IN-FLIGHT ANNEALING of DISPLACEMENT DAMAGE in GaAs LEDs

Gary M. Swift, Gregory C. Levanas, J. Martin Ratliff, and Allan H. Johnston

Jet Propulsion Laboratory
California Institute of Technology
Pasadena CA 91109

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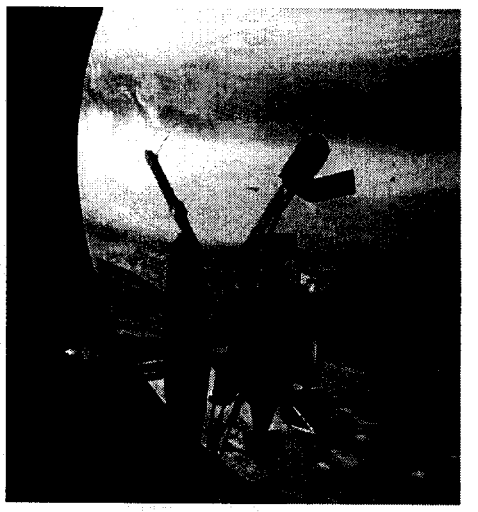
Galileo Mission Facts

- Launch: 10/18/89
- Gravity assists: Earth 12/8/90, Venus 2/10/90, Earth 12/8/92
- Asteroid encounters: Gaspra 10/29/91, Ida 8/28/93
- Jupiter orbit insertion: 12/7/95

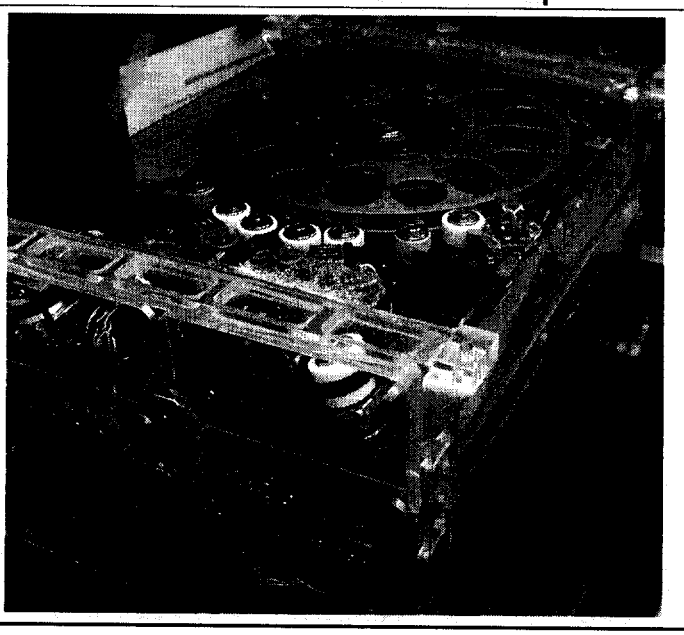
- Jovian moon flybys: 33 out of 34 orbits
- Orbit 34: Amalthea 11/4/02
- Death: Jupiter impact 9/21/03

Outline

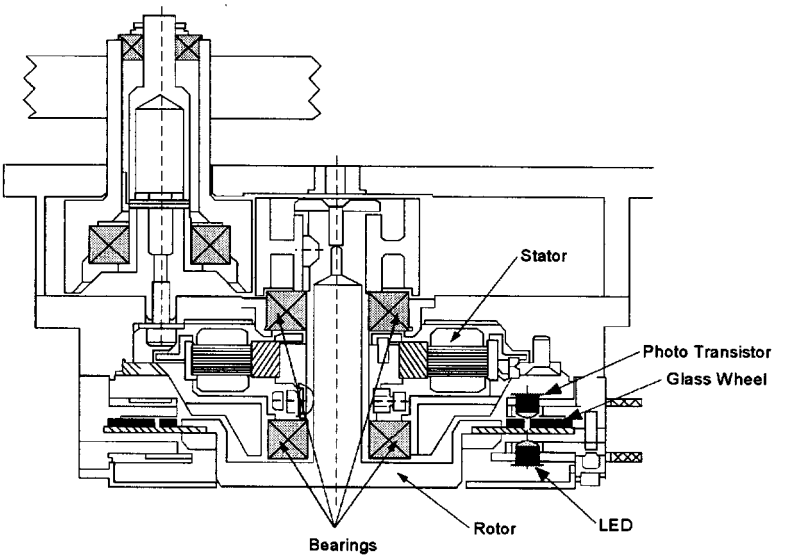
- The Tape Recorder
- The Suspect LED
- The Jovian Radiation Environment
- Annealing Data
  - In-flight
  - Ground Tests
- Modeling the Failure



Galileo Tape Recorder

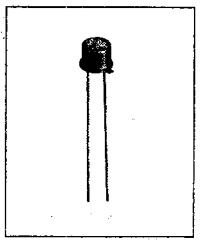


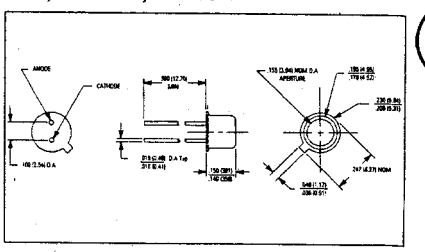
Tape Recorder Motor Assembly



The Suspect: OP133 LED

GaAs Hermetic Infrared Emitting Diodes
Types OP130W, OP131W, OP132W, OP133W





Amphoteric dopant (Si)

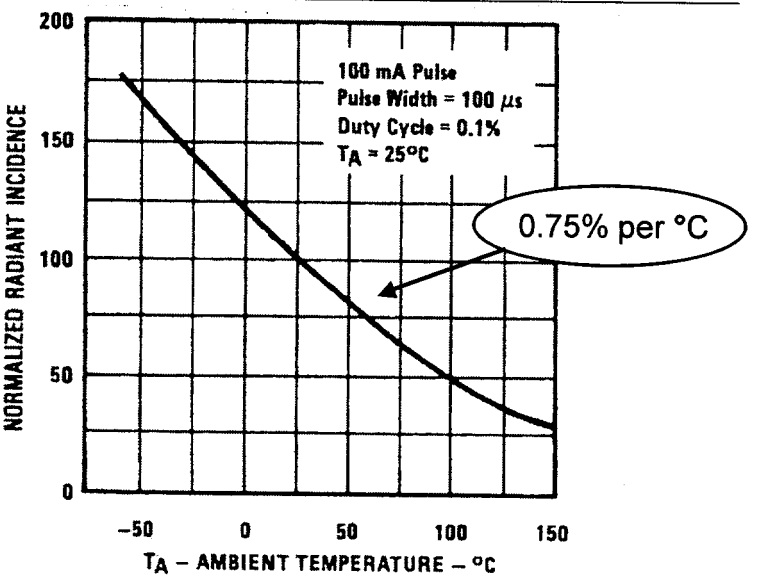
Electrical Characteristics (T_A = 25°C unless otherwise noted)

SYMBOL	PARAMETER		MIN	TYP	MAX	UNITS	TEST CONDITIONS
P_O	Radiant Power Output	OP130	1.0			mW	I_F = 100 mA(3)
		OP131	3.0			mW	I_F = 100 mA(3)
		OP132	4.0			mW	I_F = 100 mA(3)
		OP133	5.0			mW	I_F = 100 mA(3)
V_F	Forward Voltage				1.75	V	I_F = 100 mA(3)
I_R	Reverse Current				100	µA	V_R = 2.0 V
λ_P	Wavelength at Peak Emission			935		nm	I_F = 10 mA(3)
B	Spectral Bandwidth Between Half Power Points			50		nm	I_F = 10 mA(3)
$\Delta\lambda_P/\Delta T$	Spectral Shift with Temperature			+0.30		nm/°C	I_F = Constant
θ_{HP}	Emission Angle at Half Power Points			18		Deg.	I_F = 100 mA
t_r	Output Rise Time			1000		ns	$I_{F(PK)}$ = 100 mA, PW = 10 µs, D.C. = 10%
t_f	Output Fall Time			500		ns	

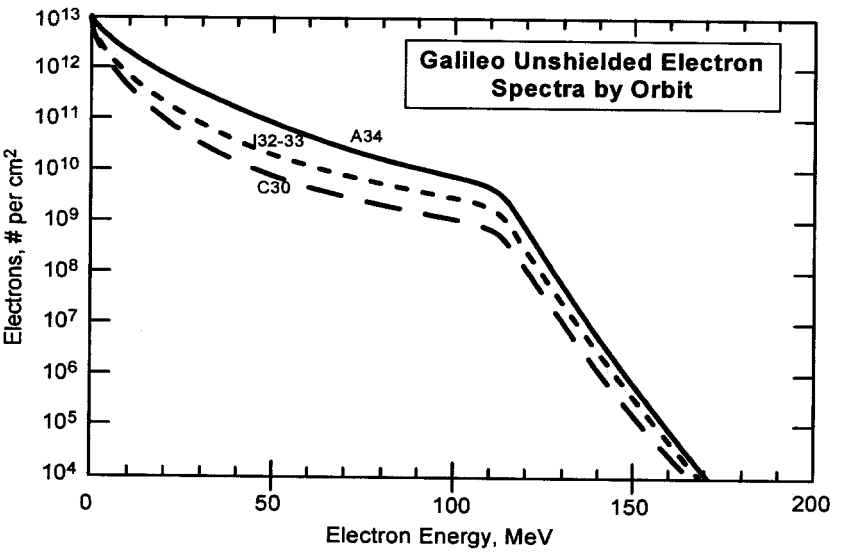
935

50

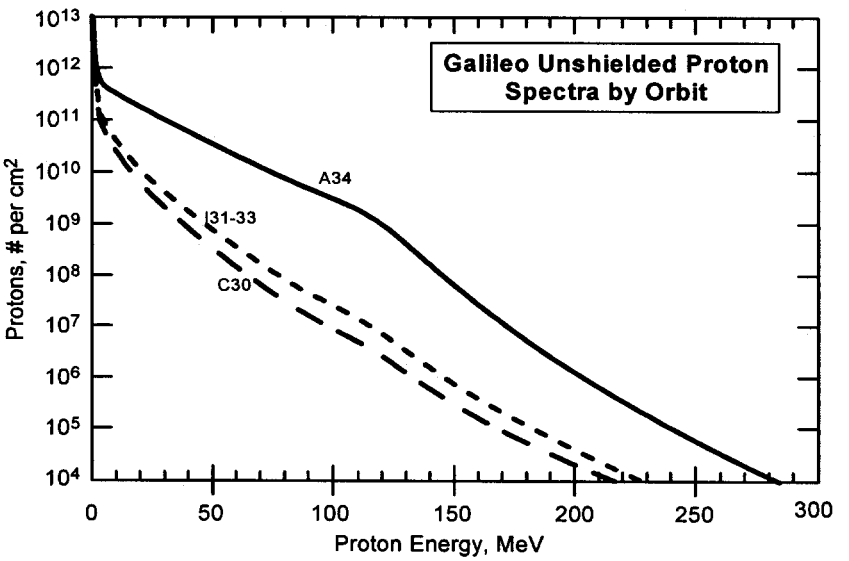
The Suspect: OP133 LED



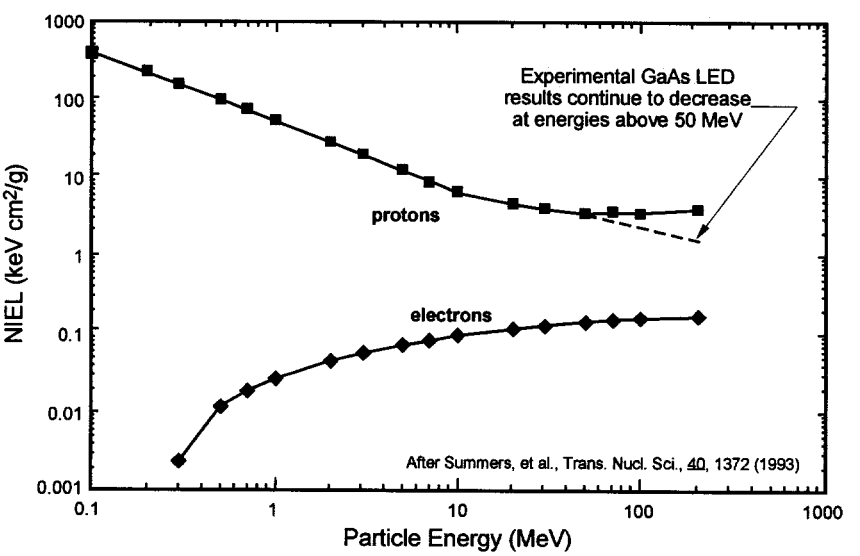
Jovian Radiation Environment

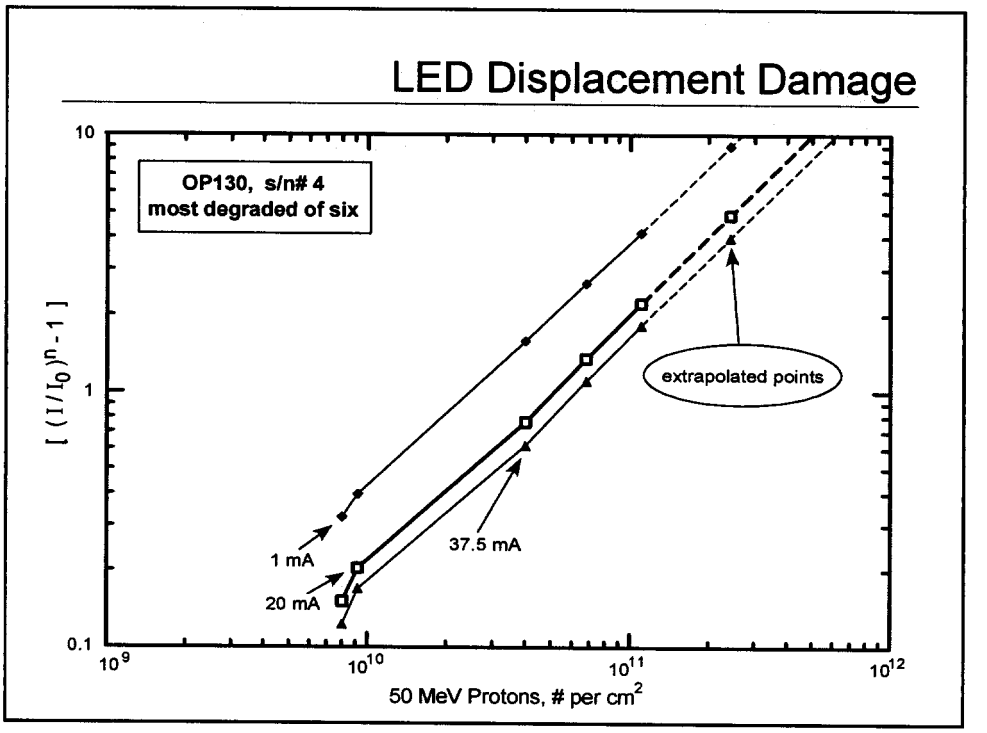


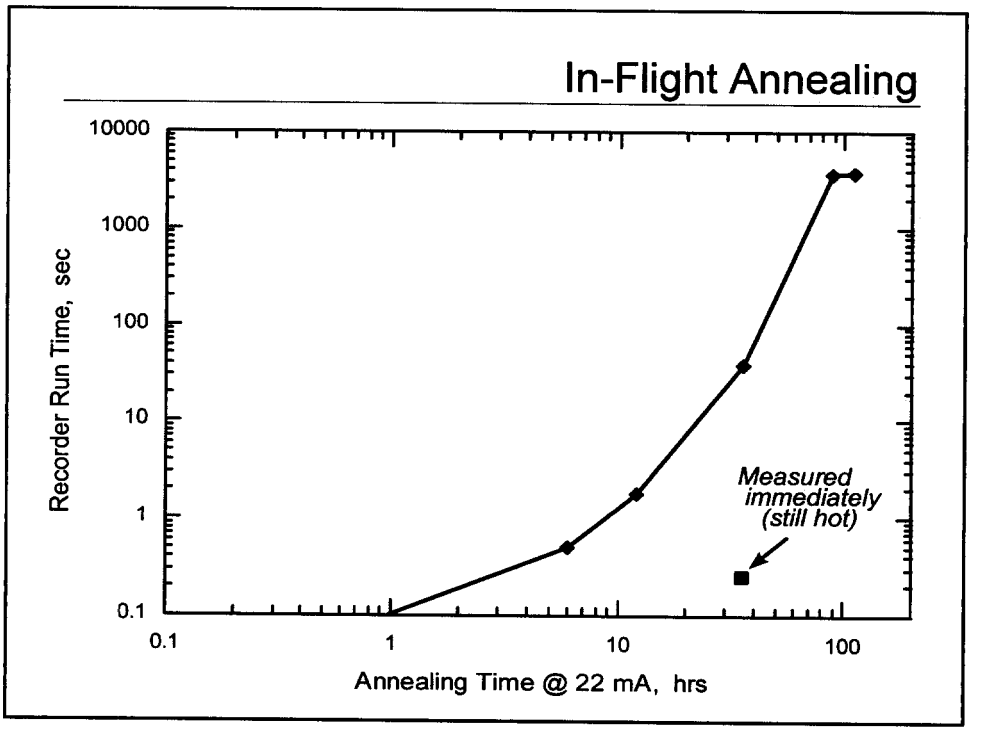
Jovian Radiation Environment

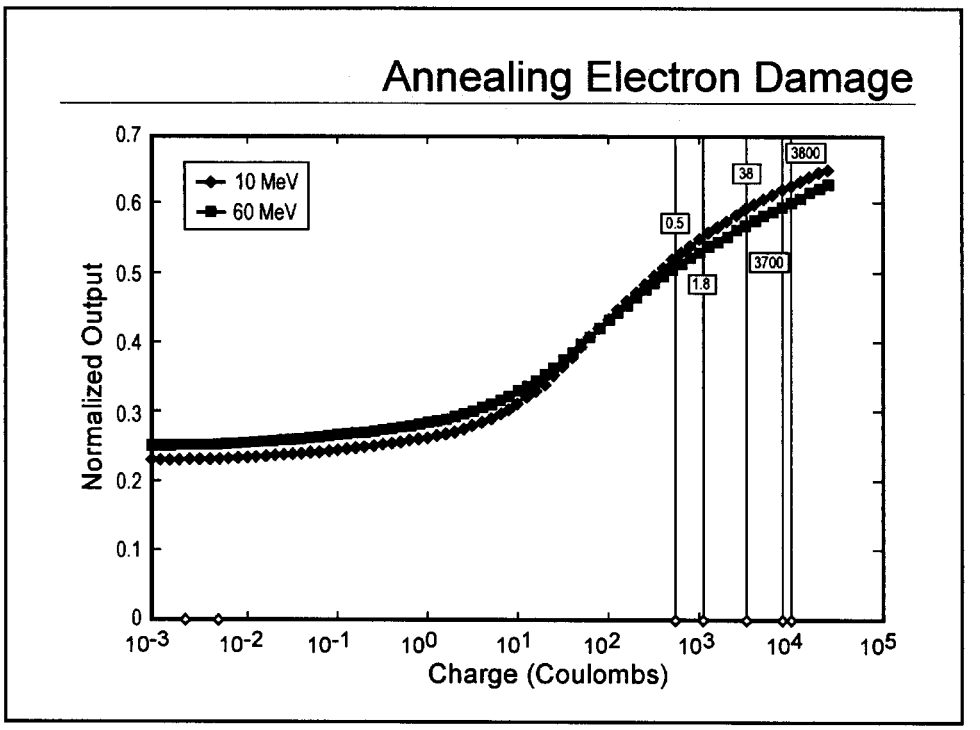


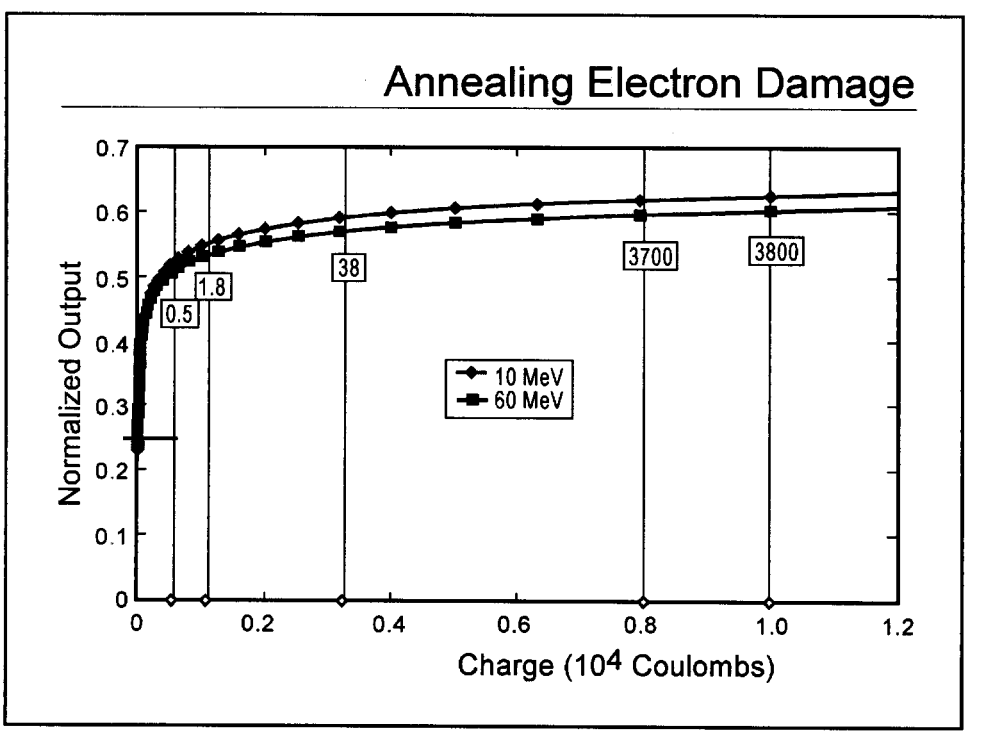
Non-Ionizing Energy Loss for GaAs




LED Displacement Damage
OP130, s/n# 4
most degraded of six
extrapolated points
1 mA
20 mA
37.5 mA
[(I/I0)^n - 1]
10
1
0.1
10^9
10^10
10^11
10^12
50 MeV Protons, # per cm^2


In-Flight Annealing
Measured
immediately
(still hot)
Recorder Run Time, sec
10000
1000
100
10
1
0.1
0.1
1
10
100
Annealing Time @ 22 mA, hrs


Annealing Electron Damage
10 MeV
60 MeV
Normalized Output
Charge (Coulombs)
0.5
1.8
38
3700
3800


Annealing Electron Damage
10 MeV
60 MeV
Normalized Output
Charge (10^4 Coulombs)
0.5
1.8
38
3700
3800

Results

The response to the Galileo recorder failure required:

1. Identification of the recorder components and circuit elements capable of causing the failure signature
2. Recognition of the role of radiation damage
3. Development and deployment of remote repair operations.

Amalthea data successfully recovered!