Value: 4

The system shall be capable of receiving and returning operational data from an intra-plant network.

Points: 3
Comply

Points: 3
System is capable of receiving and sending data to an intra-plant network.

Points: 2
No Response

Up to two inspection units are each control unit.

The electrical standard shall be IEEE-802 token passing bus or as a minimum, RS-232.

The protocol shall be the GM MAP standard which is based on current ISO, IEEE and NBS standards for local area networks.

Value: 3

The system shall include an interactive means of guiding the operator through the inspection station functions.

Points: 3
Comply

No software has been written yet to accommodate the GM MAP standard which is itself not fully defined.

Points: 3
Comply

GM MAP protocol standards may be incorporated dependent upon configuration at time of expansion.

Points: 3
No Response

Comply
The routines must include input error detection and provide operator feedback for correction of invalid data entry.

The structure of all furnished software shall be modular and written with attention to top down hierarchical design.

<table>
<thead>
<tr>
<th>44.</th>
<th>Value: <strong>3</strong></th>
<th>Points: <strong>3</strong></th>
<th>Points: <strong>3</strong></th>
<th>Points: <strong>1</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The operating system shall provide multi-level security codes (passwords) that protect the system from illegal data entry.</td>
<td>Comply</td>
<td>Comply</td>
<td>No Response</td>
</tr>
<tr>
<td></td>
<td>Access to the system data base (including measurement, sensor configuration, design rule inputs and calibration data), shall require a higher level security code.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>45.</th>
<th>Value: <strong>3</strong></th>
<th>Points: <strong>2</strong></th>
<th>Points: <strong>3</strong></th>
<th>Points: <strong>3</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The system shall perform diagnostic checks on all computer and processing equipment including CPU boards, memory devices, I/O interfaces, discrete, analog and serial ports, power supplies, sensors and peripheral devices.</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
</tr>
<tr>
<td></td>
<td>Diagnostics checks are made on most, but not all parts of the system. Except for image processor boards, diagnostics are run manually.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>46.</th>
<th>Value: <strong>3</strong></th>
<th>Points: <strong>3</strong></th>
<th>Points: <strong>3</strong></th>
<th>Points: <strong>3</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A prompting routine shall be provided to direct the operator through the initialization process.</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Points: <strong>1</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Security passwords do not exist currently. A software change can be made to meet this requirement.</td>
</tr>
<tr>
<td>Value</td>
<td>Points</td>
</tr>
<tr>
<td>-------</td>
<td>--------</td>
</tr>
</tbody>
</table>
| 47    | _3_    | Value: _3_  
The system shall be capable of start and stop by simple key board input without repeating initialization routines. (This includes both robots and the vision system.) |
|       | _3_    | Points: _3_ | Comply |
|       | _3_    | Points: _3_ | Comply |
|       | _3_    | Points: _3_ | Comply |
|       | _3_    | Points: _3_ | Comply |
| 48    | _3_    | Value: _3_  
Product configuration data must be stored on a non-volatile memory device that is readily available for alteration and can be loaded directly during system initialization. |
|       | _3_    | Points: _3_ | Comply |
|       | _3_    | Points: _3_ | Comply |
|       | _3_    | Points: _3_ | Comply |
|       | _3_    | Points: _3_ | Comply |
| 49    | _4_    | Value: _4_  
The manpower and level of technical expertise to perform system calibration must be plant personnel compatible and shall not require assistance. Calibration procedures shall be automatic and must be designed for easy implementation under the limited time constraints associated with production conditions. |
|       | _3_    | Points: _3_ | Comply |
|       | _3_    | Points: _3_ | Comply |
|       | _3_    | Points: _3_ | Comply |
|       | _3_    | Points: _3_ | Comply |
| 50    | _3_    | Value: _3_  
Set up and system calibration data must be stored on a non-volatile memory device that is readily available for alteration, can be loaded directly during system initialization and can be accessed for verification, replacement or recalibration functions. |
|       | _3_    | Points: _3_ | Comply |
|       | _3_    | Points: _3_ | Comply |
|       | _3_    | Points: _3_ | Comply |
|       | _3_    | Points: _3_ | Comply |
MEASUREMENT DATA STORAGE

Value: ___
Part number, lot number and program code shall identify each part inspected. Each of these identifiers shall not exceed a 25 alpha/numeric character limit.

Value: ___
Date and time of system operation.

Value: ___
Upon completion of an inspection sequence, a data field shall be created that contains all the necessary information for report generation.

Value: ___
The generation of inspection reports for each lot of part numbers shall be sufficient to maintain report printing synchronization (real time) with each lot as it exits from the inspection cell. Reports shall also be made available if requested manually.

Value: ___
All reports shall be available for output in either the system console (CRT) or printer.
54. Value: 4
   Individual inspection reports shall contain at a minimum:
   a. Program Code
   b. Part Number
   c. Lot number
   d. Date and Time
   e. Inspection results
      - Defect type, magnitude, x-y location, disposition (Accept/Reject).

   Points: 3
   Report software not currently available
   Points: 3
   Comply
   Points: 3
   Comply
   Points: 3
   Comply

55. Value: 3
   The objective of the system diagnostics shall be to provide the operator with automatic detection and reporting of any hardware failure, down to the board or major component level.

   The diagnostics should be done both at system power up (System Initialization) and during normal on-line operation or when manually requested.

   Points: 2
   Image processors are continually checked by sub-host processor. This is automatic without operator intervention. Diagnostics for rest of the system must be requested manually.
   Points: 2
   System diagnostics are run when system is turned on. Inspection system diagnostics are run on request. System can be configured to do these with system turn-on but not recommended due to time required.
   Points: 2
   Complies
   Points: 2
   The system includes diagnostics for maintenance personnel and for enabling an operator to define malfunctions to a service engineer. It does not have automatic diagnostics except for self testing of CPU's and communications.

56. Value: 3
   Diagnostics shall be provided for at initialization. They shall verify major components are operating properly prior to allowing operation. Failures shall be identified and reported on the system console (CRT)

   Points: 2
   Diagnostics not engaged at initialization. Component failures should be recognized by experienced operator but not reported on CRT.
   Points: 2
   See 2.7.1
   Points: 2
   Comply
   Points: 2
   See 2.7.1
57 Value: __3__
The system shall monitor the on-line operation and detect failures of major components and report on the CRT & printer. Failures which may cause inaccurate measurement should discontinue operation and initiate the alarm sequence.

Points: __2__
Image processors are continually checked by sub-host processor and automatically removed if failure occurs. Failures not reported on CRT. Failure of certain other components or power loss does not necessarily give an indication of failure. See 2 2 7 1

Comply

58 Value: __3__
The system shall provide on-line diagnostics which prevent the storage of invalid measurements.

Points: __2__
Comply with regard to image processing boards. See 2.2.7.1

Comply

59 Value: __4__
The following operating system utilities and features shall be provided to enable Delco Systems Operations personnel to perform troubleshooting and enhancement of the inspection system.

a. File Management Comply
b. Editors Comply
c. Compilers Comply
d. Link/Loaders Not included

e. Task Scheduling Comply
f. Hardware Real Time Clock Not included

50 Value: __4__
The operational sequence presented previously assumes a part to be 100% inspected for both line widths and spacing as well as the listed types of defects.

Points: __4__
Comply

Points: __4__
Comply

Points: __4__
Comply

Points: __4__
Comply

No Response

Accessed by Operators. Engineers only. Not provided to customers.
Value: ___3___ Points: ___3___ Points: ___3___ Points: ___3___ Points: ___3___
Manual operator entry of part identifiers as described in section 2.2.2 3. (Program Code, P/N, Lot No, Date/Time, Insp results)
Comply Comply Comply Comply Comply

Value: ___3___ Points: ___3___ Points: ___3___ Points: ___3___ Points: ___3___
Manual operator prompting of on-line operation to provide the capability of inspecting without input from the inspection cell controller.
Comply Comply Comply Comply After initial part number is set up, later panels are inspected by calling out parameters from an internal database

Value: ___3___ Points: ___3___ Points: ___3___ Points: ___3___ Points: ___3___
Capability of manually enabling and disabling inputs and outputs from the system console.
Comply Comply Comply Comply

Value: ___3___ Points: ___3___ Points: ___3___ Points: ___3___ Points: ___3___
Readily available materials and components shall be used wherever possible. Single source items must be identified and a statement of availability supplied.
Comply Comply Comply Comply

Value: ___3___ Points: ___3___ Points: ___3___ Points: ___3___ Points: ___2___
Troubleshooting shall be facilitated by the following:
Comply Trouble shooting is facilitated by the following:

a. Self-diagnostics that provide fault detection and reporting down to the major component level
Comply Self-diagnostics provide trouble shooting capability to sub-assy level such as camera or logic card
b. Easy access to all mechanical and electrical components
Comply No Response
30
c. Minimization of unique board proliferation
   Comply
   Comply
   Comply
   No Response
   Comply

d. Attention to modular design.
   Comply
   Comply
   Comply
   No Response
   Comply

Value: __2__
The system console (CRT) and printer enclosures must meet all of the environmental conditions stated in this specification.
Points: __2__
Comply
Points: __2__
Comply
Points: __2__
No Response
Points: __2__
Environmental requirements described in para 2.3.2.1

Value: __3__
Enclosures must have an overtemperature disconnect feature designed to provide a controlled shut-down, maintaining the integrity of the inspection cycle that is in process at the time of the shut-down.
Points: __0__
Do not Comply
Points: __3__
Comply
Points: __0__
Does not comply
Points: __0__
System does not have automatic disconnect Can be designed in as part of robotics system

Value: __3__
At power up and power down, all outputs shall default to a safe off state and remain until commanded by the controlling processor.
Points: __0__
Do not Comply
Points: __3__
Comply
Points: __0__
No Response
Points: __3__
Comply

Value: __3__
All DC power supply outputs shall have short circuit, over-voltage protection and adequate filtering.
Points: __3__
Comply
Points: __3__
Comply
Points: __3__
Comply
Points: __3__
Comply

Value: __2__
There shall be a 120 VAC, 10 amp wall duplex receptacle mounted inside the main control enclosure.
Points: __2__
Comply
Points: __2__
Comply
Points: __2__
Comply
Points: __2__
Does not currently have. Need more detail on this requirement.
<table>
<thead>
<tr>
<th>Value: <strong>3</strong></th>
<th>Points: <strong>3</strong></th>
<th>Points: <strong>3</strong></th>
<th>Points: <strong>3</strong></th>
<th>Points: <strong>3</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>All receptacles, fuses, indicators, modules, circuit boards and test points shall be permanently labeled.</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
</tr>
</tbody>
</table>

<table>
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<tr>
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<th>Points: <strong>3</strong></th>
<th>Points: <strong>0</strong></th>
<th>Points: <strong>3</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>All PROM based computer/processors shall have on-line PROM checksum error detection.</td>
<td>Do not Comply</td>
<td>Comply</td>
<td>No Response</td>
<td>System does have on-line prom checksum error</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value: <strong>3</strong></th>
<th>Points: <strong>2</strong></th>
<th>Points: <strong>3</strong></th>
<th>Points: <strong>2</strong></th>
<th>Points: <strong>3</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>There shall be a 84 AWG ground strap between all panels and sub-panels to earth ground.</td>
<td>Comply, except that strap is 8/0 AWG</td>
<td>Comply</td>
<td>Comply</td>
<td>Comply</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value: <strong>4</strong></th>
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<th>Points: <strong>4</strong></th>
<th>Points: <strong>0</strong></th>
<th>Points: <strong>4</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The main operating system computer must have a hardware real time clock.</td>
<td>Do not Comply</td>
<td>Comply</td>
<td>Does not comply</td>
<td>Comply</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value: <strong>4</strong></th>
<th>Points: <strong>2</strong></th>
<th>Points: <strong>2</strong></th>
<th>Points: <strong>2</strong></th>
<th>Points: <strong>2</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>System must operate at full accuracy under the following environmental conditions:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Ambient temperature range of 62 to 90 Deg F.</td>
<td>Does not Comply</td>
<td>Comply</td>
<td>Does not Comply</td>
<td>Does not Comply</td>
</tr>
<tr>
<td>b. Humidity levels from 30% to 100% (non-condensing)</td>
<td>Does not Comply</td>
<td>Does not Comply</td>
<td>Does not Comply</td>
<td>Does not Comply</td>
</tr>
<tr>
<td>c. Airborne contaminants such as dust and oils.</td>
<td>Excessive airborne contaminants could cause false alarms</td>
<td>Inspection will operate in a dust and oil environment. Contaminants will be reported as defects.</td>
<td>No Response</td>
<td>Airborne dust or dirt particles can cause shorts or accelerated wear of moving mechanical devices. Dust may show as defect.</td>
</tr>
<tr>
<td>d. RFI and EMI electrical noise, both conducted and radiated.</td>
<td>Excessive RFI and EMI could cause processing errors.</td>
<td>System meets FCC Class A interference requirements in industrial environment</td>
<td>No Response</td>
<td>System not affected by regular RFI and EMI noises</td>
</tr>
</tbody>
</table>

32
76  Value: 3  
Plant power source 
supplying standard 120 
VAC and 220 VAC 
Points: 3  
Comply  
Points: 3  
Comply  
Points: 3  
Comply  
Points: 3  
See para 4 of Site 
preparation document

77  Value: 4  
The delivered machine 
must pass acceptance 
tests at the purch- 
asers facility under 
the terms of the 
Purchase Order. 
Items to be used 
for the tests shall 
be from the normal 
production flow and 
typical of the 
current system. 
The tests to be per- 
formed shall consist 
of comparisons between 
the results of machine 
inspection and visual 
examination of the 
product by trained 
personnel who 
currently perform that 
task. 
Final Acceptance and 
payment by the con- 
tractor shall be 
dependent upon 
successful perfor- 
mance of these tests. 
Points: 4  
Comply  
Points: 4  
Comply  
Points: 4  
Comply  
Points: 4  
Comply

Total Value: 270  
Total Points: 192  
Total Points: 248  
Total Points: 189  
Total Points: 182
Preliminary Cost Benefit Analysis

1. Reduction of Scraped material during fabrication process

Annual scrap costs 1984 (Feb-Dec) = $215,665.64
Average monthly scrap costs 1984 = $215,665.64/11 = $19,605.97

Annual scrap costs 1985 (Jan-Dec) = $231,203.90
Average monthly scrap costs 1985 = $231,203.90/12 = $19,267.06

Annual scrap costs 1986 (Jan-May) = $125,624.70
Average monthly scrap costs 1986 = $125,624.70/5 = $25,124.94

Total = $65,664.57

Average monthly scrap costs = $21,888.19

Average Annual Scrap Costs = $21,888.19 x 12 = $262,659.28

Anticipated scrap reduction of 20% = $52,591.66

- Improved handling
- Vision inspection of artwork
- Process information feedback

2. Reduction of labor costs for repairs due to PCB opens & shorts.

Open circuits detected by Ditmco Test during 1985 = 3279

Recording & Logging 5 min x 3279 = 16395/60 = 273.3 Hrs
MRBR processing 15 min x 3279 = 49185/60 = 819.8 Hrs
Red Wire repair 10 min x 3279 = 32790/60 = 546.5 Hrs
Inspection of repair 1 min x 3279 = 3279/60 = 54.7 Hrs

Total 1694.3 Hrs

1694.3 Hrs x $20.20 = $34,224.86

Shorted circuits detected by Ditmco Test during 1985 = 358

Recording & Logging 5 min x 358 = 1790/60 = 29.8 Hrs
Rework 40 min x 358 = 14320/60 = 238.7 Hrs
Inspection of Rework 1 min x 358 = 358/60 = 6.0 Hrs

Total 274.5 Hrs

274.5 Hrs x $20.20 = $5544.90

Total Rework Costs = $39,769.76
Reduction of rework possible due to detection of open and short conditions prior to lamination of the PCB.

3. Reduction in Inspection labor by 40%.
   The current work force of nine (9) personnel would be reduced to five (5), resulting in a savings of four (4) persons.
   
   4 people X 40 Hrs/wk X 52 wks/yr = 8,320 Hrs/Year
   8,320 Hrs x $20.20/Hr = $168,064.00

4. Scrap avoidance for CCA's with internal shorts and/or opens detected during card test operations.
   Scrap costs for this cause in 1985 were $31,770.00

5. Other Cost Savings:
   - Inventory Reduction
   - Automatic collection of Defect & Payroll Data
   - Elimination of DTMCO Testing
   - Reduced storage area requirements due to improved throughput times
   - Overall Quality improvement

6. Summary
   Anticipated scrap reduction of 20% $32,591.66
   Total Rework Costs 39,769.76
   Inspection Labor reduction 168,064.00
   Higher Assembly Scrap 31,770.00
   Total Annual Cost Reduction $292,135.42

7. Investment Payback
   Cost of Equipment $400,000.00
   Payback in Years = Cost of Equipment/Annual Cost Reduction
   $400,000.00/$292,135.42 = 1.37 Years

35
Equipment Alternatives

In addition to the four suppliers in the final competition, the following lists other companies that were investigated to determine if their equipment might be capable of meeting our requirements:

- Applied Intelligent Systems, Ann Arbor, MI
- Anrad Corporation, Hauppauge, NY
- Automation Tooling Systems, Kitchener, Ontario
- Automatix Inc. Burlington, MA
- Cambridge Robotics, Watertown, MA
- Consolidated Controls, Danbury, CT
- Everett/Charles, Rancho Cucamonga, CA
- HAM Industries Inc., Macedonia, OH
- Image Technology, Carpentersville, IL
- McBain Instruments Inc., Chatsworth, CA
- MICROVU, Santa Ana, CA
- Operations Technology Inc., Blairstown, NJ
- Precision Industries Inc., Cleveland, OH
- PROJECTINA Ltd., Heerbrugg, Switzerland
- TESTERION Inc., Cucamonga, CA
- View Engineering, Chatsworth, CA

The companies indicated by "A" are ones which were given some serious attention, but were eliminated in favor of the four final contenders. These two were systems houses and would have had to integrate the various equipments required to "develop" an inspection cell. The preferred solution was to utilize a proven, standalone system which several companies had developed as their sole product line. The remaining companies on the list were eliminated due to product line maturity, speed, accuracy, and the "perceived ability to support their product in the future".

Implementation Plan/Results

Plans are currently being formulated for the installation of a "computer-type" room with controlled temperature and humidity as well as a filtered air system. With this type of environment "false alarms" caused by airborne contaminants will be minimized, if not eliminated.

The results of implementation of this equipment in the manufacturing environment will be available once the installation is completed.
### Equipment/Machining Specifications

The following is a comparison of the technical characteristics of the equipment available from the four finalists in this quest.

#### AUTOMATIC PHB INSPECTION MACHINE CHARACTERISTICS MATRIX

<table>
<thead>
<tr>
<th>Feature</th>
<th>Automation Eng Inc</th>
<th>ITEK Optical Systems</th>
<th>Optrotek, Inc</th>
<th>Hughes Aircraft Co.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspected Area</td>
<td>24&quot; x 24&quot;</td>
<td>18&quot; x 27&quot;</td>
<td>18&quot; x 24&quot;</td>
<td>24&quot; x 28&quot;</td>
</tr>
<tr>
<td><strong>Product Features</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artwork</td>
<td>Silver Halide</td>
<td>Silver Halide</td>
<td>Silver Halide</td>
<td>Silver Halide</td>
</tr>
<tr>
<td></td>
<td>Pos or neg trans-</td>
<td></td>
<td></td>
<td>Diazo Film, Pos or</td>
</tr>
<tr>
<td></td>
<td>parencies</td>
<td></td>
<td></td>
<td>Neg Glass</td>
</tr>
<tr>
<td></td>
<td>Diazo</td>
<td>Glass</td>
<td>P.A.C.</td>
<td></td>
</tr>
<tr>
<td>Inner Layers</td>
<td>Etched copper</td>
<td>Etched copper</td>
<td>Etched copper</td>
<td>Etched Copper</td>
</tr>
<tr>
<td></td>
<td>After tin-lead reflow</td>
<td>Photoresist on Copper</td>
<td>Photoresist on Copper</td>
<td>Photoresist on Copper</td>
</tr>
<tr>
<td>Pad Size</td>
<td>at 0.32 mil resolution</td>
<td>at 0.30 in min</td>
<td>at 0.30 in max</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.010 in min</td>
<td>.020 in min</td>
<td>.040 in max</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.100 in max</td>
<td>(Need more memory to accomplish this)</td>
<td>(up to 6)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>at 0.50 mil resolution</td>
<td>at 0.50 mil resolution</td>
<td>at 0.50 mil resolution</td>
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</tr>
<tr>
<td></td>
<td>Any size</td>
<td>Any size</td>
<td>Any size</td>
<td></td>
</tr>
<tr>
<td></td>
<td>at 1.0 mil resolution</td>
<td>at 1.0 mil resolution</td>
<td>at 1.0 mil resolution</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Any size</td>
<td>Any size</td>
<td>Any size</td>
<td></td>
</tr>
<tr>
<td>Line Width &amp; Spacing</td>
<td>at 0.32 mil resolution</td>
<td>at 0.32 mil resolution</td>
<td>at 0.32 mil resolution</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.0035 in minimum</td>
<td>.003 in minimum</td>
<td>.003 in min</td>
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</tr>
<tr>
<td></td>
<td>.100 in maximum</td>
<td>.024 in max</td>
<td>.035 in max</td>
<td></td>
</tr>
<tr>
<td></td>
<td>at 0.50 mil resolution</td>
<td>at 0.50 mil resolution</td>
<td>at 0.50 mil resolution</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.003 in minimum</td>
<td>.004 in minimum</td>
<td>.004 in min</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.012 in maximum</td>
<td>.024 in max</td>
<td>.035 in max</td>
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<tr>
<td></td>
<td>at 1.0 mil resolution</td>
<td>at 1.0 mil resolution</td>
<td>at 1.0 mil resolution</td>
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</tr>
<tr>
<td></td>
<td>.006 in minimum</td>
<td>.008 in minimum</td>
<td>.006 in min</td>
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</tr>
<tr>
<td></td>
<td>.024 in maximum</td>
<td>.035 in max</td>
<td>.035 in min</td>
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<td>Annular Rings</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Hole Sizes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>------------</td>
<td>-----</td>
<td>----</td>
<td>----</td>
<td>-----</td>
</tr>
<tr>
<td>Max Resolution</td>
<td>0.32 mil</td>
<td>0.50 mil</td>
<td>0.50 mil</td>
<td>0.30 mil</td>
</tr>
<tr>
<td>Detected Flaws</td>
<td>Six (6) Sizes</td>
<td>Four (4) Sizes</td>
<td>One (1) Size</td>
<td>Three (3) Sizes</td>
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<td>Min conductor spacing</td>
<td>Min conductor spacing</td>
<td>Min conductor spacing</td>
</tr>
<tr>
<td>Min/Max conductor width</td>
<td>Min/Max conductor width</td>
<td>Min/Max conductor width</td>
<td>Min/Max conductor width</td>
<td>Min/Max conductor width</td>
</tr>
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<td>Cracks &amp; Voids</td>
<td>Cracks &amp; Voids</td>
<td>Cracks &amp; Voids</td>
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<td>Cracks &amp; Voids</td>
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<td>Rough edges</td>
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<td>Rough edges</td>
<td>Rough edges</td>
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<td>Opens</td>
<td>Opens</td>
<td>Opens</td>
<td>Opens</td>
<td>Opens</td>
</tr>
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<td>Shorts</td>
<td>Shorts</td>
<td>Shorts</td>
<td>Shorts</td>
<td>Shorts</td>
</tr>
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<td>Spurious Copper</td>
<td>Spurious Copper</td>
<td>Spurious Copper</td>
<td>Spurious Copper</td>
<td>Spurious Copper</td>
</tr>
<tr>
<td>Mousebites</td>
<td>Mousebites</td>
<td>Mousebites</td>
<td>Mousebites</td>
<td>Mousebites</td>
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<tr>
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<tr>
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<td>Hole sizes</td>
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<td>Hole sizes</td>
<td>Hole sizes</td>
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<tr>
<td>Inspection Speed</td>
<td>0.32 mil Resolution</td>
<td>0.50 mil Resolution</td>
<td>0.50 mil Resolution</td>
<td>0.30 mil Resolution</td>
</tr>
<tr>
<td>2.5-25 SF/Min</td>
<td>0.30 mil Resolution</td>
<td>0.30 mil Resolution</td>
<td>0.30 mil Resolution</td>
<td>0.30 mil Resolution</td>
</tr>
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<td>0.30 mil Resolution</td>
<td>0.30 mil Resolution</td>
<td>0.30 mil Resolution</td>
<td>0.30 mil Resolution</td>
<td>0.30 mil Resolution</td>
</tr>
<tr>
<td>2.0 LF/Min</td>
<td>0.84 SF/Min</td>
<td>0.84 SF/Min</td>
<td>0.84 SF/Min</td>
<td>0.84 SF/Min</td>
</tr>
<tr>
<td>1.0 mil Resolution</td>
<td>1.0 mil Resolution</td>
<td>1.0 mil Resolution</td>
<td>1.0 mil Resolution</td>
<td>1.0 mil Resolution</td>
</tr>
<tr>
<td>2.0 LF/Min</td>
<td>0.84 SF/Min</td>
<td>0.84 SF/Min</td>
<td>0.84 SF/Min</td>
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<td>1.0 mil Resolution</td>
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<td>1.0 mil Resolution</td>
<td>1.0 mil Resolution</td>
<td>1.0 mil Resolution</td>
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<tr>
<td>4.0 LF/Min</td>
<td>2.05 SF/Min</td>
<td>2.05 SF/Min</td>
<td>2.05 SF/Min</td>
<td>2.05 SF/Min</td>
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<td>1.0 mil Resolution</td>
<td>1.0 mil Resolution</td>
<td>1.0 mil Resolution</td>
<td>1.0 mil Resolution</td>
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<tr>
<td>Load/Unload Cycle Time</td>
<td>Approx 30 Sec</td>
<td>Approx 12 Sec</td>
<td>Approx 30 Sec</td>
<td>Approx 20 Sec</td>
</tr>
<tr>
<td>Output</td>
<td>Video Display of Flaws</td>
<td>Video Display of Flaws</td>
<td>Video Display of Flaws</td>
<td>Digitized Display of Flaws</td>
</tr>
<tr>
<td>Printout XY Coordinates</td>
<td>Printout XY Coordinates</td>
<td>Printout XY Coordinates</td>
<td>Printout XY Coordinates</td>
<td>Printout XY Coordinates</td>
</tr>
<tr>
<td>Classify Fault</td>
<td>Printout Sensor ID</td>
<td>Printout Sensor ID</td>
<td>Printout Sensor ID</td>
<td>Printout Sensor ID</td>
</tr>
<tr>
<td>Printout Fault Class</td>
<td>Store data</td>
<td>Store data</td>
<td>Store data</td>
<td>Store data</td>
</tr>
<tr>
<td>Store data</td>
<td>Classify Defects by panel and Batch (Using off-line Manual Verification Station)</td>
<td>Classify Defects by panel and Batch (Using off-line Manual Verification Station)</td>
<td>Classify Defects by panel and Batch (Using off-line Manual Verification Station)</td>
<td>Classify Defects by panel and Batch (Using off-line Manual Verification Station)</td>
</tr>
<tr>
<td>Provide average (per panel or per batch) line widths for each class</td>
<td>Ink mark flaw location</td>
<td>Ink mark flaw location</td>
<td>Ink mark flaw location</td>
<td>Ink mark flaw location</td>
</tr>
<tr>
<td>Space Requirements</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insp Station</td>
<td>45 SF</td>
<td>40 SF</td>
<td>44 SF</td>
<td>50 SF</td>
</tr>
<tr>
<td>Verif Station</td>
<td>Optional</td>
<td>20 SF</td>
<td>Options available</td>
<td></td>
</tr>
<tr>
<td>Power Requirements</td>
<td>Single phase, 60 Hz, 115/230 volts &amp; 30 Amps</td>
<td>Single Phase</td>
<td>Single Phase, 115V, 60 Hz, 4KVA supplies</td>
<td>208 VAC, 3 phase, 3 wire, 30/60 Hz (30 Amps/phase max dual drops required)</td>
</tr>
<tr>
<td>Self-test &amp; Diagnostics</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Operating Environment</td>
<td>Temp 15-30 deg C. Rel Humidity 30-80%</td>
<td>Temp 45-90 deg F. Rel Humidity 20-80%</td>
<td>Temp 60-85 deg F. Rel Humidity 20-80%</td>
<td>Temp 60-80 deg F. Rel Humidity 30-70%</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------------------------------</td>
<td>-------------------------------------</td>
<td>-------------------------------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td>Cost</td>
<td>All four units cost between $300-400K, depending upon extra features ordered.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**V Measurement Procedures, Specifications and Test Results**

All equipments were tested using product from the Delco Electronics PWB Fabrication department. The same items were tested on each supplier's equipment. Tests were extensive, with the primary goals being accuracy and repeatability with minimal "false alarm" rates.

**VI Problems Encountered and How Resolved**

The only real problem encountered in the search for suitable equipment for this project dealt with the development of the technology itself. During the three years involved the technology underwent many changes and is still changing today. Comparisons of different equipments had to be made within a reasonable time span of each other in order to have a meaningful relationship. Changes in the technology primarily occurred in the machine vision/processing area. In the last three years vision has advanced from 64 levels of grey scale with binary image digitizing to 256 levels of true grey scale. This has been accomplished due to the availability of faster computers and advanced image processing algorithms. These advances have allowed systems to operate much faster and more accurately and will continue to do so even in the future.

**VII Areas for Future Concern/Development**

Consideration has been given to the tasks of integrating the PWB inspection cell with an automated material handling system, Computer Integrated Manufacturing (CIM) system, and Manufacturing Information System (MIS). Due to the higher than anticipated costs ($100,000 over run) associated with the NOI equipment and installation, acquisition of material handling equipment has been delayed. The delivered system presently does have the flexibility to operate with a material handling system and computer access for CIM and MIS does exist. Delco's long range manufacturing upgrade plan does include these options (CIM, MIS) and when available will be linked to the PWB inspection cell.

**VIII Identification of Equipment/Tooling Needs**

At present there is no need for special tooling for use of this equipment. Development of specialized material handling containers could evolve from experience gained in the use of the equipment.
IX Prototype Design Findings

At the completion of all testing and evaluation AOI Inc (formerly ITEK) was chosen as the supplier whose equipment most completely filled the needs of Delco Electronics. A Purchase Order for one (1) Multimedia Inspection System with Bar Code Labeler and two (2) Verification/Repair Stations was presented to AOI on August 28, 1986. (See Figures 1 and 2)

X IDEF Models

See Figures 3 and 4.
POWER REQUIREMENTS:

INSPECTOR:
(1) 115 VOLTS 30A
(2) 115 VOLTS 20A
(1) 115 VOLTS 10A

V&R (PER STA.):
(1) 115 VOLTS 10A

LABELLER:
(1) 110 VOLTS 5A

CONSOLE & DISPLAY:
(1) 110 VOLTS 1.5A (CONSOLE)
(1) 110 VOLTS 2A (DISPLAY)

FIGURE 2. EQUIPMENT INSTALLATION/FLOOR LAYOUT
CASH FLOW EVALUATION

| PROJECT #1: OWN IN-CIRCUIT TESTER - MILWAUKEE |

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>INVESTMENT DATA:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>DEVELOPMENT</td>
<td>* (1)</td>
<td>4</td>
<td>21</td>
<td>30</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>FACILITIES</td>
<td>*</td>
<td></td>
<td>40%</td>
<td>17%</td>
<td>9%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOOLING</td>
<td>*</td>
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<td>39%</td>
<td>15%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>TOTAL</td>
<td>(1)</td>
<td>4</td>
<td>554</td>
<td>62</td>
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<td>0</td>
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<td>PROFIT AND CASH FLOW DATA:</td>
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<td></td>
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</tr>
<tr>
<td>CASH SAVINGS</td>
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<td>34</td>
<td>103</td>
<td>284</td>
<td>370</td>
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<td>2,196</td>
<td>1,792</td>
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<td>16%</td>
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<td>TOOLING</td>
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<td>0</td>
<td>13%</td>
<td>15%</td>
<td>3%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>0</td>
<td>0</td>
<td>112%</td>
<td>164%</td>
<td>161%</td>
<td>89%</td>
<td>44%</td>
<td>3%</td>
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<tr>
<td>NET SAVINGS BEFORE TAXES</td>
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<td>0</td>
<td>(80%)</td>
<td>(141%)</td>
<td>141%</td>
<td>646%</td>
<td>1,515%</td>
<td>2,191%</td>
<td>1,789%</td>
<td>1,697%</td>
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<td>NET SAVINGS AFTER TAXES (TAX @ .37)</td>
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<td>0</td>
<td>0</td>
<td>(50%)</td>
<td>(89%)</td>
<td>89%</td>
<td>407%</td>
<td>977%</td>
<td>1,180%</td>
<td>1,127%</td>
<td>1,195%</td>
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<td>ADD DEPRECIATION</td>
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<td>164%</td>
<td>161%</td>
<td>89%</td>
<td>44%</td>
<td>3%</td>
<td>1%</td>
<td>0%</td>
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<tr>
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<td>0</td>
<td>61%</td>
<td>182%</td>
<td>230%</td>
<td>496%</td>
<td>1,022%</td>
<td>1,303%</td>
<td>1,127%</td>
<td>1,195%</td>
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<td>INVESTMENT CREDIT</td>
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<td>1%</td>
<td>1%</td>
<td>0%</td>
<td>0%</td>
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<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>NET CASH FLOW</td>
<td>1</td>
<td>(4%)</td>
<td>(554%)</td>
<td>(1%)</td>
<td>176%</td>
<td>231%</td>
<td>496%</td>
<td>1,022%</td>
<td>1,303%</td>
<td>1,127%</td>
<td>1,195%</td>
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<tr>
<td>CUMULATIVE CASH FLOW</td>
<td>1</td>
<td>(3%)</td>
<td>(557%)</td>
<td>(550%)</td>
<td>(392%)</td>
<td>(151%)</td>
<td>345%</td>
<td>1,307%</td>
<td>2,750%</td>
<td>3,877%</td>
<td>5,072%</td>
</tr>
</tbody>
</table>

PAYOFF AND RETURN ON INVESTMENT:

| PAYOFF | 4.3 YRS. |
| RETURN ON INVESTMENT (DISCOUNTED CASH FLOW) | 0.554104 |

* INPUT BY REQUEST