AD-A109 691 TRW DEFENSE AND SPACE SYSTEMS GROUP REDONDO BEACH CA F/G 9/5

HARDNESS ASSURANCE LATCHUP TEST PROCEDURE.(U)

AUG 78 A A WITTELES DNA001-77-C-0194

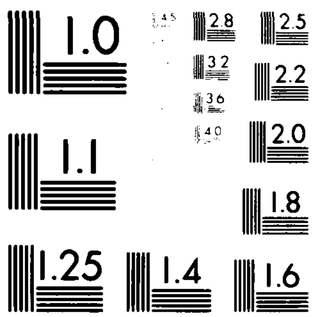
UNCLASSIFIED DNA-5595F NL

END

DATE FILMED

82

DTIC



MICROCOPY RESOLUTION TEST CHART

AD A109691

DNA 5595F

HARDNESS ASSURANCE LATCHUP TEST PROCEDURE

TRW Defense and Space Systems Group
One Space Park
Redondo Beach, California 90278

28 August 1978

Final Report for Period 25 April 1977—28 August 1978

CONTRACT No. DNA 001-77-C-0194

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED.

THIS WORK SPONSORED BY THE DEFENSE NUCLEAR AGENCY
UNDER RDT&E RMSS CODE B323077464 Z99QAXTD07207 H2590D.

Prepared for
Director
DEFENSE NUCLEAR AGENCY
Washington, D. C. 20305

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER DNA 5595F	2. GOVT ACCESSION NO. AD-A109691	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) HARDNESS ASSURANCE LATCHUP TEST PROCEDURE		5. TYPE OF REPORT & PERIOD COVERED Final Report for Period 25 Apr 77—28 Aug 78
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) A. A. Witteles		8. CONTRACT OR GRANT NUMBER(s) DNA 001-77-C-0194
9. PERFORMING ORGANIZATION NAME AND ADDRESS TRW Defense and Space Systems Group One Space Park Redondo Beach, California 90278		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Subtask Z99QAXTD072-07
11. CONTROLLING OFFICE NAME AND ADDRESS Director Defense Nuclear Agency Washington, DC 20305		12. REPORT DATE 28 August 1978
		13. NUMBER OF PAGES 20
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE N/A
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES This work sponsored by the Defense Nuclear Agency under RDT&E RMSS Code B323077464 Z99QAXTD07207 H2590D.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Dose Rate Latch-up Gamma Radiation IC Test Procedures		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The work defines the required test procedures for gamma dose rate testing of semiconductor circuits to determine their susceptibility to radiation-induced latchup.		

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

SECTION 1

PURPOSE

This test procedure defines the detailed requirements for gamma dose rate testing of semiconductor integrated circuits to determine if they are susceptible to radiation-induced latchup. This test is not deleterious and devices which have been subjected to and passed the test may be used as production hardware.

1-1 DEFINITION OF RADIATION-INDUCED LATCHUP.

There are two types of radiation-induced latchup: (1) a hard latchup, and (2) an incipient latchup. A hard latchup is a sustained functional failure. The erroneous operational condition can be stopped by cycling bias power if burnout has not occurred in the interim. Incipient latchup is characterized by a functional failure which is not sustained, but which lasts longer than can be explained by normal circuit time constants. Identification of a latchup-susceptible IC is accomplished by identifying erroneous operating states immediately after radiation exposure by exercising the device with a functional test (defined in paragraph 3-5.1).

SECTION 2

APPARATUS

2-1 INSTRUMENTATION.

The instrumentation required to command and monitor the device under test generally consists of one or more of the following or equivalent:

Description	Model No.
DVM	HP 3440A
DC Current Probe	Tek P 6042
Pulse Generator	HP 8005A
Regulated Power Supply 0-60 VDC, 0-7.5 A	Harrison 810B
Oscilloscope	Tek 7844

All instrumentation shall be periodically calibrated in accordance with General Standard MIL-C-45662A.

2-2 TIMING CIRCUITRY.

The circuitry shall provide electrical stimulus to functional test circuitry and recording equipment for the range of 50 μs to 300 μs (unless otherwise specified) after radiation test in accordance with the performance requirements (see paragraph 3-6). A typical latchup system block diagram is shown in Figure 1.

2-3 DEVICE HOLDING FIXTURE.

The holding fixture must provide an electromechanical interface between the test device and the latchup system. It must be sufficiently adaptable to accept the IC package configuration to be tested.

2-4 BIAS CIRCUITRY.

The bias circuitry shall provide loads and bias for the device under test in accordance with the specified performance requirements. The bias circuitry shall provide a stiffening capacitor for each bias supply voltage at the device. The capacitor shall assure that the voltage at the device is maintained within 10% for the duration of the transient response.

The bias circuitry should be located on a removable universal circuit card and should be located as close as practical to the device under test to avoid the effects of cable impedances and should be shielded from the radiation.

2-5 RECORDING EQUIPMENT.

Recording equipment shall be sufficient to record critical parameter data (dosimetry, input current, output voltages, etc.).

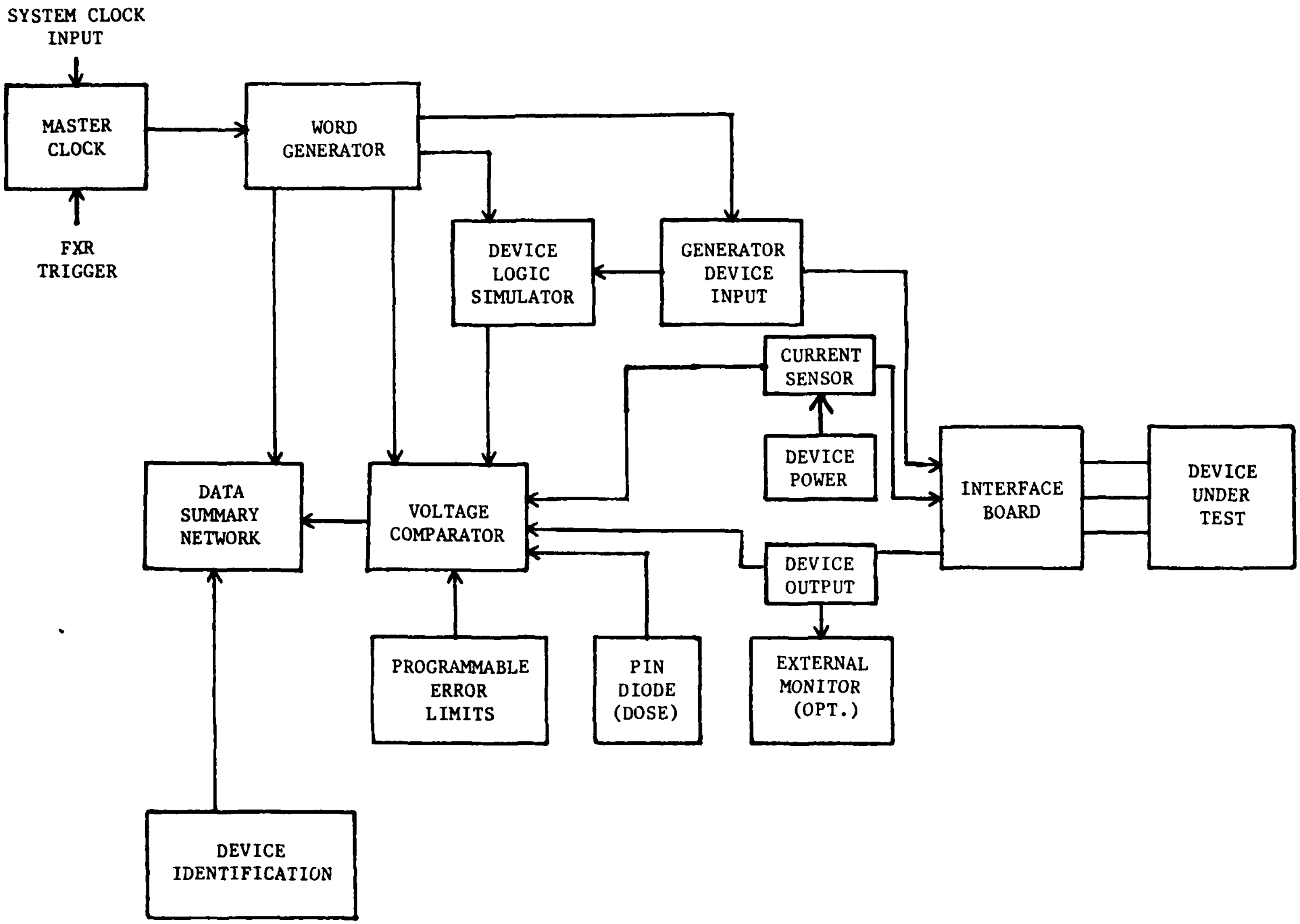


Figure 1. Latchup System

2-6 RADIATION SOURCE.

One of two radiation sources may be used with the latchup system: (1) a flash X-ray (FXR) machine, or (2) a linear accelerator (LINAC). The FXR shall be used in the photon mode and the LINAC in the e-beam mode. The LINAC beam energy must be greater than 10 MeV to insure that beam electrons are not captured in the device materials. The radiation source shall provide a uniform radiation level across the surface of the device within 20%. The dose per radiation exposure shall be 500 ± 200 rad(Si) (unless otherwise specified) with a pulse width between 20 and 100 ns or as required.

Caution: Some devices subject to latchup may have thresholds above these levels.

SECTION 3

PROCEDURE

3-1 DEVICE IDENTIFICATION.

In all cases, devices must be individually identified and traceable to the applicable recorded test data for verification of pass/fail status.

3-2 DOSIMETRY.

Dosimetry shall be used to measure the dose in rad(Si) of the radiation pulse used in the latchup test. Any dosimetry technique may be used which provides a measurement accuracy of $\pm 20\%$.

3-3 TEST SET-UP.

Apply and verify the bias voltages at the holding fixture with the device removed. Adjust timing circuitry to provide the required time interval between radiation pulse and post-test measurement. Remove bias voltage and install a control sample device, identical to the devices to be tested, into the holding fixture. Restore bias voltage and verify proper device function in accordance with the performance requirements (paragraph 3-5). Verify proper operation of all recording equipment. Perform a complete dry run using an electrical simulation of the radiation pulse to initiate the timing circuitry. Verify a pass status for all requirements except dosimetry. Remove bias voltage and control sample device, in that order. Perform a dry run radiation exposure. Check dose and dose recording equipment by verifying a pass status for the dosimetry in the recorded data.

- Exercise caution when handling devices, particularly with regard to pin alignment in the carriers and holding fixture.

- Exercise caution when attaching devices to the test circuit. Insure that bias voltages are off before attachment.

Identify test devices by serial number before insertion into the holding fixture so that traceability is maintained between the test device and its unique data set. Verify proper operation of the latchup system using the first device of each batch of common devices. Apply all appropriate voltages after the first device has been placed in the proper position in front of the radiation source. Verify proper functional operation. Bias the device in accordance with paragraph 3-5.2 and initiate the radiation environment and record all required data. Verify a pass status for all elements of the required data set. If a pass status is verified, proceed with screen test. If a failure is indicated, verify proper system operation and perform an additional radiation test. A test device exposed to 3000 rad(Si) (or as specified) or more is rejected as a failed device.

Caution: Some devices experience significant degradation at levels less than 3000 rad(Si).

3-4 SAFETY REQUIREMENTS.

All test personnel shall adhere to the health and safety requirements established by the local radiation safety officer or health physicist.

3-5 PERFORMANCE REQUIREMENTS.

3-5.1 Functional Test Requirements.

Functional test requirements shall be specified including load and bias requirements, functional test input levels and corresponding output requirements with pass/fail limits. Power supply current at the device shall be monitored before, during, and after test.

3-5.2 Small-Scale Integrated (SSI) Digital Circuit Tests.

Small-scale integrated (SSI) digital circuits shall be exposed to radiation once in each logic state. The post-irradiation functional test shall demonstrate proper device functional operation 50 to 300 μs after radiation exposure in accordance with performance requirements. The post-irradiation functional test shall demonstrate that the device will respond properly to input commands. Proper power supply current shall also be verified as part of the post-irradiation functional test.

There are two groups of digital integrated circuit devices which are latchup tested: (1) determined and (2) non-determined. Determined devices are those whose output is uniquely a function of the input, i.e., AND- and OR-gates. If the input changes, the output changes; and if the input does not change, the output does not change. Non-determined devices are those whose output is not a unique function of data inputs. For example, a J-K flip-flop output will change only with clock signal transitions when the DC set and reset inputs are inactive.

Functional tests for determined devices shall be performed as follows:

Step 1: Set device input to one of the two logic states and verify proper output.

Step 2: Radiate device, maintaining device input condition.

Step 3: Monitor device output after time interval specified in requirements and verify proper output logic state while maintaining initial logic input condition.

Step 4: Change input condition and verify a change in output condition.

Step 5: Repeat steps 1 through 4 and change the initial logic state.

A determined device whose output after radiation is not in the proper logic state or which fails to respond properly to a change in input is a failed device.

Functional tests for non-determined devices shall be performed as follows:

Step 1: Set and/or exercise device inputs and verify correct output condition.

Step 2: Radiate device, maintaining initial set input condition.

Step 3: At the prescribed time after the radiation pulse, monitor the output condition. If the output has changed from the initial condition set in Step 1, then change the input condition to properly correspond with the new output condition.

Step 4: Change the input conditions so that the output should change and verify a change in the cutput.

Step 5: Repeat steps 1 through 4 and change the initial input condition.

A non-determined device which fails to respond properly after radiation to the second change in input is a failed device; i.e., the first change in input may not change the output since the output may have already changed due to radiation. However, the second change in input condition must change the output.

3-5.3 Small-Scale Integrated (SSI) Linear Circuit Tests

A functional test shall be performed after radiation exposure and shall demonstrate proper device operation and power supply current. Power supply current shall be monitored before, during, and after exposure. There are two accetable methods for verifying proper operation.

The first method shall employ an oscilloscope and camera to record the output of the device under test after radiation exposure. Visual examination of the output behavior after radiation exposure is then used to determine failure status. A typical photograph is shown in Figure 2. Trace A shows a device output which operated properly after the radiation screen test. Trace B shows an output which failed. Note that the device output will not respond properly to the oscillating input after the radiation exposure.

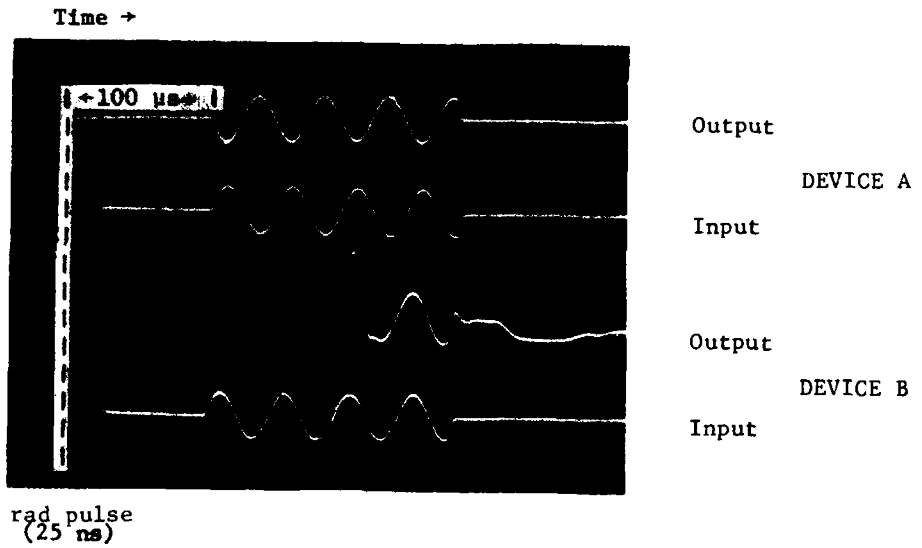


Figure 2. Linear device latchup screen test photograph (50 μs/div)

The second method uses pre-set comparators to evaluate the device output. The functional test consists of at least two different DC levels input into the device under test. The corresponding output levels are fed into the pre-set comparators for failure status determination.

3-5.4 Medium- and Large-Scale Integrated Circuit Tests.

Medium- and large-scale integrated (MSI, LSI) circuit devices normally contain more output states than can be practically monitored. An evaluation of the application of the device in the system in which the device is used must be employed to identify the input/output functions to be monitored for latchup. The selection of monitored device pins and the associated parameter limits shall be specified.

3-6 REPORTING.

Latchup test reports shall, at a minimum, include parts identification by serial number and the recorded data reporting pass/fail status.

SECTION 4

SUMMARY

The following details shall be specified in the applicable procurement document:

a. Part types (including package types) and quantities to be tested.

b. Temperature for test. The temperature shall be the highest operating temperature for the system application.

c. Requirements for data reporting and submission.

d. Test instrument requirements if other than those indicated in paragraph 2-1.

e. Electrical parameters to be measured and device operating conditions during screen test.

   (1) Worst case bias conditions for test.

      (a) Power supply voltages

      (b) Input bias

      (c) Output loading

      (d) Feedback network

      (e) External compensation network

      (f) Highest operating temperature for system

f. Time interval between radiation exposure and post-exposure functional test, if other than 50 μs.

g. Radiation dose and limits to be applied in rad(Si).

   (1) Dose limits per pulse

   (2) Total dose limits

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE

Assistant to the Secretary of Defense
ATTN: Executive Assistant

Command & Control Technical Center
ATTN: C-362, G. Adkins

Defense Advanced Rsch Proj Agency
ATTN: J. Fraser
ATTN: R. Reynolds

Defense Electronic Supply Center
ATTN: DEFC-ESA

Defense Logistics Agency
ATTN: DLA-SE
ATTN: DLA-QEL, J. Slattery

Defense Nuclear Agency
ATTN: RAEV (TREE)
4 cy ATTN: TITL

Defense Technical Info Center
12 cy ATTN: DD

Field Command
Defense Nuclear Agency
ATTN: FCP

Field Command
Defense Nuclear Agency
ATTN: FCPRL

National Security Agency
ATTN: P. Deboy
ATTN: T. Brown
ATTN: G. Daily

NATO School (SHAPE)
ATTN: US Documents Officer

Under Secretary of Defense for Rsch & Engrg
ATTN: Strategic & Space Sys (OS)

DEPARTMENT OF THE ARMY

BMD Advanced Technology Center
Department of the Army
ATTN: ATC-O, F. Ho
ATTN: ATC-T

BMD Systems Command
Department of the Army
ATTN: BMDSC-HW, R, Dekalb

Deputy Chief of Staff for Rsch Dev & Acq
Department of the Army
ATTN: Advisor for RDA Analysis, M. Gale

Harry Diamond Laboratories
Department of the Army
ATTN: DELHD-N-RBH, J. Halpin
ATTN: DELHD-N-RBH, H. Eisen
ATTN: DELHD-N-RBC, J. McGarrity
ATTN: DELHD-N-P
ATTN: DELHD-N-RBH

DEPARTMENT OF THE ARMY (Continued)

US Army Armament Rsch Dev & Cmd
ATTN: DRDAR-LCA-PD

US Army Communications R&D Command
ATTN: D. Huewe

US Army Material & Mechanics Rsch Ctr
ATTN: DRXMR-H, J. Hofmann

US Army Missile Command
3 cy ATTN: RSIC

US Army Nuclear & Chemical Agency
ATTN: Library

White Sands Missile Range
Department of the Army
ATTN: STEWS-TE-AN, T. Leura
ATTN: STEWS-TE-AN, M. Squires

DEPARTMENT OF THE NAVY

Naval Air Systems Command
ATTN: AIR 350F

Naval Electronic Systems Command
ATTN: Code 5045.11, C. Suman

Naval Ocean Systems Center
ATTN: Code 4471

Naval Postgraduate School
ATTN: Code 1424, Lib

Naval Rsch Lab
ATTN: Code 6601, A. Wolicki
ATTN: Code 6627, C. Guenzer
ATTN: Code 6816, D. Patterson
ATTN: Code 6816, H. Hughes
ATTN: Code 6600, J. McEllinney
ATTN: Code 5213, J. Killiany

Naval Sea Systems Command
ATTN: SEA-06J, R. Lane

Naval Surface Weapons Center
ATTN: Code F31
ATTN: Code F30

Naval Weapons Center
ATTN: Code 233

Naval Weapons Evaluation Facility
ATTN: Code AT-6

Naval Weapons Support Center
ATTN: Code 7024, T. Ellis
ATTN: Code 70242, J. Munarin
ATTN: Code 7024, J. Ramsey

Office of Naval Rsch
ATTN: Code 427, L. Cooper
ATTN: Code 220, D. Lewis

DEPARTMENT OF THE NAVY (Continued)

Office of the Chief of Naval Operations
ATTN: OP 985F

Strategic Systems Project Office
Department of the Navy
ATTN: NSP-27331, P. Spector
ATTN: NSP-230, D. Gold
ATTN: NSP-2015
ATTN: NSP-2701, J. Pitsenberger

DEPARTMENT OF THE AIR FORCE

Air Force Aeronautical Lab
ATTN: LTE
ATTN: LPO, R. Hickmott

Air Force Geophysics Lab
ATTN: SULL S-29
ATTN: SULL

Air Force Institute of Technology
ATTN: ENP, J. Bridgeman

Air Force Systems Command
ATTN: DLCAM
ATTN: DLW
ATTN: DLCA
ATTN: XRLA

Air Force Technical Applications Ctr
ATTN: TAE

Air Force Weapons Lab
Air Force Systems Command
ATTN: NTYC, Mullis
ATTN: NTYC, Capt Swenson
5 cy ATTN: NTYC

Air Force Wright Aeronautical Lab
ATTN: POD, P. Stover

Air Force Wright Aeronautical Lab
ATTN: TEA, R. Conklin
ATTN: DHE

Air Logistics Command
Department of the Air Force
ATTN: MMEDD
ATTN: MMETH
ATTN: OO-ALC/MM

Assistant Chief of Staff
Studies & Analyses
Department of the Air Force
ATTN: AF/SAMI

Ballistic Missile Office
Air Force Systems Command
ATTN: ENSN, H. Ward

Ballistic Missile Office
Air Force Systems Command
ATTN: ENBE
ATTN: ENSN, J. Tucker
ATTN: SYDT
ATTN: ENMG

DEPARTMENT OF THE AIR FORCE (Continued)

Foreign Technology Div
Air Force Systems Command
ATTN: PDJV
ATTN: TQTD, B. Ballard

Headquarters Space Div
Air Force Systems Command
ATTN: AQT, W. Blakney
ATTN: AQM

Headquarters Space Div
Air Force Systems Command
ATTN: SZJ, R. Davis

Rome Air Development Center
Air Force Systems Command
ATTN: RBRP, C. Lane

Rome Air Development Center
Air Force Systems Command
ATTN: ESR, W. Shedd
ATTN: ESR, P. Vail
ATTN: ESE, A. Kahan
ATTN: ESER, R. Buchanan
ATTN: ETS, R. Dolan

Strategic Air Command
Department of the Air Force
ATTN: XPFS, M. Carra

Tactical Air Command
Department of the Air Force
ATTN: XPG

DEPARTMENT OF ENERGY

Department of Energy
Albuquerque Operations Office
ATTN: WSSB

OTHER GOVERNMENT AGENCIES

Central Intelligence Agency
ATTN: OSWR/NED
ATTN: OSWR/STD/MTB, A. Padgett

Department of Commerce
National Bureau of Standards
ATTN: SEC OFC for J. Humphreys
ATTN: SEC OFC for K. Galloway
ATTN: SEC OFC for J. French

NASA
Goddard Space Flight Ctr
ATTN: V. Danchenko
ATTN: J. Adolphsen

NASA
George C. Marshall Space Flight Ctr
ATTN: L. Haniter
ATTN: EG02
ATTN: M. Nowakowski

NASA
ATTN: J. Murphy

OTHER GOVERNMENT AGENCIES (Continued)

NASA
Lewis Research Ctr
ATTN: M. Baddour

NASA
Ames Research Ctr
ATTN: G. Deyoung

DEPARTMENT OF ENERGY CONTRACTORS

Lawrence Livermore National Lab
ATTN: Tech Info Dept Lib

Los Alamos National Lab
ATTN: J. Freed

Sandia National Lab
ATTN: R. Gregory
ATTN: J. Barnum
ATTN: W. Dawes
ATTN: J. Hood
ATTN: F. Coppage

DEPARTMENT OF DEFENSE CONTRACTORS

Advanced Microdevices, Inc
ATTN: J. Schlageter

Advanced Rsch & Applications Corp
ATTN: L Palcuti
ATTN: R. Armistead

Aerojet Electro-Systems Co
ATTN: D. Toomb

Aerospace Corp
ATTN: R. Crolius
ATTN: D. Fresh
ATTN: S Bower

Aerospace Ind Assoc of America, Inc
ATTN: S. Siegel

Battelle Memorial Institute
ATTN: R. Thatcher

BDM Corp
ATTN: D. Wunch
ATTN: R. Pease
ATTN: D. Alexander

Bendix Corp
ATTN: E. Meeder

Boeing Co
ATTN: D. Egelkrout

Boeing Co
ATTN: C. Rosenberg
ATTN: I. Arimura
ATTN: A. Johnston
ATTN: W. Rumpza

California Institute of Tech
ATTN: A. Shumka
ATTN: W. Price
ATTN: A. Stanley

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

Burr-Brown Rsch Corp
ATTN: H. Smith

Charles Stark Draper Lab, Inc
ATTN: C. Lai
ATTN: R. Bedingfield
ATTN: A. Freeman
ATTN: R. Ledger
ATTN: Tech Library
ATTN: P. Greiff
ATTN: A. Schutz

Cinncinnati Electronics Corp
ATTN: L. Hammond
ATTN: C. Stump

University of Denver
ATTN: F. Venditti

E-Systems, Inc
ATTN: K. Reis

Electronic Industries Assoc
ATTN: J. Hessman

Exp & Math Physics Consultants
ATTN: T. Jordan

Ford Aerospace & Communications Corp
ATTN: Tech Info Services
ATTN: J. Davison

Franklin Institute
ATTN: R. Thompson

Garrett Corp
ATTN: R. Weir

General Dynamics Corp
ATTN: W. Hansen

General Dynamics Corp
ATTN: R. Fields
ATTN. O. Wood

General Electric Co
ATTN: J. Peden
ATTN: R. Casey
ATTN: J. Andrews

General Electric Co
ATTN: J. Palchefsky Jr
ATTN: Tech Lib
ATTN: R. Benedict
ATTN: R. Casey
ATTN: W. Patterson

General Electric Co
ATTN: J. Reidl

General Electric Co
ATTN: R. Hellen

General Electric Co
ATTN: J. Gibson
ATTN: D. Cole

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

General Electric Co
ATTN: D. Pepin

General Rsch Corp
ATTN: R. Hill
ATTN: Tech Info Office

George C. Messenger
ATTN: G. Messenger

Georgia Institute of Tech
ATTN: R. Curry

Georgia Institute of Tech
ATTN: H. Denny

Goodyear Aerospace Corp
ATTN: Security Control Station

Grumann Aerospace Corp
ATTN: J. Rogers

GTE Microcircuits
ATTN: F. Krch

Harris Corp
ATTN: J. Cornell
ATTN: T. Sanders
ATTN: C. Anderson

Honeywell, Inc
ATTN: R. Gumm

Honeywell, Inc
ATTN: C. Cerulli

Honeywell, Inc
ATTN: Tech Lib

Hughes Aircraft Co
ATTN: R. McGowan
ATTN: J. Singletary

Hughes Aircraft Co
ATTN: A. Narevsky
ATTN: D. Shumake
ATTN: W. Scott
ATTN: E. Smith

IBM Corp
ATTN: H. Mathers
ATTN: T. Martin

IBM Corp
ATTN: MS 110-036, F. Tietze

IIT Rsch Institute
ATTN: I. Mindel

Institute for Defense Analyses
ATTN: Tech Info Services

International Business Machine Corp
ATTN: J. Ziegler

International Tel & Telegraph Corp
ATTN: A. Richardson
ATTN: Dept 608

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

Intersil Inc
ATTN: D. McDonald

IRI Corp
ATTN: N. Rudie
ATTN: J. Harrity

JAYCOR
ATTN: T. Flanagan
ATTN: L. Scott
ATTN: R. Stahl

Johns Hopkins University
ATTN: P. Partridge

Kaman Sciences Corp
ATTN: J. Lubell
ATTN: N. Beauchamp
ATTN: M. Bell

Kaman Tempo
ATTN: DASIAC
ATTN: M. Espig

Kaman Tempo
ATTN: DASIAC

Litton Systems, Inc
ATTN: J. Retzler

Lockheed Missiles & Space Co., Inc
ATTN: J. Crowley
ATTN: J. Smith

Lockheed Missiles & Space Co., Inc
ATTN: E. Hessee
ATTN: E. Smith
ATTN: M. Smith
ATTN: P. Bene
ATTN: D. Phillips, DPT 62-46
ATTN: C. Thompson

M.I.T. Lincoln Lab
ATTN: P. McKenzie

Magnavox Govt & Indus Electronics Co
ATTN: W. Richeson

Martin Marietta Corp
ATTN: H. Cates
ATTN: S Bennett
ATTN: R. Gaynor
ATTN: W. Brockett
ATTN: W. Janocko

Martin Marietta Corp
ATTN: E. Carter

McDonnell Douglas Corp
ATTN: R. Kloster
ATTN: D. Dohm
ATTN: Lib
ATTN: M. Stitch

McDonnell Douglas Corp
ATTN: J. Holmgrem
ATTN: D. Fitzgerald

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

McDonnell Douglas Corp
ATTN: Tech Lib

Mission Rsch Corp
ATTN: C. Longmire

Mission Rsch Corp
ATTN: R. Pease

Mission Rsch Corp, San Diego
ATTN: J. Raymond
ATTN: V. Van Lint

Mission Rsch Corp
ATTN: W. Ware

Mitre Corp
ATTN: M. Fitzgerald

Motorola, Inc
ATTN: A. Christiansen

Motorola, Inc
ATTN: O. Edwards

National Academy of Sciences
ATTN: National Materials Advisory Brd
ATTN: R. Shane

National Semiconductor Corp
ATTN: A. London
ATTN: R. Wang

University of New Mexico
ATTN: H. Southward

Norden Systems, Inc
ATTN: D. Longo
ATTN: Tech Lib

Northrup Corp
ATTN: J. Srour

Northrup Corp
ATTN: P. Gardner
ATTN: L. Apodaca
ATTN: T. Jackson

Pacific-Sierra Rsch Corp
ATTN: H. Brode

Physics International Co
ATTN: J. Shea
ATTN: Div 6000

R & D Associates
ATTN: S. Rogers
ATTN: P. Haas

Rand Corp
ATTN: C. Crain

Raytheon Co
ATTN: A. Van Doren
ATTN: H. Flescher

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

Raytheon Co
ATTN: J. Ciccio

RCA Corp
ATTN: G. Brucker
ATTN: V. Mancino

RCA Corp
ATTN: D. O'Connor
ATTN: Office N103

RCA Corp
ATTN: R. Killion

RCA Corp
ATTN: W. Allen

Rensselaer Polytechnic Institute
ATTN: R. Gutmann

Research Triangle Institute
ATTN: SEC OFC for M. Simons, Jr

Rockwell International Corp
ATTN: V. Strahan
ATTN: V. De Martino
ATTN: V. Michel
ATTN: J. Brandford

Rockwell International Corp
ATTN: TIC BA08
ATTN: T. Yates

Rockwell International Corp
ATTN: D. Vincent

Sanders Associates, Inc
ATTN: L. Brodeur

Science Applications, Inc
ATTN: D. Millward

Science Applications, Inc
ATTN: D. Long
ATTN: V. Verbinski
ATTN: J. Naber
ATTN: V. Ophan

Science Applications, Inc
ATTN: W. Chadsey

Science Applications, Inc
ATTN: D. Stribling

Singer Co
ATTN: J. Brinkman

Singer Co
ATTN: R. Spiegel

Sperry Rand Corp
ATTN: Engineering Lab

Sperry Rand Corp
ATTN: D. Schow

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

Sperry Rand Corp
ATTN: R. Viola
ATTN: F. Scaravaglione
ATTN: C. Craig
ATTN: P. Maraffino

Sperry Univac
ATTN: J. Inda

Spire Corp
ATTN: R. Little

SRI International
ATTN: P. Dolan
ATTN: B. Gasten
ATTN: A. Whitson

Sylvania Systems Group
ATTN: C. Thornhill
ATTN: L. Blaisdell
ATTN: L. Pauples

Sylvania Systems Group
ATTN: J. Waldron
ATTN: H. Ullman
ATTN: P. Fredrickson
ATTN: H & V Group

Systron-Donner Corp
ATTN: J. Indelicato

Teledyne Ryan Aeronautical
ATTN: J. Rawlings

Texas Instruments, Inc
ATTN: F. Poblenz

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

Texas Instruments, Inc
ATTN: A. Peletier
ATTN: R. Stehlin

TRW Defense & Space Sys Group
ATTN: A. Pavelko
ATTN: P. Guilfoyle
ATTN: R. Kingsland
ATTN: O. Adams
ATTN: H. Holloway
4 cy ATTN: A. Witteles

TRW Defense & Space Sys Group
ATTN: M. Gorman
ATTN: F. Fay
ATTN: R. Kitter
ATTN: W. Willis, M/S RI/2078

TRW Systems and Energy
ATTN: B. Gililland
ATTN: G. Spehar

Vought Corp
ATTN: R. Tomme
ATTN: Library
ATTN: Tech Data Ctr

Westinghouse Electric Co
ATTN: L. McPherson

Westinghouse Electric Co
ATTN: H. Kalapaca
ATTN: D. Crichi

DATE
FILMED

2-8