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THE STATUS OF AND NEED FOR ROBOTIC APPLICATIONS IN THE AEROSPACE INDUSTRY

Walter F. Dimmick

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THE STATUS OF AND NEED FOR ROBOTIC APPLICATIONS IN THE AEROSPACE INDUSTRY

Submitted By

Walter F. Dimmick

A THESIS SUBMITTED TO THE GRADUATE FACULTY OF GEORGIA SOUTHERN COLLEGE IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE MASTER OF TECHNOLOGY

STATESBORO, GEORGIA

1989

THE STATUS OF AND NEED FOR

ROBOTIC APPLICATIONS IN THE

AEROSPACE INDUSTRY

BY

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CHAPTER I

INTRODUCTION

Industrial robots are highly advanced automation systems that utilize computers as a necessary part of their control. Robots are beginning now to revolutionize industry. By the end of the twentieth century, factory production techniques and management are predicted to undergo major changes including operations that will be monitored and controlled by computers and performed by industrial robots.

Research has shown that robots are particularly useful in a wide variety of applications in the aerospace industry, such as painting, drilling, trimming, inspection, material handling, and assembly. A successful robot application can reduce direct labor hours, consistently produce quality products, relieve people of hazardous and dangerous tasks, and perform repetitive jobs that are too tedious or too boring for human operators. Koren (6, p. 3) explains that,

> American industry hopes that robots will provide an answer to one of it's major problems: the decline in productivity. From 1947 to 1965, United States productivity increased by 3.4 percent a year. The growth rate decreased 2.3 percent in the next decade, then dropped to below 1 percent in the late 1970's, and in 1980, the rate became negative, namely, a decline in productivity. In the same period, Japanese productivity increased at an average annual rate of about 7.3 percent. With the new trend in industry of incorporation of more robots and other computerized automation in the production lines, the nation's productivity will eventually increase in the 1980's.

In view of the above, it was decided that a study was needed to survey the aerospace industry to find their motivating factors for installing industrial robots and their primary applications in the Aerospace industry. It is hoped that the results of this study will be used as an aid to improving the productivity growth rate.

PURPOSE OF THE STUDY

In view of the rising cost of labor and stringent safety and environmental regulations, robots have become valuable and often indispensable items of production equipment. It is important to examine their applications within the high-tech field of aerospace; a leader in the world of advanced manufacturing technology.

PROBLEM OF THE STUDY

The problem of this study was to determine primary areas of application for a robotic system installed in a typical aerospace manufacturing facility.

BASIC ASSUMPTIONS

The assumptions fundamental to this investigation were:

1. The study will be valuable to the aerospace and robotic industries.

2. The aerospace and robotic industries should be aware of the primary applications for robots.

3. The data needed for this study can be obtained by using a questionnaire as a survey instrument.

4. Aerospace and robotic industries would cooperate in answering the questionnaire.

LIMITATIONS AND CONTROLS

Limitations and controls were placed on this study as follows:

1. The validity and accuracy of information obtained from the questionnaire will be limited to the responses given by the participants.

2. The study is confined to major aerospace airframe manufacturers.

3. The study is confined to major robotic manufacturers and consulting firms with offices in the United States.

4. The study is confined to the years 1980 through 1988.

DEFINITION OF TERMS

The following terms are defined in alphabetical order.

Automation - automatically controlled operation of an apparatus, process, or system by mechanical or electronic devices that replace human observation, effort, and decision.

Batch Manufacturing - the production of parts or materials in discrete runs, or batches, interspersed with other production operations or runs of other parts or materials.

Cell - a manufacturing unit consisting of two or more workstations or machines, and the material transport mechanisms and storage buffers that interconnect them.

Computer-Aided-Design (CAD) - the use of an interactive-terminal workstation, usually with graphics capability, to automate the design of products. Computer-Aided-Design includes functions such as drafting and fit-up of parts.

End Effector - the subsystem of an industrial robot system that links the mechanical portion of the robot to the part being handled or worked-on, and gives the robot the ability to pick up and transfer parts and/or handle a multitude of different tools to perform work on parts.

Flexibility - pertaining to multipurpose robots that are adaptable and capable of being redirected, trained, or used for new purposes. Refers to the reprogrammability of multitask capability of robots.

Gantry Robot - an overhead-mounted, rectilinear robot with a minimum of three degrees of freedom and normally not exceeding six.

Productivity - the ratio of output to input; popularly defined as output per man-hour.

Robot - a reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks.

Robotics - the science of designing, building, and applying robots.

Robot Systems - a robot system includes the robot, end effector; any equipment, devices, and sensors required for the robot to perform its task; and any communications interface that is operating and monitoring the robot, equipment, and sensors.

SUMMARY

Robots are revolutionizing the United States industry by performing a variety of production tasks including: assembly, machining, painting, material handling, welding and inspection. A successful robotic system can reduce direct labor, maintain consistent quality, increase productivity and relieve workers of hazardous labor. To determine the status of and need for robots in the Aerospace industry, a survey was conducted.

CHAPTER II

REVIEW OF RELATED LITERATURE

INTRODUCTION

The studies referred to in this chapter are those considered most pertinent to this study on robotic applications in the aerospace industry. Aerospace manufacturing has entered into a period of change that has not been seen since the days of World War II. The need for improved productivity is required to meet global competitive challenges. There is a continual drive to reduce costs using automation. Typical examples of robotic systems utilized in aerospace manufacturing will be reviewed.

STUDIES

Michaelson's (9, p. 232) studies at Boeing show that improved productivity has become a common goal for all functions of manufacturing. The ability, however, to measure productivity gains is not always obvious. Perhaps the most frequent measure of productivity has been the direct labor content of an operation. Improvements in productivity have been aimed at reducing this labor content. Analysis now confirms that the direct labor content is not always the significant cost factor that it once was (Figure 1).

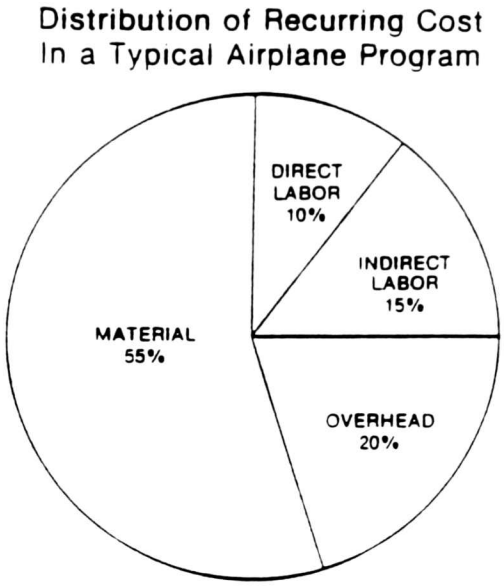

FIGURE 1. Typical recurring cost distribution.
from Michaelson (9, p. 233)

Successful projects involving automation and robotic applications have been completed or are in various stages of development and implementation at the Boeing Commercial Airline Company. One such task has been to devise methods to automate the assembly of aircraft structure. For this project, Boeing is using a robot system to drill the strut/skin assembly of the 737-300 engine strut. The operation is labor intensive and requires the drilling of 1100 holes through both aluminum and aluminum/steel combinations. The hole diameter tolerance is .0015 inch. A Gantry robot has been equipped with special multiple end effectors which will drill, countersink, inspect for hole dimensions, and install fasteners as required. A significant reduction in cycle time is forecast for the system. Boeing utilizes robots where their features are appropriate to the task.

They point out that robots do not fit all applications. They should be considered as part of an integrated system rather than looked upon as stand-alone devices. Robotic technology must be matched to the needs of the application and not the reverse.

The current manufacturing process for F-16 canopy assemblies and side-panel subassemblies has been found to be a very labor-intensive task, requiring large amounts of manual labor to drill through aluminum and steel detail parts according to Wilkerson (13, p. 1). The General Dynamics program objective was to implement a robotic system that would automate the current labor-intensive task. Initial design investigations into F-16 canopy fixture and aircraft part geometry revealed that a tool design analysis was required to permit robotic end effector access. When the design analysis was completed, a new prototype robotic drill fixture was fabricated. This prototype fixture development provided the pathway to begin tool manufacturing tasks required to integrate six subassembly robotic drill fixtures into a four-sided parts presentation system. From this basic tool design analysis, it was determined that a robot working from station-to-station offered the most cost-effective potential. This concept greatly reduced requirements for complex and expensive part-presentation. In a typical aerospace manufacturing operation, part engineering changes are common.

The lot or "batch" manufacturing approach offers the distinct advantages of introducing new engineering requirements into an ongoing production line. Before a robotic system selection is made, several factors should be reviewed, such as:

1. Part or assembly selection
2. Robot utilization (idle time vs uptime)
3. Facilities and tooling requirements
4. Technical confidence in equipment
5. Floor space requirements
6. Factory and support department inputs

A system that provides the flexibility to continue working whenever a part is available offers production a new dimension in robotics.

Reimann (10, p. 44) reports that a typical breakdown for airframe manufacturing shows roughly half the cost to be associated with assembly. In 1985, an Air Force group conducted an in-depth survey of airframe assembly. It concluded:

1. Airframe assembly represents a major opportunity to cut costs through automation and to improve quality, span time, and traceability.

2. The industry has scored some success with automation but must make a dedicated long-term commitment to reach fully integrated operation.

3. Assembly problems are not peculiar to metal structures. This is a critical point because over the next decade there will be an increasing move toward composite and hybrid structures.

4. Any automated system must be capable of responding to change. This calls for flexible automation with maximum intelligence at the lowest possible level.

The Defense Advanced Research Projects Agency and the Air Force fund two teams to develop technologies for automating manufacturing tasks. Headed by Martin Marietta, the first of these teams is developing generic technologies that will be demonstrated by using two robots to inspect the bulkheads of an F-15 aircraft. Making some 1,100 measurements now takes 25 hours. The goal with robotic implementation is 2.5 hours. Headed by Honeywell, the second team is developing generic technologies that will be demonstrated by assembling a microswitch from 17 parts randomly positioned on a tray. Assembly accounts for almost half of airframe manufacturing cost (Figure 2). Automating assembly operations would not only save on costs, but also on time, and would improve quality and traceability.

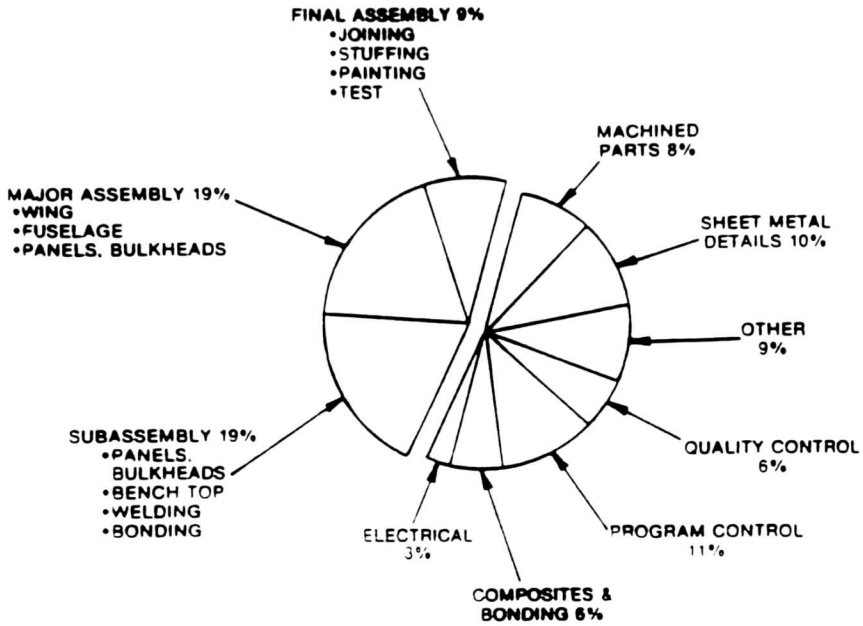

FIGURE 2. Airframe manufacturing task breakdown. from Reimann (10, p. 48)

Sikorsky Aircraft, a major helicopter manufacturer, performs a wide variety of manufacturing operations in the fabrication of aircraft. Machining, drilling, riveting, routing, deburring and detail assembly are only some of the operations performed repeatedly by their manufacturing personnel, according to Barto (1, p. 793). It became apparent after reviewing the manufacturing operations at Sikorsky, that several routine manual operations such as small hole drilling, riveting and deburring should be the major thrust for automation. The manual operations are time consuming and very labor intensive. Further research revealed that the problems were not unique to Helicopter Manufacturing but common to all Aerospace Industries.

Development of robotic systems for drilling has been addressed over the years by various airframe manufacturers such as General Dynamics, McDonnell Douglas and Lockhead-Georgia.

Humphreys, Leifield, and Ross' (5, MS87-494) study of robotic Metal Routing at McDonnell Aircraft points out that a robotic routing cell was installed in the sheet metal fabrication facility in the fall of 1986 to provide quality and productivity improvements over the conventional manual operations. Contoured aluminum panels for three aircraft programs are being trimmed by the robotic cell. The cell uses a gantry type robot and conventional trim fixtures to perform template guided routing. Cost reductions are realized through labor reductions achieved by simultaneous set-up and routing operations. Union hand router operators have been retrained and now are responsible for complete operation of the cell, including both programming and production modes.

Since the beginning of the 1980's, Avions Marcel Dassault-Breguet Aviation has been using industrial robots for production purposes, mainly in machining, assembly and quality control, according to Esmenjaud (3, MS87-492). He indicates that the selection of tasks to be robotized is based on both technical and economic criteria. Technical: The robot must meet or exceed the requirements of the job it has been designed to perform with respect to size, accessibility, tool-carrying capability, accuracy and repeatability.

Economics: The robot's ability to increase productivity must be sufficient to replace hand labor. The tasks that are well suited for robots are those that are time consuming, repetitive, and labor-intensive. Those tasks that are located in clear areas and often calling for different tools to be used several times in the same place, requiring high quality work and total compliance with process planning are also candidates for robotic applications.

A gantry robot is being tested at McDonnell Douglas, St. Louis, Missouri, to help engineers develop aircraft tooling with greater accuracy and quality in a fraction of the time needed now. In a recent test, the robot completed a task in 15 minutes that would require a day manually, according to Robotics Today (4, p. 10). The robot is being tested in a process called "master model scribing," in which the outlines of parts like doors, windows, and others, are engraved, or scribed, into a full-size model of an airframe surface called a master model. From these outlines, tools are made that will produce the parts. The system will allow engineers to plot points using computer-aided-design (CAD) equipment. Engineers draw the outlines on the computer, and the coordinates are sent to a minicomputer connected to the robot. Using a high-speed record needle, the robot then scribes the outline into the master model. Accuracy is the key in scribing into a model and the robot has matched or exceeded the accuracy achieved by hand.

In addition, robotic scribing accommodates engineering changes quickly and allows several versions of the same part to be made from one tool.

SUMMARY

The literature reviewed indicates that a diverse cross-section of the aerospace industry is utilizing robots to increase productivity, improve quality, and perform tasks better suited for machines, not human operators. It is becoming increasingly important for industry to reduce costs in order to stay competitive. Automation is a key to cost reduction in the aerospace industry.

CHAPTER III

INVESTIGATION OF THE STUDY

INTRODUCTION

The purpose of this study was to survey both the users and manufacturers of robots to find out the primary applications for robotics in the aerospace industry. A questionnaire was the main data gathering instrument in the study. Questionnaires were sent to major Aerospace Airframe Manufacturers and major U.S. Robotic Manufacturers and Consulting Firms.

SUBJECT

The companies to be surveyed were Aerospace Firms and Robotic Manufacturers, along with Robotic Consulting Firms. The knowledge gained from the respondents aided in identifying the primary applications for robotics in the aerospace industry.

MATERIAL

The questionnaire was used to gather needed information. The majority of questions used in this survey were the "closed" type requiring simple item checks which was adequate to meet the objectives of the study. In addition, this also allowed for ease of tabulation and analysis.

VALIDATION OF SURVEY

The questionnaire was submitted to the Master of Technology Graduate Faculty Consultant Panel Members of Georgia Southern College to verify the validity of the questionnaire as a data gathering instrument. The faculty panel members were utilized based on the assumption of expertise from their experience and educational background. Changes in the original questionnaire were made based on faculty member recommendations. Final approval for the questionnaire was given by the consultant panel prior to submission to the companies involved in the study.

ADMINISTRATION OF THE QUESTIONNAIRE

The questionnaire was sent by first-class mail, along with a cover letter to explain the purpose and scope of the questionnaire. A memo from the Graduate Faculty Advisor was included to certify the researcher as a participant in an authorized research project. The questionnaire, cover letter, and memo are presented in Appendix A, Page 39.

DATA COLLECTION AND ANALYSIS

The questionnaire was designed to collect the following information:

1. The type of Aerospace Industry utilizing robots.
2. The size of the Aerospace Industry utilizing robots.
3. The reasons for these companies to use robots.

4. The task considerations for using robots.
5. Basic opinions concerning robotic applications.
6. Job description of personnel working with robotics.
7. Future expectations for robot utilization.

The numerical data collected from the respondents will be arranged in the form of tables which will be presented in Chapter IV. The results will also be calculated into percentages for presentation.

The information will be divided into areas according to the subject content of questions asked on the questionnaire.

The findings, conclusions and recommendations from the data gathered and interpreted will be presented in Chapter V.

SUMMARY

The questionnaire was used to gather data from Aerospace and Robotic Industries in the U.S. The questionnaire was mailed with a cover letter, memo from the Thesis Advisor and a stamped, self-addressed return envelope. A follow-up letter was also sent with an additional copy of the questionnaire. Data received was reviewed and tabulated to compile information for the study.

CHAPTER IV

ANALYSIS OF DATA

INTRODUCTION

The data used in this study was obtained by questionnaire. One hundred fifty two were mailed to major Aerospace Manufacturing Firms and selected Robot Manufacturers and Consulting Firms. The Aerospace Companies were selected from the World Aviation Directory, (14, pp. 253-336) and the Robot/Consulting Firms were selected from the Product and Services Directory in Robotics Today, (7, pp. 25-50). From the first mailing, sixty two questionnaires were returned resulting in a forty one percent (41%) rate of return. A follow up letter and questionnaire were then sent to the companies that initially did not respond. Thirty eight additional questionnaires were returned resulting in a sixty six percent (66%) overall rate of return.

ANALYSIS OF THE DATA

The information gathered from the questionnaires was compiled. First, the questionnaires were divided into two categories: Aerospace related industries and Robot related industries. Second, the answers were tabulated and analyzed.

RESULTS OF THE ANALYSIS

The results of the questionnaire are shown in Tables 1 through 8. The number of responses, that is "checked" items, is listed in the first column and the percentage of total responses is listed in the second column. Where applicable, a third and fourth columns were added in order to compare the number of responses on an item with the total responses from the Aerospace and Robot related industries. Other tables were constructed as needed to accommodate respondent information and its presentation. Not every respondent answered every question, and several questions allowed a respondent to select more than one answer. Percentages are rounded to equal 100 in all tables.

Question number one asks the respondents what type of industry does he/she work for. This question was asked to make a clear distinction between the Aerospace related industries and the Robot related industries.

TABLE 1

TYPE OF INDUSTRIES SURVEYED

AEROSPACE INDUSTRY	NO.	%	TOTAL NO.	TOTAL %
COMMERCIAL AIRFRAME MANUFACTURER	5	25	5	5
MILITARY AIRFRAME MANUFACTURER	8	40	8	8
AEROSPACE SYSTEMS	2	10	2	2
OTHER	5	25	5	5
SUB-TOTAL	20	100	20	20
ROBOT INDUSTRY	**NO.**	**%**		
ROBOT MANUFACTURER	44	58	44	46
CONSULTING FIRM	13	17	13	14
SYSTEMS	5	7	5	5
AUTOMATION EQUIPMENT SUPPLIER	3	4	3	3
SOFTWARE DEVELOPMENT	2	2	2	2
OTHER	9	12	9	10
SUB-TOTAL	76	100	76	80
TOTAL			96	100

Twenty percent (20%) of the respondents work for Aerospace industries while eighty percent (80%) work for Robot related industries. Appendix B gives a complete list of industry types.

Question two asks the respondent for his/her job function.

TABLE 2

RESPONDENTS JOB FUNCTION

JOB FUNCTION	NO.	%
COMPANY MANAGEMENT	44	47
MANUFACTURING ENGINEERING	8	8
MECHANICAL ENGINEERING	1	1
PRODUCTION ENGINEERING	-	-
PRODUCT DESIGN, R & D	6	6
PURCHASING	-	-
MARKETING/SALES	26	28
OTHER	9	10
TOTAL	94	100

From a total of ninety four answers to question number two, the majority of the respondents (47%) are a part of company management, followed by marketing/sales personnel (28%). Appendix C gives a complete list of job functions.

Question three asks for company size as related to the number of employees.

TABLE 3

NUMBER OF EMPLOYEES AT RESPONDENTS WORK PLACE

AEROSPACE INDUSTRY COMPANY SIZE			TOTAL	
	NO.	%	NO.	%
1 - 9	0	0	0	0
10 - 19	0	0	0	0
20 - 49	0	0	0	0
50 - 99	1	5	1	1
100 - 249	1	5	1	1
250 - 499	1	5	1	1
500 - 999	1	5	1	1
1000 - 2499	2	9	2	2
2500 +	15	71	15	16
SUB-TOTAL	21	100	21	22
ROBOT INDUSTRY COMPANY SIZE	NO.	%		
1 - 9	11	15	11	12
10 - 19	12	17	12	13
20 - 49	14	19	14	15
50 - 99	10	14	10	11
100 - 249	2	3	2	2
250 - 499	3	4	3	3
500 - 999	4	6	4	5
1000 - 2499	1	1	1	1
2500 +	15	21	15	16
SUB-TOTAL	72	100	72	78
TOTAL			93	100

From a total of twenty one Aerospace industry responses to question three, fifteen companies (71%) have more than 2500 employees and from a total of seventy two Robot industry responses, fifteen companies (21%) have more than 2500 employees.

Question four asks if robots are used at the respondents work place.

TABLE 4

COMPANIES USING ROBOTS AT RESPONDENTS WORK PLACE

AEROSPACE COMPANY USING ROBOTS			TOTAL	
	NO.	%	NO.	%
YES	15	75	15	16
NO	5	25	5	5
SUB-TOTAL	20	100	20	21
ROBOT COMPANY USING ROBOTS	NO.	%		
YES	33	45	33	36
NO	40	55	40	43
SUB-TOTAL	73	100	73	79
TOTAL			93	100

From a total of twenty Aerospace industry responses to question number four, fifteen companies (75%) are using robots and from a total of seventy three Robot industry responses, thirty three companies (45%) are using robots.

Question five is a follow-up to question four. If the respondent answered no to question four, then does his/her company plan to use robots in the next five years?

TABLE 5

COMPANIES FUTURE PLANS FOR USING ROBOTS

AEROSPACE COMPANY PLANNING TO USE ROBOTS IN NEXT FIVE YEARS	NO.	%	TOTAL NO.	TOTAL %
YES	2	40	2	4
NO	1	20	1	2
UNSURE	2	40	2	4
SUB-TOTAL	5	100	5	10
ROBOT COMPANY PLANNING TO USE ROBOTS IN NEXT FIVE YEARS	**NO.**	**%**		
YES	7	18	7	16
NO	22	25	22	49
UNSURE	11	27	11	25
SUB-TOTAL	40	100	40	90
TOTAL			45	100

From a total of five Aerospace industry responses to question number five, two companies (40%) that are currently not using robots plan to use them in the next five years and from a total of forty Robot industry responses, seven companies (18%) that are currently not using robots plan to use them in the next five years.

Question six asks the respondent to indicate his/her reasons for using robots. Also, they were asked to indicate the primary reason for using robots.

TABLE 6-A

REASONS FOR USING ROBOTS

AEROSPACE INDUSTRY REASONS			TOTAL	
	NO.	%	NO.	%
INCREASE PRODUCTIVITY	13	25	13	7
CONSISTENT QUALITY	16	31	16	9
HAZARDOUS ENVIRONMENT	5	10	5	3
HEAVY, STRENUOUS WORK	1	2	1	<1
TEDIOUS, REPETITIVE WORK	9	18	9	5
MILITARY CONTRACTS ENCOURAGE HIGH TECH	6	12	6	3
OTHER	1	2	1	<1
SUB-TOTAL	51	100	51	29
ROBOT INDUSTRY REASONS	NO.	%		
INCREASE PRODUCTIVITY	30	23	30	17
CONSISTENT QUALITY	28	22	28	16
HAZARDOUS ENVIRONMENT	12	9	12	6
HEAVY, STRENUOUS WORK	11	8	11	6
TEDIOUS, REPETITIVE WORK	24	19	24	13
MILITARY CONTRACTS ENCOURAGE HIGH TECH	5	4	5	3
OTHER	19	15	19	10
SUB-TOTAL	129	100	129	71
TOTAL			180	100

From a total of fifty one Aerospace industry responses to question number six, twenty nine (56%) indicate that increasing productivity and maintaining consistent quality are important reasons to use robots and from a total of one hundred twenty nine Robot industry responses, fifty eight (45%) indicate that increasing productivity and maintaining consistent quality are also important reasons to use robots. Appendix D gives a complete list of reasons for using robots.

Table 6-B shows the respondents' primary reasons for using robots.

TABLE 6-B

PRIMARY REASON FOR USING ROBOTS

AEROSPACE INDUSTRY PRIMARY REASONS			TOTAL	
	NO.	%	NO.	%
CONSISTENT QUALITY	7	58	7	28
INCREASE PRODUCTIVITY	5	42	5	20
SUB-TOTAL	12	100	12	48
ROBOT INDUSTRY PRIMARY REASONS	NO.	%		
CONSISTENT QUALITY	8	62	8	32
INCREASE PRODUCTIVITY	3	23	3	12
REDUCE COST OF OPERATION	2	15	2	8
SUB-TOTAL	13	100	13	52
TOTAL			25	100

From a total of twelve Aerospace industry responses to part two of question six, seven (58%) indicate consistant quality as the primary reason for using robots and from a total of thirteen Robot industry responses, eight (62%) also indicate that consistant quality is the primary reason for using robots.

Question seven lists a variety of production tasks and asks the respondent to indicate his/her consideration for using a robot to perform the given task.

TABLE 7

PRODUCTION TASKS CONSIDERED APPLICABLE TO ROBOTS

STATEMENT	INDUSTRY	NO.	% WOULD USE	% WOULD NOT USE	% CURRENTLY USING ROBOT
A. SUB-ASSEMBLY (PANELS, WELDING, BENCH TOP)	AEROSPACE	19	47	11	42
	ROBOT	44	68	11	21
B. MAJOR-ASSEMBLY (WINGS, FUSE-LAGE)	AEROSPACE	14	28	36	36
	ROBOT	33	56	36	8
C. FINAL ASSEMBLY (JOINING, STUFFING, PAINTING)	AEROSPACE	18	56	28	16
	ROBOT	36	61	14	25
D. MACHINED PARTS	AEROSPACE	19	47	6	47
	ROBOT	35	69	14	17
E. SHEET METAL DETAIL PARTS	AEROSPACE	16	50	12	38
	ROBOT	33	51	39	10
F. QUALITY CONTROL/ INSPECTION	AEROSPACE	19	37	10	53
	ROBOT	36	67	19	14
G. COMPOSITES/ BONDING	AEROSPACE	16	37	13	50
	ROBOT	32	72	19	9
H. ELECTRICAL	AEROSPACE	15	60	27	13
	ROBOT	38	63	26	11
TOTAL		423			

From a total of one hundred thirty six answers from the Aerospace Industry respondents to question number seven, the majority of tasks currently performed with the assistance of a robot are: quality control and inspection, composites/bonding and machining.

From a total of two hundred eighty seven answers from the Robot industry respondents, the majority of tasks that would be considered applicable to robots are: composites/bonding, machining and sub-assembly.

Appendix E lists other tasks that were given consideration for robotic use.

Question eight asks the respondent for his/her opinion on robotic related statements.

TABLE 8

RESPONDENT'S OPINIONS REGARDING ROBOTS

STATEMENT	INDUSTRY	NO.	% AGREE	% DISAGREE	% NO OPINION
A. IDENTIFYING AND DEVELOPING A POSSIBLE ROBOTIC APPLICATION IS THE FIRST STEP IN ROBOTIC ANALYSIS	AEROSPACE	20	70	25	5
	ROBOT	70	73	21	6
B. ESTABLISHING A STAFF DEVOTED TO ROBOTICS IS USUALLY NECESSARY FOR SUCCESSFUL ROBOTIC IMPLEMENTATION	AEROSPACE	20	60	25	15
	ROBOT	71	55	35	10
C. TRAINING MAINTENANCE PERSONNEL IS NOT REQUIRED UNTIL AFTER INSTALLATION IS COMPLETE	AEROSPACE	20	5	85	10
	ROBOT	70	4	92	4
D. WHENEVER POSSIBLE, ROBOTIC SYSTEMS SHOULD BE SINGLE PURPOSE, NOT FLEXIBLE	AEROSPACE	19	16	63	21
	ROBOT	69	7	84	9
E. IT IS NECESSARY TO BUILD UP A BACKLOG OR PRODUCTION SURPLUS BEFORE SWITCHING TO A ROBOTIC WORK CENTER	AEROSPACE	19	10	74	16
	ROBOT	72	16	63	16
F. ADVANCED MANUFACTURING TECHNOLOGY, SUCH AS ROBOTICS, IS NECESSARY FOR IMPROVING ONES CHANCE OF WINNING MILITARY CONTRACTS	AEROSPACE	20	60	15	25
	ROBOT	72	40	20	40
TOTAL		542			

The opinions expressed by both the Aerospace industries and Robotic related industries vary less than eight percent (8%) on the average. The largest discrepancy is for statement F, "Advanced Manufacturing Technology, such as robotics, is necessary for improving ones chance of winning military contracts." Sixty percent (60%) of the Aerospace respondents agree while only forty percent (40%) of the Robotic industry respondents agree.

OBSERVATIONS

Both the Aerospace industries and Robotic related industries agree that robots are put on the job to increase productivity and maintain consistent quality. Primary application areas include machining, assembly and composite/bonding. The majority of Aerospace companies utilizing robots have long-term military contracts that encourage the use of high technology.

SUMMARY

This investigation was designed to identify the primary areas of application for a robotic system installed in a typical Aerospace Manufacturing Facility. Areas for robotic application were also identified, presented and discussed in this chapter.

CHAPTER V

FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

INTRODUCTION

The purpose of this study was to examine robotic systems in the Aerospace industry and determine the primary areas of application. A questionnaire was the chief data gathering instrument for the study.

FINDINGS IN THE AEROSPACE INDUSTRY

Based on the data presented in Chapter IV and additional information gathered from the returned questionnaires, the major findings of this investigation were as follows:

1. Ninety percent (90%) of the Military Airframe Manufacturers responding use robots.

2. Eighty percent (80%) of the Commercial Airframe Manufacturers responding use robots.

3. None of the General Airframe Manufacturers responding use robots.

4. One hundred percent (100%) of the Military and Commercial Airframe Manufacturers using robots are large companies (2500+ employees).

5. The most commonly given reasons for using robots were to maintain consistent quality, followed by increase productivity, tedious/repetitive work, military contracts encourage high-tech and finally hazardous environment.

6. The most commonly given task that would not be considered for robotic application is major assembly (wings, fuselage).

7. The most commonly given task that would be considered for robotic application is electrical fabrication.

8. The statement relating to robotics that is most often agreed with is, "Identifying and developing a possible robotic application is the first step in robotic analysis," followed by, "Establishing a staff devoted to robotics is usually necessary for successful robotic implementation" and "Advanced Manufacturing Technology, such as robotics, is necessary for improving ones chance of winning military contracts."

9. The statement relating to robotics that is most often disagreed with is, "training maintenance personnel is not required until after installation is complete," followed by, "it is necessary to build up a backlog or production surplus before switching to a robotic work center" and "whenever possible, robotic systems should be single purpose, not flexible."

FINDINGS IN THE ROBOT INDUSTRY

Based on the data presented in Chapter IV and additional information gathered from the returned questionnaires, the major findings of this investigation were as follows:

1. The majority of the respondents in the robot industry were robot manufacturers (44), followed by automation consultants (13), system integrators (5) and automation equipment suppliers (3).

2. Fifty five percent (55%) of the respondents do not use robots at their plant site.

3. On the other hand, forty five percent (45%) of the respondents use robots at their plant site.

4. Fifty five percent (55%) of the respondents do not plan to use robots in the next five years.

5. Twenty seven percent (27%) of the respondents are unsure if they will use robots in the next five years.

6. Eighteen percent (18%) of the respondents plan to use robots in the next five years.

7. The most commonly given reasons for using robots were to increase productivity, followed by maintaining consistant quality and tedious/repetitive work.

8. The most commonly given task that would <u>not</u> be considered for robotic application is sheet metal detail parts.

9. The most commonly given task that would be considered for robotic application is composites/bonding.

10. The statement relating to robotics that is most often agreed with is, "Identifying and developing a possible robotic application is the first step in robotic analysis," followed by, "establishing a staff devoted to robotics is usually necessary for successful robotic implementation."

11. The statement relating to robotics that is most often disagreed with is, "training maintenance personnel is not required until after installation is complete," followed by, "whenever possible, robotic systems should be single purpose, not flexible" and "it is necessary to build up a backlog or production surplus before switching to a robotic work center."

CONCLUSIONS

The purpose of the study was accomplished. The primary areas for robotic application in the Aerospace industry were identified and examined. Both the Aerospace industries and Robotic related industries agree that maintaining consistent quality and improving productivity are the primary reasons for putting robots to work in the Aerospace industry.

RECOMMENDATIONS

Based on data analysis and respondent's comments, the following recommendations are made:

1. Aerospace companies need to maintain consistent quality and increase productivity to compete in today's and tomorrow's market.

2. Military contracts should continue to encourage the use of high technology.

3. Aerospace and robotic companies should work together to identify and develop robotic applications.

4. Aerospace companies should maintain a staff devoted to state of the art technology such as robotics.

5. Maintenance personnel and programming personnel should be utilized as early as possible in a robotic implementation program.

6. Flexible automation is a major tool for improving manufacturing.

7. Assembly accounts for nearly fifty percent (50%) of the airframe manufacturing cost. Sub-assembly and composites/bonding are tasks considered to a high degree applicable to robots.

8. The design process must be integrated with manufacturing for successful robotic implementation.

SUMMARY

Aerospace and Robotic related industries agree with the majority of reasons for putting robots to work. Consistent quality and improving productivity are the primary reasons for using robots. Sub-assembly and composites/bonding tasks in the Aerospace industry are clearly candidates for robotic application.

A P P E N D I X A

QUESTIONNAIRE

COVER LETTER

MEMO FROM ADVISOR

QUESTIONNAIRE

1) Please check the predominant type of industry you are currently working for at your plant site:

- [ ] Commercial Airframe Manufacturer
- [ ] Military Airframe Manufacturer
- [ ] General Airframe Manufacturer
- [ ] Robot Manufacturer
- [ ] Consulting Firm
- [ ] Other (Please specify)_____

2) Your chief function is: (just one, please)

- [ ] Company Management
- [ ] Manufacturing Engineering
- [ ] Mechanical Engineering
- [ ] Production Engineering
- [ ] Product Design, R & D
- [ ] Purchasing
- [ ] Marketing/Sales
- [ ] Other (specify)

3) How many employees at your location? (Circle one group)

1-9 10-19 20-49 50-99 100-249 250-499

500-999 1000-2499 2500 +

4) Do you use robots at your plant site?

- [ ] Yes
- [ ] No

5) If no, do you plan to use them in the next 5 years?

☐ Yes ☐ No ☐ Unsure

6) Reason(s) for using robots at this location (Check all that apply). Also, please circle your <u>one</u> primary reason for using robots.

☐ Increase Productivity

☐ Consistent Quality

☐ Hazardous Environment

☐ Heavy, Strenuous Work

☐ Tedious, Repetitive Work

☐ Military Contracts Encourage High Tech

☐ Other (specify) _____

7) From the following list of production tasks, please indicate your consideration for using robots: (Circle the appropriate number)

	1 - Would Consider	2 - Would Not Consider	3 - Currently Using Robot(s)
A. Sub-Assembly (Panels, Welding, Bench Top)	1	2	3
B. Major-Assembly (Wings, Fuselage)	1	2	3
C. Final Assembly (Joining, Stuffing, Painting, Test)	1	2	3
D. Machined Parts	1	2	3
E. Sheet Metal Detail Parts	1	2	3
F. Quality Control/Inspection	1	2	3
G. Composites/Bonding	1	2	3

H.	Electrical	1	2	3
I.	Other (specify) _____	1	2	3
J.	Other (specify) _____	1	2	3
K.	Other (specify) _____	1	2	3

8) Please circle the appropriate number for the following statements:

		Agree	No Opinion	Disagree
A.	Identifying and developing a possible robotic application is the first step in robotic analysis.	1	2	3
B.	Establishing a staff devoted to robotics is usually necessary for successful robotic implementation.	1	2	3
C.	Training Maintenance Personnel is not required until after installation is complete.	1	2	3
D.	Whenever possible, robotic systems should be single purpose not flexible.	1	2	3
E.	It is necessary to build up a backlog or production surplus before switching to a robotic work center.	1	2	3
F.	Advanced Manufacturing Technology, such as robotics, is necessary for improving ones chance of winning military contracts.	1	2	3

9) Would you like a copy of the results when this survey is completed?

_____ Yes _____ No

Completed By _____

Title _____

Company _____

Address _____

_____

Thank you for your time and cooperation.

Please use the enclosed self-addressed, stamped envelope.

Dear Company President,

I am presently working on a thesis research topic for my Master of Technology Degree at Georgia Southern College. The topic chosen after considerable investigative work is "The Status Of and Need For Robotic Applications in the Aerospace Industry". Your company has been selected as one particularly appropriate to provide meaningful and relevant information for the study.

Would you direct the attached questionnaire to the appropriate person in your organization for completion and return it to me in the enclosed stamped, self-addressed envelope. The information you provide will be held in strictest confidence and your company's name will not be revealed. If you would like a copy of the results, please refer to Item #9 on the attached questionnaire.

May I thank you in advance for your cooperation and help in contributing information that only you can provide if my research topic is to be successfully concluded with meaningful results.

Respectfully,

Walter F. Dimmick

Walter F. Dimmick

WFD:wgb

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SCHOOL OF TECHNOLOGY
Engineering Technology Departmer
Industrial Technology Department
Military Science Department
Engineering Studies

MEMO

TO: Users and Manufacturers of Robots for the Aerospace Industry

FROM: Dr. Earl Andrews, Graduate School Coordinator E.R.a.

Mr. Walter Dimmick will be asking for information about your status of and need for robotics. A successful investigation of a research topic constitutes the major requirement in the Master of Technology Degree at Georgia Southern College. Your cooperation will be important in making his study as thorough and complete as possible. Please feel free to contact me if you have any questions. Thank you for your help. We appreciate your assistance.

NOTE: THIS IS A FOLLOW-UP REQUEST TO ANSWER THE ATTACHED QUESTIONNAIRE. THE INITIAL REQUEST WAS MAILED TO YOU MAY, 1988. THANK-YOU FOR YOUR COOPERATION.

A P P E N D I X B

COMPLETE LIST OF INDUSTRY TYPES SURVEYED

TABLE 9 LIST THE INDUSTRY TYPES RESPONDING TO THE QUESTIONNAIRE.

TABLE 9

COMPLETE LIST OF INDUSTRY TYPES SURVEYED

INDUSTRY	NO.
Commercial Airframe Manufacturer	5
Military Airframe Manufacturer	8
General Airframe Manufacturer	1
Robot Manufacturer	44
Consulting Firm	13
Aircraft Engine Manufacturer	1
Aerospace Systems	2
Tilt Rotor Development	1
Rocket Engine Manufacturer	1
Completion and Aircraft Maintenance Center	1
Government Lab	1
Electro-Optical Subsystems	1
Electronic Systems	1
Welding Research & Development	1
Automation Equipment Supplier	3
System Integrator	5
Software Development	2
Robot Distributor	1
Custom Machinery	1
Machine Tool Importer	1
Research & Development	1
Automatic Welding Equipment	1
TOTAL	96

A P P E N D I X C

COMPLETE LIST OF JOB FUNCTIONS

TABLE 10 LIST THE JOB FUNCTION OF THOSE RESPONDING TO THE QUESTIONNAIRE

TABLE 10

COMPLETE LIST OF RESPONDENTS JOB FUNCTIONS

JOB FUNCTION	NO.
MANAGEMENT	44
MANUFACTURING ENGINEER	8
MECHANICAL ENGINEER	1
DESIGN, R & D	6
MARKETING/SALES	26
MANUFACTURING RESEARCH & TECHNOLOGY	4
INDUSTRIAL MODERNIZATION	1
RESEARCH AND DEVELOPMENT	1
PROJECT MANAGER	1
APPLICATIONS ENGINEER	1
ENGINEERING MANAGER	1
TOTAL	94

A P P E N D I X D

COMPLETE LIST OF REASONS FOR USING ROBOTS

TABLE 11 GIVES A COMPLETE LIST OF REASONS FOR USING ROBOTS AS INDICATED BY THE RESPONDENTS.

TABLE 11

COMPLETE LIST OF REASONS FOR USING ROBOTS

REASON	NO.
INCREASE PRODUCTIVITY	43
CONSISTANT QUALITY	44
HAZARDOUS ENVIRONMENT	17
HEAVY, STRENUOUS WORK	12
TEDIOUS, REPETITIVE WORK	33
MILITARY CONTRACTS	11
RESEARCH & DEVELOPMENT	3
SYSTEM INTEGRATION	4
FLEXIBILITY	2
DEMONSTRATION	5
RESEARCH & EDUCATION	1
JOB SHOP	1
TRAINING	2
REDUCE COST OF OPERATIONS	2
TOTAL	180

A P P E N D I X E

COMPLETE LIST OF PRODUCTION TASKS CONSIDERED
APPLICABLE TO ROBOTS

TABLE 12 GIVES A COMPLETE LIST OF TASKS THAT WERE CONSIDERED APPLICABLE TO ROBOTS AS FURNISHED BY THE RESPONDENTS.

TABLE 12

COMPLETE LIST OF PRODUCTION TASKS CONSIDERED APPLICABLE TO ROBOTS

TASK
SUB-ASSEMBLY
MAJOR-ASSEMBLY
FINAL-ASSEMBLY
MACHINED PARTS
SHEET METAL DETAILS PARTS
QUALITY CONTROL/INSPECTION
COMPOSITES/BONDING
ELECTRICAL FAB
MACHINE LOADING/UNLOADING
PC BOARD STUFFING
BOND TOOL CLEANING
RELEASE AGENT APPLICATION
CHEMICAL PROCESSING
SOLDERING
CHEMICAL MILLING DEMASKING
PAINT LINE LOADING
ELECTRONIC ASSEMBLY
THERMAL SPRAYING
PALLETIZING
FORGING & CASTING
ADHESIVE SPRAYING
WATERJET CUTTING

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