# Predicting the Effect on Electronics

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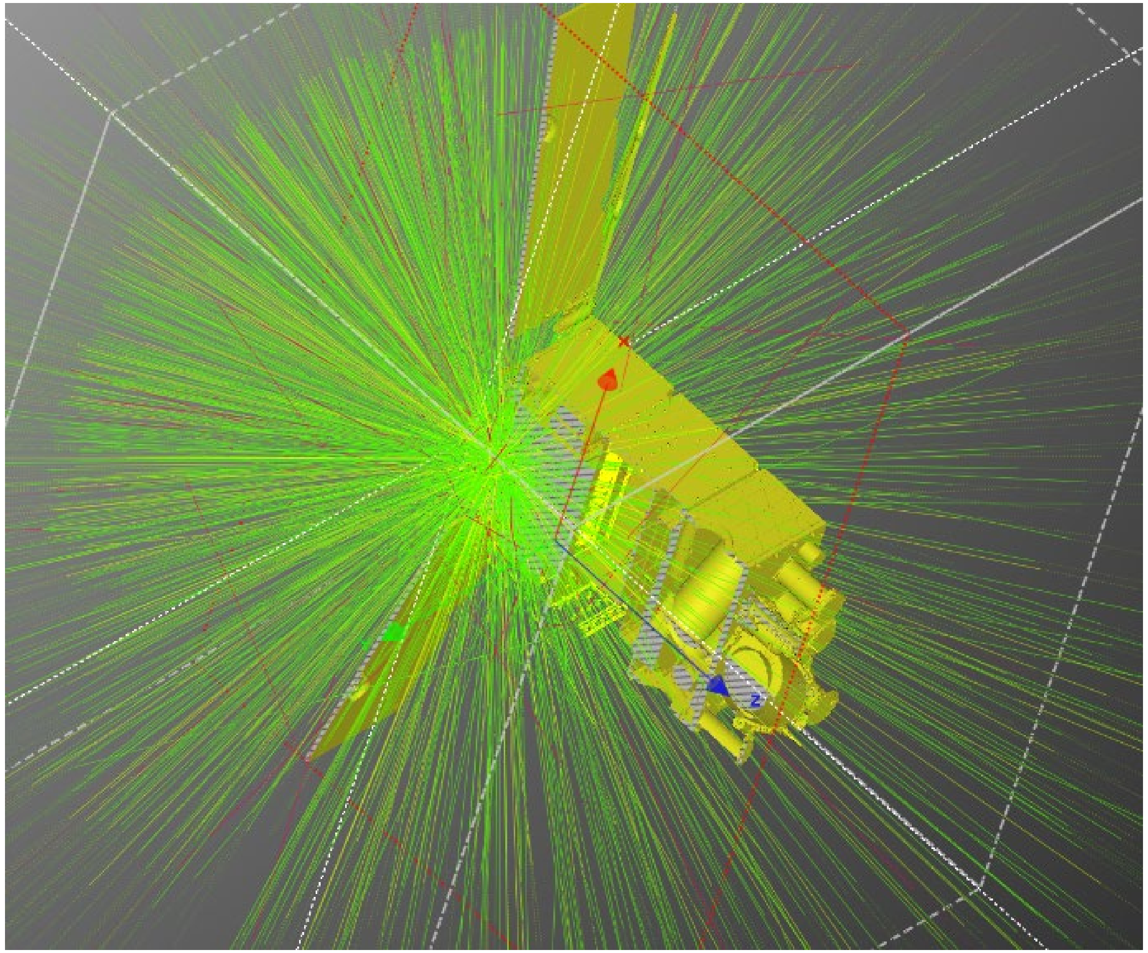
# Predicting TID Failures

- **There are two things we need to know:**
  - How much ionizing dose can the components tolerate before failing
  - What is the radiation environment for each component
- **We determine the radiation tolerance of the components using these methods:**
  - Vendor data sheets
  - Our testing
  - Radiation testing databases
- **We determine the radiation environment on the components through modeling**
  - This allows us to determine if there is a pin hole that causes a particular component to fail early

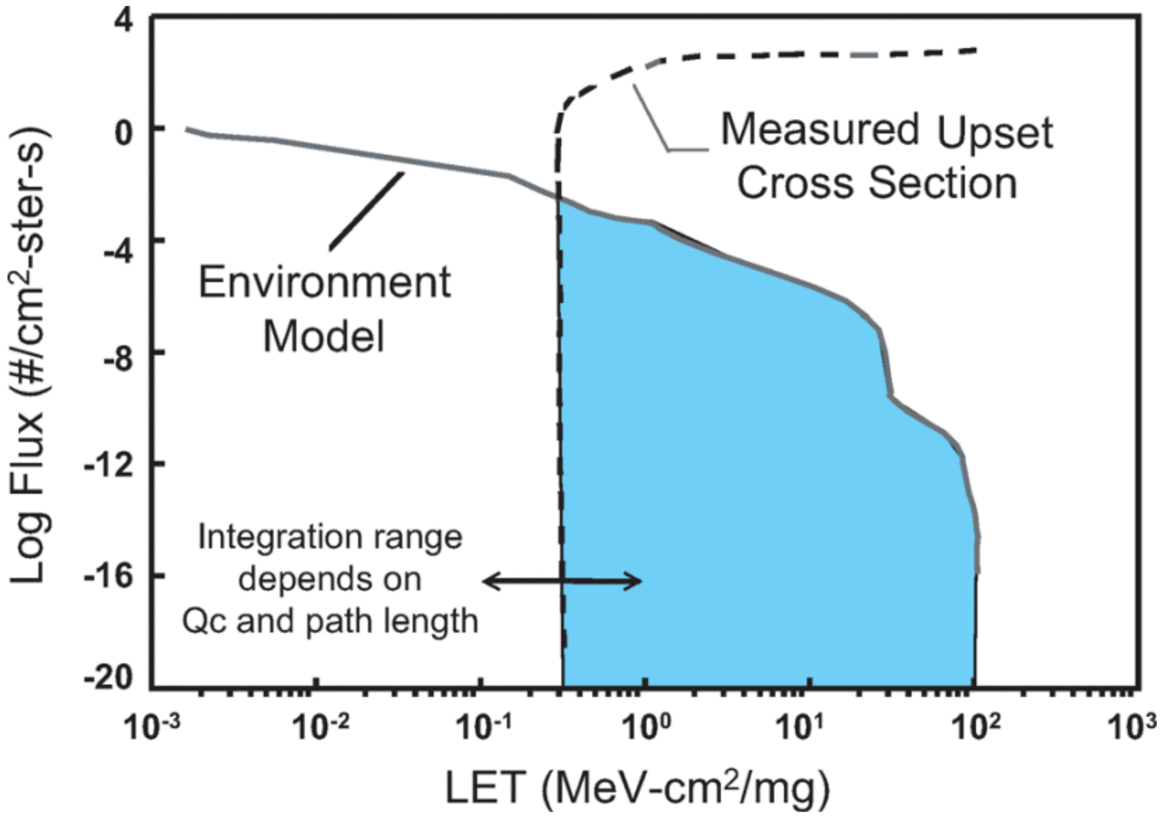


# Predicting DD Failures

- **There is generally no first step: most of this radiation cannot be shielded in a satellite, likely need to actually know it in an accelerator environment**
- **We check to make certain the components can tolerate enough 1-MeV neutron equivalents as specified in the requirements**
  - DD tends to be a step function (functional, non-functional)

# Approach to SEE in Satellites

- **Here are the steps:**
  - Model the radiation environment
  - Transport the model through the shielding
  - Convolve the SEE cross sections with the transported radiation model
- **The modeling and the transporting will be handed to you**
- **You are going to have to figure out how you want to convolve this:**
  - By hand
  - By Excel
  - By programming
- **This convolution will give you an error rate**
  - But there is still a lot of stochastic processes in the prediction




Measured upset error cross section and particle flux for a hypothetical space environment. The error rate is determined by convolving the environment model with the error cross section. [J. R. Schwank, M. R. Shaneyfelt and P. E. Dodd, "Radiation Hardness Assurance Testing of Microelectronic Devices and Integrated Circuits: Radiation Environments, Physical Mechanisms, and Foundations for Hardness Assurance," in IEEE Transactions on Nuclear Science, vol. 60, no. 3, pp. 2074-2100, June 2013.]

# Numerical Integration

- **Thoughts about it?**

# Active Volumes

- The entire slab of silicon is not sensitive to SEE – only the active volume
- The cross section is the measurement of the size of the active volume
- Do the Silicon overlayers matter?

# Poisson Statistics

# Poisson Statistics

- **“The probability of a number of events occurring in a fixed period of time if these events occur with a known average rate and independently of the time since the last event”**
- **One of the thing is predicts is the probability of a certain amount of radiation within a given time**
  - Since Poisson statistics affects how much radiation emits at any given time, it affects the error rates
  - For TID the Poisson statistics mostly normalizes
  - For SEE the Poisson statistics causes constant variation in the error rates

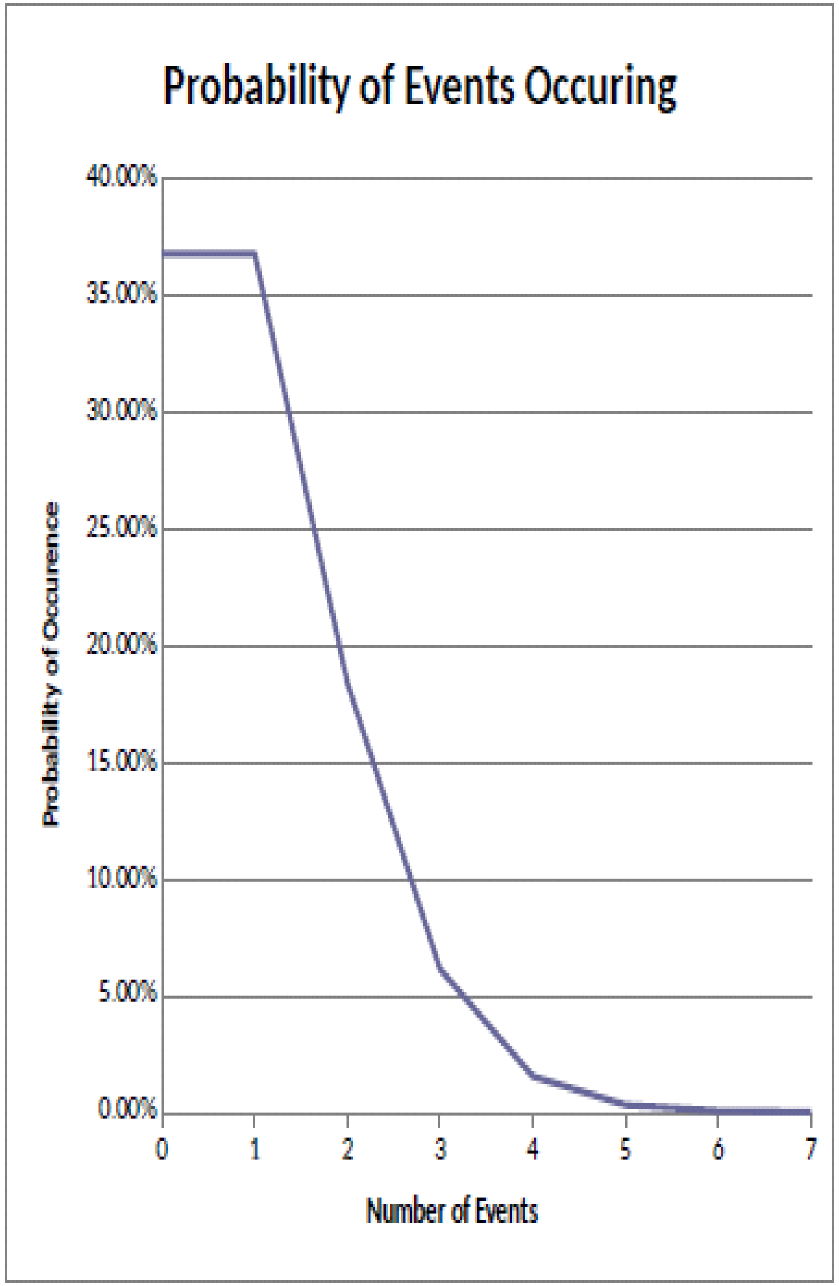
# Poisson Probability Law

- **The Poisson probability law tells us the probability that given**
  - The average number of events per unit time, λ
  - The time τ, and
  - The number of events, k
- **The probability of k events during time τ is**

$$P(k; t, t + \tau) = e^{-\lambda t} \frac{(\lambda\tau)^k}{k}$$

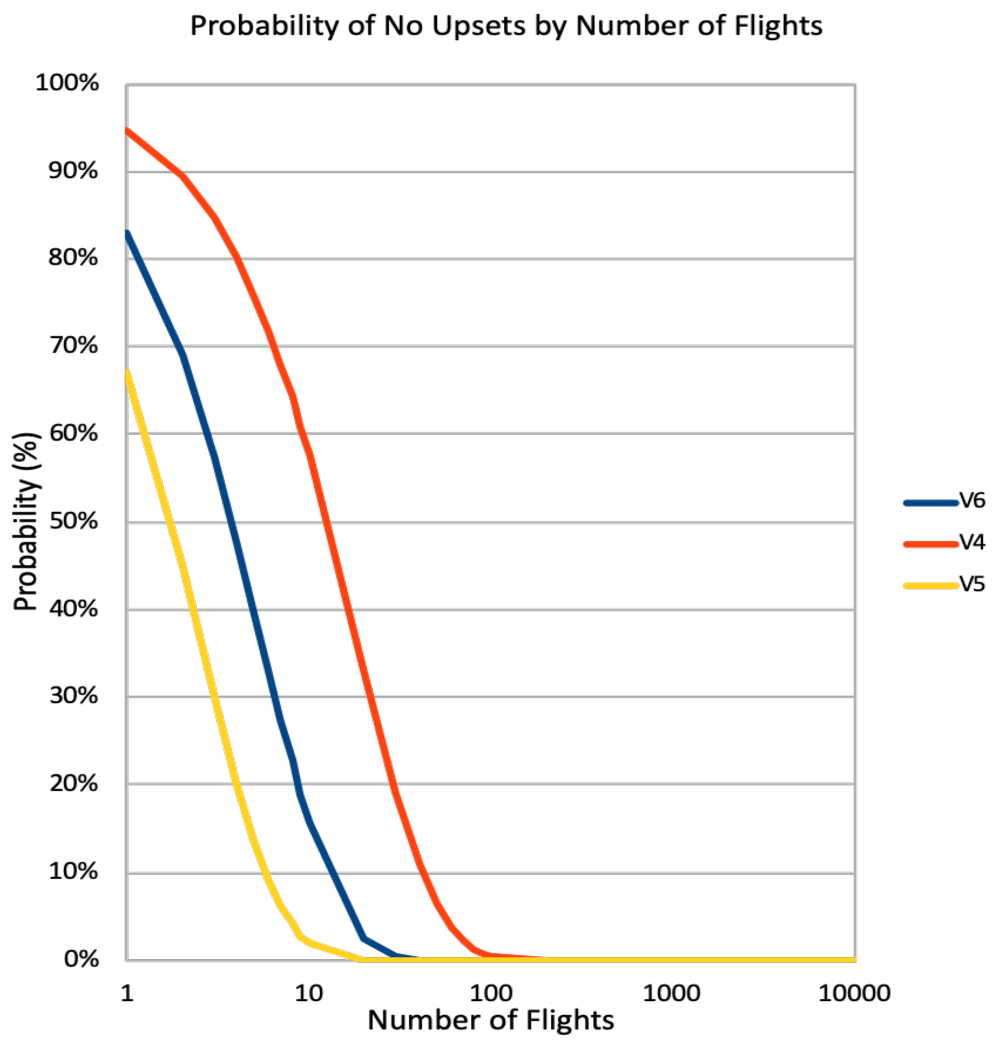
# Inter-arrival time of SEEs

- **Average rate only provides the "mean-average arrival rate" that upsets will occur at**
- **Errors will arrive based on the Poisson random process**
  - MTTU gives the likely interval that errors will arrive at
  - Poisson determines when the errors will manifest
- **There is an equal chance that no events and one event occur in one time period**
- **There is a 26% chance that 2 or more events occur**



# Inter-arrival time of SEEs

- Just because the sortie length < MTTU does not mean there will not be in-flight upsets
- At 20,000 feet, there is a 5% chance of having an upset in the first flight
- Each subsequent flight, it becomes increasingly less likely to not have an upset



# Poisson Examples

- **CREME-MC and QARM will provide you an estimate of what the error rate.**
- **You can convert that error rate into mean time to upset (MTTU) by inverting it:**
  - MTTU = 1/SER
- **Once you get to MTTU, then you can start asking questions like**
  - Given time T, what is the probability that the system is still working?
  - Given time T, what is the probability that X upsets have happened?

# What is the probability the system is still working?

- Assume that the system will fail if there are any errors. The error rate is 1 error per hour and we are interested in the first hour of operation. What is the chance that the system is still working in one hour?
- First off, our variables lambda and tau are:

$\lambda = 1 error per hour$ $\tau = 1 hour$

$$P(0 errors; 0{,}1 hour) = e^{-1*1}\frac{(1*1)^0}{0!} = e^{-1} = .36$$

# What is the probability the system is still working after two hours?

- **Same setup, except tau is different**
- **First off, our variables lambda and tau are:**

$$\lambda = 1 error per hour \qquad \tau = 2 hour$$

$$P(0 errors; 0, 2 hour) = e^{-1*2}\frac{(1*2)^0}{0!} = e^{-2} = .14$$

# What is the probability there are two errors in 1 hour?

- **Same setup, except k is different**
- **First off, our variables lambda and tau are:**

$\lambda = 1 errorperhour$ $\tau = 1 hour$

$$P(0errors; 0,1hour) = \mathrm{e}^{-1*1}\frac{(1*1)^2}{2!} = \frac{e^{-1}}{2!} = .18$$

# Homework

- **Figure out how you are going to convolve the Weibull Curves for SEE events with a radiation environment:**
  - – Reminder: the SEE curves are fit to this Weibull equation
    - F(L) = 1- exp{-[(L-L0)/W]^s}, if L > L0
    - F(L) = 0, if L < L0
  - – Reminder: make certain your units match
  - – What is the effect of onset, width and saturation on the error rate?
- **Figure out how you are going to calculate probability of failure given mean-time-to-event, the amount of time, and the number of events**