NASA Technical Memorandum 104580

Automated Inspection of Solder Joints for Surface Mount Technology

Robert M. Savage
Hyun Soo Park
Dr. Mark S. Fan

March 1993

(NASA-TM-104580) AUTOMATED INSPECTION OF SOLDER JOINTS FOR SURFACE MOUNT TECHNOLOGY (NASA) 32 p

N93-26137

Unclas

G3/38 0160389

NASA Technical Memorandum 104580

Automated Inspection of Solder Joints for Surface Mount Technology

Robert M. Savage
Hyun Soo Park
Dr. Mark S. Fan
Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and
Space Administration

**Scientific and Technical
Information Branch**

1993

Table of Contents

ABSTRACT

NASA Goddard Space Flight Center (GSFC) evaluated various automated inspection system (AIS) technologies using test boards with known defects in surface mount solder joints. These boards were complex and included almost every type of surface mount device typical of critical circuit assemblies used for space flight applications.

Six different automated inspection technologies were evaluated for use in surface mount applications. The following technologies were evaluated:

- X-ray radiography
- X-ray laminography
- Ultrasonic Imaging
- Optical Imaging
- Laser Imaging
- Infrared Inspection

Vendors, representative of the different technologies inspected the test boards with their machine. The results of the evaluation showed limitations of AIS. Furthermore, none of the AIS technologies evaluated proved to meet all of the inspection criteria for use in high reliability applications. It was found that certain inspection systems could supplement but not replace manual inspection for low volume, high reliability surface mount solder joints.

INTRODUCTION

Developments in Surface Mount Technology (SMT) have increased the density of solder joints on a printed circuit board from hundreds to thousands per board, making it more difficult to inspect fine pitch surface mounted devices. As a result, there has been significant growth in Automated Inspection Systems (AIS) capable of inspecting surface mounted devices.

With Plated Through Hole (PTH) technology, NASA has traditionally relied on manual visual inspection to inspect for defects which can affect the quality and reliability of the printed circuit board. Such inspection methods are at best, subjective; repeatability will vary from inspector to inspector using the same inspection criteria. This situation is further complicated with SMT where leads may not be visible to the human inspector.

NASA is currently using SMT in many of their projects, hence, the problem of inspecting surface mounted devices is real. Increased I/O capability and fine pitch will make manual inspection increasingly more difficult.

Automated inspection systems have begun to establish themselves in the past few years. Several competing technologies, namely, x-ray radiography, x-ray laminography, ultrasonic imaging, automated optical inspection, laser inspection, and infrared inspection have been developed to provide high speed, accuracy, and repeatability in inspecting solder joints of surface mounted devices.

The various automated inspection technologies were evaluated for suitability for NASA applications. The AIS technologies evaluated all showed limitations and weaknesses with no single AIS technology being capable of inspecting all the defect types in all the different lead configurations.

EXPERIMENT

Three different board types were designed to evaluate the AIS technologies. See Appendix A for the parts list. The boards were fabricated using FR-4 laminate, RMA soldering paste, a manual pick-and-place machine, and an IR reflow oven with 10 temperature chambers. Prior to the reflow process, certain defects were induced into the solder joints such as placing epoxy randomly on solder joints to simulate voiding and contamination. Most of the other defects were process related, screen printing and reflowing.

The first board type was a 10x10 leadless chip carrier (LCC) array consisting of 100 LCCs and 100 chip resistors. See Figure 1 for board layout and Figure 2 for actual artwork used to fabricate the boards.

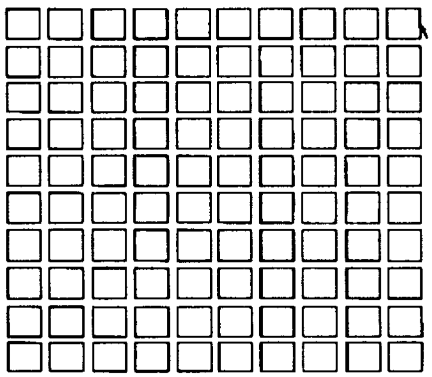


Figure 1. Board layout for Board 1. One hundred 20 pin LCCs, 50 mils.

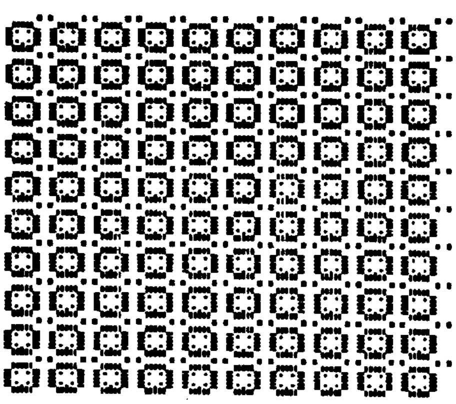


Figure 2. Artwork for Board 1.

The second board type was a single-sided board with various surface mounted devices and a variety of lead pitches and lead configurations. The lead pitch on the board varied from a low of 20 mils to a high of 100 mils. The lead configurations also encompassed a wide variety of SMT lead types, including, Gull wing, J-lead, and also leadless devices. See Figure 3 for the board layout and Figure 4 for the artwork.

The third board type had the same layout as the second board type; however, it was double sided with the mirror image of the first side on the second side. The board was designed so that the solder joints on the second side overlapped the joints on the first side.

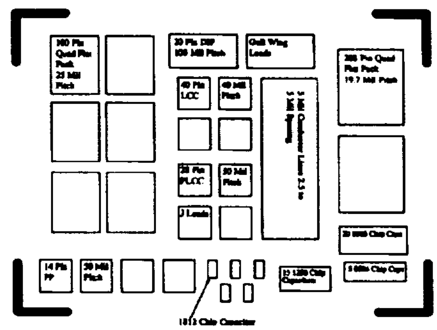


Figure 3. Board layout for Board 2.

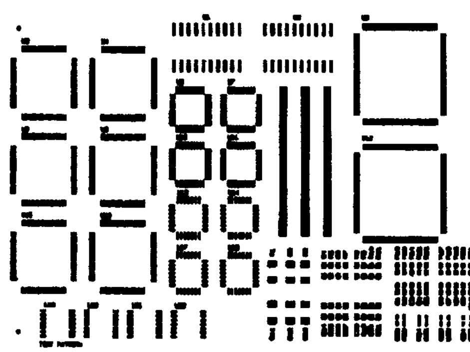


Figure 4. Artwork for Board 2.

The evaluation boards had the following known soldering defects which were identified by a NASA certified inspector:

- Shorts/bridges
- Icicles
- Solder balls
- Insufficient solder
- Excess solder
- Cold solder

- Dewetting
- Nonwetting
- Solder contamination
- Cracks
- Delamination
- Lifted pads
- Hidden voids
- Missing parts
- Misaligned joints

The boards consisted of surface mount devices with various lead configurations and lead pitch and had a high density of defects such that almost every part had some sort of defect.

The boards were used to evaluate five automated inspection technologies:

- X-ray inspection
- Automated optical inspection
- Laser inspection
- Infrared inspection
- Ultrasonic imaging

The different automated inspection technologies fall into two basic categories: internal inspection and external inspection. X-ray, infrared, and acoustic imaging have the capability to look at the integrity or construction of the solder joint and are categorized as internal. External techniques include optical- and laser-based technologies that can inspect for surface type defects only. None of the technologies can adequately perform both internal and external inspection of solder joints; hence, laser- or optical-based systems cannot inspect for internal defects such as voiding. Likewise, internal systems cannot identify surface defects such as surface contamination.

Several vendors were selected to perform the inspection using their automated inspection system. Each vendor was given one of each board type to evaluate, program, and optimize their system. Once programming was completed, we visited the vendor with all of the boards: 5 LCC boards, 6 single-sided mixed-parts boards, and 4 double-sided boards.

The following is a brief description of each technology and our evaluation of each vendor for suitability for NASA applications.

X-ray Radiography

X-ray radiography systems work by transmitting X-rays through a printed wiring board and processing the output of an x-ray detector. X-ray radiography-based systems can provide insight to hidden structural details, as well as providing information on other soldering defects. Specifically, x-ray radiography is suited to provide information on [1]

Disbonds

- Lifted leads
- Missing, misoriented, misaligned parts
- Insufficient, excess solder
- Voids
- Dewetting
- Bridging

The process is based on density measurements using grey-scale images. It can provide insight to hidden structural defects and generate 3-D images of the solder joint.

X-ray radiography systems are most successful in the inspection of single sided boards with more openly spaced parts. Double sided boards cannot be inspected accurately since parts, solder joints, and board materials will overlap, making detection of defects difficult. Furthermore, contamination, cold solder joints, and other surface defects cannot be detected because of physical limitations of x-ray systems; such defects do not affect x-ray; hence, they cannot be detected.

Vendor A: X-ray Radiography

A representative of the vendor clearly stated that they could not inspect the double-sided boards we gave them but that they could inspect the single-sided boards.

In order for their automated inspection system to locate the parts, they needed a physical description of the board layout on a floppy disk. The file must describe the position, orientation, side, and device type of every device to be inspected. In addition, they required pin coordinates for every device type relative to the device origin, usually its center. See Tables 1 and 2 for information required by the vendor.

Table 1: Device Description

Name	X	Y	Orient.	Side	Type
U4	230	430	0	0	SOIC4
U5	870	540	90	1	SOIC4
U6	530	-230	90	1	SOIC4
U7	-270	940	0	0	SOIC4
C1	430	430	180	1	CAP
C2	570	670	270	1	CAP
C3	230	-230	0	0	CAP
C4	-570	340	0	0	CAP

This data is normally extracted from pick and place data, but because we used a manual pick and place machine to place the parts, this data was not available. The data was created manually for the three different board types and submitted to the vendor with the boards. The vendor, however, declined to do the inspection and did not give us a reason.

Table 2: Pin Coordinates

Device	Pin Name	X	Y
SOIC4	1	-20	-20
SOIC4	2	20	-20
SOIC4	3	30	-20
SOIC4	4	etc.	etc.
C1	1	-6	0

Table 2: Pin Coordinates

Device	Pin Name	X	Y
C1	2	6	0

Automated Optical Inspection

Automated optical inspection (AOI) systems can inspect for visible and surface type flaws only. Probable errors that can be detected include solder bridging, lack of solder, presence or absence of a part, part orientation, lifted leads, tombstoning, solder balls, holes / pits, excess solder, and other defects which would be evident to the human inspector.

Typical image-related hardware used in AOI systems include: charge-coupled device cameras (CCDs), frame grabbers, and image-processing boards.[2]

AOI systems typically use multiple high-resolution cameras set at different angles to generate 3-D solder joint images in great detail.

AOI systems use high-resolution CCD cameras to acquire a grey-level image of the solder joint and then processes the image to determine if any defects are present. Such systems have the same limitations as human inspectors and cannot inspect hidden or internal defects.

Vendor B: Automated Optical Inspection

This vendor needed more time than the other vendors because they had to manufacture holding fixtures for each board type, as well as program their machine to inspect our boards.

The vendor was currently working on a program to test for defects in leadless chip carrier solder joints, but the program was not ready when we visited with our boards. The vendor stated that all the other parts on the board could be inspected.

The boards were inspected by the vendor's automated optical inspection system; however, the vendor did not provide us with the data because they did not believe that the data generated represented the full capabilities of their system. They attributed the variance in the data to two reasons:

- The setting on their machine was mechanically incorrect.
- The software algorithms that define the solder joints on the boards were not tailored for our boards.

Laser Inspection

Laser inspection systems operate on the same principle as automated optical inspection systems, but the CCD cameras are replaced by lasers. The laser source is focused on the solder joint surface. Light scattered from the object is imaged onto a detector to generate a high-resolution 3-D image of the object.[3] The trend of rotation of the reflected signal is examined, and the data for the external shape of the solder fillet can be determined. Such systems share the same limitations as optical systems and cannot inspect hidden joints.

Vendor C: Laser Inspection

We evaluated two different laser inspection vendors. The first vendor declined to do the inspection after reviewing our boards. They were not confident that they could inspect the boards with all the different package configurations. In order to inspect our boards, it required further development of their software. They did not have the resources at the present time.

The second laser inspection vendor could not perform the inspection. They cited the following reasons:

- There were no fiducial marks on the PCBs. Well defined fiducial marks are necessary for their system to accurately locate part and lead location.
- They claimed that the pads were longer than usual even though they were designed to IPC specs. This created excess solder conditions on many of the joints.
- Too many parts were mislocated or shifted.

Infrared Inspection

This technology requires the joint to be heated to a known temperature by focusing a laser on each solder joint for a short amount of time. An IR detector then measures the joint temperature during and after the heating process to record the infrared signature. This signature is made up of 3 phases: warm-up, peak, and cool down.[4] Each solder joint has a distinct infrared intensity curve, which is compared to a signature or curve of a known good solder joint. This comparison is used to determine if the solder joint is acceptable or not.

Vendor D: Infrared Inspection

Infrared inspection requires a statistically significant sample of good solder joints; the system must evaluate approximately six "golden boards," which are boards without any defects. From the "golden boards," the system will derive an infrared signature characteristic of each solder joint on the board. This signature will be used as a baseline or reference to determine the accept/reject criteria of future identical boards. This was not feasible to do in our evaluation. All of our boards had induced defects. Considering that we were testing three different board types, this would have required eighteen "golden boards" to teach the system; six for each type. This is not acceptable for NASA applications; NASA may only need, at most, six of one type of board, not six "golden boards" for every board type.

Ultrasonic Imaging

Ultrasonic imaging systems use specialized piezoelectric transducers to generate and receive sharp focused pulses of high frequency ultrasonic energy. By monitoring the reflection or transmission of the sound pulses, solder joint integrity defects such as voids, cracks, and disbonds can be identified. Ultrasonic inspection is usually limited to simple geometries. On densely packed boards, reflection and refraction effects can scatter the beam, making detection difficult.

For ultrasonic inspection, the PWB must be immersed in water, because sound energy at frequencies used for imaging will not travel through air.[5]

Ultrasonic inspection systems can only produce results as percentage of bonded or disbonded area. It is well suited for determining bonding area and voiding but cannot identify other types of soldering defects.

Vendor E: Ultrasonic Imaging

The inspection was performed by manually moving the acoustic transducer to various desired imaging locations on the PCB. According to the vendor, they had an automatic positioning table, but it was not available during our visit.

Because of the nature of the system, the solder joints for LCCs and J leads cannot be inspected. The resolution of the digitized image of 19.7 mil devices was too poor to extract any meaningful data. The 100 pin QFPs required a minimum of 4 images to adequately capture all the leads.

The manual positioning of the transducer proved extremely slow. The average time to image one of our single-sided boards was three hours and required approximately 50 images.

Once the images were taken, each solder joint must be justified individually. The operator had to use the mouse to draw rectangles around each solder joint to compute the percentage of the disbonded area within each rectangle. Each joint required approximately 40 to 50 seconds. The data generated only showed the percentage of disbonding and did not identify the soldering defects.

X-ray Laminography

X-ray laminography systems use a spinning beam to slice images that are.020 inch (.51mm) thick.[6] X-ray laminography systems can isolate individual layers and joints, allowing double-sided boards to be inspected without difficulty.

X-ray laminography systems work by spinning an x-ray beam and creating a focal plane. The board then moves around the plane in x-y-z directions to bring the focal plane into view. Objects above and below the image are blurred into the background. Furthermore, X-ray laminography systems have the capability to generate 3-D images by combining various focal planes.

X-ray laminography systems behave similarly to x-ray radiography systems with the addition of being able to inspect double-sided boards with overlapping solder joints.

Vendor F: X-ray Laminography

The boards were sent to this vendor along with the gerber file and the associated aperture files. The gerber file and aperture files were generated by the CAD program used to design the printed circuit boards. These files were used to program the automated inspection system for solder joint locations and pad sizes for the inspection. Each board type required 4 to 6 hours of programming time.

Boards of the same type were automatically fed and inspected, one after the other. See Table 3 for system features.

Table 3: System Features

Board Insertion Time	10 - 15 seconds
Test Time (Per Board)	7 - 8 minutes
Data Reporting Time	1 minute
Data Reporting Capability	Screen Display, ASCII File, Laser copy, SPC distribution
Data Entry Requirement	Gerber File, Aperture File
Threshold Adjustments	User's choice
Accept/Reject Criteria	Detailed defects info.

Typical solder joint defects that can be detected by the system include

- Opens
- Bridging
- Solder balls/splash
- Internal voids
- Pits/holes
- Insufficient solder
- Excess solder
- Solder thickness
- Nonwetting
- Part alignment
- Fillet quality
- Lifted leads
- Splash

The accept/reject data generated from the vendor was evaluated to determine the capabilities of their inspection system.Repeatability, false-alarm rate, and escape rate were calculated.

Repeatability is defined as

$$\frac{T-I}{T} \times 100 \qquad (1)$$

Where

T = Total number of joints inspected
I = Number of joints inconsistently called

The repeatability of accept/reject data generated by the vendor showed 81% agreement on three consecutive runs with the same board. 19% of the time, the machine called out inconsistent defects under identical operating modes and conditions. See Figure 5 for repeatability calculations

Repeatability of ACCEPT/REJECT Decisions

Pass 1

# of inconsistently called solder joints:	292
# of joints inspected:	1484

Repeatability = [(1484-292)/1484]*100=80%

Pass 2

# of inconsistently called solder joints:	287
# of solder joints inspected:	1484

Repeatability = [(1484-287)/1484]*100 = 81%

Pass 3

# of inconsistently called solder joints:	280
# of joints inspected:	1484

Repeatability = [(1484-280)/1484]*100 = 81%

Overall Repeatability

# of inconsistently called solder joints:	859
# of solder joints inspected:	4452

Repeatability = [(4452-859)/4452]*100 = 81%

Figure 5: Repeatability calculations

Utilizing two additional equations from IPC-AI-641, "User's Guidelines for Automated Solder Joint Inspection Systems," we calculated the false-alarm and escape rates. The false-alarm rate shows the percentage of solder joints incorrectly identified as a defect. The escape rate shows the percentage of defective solder joints that the machine accepted as a good solder joint.

The equations are defined as follows:

$$FAR = \frac{\Sigma IRJ}{\Sigma GJ} \times 100 \qquad (2)$$

Where

FAR = False Alarm Rate
IRJ = Incorrectly rejected joints
GJ = all good joints

$$ER = \frac{\Sigma MD}{\Sigma TD} \times 100 \qquad (3)$$

Where

ER = Escape Rate
MD = Missed defects
TD = Total defects

Using these equations, we determined that the false-alarm rates and escape rates were grossly beyond the acceptable range for any NASA application. Results from two boards are as follows:

- Type 1 board (LCC Board)
  False-alarm rate = 4%
  Escape rate = 79%
- Type 2 board (Mixed Parts)
  False-alarm rate = 33%
  Escape rate = 62%

The inspection results are poor but must be qualified. The results are attributable to the subjectivity of the human inspector, the accept/reject threshold adjustments not optimum for our boards, and the physical limitations of the vendor machines.

In order to evaluate the data, a NASA certified hand-soldering inspector inspected our boards and noted all the defects. The data generated by the AIS was then compared and the differences noted. Due to the inherent subjectivity of the human inspector, it was difficult in some cases to correctly identify a soldering defect. Also, the human inspector is not capable of finding 100% of the defects on the evaluation boards; hence, the results of the AIS machine are limited by the accuracy of the human inspector.

The numbers we calculated are also misleading, because the automated inspection system cannot inspect to the same requirements as the human inspector. Our NASA inspector inspected the boards to the requirements of NHB 5300.4(3Z), Workmanship Requirements for Surface Mount Technology, which is pending approval for use in NASA. This specification is a visual criteria. It is difficult to transfer these requirements to the automated inspection system, which considers the intensity of grey-scale images. Optimization can only be achieved through experimentation and threshold adjustment to correlate the grey-scale images to visual inspection defects. This process may take six months to optimize.

Physical limitations of the AIS also contributed to the calculated results for the false alarm rate and the escape rate. The machine could not identify certain defects such as insufficient castellation on LCCs. Half of the LCCs were not tinned prior to soldering; hence, half had poor wetting and resulted in insufficient castellation that the machine could not identify.

Appendix B shows examples of how the automated inspection system interpreted the defects on the evaluation boards:

DISCUSSION AND CONCLUSION

Advances in SMT have made visual inspection more difficult. There is an increasing need for automated inspection systems to inspect for soldering defects on surface mount devices; however, the pioneers in automated inspection technologies have not matured or kept pace with the developments of surface mount technology.

Most of the vendors we evaluated were in the beginning phase of development for automated inspection systems. Their systems have not been perfected and, thus, have many limitations.

Many of the vendors are relatively small and do not have the resources to perform inspection demos with the customer's boards. In certain instances, machines were not available for inspection and we had to wait until the vendor could finish building one.

As of this study, only the x-ray laminography vendor has matured enough to be able to inspect for soldering defects regardless of the device configuration or board layout. However, x-ray laminography showed the following limitations:

- Long programming time per board type
- Inability to determine certain defects
- Lack of repeatability

X-ray inspection may be acceptable for AIS techniques for large volume, high throughput type of work where threshold adjustments are feasible. For low volume, critical component level work typical of NASA applications, x-ray inspection techniques may not be adequate.

The calculated results for repeatability, false alarm rate, and escape rate would have been better if the boards were actual flight or production boards with a lower defect density. Our evaluation boards had soldering defects on practically every part on the board. The x-ray laminography system identified defects on almost every part; however, it misidentified many and also missed many critical defects that a human inspector would have found.

As the complexity of surface mount devices increases, there will be a greater need for an automated inspection system to perform the inspection for soldering defects. Human inspectors are subjective, and in many cases, manual visual inspection cannot inspect hidden defects. Automated inspection systems need to improve in order to be a viable alternative to human manual inspection.

No single inspection system can adequately inspect with the speed, accuracy, and repeatability as required for NASA applications. X-ray laminography technology showed the most promise but still required further development to be suitable for NASA applications.

Footnotes

1. "Alternative Inspection Techniques," NEPCON WEST 91, WS-10.
2. Bracker, William E. Jr., Christi Harris, "Automatic Optical Inspection", *Printed Circuit Assembly*, December 1989, pp 7-8.
3. Case, Steven K., "Laser Sensors for Precise Control of Hybrid Manufacturing", *Hybrid Circuit Technology*, January 1991, pp 5-11.

References

1. Baker,Paul, "Solder Joint Process Control Using 3-D Measurements", *Electronic Manufacturing*, July 1990, pp 32 to 33.
2. Berquist, Ken, "Automatic Versus Visual Inspection: Which is Truly Superior", *Surface Mount Technology*, October 1989, pp 36 - 37.
3. Briggs, M. Darrell, "Printed Wiring Board Inspection", *Applied Machine Vision Conference Proceedings*, February 27 - March 1, 1984, pp 6-7 to 6-21.
4. Hendricks, Ryan , "Automated Solder Inspection: Key to Higher PCB Yields", *Surface Mount Technology*, November 1990, pp 35 - 37.
5. Reiley, Richard V., "How to Succeed With Automatic Inspection Equipment", *Electronic Manufacturing*, July 1990, pp 28-30.
6. Vanzetti, Riccardo, Alan C. Traub, "Automatic Laser/Infrared Inspection", *Printed Circuit Assembly*, December 1989, pp 22 - 25.
7. Wolak, Jerry, "Why Automated Inspection?", *Quality*, February 1991, pp 30 - 32.

8. IPC-AI-641, User's Guidelines for Automated Solder Joint Inspection Systems.

9. NHB 5300.4(3Z), Workmanship Requirements for Surface Mount Technology, NASA Handbook, proposed 1993.

10. "The Need for Automated PWA Inspection Backgrounder", IRT 77061-A28, August 1987.

APPENDIX A: Parts List

Table 1: Part Types for Type 1 Board, Single Soded.

Quantity of components	Number of pins	Description	Pitch	Lead type
100	20	LCC	50 mil	N/A
100	N/A	1206 chip	N/A	N/A

Table 2: Part Types for Type 2 Board, Single Sided.

Quantity of components	Number of pins	Description	Pitch	Lead type
6	100	BQFP	25 mil	Gull wing
2	20	DIP	100 mil	Gull wing
4	40	LCC	40 mil	N/A
4	28	PLCC	50 mil	J-Lead
4	14	FP	50 mil	Gull wing
2	208	QFP	19.7 mil	Gull wing
6	N/A	1812 chip	N/A	N/A
16	N/A	1206 chip	N/A	N/A
20	N/A	0805 chip	N/A	N/A
8	N/A	0504 chip	N/A	N/A

Table 3: Part Types for Type 3 Board, Double Sided.

Quantity of components	Number of pins	Description	Pitch	Lead type
12	100	BQFP	25 mil	Gull wing
4	20	DIP	100 mil	Gull wing
8	40	LCC	40 mil	N?A
8	28	PLCC	50 mil	J-Lead
8	14	FP	50 mil	Gull wing
4	208	QFP	19.7 mil	Gull wing
12	N/A	1812 chip	N/A	N/A

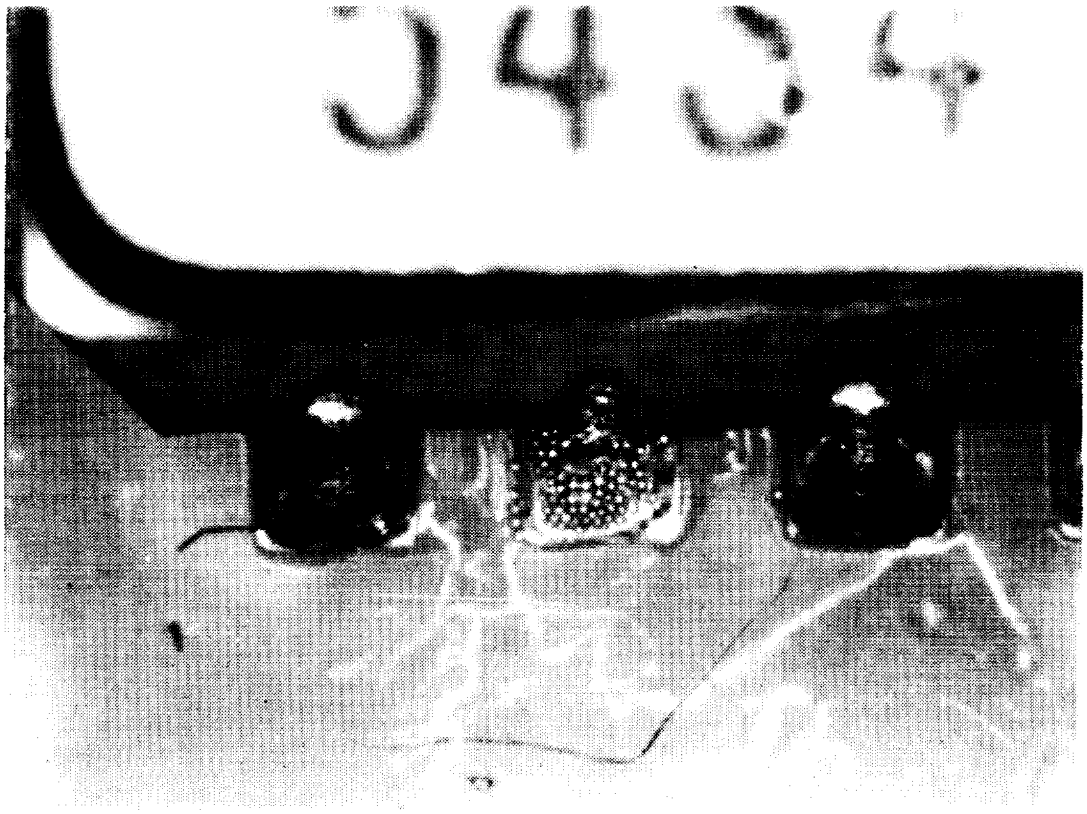
A-2 INTENTIONALLY BLANK

Table 3: Part Types for Type 3 Board, Double Sided.

Quantity of components	Number of pins	Description	Pitch	Lead type
32	N/A	1206 chip	N/A	N/A
40	N/A	0805 chip	N/A	N/A
16	N/A	0504 chip	N/A	N/A

APPENDIX B: Sample Automated Inspection Results

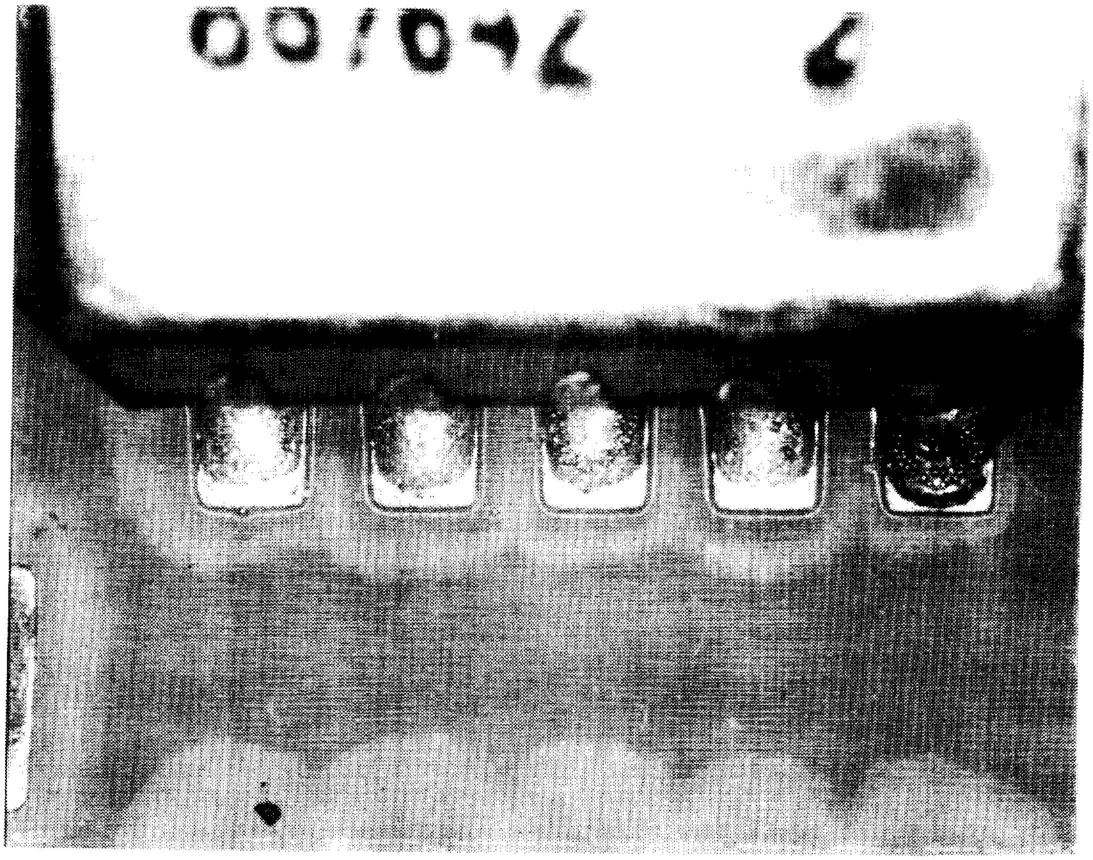
ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH



DEVICE TYPE:	20 Pin LCC
DEVICE NUMBER:	U12 - LCC array
PIN NUMBER:	10
MAGNIFICATION:	23 X
ACTUAL DEFECT:	Solder balls present on pin 10
AIS DEFECT:	No defdects identified on pin 10
COMMENT:	The automate inspection system failed to detect the presence of the solder balls.

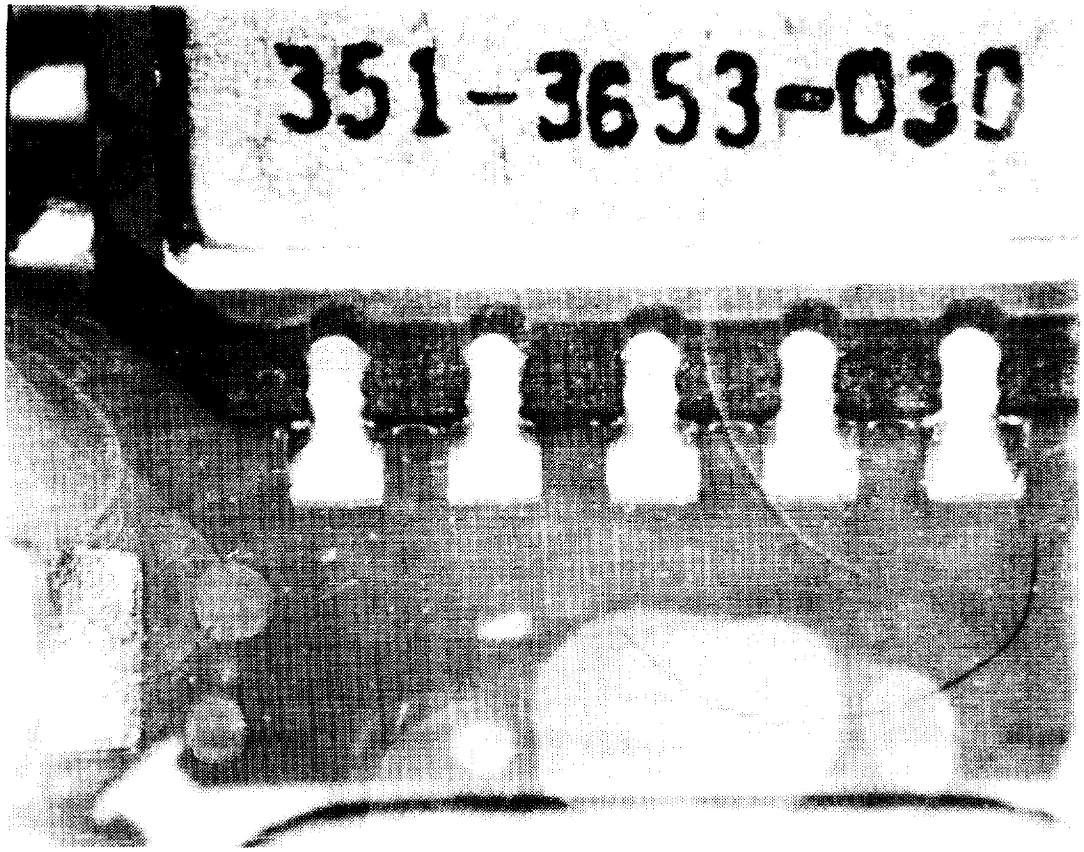
PRECEDING PAGE BLANK NOT FILMED

B-2 INTENTIONALLY BLANK



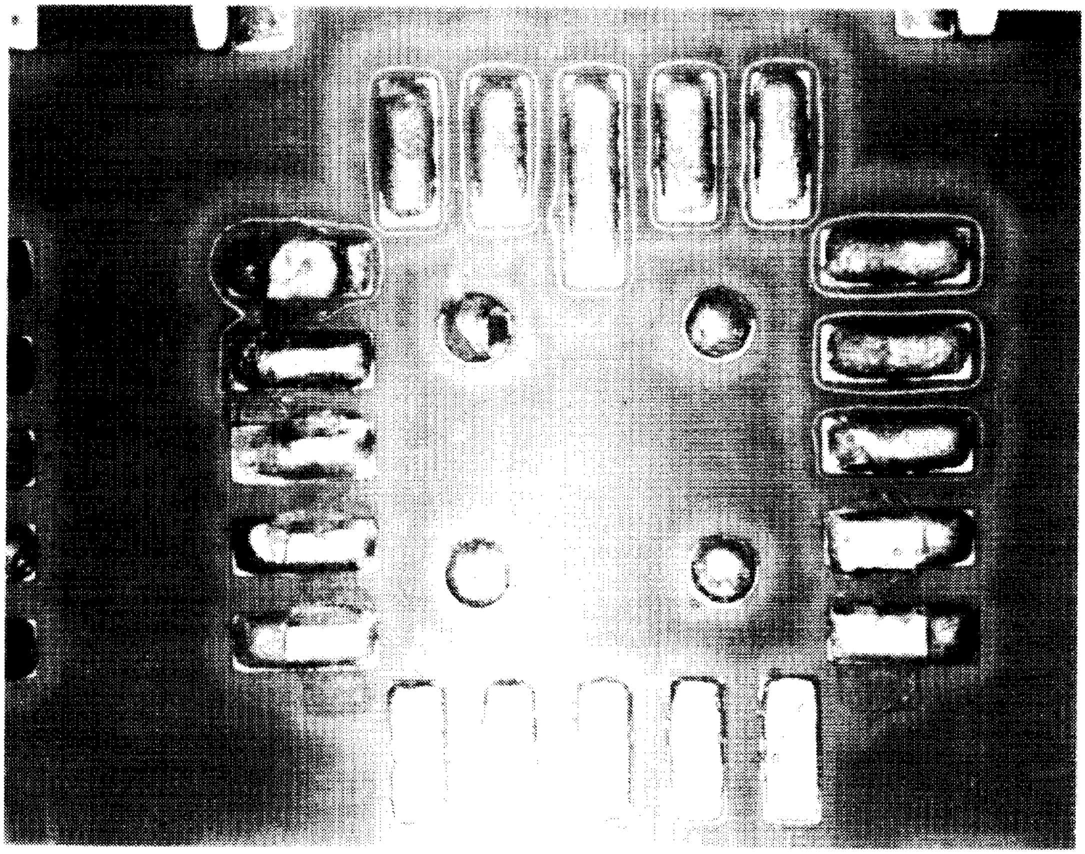
DEVICE TYPE:	20 Pin LCC
DEVICE NUMBER:	U16 - LCC array
PIN NUMBER:	8 thru 12
MAGNIFICATION:	16 X
ACTUAL DEFECT:	Non-wetting on pins 8 thru 12
AIS DEFECT:	No defects detected on pins 8 thru 12
COMMENT:	The automated inspection system failed to detect the presence of non-wetting and solder balls.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH



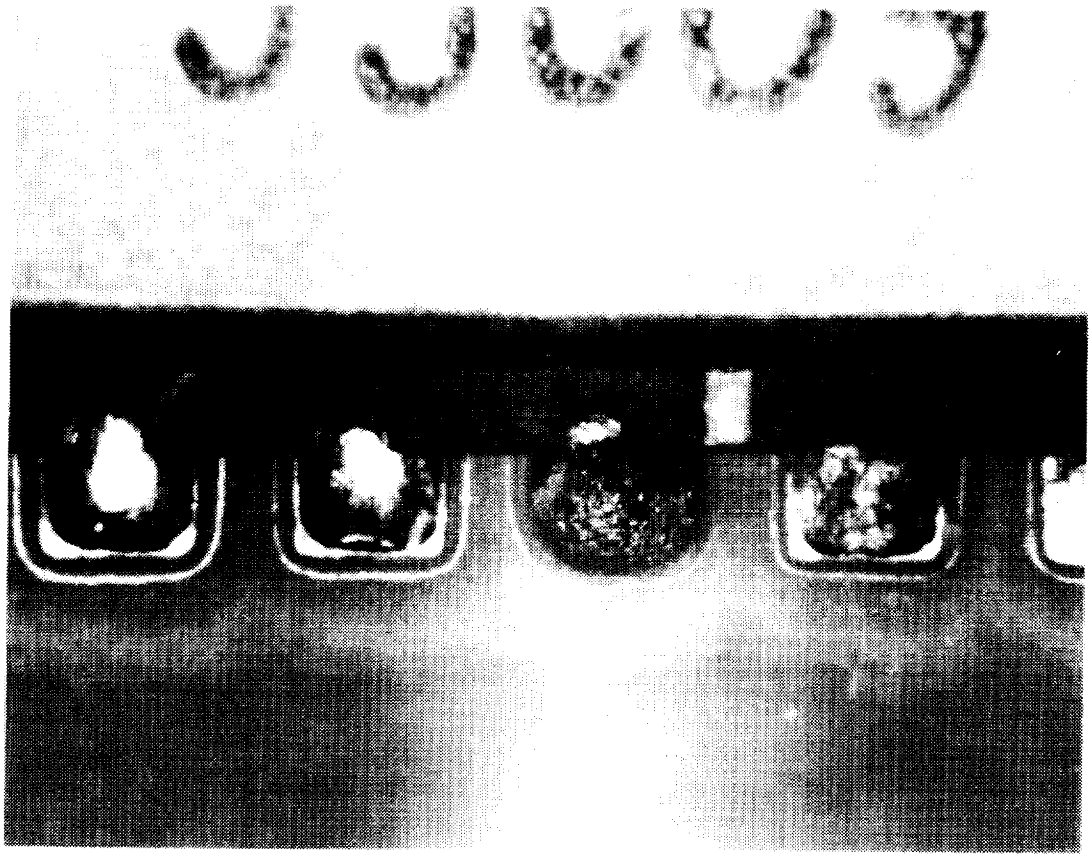
DEVICE TYPE:	20 Pin LCC
DEVICE NUMBER:	U32 - LCC array
PIN NUMBER:	8 thru 12
MAGNIFICATION:	13 X
ACTUAL DEFECT:	Insufficient Castellation fillet
AIS DEFECT:	None
COMMENT:	The automated inspection system could not detect insufficient castellation. In some cases it identified good joints as insufficient castellation.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

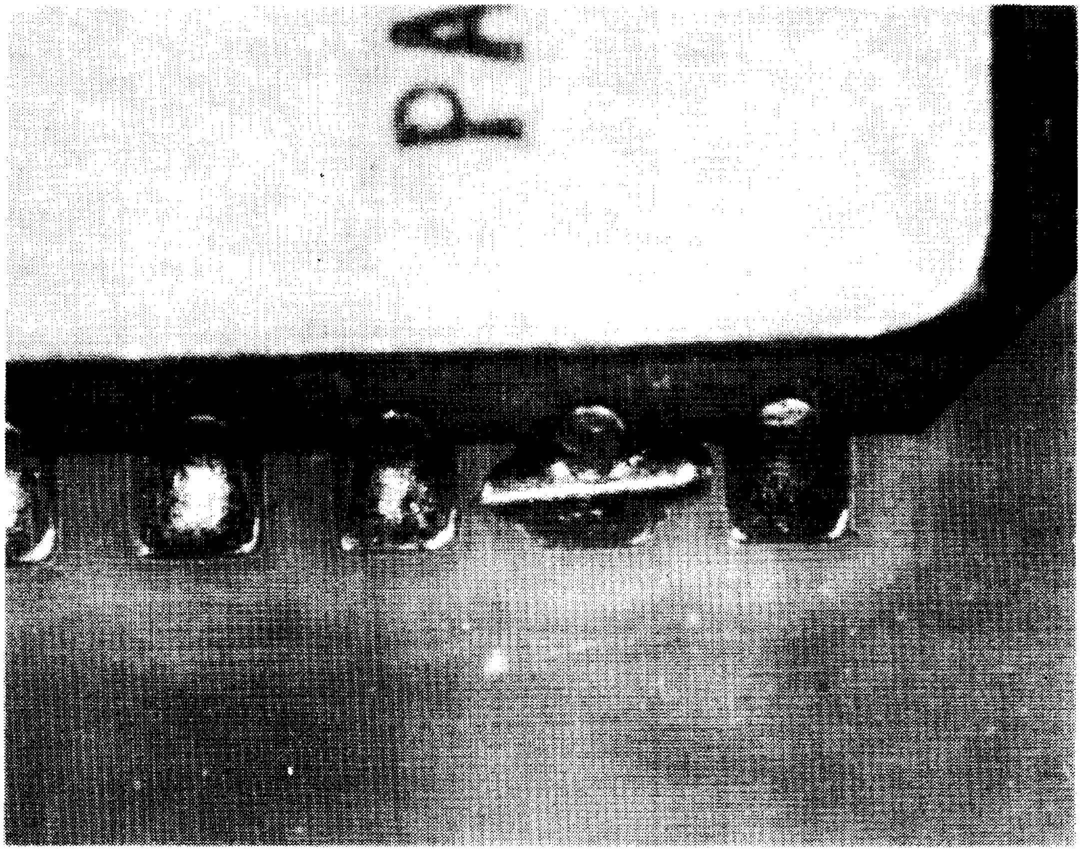


DEVICE TYPE:	20 Pin LCC
DEVICE NUMBER:	U93 - LCC array
PIN NUMBER:	N/A
MAGNIFICATION:	7.5 X
ACTUAL DEFECT:	Missing component
AIS DEFECT:	Numerous
COMMENT:	The AIS machine identified numerous soldering defects when no component was present.

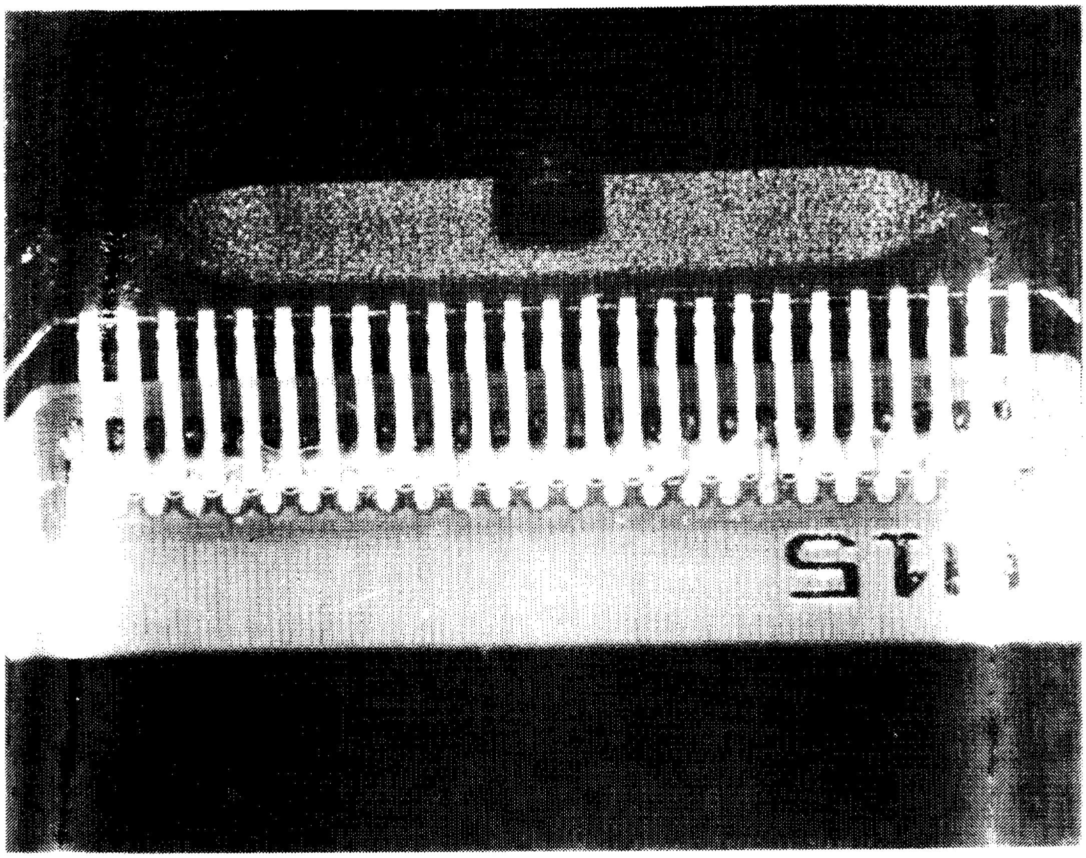
ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH



DEVICE TYPE:	20 Pin LCC
DEVICE NUMBER:	U98 - LCC array
PIN NUMBER:	11 and 12
MAGNIFICATION:	20 X
ACTUAL DEFECT:	Excess solder on pin 11, Non-wetting on pin 12
AIS DEFECT:	Excess cast on pin 11
COMMENT:	The AIS machine correctly identified excess solder condition almost every time but failed to identify non-wetting.

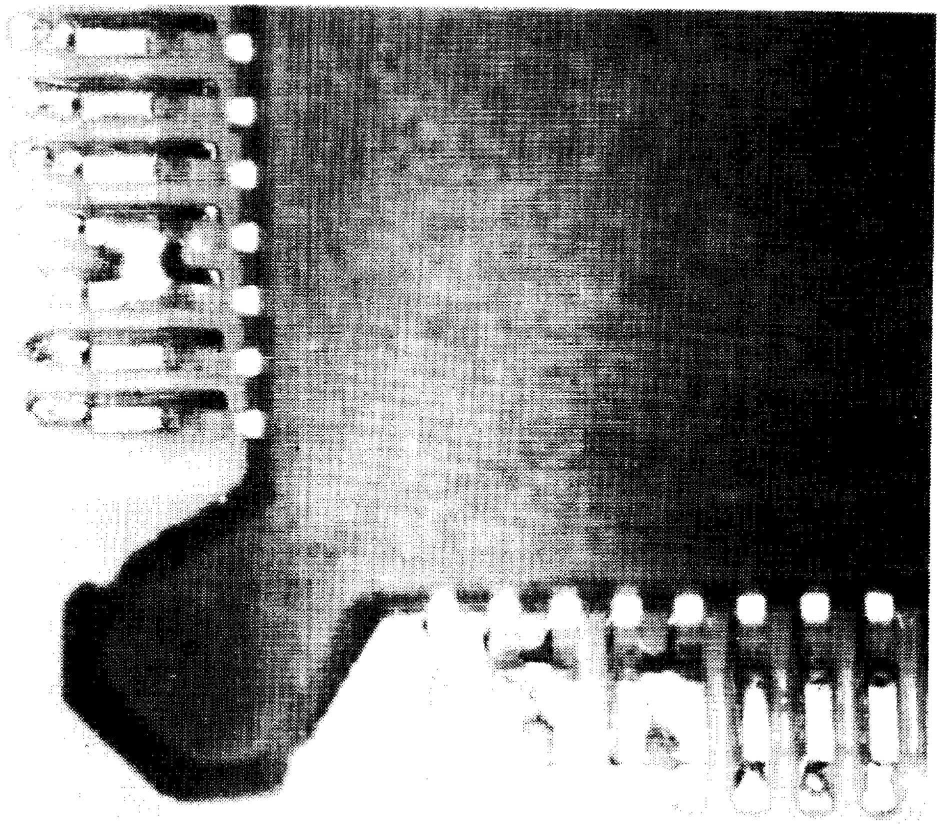


DEVICE TYPE:	20 Pin LCC
DEVICE NUMBER:	U16 - Serial No. 9110-1
PIN NUMBER:	7
MAGNIFICATION:	16 X
ACTUAL DEFECT:	Gold wire in solder joint
AIS DEFECT:	Excess cast
COMMENT:	The AIS could not identify contaminated solder joint.

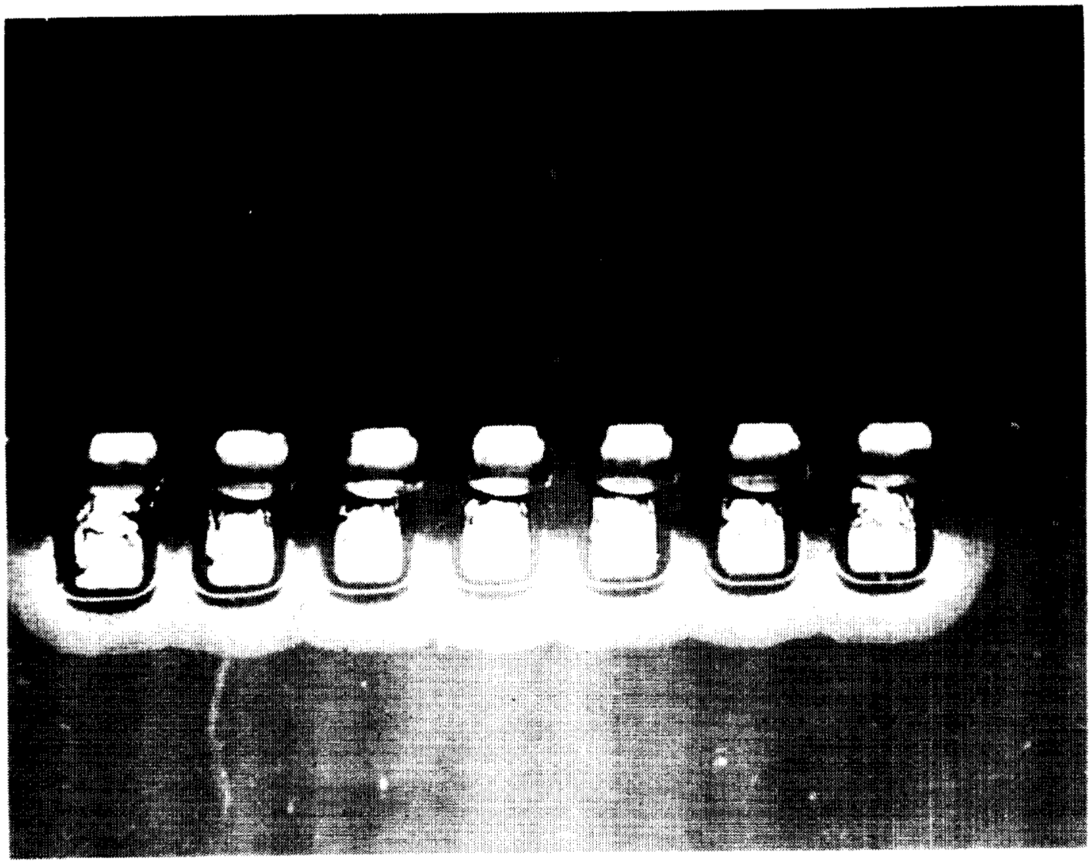


DEVICE TYPE:	100 Pin BQFP
DEVICE NUMBER:	U15 - Serial No. 105
PIN NUMBER:	1 thru 13, 89 thru 105
MAGNIFICATION:	6.3 X
ACTUAL DEFECT:	Misalignment and bridging on almost every pin.
AIS DEFECT:	Various
COMMENT:	The AIS machine incorrectly identified totally lifted lead, it identified some bridging, but not all, and it identified some bridging. The machine did not identify any defects on pin 13 even though it was misaligned and bridged.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

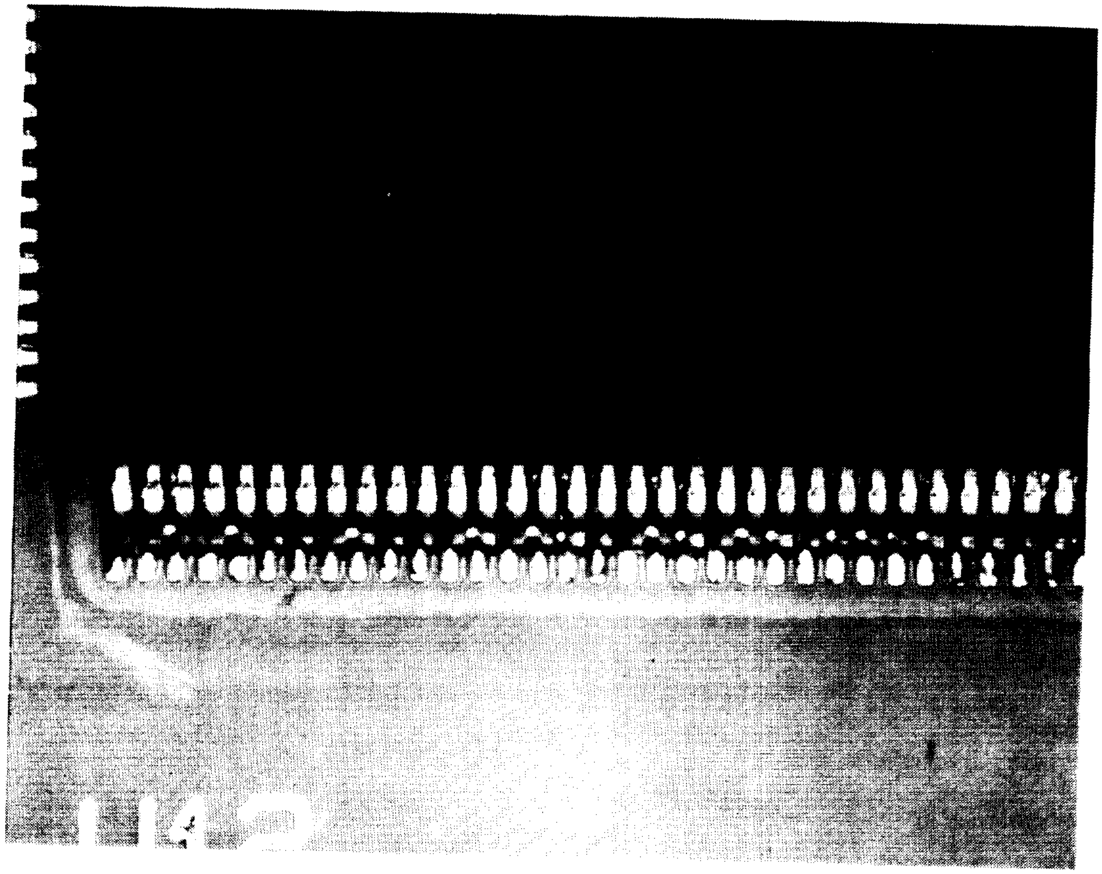


DEVICE TYPE:	100 Pin BQFP
DEVICE NUMBER:	U16 - Serial No. 105
PIN NUMBER:	32 thru 46
MAGNIFICATION:	10 X
ACTUAL DEFECT:	Pins 35 and 36 bridged, 40 and 41 bridged, 42 and 43 bridged
AIS DEFECT:	Pin 35 bridged, 36 not bridged, 42 thru 46 misaligned and pin 41 totally lifted.
COMMENT:	The AIS machine missed the bridging on pins 36, 40, 41, 42, and 43. Pins 42 thru 46 were not misaligned.

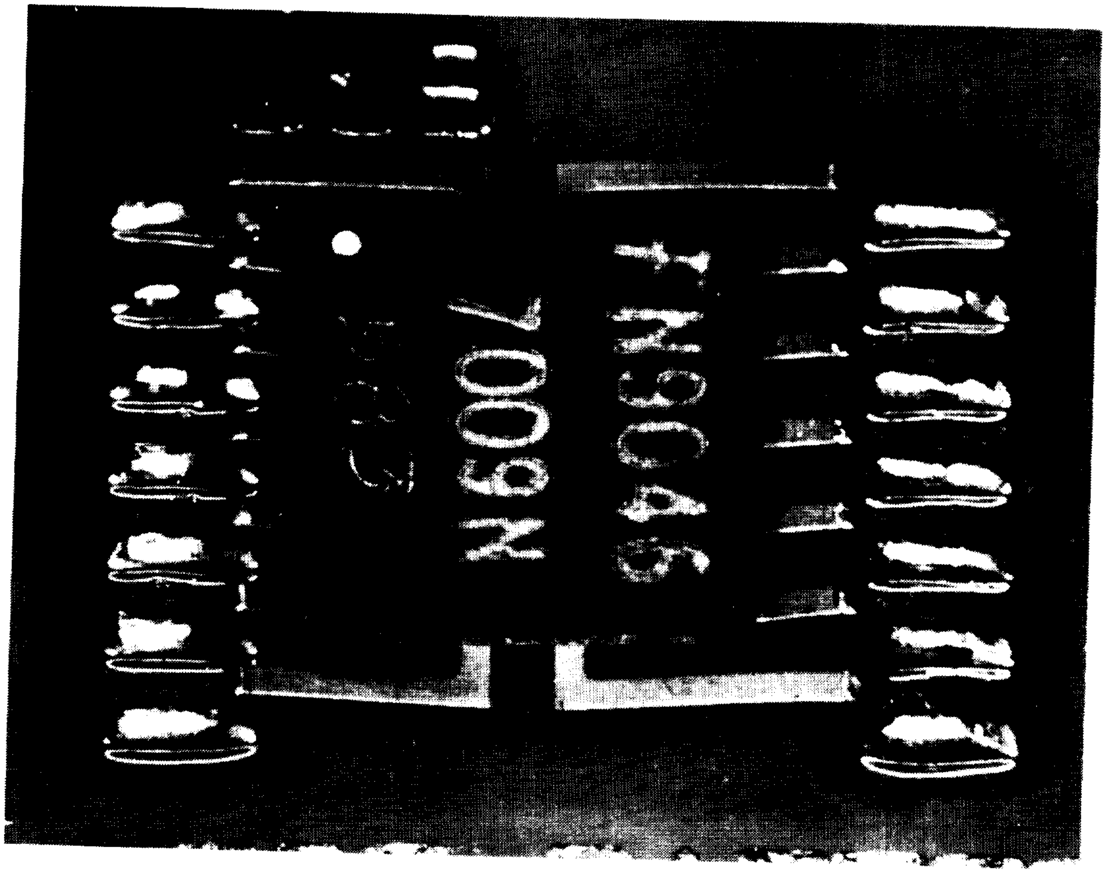


DEVICE TYPE:	28 Pin PLCC
DEVICE NUMBER:	U14 - Serial No. 105
PIN NUMBER:	19 thru 25
MAGNIFICATION:	10 X
ACTUAL DEFECT:	None
AIS DEFECT:	Misalignment for all pins on all four J-leaded devices on the PCB.
COMMENT:	None of the J-leaded devices were mis-aligned on the PCB according to visual inspection.

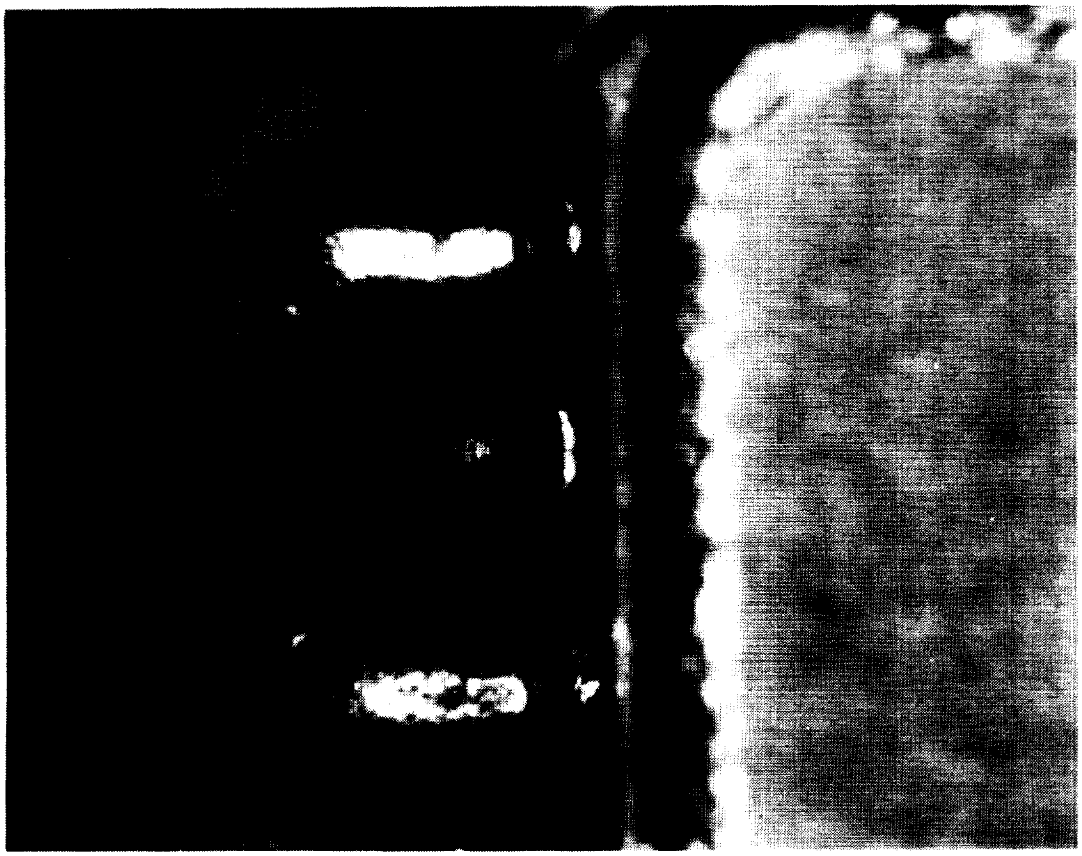
ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH



DEVICE TYPE:	208 Pin QFP
DEVICE NUMBER:	U5 - Serial No. 105
PIN NUMBER:	53 thru 84
MAGNIFICATION:	6.3 X
ACTUAL DEFECT:	Misalignment and bridging
AIS DEFECT:	Identified some of the misalignment and bridging.
COMMENT:	The AIS machine missed quite a few defects. As an example, pins 54 and 55 are bridged, but the machine only identified pin 55 as bridged. It failed to identify pins 53, 62, 65, and 69 as misaligned.

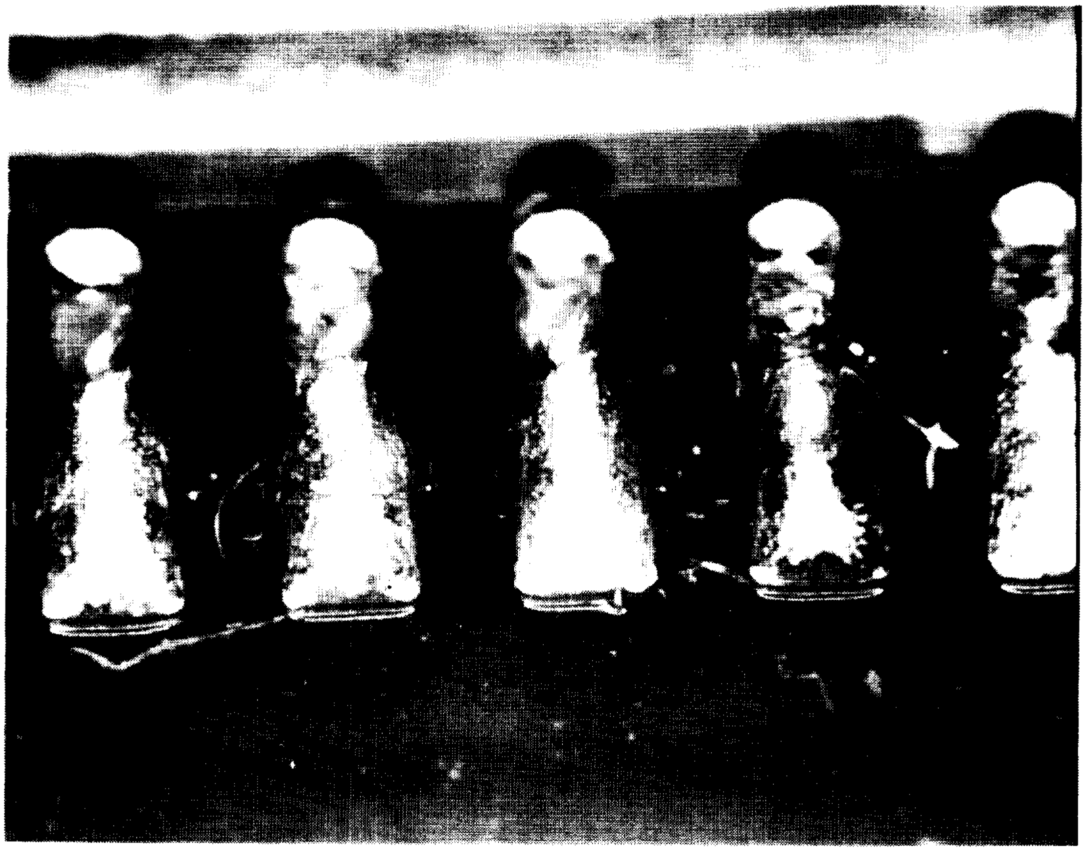


DEVICE TYPE:	14 Pin flat pack
DEVICE NUMBER:	U19 - Serial No. 105
PIN NUMBER:	All
MAGNIFICATION:	7.5X
ACTUAL DEFECT:	Excess solder on all the leads
AIS DEFECT:	Identified almost every lead as totally lifted
COMMENT:	None of the leads on the flat pack were lifted off the pad.



DEVICE TYPE:	40 Pin LCC
DEVICE NUMBER:	U10 - Serial No. 105
PIN NUMBER:	6,7,8
MAGNIFICATION:	23 X
ACTUAL DEFECT:	Excess solder on pin 7
AIS DEFECT:	Pin 6 and 8: excess cast, Pin 7: Pad coverage.
COMMENT:	The AIS system failed to identify pin 7 as excess cast but it identified pins 6 and 8 as excess cast.

DEVICE TYPE:	20 Pin DIP
DEVICE NUMBER:	U1 - Serial No. 105
PIN NUMBER:	6,7,8
MAGNIFICATION:	17 X
ACTUAL DEFECT:	None
AIS DEFECT:	Misaligned Y and Totally lifted for pins 6,7 and 8.
COMMENT:	The AIS machine incorrectly identified misalignment and lifted leads. The 3 pins in the photo did not have any defects.



DEVICE TYPE:	40 Pin LCC
DEVICE NUMBER:	U10 - Serial No. 105
PIN NUMBER:	40
MAGNIFICATION:	32 X
ACTUAL DEFECT:	Flux contamination
AIS DEFECT:	Insufficient pad and insufficient cast.
COMMENT:	The AIS machine failed to note any presence of flux on pin 40. On pin 37, the machine identified the defect as insufficient cast and also excess cast.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
March 1993

3. REPORT TYPE AND DATES COVERED
Technical Memorandum

4. TITLE AND SUBTITLE
Automated Inspection of Solder Joints for Surface Mount Technology

5. FUNDING NUMBERS
JON 310-039-09-01-25

6. AUTHOR(S)
Robert M. Savage, Hyun Soo Park, and Dr. Mark S. Fan

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS (ES)
Goddard Space Flight Center
Greenbelt, Maryland 20771

8. PEFORMING ORGANIZATION REPORT NUMBER
93B00035
Code 312

9. SPONSORING / MONITORING ADGENCY NAME(S) AND ADDRESS (ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING / MONITORING ADGENCY REPORT NUMBER
NASA TM-104580

11. SUPPLEMENTARY NOTES
R. Savage, Goddard Space Flight Center, Greenbelt, Maryland; H. Park and M. Fan, Paramax Systems, Inc. Lanham, Maryland.

12a. DISTRIBUTION / AVAILABILITY STATMENT
Unclassified - Unlimited
Subject Category 38

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
NASA/Goddard Space Flight Center (GSFC) evaluated various automated inspection systems (AIS) technologies using test boards with known defects in surface mount solder joints. These boards were complex and included almost every type of surface mount device typical of critical assemblies used for space flight applications.

- X-ray radiography
- X-ray laminography
- Ultrasonic Imaging
- Optical Imaging
- Laser Imaging
- Infrared Inspection

Vendors, representative of the different technologies, inspected the test boards with their machine. The results of the evaluation showed limitations of AIS. Furthermore, none of the AIS technologies evaluated proved to meet all of the inspection criteria for use in high-reliability applications. It was found that certain inspection systems could supplement but not replace manual inspection for low-volume, high-reliability surface mount solder joints.

14. SUBJECT TERMS
Automated Inspection, Surface Mount Technology, Quality Assurance, Inspection, Solder Joint

15. NUMBER OF PAGES
34

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL