National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

JPL is able to apply its technologies, facilities, and expertise to assist our partners in product improvement and problem solving to reduce risk.

Space Radiation Facilities

JPL Radiation Effects Group

http://parts.jpl.nasa.gov/organization/group-5144/

Outline

- Overview
- Mission Assurance Management Support
- Radiation Test Planning
- Single-Event Effects Testing
  - Heavy Ion and Proton Single Event Effects (SEE) testing (ASTM F1192 and EIA/JESD 57)
  - CF-252 screening
  - JPL's in-house SEE Picosecond Laser Lab
- Total Ionizing Dose
  - MIL-STD-883 Method 1019 testing
  - Radiation Lot Acceptance Testing (RLAT)
  - Enhanced Low Dose Radiation Sensitivity (ELDRS) testing
  - X-Ray (In-house Aracor)
- Displacement Damage
  - JPL Dynamitron (3MeV electron source)
  - Proton
- In-House ATE
- Research

Radiation Effects Group Overview

Mission Statement:

To investigate the effects of space radiation on present and future microelectronic and optoelectronic technologies, evaluate the risk of using them in specific space missions, and recommend component and design techniques for JPL and NASA programs to reduce reliability risk from space radiation.

Group Responsibilities

- Conduct evaluation studies of radiation effects on advanced microelectronic and optoelectronic devices
- Analysis of radiation data and effects on system performance
- Investigation and modeling of catastrophic failure mechanisms including latch-up, single-event hard errors and gate rupture effects, as well as dose damage from protons, electrons, and gamma.
- Support JPL projects and instruments in radiation testing, event rate prediction and data analysis
- Investigation of the effects of device scaling and design evolution on radiation susceptibility
- Maintain the Radiation Effects laboratories and instruments
- Conduct research into the basic effects of radiation interaction in EEE devices

Mission Assurance Management Support

JPL's Radiation Effect Group is founded upon decades of experience in selection, evaluation, and analysis of reliable electronic parts for aerospace missions.

- JPL REG supports designers in part selection and conducts reviews of part lists to meet the requirements of the intended space environment and mission life
- Communicate with vendors to resolve issues
- Conducts radiation tests and test planning services
- Provide analysis (circuit, transport, dosimetry, SER, etc.) and engineering services
- With direct access to JPL's Government-Industry Data Exchange (GIDEP) and NASA Alert programs, we provide inventory and records control of flight electronic parts.

Radiation Test Planning

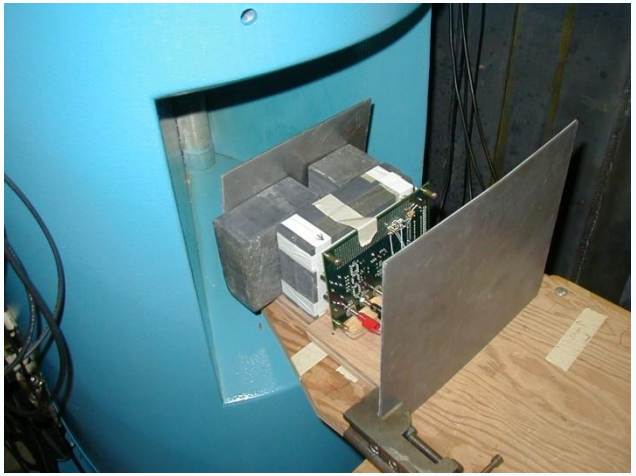
- Provide and audit radiation test plans (RTP) to ensure the highest levels of mission assurance.
  - In accordance with industry standards (ASTM 1192, Mil-STD 883 Method 1019) or to fit unique needs as applicable
  - Range issues, angular effects, application implementation, and dose rate selection are just a few examples of the many issues at the forefront of today's radiation effects testing and planning.

Radiation Effects Testing

- Single-Event Effects (Proton, Heavy Ion, Picosecond Laser, CF-252 chamber)
- Displacement Damage (Electron, Neutron and Proton)
- Total Ionizing Dose (High and Low Dose Rates)
- Extreme environment (cryogenic, high temperature, thermal cycling, etc.)
- Lifetime testing in conjunction with radiation effects

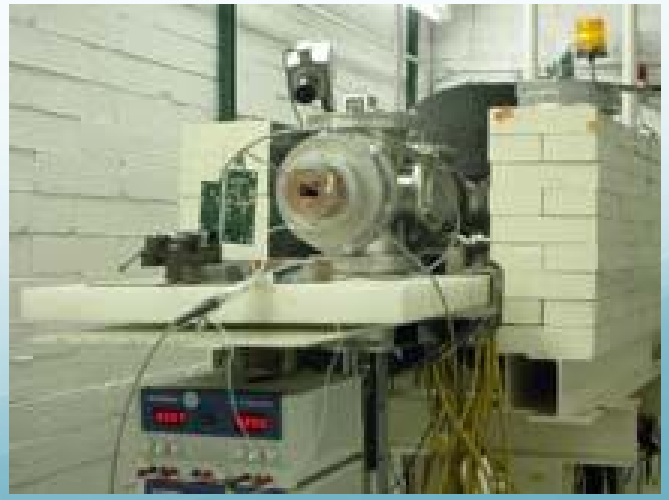
TID Testing

- JPL maintains two separate Co-60 room irradiators that allow a wide range of dose rates covering over 5 orders of magnitude.
  - High Dose Rate (HDR) source varies between 0.1 and-5 00 rad(Si)/s
  - Low Dose Rate (LDR) source varies between 0.001 and 1 rad(Si)/s
- Wide range of dose rates permits ELDRS studies, including ultra low dose rates
- All testing performed in accordance with Mil-Std-883 Method 1019.7
- ETS-300, D10 and LTS-2020 mixed signal testers available for electrical part characterization, in addition to custom bench-top parametric characterization
- The JPL Dynamitron can also be used for TID testing



Displacement Damage—Off Site

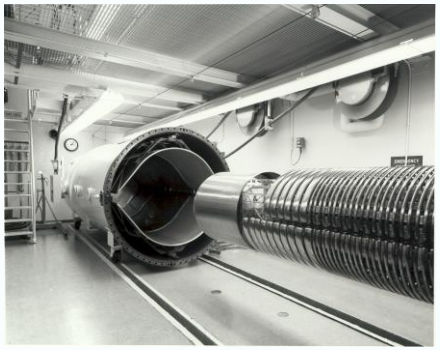
- The JPL Radiation Effects group also regularly performs proton irradiations using two off-site proton facilities
  - Crocker Nuclear Laboratory at UC Davis provides protons tunable in energy from 2 to 65 MeV
  - Indiana University Radiation Effects Research Program provides protons at 205 MeV which can be degraded to lower energies as needed
- Also available is the Boeing Radiation Effects Laboratory 14MeV Neutron beam line

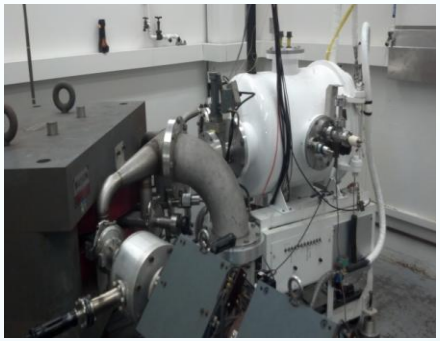


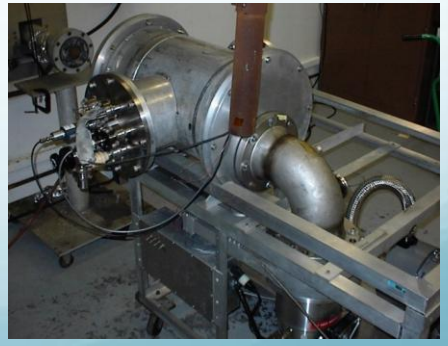
Displacement Damage—JPL Dynamitron

- The JPL Dynamitron accelerator has a long history of being used to study the effects of:
  - Displacement damage in solar cells
  - Ionization in electronic devices
  - Discoloration of cover glasses and other coatings
  - Spacecraft charging
- Beam and Chamber Characteristics:
  - Energy = 0.5 – 2.5 MeV
  - Depth-dose verified to ISO/ASTM 51649
  - Electron Flux = 10^8 – 10^{12} e/cm^2/s
  - 2 available beamlines to accommodate various configurations
  - Uniform Irradiation area (5% of Max): 6x6” in.
  - Temperature capability: - 180 to + 150 C
  - Environment: vacuum or air
  - Electrical and optical access to chamber available

Heritage systems have been integrated with automated monitoring of flux, fluence, temperature, and vacuum.







Single-Event Effects Testing

- JPL has a great deal of experience with nearly every SEE facility in the aerospace community, along with in-house screening capabilities.

JET PROPULSION LABORATORY'S SINGLE EVENT EFFECTS PICOSECOND LASER LAB

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JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

Berkeley Accelerator Space Effects BASE Facility

INDIANA UNIVERSITY BLOOMINGTON

UCDAVIS UNIVERSITY OF CALIFORNIA

Crocker Nuclear Laboratory

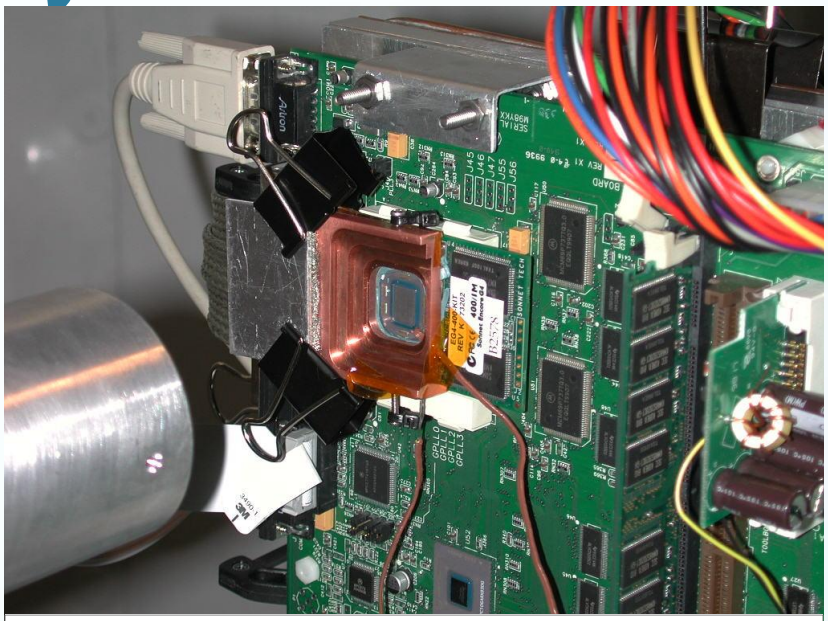
RADIATION EFFECTS FACILITY
THE CYCLOTRON INSTITUTE · TEXAS A&M UNIVERSITY

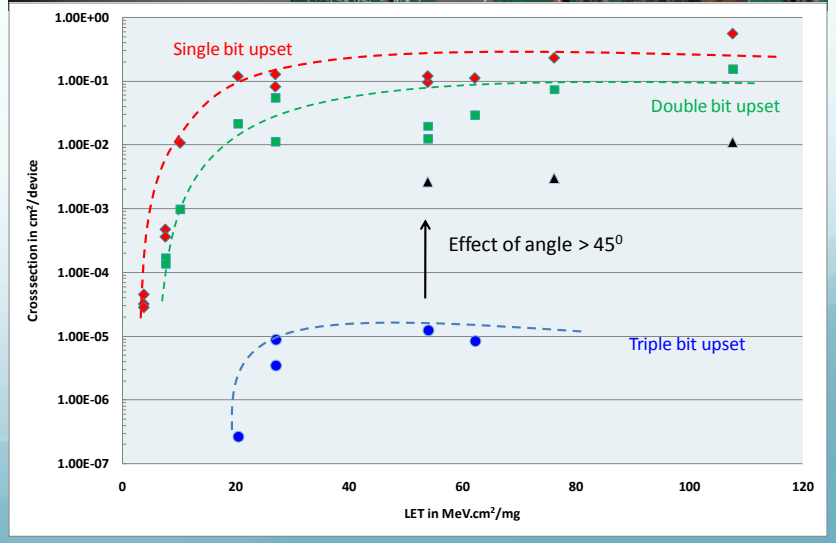
National Aeronautics
and Space Administration

SEE Testing—Texas A&M Cyclotron

- JPL is a dedicated user of the Radiation Effects Facility at The Cyclotron Institute of Texas A&M University (http://cyclotron.tamu.edu/) and has been since its start as a facility to support heavy ion effects in devices. In fact, JPL has helped design and plan many of the approaches and support fixtures the facility currently offers. This facility is able to produce ion energies up to 40 MeV/nucleon that is adequate for practically all SEE testing requirements, cf. JESD57 and ASTM-1192.

- The equipment and processes of the radiation test group are uniquely suited for testing at TAM with preparation times as low as a few days for most tests. JPL REG has experience testing DRAMs, SRAMs, SDRAM, Processors, ASICs, discrete power devices, DC/DC converters, mixed signal ICs (ADCs and DACs), FPGAs, bridge chips, analog devices (comparators, voltage regulators and operational amplifiers), and flash NVM.

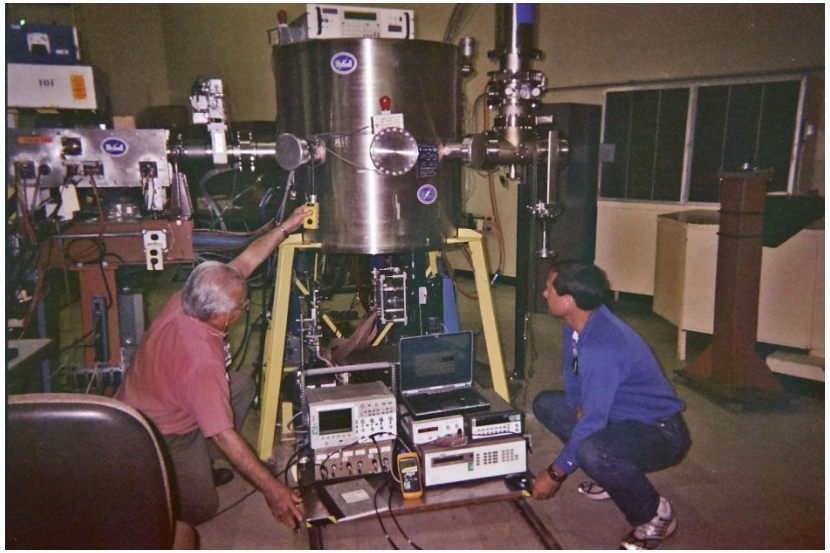


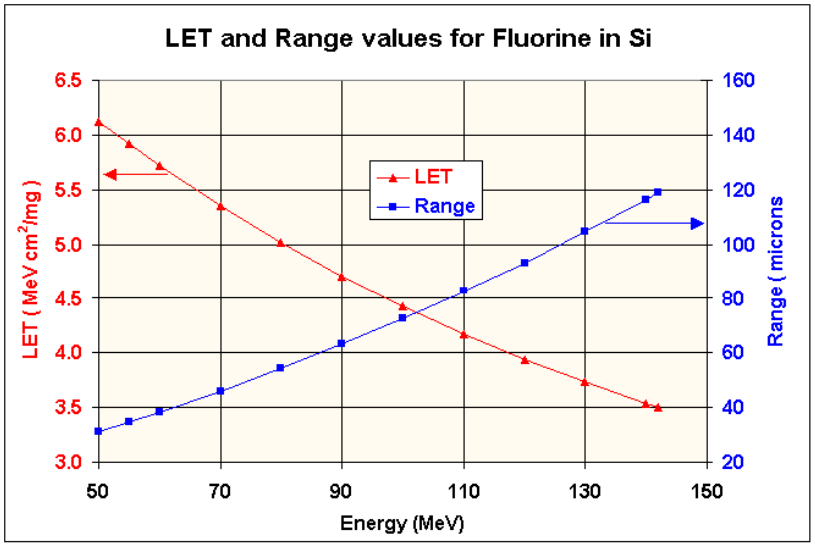


SEE Testing— Brookhaven National Lab

- Brookhaven National Laboratory's Single Event Effects (SEEs) line (http://tvdg10.phy.bnl.gov/) is another test site of choice for SEE studies for JPL projects and research. A user of this facility for over 15 years, JPL has developed efficient and reliable infrastructure to perform tests or research for any customer. The turnaround for SEE testing at BNL by JPL can be within one week if needed.

- BNL's beams allow for Single Event Upset for almost all technologies of interest. And most other SEEs can be investigate for many technologies. The energy of the ions is immediately tunable, so no straggling effects result from degraded beams.





SEE Testing—
Lawrence Berkeley National Lab

- JPL was one of the founding users of the Berkeley Accelerator Space Effects (BASE) facility at The 88 inch Cyclotron at Lawrence Berkeley National Laboratory and has been using the facility ever since. This facility provides four standard ion cocktails: 4.5, 10, 16, and 30 MeV/nucleon that are adequate for practically all SEE testing requirements, cf. JESD57 and ASTM-1192.

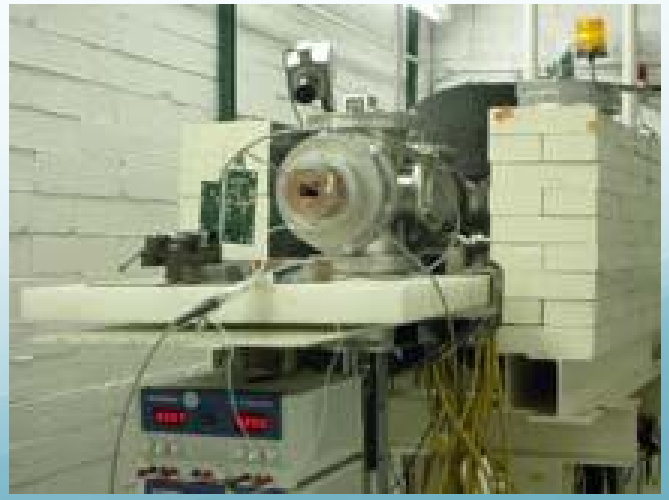
- Beyond the experience running the facility, we have a heavy inventory of interface equipment to quickly and easily bring a Single-Event Effects test together.

Ion	Cocktail (MeV/nuc)	Energy (MeV)	Z	A	Chg. State	% Nat. Abund.	LET 0° (MeV/(mg/cm^2))	LET 60°	Range (μm)	Ion
B	4.5	44.90	5	10	+2	19.9	**1.65**	3.30	78.5	B
N	4.5	67.44	7	15	+3	0.37	**3.08**	6.16	67.8	N
Ne	4.5	89.95	10	20	+4	90.48	**5.77**	11.54	53.1	Ne
Si	4.5	139.61	14	29	+6	4.67	**9.28**	18.56	52.4	Si
Ar	4.5	180.00	18	40	+8	99.6	**14.32**	28.64	48.3	Ar
V	4.5	221.00	23	51	+10	99.75	**21.68**	43.36	42.5	V
Cu	4.5	301.79	29	63	+13	69.17	**29.33**	58.66	45.6	Cu
Kr	4.5	387.08	36	84	+17	17.3	**38.96**	77.92	48.0	Kr
Y	4.5	409.58	39	89	+18	100	**45.58**	91.16	45.8	Y
Ag	4.5	499.50	47	109	+22	48.161	**58.18**	116.36	46.3	Ag
Xe	4.5	602.90	54	136	+27	8.9	**68.84**	137.68	48.3	Xe
Tb	4.5	724.17	65	159	+32	100	**77.52**	155.04	52.4	Tb
Ta	4.5	805.02	73	181	+36	99.988	**87.15**	174.30	53.0	Ta
Bi	4.5	904.16	83	209	+41	100	**99.74**	199.48	52.9	Bi
B	10	108.01	5	11	+3	80.1	**0.89**	1.78	305.7	B
O	10	183.47	8	18	+5	0.2	**2.19**	4.38	226.4	O
Ne	10	216.28	10	22	+6	9.25	**3.49**	6.98	174.6	Ne
Si	10	291.77	14	29	+8	4.67	**6.09**	12.18	141.7	Si
Ar	10	400.00	18	40	+11	99.6	**9.74**	19.48	130.1	Ar
V	10	508.27	23	51	+14	99.75	**14.59**	29.18	113.4	V
Cu	10	659.19	29	65	+18	30.83	**21.17**	42.34	108.0	Cu
Kr	10	906.45	36	84	+23	57	**30.23**	60.46	113.1	Kr
Y	10	928.49	39	89	+25	100	**34.73**	69.46	102.2	Y
Ag	10	1039.42	47	107	+29	51.839	**48.15**	96.30	90.0	Ag
Xe	10	1232.55	54	124	+34	0.1	**58.78**	117.56	90.0	Xe
N	16	233.75	7	14	+5	99.63	**1.16**	2.32	505.9	N
O	16	277.33	8	17	+6	0.04	**1.54**	3.08	462.4	O
Ne	16	321.00	10	20	+7	90.48	**2.39**	4.78	347.9	Ne
Si	16	452.10	14	29	+10	4.67	**4.56**	9.12	274.3	Si
Cl	16	539.51	17	35	+12	75.77	**6.61**	13.22	233.6	Cl
Ar	16	642.36	18	40	+14	99.600	**7.27**	14.54	255.6	Ar
V	16	832.84	23	51	+18	99.750	**10.90**	21.80	225.8	V
Cu	16	1007.34	29	63	+22	69.17	**16.53**	33.06	190.3	Cu
Kr	16	1225.54	36	78	+27	0.35	**24.98**	49.96	165.4	Kr
Xe	16	1954.71	54	124	+43	0.1	**49.29**	98.58	147.9	Xe

*Ion isotopes and charge states subject to change without notice. LETs calculated with SRIM using a pure silicon target in vacuum.

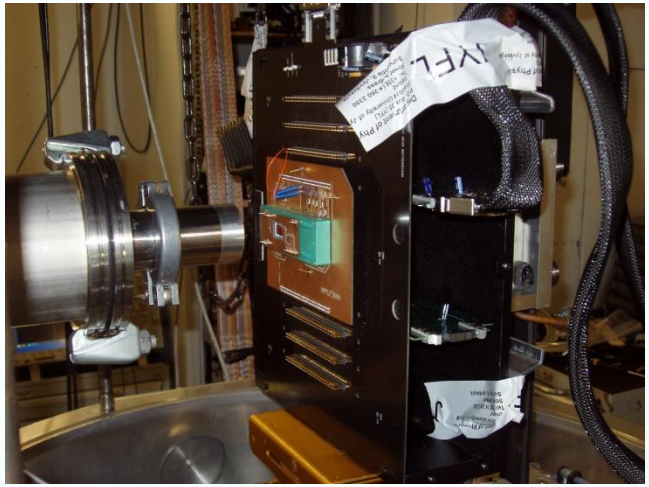
SEE Testing—Proton Irradiation

- The JPL Radiation Effects group also performs single event effects proton irradiations using two off-site proton facilities
  - Crocker Nuclear Laboratory at UC Davis provides protons tunable in energy from 2 to 65 MeV
  - Indiana University Radiation Effects Research Program provides protons at 205 MeV which can be degraded to lower energies as needed
- The group also has experience proton testing at LBNL and TRIUMF

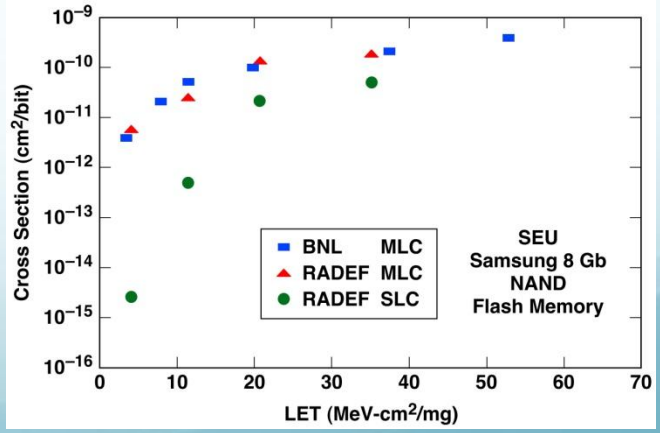


SEE Testing—RADEF

- The European Space RADiation Effect Facility (RADEF) located at Jyväskylä, Finland (https://www.jyu.fi/fysiikka/en/research/accelerator/radef/) is another test site of choice for SEE studies for JPL projects and research. JPL radiation group has been user of this facility since 2009.



- RADEF's long range ion beams allow for Single Event Upset for all technologies of interest. This facility has an excellent dosimetry for low flux beams which is very suitable for SEU measurements of memory devices.



SEE Screening—JPL's Isotopic Irradiation Facility

- JPL maintains two sites for irradiation of devices with decay products. Californium (Cf-252), Americium (Am-242), and Polonium (Po-210) sources are all available. Activity information is available upon request. All testing is done in accordance with JESD89 and JESD57 or ASTM-1192 if applicable.

- This system has proven invaluable in screening parts for missions ahead of more costly heavy ion testing.

Element	Isotope	Primary decay product	Secondary decay product	Half Life
Californium	Cf-252	6.2 MeV Alpha	Neutron, fission fragments	2.6 years
Gadolinium	Gd-148	3..2 MeV Alpha	Beta	74.6 years
Polonium	Po-208	5.3 MeV Alpha	None	138.3 days
Thorium	TH-228	5.4 MeV Alpha	None	1.6 years

JPL's SEE Picosecond Laser Lab

Current Pulsed Laser Lab Capabilities:

- Fully calibrated Spectra-Physics Ti:Sapphire mode-locked Tsunami laser that produces 2.5ps pulses with a waist size of 1.0 micron.
- Single photon picosecond pulse that can be used on many devices for SEE (SEL, SEU, SET, SEFI) analysis and screening
- Fully automated software controlled X-Y stage that can be used to correlate SEE to laser position
- Adjustable/configurable system with variable wavelengths and energy (typically 1 to 500pJ per pulse)
- Two-Photon Absorption system under development

National Aeronautics
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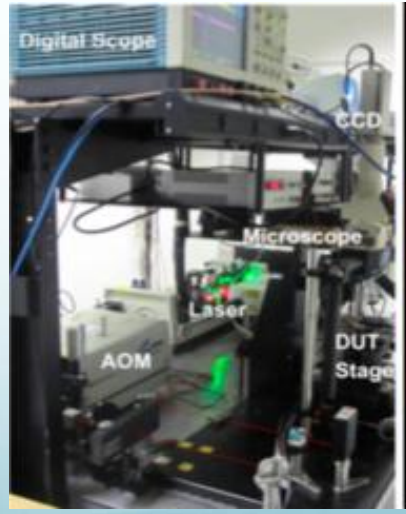
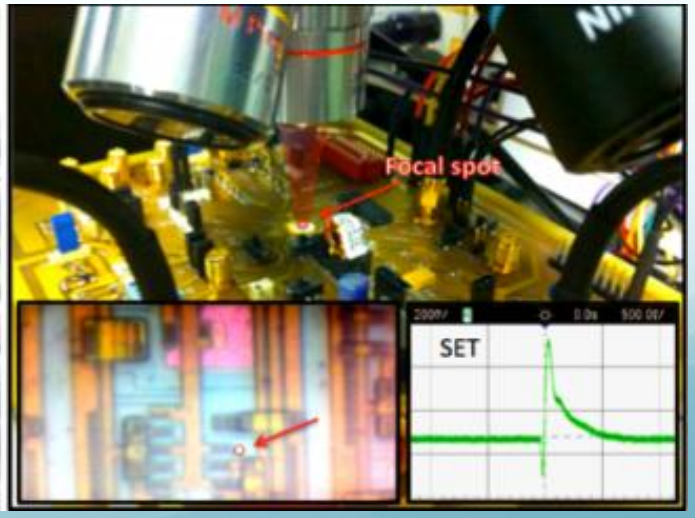
JPL's SEE Picosecond Laser Lab

The Jet Propulsion Laboratory's Single-Event Effects Picosecond Laser Lab is currently available for outside research collaboration and/or device reliability and mission assurance services.

Please see us on the web at http://parts.jpl.nasa.gov/organization/group-5144/jet-propulsion-laboratorys-single-event-effects-picosecond-laser-lab/ or contact Greg Allen (818) 393-7558 or Steve McClure (818) 354-0482 for details and quotes





In-House ATE

- JPL REG has a variety of customizable ATE that cover nearly all part technologies and test needs. The highlights of the ATE are the Credence Diamond-10, the LTS-2020, the ETS-300 and the JD Instruments Digital Test System.

In-House ATE—Credence D10

- A Credence Diamond 10 tester is available for high speed mixed signal testing
- Resources
  - Device Interface Board Utility
  - Digital Pin Electronics
  - Mixed-Signal Analog Waveform Generator
  - Mixed-Signal Digitizer
  - ±7V/256mA, 2A ganged 4-quadrant VI source
  - VIS16, 4-quadrant 16 channel VI source ±60V/600mA
  - DPS16, 4-quadrant 16 channel 6V/2A source

In-House ATE—Credence D10

- Many different types of modules
  - Expandable and flexible to test device needs
  - Based on supporting module many measurement sensitivities supported.
- Current Measurements
  - 16 bit resolution
  - Ranges from ±2μA to ±256mA
- Voltage Measurements
  - ±15mV at 8V,
- Utility Block
  - Common interfaces to standard peripheral connectors (GPIO, SPI, I^2C)

- Parametric Measurements
  - Vih/Vil at -1 to 6V, 122μV resolution
  - Many search modes – level, timing, period,
- Digital Pattern/Waveforms
  - 10ns<Period<320μs
  - 19.6 ps edge resolution
  - 4cycles/10ns
  - 128k/source
- Analog Waveforms
  - 250MS/s @ 16bit output
  - 24 bit measurement resolution
  - High speed and high resolution

In-House ATE—LTS-2020

The LTS-2020 Test System is comprised of (4) components, a computer which runs all software and test activities and test system which is made up of the mainframe test system, various application specific family boards and socket assemblies.

The computer provides an interface to the mainframe test system. A version of analog devices basic software is the test software. The various family boards provide the analog resources required for a particular test. These family boards are supported also by a number of socket assemblies which provide the DUT the interface to the system resources.

This allows for various mixed signal types of devices to be tested using the various family boards and socket assemblies available. Tests programs can be very quickly written, providing rapid turn-around time for most device tests.

Features

DAC Family Board
Op Amp Family Board
Analog to Digital Converter Family Board
Digital Family Board
Transistor Family Board

In-House ATE-ETS-300

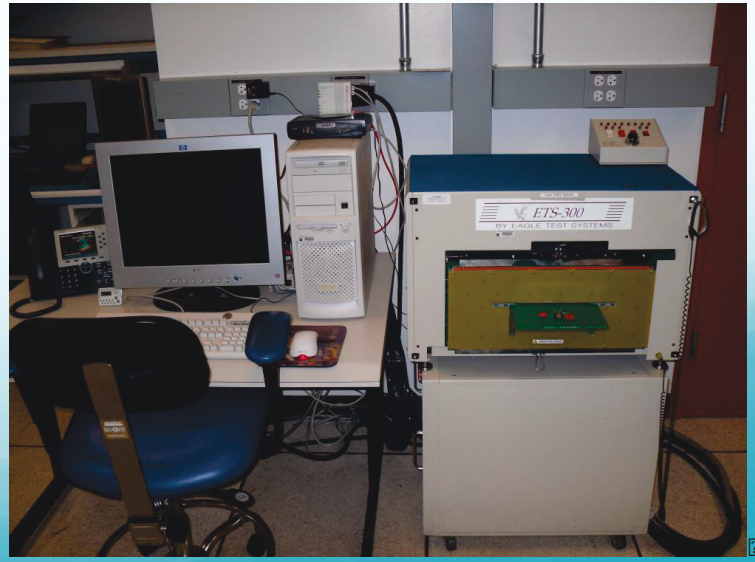
The ETS-300 is comprised of (3) components, a computer which runs all software and test activities a test-head which is the interface to the associated hardware elements of the application's test, and the systems power supply which supplies all power to the test-head and its interlocks, etc.

The computer software provides high level control. Of the hardware and a great deal of hardware flexibility is available at the application board. Visual C++®, in conjunction with Eagle's Shell, is combined to create an executable program.

The test head of the ETS-300® Family tester operates at a Distance of up to 8 feet (2.4 m) from the mainframe. The test head also has an IEEE-488/GPIB bus interface, which allows it to connect to and communicate with GPIB Instruments. The test-head is the user's interface to system's hardware resources.

Features

Floating Analog Resource Architecture
16 Channels of Analog Force/Sense (+/-100mA, +/-30V)
2 Channels of Analog Force/Sense (+/-2A, +/-100V)
32 pins of Digital Driver/ Receiver I/O Pairs
64 or 256 test vector pattern depth
Wide voltage range of 0 to +15V at 20mA of drive current
Four (4) onboard timing generators available
Data rate from local memory is 10 MHz maximum



In-House ATE-JDI ATV DTS

The ATV Digital Test System is a high speed ***testing*** and ***timing verification*** ATE using algorithmically generated test vectors or imported (from ATPG).

- Features:
  - Portable
  - Expandable (6, 10, 15, 20 Slot chassis's)
  - Separate DUT from Tester (> 100 feet)
  - Can test over coaxial cables
  - Format-able Drives – RTRN0, RTRN1, RTRNC, NRZ
  - Variable Output Range : 0 to 5.5 v
  - 50 ohm Reverse Terminated Drivers
  - Separate Compare Levels
    (VCmpH, VCmpL – variable range)

Contact info

- General
  - Steve McClure—Group Supervisor (818) 534-0482 for details and quotes
- LASER/SEE
  - Greg Allen (818) 393-7558
- SEE General
  - Leif Scheick—Group Lead (818) 354-3272
- TID Testing
  - Bernard Rax (818) 354-9799
- Dynamitron/TID Testing
  - Dennis Thorbourn (818) 354-1830

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