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Final Technical Report
January 1970

OPERATION OF RELIABILITY ANALYSIS CENTER

IIT Research Institute

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Rome Air Development Center
Air Force Systems Command
Griffiss Air Force Base, New York

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OPERATION OF RELIABILITY ANALYSIS CENTER

Harold A. Lauffenburger
IIT Research Institute

FOREWORD

This Technical Report was prepared by IIT Research Institute, 10 West 35th Street, Chicago, Illinois, under Contract F30602-69-C-0101, Project 6528, for Rome Air Development Center, Griffiss Air Force Base, New York. It relates to the work performed during the past thirteen months of the contract period, 1 August 1968 to 31 August 1969. This report is identified by IIT Research Institute as IITRI FR-E6122.

Mr. John L. Fuchs, EMNRR, monitored the program for Rome Air Development Center.

The following IITRI personnel contributed to this project: G.T. Jacobi, H.A. Lauffenburger, P.A. Llewellen, H.C. Edfors, B.F. Lathan, T.R. Myers, B.A. Petersen, I. Krulac, V. Scanlon and S. Scott.

Distribution of this report is restricted to protect critical technical know-how, under the provisions of the U. S. Mutual Security Acts of 1949.

This Technical Report has been reviewed and is approved.

Approved: John L. Fuchs
JOHN L. FUCHS
Reliability Engineering Section
Reliability Branch

Approved: Joseph J. Naresky
JOSEPH J. NARESKY
Chief, Reliability & Compatibility Division

FOR THE COMMANDER: Irving J. Gabelman
IRVING J. GABELMAN
Chief, Plans Office

ABSTRACT

The Reliability Analysis Center is a service for the dissemination of reliability and experience information on microelectronic devices. It is administered for the Department of Defense by the Rome Air Development Center, Air Force Systems Command, and operated for that Center by IIT Research Institute. Its objective is to improve electronic systems reliability through a more fundamental understanding of microcircuit reliability factors and failure mechanisms. A total of 255 inquiries were answered from 207 individuals representing 104 different organizations. Additionally, regular Center publications are being mailed to 375 permanent users from 264 organizations. The data files currently contain 3191 documents of which 1597 contain summarized reliability test and experience data. The tabular failure rate and failure mode products were updated and reissued twice with each issue containing substantially more entries than the previous. Three technical monographs were distributed and another is now in printing. The File Bibliography was reissued in completely redesigned and expanded form. It now allows users to make simple searches on selected high usage terms. Data collection continued as a major effort. Primary emphasis was given to expanding the quality and quantity of malfunction data acquired from system level experience.

EVALUATION

The objective of this effort was the initial operation of a Reliability Analysis Center (RAC). The RAC serves as the central Department of Defense activity for the collection, storage, reduction, organization, review, assessment, analysis, and dissemination of information and experience data bearing on the reliability of microelectronics and discrete semiconductor devices. The RAC is concentrating on the modes and mechanisms of failure encountered during fabrication, testing, and operation of such circuits and devices, and the influence and contribution of part design, material, manufacturing techniques, configuration, test practices, screening practices, and electrical and environmental stresses on the nature of failures. This objective was met with the initial operation limited to microelectronic devices. An initial, meaningful data base had been acquired on microelectronic devices through a previous concerted data collection effort. The system concepts also developed under a previous contract were put into practice. This included detailed operating procedures for each task which define task objectives, personnel qualifications and responsibilities, forms employed, and detailed procedures for accomplishing the specified function. The operation included processing of accumulated information and data into files, performing retrieval and analysis operations, and preparing a series of output products. These outputs include Microelectronic Failure Data Tabulations, Microelectronic Failure Rate Tabulations, Microelectronic File Bibliographies, and Technical Monographs. Also, during the effort, 255 direct inquiries were answered.

The results of this effort provide the users with timely, high quality data for their use in improving, selecting, evaluating, and establishing reliability and quality assurance procedures for, and applying parts in the design, development, production, and operation of, reliable military systems and equipments. The system and procedures of operation employed during this effort will be utilized in the continued operation, development, and expansion of the Reliability Analysis Center.

John L. Fuchs

JOHN L. FUCHS
Project Engineer

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SECTION I

INTRODUCTION

This report covers a thirteen (13) month period of operation of the Reliability Analysis Center from August 1, 1968 to September 1, 1969. It is primarily an administrative report, documenting the results of Center operations. Particular emphasis has been placed in this report on those functions which directly affect user acceptance of the Center services.

Major technical development and implementation problems were solved during the previous contract period. Results of that effort were organized into a set of internal operating procedures which are documented in report RADC-TR-68-339, volumes 1 and 2, October 1968. Operations have been carried out according to these procedures except for minor modifications found through experience to improve information processing.

A significant effort was directed toward developing the user community and responding to user inquiries. This effort resulted in a steady increase of permanent users and in the number of ad hoc inquiries for assistance directed to the Center. User confidence in the competence of Center technical personnel were enhanced appreciably through participation in industry and society committee activities, technical paper presentations and private communications via visits and telephone with numerous industry and government individuals.

SECTION II

DESCRIPTION AND SERVICES OF THE RELIABILITY ANALYSIS CENTER

1. OBJECTIVES

The Reliability Analysis Center (RAC) has been established by the Department of Defense as a centralized activity for the collection, storage, reduction, organization, review, assessment, analysis and dissemination of information and experience data relating to reliability of microelectronic devices. Its operation is administered and guided by the Rome Air Development Center, U.S. Air Force. The primary objectives of the Center are:

- to upgrade systems reliability through centralized collection, analysis, and dissemination of reliability and experience information;
- to provide better understanding of the nature of failures in microcircuits leading to improved designs and applications; and
- to reduce costs by eliminating duplicate testing of microcircuit devices by DOD contractors.

Its primary mission is to provide a broader knowledge and a deeper understanding of the nature of device failures and their causes by analysis, review and evaluation of available information and its synthesis into a data file, publications, reliability prediction models, and techniques. Key users within the electronic Government-industry complex are thus provided timely, high-quality data for their use in improving, selecting, evaluating, establishing reliability and quality assurance procedures for, and applying parts in the design, development, production and operation of reliable military systems and equipments.

2. SCOPE OF RELIABILITY ANALYSIS CENTER OPERATIONS

The Reliability Analysis Center's efforts are directed toward those devices which are of immediate significance to the development of cost effective military equipment and systems. The present scope of the Center encompasses microelectronic circuits, including monolithic integrated circuits, hybrid circuits, and large scale arrays.

The Center analyzes and disseminates information that is generated during all phases of device fabrication, testing, equipment assembly, and operation. RAC data files are continually updated through information collected from device and equipment manufacturers, system contractors, and field operations. Collection efforts concentrate on failure mode and mechanism analysis; material, device and process technology; quality assurance and reliability practices; test results; and application experience.

A major feature of the Center is its analysis capability. Information that is processed into its files is carefully classified according to generic device descriptors that encompass material, design and process control characteristics. Correlation studies-which isolate dependencies and interrelationships among device properties, operating environments, and failure incidence-can be extended to new situations, to new devices and to new applications.

The Center coordinates its responsibilities with other government and industrial information systems, data exchange programs, and report distribution centers-complementing these services when necessary, but with minimum duplication.

3. USER SERVICES

The services of the Reliability Analysis Center are available to qualified engineering and management personnel in government and industry who are associated with the procurement, research and development, manufacturing, testing, and deployment of electronic military and space systems. Persons who are employed by DOD, as well as its contractors and subcontractors, are automatically qualified to receive RAC services, and they may make direct application to IIT Research Institute for assistance. Others who are interested in using the services of the Center should establish their qualifying status through the Rome Air Development Center. User services of the Center fall into three classifications: periodically scheduled publications, technical monographs, and ad hoc inquiries.

a. Periodically Scheduled Publications

As part of the Center's continuing service, a series of standard format publications is distributed to a list of regular users. These are issued and updated at regular intervals. They are as follows:

- Failure Data Tabulation: This publication lists in tabular form each reported microelectronic device failure for which the mode and/or mechanism of failure has been isolated. Entries are identified and organized by the most significant generic device property descriptors. Such relevant supporting information as environment, load stress, prior screening and burn-in, and time of failure are also provided; these permit classification and assessment of the major design, fabrication, test and application factors that influence the mode of failure.

- Failure Rate Tabulation: This publication arranges generic part level failure rates according to significant device properties and test or application stress conditions. For increased confidence in reported values, engineering and statistical analysis techniques are used to combine data for devices from a common generic class and from equivalent stress environments. Appropriate test/usage statistics and the relative contribution of predominant failure modes support each failure rate entry.

- Source Document Bibliography: Issued periodically, this bibliography itemizes each active source document on file. Titles are organized according to end-use subject categories, such as circuit/device theory, fabrication techniques, failure analysis studies, part level data, and application reliability data. Each title gives all standard bibliographic information required, plus such identifying features as DDC numbers and contract numbers. References to reliability data also include a statement of environment and stress conditions.

b. Technical Monographs

Specific technical problem areas are treated in technical monographs, which are published as problems of widespread concern arise. These are authoritative introductions to the state of the art, and provide professional guidance in selected topic areas. Emphasis is placed upon those aspects of device design, fabrication, quality assurance, and application that influence reliability. These monographs include a bibliography, a survey of current knowledge and practices, and an analysis of relevant data; they usually contain guidance, based upon engineering practice, in the selection, design, analysis, and application of microelectronic and semiconductor devices.

c. Ad Hoc Inquiry Service

One of the most important services of the Center is to answer, within the scope of its activity, specific inquiries for technical information and assistance. This service is intended to provide valid technical information and engineering data on explicit problems of immediate concern. Specialists in reliability and device technology are available to work directly with the user to define his problem, perform the required file search and information analysis, and prepare appropriate answers. Typically, responses take one or more of the following forms: analysis of specific numerical data; technical discussion of narrow problem areas; defined topic bibliographies and abstracts; and references to other data sources.

4. DATA SOURCES

In order to remain responsive to the needs of its users, RAC must remain abreast of the rapid advances being made in microelectronic technology and industrial practice. This requires the full cooperation of many contributing organizations and agencies.

Reports emanating from many government-sponsored R&D studies are automatically furnished to RAC. A growing number of systems and equipment hardware contracts provides for automatic reliability data submission to RAC. However, much of the Center's input is dependent upon voluntary contributions. To lessen the burden on contributors, information is accepted in its original form; special formats and data codes are not required.

Major source types contributing to the RAC information files are:

- Military systems program offices
- Other government agencies (e.g., DDC and DESC)
- Systems contractors
- Equipment manufacturers
- Device manufacturers
- Independent R&D organizations
- Other data exchange programs (IDEP, FARADA, etc.)
- Symposia, conferences, seminars, etc.

The following are among the large variety of reports and documents pertaining to microelectronics and semiconductors that are currently being collected and processed into RAC files:

- R&D reports
- Test reports
- Contractor reliability reports
- Field reliability reports
- Vendor reliability reports
- Failure analysis reports
- Physics of failure study reports
- Burn-in and screening analysis reports
- Data center output reports
- Open technical literature
- Procurement & test specifications (user & government)
- Vendor product specifications
- Vendor process & material specifications
- Device development & reliability improvement reports
- Quality assurance specifications
- Vendor technical and application information
- Vendor catalogs

5. CENTER OPERATIONS

Major internal operational elements of the RAC system are shown in Figure 1. The functions and procedural requirements of each identified operation has been fully developed and documented under earlier contract #AF 30(602)-4265. The complete procedures appear in volumes 1 and 2 of final report #RADC-TR-68-339, October 1968, documenting the results of this contract. The functions are briefly described in the following paragraphs.

A continuous data collection program has been established which is designed to systematically identify and tap potentially useful data sources. Wherever possible, new electronic systems are identified early in their development phase and communications channels established so data are made available to the Center as generated during subsequent phases of its life cycle.

Incoming documents receive a thorough evaluation by staff engineering personnel to assure that the information contained therein is relevant, consistent, and fully documented. Where deficiencies occur, attempts are made to obtain clarification from the source. When this fails, the document is rejected.

After initial screening, all numerical data amenable to reliability oriented analyses are extracted and reduced to summary form. Each summary carries a full complement of identifiers that describe the physical properties of the device under examination and the surrounding environments. The identifiers are assigned according to a pre-established set of descriptor terms, developed to provide for meaningful transfer of prior experiences to new situations. Indexing is accomplished employing a semi-fixed concept term thesaurus that presently contains approximately 1200 terms. These terms are organized under several subject headings, covering pertinent device, document, and content identification descriptors. Each document entered into the files is indexed with from 15 to over 50 terms, depending on the complexity and applicability of its subject matter.

Information storage and retrieval is accomplished with a semimanual system which provides the means for quick and direct recall of data for analysis and evaluation as required for preparation of the Center's outputs and for responding to queries. The information storage and retrieval system is comprised of an integrated document library, Termatrex system, and machine system.

File information may be subjected to a wide variety of analyses as required by the problem posed. Frequently, large amounts of textual content must be surveyed and reduced to meaningful form to answer a particular user question. Where necessary, this evaluation is supplemented with computer aided analysis of statistical data. These procedures range from computation

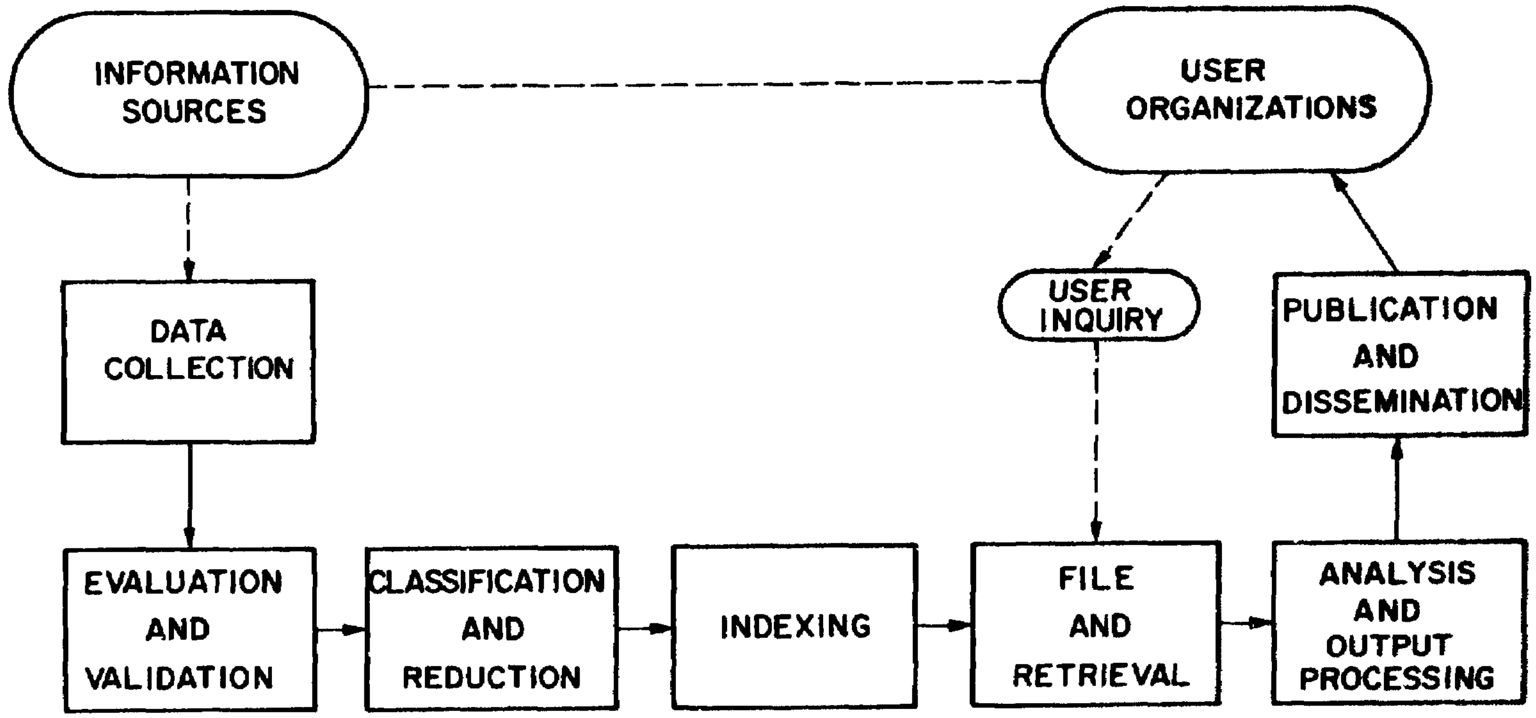

Figure 1 System Elements

of failure rates using Chi-squared distribution to multi-regression analysis.

Center outputs take one of two forms: typewritten reports and oral (usually telephone) consultation. Regular Center reports are disseminated to all qualified, permanent users as they are published. Technical papers are prepared and published as the opportunity arises. Other reports and consultative services are generated in direct response to a user problem and are generally made available only to him.

SECTION III

MEETINGS AND CONFERENCES

IIT Research Institute project staff members participated in a number of meetings, conferences and other industry and professional activities in pursuit of the Reliability Analysis Center objectives. This participation is documented in Table I. The various activities are classified according to the primary purpose of the meeting into the following categories:

a. Technical Direction and Management

b. User Orientation

c. User Services

d. Data Acquisition

e. Conferences and Symposia

f. Committee Activity

In some cases, several functions were performed by a given meeting. When this occurred, it is listed in that category corresponding to the main objective of the meeting. Typically, promotion of Center functions and input data solicitation are carried out simultaneously during a visit to a military contractor facility.

Table I

MEETINGS AND CONFERENCES

A. TECHNICAL DIRECTION AND MANAGEMENT

Date	Organization	Outside Participants	IITRI Participants	Meeting Place	Purpose
10/28/68	Material Lab. Wright-Patterson AFB	E. Dugger	G. T. Jacobi	Wright-Patterson AFB	Center User Charges
11/25-27/68	RADC	J. Fuchs	G. T. Jacobi RAC Staff	IITRI	Technical Direction
1/15/69	RADC	M. Haus J. Fuchs	G. T. Jacobi	Griffiss AFB, NY	Technical Direction
2/11-13/69	RADC	J. Fuchs	G. T. Jacobi RAC Staff	IITRI	Technical Direction
5/23/69	RADC	M. Haus J. Fuchs	G. T. Jacobi H. A. Lauffenburger	Griffiss AFB, NY	Technical Direction
6/2/69	DOD	M. Haus W. Christensen C. Porter	G. T. Jacobi	Pentagon, Washington, D.C.	RAC User Charges
8/14/69	RADC	M. Haus J. Fuchs	G. T. Jacobi	Griffiss AFB, NY	Technical Direction

Table I

MEETINGS AND CONFERENCES

B. USER ORIENTATION

Date	Organization	Outside Participants	IITRI Participants	Meeting Place	Purpose
9/19/68	Gen. Electric Co.	J. Fuchs-RADC G.E. Engrs.	G. T. Jacobi	Schenectady N.Y.	Oral Presentation on Center
2/19/69	RADC	H. Martin R. Mullin J. Dibrino	H. A. Lauffenburger	Johnsville Pa.	RAC Services & Data Solicitation
2/19/69	Burroughs Corp. Great Valley Lab.	J. Bubnekovich R. Lull J. Durkin W. Herrick	H. A. Lauffenburger	Paoli, Pa.	RAC Services & Data Solicitation
4/17/69	RADC		G. T. Jacobi	Griffiss AFB	RAC Briefing
4/25/69	Andrews AFB		G. T. Jacobi		RAC Briefing
4/30/69	NASA Hdqrs.	C. Watt L. Murphy C. Pontius T. Tsacoumis	T. R. Myers	Washington D.C.	RAC Services
4/26/69	Autonetics Div.	D. Brown	H. A. Lauffenburger H. C. Edfors	IITRI	RAC Services
7/9/69	Martin-Marietta	E. Strachota V. Leggio R. Culp	H. A. Lauffenburger	Denver, Colo.	RAC Services Data Solicitation

Table I

MEETINGS AND CONFERENCES

C. USER SERVICES

Date	Organization	Outside Participants	IITRI Participants	Meeting Place	Purpose
5/13/69	Boeing Co.	D. Porter	G. T. Jacobi H. A. Lauffenburger	IITRI	Data Needs for RAC Contract
6/23/69	ARINC Research	S. Schneider	H. A. Lauffenburger T. R. Myers	IITRI	ARINC Data Needs

Table I

MEETINGS AND CONFERENCES

D. DATA ACQUISITION (Page 1)

Date	Organization	Outside Participants	IITRI Participants	Meeting Place	Purpose
9/19-20/68	NASA PRINCE/ APIC	H. Garrett, Jr. R. Rich	H. Lauffenburger H. C. Edfors	Huntsville, Ala.	PRINCE/ APIC Collection
11/15/68	McCrone Assoc.	W. C. McCrone C. Gibson	H. Lauffenburger T. R. Myers	Chicago, Ill.	IC Failure Analysis Techniques &Facilities
11/14/68	Collins Radio		H. C. Edfors	Cedar Rapids, Ia.	Data Collection
11/21/68	Collins Radio		H. C. Edfors	Dallas, Tex.	Data Collection
11/21/68	Texas Inst. Gov't. Prod. Div.		H. C. Edfors	Dallas, Tex.	Data Collection
11/22/68	Gen. Elec. Co. Apollo Support Group		H. C. Edfors	Houston, Tex.	Apollo Data Bank
11/22/68	Motorola, Inc. Mil. Elect. Div.	F. Dreste	T. R. Myers	Phoenix, Ariz.	Data Collection
12/5-6/68	RADC	J. L. Fuchs T. O'Connell	T. R. Myers	Griffiss AFB, NY	Screening Techniques

Table I

MEETINGS AND CONFERENCES

D. DATA ACQUISITION (Page 2)

Date	Organization	Outside Participants	IITRI Participants	Meeting Place	Purpose
12/11/68	Philco-Ford SRS Div.	M. Economy	H. Lauffenburger	Palo Alto, Calif.	Data Collection
12/13/68	Lockheed Mis. & Space Company	H. Chankin	H. Lauffenburger	Sunnyvale, Calif.	Data Collection
1/24/69	TRW Systems	J. Connor	G. T. Jacobi	IITRI	Data Input Req.
3/5/69	Hallicrafters, Inc.	H. Berg	H. C. Edfors	Rolling Meadows, Ill.	Data Collection
3/27/69	Naval Ammunition Depot	R. Saum R. Hedinger B. Carter M. Hicks L. Eccles M. Jackson	H. C. Edfors	Crane, Ind.	Data Collection
4/7/69	Norden Div., U.A. Corp.	M. H. Yoel	T. R. Myers	Norwalk, Conn.	Data Collection
4/8/69	Sanders Assoc.	R. Hollis	T. R. Myers	Nashua, N.H.	Data Collection
4/10/69	Crystalonics Div. Teledyne Corp.	T. Kaufmann L. Thomas	T. R. Myers	Cambridge, Mass.	Data Collection

Table I

MEETINGS AND CONFERENCES

D. DATA ACQUISITION (Page 3)

Date	Organization	Outside Participants	IITRI Participants	Meeting Place	Purpose
4/11/69	Sprague Elec. Co.	W. Campbell W. Monoghan	T. R. Myers	Wooster, Mass.	Data Collection
4/16/69	General Dynamics Corp. Ft. Worth Div.	C. Brown J. Paige R. Kahm J. Prindl E. Haines	H. C. Edfors	Ft. Worth, Tex.	Data Collection

Table I

MEETINGS AND CONFERENCES

E. CONFERENCES, SYMPOSIA, ETC. (Page 1)

Date	Organization	Outside Participants	IITRI Participants	Meeting Place	Purpose
8/20-22/68	WESCON		H. Lauffenburger	Los Angeles, Calif.	Attend IEC Packaging & Microelectronics Symposia
10/1-3/68	GOMAC		G. T. Jacobi T. R. Myers	Washington, D.C.	Attend Sessions
10/17-18/68	FTD Wright-Patterson AFB		G. T. Jacobi	Dayton, Ohio	FTD Activity Briefing
10/28-30/68	Hybrid Microcircuit Symposium		B. F. Lathan	Rosemont, Ill.	Committee Participation and Attend Sessions
11/19/68	ICE Corp.	Staff	T. R. Myers	Phoenix, Ariz.	Attend LSI Seminar
12/2-4/68	Rel. Physics Symp.		G. T. Jacobi H. Lauffenburger T. R. Myers	Washington, D.C.	Present Tech.Paper Attend Sessions

Table I

MEETINGS AND CONFERENCES

E. CONFERENCES, SYMPOSIA, ETC. (Page 2)

Date	Organization	Outside Participants	IITRI Participants	Meeting Place	Purpose
1/21-23/69	1969 Rel. Symposium		G. T. Jacobi H. Lauffenburger H. C. Edfors	Chicago, Ill.	Committee Participation, Attend Sessions
3/27/69	IEEE Convention		G. T. Jacobi	New York, N.Y.	Attend Hybrid Microelectronic Session
3/28/69	IC/Systems Seminar		G. T. Jacobi	New York, N.Y.	Attend Sessions
4/9/69	IEEE-CADAR		T. R. Myers	Cambridge, Mass.	Computer-aided LSI Design Seminar
4/15/69	General Dynamics	L. P. Michaelis	H. C. Edfors	Ft. Worth, Tex.	Semiconductor Fact Finding Conference
4/30/69 5/1-2/69	1969 Electronic Components Conf.		T. R. Myers	Washington, D.C.	Present Tech.Paper, Attend Sessions

Table I

MEETINGS AND CONFERENCES

E. CONFERENCES, SYMPOSIA, ETC. (Page 3)

Date	Organization	Outside Participants	IITRI Participants	Meeting Place	Purpose
5/7/69	IEEE Rel. Group, Chicago Section		G. T. Jacobi	Chicago, Ill.	Present Tech. Paper
6/24-25/69	Nat'l. Engrg. Info. Conference		H. Lauffenburger	State Dept.	Attend Sessions
7/7-8/69	AIAA Rel. and Maintainability Conference		H. Lauffenburger	Denver, Colo.	Present Tech. Paper, Attend Sessions

Table I

MEETINGS AND CONFERENCES

F. COMMITTEE ACTIVITY (Page 1)

Date	Organization	Outside Participants	IITRI Participants	Meeting Place	Purpose
8/19/68	EIA MED-43	Committee	H. Lauffenburger	Los Angeles, Calif.	IC Reliability
9/25/68	EIA MED-20	Committee	H. Lauffenburger	Washington, D.C.	IC Terms & Definitions
12/4/68	EIA MED-20	Committee	H. Lauffenburger	Washington, D.C.	IC Terms & Definitions
12/12/68	EIA MED-43	Committee	H. Lauffenburger	San Francisco, Calif.	LSI Reliability
2/18/69	MED-43	Committee	H. Lauffenburger	Phila. Pa.	Coordinate User Guide for Microcircuit Failure Analysis
4/24/69	MED-20	Committee	H. Lauffenburger	DesPlaines, Ill.	IC Elect. Parameters
4/29/69	MED-43	Committee	T. R. Myers	Washington, D.C.	IC Reliability
5/21-22/69	MED-20	Committee	H. Lauffenburger	DesPlaines, Ill.	IC Elect. Parameters

Table I

MEETINGS AND CONFERENCES

F. COMMITTEE ACTIVITY (Page 2)

Date	Organization	Outside Participants	IITRI Participants	Meeting Place	Purpose
7/23/69	Delco Radio	B. Schertz K. Doversberger	H. Lauffenburger	Kokomo, Ind.	Coordinate MED-20 Sub-Comm.Tasks; Data Solicitation
7/28-29/69	MED-43 Sub-Committee	Committee	H. Lauffenburger	Houston, Tex.	LSI Reliability
8/18/69	MED-43	Committee	H. Lauffenburger	San Francisco, Calif.	LSI Reliability
8/18-19/69	MED-20	Committee	H. Lauffenburger	San Francisco, Calif.	IC Terms & Definitions

SECTION IV

USER ORIENTATION

The problem of reaching potential users of the RAC services was recognized during the development and implementation phases of the Center. A well designed, attractively illustrated booklet was developed and printed under the previous contract. This booklet, entitled "Reliability Analysis Center/An Introduction," describes the scope functions, services and how to use the Center in a concise, easy-to-read form. Mailed to a large number of industry contacts in July 1968, it resulted in the first group of eventual Center users. With this booklet as the primary item of publicity literature, promotional thrust was pursued in three main areas:

Publicity material distribution

Oral presentations

Personal communications

To support mass mailings, a smaller three-page condensed version of the basic introductory document was developed. This is an inexpensive foldout type flyer that has proven effective both for large volume mailings and for handout purposes. A total of 15,000 flyers and 5,000 envelopes were printed. Of these, approximately 5,150 have been distributed. Major mailings were made to:

1. Members of the IEEE Reliability group (approximately 2,500) and

2. Attendees of the Computer-Aided System Design Seminar, Cambridge, Mass., April 9, 1969.

Other mailings were made as prospects were identified.

Additionally, these flyers have been handed out in sizable volume at the various conferences and symposias attended by staff personnel. A copy was enclosed with each proceedings furnished registrants of the 1969 Reliability Symposium held in Chicago, Illinois. They were also made available to attendees of the following conferences:

1968 Reliability Physics Symposium, Washington, D.C.

1969 Electronics Components Conference, Washington, D.C.

8th AIAA Reliability & Maintainability Conference, Denver, Colo.

Formal oral presentations were made to three (3) industrial organizations and three (3) governmental facilities. They are:

Industrial Organizations

General Electric Co., Schenectady, N.Y.	9/19/68
Burroughs Corp., Great Valley Laboratory, Paoli, Pa.	2/19/69
Martin-Marietta Co., Denver, Colo.	7/9/69

Government Facilities

Naval Air Dev. Center, Johnsville, Pa.	2/19/69
Rome Air Dev. Center, Griffiss AFB, N.Y.	4/17/69
Andrews AFB, Washington, D.C.	4/25/69

Presentations are augmented with a set of viewgraph slides, especially designed to illustrate the major features, operations, and services of the Center. A second set of these slides have been furnished to the sponsor for their use.

More informal presentations were made to other organizations. They are made a part of all data solicitation visits to insure that the potential data contributor has a full awareness of the services provided. New users have been added as the result of this promotional effort with prospective contributors.

Presentation of technical papers at conferences and symposia represents another valuable mode of publicity. Aside from increasing awareness of services via the oral presentation and subsequent publication in proceedings, potential users are able to evaluate the usefulness of available data for their specific needs. Further, and perhaps most important, such presentations permit Center personnel the opportunity to demonstrate their technical competence which is absolutely essential to wide acceptance by industry engineers. The following technical papers were presented during the contract period:

- Failure Data Feedback: The Reliability Analysis Center, G. T. Jacobi and H. A. Lauffenburger, 1968 Reliability Physics Symposium, Washington, D.C., Dec. 1968, and IEEE Reliability Group, Chicago Section, May 1969.
- Flip-Chip Microcircuit Bonding Systems, T. R. Myers, 1969 Electronic Components Conference, Washington, D.C., May 1969.

- A System for Effective Transferral of Microelectronic Reliability Experience, H. A. Lauffenburger and J. L. Fuchs, 8th Reliability & Maintainability Symposium, Denver, Colo., July 1969.

Two additional papers were prepared for future presentation. They are:

- Summary and Interpretation of Reliability Data on Various Microcircuit Bonding Techniques, H. A. Lauffenburger and T. R. Myers, 15th Annual Holm Seminar on Contact Phenomena, Chicago, Ill., Nov. 11-14, 1969.

- LSI Reliability Assessment and Prediction, H. A. Lauffenburger and T. R. Myers, Annual Symposium on Reliability, Los Angeles, Calif., Feb. 1970.

Personal contact between RAC staff members and those of outside organizations affords an effective means of publicizing Center activities. There are many opportunities where this is pursued. Attendance at technical symposias, and participation in various industry (i.e., EIA) and professional society (i.e., IEEE) activities, have been used to advantage. Again, familiarizing individuals with Center services, demonstrating technical competence and conveying a cooperative attitude are primary objectives.

In spite of our continuing promotional efforts, there are still a large number of organizations and individuals engaged in microcircuit activities that are not using the services because they are not aware of its existence. Frequently, individuals contact the Center as a result of chance conversations with users both from another division of the same company and outside organizations. Another form of outside publicity was an article on the Center that was published in Evaluation Engineering magazine, Vol. 8, #2, March/April 1969. This magazine is directed to reliability and component evaluation engineers. It drew an excellent response, particularly from among reliability people at military facilities.

SECTION V

USER SERVICES

1. STANDARD PUBLICATIONS

A series of technical products are prepared and issued at periodic intervals. These products are identified as:

Microelectronic Failure Data

Microelectronic Failure Rates

Microelectronic File Bibliography

Technical Monographs

The content of these products were described previously in Section II-3 of this report. The first three (3) are periodically updated with the newly released issue completely obsoleting the previous issue. Since inception of RAC services, three (3) issues of the tabular products (Failure Rates and Failure Data) have been published. There has been a steady expansion in the data content in each succeeding issue. This is illustrated in Table II in terms of line entry count. There is a separate line entry for each unique data entity. There may also be an increase in the amount of data (e.g., number of parts tested, number of part hours) contained in a given line entry. This is not reflected in the table. It is expected that the number of line entries will increase at a continually slower rate for several reasons.

First, as the variety of device configurations and stress environments represented in the tables expands, a greater proportion of newly acquired data will fall into an existing category (line entry) rather than a unique one. Secondly, since the rate of increase of the nth issue is based on the size of the (n-1) issue, the reference is becoming continuously larger. Finally, the time period available for acquisition of new data was substantially shorter (7 months compared to 4 months) between the second interval as compared to the first. Eventually, the number of line entries will tend to stabilize, especially when purging of outdated data is undertaken.

The File Bibliography has been reissued once. The scope, content and, consequently, usefulness of this product has been enhanced substantially from the original issue. Details of this design modification are contained in paragraph (a) below.

Table II

TABULAR PRODUCT DATA CONTENTS

PRODUCT IDENTITY	ISSUE	LINE ENTRIES NUMBER	LINE ENTRIES ENTRIES % CHANGE FROM PREVIOUS
Failure Rates	July, 1968	224	----
" "	Feb., 1969	375	67.5
" "	June, 1969	504	34.5
Failure Data	July, 1968	134	----
" "	Feb., 1969	227	69.2
" "	June, 1969	312	37.5

Once published, a technical monograph remains active until such time as newer technology reduces the usefulness of the material presented. Among other criteria, topics are selected which appear to have a relatively long useful interest span. All technical monographs issued to date are still of current interest. The following technical monographs have been prepared and/or issued to date:

TM 68-1: Face Down (Flip Chip) Microcircuit Bonding Systems, July, 1968.

TM 68-2: Failures of Aluminum Metalizations on Silicon Integrated Circuits, July, 1968.

TM 69-1: Screening of Integrated Circuits, May, 1969.

TM 69-2: Silicon Nitride Surface Passivation, prepared August, 1969; to be issued in September, 1969.

a. File Bibliography Redesign

The File Bibliography was completely redesigned between the initial issue and the June, 1969 updating. Originally, it contained only bibliographic reference descriptor information. These were organized into thirteen (13) broad subject categories. Within each, references were ordered alphabetically by author.

The revised design features a complete abstract for each reference cited and provisions for retrospective searches. It is organized in three sections with different color pages employed for each for ease of use. The sections are:

Section I - Term Selection Table (yellow pages): contains a subset of the RAC index thesaurus selected to be most valuable to a user. The primary terms are listed alphabetically with subterms listed under each primary term.

Section II - Term/Document Index (green pages): an alphabetical listing of the terms in the Term Selection Table. Each term is followed by a complete list of accession numbers. Each accession number corresponds to a document containing information on that term.

Section III - Annotated Bibliography (white pages): contains bibliographic and abstract information for each pertinent document, listed in accession number order.

To use the bibliography, the correct term(s) is selected from Section I. Section II is then accessed using the selected term(s) for corresponding accession numbers. After identifying the pertinent accession number, bibliographical and abstract information are obtained from Section III. A search can be undertaken with any number of terms.

The current bibliography contains 244 index terms and approximately 1,100 bibliographic references. It is expected that this basic design will be useful for the foreseeable future. The index term set may be revised in succeeding issues to reflect trends in user interests. Obviously, the bibliographic references will be changed with data base additions and deletions.

User reaction has been very favorable. A sizable number of multiple copy requests have been received. Also, some individuals have expressed their satisfaction during telephone and personal discussions.

b. Product Dissemination

The standard publications are printed in volume and disseminated to regular users of the Center and in response to requests for specific information. For example, routine requests for failure rate information may be answered by furnishing the Microelectronic Failure Rates tabulation and pointing out particular line entries of interest.

Technical Monograph 69-1 - Screening of Integrated Circuits is proving to be especially popular among users. In the short time since publication, there have been numerous requests for multiple copies. Some users ask for as high as 10-12 copies for internal distribution at their facility. Users have indicated that this document is the first concise treatment of the reasoning behind, the expected reliability improvement, and the costs incurred in applying the screening provisions of specification MIL-STD-883.

Quantities published and disseminated of each issue of the regular Center products are presented in Table III. Although the initial issues were prepared and issued in July, 1968, they were not actually distributed until September. The delay resulted from late issuance of the follow-on contract and time required to prepare the original distribution lists. Subsequent issues were mailed to the existing user list promptly upon completion of printing.

Table III

PRODUCT PUBLICATION QUANTITIES

PRODUCT IDENTITY	ISSUE DATE	QUANTITY PRINTED	QUANTITY DISSEMINATED TO RADC	QUANTITY DISSEMINATED TO USERS
Failure Rates	July, 1968	500	250	175
Failure Rates	Feb., 1969	400	50	350
Failure Rates	June, 1969	750	50	410
Failure Data	July, 1968	500	250	175
Failure Data	Feb., 1969	400	50	350
Failure Data	June, 1969	750	50	445
File Bibliography	July, 1968	500	180 (1)	325
File Bibliography	July, 1969	750	50	425
Monograph TM 68-1	July, 1968	750 (2)	180 (1)	397
Monograph TM 68-2	July, 1968	750 (2)	180 (1)	366
Monograph TM 69-1	May, 1969	750	50	442
Monograph TM 69-2	Sept. 1969	750	(3)	(3)

NOTES: (1) 250 copies were originally furnished RADC. Approximately 70 copies were later returned to satisfy user requests

(2) Initial printing was 500 copies. A second printing of 250 copies was made to satisfy user requirements

(3) This document is still in printing at conclusion of contract period

c. Permanent Users

At the close of the contract period there were a total of 375 individuals on the permanent mailing list receiving RAC technical publications.

The increase in registered permanent users by month is shown in Figure 2. Note that the initial rate of increase was nearly constant until February when a dramatic rise took place. Two events are responsible for this jump. First, RADC turned over their file of eighty-one (81) permanent users to IITRI during the month. At the same time, the effects of the January mass mailing to IEEE Reliability Group members was being realized with a total of 63 new permanent users. A second significant increase occurred in April as a result of the Evaluation Engineering article.

Some small amount of shrinkage has taken place due to individuals changing jobs or companies and not being replaced. This is not reflected in the figure, but accounts for the difference between the cumulative total shown thereon and that of Table IV.

Not all users receive the entire series of available publications. Some users have requested multiple copies for redistribution within their organization. The breakdown of the number of users receiving each product type and total number of copies of each mailed to permanent users is as follows:

PRODUCT TYPE	NUMBER USERS	ADDITIONAL COPIES	TOTAL COPIES
Failure Rates	371	9	380
Failure Data	368	9	377
File Bibliography	361	8	369
Technical Monographs	338	9	347

An analysis of permanent users by type of organization is shown in Table IV. In total, 134 unique non-government organizations are represented. Of these, 117 or 87 percent are in the aerospace industry with the remainder consisting of device vendors, educational institutions and independent R&D organizations.

Including governmental facilities, there are a total of 264 separate and distinct organizational facilities or divisions receiving RAC publications on a permanent basis.

The U. S. Navy is the largest governmental user of RAC products with 15 separate installations and 18 individuals regularly receiving its publications.

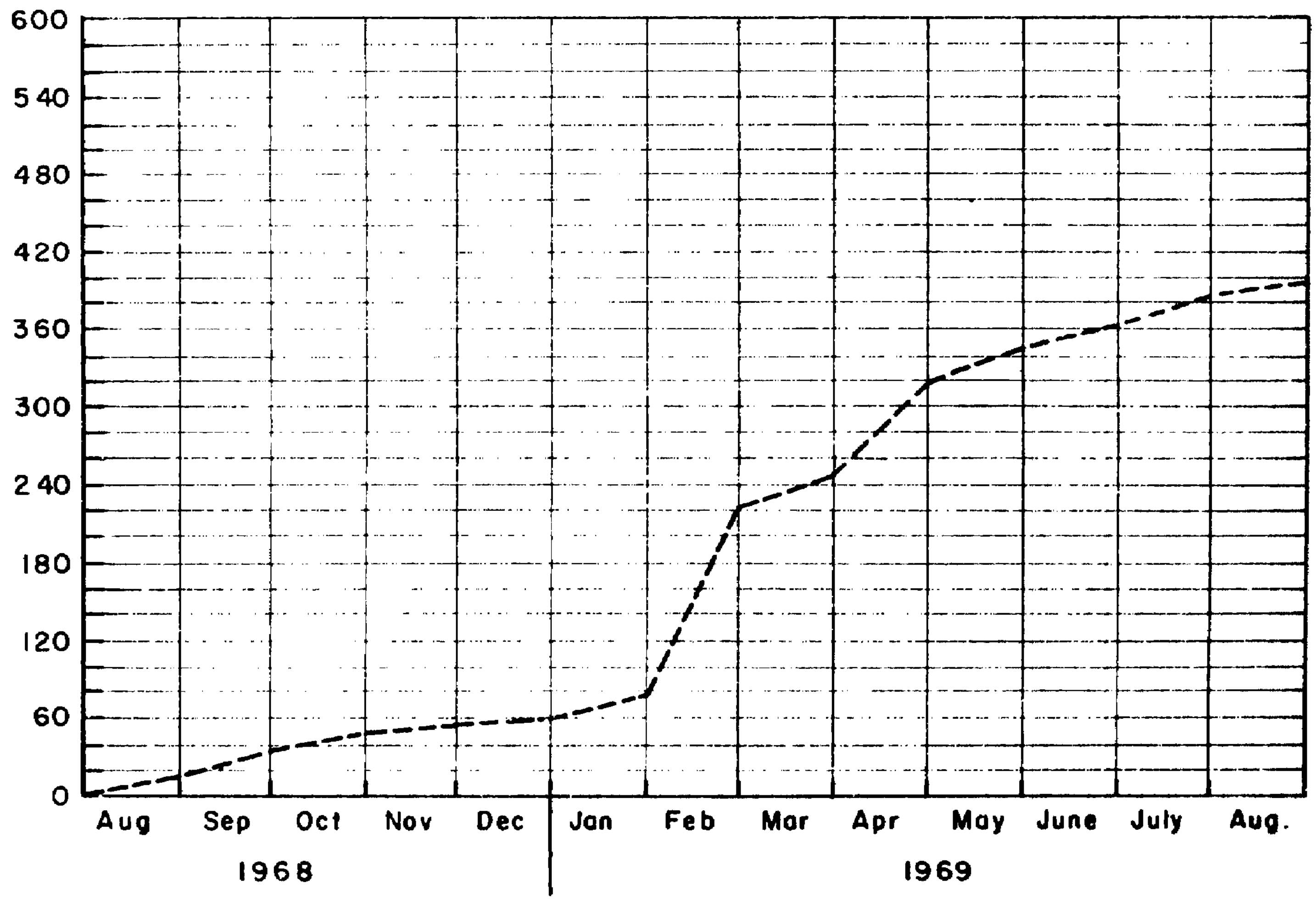

Figure 2 Cumulative Registered Users

Table IV

PERMANENT USERS BY ORGANIZATION TYPE

Type of Organization	NUMBER ON PERMANENT MAILING LIST Organizations	Divisions or Facilities	Individuals
Aerospace Industry	117	203 [1]	289
Consultants, Educational Institutions	13	14	19
Device Vendors	4	5	6
Government Agencies			
Air Force		9	12
Army		5	12
Navy		15	18
NASA		5	10
DOD		5	6
Other		3	3
	134 [2]	264	375

NOTES: (1) Five (5) of these divisions are IC device manufacturers

(2) Considers only non-governmental organizations

A complete listing of the organizations, divisions or facilities and the number of users at each appears in Appendix I. This listing does not include the 20 individual users within the Rome Air Development Center.

2. DIRECT INQUIRY SERVICE

To achieve widespread acceptance of its services, an information analysis center must be responsive to the users' needs. These can best be evaluated by an analysis of the types of organizations and individuals calling upon the Center for assistance, the nature of the problems posed and the satisfaction gained by the user from the information and services supplied. The latter is perhaps the most important criteria. To maintain continual feedback of user satisfaction, a service evaluation card was mailed to each user several weeks after responding to his inquiry. The response was most gratifying with the majority of individuals completely satisfied with the assistance provided. Details of the service evaluation will be given later. To help appreciate the significance of the user replies, an analysis of the organizations utilizing this service and the nature of the responses provided will be presented first.

a. Analysis of User Inquiries

The cumulative inquiries received by month through August 1969 are plotted in Figure 3. As of this date, there have been a total of 255 inquiries received from individuals in government and industry. Table V summarizes the number of inquiries received by type of organization. Two hundred nineteen or 85.5 percent of the inquiries have been submitted by non-governmental organizations. The aerospace industry accounts for nearly all of these. Although the criteria of classification is quite arbitrary, large contractors have submitted 166 inquiries while medium or smaller contractors have called upon the Center for services on 44 different occasions.

Inquiries submitted by government agencies included the Air Force, Army, Navy, NASA, and DOD, plus those classified as "other" (NBS, Coast Guard, etc.). As was found with permanent Center users, the largest number of inquiries were submitted by personnel from the various Navy installations. Eighteen inquiries or 50 percent of the inquiries received from governmental agencies originated at Navy installations.

A complete alphabetical listing of the organizations using the direct inquiry service and the number of requests submitted by each is given in Appendix II.

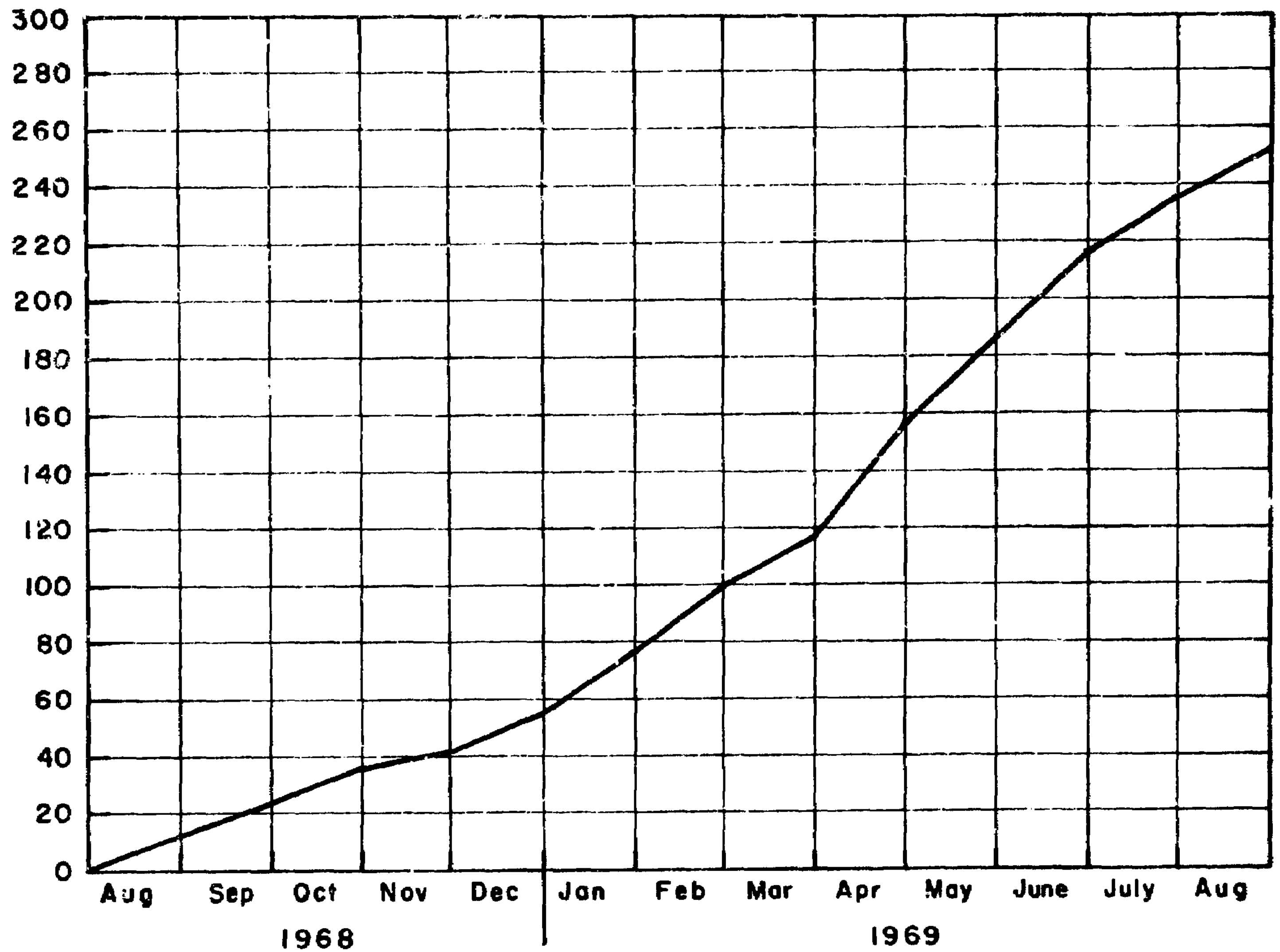

Figure 3 Cumulative Inquiries

Table V

SUMMARY OF DIRECT USER INQUIRIES BY ORGANIZATION TYPE

Type of Organization	No. of Inquiries			% Total		
Non-Government			219			85.8
Aerospace Industry		210			82.4	
Major Contractors	166			65.2		
Medium and Small	44			17.2		
Educational; Independent R&D Organizations		8			3.1	
Foreign		1			0.4	
Government Facilities			36			14.2
Air Force		4			1.6	
Army		6			2.3	
Navy		18			7.1	
NASA		4			1.6	
Other		4			1.6	
Grand Total			255			100.0

An analysis of the type of services provided in response to user inquiries appears in Table VI. Although questions posed are extremely varied and not amenable to concise categorization, the table does provide an insight into the type of information that was supplied by RAC. Some inquiries pose more than one problem; therefore, the number of responses (263) is greater than the number of inquiries.

A representative sampling of the questions posed by user inquiries is presented in Appendix III. No one single type of inquiry dominates, although RAC technical publications are provided in approximately 30 percent of cases. This does not include applications for placement on the permanent RAC mailing list. Experience has shown that the RAC technical publications serve to satisfy many specific user information needs. There have been, as noted previously, a number of requests for multiple copies of certain publications, notably technical monographs and more recently the updated File Bibliography. Technical papers prepared for presentation at conferences and symposia are proving to be quite valuable in answering inquiries. These papers report on results of analyses of certain portions of the data base and serve user needs for such information as failure rates vs stress, failure rates vs time, failure modes vs environment, etc.

Although there are only 10 inquiries shown for MSI/LSI information, this is an area where interest is just beginning to build up. Most inquiries for LSI information have been received within the last two months.

Users continue to request failure rates and other reliability data on specific device types. Such requests were included in 34 or 13.3 percent of inquiries handled. In some cases, users are satisfied when the rationale for classifying data according to device properties in lieu of nomenclature is explained. Others are not convinced and believe the Center's value is impaired by pursuing this policy.

Referrals play an important role in RAC services. Referrals are made for several reasons: 1) data request is for discrete parts; 2) the user specifically requests referral to workers having intimate knowledge in a particular speciality and 3) other centers are chartered to offer assistance in the specific problem area.

b. Communication Modes and Response Time

An analysis of the modes of communication employed by users in directing inquiries to RAC and subsequent responses are shown in Table VII. As expected, the telephone and mails are used almost exclusively. Telephone calls predominate for incoming inquiries, accounting for 77 percent of the total.

Table VI

ANALYSIS OF DIRECT INQUIRIES BY INFORMATION PROVIDED

Type of Information	No. of Responses	% Total
Failure Rate Data	39	14.8
Failure Modes and Failure Isolation	30	11.4
Technical Reliability Information	38	14.4
MSI/LSI Reliability Data and Prediction	10	3.8
Test/Screening Procedures, Specifications	16	6.1
Reliability Technology, Prediction	10	3.8
RAC Technical Publications	79	30.1
Referrals to Other Data Sources	21	8.0
Information on RAC Services	20	7.6
Totals	263	100 %

Table VII

COMMUNICATION MODES FOR DIRECT USER INQUIRIES

Communication Mode	Incoming Inquiry Number	Incoming Inquiry % Total	RAC Response[(1)] Number	RAC Response[(1)] % Total
Telephone	196	77.0	119	45.0
Mails	49	19.2	142	53.8
Wire	6	2.3	1	0.4
Visit or Personal Contact	4	1.5	2	0.8
Totals	255	100 %	264	100 %

(1) More than one reply was furnished for some inquiries

Responses are nearly equally divided between the phone and mails. This is somewhat misleading because a relatively large number of inquiries are answered during the initial call to the Center. Early in the program the telephone also was used as the primary response mode. Midway through the contract period this policy was changed to conserve resources. Subsequently, responses were made by mail unless the user was willing to accept a collect call or a call back was necessary to fully define the problem. Note that the number of responses surpass the number of inquiries; this resulted because more than one reply was made on some inquiries in order to provide faster response. Typically, a telephone call is followed up with more complete written material.

Speed of response is an important consideration in serving users' information needs. Center staff members place top priority on preparing inquiry responses. Table VIII provides an analysis of achieved response time for the 255 inquiries. Where more than one response was submitted, only the first one is indicated on the chart.

Over 21 percent of inquiries were answered during the initial telephone exchange. Another 23 percent were answered during the same working day with a total of 62.8 percent or nearly two-thirds of the inquiries being answered within one working day of inquiry receipt. Most of those in the longest time category, greater than one week, required a fairly extensive file survey or information that had to be acquired from external sources. Some of these result during tabular product update cycles. During these periods, all available resources are channeled to data analysis for preparation of the listings.

c. User Satisfaction

In order to remain responsive to the data needs and changing requirements of the user community and to measure the effectiveness of its services, a user evaluation procedure has been implemented. Within 2-3 weeks of the inquiry response a paid reply post card is mailed to the user to assess the quality of service rendered. Figure 4 is a mockup of the service evaluation card employed. The information supplied by RAC to the user is briefly described in the space indicated along with the reply date.

Over 78 percent of the cards mailed out during the contract period have been returned. The replies are summarized in Table IX. All users were satisfied with the response time. Over 60 percent expressed complete satisfaction with the level of detail and relevancy of the information furnished. Approximately 30 percent were partially satisfied with the information, whereas only a small ercentage indicated dissatisfaction.

Table VIII

ANALYSIS OF RESPONSE TIME TO USER INQUIRIES

Response Time (working days)	Number of Responses	% Total
Direct[1]	54	21.2
Same day	58	22.8
1 day	48	18.8
2 days	31	12.2
3 days	25	9.8
1 week	20	7.8
Greater than 1 week	19	7.4
Total	255	100 %

(1) The users question was answered immediately during his call to the Center.

Dear

Tho Reliability Analysis Center has recently furnished you information sought by direct inquiry. By filling out and mailing the attached postal card, you can help make this service even more valuable. For your convenience, a description of the supplied information and date of transmittal are already indicated on the card.

Thank you for your assistance.

Sincerely,

G. T. JACOBI
Technical Director, RAC

RAC USE ONLY /

INFORMATION SUPPLIED

____

______________________ DATE ________

	YES	NO	PARTIALLY
1. Did the information serve your needs?	☐	☐	☐
2. Did it contain desired detail?	☐	☐	☐
3. Was response time satisfactory?	☐	☐	☐

COMMENTS ______________________

____

____

SIGNED ______________________

Figure 4 Inquiry Follow-up Card

Table IX

ANALYSIS OF USER SATISFACTION

Responses from 173 user evaluation cards

Category	Percent Responses Yes	Partial	No
Response Time Satisfactory	100.0	0	0
Received Desired Information Detail	62.5	29.1	8.4
Information Served User Needs	62.1	34.9	3.0

- Respondees Providing Written Comment: 58%
- Returns from Cards Mailed: 78.6%

Further insight into user satisfaction can be gained from a review of the comments furnished on the evaluation card. User interest in a service for microelectronic reliability data is indicated by the fact that 58 percent took time to include some comment on the evaluation card. Most were complimentary with many offering constructive suggestions. A number of the comments are included in this report to augment the statistical data. They are separated into three tables as follows:

Table X - Selected User Comments (Complimentary)
Table XI - Suggested User Service Improvement (selected)
Table XII - User Comments Accompanying "NO" Responses

Table XI contains the essential user suggestions for service improvement. Some are relatively trivial. Most significantly, many users are interested in a similar service for other electronic components. Others state a need for information identified by part number and manufacturer.

All comments accompanying a "NO" reply are included in Table XII. In the majority of cases it is recognized that the information of interest is on a new class of devices where data just is not yet available. Others were seeking data on devices outside of the RAC scope.

In summary, the service evaluation is providing useful feedback information to the Center. While the majority of users are quite satisfied with service being received, others offer constructive criticism for service improvement. These suggestions must be actively considered and those concerned with operating procedures diligently evaluated. Data collection efforts will be directed to those areas where a definite need is being expressed for information on new technologies within our preview.

3. TECHNICAL PAPERS

A number of technical papers were presented and/or published during the contract period. These papers drew upon the data and information contained in the Reliability Analysis Center data base and the expertise of the RAC technical staff. These papers serve to consolidate the large amount and diversity of accumulated data into summarized form for ready access by user organizations. As stated previously, many users have requested copies of these papers. They have also been invaluable in answering direct user inquiries.

A listing of papers, authors and abstracts are given in the following paragraphs.

Table X

SELECTED USER COMMENTS (COMPLIMENTARY)

9816	Your information was very good. As yet I haven't checked out all the leads. Many thanks.
9819	The material was very excellent and very useful. Estimated time saved, 12 hours labor.
9845	The response time was excellent and the information well organized for further research.
9893	Very impressed by data and service. Would appreciate being informed as to complete scope of data and services available from your Center.
9905	Excellent service and timely information.
9914	Your information proved to be quite timely.
9917	Your information on who was working on Integrated Circuit Corrosion Problems led me to the desired personnel.
9930	Lot and source information - number tested versus number failed - makes information very useful. Very good. Continue to define all controls!
9945	Some of the information transmitted was more recent than I had - plus sources of data which I did not have. Engineering appraisal analysis was also unexpectedly received. (I didn't expect it and it was of good depth and quality)
9947	Reports are excellent. Continued efforts in this area are well worth while. Certainly the need exists.
9975	Report directly applicable to our current work for the Navy and much appreciated.
9996	Major value was in pointing direction in which problems occurred under various environments. Very useful data.
0009	Most comprehensive and extremely valuable in "selling" part improvement via screening.

Table X

SELECTED USER COMMENTS (COMPLIMENTARY)

0020	The reports which I continue to receive from you are supplying fundamental data in support of our current theory of dormant λ's.
0021	The desired information was provided in a very timely manner and was presented in the necessary technical depth.

Table XI

SUGGESTED USER SERVICE IMPROVEMENT (SELECTED)

9848	Data would be more helpful if the manufacturer is identified.
9858	More detail on storage consequences of screening would have been useful.
9885	This service is excellent and should be expanded in scope, availability and ease of obtaining information.
9887A	The IC failure rate and failure modes are not elsewhere available. Manufacturers and part numbers would be extremely valuable. Could use the same thing on all other 3E parts.
9892	Suggest accelerating data collection on other devices such as relays, transistors, etc.
9903	Data greatly appreciated. However, wish it were possible to relate data to actual programs and missions. Also appreciate the information received via telephone conversation.
9926	This particular application required more depth toward discrete logic versus micro logic. Have asked our documentation center to continue service.
9935	It would be helpful to have a cross reference - manufacturers part number versus line in Microelectronic Failure Rate.
9982	Reported sample sizes were rather small but we realize the problem in making them larger.
9977	Failure rate by vendor is needed.
0013	Since cracked solder joints on PC Boards seems to be a general industry problem, could RAC act as a clearing house for reports hereon.
0014	I feel that some agency possibly RAC, should consolidate the information on industrial type devices similar to what has been done on the MIL types.

Table XI

SUGGESTED USER SERVICE IMPROVEMENT (SELECTED)

0016	Suggest imprinting title on end binding spline so readable in bookshelf!
0041	I think that the manufacturers name and part number should be listed with each entry number.

Table XII

ALL USER COMMENTS ACCOMPANYING "NO" RESPONSES ARE LISTED BELOW

9830	Complete information was not available at RAC. Personal attention to the request through phone contact was highly satisfactory.
9865	Had to check the two "No" blocks because no information was available. Service was good.
9891	Data in technical publications was too limited.
9904	The detail was insufficient to make the practical decision of "From which manufacturer do I buy the product and in what material". I'd like to make arrangements to discuss this.
9934	Detailed information concerning discrete component "wear-out" failure mode was not available.
9962	I need a larger number of data points with the time domain. I'm sure this type of data is very difficult to obtain.
9965	There was no hermeticity versus operational life data available. Still interested!
9967	The detailed data I was seeking was not readily available, however, the contact at RADC given to me gave me some information.
9970	LID devices are too new and we recognize that little information is available.
9998	The information provided served to confirm my previous knowledge rather than to increase or modify it.
0007	The information obtained is sufficient for general failure rate indication but not for what we plan to do. i.e. trade-off and part selection.
0011	The information I requested was unavailable to RAC. Otherwise the personnel I contacted were friendly and helpful.

NOTE: Four (4) users replying "NO" to one (1) or more questions did not furnish explanatory comments.

- Failure Data Feedback: The Reliability Center, G. T. Jacobi and H. A. Lauffenburger, presented at 1968 Reliability Physics Symposium, Washington, D. C. Dec. 1968.

ABSTRACT

The use of mathematical models for prediction of microelectronic circuit reliability is becoming increasingly more appealing as devices become more complex and costly. Although varying in degree of sophistication nearly all proposed models equate reliability factors to physical device properties, controls during fabrication (including post production screens) and end-use operating environments. Current disagreement among workers centers around classification and weighting of various influencing factors. This problem stems from the difficulty in acquiring adequate quantities of suitably documented experience and failure data for determining and validating these factors.

This paper describes the contributions of the Reliability Analysis Center (RAC) toward solving this difficulty. The Center is administered for the Department of Defense by Rome Air Development Center, U. S. Air Force. The objectives and essential features, including data source solicitation, data classification, and user services are briefly discussed. The major portion of the paper is devoted to describing results of an analysis performed on failure mode data contained in RAC files. The study was undertaken to determine methods by which this data could be reduced and be made amenable for model building and verification.

Results indicate that observed failure modes have a tendancy to be dependent upon the stress environment. Overall, bonds and electrical degradation account for the largest majority of observed failure. Under electrical stress conditions, surface problems are a major failure cause, whereas at physical environments, bonds and package failures predominate. There is some correlation between bond failure incidence and the interconnection system employed.

One difficulty encountered is that a large percentage of observed failures are not adequately autopsied to isolate the source or cause of failure.

- Flip-Chip Microcircuit Bonding Systems, T. R. Myers, presented at 1969 Electronic Components Conference, Washington, D. C., May 1969

ABSTRACT

To date many approaches to facedown (flip-chip) die bonding have been tried and evaluated. The approach of bonding an integrated circuit chip facedown to substrate with a mating conductor pattern is basically the same in all cases, but the manner in which this is accomplished varies widely.

In flip-chip bonding the substrate provides support for the interconnect pattern and the chip bonded to it, as well as providing a heat sink for power dissipated in the chip. Glass, alumina, and printed circuit boards have been used successfully as substrates, but alumina is generally chosen for its thermal conductivity.

Assembly consists of bonding the chip to the substrate and presents the unique problem of aligning the chip accurately over the substrate. This critical registration can be achieved visually through a transparent substrate, through the use of split optics systems, infrared microscopy, and other means. Thermocompression, ultrasonic, and solder bonding are all capable of producing satisfactory bonds, but the bonding method is generally dictated by the metallurgy system.

Glass passivation over the chip metallization is highly desirable for mechanical and chemical protection of the chip. External leads which do not pass through the package hermetic seal are preferable.

Ultimately, a compatible combination of the aforementioned materials, geometries, processes, and techniques must be found to yield a packaged microcircuit providing the required system functions. Many studies on the various aspects of bonding flip chips have been performed.

Total production rate increases of from 3:1 to 5:1 over similar wire bonded units have been reported. Chips with up to 24 bumps can be bonded at reasonably good yields but the 10 to 14 bump variety is preferred.

Overall packaged circuit failure rates of 0.003 to 0.09 percent/Khr have been reported, but reliability data is quite limited. More reliability studies are required to validate potential improvements of flip chip.

- A System for Effective Transferral of Micro-Electronic Reliability Experience, H. A. Lauffenburger and J. L. Fuchs, presented at the 8th Reliability and Maintenance Symposium, Denver, Colo., July 1969.

ABSTRACT

The Reliability Analysis Center, operating under DOD auspices, fulfills the need for a centralized source of microcircuit reliability data. Collected test and experienced data is analyzed and disseminated to users in government and industry. Distribution is through failure mode and failure rate publications, technical monographs, and direct inquiry service. A recent study of accumulated data on monolithic integrated circuits indicates predominant failure mode in both laboratory and end-use environments is lead-die bond defects. Package and surface related defects are decreasing while metallization problems are becoming more predominant. Eighty percent of equipment IC removals are not autopsied. Thermal storage failure rates fit the Arrhenius model with an acceleration of 170 between 125°C and 25°C. Effects of temperature and applied voltage at operating test stresses are illustrated graphically. Orbiting satellite and manned aircraft in-system failure rates are, respectively, 1.95 and 10.2 times those for 25°C ring counter tests.

- Summary and Interpretation of Reliability Data on Various Micro-Circuit Bonding Techniques, H. A. Lauffenburger and T. R. Myers, to be presented at the 15th Annual Holm Seminar on Contact Phenomena, Chicago, Ill., November 11-14, 1969.

ABSTRACT

Experience has shown that the lead-to-die bonds employed in monolithic semiconductor microcircuits represent a major source of device unreliability. Various metallurgy systems and bonding techniques have been used. None have proven completely satisfactory under all application environments. This paper presents a survey of

reliability data on the bonding systems in current widespread use. It reviews the metallurgy systems and bonding techniques, then relates reliability experience to the inherent and process factors of each. Typically bonds account for from 20 to over 60 percent of all isolated failures. Gold-aluminum bonds are the worst offenders since they are subject to intermetallic compound formation in addition to process errors. Failure rates for the Au-Au and Al-Al systems are quite low and essentially independent of applied stress. Au-Al bonds exhibit failure rates only slightly higher than the other two systems at 25°C, but are highly temperature dependent. At 200°C bond failure rate has increased by nearly 1-1/2 orders of magnitude.

Process related bond defects can be effectively reduced as well designed screening techniques applied to 100 percent of devices prior to use.

- Reliability Assessment and Prediction, H. A. Lauffenburger and T. R. Myers, to be presented at 1970 Annual Symposium on Reliability, Los Angeles, Calif., Feb. 1970.

ABSTRACT

Assuring reliability in the LSI age presents some unique problems not previously encountered by electronic systems and equipment manufacturers. Greater emphasis must be given to designing reliability into the product from the early system concept stage and continuing on through deployment. The LSI component supplier becomes an intimate member of the design team and must share in its decisions and responsibilities. Reliability assurance practices necessarily will emphasize control. Supplier selection, design reviews and in-process inspections play increasingly important roles in establishing confidence in product acceptability. Except for functional parameters, qualification and lot acceptance testing of complete production items probably will decrease in importance, although screening and burn-in appear to still be economical means for detecting discrepant components.

Quality assurance and life tests will concentrate on specially designed test elements to determine design and process capability, failure mechanism kinetics and adequacy of production controls. Reliability levels are estimated with data from these elemental tests using appropriately structured mathematical models. Since laboratory testing becomes increasingly less attractive from an economic point of view, better utilization of field operational history is essential. Although the advent of LSI has brought with it new problems and challenges, it also has provided the reliability engineering profession an opportunity to make an even greater impact on electronic system reliability than ever before.

4. ASSESSMENT OF THE RADC IC RELIABILITY PREDICTION MODEL USING RAC FILE DATA

An in-depth analysis was performed of the RAC data base to evaluate the validity and accuracy of the IC prediction model contained in the RADC Reliability Notebook Report, RADC TR-67-108, Vol. II. This model is used by practicing reliability engineers with varying degrees of success. The evaluation was undertaken to develop guidance material for RAC users in regard to the utility of this model and possible constraints in its use.

By various statistical procedures comparing observed failure rate values (λ_o) to model predicted values (λ_p) it was possible to explore the suitability of the model's form and the appropriateness of the variables employed.

Results of the study indicate that as a prediction model for the present RAC data base the RADC model is inadequate. However, it seems to be valid in the variables that are used and in the general multiplicative form that it takes. Analysis to the RAC data base indicates that at least two of the model variables require substantially altered form. Also, additional model terms are required to better fit the RAC data. One of these additional model terms is a factor to identify the data source.

A preliminary report has been forwarded to RADC for review and comment prior to publication.

SECTION VI

DATA ACQUISITION AND PROCESSING

1. DATA ACQUISITION

Data acquisition efforts continue to be directed along five main channels as follows:

1. Direct solicitation from vendors, equipment manufacturers and governmental organizations.

2. Abstracting services listing reviews (TAB, STAR, and others).

3. Direct distribution from government funded R&D efforts.

4. Technical conference, symposia, etc., attendance and procedings.

5. Open literature : technical journals, trade magazines, etc.

Procedures have been formalized in most of these areas to routinize the effort and promote economy and efficiency as well as insure thoroughness of coverage. For example, definite assignments and schedules have been established for the review of abstracting service bulletins and technical magazines. Although the methodology has been established and ordering processes carried out routinely, some difficulty has been experienced in obtaining necessary authorizations from the cognizant governmental agencies for certain R&D technical reports, particularly those marked for "limited" distribution.

With the rapidly advancing microcircuit technology, we are finding that the delay on acquiring R&D technical reports is hampering customer services. Delays of 6 to 12 months are frequently encountered between report publication and abstract service listing. To circumvent this difficulty, greater emphasis is being given to identifying contract research as soon as possible after the contract is negotiated, then requesting that RAC be placed directly on the mailing list. To obtain more positive response to these requests a procedure whereby they be made on RADC letterhead is being developed.

a. Data Acquisition from System Development Programs

It is recognized that the greatest need is for actual reliability experience and test data derived from development, fabrication, testing and deployment of military electronic systems and equipments. In the past, this source has been the most difficult to effectively tap. Solicitation efforts usually resulted in acquisition of scattered reports that were readily available. Field data, when obtained at all, is difficult in all but a few cases (e.g. Minuteman) to relate back to specific device configurations. Seldom are field malfunctions adequately autopsied for failure causes and usually it is not even possible to obtain the necessary total part hour/number of failure statistics.

In order to obtain order from this situation and acquire meaningful experience data, a new approach was developed and implemented. Termed the "Program Approach," data acquisition is integrated with systems development. The major development phases were identified (see Figure 5) and specific data input requirements from each were identified. Each development phase generates a unique class of data, which when integrated by RAC will provide a total reliability history of the devices employed. For example, during the development stage, device procurement specifications and system electrical and thermal stress information is developed. During production, qualification lot acceptance and screening/burnin results become available. Finally, malfunctions occurring at the field on a particular system are completely traceable to device configuration, applied stress levels and screening effectiveness.

Specific data items expected at each development stage with suggested formats are shown in Appendix IV. Appendix V contains a specification "Data Input Guidelines for Microcircuit Reliability Test Programs" which was issued to define specific RAC input requirements for device level reliability test programs conducted by contractors.

System development programs are identified as early as possible using various information sources such as:

1. System Project Office (SPO) contacts
2. Defense Marketing Services DMS publication
3. Periodical and newspaper accounts
4. RAC staff member acquaintances
5. Knowledge of subsystem contracts or equipment contracts.

Initial solicitation contacts with the contractor or SPO establish the system reliability data requirements. Where they are not quantified, further activity is terminated as very little useful data will be documented. Programs having reasonable reliability requirements are catalogued and subsequent contacts are scheduled to coincide with key review points at which time the

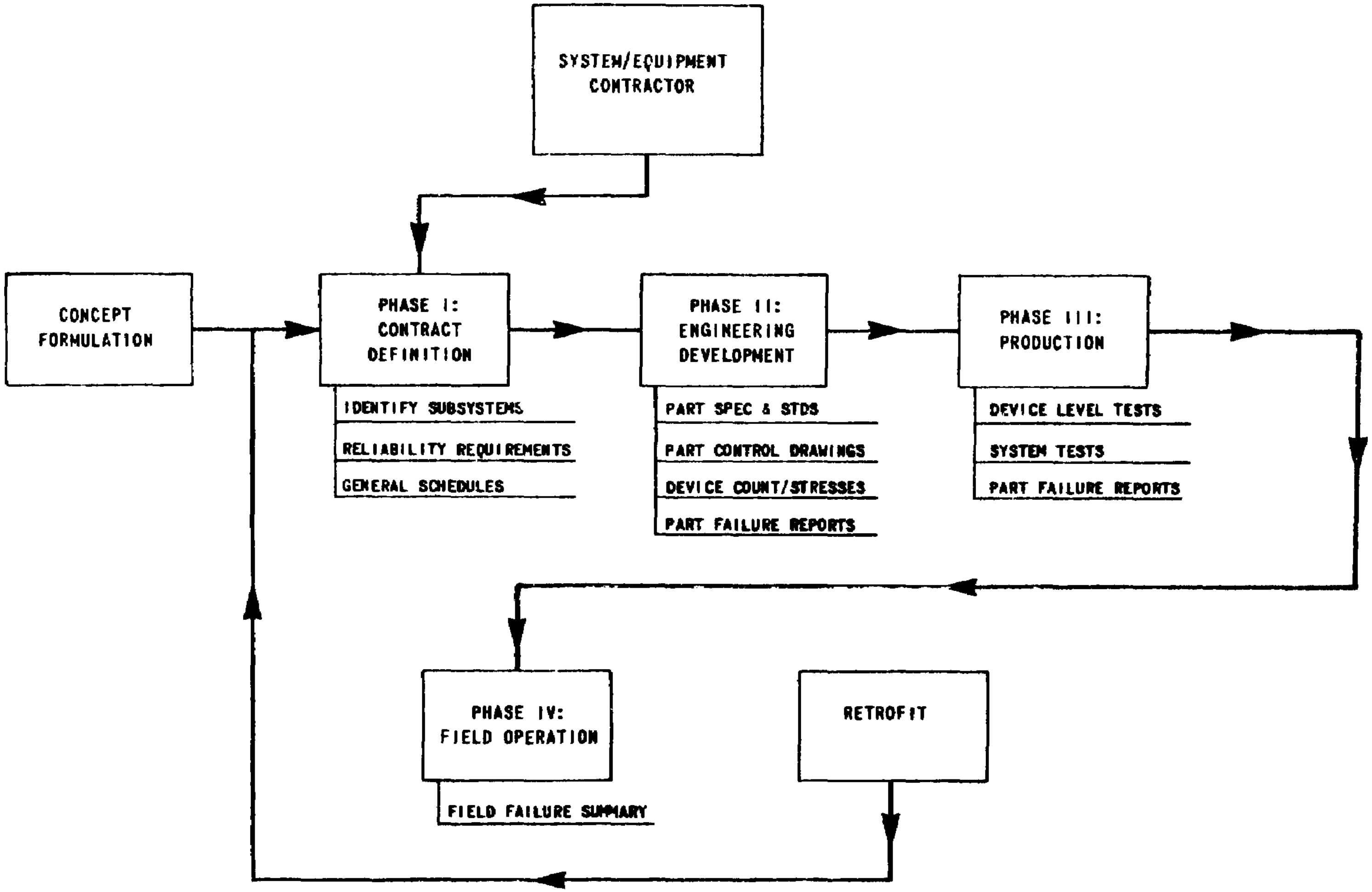

Figure 5 Program Cycle Development

prescribed data items are expected to be available. Subcontractors are also identified and their reliability activities pursued in the same manner.

b. Contacts and Acquisitions

Data solicitation contacts were made to one hundred eighteen (118) different organizations during the contract period. These included device vendors, aerospace contractors and government agencies. Numerous contacts were made to such organizations as indicated on Table XIII. Hybrid device vendors are shown separately because a general survey questionnaire was mailed to all those identified from literature, buyers guides and industry contacts to ascertain their market area and reliability data accumulations. Most proved to be developmental with little or no available data. Consequently, follow-up activity was minimal.

Discounting the forty (40) hybrid vendors an average of slightly over six contacts were made to each organization with which data negotiations were carried on. The largest number of contacts were made with Collins Radio/Cedar Rapids and Burroughs Corporation/Paoli, Pennsylvania with 23 and 18 contacts respectively.

These data solicitation efforts have resulted in significant collections of test data and supporting information from a number of organizations. Among those contributing substantial amounts are:

Collins Radio, Dallas, Texas
Motorola, Phoenix, Ariz.
Radiation, Inc. Systems Div.
Norden Division, United Aircraft, Norwalk, Conn.
AC Electronics, Milwaukee, Wis.
Burroughs Corp., Paoli, Pa.
Fairchild Semiconductors
Texas Instruments, Dallas, Texas
Sanders Associates, Nashua, N.H.
Semiconductor Specialists, Elmhurst, Ill.

The Norden collection, on F-111 Integrated Display System, is the first major contribution under the "Program Approach." It contains nearly the entire package including: parts counts listing; reliability prediction data and rationale with stress analysis; system operation elapsed time data; and failure listings. They have promised to furnish device identification cross-reference and device procurement specifications.

The trip to General Electric, Houston, (see Section III) resulted in identification of approximately 300 IC documents from the Houston Apollo data files. These have been subsequently furnished to the Center. There are some failure analysis reports, but the number of documents from this collection is relatively

Table XIII

SUMMARY OF DATA SOLICITATION CONTACTS

Type of Organization	Number of Organization	Number of Contacts	
		Phone/ Letter	Visit
Device Vendors	22	133	3
Hybrid Vendors (Initial Contact)	40	55	0
Aerospace Contractors	59	291	14
Government Facilities	7	38	2
Totals	118	517	19

small. The group of 67 documents from the PRINCE/APIC collection at Huntsville have also been received. These are somewhat outdated and do not contain too much current information.

A total of twenty-eight (28) device descriptions were acquired. Some of these were furnished by device vendors and others were prepared internally from information extracted from catalogs, technical literature, and personal communication with vendor technical personnel.

A statistical count of document acquisition is presented in the following section in conjunction with processing and file status.

2. DATA PROCESSING OPERATIONS

a. Procedures

Document entry processing continued essentially according to established procedures. Several improvements have been incorporated into the file system and processing procedures to enhance capability and improve operations. The more significant of these are described in the paragraphs below.

An increasing amount of information furnished to RAC has some proprietary restrictions placed on its use and dissemination. The most common restriction is that the data source prefers that the manufacturer(s) of the devices tested are not identified. Also, he may wish to remain anonymous. A procedure has been established whereby such restricted information items are encircled in red. A special yellow translucent plastic termatrex card is also drilled with the accession number of documents containing restricted information. During searches, this special card immediately flags such documents and assures that the designated propriety is respected.

Specification indexing has been revised to enhance retrieval. Since RAC obtains numerous proposed specifications, two separate terms are employed; one for those actually released and a second for developmental or proposed specifications. Specifications can be retrieved by Type (i.e., Packaging, Quality Control Manual), by Content (i.e., Test Technique and Procedure, Visual Inspection Procedure) and by Source (i.e., Government, Vendor, User).

It was found that direct user inquiries frequently contain important information on IC device malfunction and failure modes. To expedite access to this information user inquiries are being processed directly into the RAC retrieval system.

A total of eighty (80) new terms, including 22 new device manufacturers have been incorporated into the Term Thesaurus.

There has been an additional backlog of 500 terms identified during normal indexing operations that need to be reviewed for possible incorporation. The review is expected to take place early in the forthcoming contract period.

The computer failure rate computation program was modified to accommodate data where a large number of failures are reported. Instead of expanding the stored F and χ^2 value tables, provisions have been incorporated to manually enter the former (for large df values) and internally generate the latter. Also, a computer regression analysis program was written for the RUSH system and exercised on failure rate data to ascertain compliance with the Arrhenius model. The results of this analysis were incorporated into a technical paper authored by staff personnel. The program itself is expected to find wide application for correlation studies on reliability data.

Other changes of lesser importance include:

- Data summaries are filed into loose leaf folders for ease in handling. All processing papers are located in their original folders.
- Proceedings and books that are used frequently have been placed on a bookshelf for handy reference. Green tabs are placed on their file folders to show that the document is on the bookshelf.
- The author file was changed to a corporate author file. A separate file is kept in alphabetical order in black loose leaf folders.
- The vendor catalog file has been revised. Each vendor now has one document number. Information from each vendor has been filed in a loose leaf folder.
- Journal articles of limited importance are kept in a separate General Journal Article file. This file now has approximately 100 articles. An alpha card file, by author, is available for retrieval.
- Individual papers from Symposium Proceedings of interest to RAC are assigned distinct accession numbers and drilled directly into the retrieval system.

b. File Status

At the close of the contract period, the RAC file holdings totaled 3191 documents, representing an increase of 2055 during the current program. As noted in Table XIV, 1365 of these are considered source documents. A source document is defined as one which has been acquired from an external information source.

Table XIV

SUMMARY OF RAC FILE HOLDINGS

Document Type	8/1/68	Additions	8/31/69
Failure Mode/Problem Area Report		77	77
Journal Articles	62	193	255
Specifications	13	115	128
Proceedings, Symposia Conferences	18	26	44
Bibliography, Surveys and Reviews, Handbook	17	31	48
Technical Reports, R/D Reports, etc.	286	239	525
Test Data, μ-Notes	165	123	288
TOTAL SOURCE DOCUMENTS	561	804	1365
Summaries	575	1022	1597
Device Description		28	28
Inquiry		201	201
TOTAL NON-SOURCE DOCUMENTS	575	1251	1862
TOTAL NUMBER OF DOCUMENTS IN RAC FILE	1136	2055	3191

Source documents are classified in Table XIV according to broad type groupings. Technical (R&D) reports comprise the largest single type of source documents with 525 document holdings or approximately 38% of the total. Current files contain 288 test reports, an increase of 123 during the contract period.

Other file holdings include Device Description, User Inquiries and internally generated Data Summaries. The latter are derived by reducing statistical failure rate and failure mode data to a convenient formal for subsequent processing of output tabulations. During the contract period 1022 Data Summaries were processed into the system.

At the close of the contract, another 350 source documents were at various stages of entry processing. This represents a four month processing backlog. Indexing is one of the largest contributors to processing delays. It must be done very carefully with highly competent, well motivated personnel, to insure that later file searches produce relevent information. This problem has been reviewed to determine steps that might be taken to enhance indexing speed. The problem appears to be universal with information centers with no real breakthrough reported. In spite of this difficulty, the data files and retrieval system have provided excellent support to RAC technical staff in servicing the needs of Center users.

APPENDIX I

ALPHABETICAL LISTING OF PERMANENT USERS

APPENDIX I

ALPHABETICAL LISTING OF PERMANENT USERS

COMPANY NAME	NO. USERS
AC ELECTRONICS	
Div. of GMC, Goleta, California	1
ADVANCED COMMUNICATIONS, INC.	
Chatsworth, California	1
AEROJET-GENERAL CORP.	
Azusa, California	1
Space General Plant, El Monte, California	1
AEROSPACE CORP.	
El Segundo, California	1
Reports Acquisition, Los Angeles, California	3
AIRBORNE INSTRUMENTS LAB.	
Deer Park, New York	1
AIRCRAFT RADIO CORP.	
Boonton, New Jersey	2
AIRESEARCH MFG. CO.	
Torrance, California	1
AMELCO SEMICONDUCTOR	
Mountain View, California	1
AMERICAN SCIENCE & ENGNG., INC.	
Cambridge, Massachusetts	1
AMMANN & WHITNEY	
New York, New York	1
AMPEX CORP. TECH. LIBRARY	
Redwood City, California	1
APPLIED TECHNOLOGY	
Palo Alto, California	1
ARINC RESEARCH CORP.	
Annapolis, Maryland	1
Western Div., Santa Ana, California	2
ARMA	
Div. of Ambac Ind., Garden City, New York	1

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APPENDIX I (Cont.)

ASTRO COMMUNICATION LAB.	
Gaithersburg, Maryland	1
AUTOMATIC ELECTRIC LAB., INC.	
Northlake, Illinois	1
AVCO CORP.	
Electronics Div., Cincinnati, Ohio	3
Ordnance Div., Richmond, Indiana	1
Avco Systems Div., Wilmington, Massachusetts	1
BALDWIN ELECTRONICS, INC.	
Little Rock, Arkansas	1
BASLER ELECTRIC CO.	
Highland, Illinois	1
BATTELLE MEMORIAL INST.	
Columbus, Ohio	2
BELL AEROSYSTEMS CO.	
Buffalo, New York	6
BELL TELEPHONE LABS., INC.	
Allentown, Pennsylvania	1
Whippany, New Jersey	1
BENDIX CORP.	
Bendix Communications Div., Baltimore, Maryland	1
Environmental Science Div., Baltimore, Maryland	1
Mishawaka, Indiana	2
Navigation & Control Div., Teterboro, New Jersey	2
BIRD ENGNG-RESEARCH ASSOC., INC.	
Vienna, Virginia	1
BOEING COMPANY, THE	
Aerospace Group, Seattle, Washington	1
Space Div., Huntsville, Alabama	1
BURROUGHS CORP.	
Defense Space & Special Systems Group, Paoli, Pa.	2
CANADIAN MARCONI CO.	
Montreal, Canada	1
CENTER FOR NAVAL ANALYSES	
Arlington, Virginia	1

APPENDIX I (Cont.)

CHALLENGER RESEARCH INC.	
Rockville, Maryland	1
CLEVITE CORP.	
Ordnance Div., Cleveland, Ohio	2
COLLINS RADIO CO.	
Cedar Rapids, Iowa	1
Dallas, Texas	1
Newport Beach, California	2
Toronto, Ontario, Canada	1
COMPUTER APPLICATIONS INC.	
Ridgecrest, California	1
CONDUCTRON CORP.	
Ann Arbor, Michigan	1
Conductron-Missouri, St. Charles, Missouri	2
CONSULTANT SERVICES INST.	
Livingston, New Jersey	1
CONTROL DATA CORP.	
Minneapolis, Minnesota	1
CRYSTALONICS	
Div. Teledyne, Inc., Cambridge, Massachusetts	1
DOUGLAS UNITED NUCLEAR, INC.	
Richland, Washington	1
DREXEL INST. OF TECHNOLOGY	
Philadelphia, Pennsylvania	1
DYNAMIC CONTROLS CORP.	
South Windsor, Connecticut	1
DYNAMICS RESEARCH CORP.	
Stoneham, Massachusetts	1
ELECTRONICS COMMUNICATIONS, INC.	
St. Petersburg, Florida	1
ELECTRO-MECHANICAL RESEARCH, INC.	
Telemetry Div., Sarasota, Florida	1
ELECTRO-OPTICAL SYSTEMS, INC.	
Pasadena, California	1

APPENDIX I (Cont.)

ELECTRONIC ARRAYS, INC.	
Mountain View, California	1
ELECTRONIC IMAGE SYSTEMS CORP.	
Cambridge, Massachusetts	1
EMERSON ELECTRIC CO.	
St. Louis, Missouri	1
CHANDLER EVANS, INC.	
Control Systems Div., West Hartford, Connecticut	1
FAIRCHILD SEMICONDUCTOR	
Mountain View, California	2
Palo Alto, California	1
FARRINGTON MANUFACTURING CO.	
Springfield, Virginia	1
FEDERAL ELECTRICAL CORP.	
Huntsville, Alabama	1
GAERTNER RESEARCH INC.	
Stamford, Connecticut	1
GENERAL DYNAMICS CORP.	
Convair Div., San Diego, California	1
Electronics Div., Rochester, New York	1
Fort Worth Div., Fort Worth, Texas	1
GENERAL ELECTRIC CO.	
Daytona Beach, Florida	1
Defense Electronics Div., Binghamton, New York	2
Defense Electronics Div., Syracuse, New York	6
Electronic Systems Div., Pittsfield, Mass.	1
Houston, Texas	1
King of Prussia, Pennsylvania	1
Missile & Space Div., Bethpage, L. I., New York	1
Missile & Space Div., Huntsville, Alabama	2
Missile & Space Div., Philadelphia, Pa.	1
Oklahoma City, Oklahoma	1
Phoenix, Arizona	1
Research & Development Ctr., Schenectady, N.Y.	1
St. Petersburg, Florida	1
Utica, New York	5
GENERAL TIME CORP.	
Wheeling, Illinois	1

APPENDIX I (Cont.)

GEORGIA INST. OF TECHNOLOGY	
Physical Sciences Div., Atlanta, Georgia	2
GRUMMAN AIRCRAFT	
Bethpage, Long Island, New York	2
GULF AIRBORNE INSTRUMENTS, INC.	
Smithtown, New York	1
GULF GENERAL ATOMIC INC.	
San Diego, California	1
GULTON INDUSTRIES, INC.	
Data Systems Div., Albuquerque, New Mexico	1
GYRODYNE CO. OF AMERICA, INC.	
St. James, Long Island, New York	1
HALLICRAFTERS CO.	
Rolling Meadow, Illinois	1
HAMILTON STANDARD	
Div. of United Aircraft Corp., Farmington, Conn.	1
Div. of United Aircraft Corp., Windsor Locks, Conn.	3
HARRY DIAMOND LABORATORIES	
Washington, D.C.	1
HARTMAN SYSTEMS CO.	
Huntington Station, New York	1
HAZELTINE CORP.	
Braintree, Massachusetts	1
Little Neck, New York	1
HEWLETT-PACKARD CO.	
Colorado Springs, Colorado	1
HOFFMAN ELECTRONICS	
Military Products Div., El Monte, California	1
HONEYWELL, INC.	
Aerospace Div., Minneapolis, Minnesota	2
Computer Control Div., Framingham, Massachusetts	1
Electronic Data Processing Div., Waltham, Mass.	2
Honeywell Aero Div., Roseville, Minnesota	1
Hopkins, Minnesota	2
Ordnance Div., St. Louis Park, Minnesota	1
St. Petersburg, Florida	2
Tampa, Florida	2

APPENDIX I (Cont.)

HRB-SINGER, INC.	
State College, Pennsylvania	1
HUGHES AIRCRAFT CO.	
Data Systems Div., Culver City, California	3
Fullerton, California	1
Missile Systems Div., Canoga Park, California	1
Space Systems Div., El Segundo, California	1
Tucson, Arizona	1
INT'L BUSINESS MACHINES CORP.	
Boulder, Colorado	1
Federal Systems Div., Owego, New York	3
Hopewell Junction, New York	4
Poughkeepsie, New York	2
San Jose, California	1
ITT	
Avionics Div., Nutley, New Jersey	2
Defense Communications Div., Nutley, New Jersey	1
ITT Gilfillan Inc., Van Nuys, California	1
JET PROPULSION LABORATORY	
Pasadena, California	3
KAISER AEROSPACE & ELECTRONICS CORP.	
Palo Alto, California	1
KLEINSCHMIDT	
Div. of SCM Corp., Deerfield, Illinois	1
KOLLSMAN INSTRUMENT CORP.	
Elmhurst, New York	1
Syosset, New York	2
WILLIAM X. LAMB & ASSOC.	
Woodland Hills, California	1
LITTON INDUSTRIES	
Monroe International Div., Orange, New Jersey	2
LITTON SYSTEMS, INC.	
Data Systems Div., Van Nuys, California	3
LOCKHEED	
Lockheed-California Co., Burbank, California	1
Lockheed Electronics Co., Plainfield, New Jersey	2
Lockheed Missiles & Space Co., Sunnyvale, Calif.	6
Lockheed Palo Alto Research Lab., Palo Alto, Calif.	2

APPENDIX I (Cont.)

LORAL ELECTRONIC SYSTEMS	
Div. of Loral Corp., The Bronx, New York	1
LTV ELECTROSYSTEMS, INC.	
Garland Div., Dallas, Texas	1
MAGNAVOX COMPANY	
Fort Wayne, Indiana	1
MARTIN MARIETTA CORP.	
Denver, Colorado	3
MASSACHUSETTS INSTITUTE OF TECHNOLOGY	
Concord, Massachusetts	1
MAXSON ELECTRONICS CORP.	
Great River, Long Island, New York	1
MELPAR, INC.	
Falls Church, Virginia	1
MOTOROLA INC.	
Chicago, Illinois	1
Gov't. Electronics Div., Scottsdale, Arizona	1
Semiconductor Products Div., Phoenix, Arizona	1
MC DONNELL DOUGLAS CORP.	
Douglas Aircraft, Long Beach, California	1
St. Louis, Missouri	2
Western Div., Huntington Beach, California	3
Western Div., Santa Monica, California	1
MC GRAW-EDISON POWER SYSTEMS DIV.	
South Milwaukee, Wisconsin	1
NATIONAL CASH REGISTER CO., THE	
Electronics Div., Hawthorne, California	3
NATIONAL RADIO CO., INC.	
Melrose, Massachusetts	1
NEW YORK UNIVERSITY	
New Yor, New York	1
NORTH AMERICAN ROCKWELL CORP.	
Autonetics Div., Anaheim, California	4
Columbus Div., Columbus, Ohio	1
NORTH ELECTRIC COMPANY	
Galion, Ohio	1

APPENDIX I (Cont.)

NORTHROP	
Northrop/Norair, Div. of Northrop Corp., Hawthorne, California	1
Northrop/Nortronics, Hawthorne, California	2
Ventura Div., Newbury Park, California	1
OLIVETTI UNDERWOOD CORP.	
Englewood Cliffs, New Jersey	1
New York, New York	1
PHILCO-FORD CORPORATION	
C & E Div., Willow Grove, Pennsylvania	1
Microelectronics Div., Blue Bell, Pennsylvania	1
Space & Re-Entry Systems Div., Palo Alto, Calif.	2
WDL Div., Houston, Texas	1
PHILLIPS PETROLEUM CO.	
Atomic Energy Div., Idaho Falls, Idaho	1
PLANNING RESEARCH CORP.	
Los Angeles, California	1
PRD ELECTRONICS, INC.	
Westbury, Long Island, New York	1
RADIATION INC.	
Systems Div., Melbourne, Florida	2
RADIO ENGINEERING LABORATORIES	
Long Island City, New York	1
RAYTHEON COMPANY	
Equipment Div., Norwood, Massachusetts	2
Equipment Div., Wayland, Massachusetts	2
Lexington, Massachusetts	1
Missile Systems Div., Andover, Massachusetts	2
Military Systems Div., Bedford, Massachusetts	1
Missile Systems Div., Lowell, Massachusetts	1
Santa Ana, California	1
RADIO CORP. OF AMERICA	
Burlington, Massachusetts	1
Camden, New Jersey	3
Moorestown, New Jersey	1
Somerville, New Jersey	1
RF COMMUNICATIONS, INC.	
Rochester, New York	1

APPENDIX I (Cont.)

SANDERS ASSOCIATES, INC.	
Nashua, New Hampshire	1
Plainview, New York	1
SANDIA CORPORATION	
Albuquerque, New Mexico	1
SANGAMO ELECTRIC CO.	
Springfield, Illinois	1
SCIENTIFIC-ATLANTA, INC.	
Atlanta, Georgia	1
SINGER-GENERAL PRECISION, INC.	
Kearfott Div., Pleasantville, New York	1
SPACECRAFT, INC.	
Huntsville, Alabama	1
SPACE/DEFENSE CORP.	
Birmingham, Michigan	1
SPERRY RAND CORP.	
Sperry Flight Systems Div., Phoenix, Arizona	1
Sperry Gyroscope Div., Great Neck, New York	2
Sperry Marine Systems Div., Charlottesville, Va.	1
Univac Federal Systems Div., St. Paul, Minnesota	1
WALTER V. STERLING, INC.	
Los Altos, California	1
STEWART-WARNER MICROCIRCUITS, INC.	
Sunnyvale, California	1
SYLVANIA ELECTRIC PRODUCTS, INC.	
Semiconductor Div., Woburn, Massachusetts	3
Waltham, Massachusetts	3
Western Div., Mountain View, California	2
SYSTEMS GENERAL CORP.	
McLean, Virginia	1
TASKER INSTRUMENTS CORP.	
Chatsworth, California	1
TELEDYNE COMPANY	
Geo. Tech., Dallas, Texas	1
Teledyne Systems, Los Angeles, California	1
Teledyne Systems, Northridge, California	1
Teledyne Telemetry, Los Angeles, California	1

APPENDIX I (Cont.)

TENSOR RESEARCH, INC.	
Vienna, Virginia	1
TRW SYSTEMS GROUP	
Clearfield, Utah	1
IRC Div., Philadelphia, Pennsylvania	1
Redondo Beach, California	3
TRW Semiconductors, Inc., Lawndale, California	1
UNIDYNAMICS	
Library, St. Louis, Missouri	1
UNITED AIRCRAFT CORP.	
Electronics Components Div., Trevose, Pennsylvania	1
Norden Div., Norwalk, Connecticut	3
Norden Div., Trevose, Pennsylvania	1
Pratt & Whitney Aircraft, East Hartford, Conn.	1
Sikorsky Aircraft, Stratford, Connecticut	1
UNITED CONTROL CORP.	
Aerospace Div., Redmond, Washington	1
UNIVAC PARTS	
Federal Systems Div., St. Paul, Minnesota	1
UCLA	
Los Angeles, California	1
VALUE ENGINEERING COMPANY	
Alexandria, Virginia	1
VITRO LABORATORIES	
Silver Spring, Maryland	1
WESTERN ELECTRIC	
Defense Activities Div., Greensboro, N. Car.	1
Greensboro Shops, Greensboro, North Carolina	1
WESTERN UNION	
Mahwah, New Jersey	1
WESTINGHOUSE ELECTRIC CORP.	
Surface Div., Baltimore, Maryland	1
WESTON INSTRUMENTS, INC.	
Newark, New Jersey	1
WOODWARD GOVERNOR COMPANY	
Fort Collins, Colorado	1

APPENDIX I (Cont.)

U.S. AIR FORCE

AFSC Andrews Air Force Base, Washington, D.C.	3
AIR FORCE AVIONICS LAB. Wright-Patterson AFB, Ohio	1
DEPT. OF AIR FORCE HEADQUARTERS Ogden Air Material Area, Hill AFB, Utah	1
AIR FORCE LIAISON REPRESENTATIVE Dallas, Texas	1
AIR FORCE UNIT POST OFFICE Los Angeles, California	1
AIR FORCE WEAPONS LAB. Kirtland AFB, New Mexico	1
MC CLELLAN AIR FORCE BASE Sacramento, California	1
ROME AIR DEVELOPMENT CENTER Griffiss AFB, New York	1
U.S. AIR FORCE HEADQUARTERS Washington, D.C.	2

U.S. ARMY

ARMY MISSILE COMMAND HDQRTS. Redstone Arsenal, Alabama	3
U.S. ARMY ELECTRONICS COMMAND Fort Monmouth, New Jersey	1
U.S. ARMY MALLARD PROGRAM OFFICE New Shrewsbury, New Jersey	1
U.S. ARMY MATERIAL COMMAND Fort Monmouth, New Jersey	1
DEPT. OF ARMY PICATINNY ARSENAL Dover, New Jersey	6

APPENDIX I (Cont.)

U.S. DEPT. OF DEFENSE

DEFENSE RESEARCH & ENGNG.	
Communications Electronics, Washington, D.C.	1
Office of Director, Washington, D.C.	2
DEFENSE SUPPLY AGENCY	
Cameron Station, Alexandria, Virginia	1
Defense Electronics Supply Ctr., Dayton, Ohio	1
Defense Contract Admin., Services District, Orlando, Florida	1

U.S. NAVY

APPLIED SCIENCE LABORATORIES	
Brooklyn, New York	1
ASTRONAUTICS GROUP	
Pt. Mugu, California	1
AVIATION ENGINEERING SERVICE UNIT	
Philadelphia, Pennsylvania	1
AVIATION SUPPLY OFFICE	
Philadelphia, Pennsylvania	1
NAVAL AVIONICS FACILITY	
Indianapolis, Indiana	2
NAVAL ELECTRONICS SYSTEMS COMMAND	
Washington, D.C.	1
NAVAL FLEET MISSILE SYSTEMS	
Corona, California	1
NAVAL ORDNANCE STATION	
Forest Park, Illinois	1
NAVAL RESEARCH LABORATORY	
Washington, D.C.	2
NAVAL SHIP ENGINEERING CENTER	
Hyattsville, Maryland	1
Norfolk, Virginia	1
NAVAL UNDERSEA WARFARE CENTER	
San Diego, California	1

APPENDIX I (Cont.)

U.S. NAVY (Cont.)

NAVAL WEAPONS QUALITY ASSURANCE OFFICE Washington, D.C.	1
ORDNANCE LABORATORY, WHITE OAK Silver Spring, Maryland	1
PUGET SOUND NAVAL SHIPYARD Bremerton, Washington	1
UNDERWATER SOUND LABORATORY New London, Connecticut	1

NASA

AMES RESEARCH CENTER Moffett Field, California	2
ELECTRONIC RESEARCH CENTER Cambridge, Massachusetts	1
GODDARD SPACE FLIGHT CENTER Greenbelt, Maryland	1
MARSHALL SPACE FLIGHT CENTER Huntsville, Alabama	3
NASA HEADQUARTERS Electronic & Control Div., Washington, D.C.	1
Technical Applications Div., Washington, D.C.	2

OTHER GOV'T AGENCIES

COAST GUARD HEADQUARTERS Electronics Energy Div., Washington, D.C.	1
FEDERAL AVIATION ADMINISTRATION Washington, D.C.	1
NATIONAL BUREAU OF STANDARDS Washington, D.C.	1

APPENDIX II

ALPHABETICAL LISTING OF DIRECT USER INQUIRIES BY ORGANIZATION

APPENDIX II

ALPHABETICAL LISTING OF DIRECT USER INQUIRIES BY ORGANIZATION

ORGANIZATION NAME	NO. USERS
AEROJET-GENERAL	
Azusa, California	5
Sacramento, California	1
AEROSPACE CORP.	
El Segundo, California	3
Los Angeles, California	1
AEROSPACE RES. AP. CENTER (ARAC)	
Indiana Univ., Bloomington, Indiana	1
AIRESEARCH MANUFACTURING	
Torrance, California	2
AMP, INC.	
Harrisburg, Pennsylvania	1
ARINC RESEARCH	
Annapolis, Maryland	1
Western Div., Santa Ana, California	2
ARMA	
Div. of Ambac Ind., Garden City, New York	1
AUTOMATIC ELECTRIC	
Northlake, Illinois	1
AUTONETICS	
Anaheim, California	1
AVCO CORP.	
Tulsa, Oklahoma	2
BATTELLE MEMORIAL INSTITUTE	
Columbus, Ohio	1
BELL AEROSYSTEMS	
Buffalo, New York	1
BELL & HOWELL	
Pasadena, California	1

APPENDIX II (Cont.)

BENDIX CORPORATION	
Detroit, Michigan	1
Kansas City, Missouri	1
Mishawauka, Indiana	1
BOEING CORP., THE	
Aerospace Group, Seattle, Washington	5
BRADDOCK, DUNN & MC DONALD	
El Paso, Texas	1
BURROUGHS CORPORATION	
Paoli, Pennsylvania	3
CHICAGO AERIAL SURVEY	
Barrington, Illinois	2
CLEVITE ORD. DIVISION	
Cleveland, Ohio	2
COLLINS RADIO CO.	
Cedar Rapids, Iowa	2
Dallas, Texas	1
Newport Beach, California	1
COMMUNICATONS & SYSTEMS CO.	
Paramus, New Jersey	1
COMPUTER APPL. INC.	
Ridgecrest, California	1
CONDUCTRON-MISSOURI	
St. Charles, Missouri	1
CONTROL DATA CORP.	
Minneapolis, Minnesota	1
CONVAIR	
San Diego, California	1
DOUGLAS UNITED NUCLEAR	
Richland, Washington	1
DU PONT CO.	
Wilmington, Delaware	2
DYNAMIC CONTROLS	
South Windsor, Connecticut	1
DYNAMICS RESEARCH CORP.	
Stoneham, Massachusetts	2

APPENDIX II (Cont.)

ELECTRONIC IMAGE SYSTEMS	
Cambridge, Massachusetts	1
EMR TELEMETRY	
Sarasota, Florida	2
FAIRCHILD-HILLER	
Germantown, Maryland	1
FEDERAL ELECTRIC SYSTEMS	
Huntsville, Alabama	2
GENERAL DYNAMICS	
Rochester, New York	1
GENERAL ELECTRIC CO.	
Aerospace Elect. Div., Utica, New York	4
Armamant Dept., Burlington, Vermont	1
Aircraft Engine Dept., Cincinnati, Ohio	2
Apollo Systems Div., Daytona Beach, Florida	2
Heavy Military Div., Syracuse, New York	1
Huntsville, Alabama	1
King of Prussia, Pennsylvania	1
Oklahoma City, Oklahoma	2
Ordnance Div., Pittsfield, Massachusetts	1
Philadelphia, Pennsylvania	1
Phoenix, Arizona	2
Schenectady, New York	2
GENERAL TIME CORP.	
Wheeling, Illinois	2
GEORGIA INSTITUTE OF TECHNOLOGY	
Atlanta, Georgia	2
GULTON IND.	
Metuchen, New Jersey	1
HALLICRAFTERS	
Rolling Meadows, Illinois	1
HAMILTON STANDARD	
Div. of United Aircraft, Windsor Locks, Conn.	3
HAZELTINE CORP.	
Braintree, Massachusetts	1
Green Lawn, New York	1
Little Neck, New York	1

APPENDIX II (Cont.)

HONEYWELL, INC.	
Aerospace Div., St. Petersburg, Florida	3
Computer Control Div., Framingham, Mass.	2
Hopkins, Minnesota	1
Minneapolis, Minnesota	4
Tampa, Florida	2
HUGHES AIRCRAFT CO.	
Culver City, California	2
Fullerton, California	1
HUGHES RESEARCH LABS.	
Malibu, California	1
IIT RESEARCH INSTITUTE	
Ceramics Div., Chicago, Illinois	1
IBM	
Hopewell Junction, New York (for German facil.)	1
Owego, New York	1
Poughkeepsie, New York	1
ITT	
Nutley, New Jersey	1
JET PROPULSION LABORATORY	
Pasadena, California	2
KLEINSCHMIDT LABS.	
Deerfield, Illinois	1
KOLLSMAN INST. CORP.	
Syosset, New York	1
LEAR SIEGLER CO.	
Wyoming, Michigan	1
LITTON DATA SYSTEMS	
Van Nuys, California	4
LOCKHEED MISSILES & SPACE CO.	
Elec. Sciences Lab., Palo Alto, California	2
Plainfield, New Jersey	1
Sunnyvale, California	3
LTV ELECTRO SYSTEMS	
Dallas, Texas	1

APPENDIX II (Cont.)

MARTIN MARIETTA CORP.	
Denver, Colorado	6
Orlando, Florida	1
MOTOROLA INC.	
Chicago, Illinois	1
MC DONNELL DOUGLAS	
Astronautics Div., St. Louis, Missouri	2
Huntington Beach, California	4
Santa Monica, California	1
NORTH ELECTRIC CO.	
Gallion, Ohio	1
NORTRONICS	
Hawthorne, California	2
PHILCO-FORD CORP.	
Palo Alto, California	1
Willow Grove, Pennsylvania	5
PRD ELECTRONICS	
Syosset, New York	9
PROBABALISTIC SOFTWARE INST.	
Tujunga, California	1
RADIATION, INC.	
Melbourne, Florida	5
RADIO CORP. OF AMERICA	
Camden, New Jersey	1
RAYTHEON COMPANY	
Andover, Massachusetts	3
Bedford, Massachusetts	3
CADPO, Norwood, Massachusetts	3
Computer Off., Santa Ana, California	1
Lexington, Massachusetts	1
Wayland, Massachusetts	3
SANGAMO ELECTRIC	
Springfield, Illinois	1
SANDERS ASSOC.	
Nashua, New Hampshire	1
SANDIA CORP.	
Albuquerque, New Mexico	2

APPENDIX II (Cont.)

SIEMENS	
Munich, Germany	1
SIKORSKY AIRCRAFT	
Stratford, Connecticut	1
SINGER-GENERAL PRECISION	
Pleasantville, New York	1
SPACECRAFT, INC.	
Huntsville, Alabama	1
SPERRY RAND	
Flt. Systems Div., Phoenix, Arizona	3
Marine Div., Charlottesville, Virginia	1
Microwave Div., Clearwater, Florida	1
Res. Lab., Sudbury, Massachusetts	1
STERLING, WALTER C. INC.	
Los Altos, California	1
STEWART-WARNER	
Sunnyvale, California	1
SYLVANIA ELECTRIC	
ME Oper., Waltham, Massachusetts	1
Mountain View, California	1
Semiconductor Div., Woburn, Massachusetts	1
TELEDYNE, INC.	
Teledyne Systems Co., Northridge, Calif.	2
Telemetry Div., Los Angeles, California	1
TRW INC.	
Redondo Beach, California	4
UNITED CONTROLS	
Redmond, Washington	1
UNIVAC	
Div. of Sperry Rand, Rel. Sect., St. Paul, Minn.	2
USM MACHINERY CO.	
Beverly, Massachusetts	1
WESTINGHOUSE ELECTRIC	
Aerospace Div., Baltimore, Maryland	1

APPENDIX II (Cont.)

U.S. AIR FORCE

AIR FORCE MATERIALS LAB. Wright-Patterson AFB, Ohio	1
AIR FORCE WEAPONS LAB. Kirtland AFB, New Mexico	1
ROME AIR DEVELOPMENT CENTER Griffiss AFB, New York	2

U.S. ARMY

ARMY MISSILE COMMAND Redstone Arsenal, Huntsville, Alabama	4
PICATINNY ARSENAL Dover, New Jersey	2

U.S. NAVY

CENTER FOR NAVAL ANALYSES Arlington, Virginia	1
FLEET MISSILE SYSTEMS Analysis & Eval. Group (FARADA) Corona, Calif.	1
NAVAL AVIATION SERVICE Philadelphia, Pennsylvania	1
NAVAL AVIONICS FACILITY Crane, Indiana Indianapolis, Indiana	 2 5
NAVAL SHIP ENGR. CENTER Norfolk, Virginia	1
PUGET SOUND NAVAL SHIPYARD Bremerton, Washington	1
U.S. NAVAL ORD. LAB. Silver Spring, Maryland	1
U.S. NAVAL WEAPONS Washington Navy Yard, Washington, D.C.	1
U.S. NAVY ASTRONAUTICS Pt. Mugu, California	2

APPENDIX II (Cont.)

U.S. NAVY TORPEDO PLANT Forest Park, Illinois	1
U.S. NAVY UNDERWATER SOUND LAB. New London, Connecticut	2

NASA

AMES RESEARCH CTR. Moffett Field, California	2
ERC Cambridge, Massachusetts	1
GODDARD SPACE FLIGHT CENTER Greenbelt, Maryland	1

OTHER GOV'T. AGENCIES

ALBANY METALS RES. CENTER U.S. Bureau of Mines, Albany, Oregon	1
COAST GUARD HEADQUARTERS Washington, D.C.	2
NATIONAL BUREAU OF STANDARDS Washington, D.C.	1

APPENDIX II

REPRESENTATIVE USER INQUIRIES

APPENDIX III

REPRESENTATIVE USER INQUIRIES

Inquiry ID	Information or Assistance Requested
9806	What is current industry practice on operational screening (burn-in) of IC's?
9815	What improvement is expected from screening of semiconductors - furnish comparative data.
9825	Provide reliability test data on dielectrically isolated IC devices.
9829	What is the expected relative occurrence of predominant failure modes of 930 series DTL IC devices in computer checkout systems?
9849	Furnish bibliographic references on thin film device fabrication process factors that influence reliability.
9862	What reliability test data is available on MSI devices of 40-100 gate complexity? Also, what is rationale for projecting IC failure rates to MSI?
9865	Provide information concerning guidelines for derating IC's.
9875	Require failure rate data on dual-in-line ceramic TTL devices in an airborne environment.
9876	Provide test data for digital IC devices under AGREE equipment test conditions.
9879	What failure data is available on the SUHL family of IC devices in field environment? Provide references of users of these devices.
9884	What are possible mechanisms causing melting metalization of a hi-rel Op-Amp device under system operating conditions?
9888	Provide information in IC package hermeticity (leak rate) vs. life expectancy.
9892	What process control techniques can be used with hybrid IC devices to assure reliability without large scale testing?

APPENDIX III (Cont.)

Inquiry ID	Information or Assistance Requested
9894	Is ultrasonic tin dipping of component leads accepted industry practice? Does the method induce unusual stresses within devices that may affect reliability?
9912	Require information on the influence of glass passivation - including advantages, disadvantages, potential problems, etc.
9927	Making a feasibility study of plastic IC devices for use in air-conditioned, ground-based application - require reliability data and evaluation procedures.
9929	Request data on failure rates of bonds typical of thin film circuitry, e.g., gold-gold thermocompression, gold-aluminum thermocompression, aluminum-aluminum thermocompression, etc.
9936	How do failure rates of commercial grade IC devices compare with MIL grade?
9945	Systems contractor requested an appraisal of his methodology for estimating IC reliability based on their available data.
9946	Require data and guidance information on current quality assurance practices for LSI components.
9953	Setting up a component failure analysis laboratory; desire references to organizations with operating facilities for consultation purposes.
9962	Require long life test data on IC and discrete semiconductor devices for use as basis in estimating reliability out to 50,000 hours.
9971	To what extent do surface defects in the SiO_2 layer increase due to ultrasonic bonding of flip chips?
9982	Provide failure rate data on 709-741 series of Op-Amps applicable for ground equipment operating in controlled ambient of 50°C.
9983	Furnish a comprehensive bibliography on materials, processes and experience of various IC wire bond systems.

APPENDIX III (Cont.)

Inquiry ID	Information or Assistance Requested
9995	Desire any available data or information on corrosion susceptibility of tin-plated IC leads used in conjunction with gold-plated sockets.
9998	What methods are available for reliability prediction of LSI devices?
0008	Require data on acceleration factors of thick film hybrid circuit resistors. Also, to what extent are hot spots and substrate cracks detrimental?
0019	Furnish six (6) additional copies of Technical Monograph TM 69-1, "Screening of Integrated Circuits."
0021	Desire failure rate and other reliability data on T.I. LSI components.
0023	What are long term physical mechanisms that can lead to drift failure modes or other subtle effects that may influence survivability in a nuclear environment?
0028	Request assistance in isolating possible cause of "Zap" type IC failures in operating computer system.
0045	Desire information on MOS-MSI failure rates and prediction techniques. Also, what reliability data is available on IC devices fabricated using ion implantation techniques?
0046	Interested in comparative failure rates of IC devices housed in glass, plastic, ceramic and metal packages.
0053	Desire recommendations for alternate source for Sylvania SUHL II device family for high frequency, high load application.
0054	Supply information on temperature and electrical derating practices for IC and discrete semiconductor devices.

APPENDIX IV

INPUT DATA REQUIREMENTS FROM
SYSTEM/EQUIPMENT CONTRACTORS

APPENDIX IV

INPUT DATA REQUIREMENTS FROM SYSTEM/EQUIPMENT CONTRACTORS

(A) EQUIPMENT/SYSTEMS CONTRACTOR - Engineering Development

Output Report Type Name	Source/Content	When Furnished
Device Procurement Control Specifications	- Individual device specs., general test specs., screening specs., packaging specs. and other referenced documents.	A complete set furnished as a package upon production release; revisions furnished as issued.
Device Count and Application Stress Listings	- Tabular listings of the number and approximate application stress of each unique microcircuit device sales type organized by identifiable system functional assembly. (see ref. form RAC 68-6)	Completion of equipment/system development.
Equipment R & D Test Reports	- Results of bench, life and environmental testing of assemblies and system elements.	Completion of equipment system development. Separate reports required for each unique system/equipment entity.

APPENDIX IV

INPUT DATA REQUIREMENTS FROM SYSTEM/EQUIPMENT CONTRACTORS

(B) EQUIPMENT/SYSTEM CONTRACTOR - Production Phase

Output Report Type Name	Source/Content	When Furnished
Device Level Test Reports	- Device Qualification Test Reports - Lot Acceptance Test Reports - Screen & Burn-In Test Reports - Special Life or Environmental Test Reports	Furnished as issued--must be identified according to procurement control spec number. These reports may be generated by device vendors if testing is performed by them.
Production/Post Production Inspection, Qualification, Category I and Reliability Demonstration Tests	- Inprocess equipment malfunctions caused by integrated circuits. - Post-Production checkout of equipment resulting in microcircuit failures - Reliability demonstration or Category I test results noting microcircuit failures, if any.	Summary reports issued quarterly during production phase. (see form RAC 68-16)
Failure Analysis Summary	- Tabular listing of all microcircuit failure occurrences and the responsible modes and mechanisms; also, corrective action taken where applicable.	Furnished by Contractor at quarterly intervals during design, production, test and post production phases. See: AFSCM 310-1G R-104, R-105 and form RAC 68-17.

APPENDIX IV

INPUT DATA REQUIREMENTS FROM SYSTEM/EQUIPMENT CONTRACTORS

(C) PRIME CONTRACTOR - Equipment/Systems Test & Operation

Output Report Type Name	Source/Content	When Furnished
Mission Failure Summary Report	- Results of field testing: Category I & II test reports; installation, check-out, operation & maintenance malfunctions. - Characterization of test or mission profile; count of missions performed; and failure count by device and functional assembly.	Summaries to be furnished at completion of a specified test program and/or at calendar intervals whichever is appropriate.

RAC 68-6

DEVICE/COUNT APPLICATION STRESS SUMMARY

page of

originator/contractor	contract num	report num	date
	equipment/assembly name	nomenclature	
prime contractor	primary function	type application	
cognizant system project office	ENVIRONMENTAL PROTECTION		
	TEMP CONTROL: heated / refrig / forced	temp / duty ~	other
system/subsystem used on	VOLTAGE/CURRENT PROTECTION: surge / volt / current	shock/vibr mounts	

DEVICE NUMBER	DEVICE NAME	MANUFACTURER	NUMBER USED	% VOLT RATING	% PWR RATING	DEVICE TEMP*

* At 25°C ambient outside housing

Prepared by-Signature | Title

RELIABILITY ANALYSIS CENTER
10 West 35 Street
Chicago, Illinois 60616

RAC PERIODIC SUMMARY - MICROELECTRONIC MALFUNCTIONS IN EQUIPMENT

PAGE ____ OF ____

PROGRAM NAME:	NAME AND/OR DESCRIPTION OF TEST	CONTRACT NUMBER	REPORT NUMBER	DATE
ORIGINATOR/CONTRACTOR:	SYSTEM/SUBSYSTEM USED ON NUMBER OF UNITS MONITORED	EQUIPMENT/ASSEMBLY NAME	NOMENCLATURE REPORTING PERIOD: START END	

SERIAL NUMBER	APPLICABLE TEST SPEC.	NUMBER TIMES FAILED	TIME TO FAILURE (IF APPLIC.)	FAILURES CAUSED BY MICROELECTRONICS				FAILURE ANALYSIS REPORT NUMBER
				DEVICE NUMBER	DEVICE NAME	MFR.	NUMBER FAILED	

PREPARED BY: TITLE:

RAC 68-16

FAILURE ANALYSIS REPORT

RELIABILITY ANALYSIS CENTER
10 West 35 Street
Chicago, Illinois 60616

REPORT NO.

IDENTIFICATION

PROGRAM NAME:	EQUIPMENT	DEVICE	
CONTRACTOR:	NAME:	NAME:	MFR.:
SYSTEM:	DESIGNATION:	USER NO.:	MFR'S NO.:
CONTRACT NO.:	SERIAL NO.:	APPLIC. SPEC. NO.:	MFR'S LOT CODE:

a) HISTORY b) ANALYSIS c) CONCLUSIONS d) RECOMMENDATIONS

RAC USE ONLY
MEL CATEGORY:
FCTL. CATEGORY:
PKG CNFG:
OPRNL TYPE:
QUAL. CLASS:
INTRCON SYSTEM:
CKT CPXTY:
RAC USE ONLY

CONTINUE ON ADDITIONAL SHEETS AS NEEDED

REPORTING ORGANIZATION:	SIGNATURE & TITLE:	DATE:

RAC 60-17

INSTRUCTIONS FOR PREPARING FAILURE ANALYSIS REPORT

1. Complete all applicable identification items as indicated. Device identity and applicable user specification information is particularly essential.

2. Attach any photos, sketches or other diagrams.

3. Free form may be used to complete items a) through d) continuing on additional sheets as needed.

   a) HISTORY: Background information will include special screening or burn-in requirements for the device if applicable. State conditions leading to malfunction and how discovered. Show the approximate environment (where applicable), number or relative percentage of items affected plus any other information indicating the source and nature of problems encountered.

   b) ANALYSIS: State facts of the problem and failure modes and mechanisms discovered.

   c) CONCLUSION: State the cause of failure as completely as possible.

   d) RECOMMENDATION: Suggestions to prevent recurrence of the same problem.

APPENDIX V

DATA INPUT GUIDELINES FOR MICROCIRCUIT RELIABILITY TEST PROGRAMS

APPENDIX

SP-ID-03
8-20-69

RELIABILITY ANALYSIS CENTER

DATA INPUT GUIDELINES FOR
MICROCIRCUIT RELIABILITY TEST PROGRAMS

1.0 Purpose and Scope

The Reliability Analysis Center (RAC) serves as a centralized activity, under Dept. of Defense auspices, for the collection, reduction, analysis and dissemination of reliability information on microelectronic devices. The Center draws its input information from the reliability test programs and studies conducted as regular ongoing functions by industrial and government agencies in support of their device development, fabrication and deployment operations. Data resulting from device level quality assurance and reliability demonstration tests represent particularly rich sources of input data. Such activities are performed by reasonable control over test vehicle identification, test design and data gathering procedures. This document defines the specific data elements and items resulting from these activities that are desired for input to the Center.

2.0 General Provisions

2.1 Proprietary Data

All furnished data items of a proprietary nature shall be positively identified as such by the source. Internal handling procedures will assure positive security of sensitive information.

2.2 Formats

RAC will accept data in any form that is convenient to the source organization. Primary concern is that furnished data and information contain positive identification and descriptive items as defined in appropriate paragraphs below. Formats incorporated herein are for guidance purposes and may be used at the option of the source organization.

2.3 Certification

To enhance credibility, data of the types described herein and furnished to RAC shall contain the signature of an appropriate company officer certifying to its factual completeness and accuracy.

PRECEDING PAGE BLANK

3.0 Types of Data

Data covered by these guidelines includes that generated as a result of quality assurance, lot acceptance or other special reliability test programs. Tests shall include, but not necessarily be restricted to: burn-in tests, life tests, thermal storage, accelerated and step stress tests, and environmental tests. Data and information to be furnished for each reported test shall be as follows:

3.1 Device Design Information

3.2 Screening and Burn-In Procedures

3.3 Test Design

3.4 Variables Measurements Data

3.5 Analysis Results

3.6 Failure Autopsy Findings

4.0 Detailed Data Requirements

The desired specific information items to be furnished for each type of information and data are described in the following paragraphs.

4.1 Device Design Information

Each unique device design employed in the test program shall be completely described to permit positive identification and classification. The essential data items are as shown in the following formats which accompany this specification.

4.1.1 Microelectronic Device Family Information

This form contains data items which generally are common to a number of device types of the same general design and fabricated by similar processes using identical materials. Only one such set of information is required for each designated family used in the test program.

4.1.2 Microelectronic Device Packaging Information

This form contains data items pertinent to a particular package design. One set of information is required for each package type employed in the test vehicles.

4.1.3 Detailed Microelectronic Device Information

Data items pertaining to specific device types are itemized on this form. The specified information is required on each unique device configuration employed in the test program.

4.2 Screening and Burn-In Procedures

A complete history of all screening and burn-in procedures or other stabilizing influences to which test vehicles were subjected subsequent to fabrication and prior to employment in the test program shall be provided. Typical data items include:

- screen test name
- applied stress conditions
- stress duration
- failure criteria
- specification reference
- failure cause(s) of screen dropouts.

4.3 Test Design

Test design information items shall include:

- stress name
- stress conditions (thermal, electrical, physical and atmospheric)
- test duration
- test procedures
- specification references
- sample size
- failure criteria

plus other pertinent information as may be required to properly classify and interpret results.

4.4 Variables Measurements Data

The initial and periodically measured values of each device parameter monitored during the test program shall be documented for submission. In addition, the reported results shall include:

manufacturing data of test vehicles

maturity status of test vehicles (e.g. developmental, prototype, pilot production or production)

data test initiated

date of each readout

failure mode of each failing test specimen

test completion data

signature(s) of test personnel.

4.5 Analysis Results

Summary data resulting from reduction and analysis of variables measurements data shall be furnished to the Center whenever such analyses are undertaken by the source organization. Summary data must be sufficiently documented to permit interpretation and understanding of the analysis method, assumptions and criteria employed, the variables or parameters treated and the findings observed. Some common analyses of interest are:

4.5.1 Failure attributes summary - indicate failure criteria, number tested, number failed, time to failure of failed specimens, and total part hours.

4.5.2 Failure vs. stress level

4.5.3 Failure vs. time distributions - Weibull, Gamma, exponential, etc.

4.5.4 Failure rate vs. stress

4.5.5 Parameter drift vs. time

4.5.6 Parameter density histogram

4.5.7 Parameter stability - correlation plot of pre- vs. post-test parameter values

4.5.8 Failure mode and mechanism summaries

4.6 Failure Autopsy Findings

Autopsy findings of each failed test vehicle shall be furnished. A Failure Analysis Report form is included herewith to indicate the desired information items. It is permissable to document findings of several failures having a common mode and cause of failure in a single report. The test and stress condition and time to failure shall be reported for each failed specimen observed.

RELIABILITY ANALYSIS CENTER

MICROELECTRONIC DEVICE FAMILY INFORMATION

(one form required for each device family e.g. common batch process area or production line)

MANUFACTURER	DEVICE FAMILY DESIGNATION	APPLICABLE DEVICE TYPE NUMBERS

BASIC TECHNOLOGY *(check box for technology used)*

☐ EPITAXIAL DIFFUSED ☐ SINGLE CHIP ☐ HYBRID ☐ MOS ☐ MONOLITHIC WITH COMPATIBLE THIN FILM ELEMENTS

☐ TRIPLE DIFFUSED ☐ MULTICHIP ☐ THIN FILM ☐ THICK FILM

☐ WITH BURIED LAYER ☐ OTHER (SPECIFY) ____________

SUBSTRATE MTL

☐ SI, ☐ P-TYPE, ☐ N-TYPE

☐ OTHER ____________

ISOLATION METHOD

☐ JUNCTION

☐ RESISTIVE

DIELECTRIC

☐ AIR ☐ CERAMIC

☐ SiO_2 ☐ GLASS

☐ OTHER ____________

METAL INSULATOR SEMICONDUCTOR DEVICES

DIELECTRIC TYPE

☐ OXIDE ☐ NITRIDE

☐ OTHER ____________

IGFETS

☐ ENHANCEMENT MODE ☐ P-CHANNEL

☐ DEPLETION MODE ☐ N-CHANNEL

DIELECTRIC THICKNESS

TRANSISTORS ____________

CAPACITORS ____________

SURFACE PASSIVATION

☐ OXIDE ☐ NITRIDE ☐ GLASS MINIMUM THICKNESS ____________

ADDITIONAL PASSIVATION: ____________

INTERCONNECTION METALIZATION

☐ ALUMINUM ☐ GOLD ☐ OTHER(S): ____________

THICKNESS(ES): ____________

FILM DEVICES

☐ CAPACITORS ☐ RESISTORS ☐ INDUCTORS

CONDUCTOR MTL & THICKNESS: ____________

RESISTOR MTL & THICKNESS: ____________

DIELECTRIC MTL & THICKNESS: ____________

FORM RAC 69-2A PAGE 1

QUALITY CONTROL CHECKS - SPECIFY METHOD OR PROCEDURE USED TO CHECK AND/OR CONTROL THE FOLLOWING PARAMETERS BEFORE SEALING THE PACKAGE (E.G. ELECTRICAL FUNCTION: PROBING)

1. SHEET RESISTIVITY
   A. SEMICONDUCTOR:
   B. METALIZATION:
2. JUNCTION PROFILES:
3. PASSIVATION THICKNESS:
4. PASSIVATION QUALITY:
5. OHMIC CONTACTS:
6. ELECTRICAL FUNCTION:
7. METALIZATION ADHERENCE:
8. METALIZATION THICKNESS:
9. BOND STRENGTH (WIRE OR FLIP-CHIP)

FORM RAC 68-2A PAGE 2

RELIABILITY ANALYSIS CENTER

MICROELECTRONIC DEVICE PACKAGING INFORMATION

(one form required for each package type)

MANUFACTURER :

PACKAGE DESIGNATION :

JEDEC NUMBER :

NUMBER OF LEADS :

PACKAGE CONFIGURATION: ☐ CAN ☐ FLAT PACK ☐ DUAL IN LINE ☐ MODULE

PACKAGE MATERIALS	LEAD TO PKG SEAL	LID TO BASE SEAL
LID ____________	☐ CERAMIC	☐ CERAMIC
____________	☐ GLASS	☐ GLASS
	☐ PLASTIC	☐ WELD
BASE ____________	☐ OTHER: ____________	☐ OTHER: ____________
____________	____________	____________

DIE BONDING METHOD

☐ EUTECTIC ALLOY BRAZE
☐ GLASS FRIT
☐ SOLDER
☐ BEAM LEAD
☐ FLIP CHIP
☐ OTHER ____________

FLIP CHIP / BEAM LEAD BONDING (IF USED)

METALIZATION MATERIAL (S)
(IF METALIZATION IS USED TO CONNECT DIE TO PACKAGE LEADS) :

____
____
____
____

DIRECT BONDING METHOD

☐ THERMOCOMPRESSION
☐ ULTRASONIC
☐ SOLDER
☐ SOLDER AND METAL BALLS
OTHER : ____________

WIRE BONDING

WIRE MATERIAL

☐ GOLD
☐ ALUMINUM
☐ OTHER ____________

BONDING METHOD

☐ BALL THERMOCOMPRESSION
☐ WEDGE THERMOCOMPRESSION
☐ STITCH THERMOCOMPRESSION
☐ ULTRASONIC
☐ OTHER ____________

SUBSTRATE BONDING (If an insulating substrate is used, such as with thin film, multichip, flip chip, and beam lead construction, specify method of bonding substrate to package.

FORM RAC 68-3A

RELIABILITY ANALYSIS CENTER

DETAILED MICROELECTRONIC DEVICE INFORMATION

(One form required for each device type number)

MANUFACTURER	DEVICE TYPE NUMBER	DEVICE NAME

(This space for RAC use only)

MEL CTGY ____________ OP TYPE ____________ ISOL MTD ____________

FCTL CTGY ____________ QUAL CLASS ____________ CKT CPXTY ____________

PKG CNFG ____________ INTERCON SYST ____________

FUNCTIONAL PROPERTIES

SCHEMATIC DIAGRAM: Attach schematic diagram of circuit showing all circuit components including isolation diodes or regions, zener diodes on IGFET gates, and method of connecting transistors as diodes.

CHIP TOPOGRAPHY: Attach photograph or scale drawing of top surface of chip showing device layout, interconnect pattern and bonded wire layout.

PROCESSING DETAILS

PROCESS FLOW CHART: Attach copy of process flow chart.

SPECIAL PROCESSING: Detail Special Non-Standard processing steps required by users. Give user name and specify number if applicable.

POST PRODUCTION SCREENING

TEST SPECIFICATIONS: Give specification source and number: ____________

(If other than military specification is used, please provide a copy of specification used or details of screening and burn-in procedures).

DESTRUCTIVE TESTS: Indicate any limit or other destructive tests (i.e., Step Stress) that are conducted on each lot as part of Lot Acceptance procedure. State stress type and conditions and whether test vehicles are marketable items, non-functional items, or special test patterns.

DEVIATIONS FROM STANDARD FAMILY PROCESSING: Specify any deviations from standard family processing (as described in Form RC 68-2) peculiar to this part number, and not otherwise specified.

FORM RAC 68-4 A

FAILURE ANALYSIS REPORT

FAILURE ANALYSIS REPORT	RELIABILITY ANALYSIS CENTER 10 West 35 Street Chicago, Illinois 60616	REPORT NO.

IDENTIFICATION

PROGRAM NAME:	EQUIPMENT	DEVICE	
CONTRACTOR:	NAME:	NAME:	MFR.:
SYSTEM:	DESIGNATION:	USER NO.:	MFR'S NO.:
CONTRACT NO.:	SERIAL NO.:	APPLIC. SPEC. NO.:	MFR'S LOT CODE:

a) HISTORY b) ANALYSIS c) CONCLUSIONS d) RECOMMENDATIONS

RAC USE ONLY
REL CATEGORY:
FCTL. CATEGORY:
PKG CNFG:
OPRNL TYPE:
QUAL. CLASS:
INTRCON SYSTEM:
CKT CPXTY:
RAC USE ONLY

CONTINUE ON ADDITIONAL SHEETS AS NEEDED

REPORTING ORGANIZATION:	SIGNATURE & TITLE:	DATE:
RAC 68-17		

INSTRUCTIONS FOR PREPARING FAILURE ANALYSIS REPORT

1. Complete all applicable identification items as indicated. Device identity and applicable user specification information is particularly essential.

2. Attach any photos, sketches or other diagrams.

3. Free form may be used to complete items a) through d) continuing on additional sheets as needed.

   a) HISTORY: Background information will include special screening or burn-in requirements for the device if applicable. State conditions leading to malfunction and how discovered. Show the approximate environment (where applicable), number or relative percentage of items affected plus any other information indicating the source and nature of problems encountered.

   b) ANALYSIS: State facts of the problem and failure modes and mechanisms discovered.

   c) CONCLUSION: State the cause of failure as completely as possible.

   d) RECOMMENDATION: Suggestions to prevent recurrence of the same problem.

UNCLASSIFIED

Security Classification

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3. REPORT TITLE

OPERATION OF RELIABILITY ANALYSIS CENTER

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final Report for period 1 August 1968 to 31 August 1969

5. AUTHOR(S) (First name, middle initial, last name)

Harold A. Lauffenburger

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
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13. ABSTRACT

The Reliability Analysis Center is a service for the dissemination of reliability and experience information on microelectronic devices. It is administered for the Department of Defense by the Rome Air Development Center, Air Force Systems Command, and operated for that Center by IIT Research Institute. Its objective is to improve electronic systems reliability through a more fundamental understanding of microcircuit reliability factors and failure mechanisms. A total of 255 inquiries were answered from 207 individuals representing 104 different organizations. Additionally, regular Center publications are being mailed to 375 permanent users from 264 organizations. The data files currently contain 3191 documents of which 1597 contain summarized reliability test and experience data. The tabular failure rate and failure mode products were updated and reissued twice with each issue containing substantially more entries than the previous. Three technical monographs were distributed and another is now in printing. The File Bibliography was reissued in completely redesigned and expanded form. It now allows users to make simple searches on selected high usage terms. Data collection continued as a major effort. Primary emphasis was given to expanding the quality and quantity of malfunction data acquired from system level experience.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Reliability Information						
Information Analysis Center						
Microelectronics						
Data Center						
Data Products						
User Services						
User Operations						
Data Collection						
Data Processing						

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