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Estimating the Reliability of Electronic Parts in High Radiation Fields

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Chester Everline, Karla Clark, Guy Man, Robert Rasmussen, Allan Johnston, Charles Kohlhase, and Todd Paulos

Author Affiliations

- Chester Everline
- Karla Clark
- Guy Man
- Robert Rasmussen
- Allan Johnston
- Charles Kohlhase

- Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA

- Todd Paulos

- Alejo Engineering, Inc., Simi Valley, CA, USA

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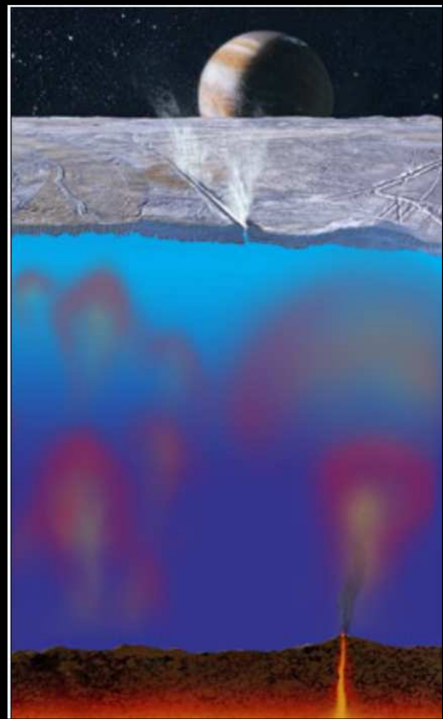
Why Europa?

- Geophysically interesting
- Large, warm, salty ocean

  ⇒ habitability
- An orbiting spacecraft with a capable payload could explore Europa, assess its habitability, and search for landing sites that could facilitate future in-situ exploration.



Artwork by Michael Carroll (http://solarsystem.nasa.gov/scitech/display.cfm?ST_ID=1989)

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The Challenges

- Protecting the orbiter from Jupiter's radiation.*
- Assembling the probe in a sterile environment so that microbes from Earth don't mix with ***those from Europa***.*
- From an engineering perspective, the technical challenge to the conceptual Europa Explorer mission is protecting the spacecraft from the harsh radiation environment.

* E. Hand, "Moonlighting missions", *Nature*, 450 (931), December 13, 2007.

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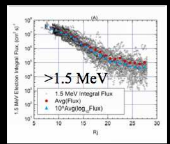
The Approach



Statistical Environment Model

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Part Category	Mean Rating, Mrad	Scaling Factor	Cov
Digital	1	3	0.15
Mem	1	2	0.15
Lin	1	2	0.15
Spec Lin	0.15	2	0.15
I/O	1	3.5	0.15
ADC	1	2	0.15
Hybrid	1	1.5	0.20
Xstor	1	3	0.15
MOSFET	0.6	1.5	0.15
Other	1	1.5	0.15
Sensors	1	2	0.15
GaAs	8	3	0.15

Part Failure Model

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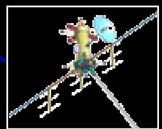
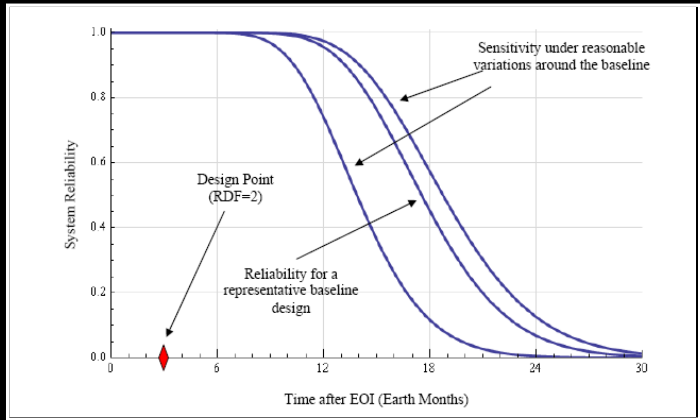


Flight System Reliability Model



Estimated Mission Life (The Assessment Results)

5

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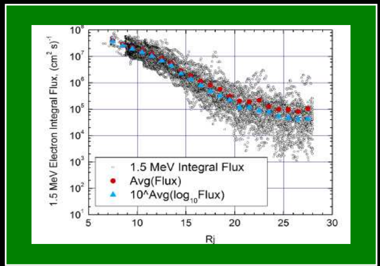
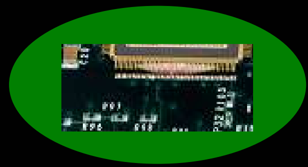
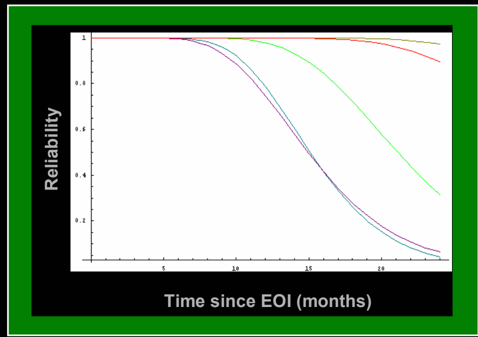
Parts Model







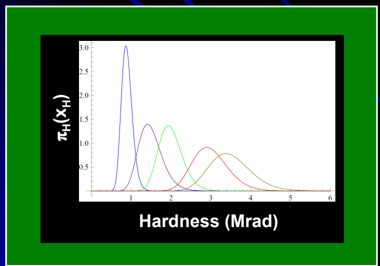
$$\int_0^{\infty}\int_0^{x_D}\pi_D(x_D,t)\pi_H(x_H)\,dx_H\,dx_D = P(t) = 1 - R(t)$$

Probability Density Function for Absorbed Dose, x_D

Probability Density Function for Radiation Hardness, x_H

Failure Probability (Time Dependent)

Time Dependent Reliability



6

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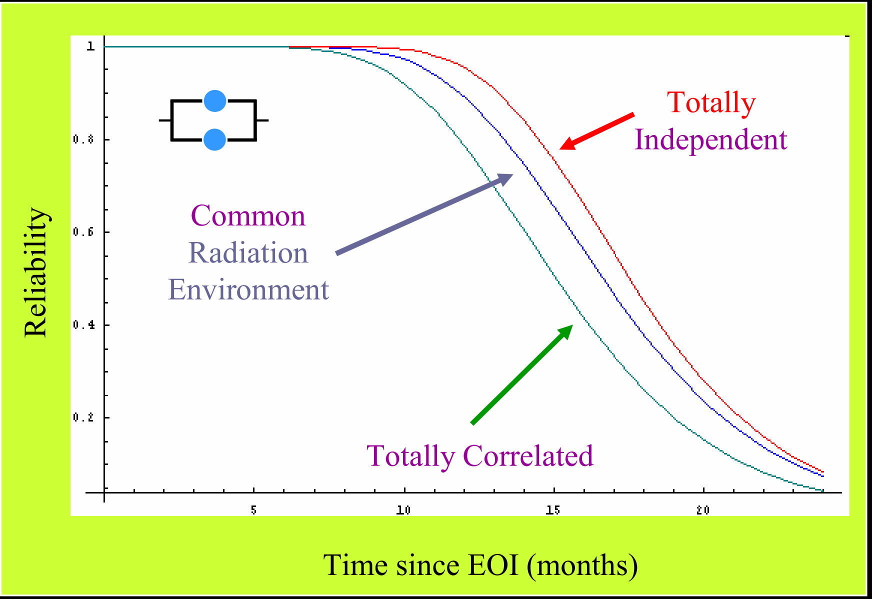
Flight System Reliability Concerns

- Multiple parts do not have independent reliabilities.
  - Some parts have highly correlated radiation environments.
  - There are within-batch correlations of part hardness.



7

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Flight System Reliability Model

- First principles approach → first order estimates
- Reliance on expert judgment
- Sources of uncertainty (from a PRA perspective)
  - Configuration of the spacecraft assemblies and subsystems (conceptual design)
  - Dependencies among part reliabilities
  - Model approximations and data
  - Others
- Assessment of uncertainties relied on sensitivity studies involving systems engineers and PRA staff

8

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Interpretation of the Assessment Results

- An appropriate perspective is that the results demonstrate the degree of confidence in a design process rather than representing a rigorous technical analysis of a specific flight system design.
- The deliberative process associated with their development involved discussing various flight system configurations, understanding failure mechanisms and modeling approaches, then integrating these with the techniques previously described.

9

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Conclusions

- A new approach to estimate mission lifetime for space missions in a high radiation environment has been shown.
- It is a paradigm shift for mission design.
- Since the approach is only a first order estimate, future efforts need to ensure model completeness and obtain statistical data for reducing epistemic uncertainty.
- These efforts have begun.

10

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