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GPO PRICE	$
CSFTI PRICE(S)	$
Hard copy (HC)	3.00
Microfiche (MF)	.65

ff 653 July 65

IDC

FACILITY FORM 602

N68-36368	
(ACCESSION NUMBER)	(THRU)
85	1
(PAGES)	(CODE)
CR-97217	C9
(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

R07-52764

R-8090-2

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AN INDEPENDENT MANAGEMENT CRITIQUE OF THE NASA MICROELECTRONIC RELIABILITY PROGRAM

Report to:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
ELECTRONICS RESEARCH CENTER
575 Technology Square
Cambridge, Massachusetts 02139

Contract NAS 12-147

Submitted by:

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February, 1967

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PREFACE

This report for management was prepared under Contract NAS-147. The subject covered was assigned as an additional item of work to the basic work statement for the design and development of the Data Bank envisioned for use in NASA's Microelectronic Reliability Program.

The engineering report covering the Data Bank development and design project has been submitted separately.

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I. SUMMARY

A. Purpose and Scope

1. Purpose

The purpose of this independent management study was to perform an in-depth critique on the proposed NASA Microelectronic Reliability Program encompassing the following:

(a) Identify major problem areas

(b) Suggest areas where the proposed methodology may be inadequate to accomplish the stated goals

(c) Evaluate the probable effectiveness of the program in increasing the reliability of microelectronics and reducing the cost of procuring reliable microelectronics

(d) Suggest alternatives to any of the proposed approaches if any seem inadequate

(e) Estimate the acceptability of this program to microelectronics manufacturers and equipment and systems designers in industry and in NASA Centers

(f) Suggest how this program should be presented to industry and the Department of Defense to give it the best chance of being understood and accepted.

2. Scope

This critique, assigned as a task in addition to the design and development of the Microelectronic Data Bank, originally consisted of two basic elements: evaluation of the probable effectiveness of the Microelectronic Reliability Program, and an estimate of its acceptability to potential participants.

The critique has been extended into a third area -- identification of problem areas that have a major bearing on the success of the overall Program.

The field interviews necessary to survey the potential user community's requirements for Data Bank services provided an excellent opportunity to gather in-depth attitudes toward the NASA Program among microelectronic manufacturers, NASA Centers, and contractors.

B. Conclusions

1. General

NASA's Microelectronic Reliability Program is developing a set of procedures that have definite potential for increasing the reliability of devices produced for NASA's use. Preparation of specifications, standards, survey procedures, procurement procedures, and the operation of the Data Bank as a communication system reaching all NASA participants will reduce unnecessary duplicate expense.

By focusing on the difficult underlying technical problems of quality assurance in the new microelectronic technology, NASA has developed a position of leadership in the development of microelectronic reliability programs among Government agencies. Likelihood of the success of this Program in dealing with microelectronic suppliers, however, can be greatly increased if NASA combines forces with other Government agencies, principally DOD, and presents common procedural requirements to industry.

2. Problem Areas

The most serious immediate problem is the lack of adequately trained professional manpower to implement the Program.

The most significant technical problems are those already familiar to Subcommittee members, namely developing effective line certification procedures acceptable to industry and developing a sufficient depth of technical understanding to allow for the introduction of abridged qualification tests on new devices that are members of a "qualified" family.

The Subcommittee has understandably given first attention in the overall Program to effectively increasing device reliability and decreasing costs during <u>production</u>. Equally essential to successful NASA missions, however are two other areas -- application engineering, and end-use handling. The improvement of device reliability in these areas should be added to the current list of Program objectives.

The singular managerial problem relates to the limitation of future Program effort by a committee organization. It is entirely appropriate that past efforts have been conducted by a committee. The increased thrust required for the Program to meet its specific goals, however, dictates a more vigorous approach and a clearer line of accountability than the committee structure provides.

3. Effectiveness

The design of the Microelectronic Reliability Program is sound and potentially effective. While the probable effectiveness of the Program in meeting its two primary goals of increasing reliability and decreasing costs is high, attaining them is highly dependent upon the effort and skill with which the Program is implemented -- especially at the interface with microelectronic manufacturers.

The majority of respondents to our interview program agreed that proper implementation of procedures currently being developed under the Program will increase the reliability of circuits manufactured for NASA. The majority also agreed that quality assurance methods must focus on assuring product homogeneity. The concept of line certification proposed within the Program bears directly on this aspect of microelectronic technology.

Working contrary to full realization of Program effectiveness, however, are two conditions: first, the proposed line certification procedures will be difficult to implement and will require an adequate number of highly trained personnel; and second, the proposed procedures will not guarantee that all manufacturers will honestly adhere to all quality assurance requirements.

There is widespread agreement that a properly implemented Program will reap sizable efficiencies and accompanying cost savings. These savings, however, will be difficult to measure, for two primary reasons. First, the magnitude of the Program, and its impact on the several levels of design, applications, and quality assurance would make quantitative measurement prohibitively expensive. Second, demands for project resources that are saved by the Program will undoubtedly be refocussed either on furthering technological advances or on improving the effectiveness of other projects.

We conclude that the NASA Microelectronic Reliability Program is the best current approach to meeting a recognized need in microelectronic quality assurance.

4. Acceptance

On the basis of our field interviews, we conclude that the Program enjoys a high likelihood of acceptance by NASA Centers and contractors. Acceptance by manufacturers, although ultimately favorable, will require careful presentation and implementation by highly-trained personnel.

NASA contractors are not only willing to accept the Program, but anxious for it to be implemented. Contractors were generally skeptical of NASA's being able to enlist manufacturer cooperation in accepting and honestly employing line certification procedures. Their overall enthusiastic support of the Program stems from their potential access to better application data and awareness of experience history from other users.

Technical personnel at NASA Centers were also skeptical of manufacturer acceptance of line certification procedures. All of them were interested in the Program plan to provide access to experience history and technical information on microelectronics in greater depth. Some did express fear that the Program might overemphasize the forced use of qualified devices, even though some unique technical problems require the use of non-standard and non-approved devices. Quality assurance personnel were far more anxious to see the Program plans implemented.

All major manufacturers will accept the Program procedures. The only procedures they may hesitate to endorse are those for line certification. But the evidence indicates that vendors will accept them, too, if they understand them.

C. Recommendations

1. Better Documentation

A program with such potential importance to NASA warrants better documentation for informing management of the Program objectives, progress, and long-range plans. Prospective participants in the Program also lack adequate documentation of objectives and the underlying technical problems in quality assurance. If needed, additional funds or manpower should be allocated to the preparation of these materials.

2. Prepare and Initiate Plans for Manpower Training

The Microelectronic Subcommittee should appoint a group to prepare educational materials and select manpower for formal training in implementing the survey and certification procedures being developed under the Program. A training program should be activated soon, whether responsibility for it rests within or beyond the subcommittee.

3. Broaden Program Objectives

The Program should encompass increasing the reliability of microelectronics in application engineering and end-use handling. These objectives should be explicitly added and steps taken to achieve these ends. The Data Bank facility operating under the Program can provide the communication means necessary to disseminate information related to these subjects. The Subcommittee, however, should examine the need for related studies and procedural developments.

4. Promote Compatibility of Quality Assurance Procedures

NASA's progress in the development of the Reliability Program will enable NASA to perform a dual service if its quality assurance procedures are made compatible with those of the Department of Defense. First, it can assist a sister Government agency on an important problem. Second, it can maximize the likelihood that the microelectronics industry will respond favorably to QA procedures, thus enhancing participation in the combined space/defense business.

5. Investigate Factors Affecting Microelectronic Device Performance

Because of the current limitation on technical knowledge of device performance, and the resultant inability to abridge qualification tests on new members of a previously qualified family, the Subcommittee should prepare plans for an appropriate investigation. This will require a substantial laboratory study program to determine the degree of coupling between the factors that affect performance characteristics. In addition, there must be accumulated sufficient statistical evidence to provide a basis for extrapolating prior test results on qualified devices to new devices of the same family.

6. Organize for Optimum Program Results

The present Subcommittee should explore alternate forms of organization that will provide the maximum driving force toward full realization of the Program objectives. Once NASA management has approved the Subcommittee's choice, there should be a full assignment of responsibility to it for the major task of implementing Program goals. The present Subcommittee should be maintained, however, to function as an overseer group that determines future policies and overall direction for the Program.

7. Prepare Long-Range Plans

Identify the implications of the implementation of present procedures being developed and identify plans for the activities, resources required, and schedules for the achievement of specific milestones.

II. INTRODUCTION

A. Background

The Microelectronics Subcommittee of the NASA Parts Steering Committee was established about two years ago in recognition of the unique problems that pertain to microelectronic technology. The Subcommittee has representatives from all NASA design and research centers, and its activities are coordinated by the Office of Reliability and Quality Assurance at NASA Headquarters.

The Microelectronic Reliability Program being developed by the Subcommittee faces a major frontier. Microelectronic technology is new. Methods for assuring high quality during production are new.

The Program seeks to achieve two primary objectives:

(1) Increased reliability in the production of microelectronics procured for NASA, and

(2) Reduction in duplicative costs associated with their procurement.

The need for developing a NASA-wide approach to microelectronic reliability assurance is clear, however, to anyone discussing this subject with suppliers. The NASA organization, therefore, must speak with one voice if it is to have a significant effect on persuading manufacturers to meet NASA's requirements for reliability assurance.

An important element in the Reliability Program is the communication system that gathers data and provides information services to personnel requiring access to technical data needed in decisions that affect reliability. The data collection activity, the repository, the dissemination, and the communication features of the Microelectronic Reliability Program are functions of the Data Bank.

Information Dynamics Corporation, NASA's contractor for the design and development of the Data Bank, was asked to provide an independent management critique for the overall Microelectronic Reliability Program.

B. Critique

1. First Steps

First it was necessary to understand the full scope of the Microelectronic Reliability Program, its objectives, goals, and action plans.

The Flow Chart(on page A-10 of the Appendix) shows the majority of constituent activities intended within the program scope. The available detailed plans and procedures being developed for each of these activities were reviewed in an attempt to identify problem areas.

2. Evaluation of Probable Effectiveness

No better method was found for evaluating probable effectiveness than to solicit the attitudes and opinions of decision-makers upon whose actions effectiveness of the Program depends. Many of the prospective participants have had direct experience in dealing with microelectronic suppliers on the subject of reliability and possess value judgments useful to the evaluation. Their viewpoints were solicited during the field interviews. There are, of course, a number of technical considerations that will influence program effectiveness, but this investigation did not attempt to evaluate the Program on its technical merit.

3. Estimating Program Acceptance

Acceptance of the Program by participants was noted in terms of (1) Program actions, (2) Program objectives, (3) Program goals, and (4) features of the operating systems proposed. Again, the best value judgments for making this estimate were derived through field interviews and analysis of the results collected. Viewpoints of representative decision-makers whose acceptance of the Program is essential were considered most important.

4. The Data Collection Method

Value judgments of participants in the Program were obtained through direct interviews during visits with microelectronic vendor organizations, NASA Centers, and NASA contractors. The purposes of the interviews were twofold -- (1) to extract an expression of the requirements of engineering, manufacturing, and reliability-related user communities for technical information services (for use in the design of the Data Bank), and

(2) to discuss and solicit reactions to NASA's plans for the overall Microelectronic Reliability Program.

After the interviews, a set of tentative reaction summaries was constructed. Copies were then sent to the interviewees for confirmation of their recorded viewpoints (see Appendix A). Of the forty persons interviewed, 25 percent returned the summaries, and they were all validated. On the basis of those returned, it is safe to conclude that the tentative tallies are substantially accurate, although they have not been confirmed.

III. PROGRAM CRITIQUE

A. Introduction

During the course of this limited study, the investigating team developed a great respect for what has been achieved to date through the convictions, dedication, and efforts of a relatively small group of men working on, and in support of, the Microelectronic Subcommittee of the NASA Parts Steering Committee. Through their efforts, NASA, without even establishing a formalized program, seems to have achieved a position of leadership in getting at the very difficult problems of quality assurance in the new technology of microelectronics.

Recognizing the vital importance of the subject of microelectronic reliability to NASA's success, especially in future deep-space missions, this critique is offered with the intention of stimulating a vigorous discussion and examination of the "follow-on" stages of the Program. What might be considered the "design phase" of the Program to date, appears to be effective and adequate to achieve major goals of the Program. Though plans and action steps may be in the offing for implementing the several activities needed to carry out the Program work, we did not discover these.

We foresee a major program requirement for educating NASA personnel, NASA contractor personnel, and microelectronic supplier personnel to an understanding of this new approach to quality assurance. Further, recruiting and training the NASA personnel needed to serve in survey teams and as quality control residents will require a substantial effort.

B. Problem Areas - Candidates for Improvement

It is recognized that the Program must operate within a given set of constraints:

- ☆ It operates at a frontier of technological knowledge
- ☆ New functional and procedural practices are necessary to achieve quality and reliability in the microelectronic field
- ☆ NASA operates as a Government agency interfacing with microelectronic suppliers in private industry

- ☆ There are limits to available resources in funds, time, and manpower

- ☆ At present, the Program carries out tasks via a subcommittee organization.

The following suggestions indicate areas where improvements in the Program appear feasible and important. Some suggestions may lie outside the scope of the Program as visualized by the Subcommittee. However, these pertain to the Program's objectives and are therefore suggested as areas for consideration.

1. Technical Work

1.1 Abridged qualification tests

Basic problems in microelectronic technology must determine the direction the Program takes. The question of just how qualification testing can be done in an abridged manner for new family members depends on technological understanding. It is suggested the Program include a specific investigative program plan to develop a better understanding of the coupling between the many factors affecting device performance. When new family members are introduced, they can thus be safely qualified with abridged tests that aim directly at factors which cannot be assumed to be equivalent to those incorporated in previously qualified family members.

1.2 Integrated technical work

Technical knowledge is a powerful force in developing relationships between organizations. NASA appears to be rapidly developing a position of leadership in the microelectronic field. The Program should continue to emphasize the development of practical solutions to difficult technical problems while establishing interagency policy on microelectronic reliability. Continuing the close relationship between laboratory investigations and the development of Program procedures plus specifications and standards will foster a strong and successful program. The technical data gathering, repository, and dissemination functions assigned to the Data Bank should be operated in close conjunction with the technical work of the Program, rather than as a separate entity.

1.3 Education and training

A technical frontier is not fully developed just because it is crossed. Needs of the personnel expected to follow and apply new knowledge (i.e., applications engineers and quality assurance personnel) will have to be considered to assure that follow-through is achieved to a point of successful program implementation. The Program should thus include plans that will insure adequate transfer of information and instruction to all participants once the procedures for surveys, evaluations, and certifications are developed. Moreover, the objectives of the Microelectronic Reliability Program should be clarified as embracing a concern beyond the hard core of reliability in production. In particular, increased reliability in application and use should also be considered as objectives of the Program.

2. New Functional and Procedural Requirements

In the microelectronics field, problems of materials and process technology, circuit performance, and systems application are becoming fused more closely. The close coupling of these areas of technology is forcing major changes in the functional roles of device manufacturers, equipment suppliers, and system contractors. Also, microelectronic specifications, standards, and workable procedures for quality assurance are sparse -- only partially developed and without the benefit of a long-standing acceptance in an established industry.

As part of the Program, a specific plan is required to assure the timely availability of an adequate supply of technical professional manpower with sufficient business experience and technical skill to handle program implementation, especially in the field.

3. Interfacing with Industry and DOD

A powerful factor influencing the Program's future will be the attractiveness of the space and defense markets versus that of the commercial market for microelectronics. As commerical uses increase, space and defense interests will fare best if they can combine forces in dealing with industry.

Application experience history, reliability data, and technological know-how can be pooled to the advantage of both space and defense programs. However, each of these has its own mission requirements for technical information services and must retain operational control over support facilities required to provide these services. NASA should propose persuasive plans to DOD for making compatible their approaches to industry. NASA should also:

(a) Develop microelectronic specifications and standards

(b) Develop quality assurance procedures

(c) Establish agency-wide reliability data collection, repository, and information service facilities

(d) Train field personnel responsible for implementation of program procedures interfacing directly with industry suppliers at the plant working level.

4. Allocation of Resources

The level of investigation in this study did not include an evaluation of present or planned Program resources and their intended use. Clearly, the objectives of the Program should be given high priority when allocating resources. Analyses of cost savings to be realized through implementation of such a program are largely academic; it is clear that the Program will increase the reliability and effective use of scarce manpower, money, machines, and material resources of NASA, with a value far in excess of the cost needed to implement the Program.

5. Organizational Approach to Program Implementation

The Program operates through committee action. This has its benefits and its drawbacks.

Obviously, the impact of the activities of the Program will be felt throughout all NASA Centers and must be responsive to the requirements of programs at each. Accordingly, an organization such as the Subcommittee can serve the need for technical representation now and in the longer-range future. A great deal of pressing technical work is necessary to carry out future planning and implementation phases of the Program. Since it is difficult to assign tasks to members of a committee to meet tough demands for performance on schedule and for the use of allocated funds, the Subcommittee might function primarily as an advisory and approval board. It could then assign the bulk of detailed technical work to an organization within NASA which can be held responsible for carrying out the technical tasks.

Two areas will soon require work as an integral part of the Program -- education and long-range planning.

5.1 Education

The technical subject matter with which the Reliability Program is concerned is relatively complex. The reasons why screen tests are not sufficient, for example, and the reasons why the Data Bank must collect and analyze raw test data in addition to summary reliability data are not obvious. The way in which circuit qualification tests can be foreshortened when previous family members have been qualified is not a simple story. Even many of those in close contact with the Microelectronic Reliability Subcommittee have not had time to fully understand the technical complexity of the subject. Some attention must therefore be given to making an organized effort to prepare educational materials and a formal method for educating those who will influence and be influenced by the Microelectronic Reliability Program.

5.2 Long-range planning

The Program is moving ahead and building up momentum. Plans may not yet have been drawn in anticipation of future program requirements. Future activities such as education and training will require substantial lead time to implement. Responsibility for planning these activities should be assigned very soon.

C. Program Acceptance

1. Introduction

In gathering data to provide the basis for estimating Program acceptance, we interviewed forty individuals from eleven organizations, including three manufacturers, three NASA Centers, and five NASA contractors (see Figure 1). Their views were solicited during personal interviews that covered these subjects:

☆ Objectives of the NASA Microelectronics Reliability Program

	Circuit Designers (equipment)	Circuit Specialists	Equipment Packaging	Procurement Buyers	Quality Assurance	Quality Control	Research Directors	Reliability Engineering
	CD	CS	EP	PB	QA	QC	RD	RE
NASA CENTERS								
Ames	1				2			
JPL		1			2			
MSFC	5	1	1		1		1	2
CONTRACTORS								
Lockheed	1	1	1		1			
Hughes	2	1			1			
North American		1			1			
General Electric	1	1			1	1	1	3
Douglas	1				1			
VENDORS								
Westinghouse					1			
Fairchild					1			
Sylvania						1		

Figure 1. Job Classifications of Persons Interviewed

☆ Program Goals

☆ Program Actions (expected from participants)

☆ Data Bank Service Requirements.

In the following analysis, the reactions of each user group are related to the collective view of all forty persons interviewed.

These interviews, limited by available travel funds, were by no means exhaustive. They were, however, sufficient in number to show strong patterns on nearly all points discussed. To make the returns as authentic as possible, we gave each person interviewed an opportunity to audit the manner in which his viewpoint was recorded. Of the persons interviewed, 25 percent or more of each group replied to the validation check. Nearly all of these replies confirmed our interpretation. It is assumed the other 75 percent were satisfied that their viewpoint was satisfactorily interpreted.

The bar charts, included as Figure 2, summarize the reactions of all forty respondents to statements in four main categories. The solid bar represents the response of the group listed at the bottom of the page to the statement listed at the right of the bar, while the hollow bar represents the response of all forty interviewees.

Program acceptance will depend on many factors beyond those discussed in interview, not the least of which will be the details of actual implementation. The viewpoints expressed by persons in each of the major participating groups indicates clearly that the climate now holds strong promise for Program acceptance by the NASA Centers, by the NASA contractors, by equipment designers, and by the suppliers of microelectronics for NASA use.

2. Microelectronic Manufacturers

Due to the preliminary and developmental status of procedures for vendor surveys, line certification, and circuit qualification, interviews with manufacturers were intentionally limited to those aware of the Microelectronic Reliability Program through prior contact with NASA Subcommittee members. The Program must be carefully presented to microelectronic suppliers. We found that where it had been, the manufacturer was cooperative.

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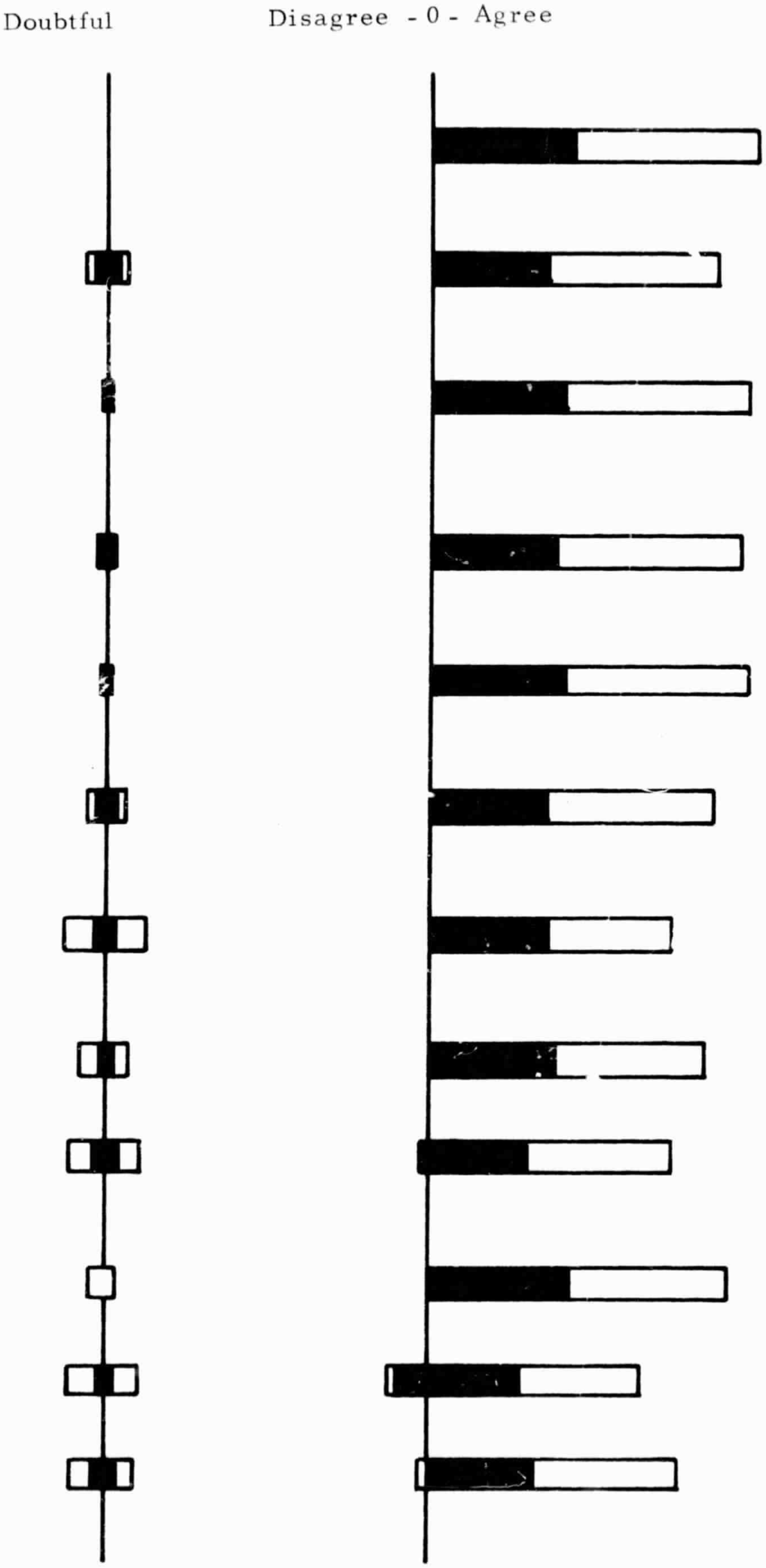

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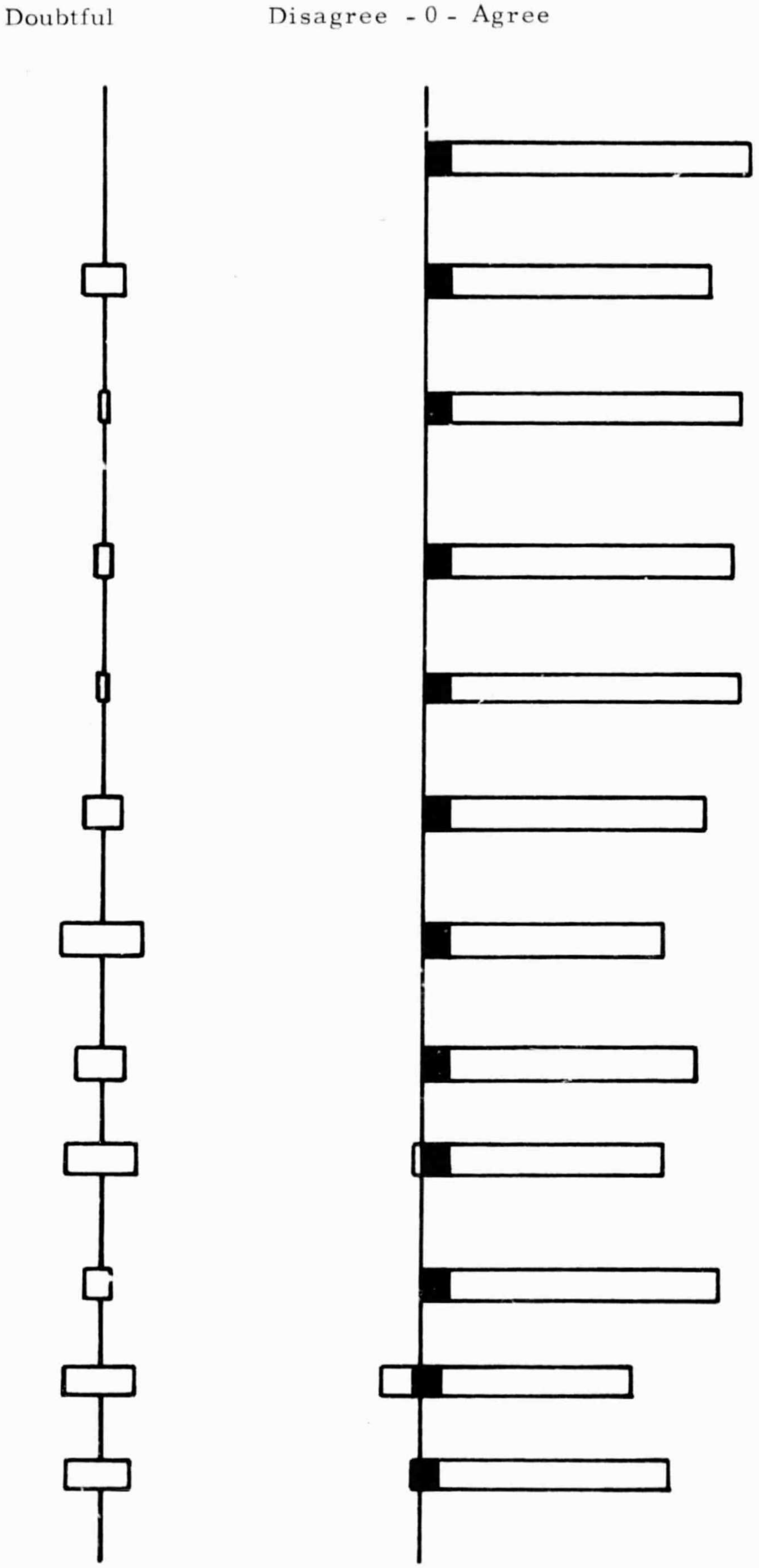
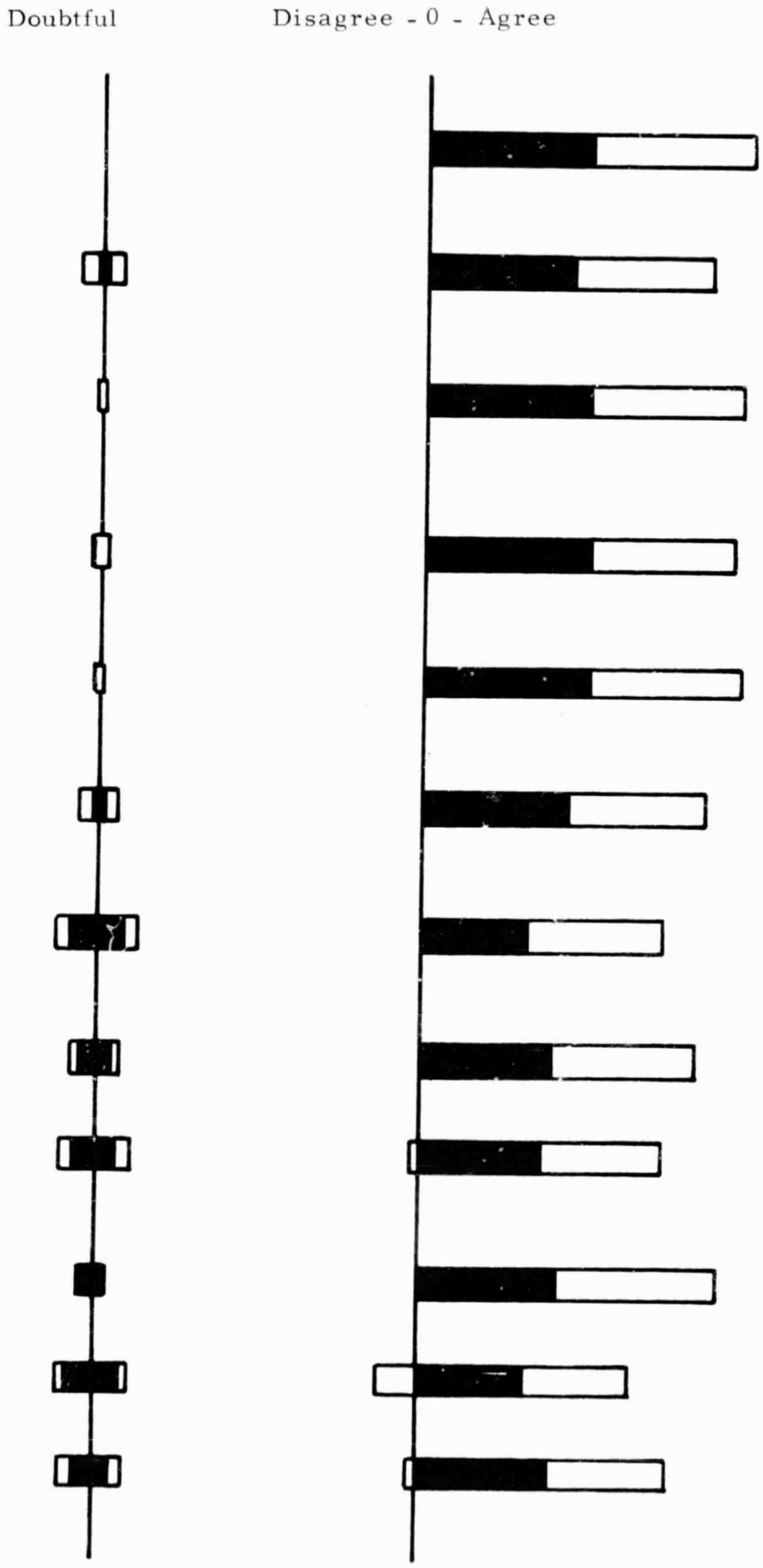


MICROCIRCUIT SUPPLIERS



NASA SYSTEM CONTRACTORS

1.0 Program Objectives

1.1 Though NASA missions may be judged successf
manned space flight missions of longer duration require a high
has been demonstrated for many of the units now being used.

1.2 Microelectronic vendors can be expected to bet
ity assurance if NASA Centers will coordinate their requireme
and related procurement specifications.

1.3 This program should provide constructive help
lizing microelectronics by collecting, organizing, and furnish
maintain awareness of availability, make selection amongst al
program use.

1.4 This program will enable better <u>application</u> of
<u>system</u> reliability by providing a communication channel that
to benefit from the experience of their remote colleagues.

1.5 This program should eventually assist in achie
providing more substantial and authoritative data on actual re
tronics used in electronic equipment.

1.6 By reducing the amount of redundant investigat
circuit application is encountered, this program should impro
NASA Centers and within their contractor project teams.

1.7 If responsive to the information and data needs
lizing microelectronics, the cost of implementing the propose
Bank is likely to be several times repaid through savings in p

1.8 It is definitely possible that the increased micr
a comprehensive program as this may prevent the abort of a

1.9 The program of qualification and information s
result in speedier procurement and, therefore, allow improve
equipment employing microelectronics.

1.10 It is important to obtain meaningful quality ass
produced if reliability requirements are to be met.

1.11 Information available from even 100 percent sc
to make statistically sound statements about the projected rel

1.12 Line evaluation as a means of assuring a highe
tenance of known limits on process controls (if properly imple
electronic reliability.

am Objectives

Though NASA missions may be judged successful up to this time, it is recognized that future flight missions of longer duration require a higher order of reliability in microelectronics than onstrated for many of the units now being used.

Microelectronic vendors can be expected to better meet NASA's needs for reliability and qual- if NASA Centers will coordinate their requirements for qualification tests, methods for testing, ocurement specifications.

This program should provide constructive help to each of the NASA Centers procuring and uti- lectronics by collecting, organizing, and furnishing engineering data and information needed to eness of availability, make selection amongst alternatives, and determine status of present

This program will enable better <u>application</u> of microelectronics and thereby foster improved ility by providing a communication channel that facilitates group learning and allows participants the experience of their remote colleagues.

This program should eventually assist in achieving improved overall system reliability through e substantial and authoritative data on actual reliability and performance history of microelec- n electronic equipment.

By reducing the amount of redundant investigation now needed at each center each time a new ation is encountered, this program should improve the utilization of skilled manpower, both at and within their contractor project teams.

If responsive to the information and data needs of engineers and others on project teams uti- ectronics, the cost of implementing the proposed program and operating the associated Data to be several times repaid through savings in present manpower effort required.

It is definitely possible that the increased microelectronic use reliability resulting from such ive program as this may prevent the abort of a costly mission.

The program of qualification and information services from the associated data bank should lier procurement and, therefore, allow improvements in project scheduling on electronic ploying microelectronics.

It is important to obtain meaningful quality assurances on each lot of microelectronic units liability requirements are to be met.

Information available from even 100 percent screening acceptance tests alone is insufficient tically sound statements about the projected reliability of the units.

Line evaluation as a means of assuring a higher degree of product homogeneity via main- wn limits on process controls (if properly implemented) should result in increased micro- ability.

Figure 2

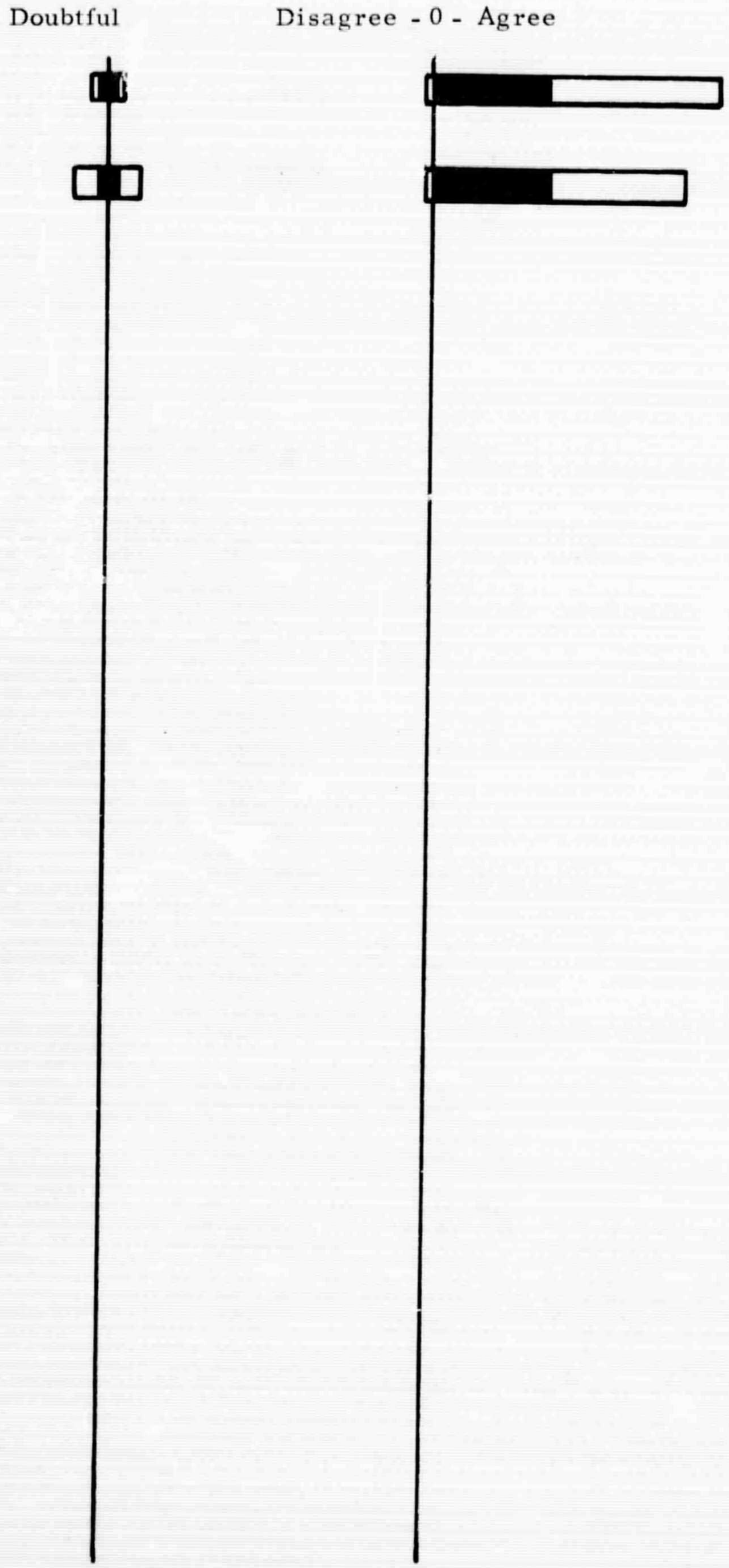
1.13 A combination of screen tests (acceptance) and
of reliability than from screening alone.

1.14 Line evaluation procedures in combination with
nificant degree of quality assurance over production of new ci
fied circuit) without requiring complete circuit qualification t

n of screen tests (acceptance) and line evaluation can provide a higher assurance
ening alone.

on procedures in combination with circuit qualification tests can achieve a sig-
surance over production of new circuits being developed (same family as quali-
ng complete circuit qualification tests for each new circuit.

Figure 2



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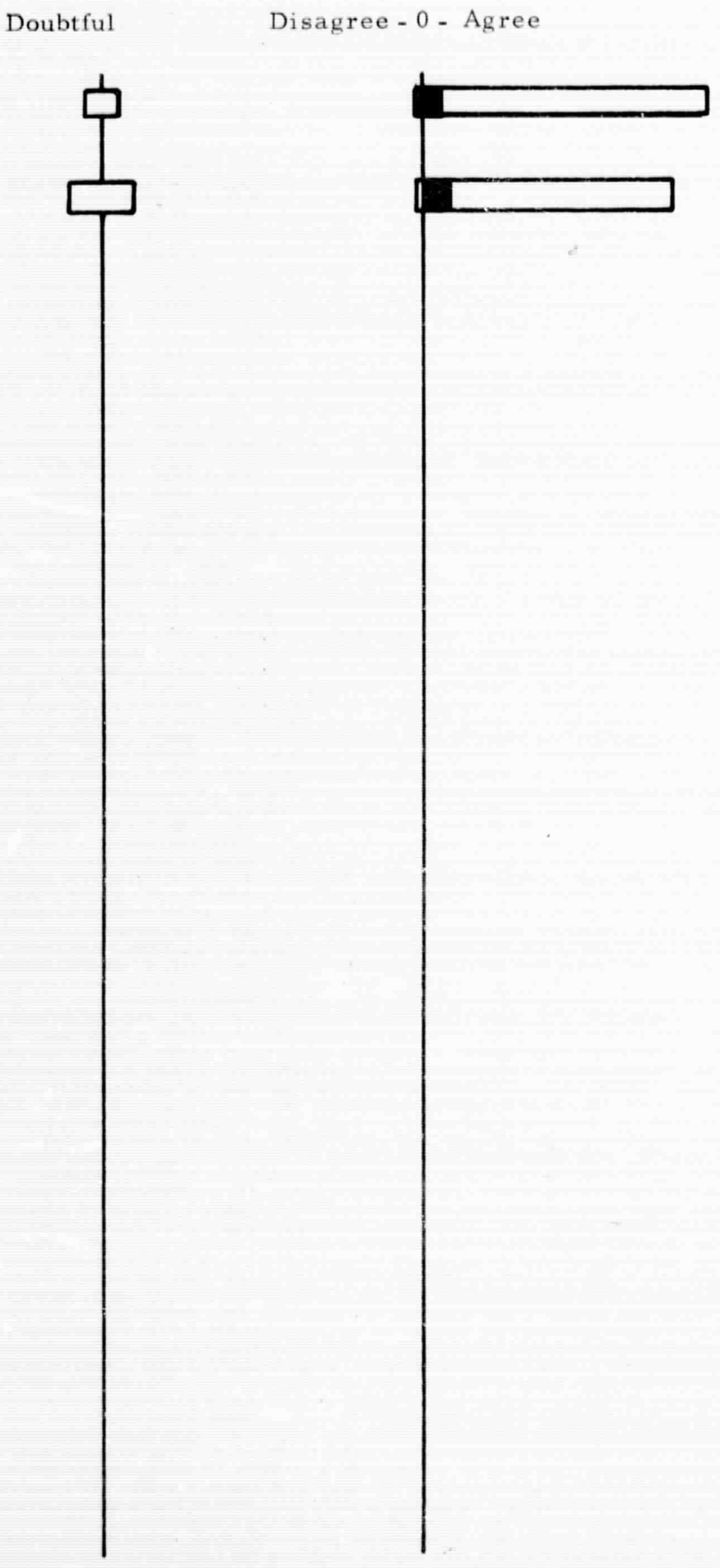


MICROCIRCUIT SUPPLIERS

NASA SYSTEM CONTRACTORS

2.0 Program Goal

2.1 Vendor surveys are an established and acceptable purchasing organization as to the capability, responsibility, and

2.2 Performance of VAL surveys of microelectronic stantially assist both user groups and the vendors by reducing re gations of supplier capabilities.

2.3 Except for approval status, the detailed findings o Program Coordinator, are not needed in the field and should be

2.4 A vendor's survey need not be repeated more than circumstances warrant it.

2.5 Line evaluation procedures (that assure maintenan in the manufacturing cycle) provide a <u>technically valid</u> means of a direct effect on the homogeneity and therefore reliability of uni

2.6 With care, (and with industry's help), NASA shou which will provide the required visibility of "satisfactory" proce how.

2.7 Reliance on line evaluations as a basis for extrap a family with prior qualified (full qualification tested) circuits is qualification tests.

2.8 Assuming a prior family circuit member has bee and/or application of a new circuit have been <u>differentially</u> quali the new circuit is warranted <u>from an evaluated line</u> than from a

2.9 The qualified line concept, if properly done, shou fication tests (approximately $20,000 each) for each and every n use of new circuits at less cost.

2.10 It is desirable that NASA develop a common set o program utilizing personnel from NASA Centers who understand <u>in the field.</u>

2.11 Highly qualified technical personnel skilled in mi out the program.

2.12 The VAL, LEL, and QCL concepts are compatibl responsibility for circuit selection, qualification and procuremer

ıd acceptable method in industry for providing assurance to a
ısibility, and dependability of the product producer.

roelectronic manufacturers by NASA-wide teams will sub-
y reducing repetitive and redundant time-consuming investi-

lled findings of VAL surveys, though important to the NASA
nd should be held confidential.

ted more than once every three years unless major changing

ure maintenance of adequate process control at critical points
lid means of monitoring significant factors which would have
iability of units produced.

, NASA should be able to establish line evaluation procedures
actory" process control without jeopardizing proprietary know-

is for extrapolating reliability expectations for new circuits in
d) circuits is sufficient to eliminate <u>any</u> need for new circuit

nber has been qualified and critical differences in manufacture
<u>entially</u> qualified, a higher level of confidence in reliability of
<u>than from an unevaluated line.</u>

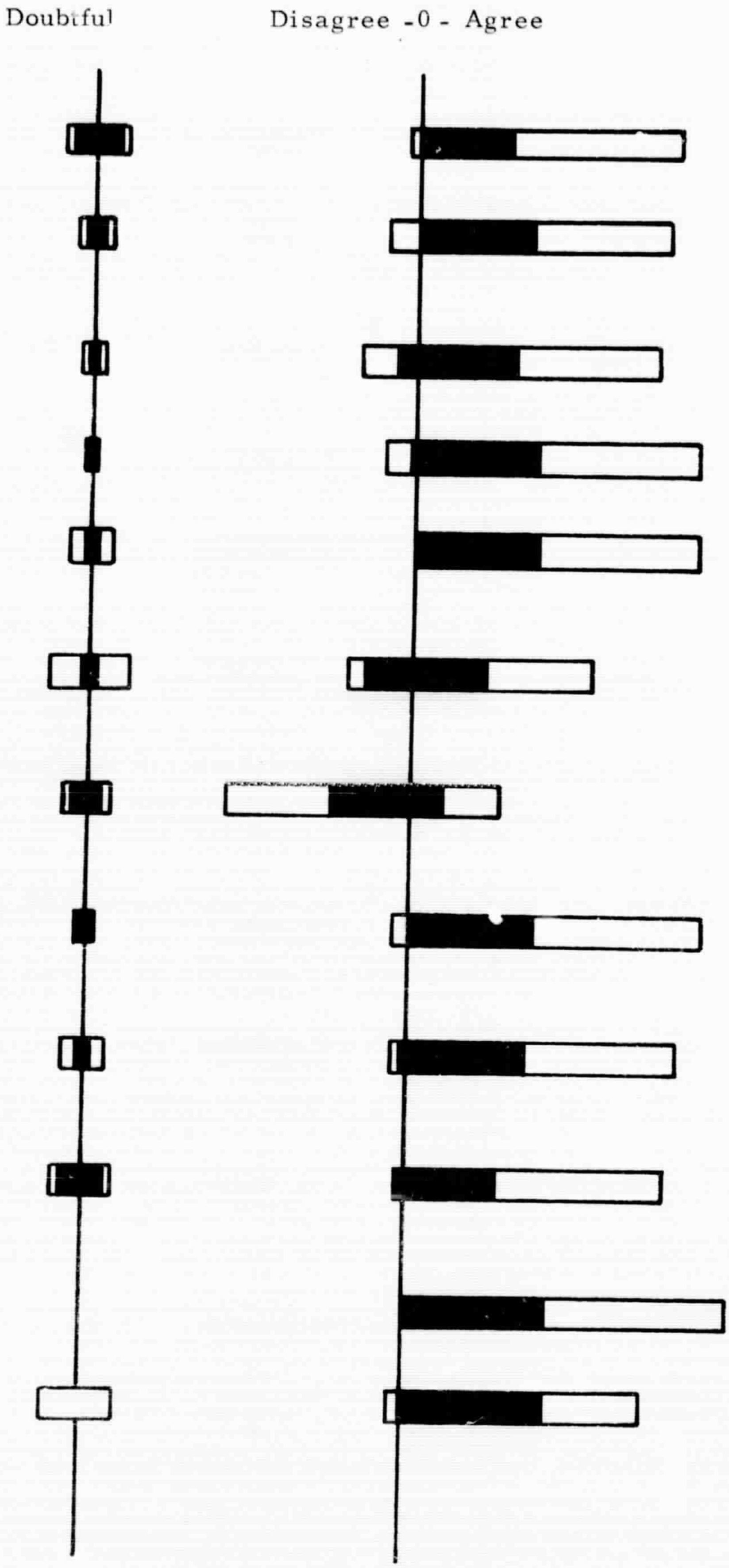
ly done, should substantially reduce the necessity for <u>full</u> quali-
h and every new circuit, thereby enabling greater NASA program

common set of guidelines and specifications to implement the
ho understand procurement practices and related program needs

skilled in microelectronic technology will be required to carry

re compatible with the specific goal of retaining decentralized
d procurement action.

Figure 2



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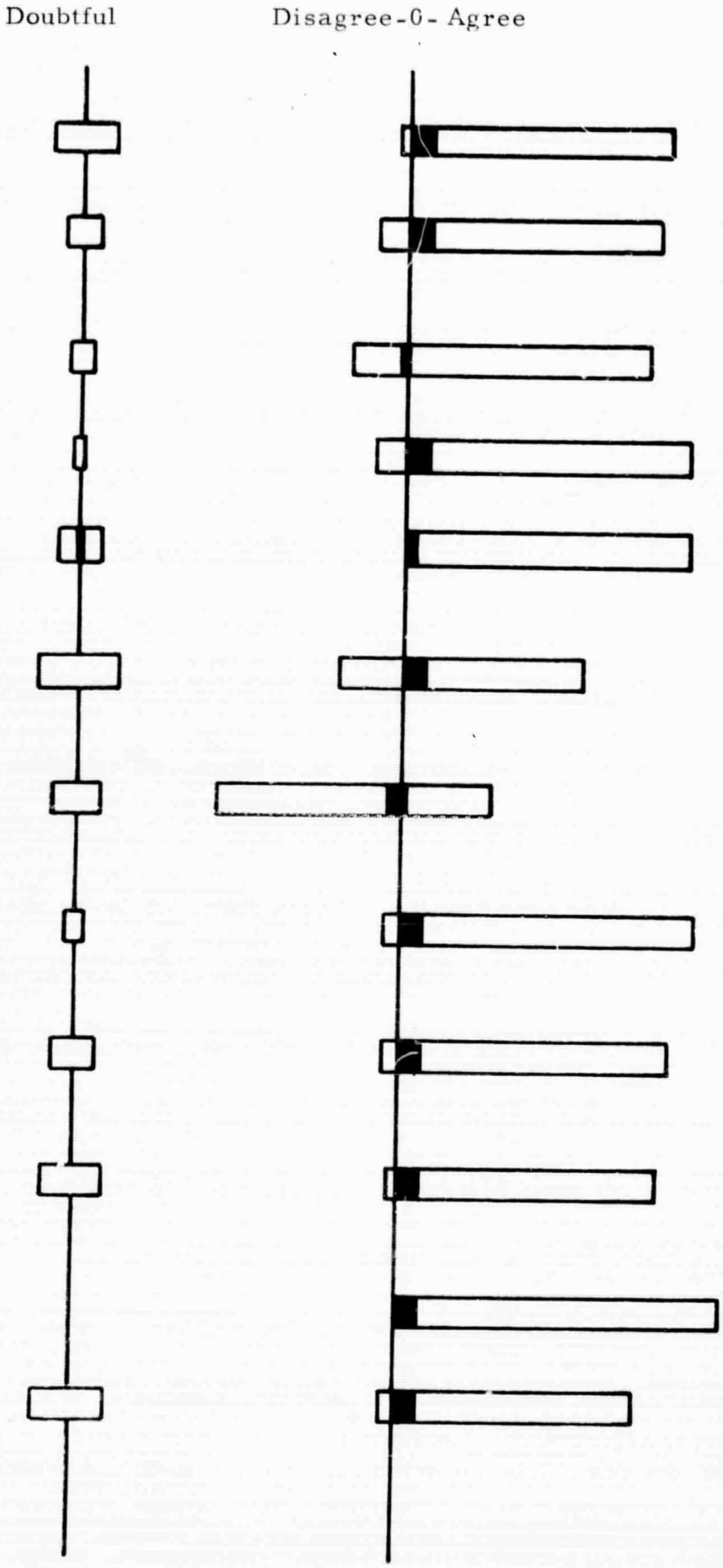
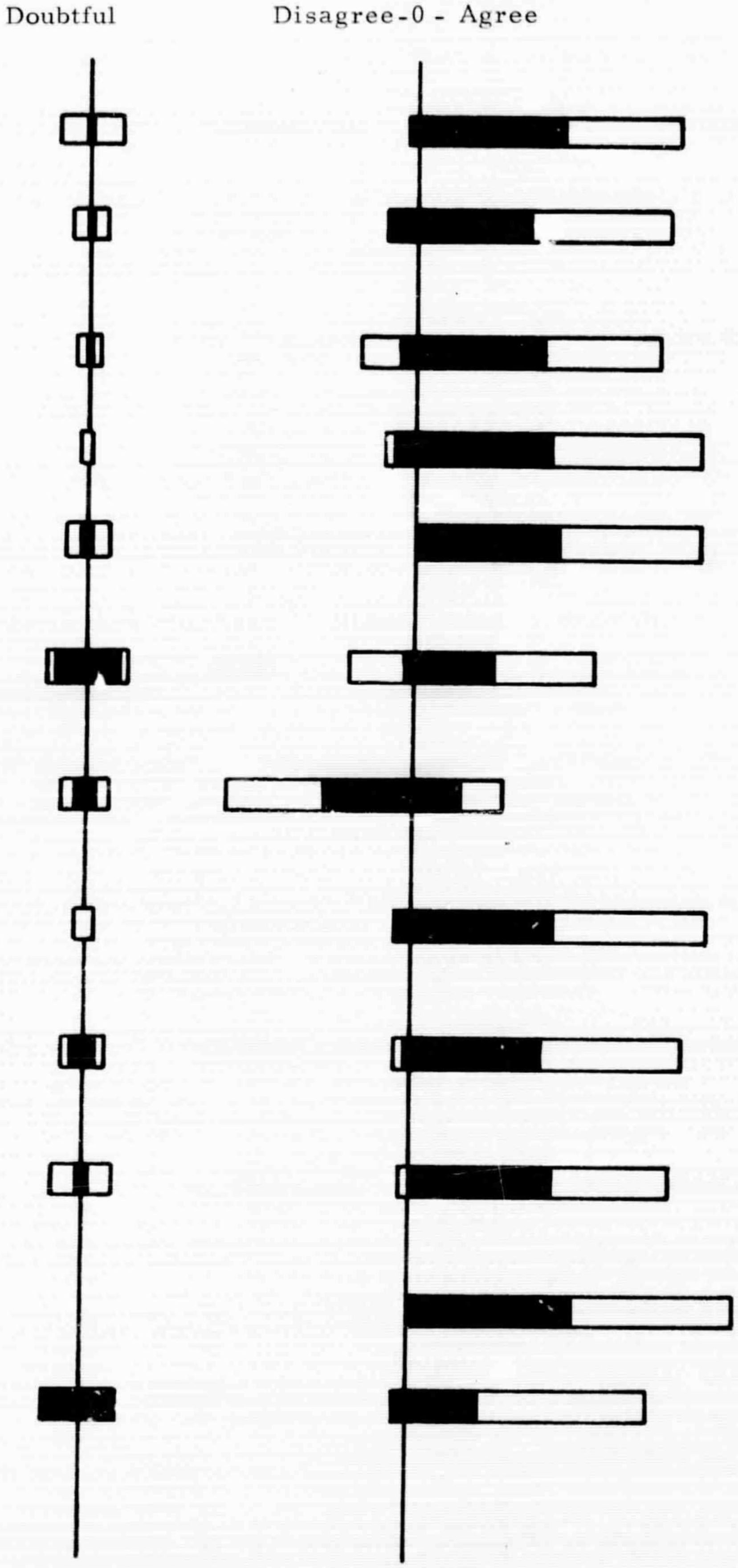


MICROCIRCUIT SUPPLIERS



NASA SYSTEM CONTRACTORS

2.13 The Data Bank must be user servic
means, accepted and used throughout the NASA pr

2.14 Technical information provided by
subject of reliability alone if major service needs

2.15 The Data Bank activity should (on i
microelectronic information and data of prime ne
amongst NASA Centers, their contractors, and su

2.16 The Data Bank should also serve a
technical data on type, performance characteristi
tion history, field performance history, etc., as
microelectronic performance.

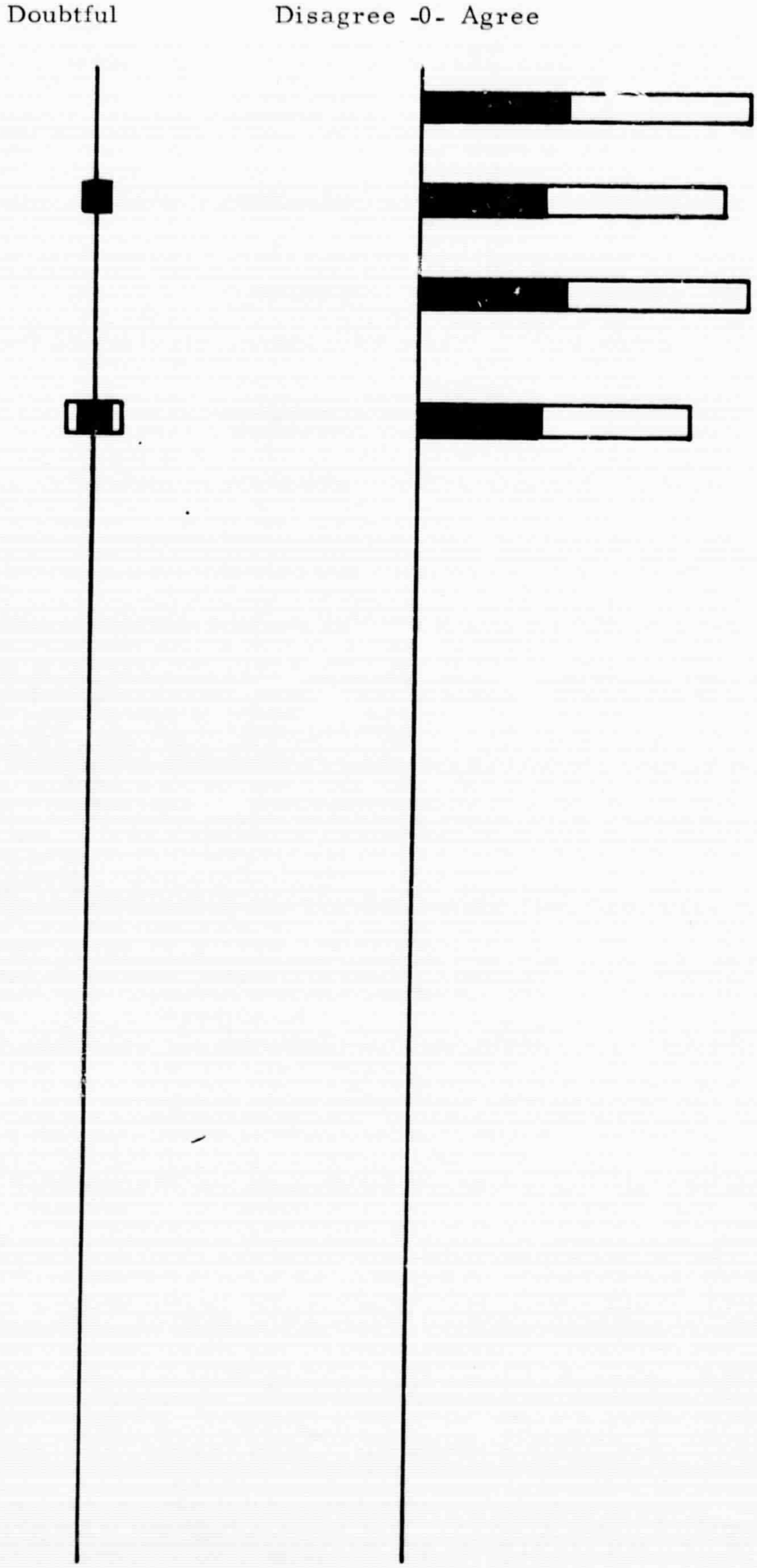
ice oriented in its design to become an effective communication rograms.

the program's Data Bank must be broader in scope than the s of users in the field are to be met.

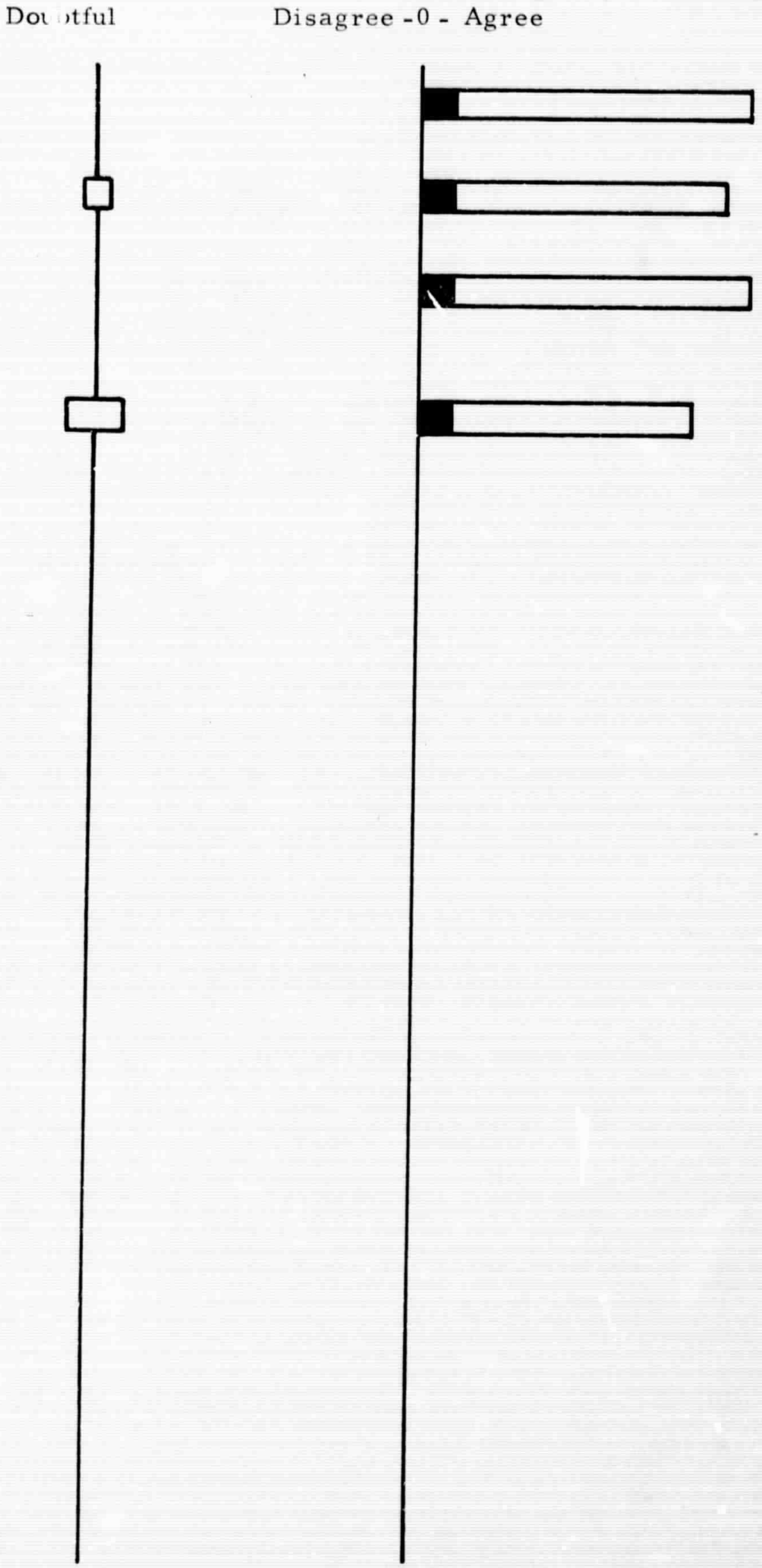
its own initiative) obtain, communicate, and encourage use of eed in device selection, quality assurance, and related decisions subcontractors.

as a research capability for storage, retrieval, and analysis of tics, microelectronic fabrication method, test results, applica- s needed for microscopic investigations of cause and effect of

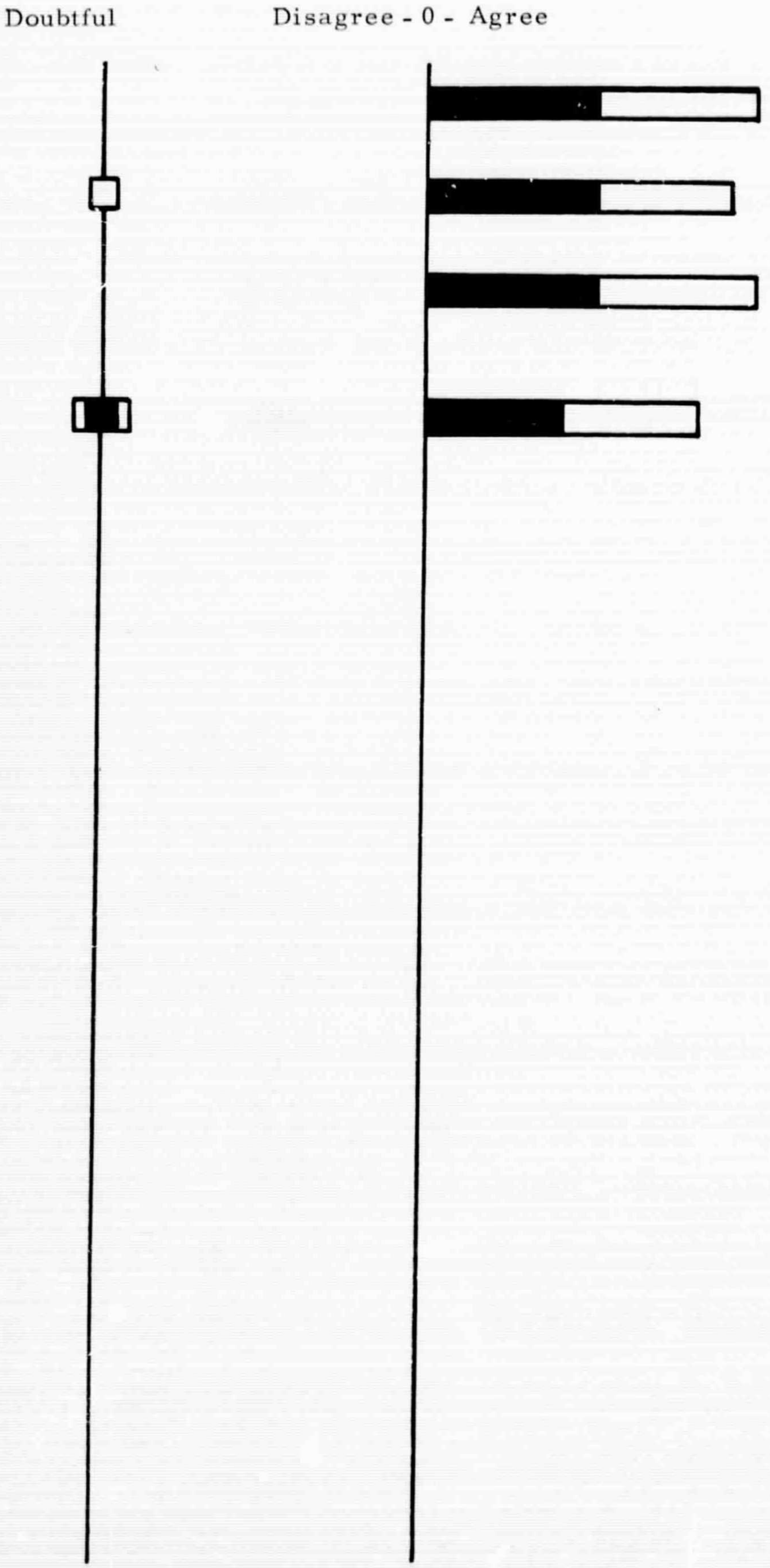
Figure 2



NASA CENTERS



MICROCIRCUIT SUPPLIERS



NASA SYSTEM CONTRACTORS

22-45

3.0 Program Actions

3.1 The program will require develo
that these be developed with the help of personn

3.2 The survey teams must be mann
be assembled using manpower skills in microel

3.3 NASA Centers and their system
data of early value to the Data Bank.

3.4 NASA Centers and their contract
and to update the Data Bank with information co

3.5 NASA Centers and their contract
their system application when the procedures a

3.6 NASA Centers and their contract
tion gathering and evaluation time, in the costs
qualification tests, and in carrying out microel

opment of guidelines, procedures, and standards. It is appropriate nel at various NASA Centers.

ned by competent technical personnel. It is appropriate that teams lectronics at NASA Centers.

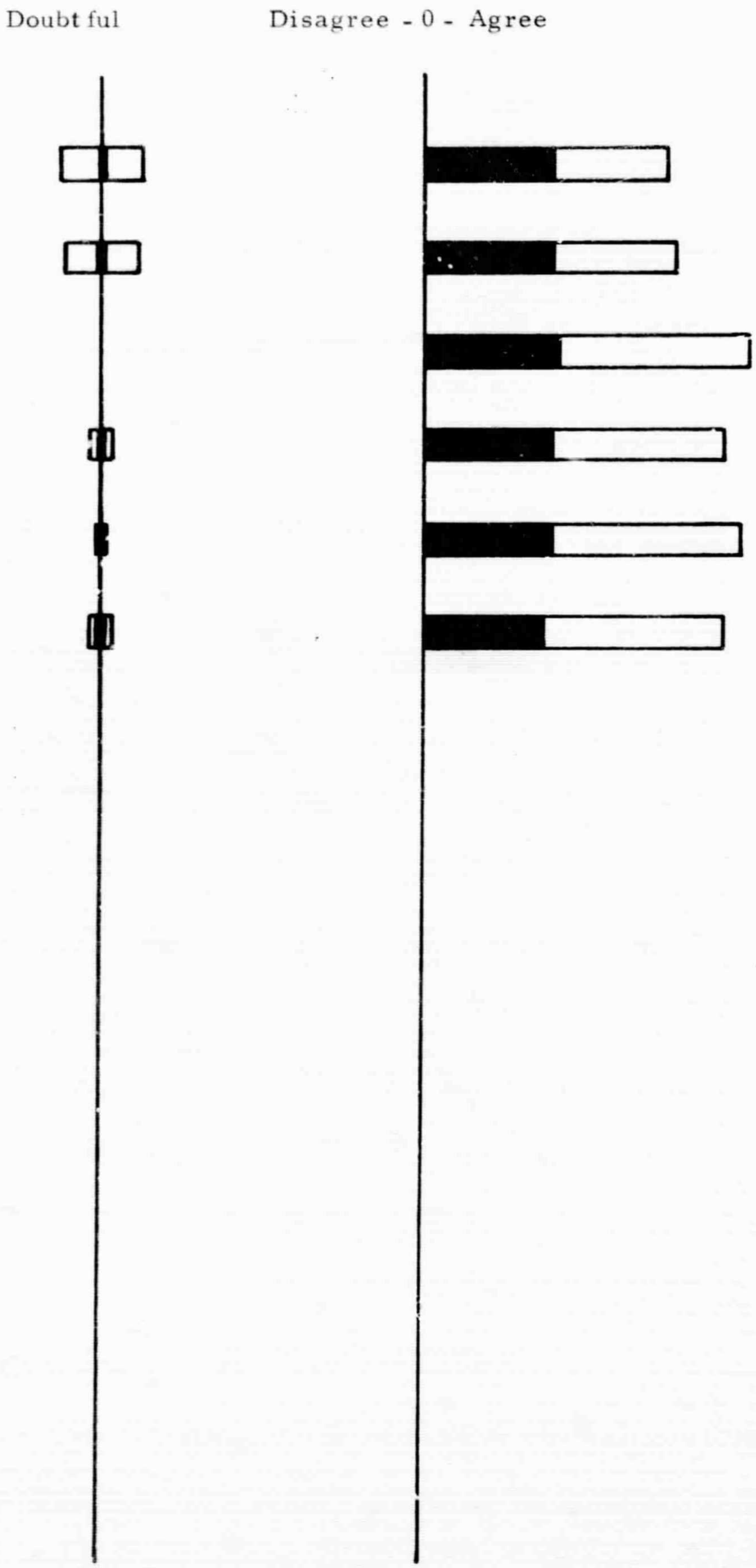
. contractors will be able to supply a substantial amount of useful

ctors can be expected to utilize those Data Bank services described oncerning their own procurement, test, and use of microelectronics.

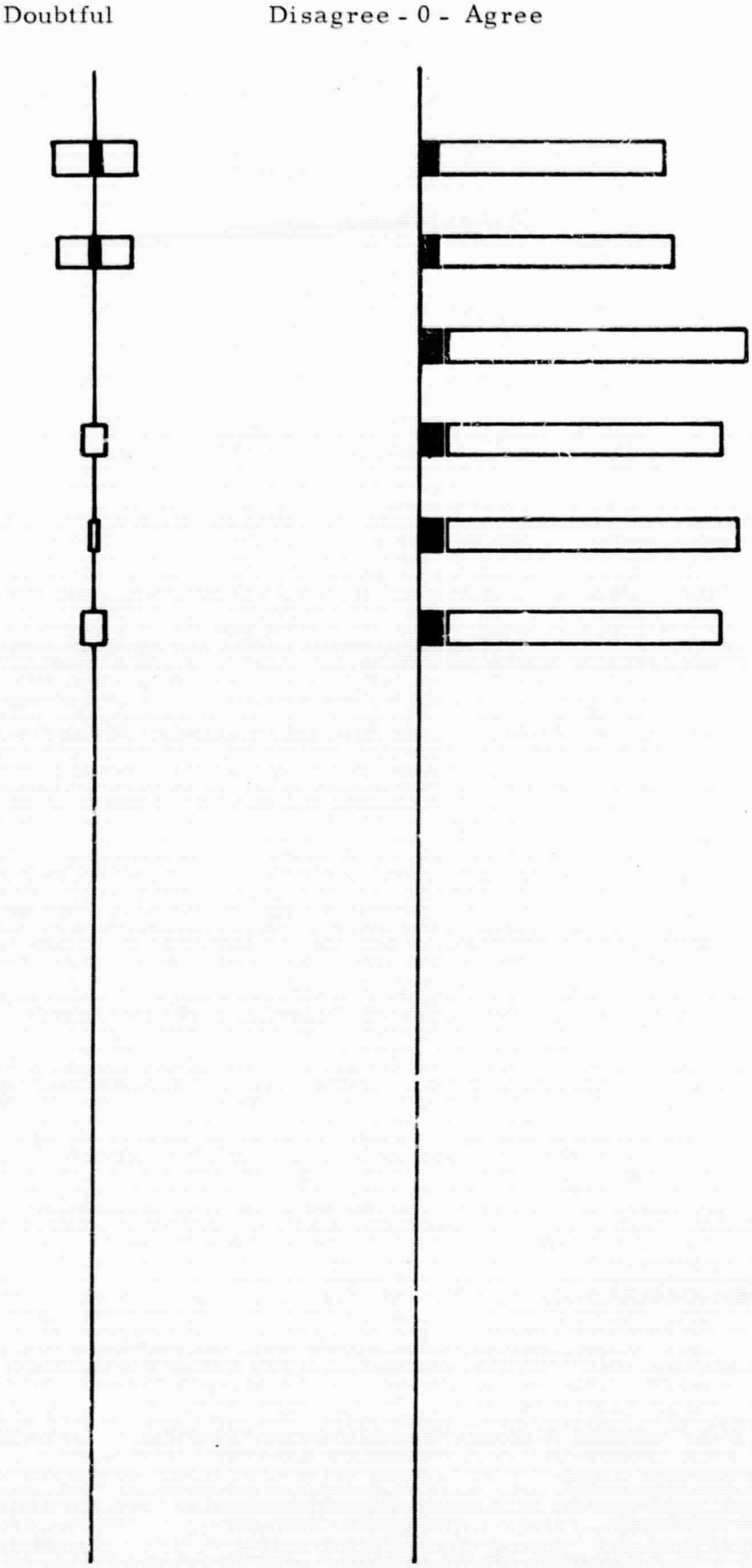
ctors will be able to achieve higher microelectronic reliability in and information services of this program are implemented.

ctors will be able to achieve significant direct savings in informa- s of preparing specifications, in requirements for evaluation and lectronic procurements.

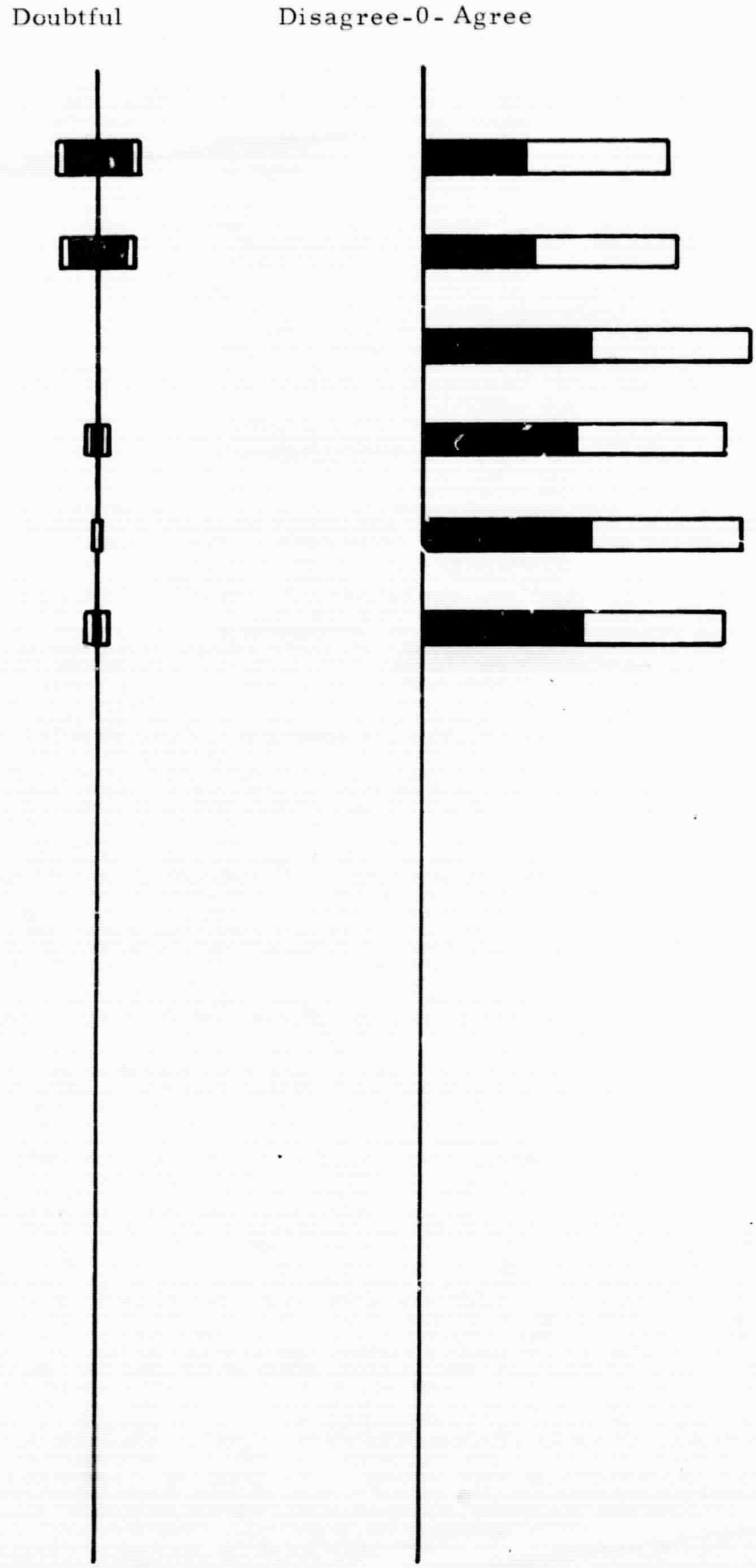
Figure



NASA CENTERS



MICROCIRCUIT SUPPLIERS



NASA SYSTEM CONTRACTORS

23-45

4.0 Data Bank Service System Operation

4.1 NASA contractors, as well as the formation services to select, evaluate, apply, an

4.2 Certain program-developed inform inappropriate to let out of NASA control and, ther

4.3 The Data Bank can profitably serv oriented (equipment design, quality assurance, et and (2) as a research support tool enabling analyt

4.4 The Data Bank should not serve as related to microelectronics, but should select da measure of value added to the Bank.

4.5 Collection, evaluation, selection, to maintain the Data Bank and its services.

4.6 Remote access to the computer-ba computer-aided design steps in microelectronic a perience history.

4.7 Much of the data and information n data, test reports, etc.) and can best be dissemi files that are updated with current information fr

4.8 Printed catalogs (device paramete widely distributed within NASA Centers and contr files and search facilities of the Data Bank.

4.9 If the operating Data Bank is desig specialists, equipment packaging engineers, proc control reliability engineers, and research direc other users should find the Data Bank adequate to

4.10 The time required to get informati not exceed a few hours and preferably be less tha

4.11 The system should contain informa passive thin films, passive thick films, multichip on

as the Centers, should have direct decentralized access to data and in-
ply, and determine prior NASA approval of all available microelectronics.

information such as full-text details of VAL and LEL surveys would be
ıd, therefore, must be restricted to specific NASA-approved users.

ly serve two important functions: (1) as a facility that communicates job-
ance, etc.) data and information to decentralized NASA project personnel,
analytic correlation studies and specialized searches.

erve as a general collection point for any and all information and data
lect data on the basis of a definite criteria combining authenticity and a

ection, and data extraction will be basic input processing operations neede
.

uter-based Data Bank at each of the NASA Centers would be desirable for
tronic applications and for analytic compilations of device operating ex-

ation needed at decentralized points will be textual in nature (application
isseminated as hardcopy and/or micrographic decentralized resource
ation from the centralized Data Bank facility.

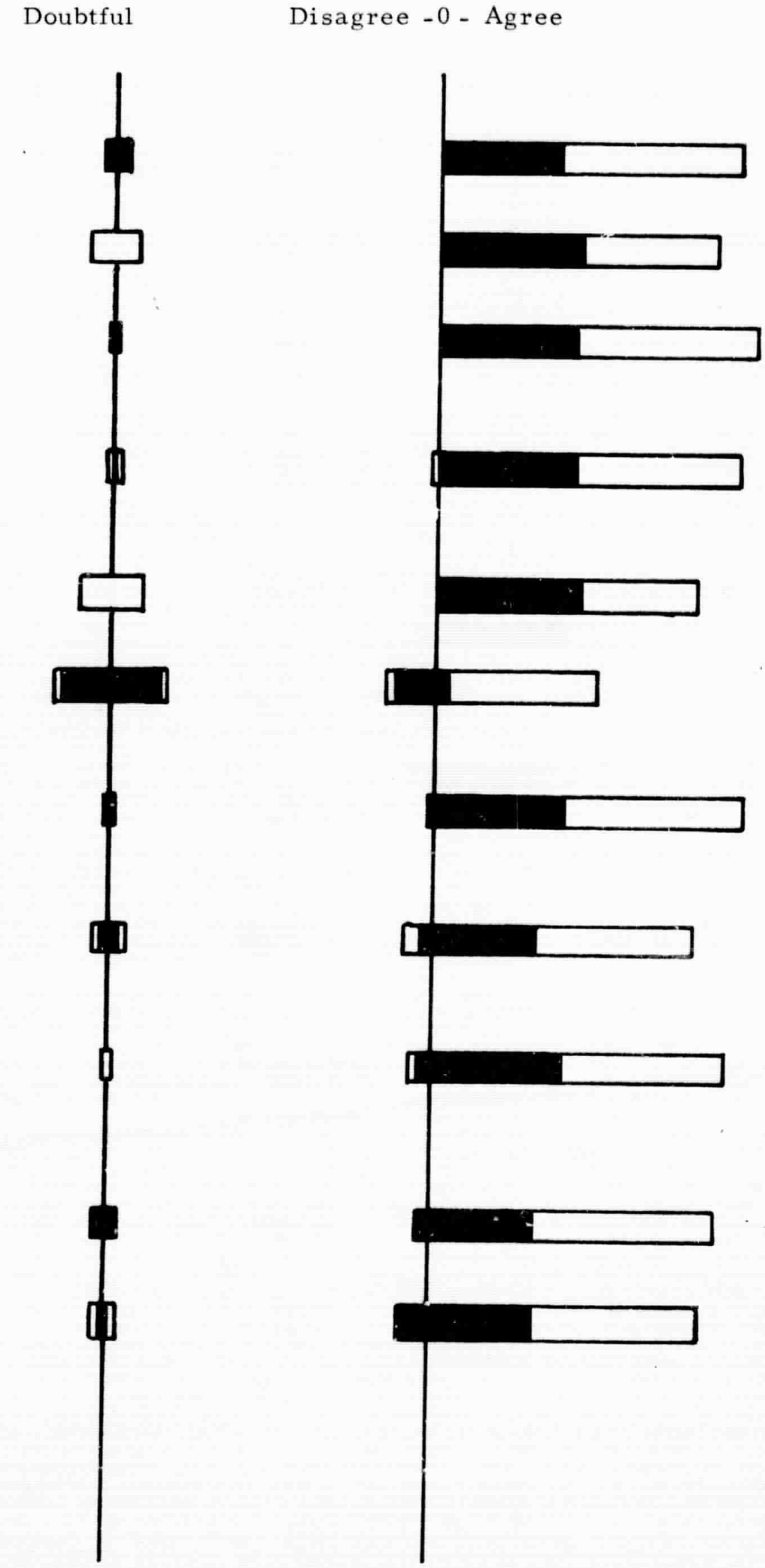
rameter listings), Data Bank indexes and other printed products should be
ıd contractor organizations to assure convenience and ready access to dat
k.

is designed to serve the job requirements of circuit designers, component
rs, procurement buyer specialists, quality assurance specialists, quality
h directors (pursuing advanced technology in microelectronic labs), the
quate to serve their needs.

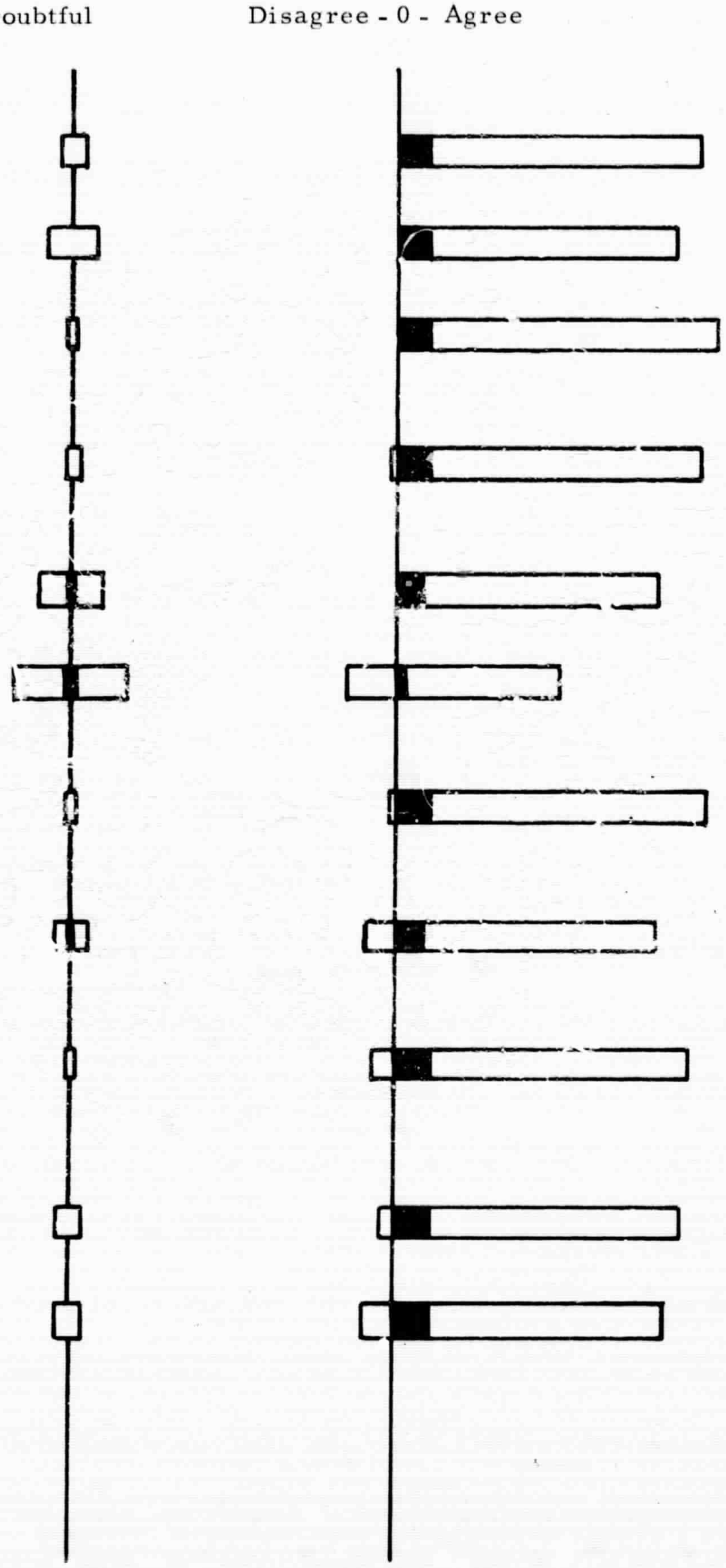
formation and data from the system in response to needs in the field shoul
less than 30 minutes.

information on all microelectronics including monolithics, compatibles,
ultichip, active thin films, and magnetic thin films.

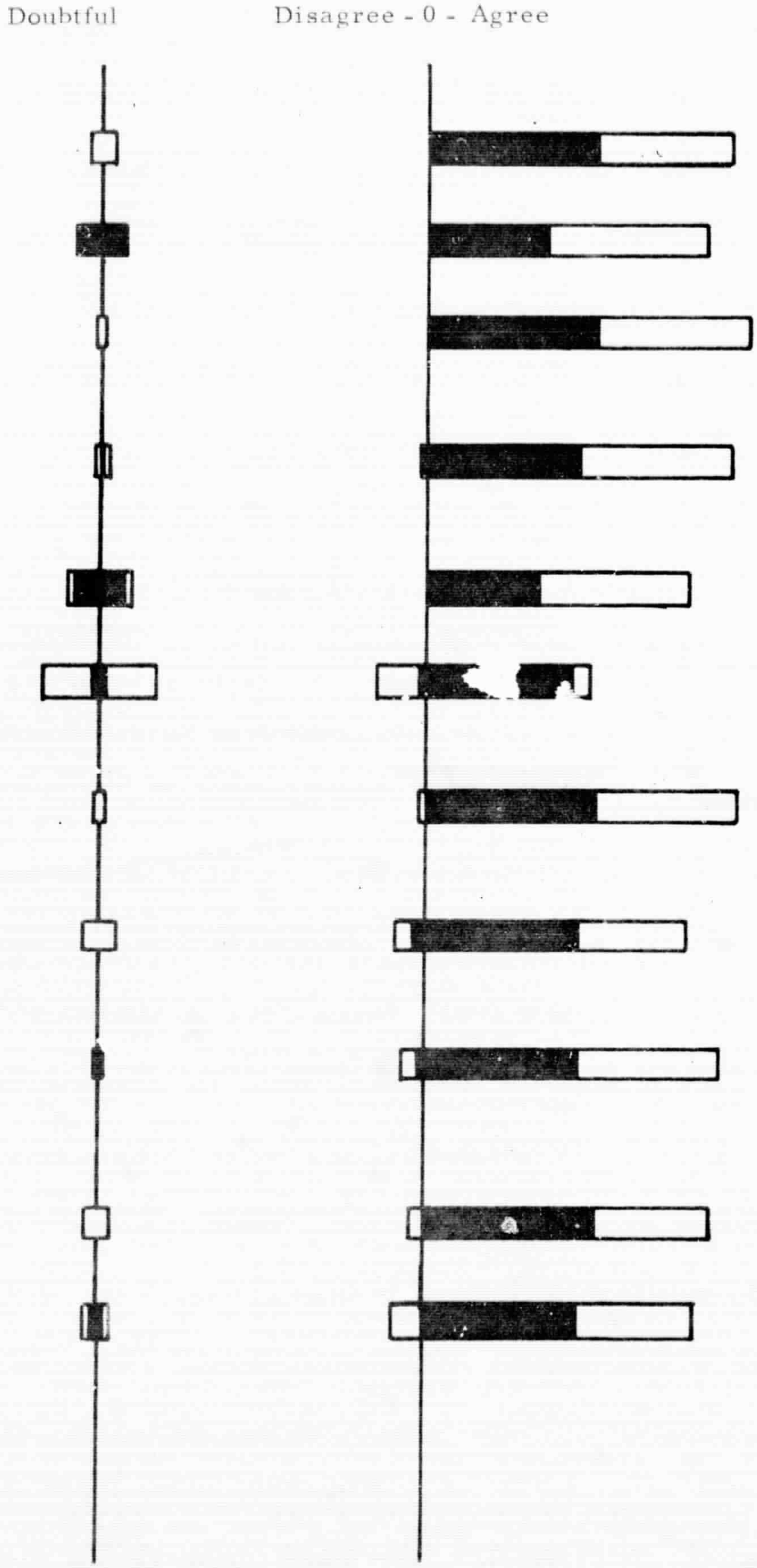
Figure 2



NASA CENTERS



MICROCIRCUIT SUPPLIERS



NASA SYSTEM CONTRACTORS

It is interesting to note that the expectations of many technical people at NASA Centers and NASA contractors toward the position of manufacturers on question 2.6 (page 21 were excessively pessimistic. However, vendor representatives were far more positive in their reaction to this question. These experienced and responsible members of industrial organizations were probably putting their best foot forward during the talking stage.

Results of interviews indicated that microelectronic manufacturers (1) will listen, (2) will think about the Program objectives, (3) will agree that the Program objectives are important, and (4) will participate in a guarded but cooperative manner, if pressed to do so by contractual requirements to the point where there is a <u>real</u> possibility of compromise in the integrity of their proprietary position. Though difficult to display analytically, we believe the interviews show further that implementation of Program surveys and certifications of the NASA microelectronic supplier facilities will at all times require skillful handling by mature, experienced, and technically sound NASA representatives.

Results of the interviews mean to us that the Program has definite potential for vendor acceptance.

3. NASA Centers

Four NASA Centers, in addition to the Electronic Research Center (ERC), were visited, including Ames, JPL, MSFC at Huntsville, and Goddard. Each of these Centers has an active participant in the work of the Microelectronics Subcommittee. The majority of persons interviewed, however, are not involved in the work of this Subcommittee, and some were not aware of its work.

The prime concern among these NASA personnel appeared to be the intent of the Program. The engineers hoped better technical information would be supplied to help solve difficult application problems; quality assurance personnel hoped the Program would provide a more integrated system for reporting the experience of other NASA users, and make available detailed back-up data without excessive delay.

Technical personnel at the NASA Centers were skeptical about vendors allowing NASA to make detailed line certifications.

4. NASA Contractors

All NASA contractor personnel interviewed were very interested. They have a deep concern with the subject of microelectronic reliability and recognize the need for a program that will achieve better control over quality assurance. They are not without experience. Most of them have had previous experience with other programs such as IDEP and Prince/APIC. The contractors provided more substantive information on service features needed in the Data Bank than did either of the other groups interviewed. They can recite the limitations of existing information services, the shortcomings of previous programs, and the areas of greatest difficulty in implementing the proposed Microelectronic Reliability Program concepts. Some of the more significant comments expressed were as follows:

- ☆ "We agree on program objectives and the merit of the program. The realism of approach taken will determine the feasibility of attaining these goals. Prepare to bite the bullet to pay for the cost."
- ☆ "We are beginning to doubt that screen tests alone provide the necessary insight into reliability -- something more appears to be necessary."
- ☆ "NASA will have difficulty in devising a foolproof system to assure awareness of manufacturers process method changes."
- ☆ "Beyond all doubt, there should be a several-fold savings in values received vs. operating costs for a really good comprehensive program. It will be difficult to measure this by any simple method."
- ☆ "90% of the problems in spacecraft reliability result in people goofing along the line, but the other 10% are in engineering. The supply of parts must be given exhaustive attention, as the space business cannot be run on any expected complaint ratio other than zero."

☆ "This is a very big job you are undertaking; nevertheless, it is a job that has to be done."

☆ "We also need to know what non-NASA program users are experiencing in their use of microcircuit applications."

☆ "To get the details of experience history described in terms of actual device application environment, -- that is, the conditions of heat, thermoconductivity, mechanical vibration, and so on -- will require that NASA pay the extra expense of having this data accumulated."

☆ "IDEP, Prince and other systems of this kind yield less than 1% of the information needed. These provide parts reliability report data only and are of little significance to solving the circuit design problem."

☆ "We have useful data now buried in our files from existing programs that could be useful to the data bank in the reliability program. It would require use of our professional time to dig this out in a useful form. We would have to be paid to do this."

☆ "At the present time, due to the inaccessibility of other people's test results, each organization wishing to use a relatively new component is faced with the prospect of performing all the necessary qualification tests or using outdated but reliable components. Otherwise, you take the risk of using unproved items where state-of-the-art advances are required."

☆ "The vendor salesmen will promise anything but will not be able to provide engineering with the data they really need."

☆ "We doubt that NASA can successfully require vendors to submit to line certification and vendor survey inspection on a continuing basis, since governmental applications of integrated circuits account for such a small volume of the total integrated circuit market."

☆ "We are enthusiastic about the program goals, but have doubt that the vendor line certification can be successfully executed. The technical data bank aspect of the program should not degenerate into a set of services resembling that of IDEP, which is seldom used by most technical personnel because of the unavailability of detailed information."

☆ "Manufacturers will not allow process information to get into NASA's hands."

☆ "Yield and reliability are closely related. Since yield information is very proprietary, reliability information is likely to be hard to come by."

☆ "We have for years had contractual requirements that suppliers not change manufacturing methods without advising us; however, we find this difficult and sometimes impossible to enforce. Suppliers do lose their technology of manufacture without knowing why, and all indications to date are that suppliers will attempt to cover this up as long as possible."

☆ "There are usually one or two key men in a production operation who know the idiosyncrasies and weak points of the entire production facility. These men are the real weather vanes; if they could somehow be tapped as a source of knowledge, one might maintain an awareness of the current status of a vendor's production facility."

☆ "Specifications, no matter how detailed, do not assure quality or reliability. They serve an important function as documented guidelines only. Quality assurance is only achieved by keeping tab on the production operations in such a way as to track the quality history of devices produced through the line."

☆ "Today our standard inspectors are familiar with finishes, parts, standard mechanical inspection techniques, and so on. These men are not familiar with microelectronics and have a difficult job of inspecting them. An adequate number of specialists in this technology is really not available and NASA will have to undertake an extensive training program if the objectives of the program are to be fulfilled."

☆ "The key will be identification and training of personnel as to the criteria on which to judge satisfactory conditions."

☆ "We spend 10- to 40,000 dollars per item to meet microelectronic qualification tests. Savings in eliminating multiple qualification tests should be considerable. Perhaps of equal importance would be the savings in time for overall project schedules."

☆ "There are two sources of information from the supplier (a) the marketing team, and (b) the technical engineering group. The former is a good source of information, though not reliable on technical detail. The latter seldom will supply information, but when they do, it is technically correct in detail."

☆ "The technical data bank aspect should provide a "latest information" service to any user who feels the need for last minute checks."

- ☆ "DOD has not until recently faced up to centralizing data on parts reliability. Air Force is now pulling together the Reliability Central. Navy has seen the need coming, but has been more self-contained in their approach in procurement. DOD has said that they do not wish to standardize IC's at this time (but feel sure they are gathering data not announced). Forthcoming DOD action is probably to come from the Defense Electronic Supply Agency."
- ☆ "We have contracts including fixed price maintenance responsibility. In a situation like this, we have a definite interest in reliability and we can be expected to support heavily any programs advancing the availability of data required for high-reliability parts selection."

D. Probable Effectiveness

1. Introduction

We have evaluated the probable effectiveness of the Microelectronic Reliability Program in terms of how well the Program will work, with emphasis on the degree of achievement of specific goals.

The Program objectives of achieving increased reliability and reducing procurement costs are obviously worthy of a great deal of effort. We have not attempted to appraise the magnitude of dollars potentially saved or the percentage reduction in likelihood of mission failures. These are not subjects to be investigated solely on the basis of whether or not the Program will achieve direct cost savings worth the cost of their attainment. NASA must achieve the highest reliability attainable and must speak with a more unified voice in order to more effectively influence the microelectronic manufacturers to achieve higher reliability. The question we have considered is the probable success and degree of effectiveness of the concepts and related procedures of the present Microelectronic Reliability Program.

2. Increasing Reliability

Any increase in reliability of microelectronic devices will be brought about by improvements in three constituent areas: (1) higher-quality production, (2) superior selectivity devices, and (3) improved physical and electrical handling after production.

2.1 Microelectronic production

The Microelectronic Reliability Program currently places major emphasis on developing procedures for achieving higher reliability in the first area, the production of microelectronic devices.

2.1.1 Vendor surveys

A goal of present procedures being developed under the Program is to increase credibility of the supplier's claim of ability to supply high-quality products by first evaluating his organization via a vendor survey. We found no evidence in field interviews to indicate that this procedure will encounter obstacles. On the contrary, the practice has ample precedence throughout industry. Implementing this procedure should not be difficult. Through its use, it should be possible to differentiate between the marginal organizations and those with sufficient resources and technological know-how to qualify as NASA microelectronic suppliers.

2.1.2 Line certification

The concept of line certification, as a means of providing greater visibility of a vendor's proper manufacturing process contols during production, encounters more controversy. Many who are technically astute agree that screen tests of even 100 percent of units delivered cannot provide the level of quality assurance desired. Still, some microelectronic vendors, particularly those most interested in commercial markets, would prefer to see NASA limit the use of screen tests. Other microelectronic vendors, who've already responded to requirements for high-quality devices critical to the national defense and space projects, agree that screen tests, by themselves, are inadequate, and they agree that it is necessary to push beyond this point to assure quality. The problem comes in the method chosen to obtain higher quality.

The complexity of microelectronic devices and the processing technology used to manufacture them present major challenges in developing reliable production methods. This is evidenced by the relatively low percentage yields being realized by all manufacturers today. These yields would be completely unsatisfactory to a manufacturer of discrete components. They are acceptable to profit-oriented industry only because of the relatively low unit production cost, notwithstanding the low yield. Clearly, low yields are evidence of limited ability to control materials and fabrication processes. No manufacturer is intentionally operating at low yields. Limited control adds up to uncertainty in quality of end product. Assurance of adequate process control is a worthy target for Microelectronic Reliability Program efforts, and the line certification concept aims directly at this aspect of quality assurance.

The matter of yield and the manufacturer's understanding of his process technology are subjects of proprietary importance. Any method of developing greater visibility of the supplier's capability to control and know what goes on in his process operates in proximity to difficulty and must be carried out very carefully. The approaches being developed under the NASA Microelectronic Reliability Program clearly consider these aspects of the problem. These neither tell the vendor how to make his device nor require a one hundred percent disclosure of process technology to an "outsider." The approach now being developed to allow the vendor to specify his own critical process points, in process steps that he himself defines, appears ideal. As process technology becomes more widely understood, the degree of the manufacturer's willingness to disclose more detail should increase. Use of the proposed procedure will allow the level of visibility to advance along with the willingness of the supplier to provide information.

In order for line certification procedures to be effective, all personnel expected to implement this aspect of the Program, including the team performing certification surveys, must be in full possession of both a technical and business understanding of what they are doing. A short course in microelectronics, similar to those given to regular plant inspectors, won't work; instead, there should be a training program comparable to those employed by manufacturers of microelectronics for production supervisors.

In summary, people in the field who have thought about this problem believe that higher reliability can be achieved in the production of microelectronics through implementation of procedures that provide higher visibility of retention of process control within limits. They all believe this will be difficult and that success will depend on the care and effort taken to communicate and implement the concepts. No one believes these procedures will preclude vendors from trying to "get by" or "make do" when production troubles develop, but they will make such occasions more apparent.

Despite the recognized limitations and precautions that have to be observed in pursuing this approach, we believe that line certification will increase reliability more than one hundred percent screen tests would. We were not able to identify, in field discussions, any alternate suggestions for obtaining greater assurance of product homogeneity or reliability of units produced.

2.1.3 Circuit qualification

Present plans of the Microelectronic Reliability Program call for development of circuit qualification procedures.

It is desirable that some means be found to reduce the amount of qualification testing and associated expense (approximately $40, 000 each) for each new device introduced. The avenue being pursued to reduce qualification testing emphasizes similarity between members of the same family.

At the present time the Program has not yet proposed a specific set of procedures for circuit qualification. It is certain that both vendor surveys and line certification are to be prerequisites. The concept of reducing the extensiveness of qualification tests needed for new devices in previously "qualified" families has not been accompanied by an adequate technical explanation of how abridgment can safely be achieved. Through sufficient laboratory work, it should be possible to identify the degree of coupling between performance and design and construction elements. If it is possible to demonstrate with sufficient statistical evidence, for instance, that a particular bonding method is successful regardless of the circuit or land configuration within a qualified family, qualification tests relating only to mechanical adequacy of bonding might be safely abridged. Each of these questions of coupling, however, has to be examined directly and frequently rechecked to be certain that tertiary factors have not created an unexpected degree of coupling. Only after the development of a deep insight into the degree of interdependencies of all aspects of the design and performance characteristics of a device will it be possible to safely extrapolate prior qualification test results to new family members. (One of the purposes of the Data Bank is to provide the capability for collection, assembly, and analysis of test and experience reliability data necessary to determine and monitor cause and effect patterns on a NASA-wide basis.) Until a deeper experience history is developed, it appears necessary to qualify each new device by a full set of tests without abridgment.

Qualification test costs can be reduced, however, as described below in a relatively short time by communicating test results and thus reducing the amount of duplicate testing of the same device by different users.

2.1.4 Developing supporting specifications and standards

Development of specifications and standards is an essential part of the Program. Design specifications may eventually be developed for NASA or interagency use for a few high-quantity microelectronic devices. Greater emphasis is being given at the present time to the control drawing method of specifying a device. The control drawing calls out specifications and standards which refer to the prerequisite fulfillment of the vendor survey, the line certification, and the circuit qualification procedures. These documents have not yet been finalized and made available for detailed review.

In order for the Program to be effective, an entire family of test specifications for screen tests and for qualification tests (both full-scale and abridged) have to be developed. Before they are considered satisfactory, the specifications and standards will have to be "proven" under conditions that simulate actual production activities. Their development should be in close proximity to laboratory work being devoted to failure analysis and reliability studies. Ideally, advance technology research, failure analysis, development of specifications and standards, and maintenance of the Data Bank can be kept in close operational proximity. Each of these component areas requires frequent access to both the specialized expertise and the current information available among these related activities. The Air Force at RADC, for instance, has experienced considerable improvement in the availability of hard-to-get microelectronic information for their Reliability Central due to the proximity of their microelectronic laboratories. This association does not exist in other technology areas, and they see the difference.

Screen tests will undoubtedly continue to reflect specific requirements unique to particular applications for which procurements are made. The failure criteria may, therefore, be different for the same device used in different applications. This works against the idea of accumulating additive reliability data. However, there is a way around this problem; that is to collect and check all raw data at time of screen testing against some standard set of failure criteria used for normalizing purposes in the computation and maintenance of reliability figures. This is being proposed as part of the Data Bank design concept.

Specifications and standards intended for NASA-wide use can best be developed by joint activity of experienced personnel from several Centers participating in the Program. Certain initial basic and overall governing specifications are being developed jointly in this manner at the present time. Eventually, developing the additional detailed specifications and standards will have to be assigned to a responsible group, if this job is to be done efficiently. Perhaps the Microelectronic Subcommittee, as a continuing function, can serve as a specifications and standards review board. This arrangement would insure that technical personnel from all major NASA Centers participate in review and approval.

2.2 Application of microelectronics

Both the technical complexity of the subject and the rapid growth of the number of new devices introduced into the microelectronic field burden the ability of engineers to obtain and assimilate all the information necessary to properly apply devices. The Data Bank can alleviate this problem.

At the present time approximately fifty percent of NASA's funds go to the electronics industry. By 1970, an estimated sixty percent will go into electronic components. Coupling these facts with the universal prediction that microelectronics will dominate electronic equipment design in the very near future indicates the importance of taking all steps possible to provide assistance at the early stages of device selection, packaging design, and application. The best possible use of available devices must be made to achieve the most reliable equipment. As NASA's contractor for design and development of the Data Bank, we have chosen to emphasize this point in order that the Data Bank not be visualized as only a repository for reliability data. It should serve as the communication network within the Microelectronic Reliability Program, carrying all information necessary to assure a properly informed and therefore more reliable application of devices.

Field investigations showed that much of the in-depth technical information necessary for appropriate application of microelectronic devices is not available to those that need it when they need it. The common catalog data and specification sheets of the manufacturers, available through marketing organizations, are sufficient only for initial selection. The in-depth data, including the full scope of parameter data for widely varying ranges of operating conditions, can be obtained by contact with the technical organizations of the suppliers. By including such in-depth application data in the services provided by the Data

Bank, the Program will further serve the interests of increasing the reliability of microelectronics employed in spacecraft.

It is hoped that the Data Bank can also serve as a single point of collection and possibly negotiation for advanced information from manufacturers willing to disclose their plans for introducing new devices. This will serve advanced planning groups with additional information needed for estimating reliability of future missions with more stringent reliability requirements.

The Program should also monitor developments in computer-aided microelectronic design. This technology may develop an approach for better device design and application through use of simulated performance evaluation. Should this technique prove advantageous, the Data Bank could monitor requirements of the computer-aided approach for parameter values used and be prepared to provide such information computed from an analysis of both test and field history reliability data.

Early documents describing the Program did not emphasize this communication and dissemination role of the Data Bank. However, during the course of this study, oral endorsement of this role has been tacitly given. It thus appears that a method is available for assuring that adequate application data is made available to device users.

The importance of microelectronic technology to future NASA missions suggests that the Reliability Program take initiative to assure that NASA makes adequate preparations for training NASA Center engineers and others associated with the selection and application of microelectronics in spacecraft. Training programs could be extended to include contractor personnel. At a minimum, NASA should make every effort to assure that its own personnel are thoroughly trained in this technology.

2.3 Improved physical handling

The manner in which microelectronic devices and assemblies are handled from the instant they are received until the system is shipped out has a direct bearing on overall operating reliability.

Contractor studies have been reported that show failure rates during system tests several times higher than those expected from device tests. Shipping, testing, and assembly stresses are responsible for a significant portion of this failure rate increase.

Therefore, the specifications and standards developed for NASA-wide use should include specifications and standards for proper handling to protect against mechanical damage during shipment, and standard operating procedures for lead-joining methods and mounting and handling during overall system checks. This subject is partly considered in the original draft of NASA Spec NPC1000 GEN now being developed but should be supplemented with further guidelines for standard practices for handling devices after they are received by user organizations.

Again, the Data Bank can serve as a "group learning" mechanism that can communicate experiences both favorable and unfavorable throughout the user community. Such subjects of special importance can be given a position of prominence at any time in the spectrum of publications and information services provided by the Data Bank.

3. Reducing Costs

The three major areas where cost savings should materialize as a result of the Microelectronic Reliability Program efforts are:

- ☆ Procurement
- ☆ Application
- ☆ Usage

3.1 Procurement

Program plans specifically aim at reduction of procurement costs in the areas of:

- ☆ Development of specifications and standards that can serve multiple use throughout NASA Programs both at NASA Centers and NASA contractor locations

☆ Reductions in the duplication of effort in performing vendor and production-line surveys

☆ Alignment of requirements and procedures for performance of evaluation tests at time of qualification of new circuits

☆ Organization and simplification of methods for data collection and exchange among all participants engaged in the selection, procurement, application, and use of microelectronics.

On the basis of opinions expressed in field interviews, there is no question as to the effectiveness of the Microelectronic Reliability Program in reducing costs associated with procurement of microelectronics. Several of the NASA Centers have individually developed initial specifications and standards applicable to microelectronics, as they have had no satisfactory alternatives. Since many of the basic requirements within these specifications and standards are common throughout NASA, continued development of them by individual Centers would result in higher costs than would their preparation under a coordinated NASA-wide program.

NASA Centers and their contractors have project responsibilities for procuring and using microelectronics. Without common guidelines on vendor and production-line surveys, there would continue to be duplication that would confuse the vendor. Vendors tend to look at Government agency operations critically and would not hesitate to expense the Government for multiple surveys performed for NASA Centers and project groups.

Evaluation and qualification test procedures, both their design and utilization, represent substantial costs. A complete qualification test of a new microelectronic device can cost $20,000 to $40,000. By pulling together technical requirements throughout NASA's Programs, arbitrary differences can be resolved, and effort can be concentrated on developing a more penetrating approach to the difficult problems associated with microelectronic testing. Costs can, therefore, be reduced in areas where they were formerly expended preserving arbitrary differences. This will continue if an organized approach is not taken. It is doubtful that resources presently devoted to the design and implementation of microelectronic testing will be reduced, because reliability obtainable from microelectronics can be advanced by refocusing savings in technical skills and available resources at each of the NASA Centers on the difficult problems still confronting the technologists.

Judging from interviews in the field, there is general agreement that parts data collection and exchange programs now present a confusing and inadequate picture to those requiring microelectronic information. The existing programs do not satisfy the needs of the microelectronic user in supplying specific data and information required to make specific job-related decisions in the procurement, application, and use of microelectronics. These decisions usually have to be made within a given time period. At the present time, technical people are pursuing bits and pieces of information available from a number of sources. If experience indicates a source is not likely to be able to provide the necessary information, it is quickly dropped from the "circuit." Services which provide data after receipt of a formal request take too much time. The time cycle for providing engineering data and information should not be confused with that for providing technical reports primarily of use to advanced development and basic research personnel.

Most of the data that should be collected to serve microelectronic users in NASA Programs is not available from existing data banks or technical information services. Field personnel, particularly contractors, anticipate considerable assistance and related savings from the operation of the Program's proposed Data Bank.

3.2 Application

If the Microelectronic Reliability Program extends its field of concern to serving the goals of improved application and use of devices as well as improving reliability during the manufacturing stages, it can effect additional savings. The activities necessary to achieve these savings, and the goals, lie principally in the areas of:

☆ Collection and dissemination of in-depth microelectronic application data

☆ Communication of NASA-wide application experience history and reliability experience among the Centers.

No existing commercial or Government-sponsored service provides the information required in the scope, depth, or specificity needed by engineers making selection or design application of microelectronics in electronic equipment intended for NASA's use. As a consequence, individual engineers spend inordinate amounts of time combining these "pieces." Some Centers have recognized the importance of minimizing this duplication of efforts, for example, JPL, who initiated its own in-house Microelectronic Technical Data Bank.

Commercial services, such as VSMF (Vendor Specification Microfilm File) and ASCAM (Aerospace Catalog Microfilm), provide this type of service at a subscription cost of approximately $4000 per year. These services do not provide the information needed for the Microelectronic Reliability Program, but they illustrate industry's recognition of the savings in technical manpower offered by an organized reference system.

Data Banks containing parts information and reliability test results serve the important function of minimizing duplicative testing by potential users who need to prove out the applicability of the part in question under conditions of their requirements.

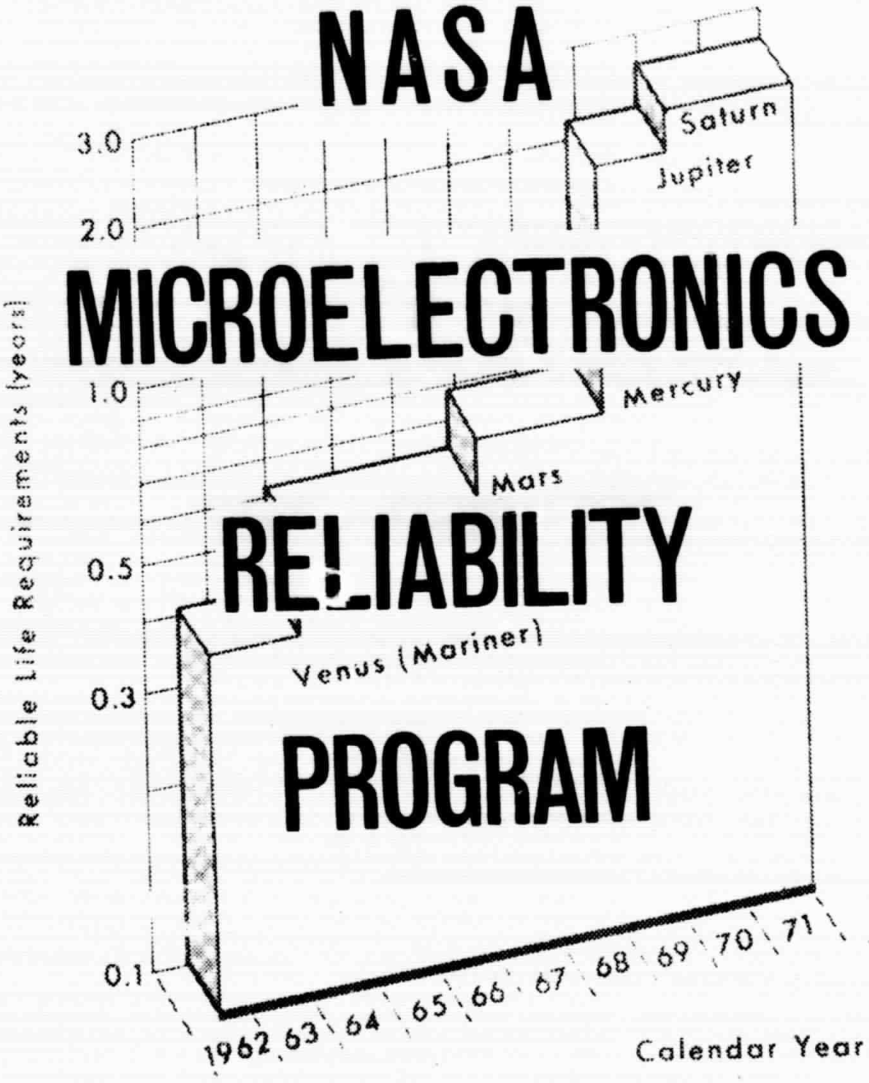
This need exists, perhaps more intensely, in the microelectronic field where the expense of tests and device performance functions are more heavily concentrated. Separation of a microelectronic test program into individual component areas is more difficult and less justifiable because of the uncertainties in coupling between different influences on performance. Investment in testing programs is substantially higher, therefore, than necessary for testing most non-microelectronic device parts. Collection, analysis, retention, and dissemination of the results of test programs have payoff potential in direct dollar savings and time savings. These savings should be included along with the Program's objectives of reducing costs associated with procurement of microelectronics.

3.3 Usage

Indirectly, all efforts of the Program toward increasing microelectronic reliability should result in "use" savings because higher reliability will equate to a lower cost/effectiveness ratio for many systems. One specific area suggested for further consideration as part of the Program is the development of improved procedures for physical handling and storage of microelectronics. This could lead to cost savings, as microelectronic devices have a very high per-unit cost by the time they are manufactured, qualified, tested, and made available for use.

Selected comments from industry on the...

NASA MICROELECTRONICS RELIABILITY PROGRAM



INFORMATION DYNAMICS CORPORATION
Boston Washington, D. C.

December 1966

FOREWORD

In carrying out systems engineering responsibilities for the design and development of NASA's Microelectronic Technical Data Bank, Information Dynamics Corporation, IDC, conducted a set of field interviews to determine user data service requirements. As a part of that effort, there arose the need for an introductory explanation of the need, objectives, and goals of NASA's overall Microelectronic Reliability Program.

This document presents IDC's introductory description of the NASA program. In addition, it presents a structured summary of reactions expressed during field interviews on high points relating to the Program objectives, goals, and action plans. Finally, it describes specific Technical Data Bank service concepts being considered for implementation and indicates expected user reactions to these services as voiced by future program participants. The NASA Centers, their system contractors, subcontractors, and microcircuit vendors are considered as a single composite group in this analysis.

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LIST OF EXHIBITS AND FIGURES

A. NASA'S NEED FOR A MICROCIRCUIT RELIABILITY PROGRAM

> "Available electronics equipment does not meet the needs of many current and future space programs. Most of the electronics equipment available today is an outgrowth of commercial or military technology which was predicated on different applications in a much less severe environment than space. For example, electronics equipment developed in accordance with military specifications will operate reliably at temperatures up to 165° F, whereas future space missions will require maximum temperatures of hundreds, or even thousands, of degrees. Space electronics is a relatively new field; there is no pipeline filled with proven components, techniques and practices that can be used to build envisioned operational systems. Further, there is little likelihood that they will develop independently. Since space-qualified electronic components and systems, once achieved, represent a limited market, industrial firms find little incentive to invest heavily in research and development to provide them."[1]

Electronics is an essential element in every aspect of space flight. Launch vehicles and spacecraft are controlled, stabilized, guided, and tracked electronically. They gather scientific information, process it, and transmit it back to earth by electronic means. On earth, the information is received, analyzed, and recorded -- again electronically. Electronic devices constitute the senses, nerves, and brain of flight vehicles. Without electronic sensors, communication links, controls, and computing facilities, present achievements in space exploration would have been inconceivable.

The largest single cause of space flight failures is electronic failure. Most current failures result from the marginal reliability of electronic parts in space. Ranger V operated perfectly for the first seventy-three minutes of its journey to the Moon. At the end of that time, a short circuit developed in the power distribution system. Within a few hours, the spacecraft's batteries were completely drained and communications control and guidance failed. The otherwise successful Telstar satellite

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[1] Quotation from Administrator Webb's letter to Hon. John W. McCormack, January 31, 1964, Letter of Transmittal, Congressional Report on the Electronic Research Center.

encountered technical difficulties early in its operational life because its transistors and solar cells were unable to withstand conditions in space. Many other examples illustrate the difficulties that have, in the past, been presented by electronic devices. Only relatively simple systems -- incapable of doing many of the needed space jobs -- have demonstrated reliability adequate to count on operation beyond a relatively short time.

The space electronics problem grows out of several basic factors. First is the space environment itself. Although electronic equipment of great complexity, capability and reliability can be made to operate on Earth, it is in space, beyond the Earth's protective sheet of atmosphere, that electronic equipment meets its crucial tests. In the near perfect vacuum of space, insulation cracks and dries. Radiation damages transistors, diodes and solar cells. Both temperature levels and cycles are more extreme.

As probes become deeper and scientific objectives broaden, operating conditions become still more severe and must be endured for longer times. The reliable operating life requirements for planetary missions are portrayed in Figure 1. Temperatures, more extreme than those encountered in near-Earth space, will require electronics systems capable of meeting performance specifications presently unachievable. Heat near the Sun will destroy plastics, overheat components, and boil away liquids. The atmospheres of other planets, such as Mars and Venus, will present new sets of hostile conditions under which equipment must operate reliably. The plasma streaming from the Sun, and the high-energy elementary particles produce environmental effects totally unlike those found on Earth. The high gravitational and intense radiational fields of Jupiter will impose still other harsh demands. Planetary probes that can withstand sterilization temperatures without being damaged and their reliability impaired, or their useful lifetime shortened, must be devised to avoid contamination of other bodies in space.

Another serious difficulty grows out of this basic fact: to perform advance missions, launch vehicles and spacecraft will be more complex, and hence inherently more susceptible to failure. An example of the trend toward ever increasing complexity can be seen in successive generations of space vehicles. Many points in the electronic circuitry and other systems of vehicles are monitored and telemetered back to Earth. The Redstone had about 100 such test points; Jupiter had 250; Saturn I has some 1000, and Saturn V will have nearly 2300. Prior to on-board computers, the number of test points was roughly proportional to the

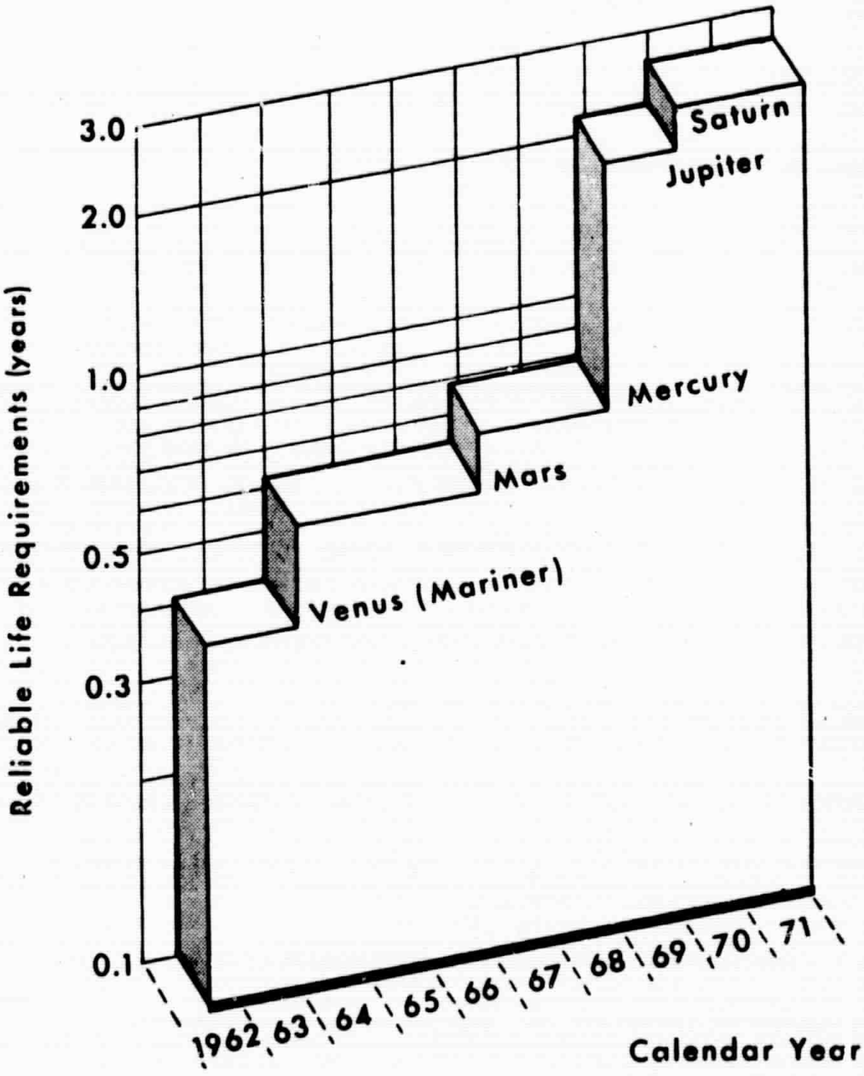


Figure 1

Reliable Life Requirement for Future Planetary Missions complexity of the equipment on board. In the future, complexity will substantially increase as more data processing is performed by on-board equipment.

A third factor limiting the capability in space stems from the fact that space systems are new and will, for the most part, remain predominately few-of-a-kind development items. Lack of a production follow-on rules out the normal opportunity to isolate and correct faults and weak points as operational experience grows. The expense of space systems in launch operations precludes the trial-and-error approach. Rarely has man attempted in the past to build machines that must operate throughout their useful lives without maintenance or attention. But this is essential in space where human life, as well as multimillion dollar spacecraft, could be lost because of the breakdown of a single minor part.

Wherever performance characteristic requirements can be met, microelectronic circuits are attractive for use in NASA programs because of the higher order reliability they potentially offer. Whole functioning circuits, such as basic amplifiers or logic networks, can be made from a single block of semiconductor material. The resulting circuit may be a single monolithic structure with the potential reliability approaching that of a single semiconductor device. It replaces, perhaps, scores of parts, eliminating the troublesome failure-causing connections between them, and consequently increasing overall system life. The microelectronic function block is also attractive because it drastically reduces size and power consumption.

Future NASA missions will require development of the full potential in reliability that microcircuit technology can provide. Self-checking, redundant, and reprogramming systems design, and the longer-range concepts of self-organizing systems, provide additional avenues to reliability. However, the basic devices must be designed, produced, and applied, using the best scientific research, engineering, and production skills available to meet NASA's requirements.

B. OBJECTIVES OF THE PROGRAM

A NASA Reliability Subcommittee on Microcircuits has been assembled with representatives from each of the major NASA Centers using microcircuits on space projects. The intent of this group is to achieve, through joint action of the individual Centers and NASA Headquarters, a cohesive and coordinated program. The program has two primary objectives:

1. Increase reliability in space-borne equipment utilizing microcircuits.
2. Reduce duplicative costs associated with the present procurement of microcircuits.

NASA's Electronic Research Center, ERC, is focusing several research efforts and manpower resources directly in support of programs to increase reliability in microcircuits. While ERC will play a major role in pursuing reliability program objectives, it will be advisory to and in support of project responsibilities and technical expertise residing at the NASA Centers.

Achieving Increased Reliability

Increased reliability is needed to accomplish long life capability wherever electronic equipment is used in systems for space exploration. In addition to exploratory development of new microcircuit devices, the present processes of circuit design, manufacture, and application of microcircuits must be examined to identify those areas where procedural and technique improvements can be made.

NASA has several contracts with industrial firms to examine new techniques and new phenomena with the objective of achieving the higher stress properties required for performance in hostile environments. Other contracts are focused on developing a better understanding of present-device technology with special emphasis on reducing failures resulting from limited knowledge of how to design and produce reliable, long-life microcircuits.

Several of the major NASA Centers have microcircuit laboratory facilities participating in development of a better understanding of how to apply microcircuits to meet space mission requirements. Through the Subcommittee, the Centers are working together towards the development of more effective and uniform means of specifying their requirements.

Large Scale Integration (LSI) looks particularly attractive, representing one of the areas where microcircuit design considerations are being given intense study. Using this design concept, placement of larger functional blocks of circuitry on a single surface further exploit reductions in external connections and homogeneity in both active and passive elements.

NASA is looking to industry to develop and manufacture the microcircuits needed to build the electronic equipment for space missions. Both NASA Centers and their systems contractors need to employ technically sound and effective means for assuring that devices are manufactured under conditions demonstrated to be capable of producing the very high quality products needed. This is a tough challenge, considering the rapid development of microcircuit technology.

In contrast to discrete electronic components, microcircuits are more "custom"-made. Therefore, the number of units over which investments for quality assurance must be amortized is fewer. NASA recognizes the need to develop in cooperation with industry, a workable reliability program that will enable NASA to meet its mission goals.

No less important than the proper design and manufacture of reliable devices is the necessity for skill in applying microcircuits in every sense -- electrically, mechanically, thermally, etc. Due to the high decentralization of NASA project groups, a more effective means is needed to achieve rapid, comprehensive, and accurate communication of microcircuit data and information in order to fully exploit detailed engineering knowledge accumulated on performance characteristics in NASA space programs.

Specific features of NASA's microcircuit reliability program plan are addressed to these areas of need. When coupled with expected advances in new microcircuit technology, NASA will be on its way to achieving the higher orders of reliability in electronic equipment required for future missions.

Reducing Non-essential Costs

A large measure of the success of NASA programs to date can be credited to the manner in which projects are carried out amongst the decentralized capabilities of NASA Centers. In an area of technology so universal and vital in impact on NASA missions as the application of microcircuits, there will be duplication of effort. NASA Centers must continue to carry out work on a decentralized basis to meet project requirements. Much of the duplication in learning, study, and investigation of microcircuit technology is important to retain for that reason. On the other hand, several research and procedural areas exist where coordination amongst the Centers is necessary to produce more effective use of manpower, to reduce the expense of device testing, and to increase the rate of NASA-wide data gathering necessary to make maximum use of this rapidly advancing technology.

Three areas where new NASA-wide practices can pay off bear examination:

1. Reduced duplication of application engineering effort
2. Development of more effective and efficient testing methods
3. Organizing a method for pooling experience history

Each of these is being given specific consideration in the NASA Microcircuit Reliability Program.

1. Reduced Duplication of Application Engineering Effort

At the present time, NASA Centers are procuring and applying microcircuits on what may be considered an independent basis. There are no NASA-wide specifications or standards describing performance characteristics, qualification tests, screen or acceptance tests, or other basic engineering documents used in microcircuit work. One of the activities of NASA's Microelectronics Reliability Program is the preparation of specifications and standards through joint participation of NASA Centers. These will eliminate arbitrary differences and combine basic requirements, where feasible, into guidelines, procedures, and specifications for NASA-wide use. This will substantially assist in the technical work of preparing specifications and data packages for microcircuit procurements.

The opportunity to reduce unessential duplication of engineering effort actually begins much earlier than at the point of procuring the devices. Besides vendor salesmen, there are only a few limited commercial microcircuit data and information services available to assist in keeping electronic equipment design engineers abreast of new applications information and new additions to microcircuit manufacturers' product lines. Far greater assistance, than available now from any source, can be provided by a NASA-wide system that will provide equipment designers with applications data in depth containing "hard to get" manufacturers' engineering parameter spectra data on microcircuit devices. These additional data have been obtained by a few equipment designers through their working closely with suppliers. However, for many prospective users, this data is hard to get on all devices of interest as it has not been made generally available through initiative of the manufacturers. Advanced information on new developments can also be obtained, though this is obviously not generally publicized by the manufacturer.

When an equipment designer focuses his interest on a few particular microcircuit devices, the data desired to refine the application choices quickly exceeds the marketing-type information generally distributed. At present, the best channel for obtaining additional information is the vendors' marketing organization. Since it is the intent of the vendor to fully investigate the sales opportunity of each considered use, the investment of an engineer's time required to obtain the desired data via this source is frequently in excess of what it should be. We are not saying that the marketing organization of the vendor cannot be of service to the equipment designer. Certainly it can be. However, efficiency for all concerned would be better served if the equipment designer can get technical information at a time and in the depth desired without feeling he has to negotiate or swap "something of value" for the information he needs.

The NASA Reliability Program concept includes a Technical Data Bank which will serve not only as a repository, but as a communication channel for application engineers and others to obtain current and comprehensive information on what is available and back up technical information in depth. The system will also provide a means for providing up-to-date reference documents such as specifications, procedures, and guidelines as produced under the Reliability Program for NASA-wide use in microcircuit procurements.

2. Development of More Effective and Efficient Testing Methods

Another result of the relatively uncoordinated actions presently taking place at NASA Centers using microcircuits, is the difference in approaches to specifying test procedures. This is a complex subject, as testing relates very much to specific device and intended application use. Because the subject is complex, ERC is examining underlying theory while subcommittee efforts are developing some of the procedures for carrying out both circuit qualification tests and screen tests on the basis of experience to date. These tests, of course, bear directly on the measurement and assurance of reliability. They are being carefully considered under the Microelectronics Reliability Program.

Due to the rapid introduction of new microcircuit devices and future trends of large-scale integration, it is already clear that traditional life testing methods of qualifying electronic components will be unsuitable for microcircuits. It is estimated that in the next four years the present number of 1300 device designs will grow to 10,000. If even a sizeable fraction of these new devices were to require full qualification tests at approximately $20,000 each, the expense would be enormous. Further, it can be shown that 129,600,000 circuit test hours, allowing only one failure, are required to obtain a 0.003 percent per thousand hour failure rate at a 90% confidence level. Also, the assumption of consistency and homogeneity in microcircuit devices of the same type produced over a period of such life testing is far less likely than in the case of more conventional and individually less complex components produced by a less rapidly changing technology.

Fortunately, microelectronic devices, though different in their performance characteristics, are produced within a relatively few number of "families." The family categories are closely tied to manufacturing methods and process steps as integrated into operating manufacturing lines. The Microelectronic Reliability Program is giving special attention to developing a technically sound basis for reducing the amount of individual circuit type qualification tests by concentrating on procedural methods for assuring that manufacturing line process controls at critical points are within limits necessary to assure the homogeneity of device properties. This approach offers promise of reducing the expense and time consumed in performing qualification tests for new types of units manufactured from a line that is kept under satisfactory process control.

3. Organizing a Method for Pooling Operating Device Experience History

NASA's programs embrace many and varied applications for microcircuits. Considerable overlap in environmental and circuit conditions for these applications exists amongst projects. A service under consideration for the Reliability Program Technical Data Bank is the collection of experience history from among the several NASA projects to bring pooled experience to all present and prospective NASA program users of microcircuits. It is recognized that this will require a considerable effort to assure the validity of data and their compatibility prior to producing cumulative compilations or mixing of the data from different sources. This objective certainly cannot be achieved through indiscriminating acceptance of data from all sources, followed by compilations produced in a haphazard manner. The effort required to maintain quality and validity of pooled operating experience history may be considerable. For many NASA programs the only data likely to be in existence would be from prior NASA work. The data bank simply provides a mechanism for collecting and organizing NASA produced environmental test data on microcircuits. The high expense of running duplicative microcircuit tests under unique operating conditions represented by space environments can be partially reduced if an orderly and effective data bank is operated in this way.

C. ACHIEVING INCREASED RELIABILITY WITHOUT RETARDING NEW TECHNOLOGY DEVELOPMENT

Alternative Methods Needed

Reliability is an essential feature of microcircuits used for NASA programs. At the same time it is recognized that in order to develop the capability of improved performance within high stress environments encountered in space missions there must be a vigorous, continuing development of new microcircuit technology. Some alternative to the use of traditional quality assurance procedures for procuring and qualifying devices according to individual standard parts specifications is called for.

The underlying philosophy of an approach being developed by the Microelectronics Subcommittee concentrates on a manufacturing process line evaluation method to monitor variables effecting homogeneity of the units produced. The concept is based on the conviction that screen tests at time of acceptance cannot, by themselves, give adequate assurance on microcircuit reliability.

Where large quantities of relatively simple discrete electronic components are manufactured by well-known process steps, a statistically sound basis can be built up for using small lot sample tests in maintaining overall production quality. This procedure rests on the knowledge of the behavior of the characteristics of a very large number (the universe) of units produced by the known manufacturing method. Where the behavior of characteristics of a large number are not known, or are sporadic, it is impossible to make statistically sound statements about the degree of equivalence in properties of a sample lot to those of the universe.

Assuring Homogeneity

The universe for microcircuits is not known and also appears to be non-statistical in pattern; therefore, no theoretical basis can be provided for drawing conclusions about a production lot from the testing of a small lot sample. This situation has a direct bearing on the methods for acceptance testing of microcircuits. It results in the necessity to perform 100% screen tests prior to acceptance of any units in a manufactured lot. There is insufficient basis to draw conclusions about the probability of any of the units being alike. They all must be tested.

To assure the adequacy of devices to meet certain environmental stresses, a number of initial units are life tested at high-stress levels. These tests either destroy or endanger further satisfactory operation of the device. These qualification tests, therefore, cannot be performed each time a manufactured lot is screened for acceptance. Still, there must be some way of providing assurance that units receiving 100% screen tests possess a similar, if not identical, ability to meet the high-stress conditions met in earlier qualification tests. The lack of a statistically sound basis for stating the probable equivalence of any manufactured lot to the units previously qualified still presents a problem. Each manufactured lot can be considered as a sample lot related to a universe of units that still shows no useful statistical properties at the present time.

The most direct assurance of the ability of manufactured units to withstand stress levels equivalent to those tested at time of qualification is that of assuring the homogeneity of units manufactured. This is the objective of line evaluation. In short, the microcircuit manufacturer will be asked to identify his critical process steps and the limit of the process control variables tolerable at these points. Continuing documented evidence is then to be made available showing that manufactured lots subsequent to those submitted to qualification tests have been produced by the same line maintained within control limits. In this manner, the Reliability Program expects to substantially increase the assurance that units passing acceptance tests (screen tests) have properties equivalent to those units given previous qualification tests.

Reducing the Expense of Qualification Testing

Another problem is the expense associated with qualification testing. In order to reduce the expense of completely testing each new microcircuit design introduced, a basis is needed for extrapolating qualification test results of family member devices tested in the past. Here the program rationale depends on consistency of the manufacturing processes employed to produce devices in the same family.

The Subcommittee is investigating the feasibility of using circuit qualification test procedures that will allow technically sound extension of a portion of the qualification tests to apply to new members of the same families that have produced circuits demonstrating satisfactory qualification test results. This, too, requires assurance that homogeneity and consistency have been maintained in the manufacturing method at the time qualification test units were tested and the time when new family members are introduced and qualified via abridged qualification tests. If manufacturing changes are introduced, they must be shown by experiment to not have deteriorating effects on quality and that extrapolation of previous qualification test results will have a technically sound basis. Otherwise, new circuit qualifications will be required.

In Summary

The two objectives of line evaluation are (1) to provide a method for maintaining visible evidence of adequate process control, thereby assuring homogeneity of units manufactured at different times, and (2) removing the need to constrain design choices to the use of standard microcircuits which could be rapidly obsoleted by new microcircuit designs.

It is recognized that peripheral access to a microcircuit manufacturer's process technology borders on his specialized know-how in a business-sensitive way. By giving the manufacturer the initial opportunity to identify critical process points, he chooses the extent of exposure of his proprietary know-how. In most cases, vendors will be able to provide ample areas for visible evidence that production is conducted within established process control limits at all times.

D. SPECIFIC PROGRAM GOALS AND OPERATING PLANS OUTLINED

The NASA Microelectronics Reliability Program is a system of carefully defined surveys, specifications, tests and data exchange methods being designed to give NASA and its system contractors information on qualified sources of supply for reliable microelectronic components. By its application, procurement can be speeded up, duplication of effort and costs can be reduced, and high confidence in the reliability of the microelectronic products can be developed. The Flow Diagram of Figure 2 depicts the major program activities under development.

The line evaluation, data exchange, and standardization aspects of the program are to be handled on a NASA-wide basis. Detailed specification for individual circuits and procurement action will be carried out by individual NASA Centers or contractors who place their own orders with qualified vendors. The provisions of the Program will be applicable to all NASA Centers and to all contractors to the extent called out in their contracts.

Vendor Approved List (VAL)

Procedures are being developed to enable the performance of vendor quality surveys as the first step in the process of qualifying a vendor's product for use by NASA and its contractors. The survey team will be NASA approved with representatives from NASA Centers. The surveys will be performed in a manner to answer the question: "Is this manufacturer likely to be a responsible and dependable producer of microelectronic products for NASA programs?". The survey will evaluate the vendor's financial position, technical capability in general, reputation of management and internal control procedures to answer this question.

These surveys will be similar in most respects to vendors' surveys now conducted as a standard practice in industry as well as in government procurement.

Line Evaluation List (LEL)

As described earlier, the assurance of a manufacturer's line being kept within limits of critical process control points is an essential part of the reliability assurance method to be used in procuring microcircuits. It also provides the sound technical rationale needed to shorten qualification tests on new microcircuits of previously qualified family units.

Line evaluation, then, establishes a vendor as a qualified source of families of microcircuits within certain carefully defined limits. In

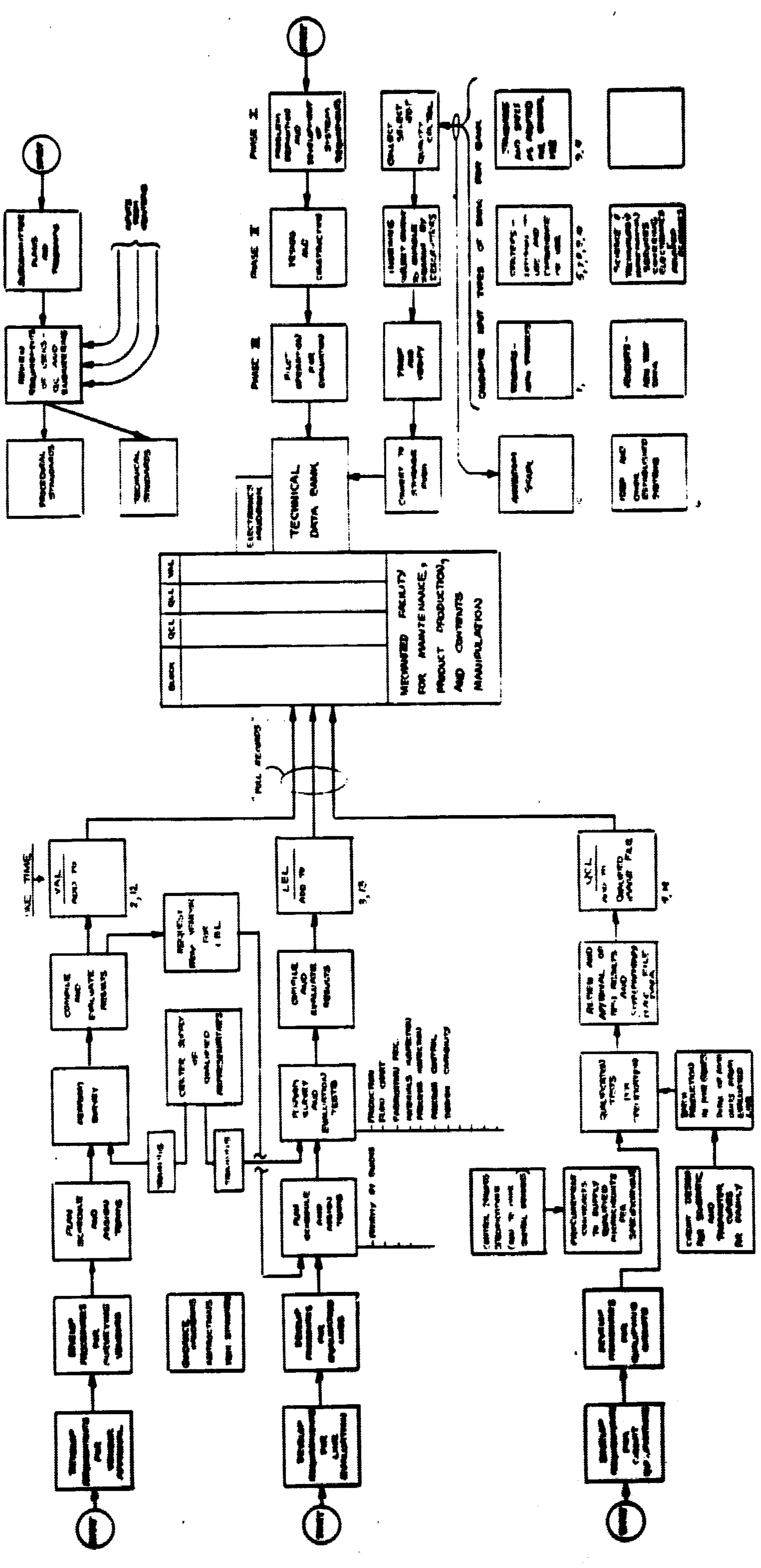


Figure 2. Plan of Action Diagram

general, vendor quality surveys are done once per vendor, whereas line evaluations are usually done for each family of microcircuits that a vendor may wish to be evaluated. Each specific circuit type to be purchased under the Program will be subjected to circuit qualification by the actual buyer prior to its production, with each circuit identified by a discrete part number normally qualified only once.

The approach being taken to develop LEL procedures is to solicit from a manufacturer the identification of his critical process steps and the limits within which process control must be maintained in order to achieve the desired end product in all its properties. The survey to be performed for line evaluation includes the collection of substantial process flow data and verification that internal process manufacturing quality control points are incorporated by the manufacturer and that these quality control procedures are, in fact, understood and carried out by manufacturing personnel on the line.

Evaluation of a vendor's line means that he is eligible to receive requests for quotations from NASA Centers or their contractors for delivery of microcircuits within the circuit families for which he has had lines qualified.

Qualified Circuit Lists (QCL)

When required by NASA Centers or their contractors, specific microcircuits will undergo qualification tests which fully qualify the unit for its application under electrical circuit and environmental conditions. Each circuit will normally be qualified only once. However, full records on results of qualification tests will be maintained in the Technical Data Bank available throughout the NASA system and additional qualification tests may at times be necessary to validate the utility of the device under substantially different conditions.

As new circuit designs are introduced within families that have produced qualified circuits, the qualification tests for the new units may be abridged. Which tests may be omitted is left to be determined for each case at the time qualification of the new unit is requested.

Technical Data Bank

It has been recognized that the Reliability Program requires a capability for providing storage, retrieval and analysis of technical data on the type of performance characteristics, microcircuit fabrication methods, tests results, application history, field performance history and status of VAL, QLL and LEL. This is intended to provide a permissive, yet rapid, channel of communication -- transcending both time and distance -- amongst NASA Centers and their contractors. It will facilitate group learning and will result in better use of microcircuits on NASA programs.

The Technical Data Bank under consideration focuses on eight (8) types of key users, including circuit designers, component specialists, equipment packaging engineers, reliability engineers, procurement buyers, quality assurance, quality control and research directors. The need for technical information and data services required by these user groups when dealing with microcircuits is being carefully examined in order that the Technical Data Bank may responsively provide the required information services.

Section E describes the Technical Data Bank service concepts in detail.

E. VIEWPOINTS OF PROSPECTIVE PARTICIPANTS

Information Dynamics Corporation, NASA's contractor for the design and development of the Microelectronic Technical Data Bank, has conducted approximately 30 field interviews with NASA Centers, NASA prime contractors, subcontractors and microelectronic manufacturers as future participants in the program. The primary objective of these interviews has been the determination of information service needs. Services must be specific and responsive to the decision-making associated with the application and use of microcircuits within NASA programs. These trips have also afforded an opportunity to obtain the viewpoints and reactions of personnel in these organizations to aspects of the overall Reliability Program.

The attached foldouts of Exhibit I summarize the viewpoints of interviewees on the points indicated. These are grouped under the areas of:

- Program Objectives
- Program Goals
- Program Actions (as required of participants)
- Technical Data Bank Service System Operation
- Specific Data Bank Service Concepts

An overall statement concerning these findings is that the overall Reliability Program, in its early stage of development, is recognized as a necessary program with potential to provide a technically sound approach towards the objectives of achieving higher microcircuit reliability, while at the same time reducing substantial costs presently associated with procurement and application.

The specific Data Bank services under consideration are listed and described in Exhibit II. The priority of need expressed by interviewees is grouped and shown under three (3) levels:

A. Essential
B. Desirable
C. Optional

Note that these services are being designed to meet information needs at the level of specificity indicated in Exhibit III.

Figures 3 and 4 depict the expected deployment of Data Bank facilities and the nature of access capabilities at each node in the system.

ACCESS NODES & DATA RETRIEVAL CAPABILITIES

	ACCESS NODE	INDEXES	FULL TEXT FILES	COMPUTER MANIPULATION CAPABILITIES
INDIVIDUAL DESK-TOP	1	X		
NASA CONTRACTORS AND SUB-CONTRACTORS	2	X	X LIMITED	
NASA CENTERS	3	X	X	
NASA-ERC	4	X	X	X

Figure 3

DEPLOYMENT OF SERVICE CAPABILITIES

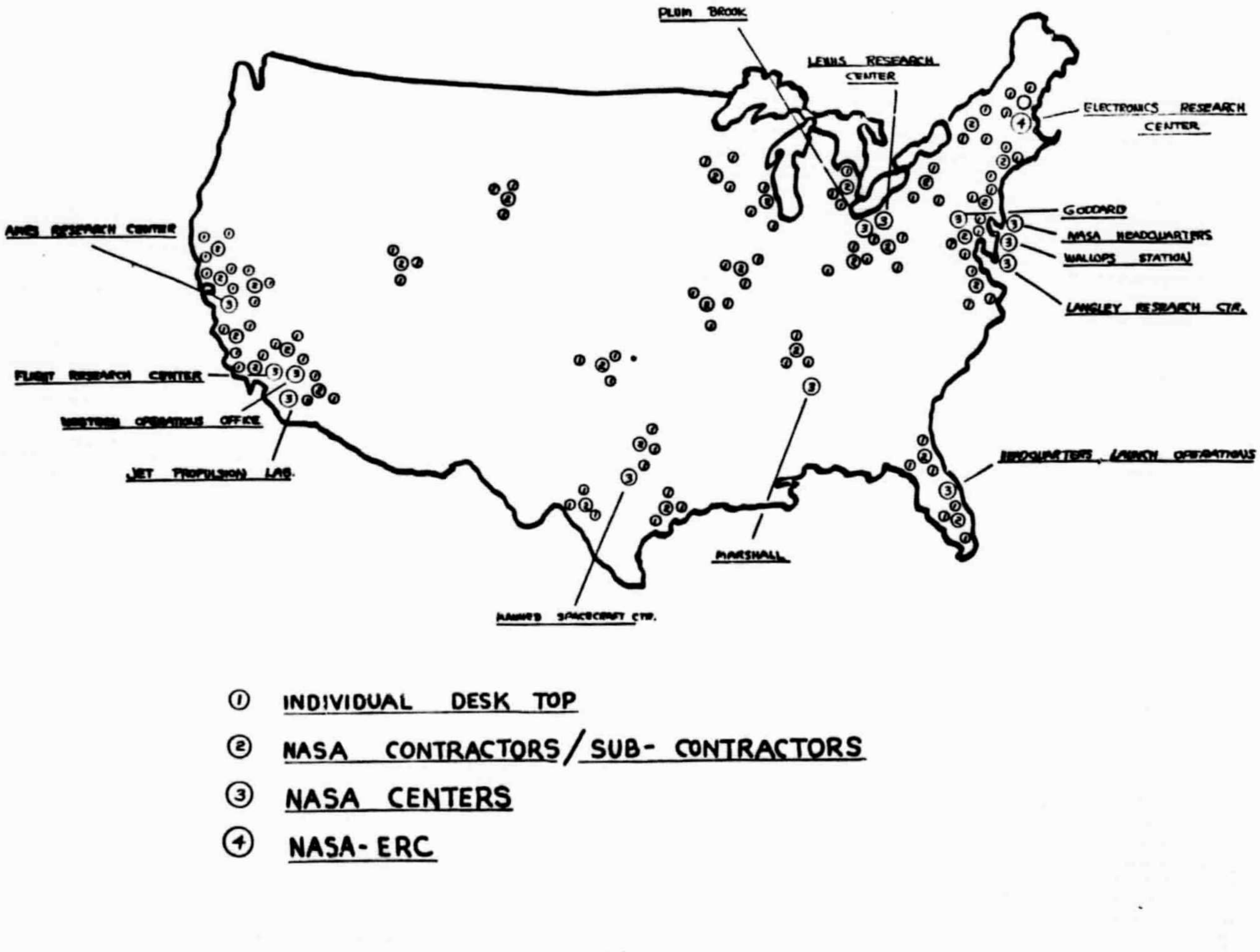
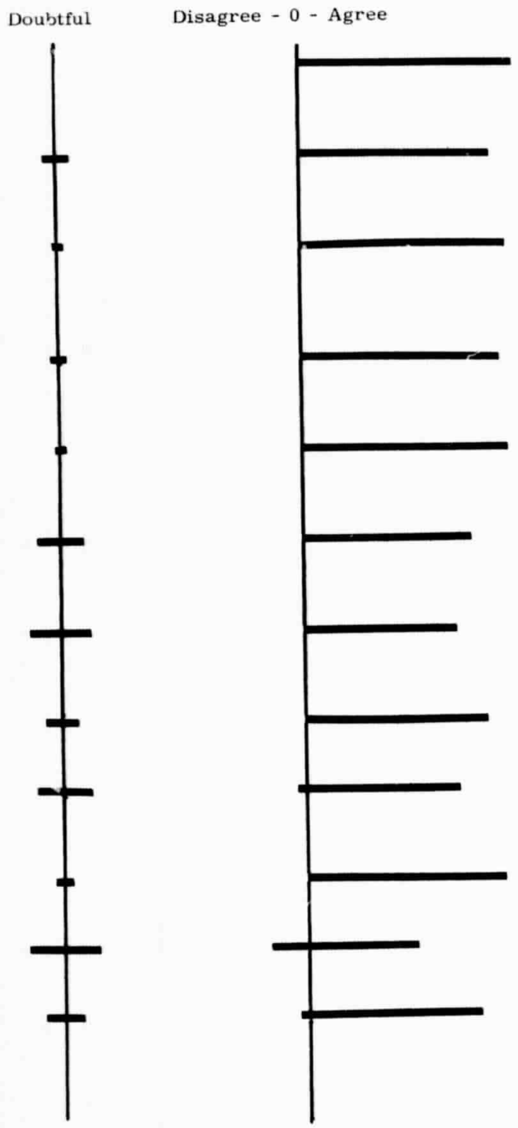


Figure 4



1.0 <u>Program Objectives</u>

1.1 Though NASA missions may be judged successful up to this time, it is recognized that future manned space flight missions of longer duration require a higher order of reliability in microcircuits than has been demonstrated for many of the units now being used.

1.2 Microcircuit vendors can be expected to better meet NASA's needs for reliability and quality assurance if NASA centers will coordinate their requirements for qualification tests, methods for testing, and related procurement specifications.

1.3 This program should provide constructive help to each of the NASA centers procuring and utilizing microcircuits by collecting, organizing, and furnishing engineering data and information needed to maintain awareness of availability, make selection amongst alternatives, and determine status of present program use.

1.4 This program will enable better <u>application</u> of microcircuits and thereby foster improved <u>system</u> reliability by providing a communication channel that facilitates group learning and allows participants to benefit from the experience of their remote colleagues.

1.5 This program should eventually assist in achieving improved overall system reliability through providing more substantial and authoritative data on actual reliability and performance history of microcircuits used in electronic equipment.

1.6 By reducing the amount of redundant investigation now needed at each center each time a new circuit application is encountered, this program should improve the utilization of skilled manpower, both at NASA centers and within their contractor project teams.

1.7 If responsive to the information and data needs of engineers and others on project teams utilizing microcircuits, the cost of implementing the proposed program and operating the associated technical data bank is likely to be several times repaid through savings in present manpower effort required.

1.8 It is definitely possible that the increased microcircuit use reliability resulting from such a comprehensive program as this may prevent the abort of a costly mission.

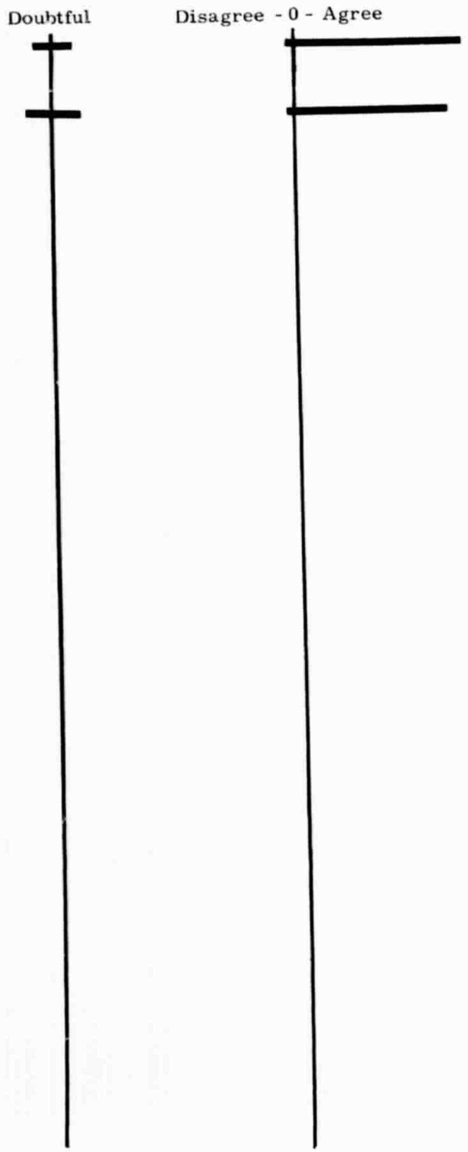
1.9 The program of qualification and information services from the associated data bank should result in speedier procurement and, therefore, allow improvements in project scheduling on electronic equipment employing microcircuits.

1.10 It is important to obtain meaningful quality assurances on each lot of microcircuit units produced if reliability requirements are to be met.

1.11 Information available from even 100% screening acceptance tests alone is insufficient to make statistically sound statements about the projected reliability of the units.

1.12 Line evaluation as a means of assuring a higher degree of product homogeneity via maintenance of known limits on process controls (if properly implemented) should result in increased microcircuit reliability.

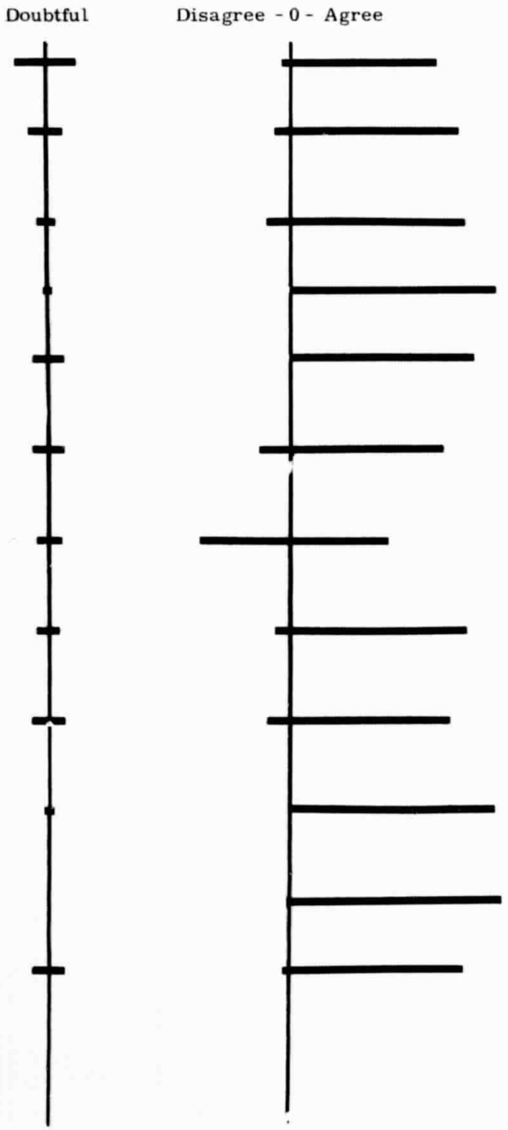
EXHIBIT I



1.13 A combination of screen tests (acceptance) and line evaluation can provide a higher assurance of reliability than from screening alone.

1.14 Line evaluation procedures in combination with circuit qualification tests can achieve a significant degree of quality assurance over production of new circuits being developed (same family as qualified circuit) without requiring complete circuit qualification tests for each new circuit.

EXHIBIT I
22



2.0 Program Goal

2.1 Vendor surveys are an established and acceptable method in industry for providing assurance to a purchasing organization as to the capability, responsibility, and dependability of the product producer.

2.2 Performance of VAL surveys of microcircuit manufacturers by NASA-wide teams will substantially assist both user groups and the vendors by reducing repetitive and redundant time-consuming investigations of supplier capabilities.

2.3 Except for approval status, the detailed findings of VAL surveys, though important to the NASA Program Coordinator, are not needed in the field and should be held confidential.

2.4 A vendor's survey need not be repeated more than once every three years unless major changing circumstances warrant it.

2.5 Line evaluation procedures (that assure maintenance of adequate process control at critical points in the manufacturing cycle) provide a technically valid means of monitoring significant factors which would have a direct effect on the homogeneity and therefore reliability of units produced.

2.6 With care, (and with industry's help) NASA should be able to establish line evaluation procedures which will provide the required visibility of "satisfactory" process control without jeopardizing proprietary know-how.

2.7 Reliance on line evaluations as a basis for extrapolating reliability expectations for new circuits in a family with prior qualified (full qualification tested) circuits is sufficient to eliminate any need for new circuit qualification tests.

2.8 Assuming a prior family circuit member has been qualified and critical differences in manufacture and/or application of a new circuit have been differentially qualified, a higher level of confidence in reliability of the new circuit is warranted from an evaluated line than from an unevaluated line.

2.9 The qualified line concept, if properly done, should substantially reduce the necessity for full qualification tests (approximately $20,000 each) for each and every new circuit, thereby enabling greater NASA program use of new circuits at less cost.

2.10 It is desirable that NASA develop a common set of guidelines and specifications to implement the program utilizing personnel from NASA centers who understand procurement practices and related program needs in the field.

2.11 Highly qualified technical personnel skilled in microcircuit technology will be required to carry out the program.

2.12 The VAL, LEL, and QCL concepts are compatible with the specific goal of retaining decentralized responsibility for circuit selection, qualification and procurement action.

EXHIBIT I
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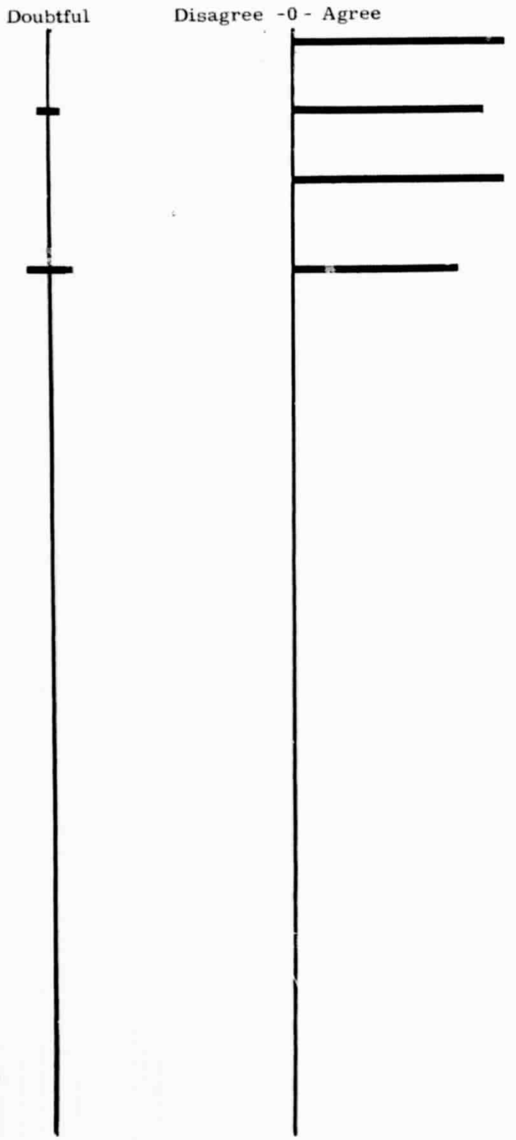


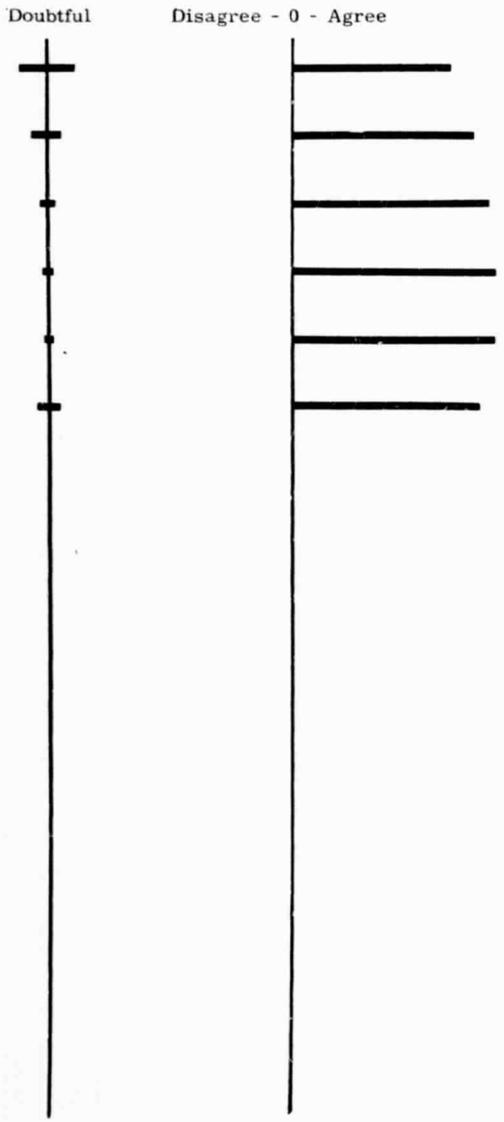
2.13 The technical data bank must be user service oriented in its design to become an effective communication means, accepted and used throughout the NASA programs.

2.14 Technical information provided by the program's technical data bank must be broader in scope than the subject of reliability alone if major service needs of users in the field are to be met.

2.15 The data bank activity should (on its own initiative) obtain, communicate, and encourage use of microcircuit information and data of prime need in device selection, quality assurance, and related decisions amongst NASA centers, their contractors, and subcontractors.

2.16 The data bank should also serve as a research capability for storage, retrieval, and analysis of technical data on type, performance characteristics, microcircuit fabrication method, test results, application history, field performance history, etc., as needed for macroscopic investigations of cause and effect of microcircuit performance.

EXHIBIT I



3.0 Program Actions

3.1 The program will require development of guidelines, procedures, and standards. It is appropriate that these be developed with the help of personnel at various NASA centers.

3.2 The survey teams must be manned by competent technical personnel. It is appropriate that teams be assembled using manpower skills in microelectronics at NASA centers.

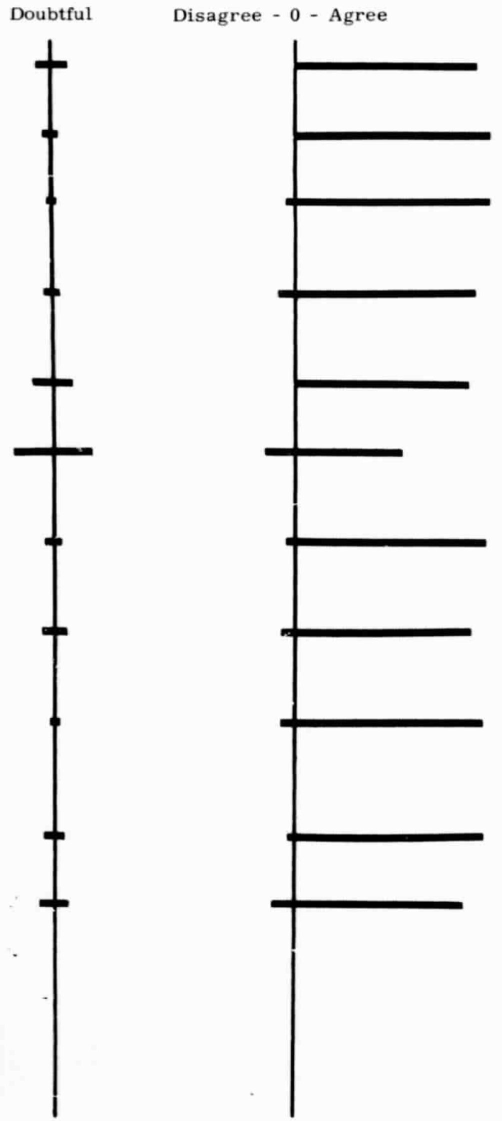
3.3 NASA centers and their system contractors will be able to supply a substantial amount of useful data of early value to the data bank.

3.4 NASA centers and their contractors can be expected to utilize those data bank services described and to update the data bank with information concerning their own procurement, test, and use of microcircuits.

3.5 NASA centers and their contractors will be able to achieve higher microcircuit reliability in their system application when the procedures and information services of this program are implemented.

3.6 NASA centers and their contractors will be able to achieve significant direct savings in information gathering and evaluation time, in the costs of preparing specifications, in requirements for evaluation and qualification tests, and in carrying out microcircuit procurements.

EXHIBIT I



4.0 Technical Data Bank Service System Operation

4.1 NASA contractors, as well as the centers, should have direct decentralized access to data and information services to select, evaluate, apply, and determine prior NASA approval of all available microcircuits.

4.2 Certain program-developed information such as full text details of VAL and LEL surveys would be inappropriate to let out of NASA control and, therefore, must be restricted to specific NASA approved users.

4.3 The data bank can profitably serve two important functions: (1) as a facility that communicates job-oriented (equipment design, quality assurance, etc.) data and information to decentralized NASA project personnel and (2) as a research support tool enabling analytic corrolation studies and specialized searches.

4.4 The data bank should not serve as a general collection point for any and all information and data related to microcircuits, but should select data on the basis of a definite criteria combining authenticity and a measure of value added to the bank.

4.5 Collection, evaluation, selection, and data extraction will be basic input processing operations needed to maintain the data bank and its services.

4.6 Remote access to the computer-based technical data bank at each of the NASA centers would be desirable for computer-aided design steps in microcircuit applications and for analytic compilations of device operating experience history.

4.7 Much of the data and information needed at decentralized points will be textual in nature (application data, test reports, etc.) and can best be disseminated as hardcopy and/or micrographic decentralized resource files that are updated with current information from the centralized data bank facility.

4.8 Printed catalogs (device parameter listings), data bank indexes and other printed products should be widely distributed within NASA centers and contractor organizations to assure convenience and ready access to data files and search facilities of the data bank.

4.9 If the operating data bank is designed to serve the job requirements of circuit designers, component specialists, equipment packaging engineers, procurement buyer specialists, quality assurance specialists, quality control reliability engineers, and research directors (pursuing advanced technology in microcircuit labs), the other users should find the data bank adequate to serve their needs.

4.10 The time required to get information and data from the system in response to needs in the field should not exceed a few hours and preferably be less than 30 minutes.

4.11 The system should contain information on all microcircuits including monolithics, compatibles, passive thin films, passive thick films, multichip, active thin films, and magnetic thin films.

EXHIBIT I

Reaction to Specific Set of Data Bank Service Concepts

The specific set of service concepts now under consideration is displayed on the attached worksheet in matrix form with an indication of the users considered as primarily concerned with each of the services.

The following is an explanation of each of the service concepts:

#1. Includes performance data as widely available from manufacturers' data sheets, as supplied in response to specialized requests from manufacturers engineering and QA group, experience history (favorable or unfavorable use of microcircuit under known conditions of environment envelope) plus any other points of information feasibly acquired and organized for presentation in graphic record form. This may also expand to include a computer data file styled for use in computer-aided design facilities (the computer program would be identified under Service 19 below).

#2. Simply a listing of vendors with a current approval status.

#3. Same as 2 with a line evaluation status.

#4. Same as 2 with a specific microcircuit qualification status.

#5. This file (primarily graphic text) will operate as a directory that includes substantive information on quantities, etc. that responds to the requirement to facilitate and encourage group learning and mutual benefit from group experience.

#6. In a fashion compatible with existing reliability report systems, this system will also provide access to data and information reported on life tests, field failures, failure analyses, in short, all useful information relating to reliability. Also in a fashion yet to be developed, a degree of quality control of entry of the reports into the system will be exercised to screen out those reports containing information of questionable validity. It is recognized that some reports contain invalid findings and may, if misleading, trigger costly actions detrimental to NASA's interests. The service will, therefore, not blindly accept reports from all sources at all times.

#7. Screening is expected to continue. Line evaluation is not intended to be a replacement for acceptance testing. The screening procedures used for acceptance testing are to be included as information in the system, as are results of screening tests.

#8. The full-text report resulting from qualification tests is considered necessary to be made available in the field in order to enable a determination of the applicability of extent and conditions of qualification tests to cover new applications.

#9, 10, 11. Recognize the necessity to present full-text specifications from the general through first level and detailed reference specifications needed when preparing control drawings.

#12, 13, 14. If considered a formal part of the technical data bank, these will have availability restricted to authorized NASA personnel only.

#15. This is the "red flag alert" feature which will probably have both "positive breakthrough" and "negative alarming event" messages. Present plans call for decentralized NASA centers to determine the need and desirability of further propagation of these messages to their contractors.

#16. This service is the use of centralized computer manipulation and data file capabilities to perform complex searches both for the decentralized user communities as well as to perform analytic evaluations for the microcircuit research programs in NASA (see Service 20).

#17. This data bank can better negotiate and maintain active access to outside sources of information and will pursue within limits the handling of traffic when called upon to contact such other sources.

EXHIBIT II

#18 An easily obtained listing from existing collection and processing activities within NASA's Scientific and Technical Information Facility can be included in the graphic files in this system.

#19. In similar fashion to paragraph 18 above, a listing of computer programs related to microcircuit facilities will achieve expanded awareness and greater exploitation of NASA investments in computer programs.

#20. Primarily considered as a concentration of data files in machine-readable form, this capability will be manipulated for survey analyses (e.g., correlations of failure modes with application, failure modes with manufacturing technique, etc.) of value to research directors and others engaged in advancing new microcircuit technology.

USER CODES

CD	Equipment Circuit Designer
CS	Component Specialist
EP	Equipment Packaging Engineer
PB	Procurement Buyer
QA	Quality Assurance
QC	Quality Control
RD	Research Directors
RE	Reliability Engineer

MICROELECTRONIC DATA BANK SERVICE CONCEPTS

Relative Priority of User Requirement A	B	C	Service No.	Description	For Specific User Groups
23	4	1	1	Provide Performance Data (e. g., Mfg. Data Sheets, User Specialized Knowledge, etc.) on ALL I. C.'s in terms of Appl. Characteristics	CD CS EP RD RE 1' Computer Analysis Design
20	6	2	2	List Approved Vendors (VAL) & Maintain Current Status	CD CS EP QA QC RE All Prime Users
21	6	1	3	List Qualified Lines (QLL) & Maintain Current Status	CS QA RD NASA Control
23	4	1	4	List Qualified Circuits (QCL) & Maintain Current Status	CD CS PB QA QC RD RE NASA Control
20	6	2	5	Provide Access to Who (Program, Prime & Subcontractor) is Using Specific Devices (Quan-% Del. on Schedule & Application)	CD CS EP PB QA RE Control Access
18	9	1	6	Provide Access to All Valid Reports (both negative & positive) on Reliability Test Results, Failure Analysis Rpts. & Field Failures	CD CS EP QA QC RD RE Control Access
16	8	4	7	Provide Adequate Information to Show Basis of Screening Procedures for I. C.'s Used	CS QA QC RE
17	9	2	8	Provide Necessary Information to Determine Adequacy of Previous Qualif. Test Results (e. g., Qual. Specs., Test Proc., Results, etc.)	CS QA RE
5	11	12	9	Provide Access to General (Basic) Specifications to be cited on Control Drawings	CS PB QA QC
5	11	12	10	Provide Access to All Detailed Specs (e. g., Procurement Quality Assurance, etc.) Used by Others (NASA) For the Same Device	CD CS EP PB QA QC RE All Prime Users
1	9	18	11	Provide Access to "First Level" of Referenced Supporting Standards and Specs.	CS EP PB QA QC RE
1	5	22	12	Provide Access to Full-Text Reports of Surveys Made for VAL	CS QA RE NASA Control
1	4	23	13	Provide Access to Full-Text Reports of Surveys Made for QLL	CS QA RD RE NASA Control
1	16	11	14	Provide Access to Full-Text Reports of Tests Made for QCL	CS QA RD RE NASA Control
10	9	9	15	Provide Routine Input (Even Daily) Addendum Notices to Designated Control Points (NASA & Qualified Recipients)	NASA (QA) to CS's at all
12	10	6	16	Provide Mechanized Capability for Performing Data Bank Search per Logic Statements of Specialized Queries (EX. Fail. Rpts. on Lead Bonding under Radiation)	CD CS EP PB QA QC RD RE All Prime Users
3	15	10	17	Provide Referral to Other Information Sources Which May be of Help to Respond to User Query	CD CS EP PB QA QC RD RE All Prime Users
1	11	16	18	Provide Bibliography (Listing) of Reports on Microelectronic Technology	CD CS EP PB QA QC RD RE All Prime Users
1	8	19	19	Provide and Maintain Electronic Related Computer Program Library Service	CD CS RE
6	10	12	20	Assist in Identifying Areas Req. Further Research	RD For the Research Community

Generic Equipment Design Decision Making to be Aided by the Microelectronic Data Bank

1. What microelectronic devices exist at present time and are readily available?

2. What microelectronic devices are in development and when are these expected to be available?

3. Which microelectronic devices appear to be candidates for my further consideration in solving my functional design problems?

4. How close do these candidates match my particular applications problems?

   A. In terms of basic characteristics

      function
      input/output
      power requirements
      dissipation
      amplification
      speed
      response
      purchasing
      family of devices (known fabrication techniques)
      shock
      vibration
      temperature range
      degradation
      other known performance characteristics
      (e.g., parameter distribution,etc.)

   B. In terms of reliability indicators

      qualification of device
      usage experience (successful and unsuccessful)
         a. relevant application experience (understress)
         b. adverse experience (if any)
         c. MTBF

EXHIBIT III

C. In terms of vendor performance
qualification of vendor
timely delivery

5. What have been the causes of adverse operations (if reported)?

   A. Identify types of field failures experienced.
   B. Review failure analysis results (if reported and valid).
   C. Review failure modes identified.

6. Have previous device qualifications programs been adequate for my particular application problems?

   A. Review specification used for qualifications of devices.
   B. Review procedures used for qualifications of devices.
   C. Determine program qualifying the device.

7. What additional qualifications of acceptance testing must be done to meet my specific requirements?

   A. Review general specs on microelectronics.
   B. Review specific specs on devices.
   C. Screening tests (specifications, procedures and reports).

8. How do I initiate preparation of documentation to specify the component desired, identify limitations or critical parameters and the testing essential to my application?

   A. Refer to previous procurement specifications.
   B. Refer to control drawings prepared on other procurements.
   C. Refer to 2nd order specifications (weldability, etc.).

   Note these items A, B, and C are necessary until NASA-wide use of approved standards or specifications is in effect.

9. Where can I get successful operating hours, failure rate and failure mode data to calculate life expectancy of the equipment packaging design?

10. Is there any correlation between certain types of failure modes for a particular device and equipment packaging design?

EXHIBIT III

11. Is there any correlation between certain types of failure modes for a particular device and equipment operational ambients?

    1. Shock
    2. Vibration
    3. Temperature (operating and storage)
    4. Solar radiation
    5. Nuclear radiation
    6. Humidity and moisture
    7. Salt spray
    8. Pressure
    9. Thermal shock
    10. Radio frequency interference
    11. Acceleration
    12. Fungus
    13. Immersion
    14. Electrical pulsing

12. Is there any correlation between certain types of failure modes for a particular device and equipment fabrication techniques?

    1. Flow solder
    2. Lead bending
    3. Potting
    4. Hand soldering
    5. Welding
    6. Handling
    7.

13. Is there any correlation between certain types of failure modes for a particular device and the device manufacturing process?

    A. Screen tests (specification, procedures, reports and normalized test data for computer manipulation).

14. What is in the technical report literature pertinent to the usage (manufacture or reliability) of a particular type or family of devices?

EXHIBIT III