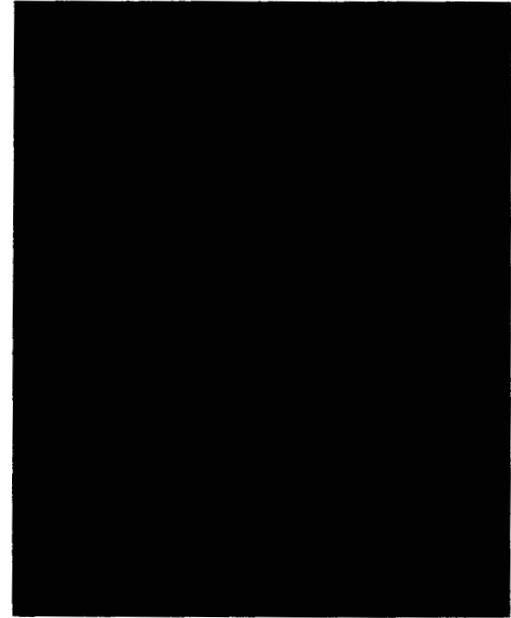
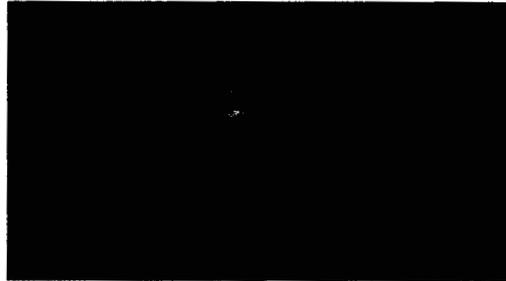
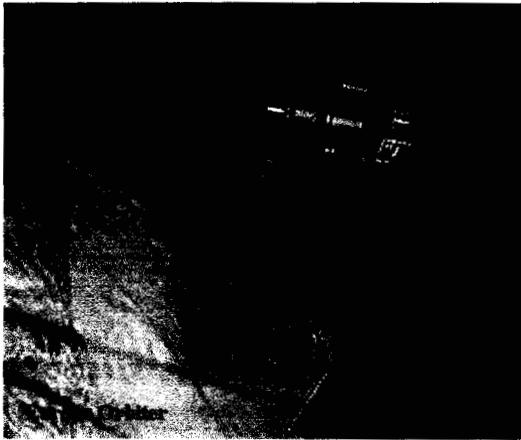




Briefing to the Compact Flash Association, May 2002
Memories in Space. The Challenge of The Real World



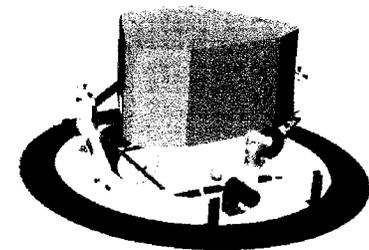
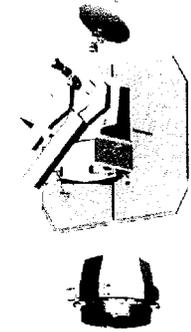
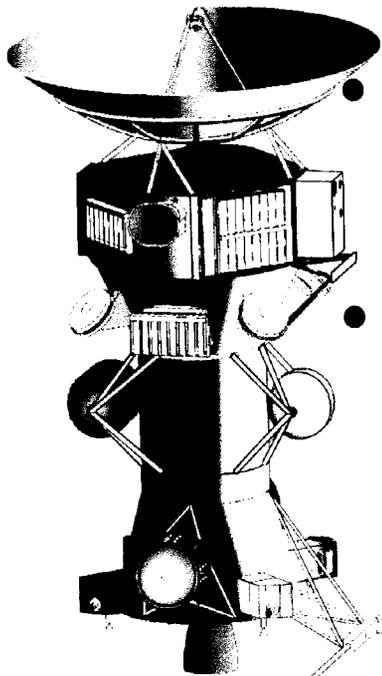
Jet Propulsion Laboratory
California Institute of Technology
May 21, 2002





Agenda

- 4:00 Overview
- 4:20 Effects of Radiation on Flash Devices
- 4:50 JPL Testing & Consulting Capabilities



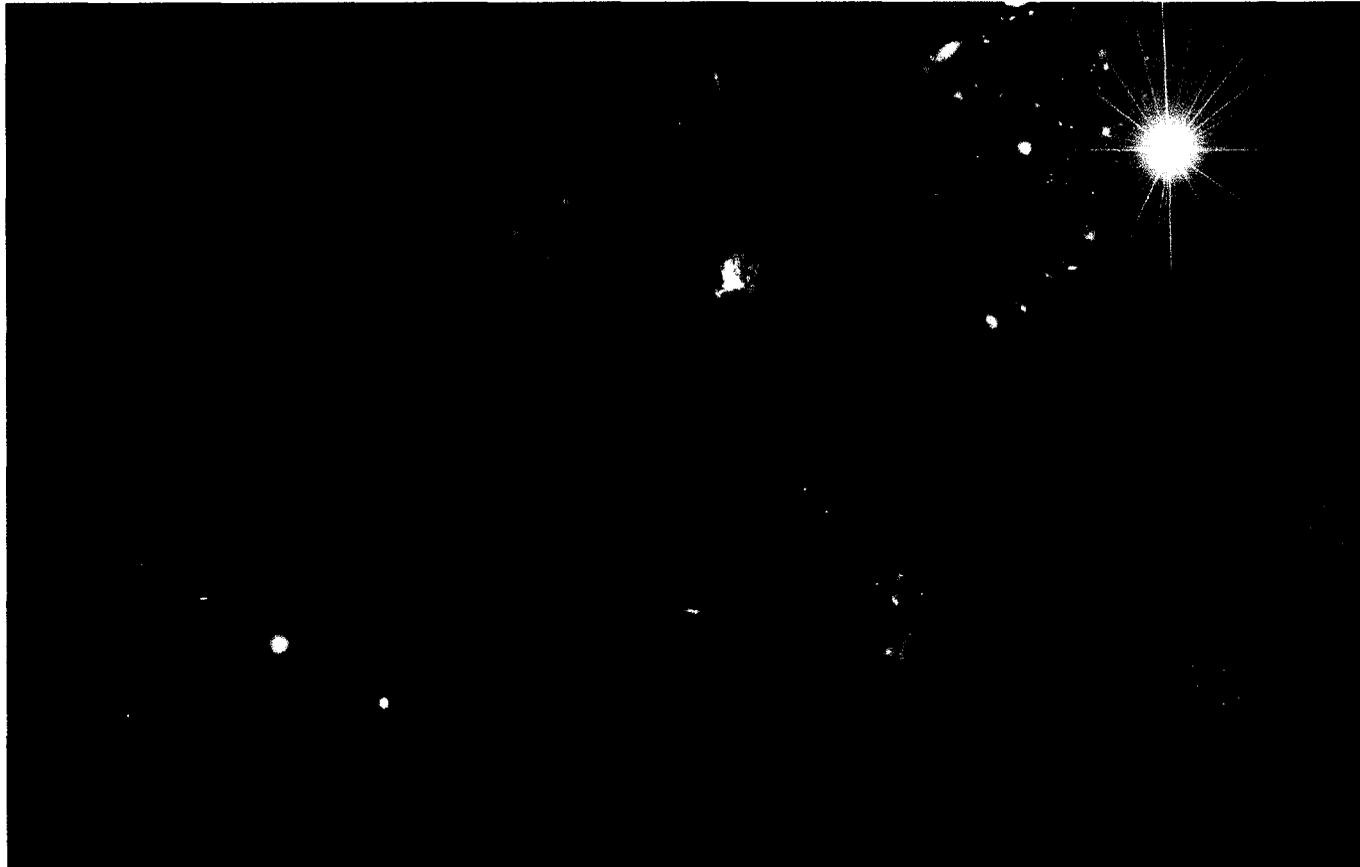


Briefing to the Compact Flash Association, May 2002

Understanding and Searching for the Origins of Life



- Evolution and Destiny of the Universe and our Solar System
- Evidence of extra terrestrial life Extra terrestrial intelligence
- Evidence of pre-biotic chemistry
- Is life abundant in the Universe; our Solar System ?
- Are there other habitable places in our Solar System ? Future human outposts ?





Acknowledgement

This package represents the hard work of several authors. The work described in this presentation was conducted at the Jet Propulsion Laboratory, California Institute of Technology under contract with the National Aeronautics and Space Administration.

This material is intended for tutorial, educational use only.



Presenters

- Taher Daud, Scientist, at JPL for 22 years.
Neural network specialist
- Leif Schieck, Scientist, at JPL for 6 years.
Radiation Effect specialist
- Karl Strauss, Senior Engineer, at JPL for 16 years. Memory System design specialist



Briefing to the Compact Flash Association, May 2002 Outer Solar System Exploration



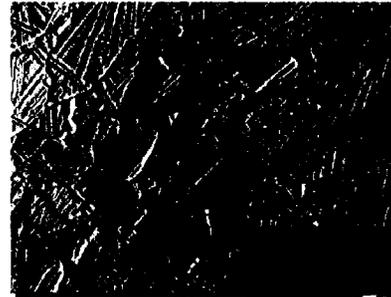
Cassini/Huygens



**Galileo-
Europa**



Europa Orbiter



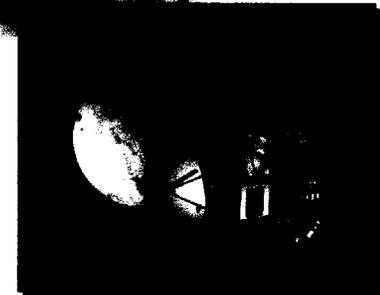
Europa Lander



Titan Explorer



**Comet Nucleus
Sample Return**



Pluto/Kuiper Express



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Astrophysics



Space Interferometry Mission (SIM)

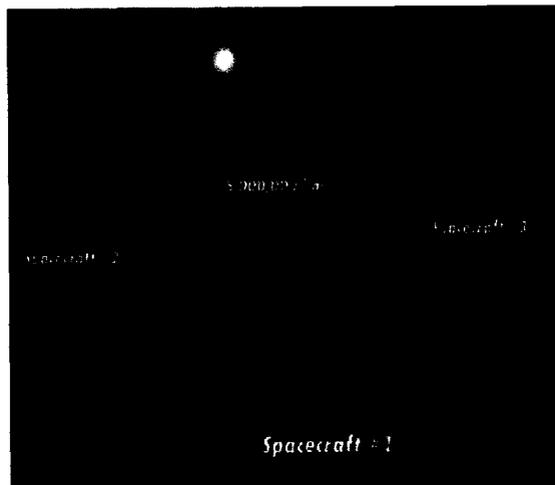


Space based Interferometry

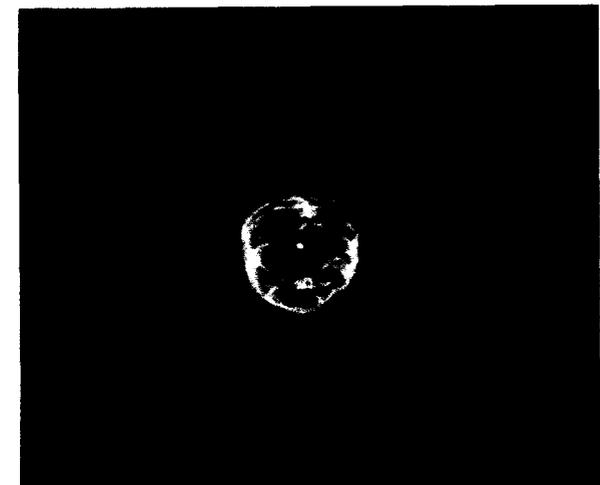
- High precision metrology
- Picometer laser interferometry
- Highly miniaturized electronics
- High performance computing
- Disturbance reduction control
- Inertial sensors



Laser Interferometry Space Antenna (LISA)



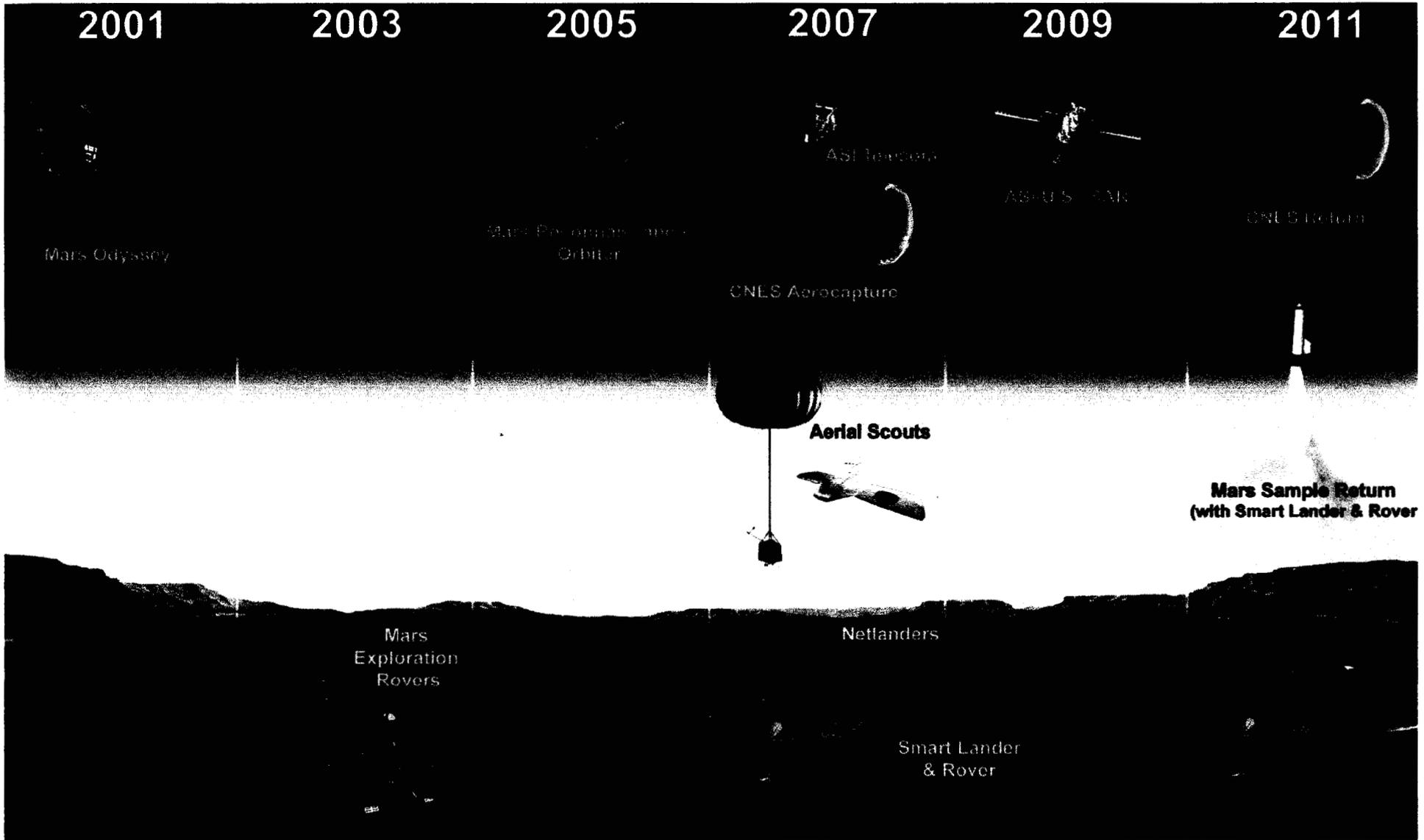
- Long duration missions (100 y)
- Solar Sails/propulsion
- Evolvable Systems
- Inflatable structures for high aperture - communications
- Energy harvesting
- On board autonomy
- Low Temperature/ambient electronics



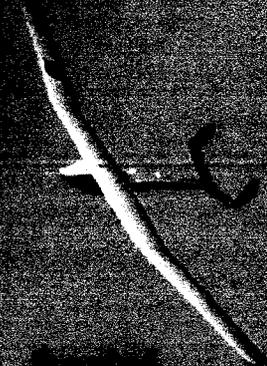
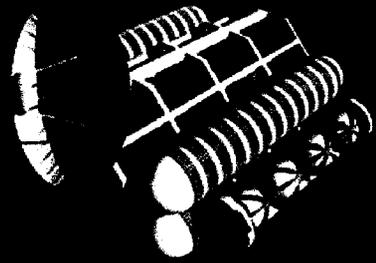


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The Mars Exploration Plan



2007 Mars Scout Mission



2007
Mars Scout Mission



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2007 Smart Lander/Rover Mission



GUIDED ENTRY

Conduct Significant Science

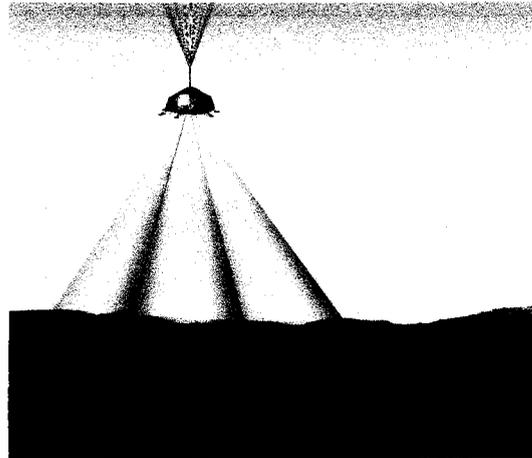
- Sub-surface drilling
- In-situ soil/rock analysis
- Atmospheric measurements



SURFACE MOBILITY

Approach

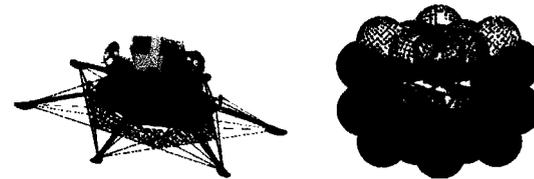
- Strong, multi-disciplinary team
 - NASA centers
 - Industry
 - Universities



HAZARD DETECTION/AVOIDANCE

Demonstrate Next-Generation Lander/Rover Capabilities

- Global access
 - latitude range
 - surface elevation
 - rugged terrain
- Accurate/safe landing
- "Go-to" mobility
- Extended mission operations



ROBUST TOUCHDOWN SYSTEM



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Europa Orbiter





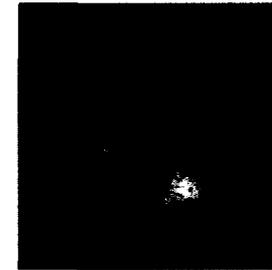
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Europa Orbiter Mission

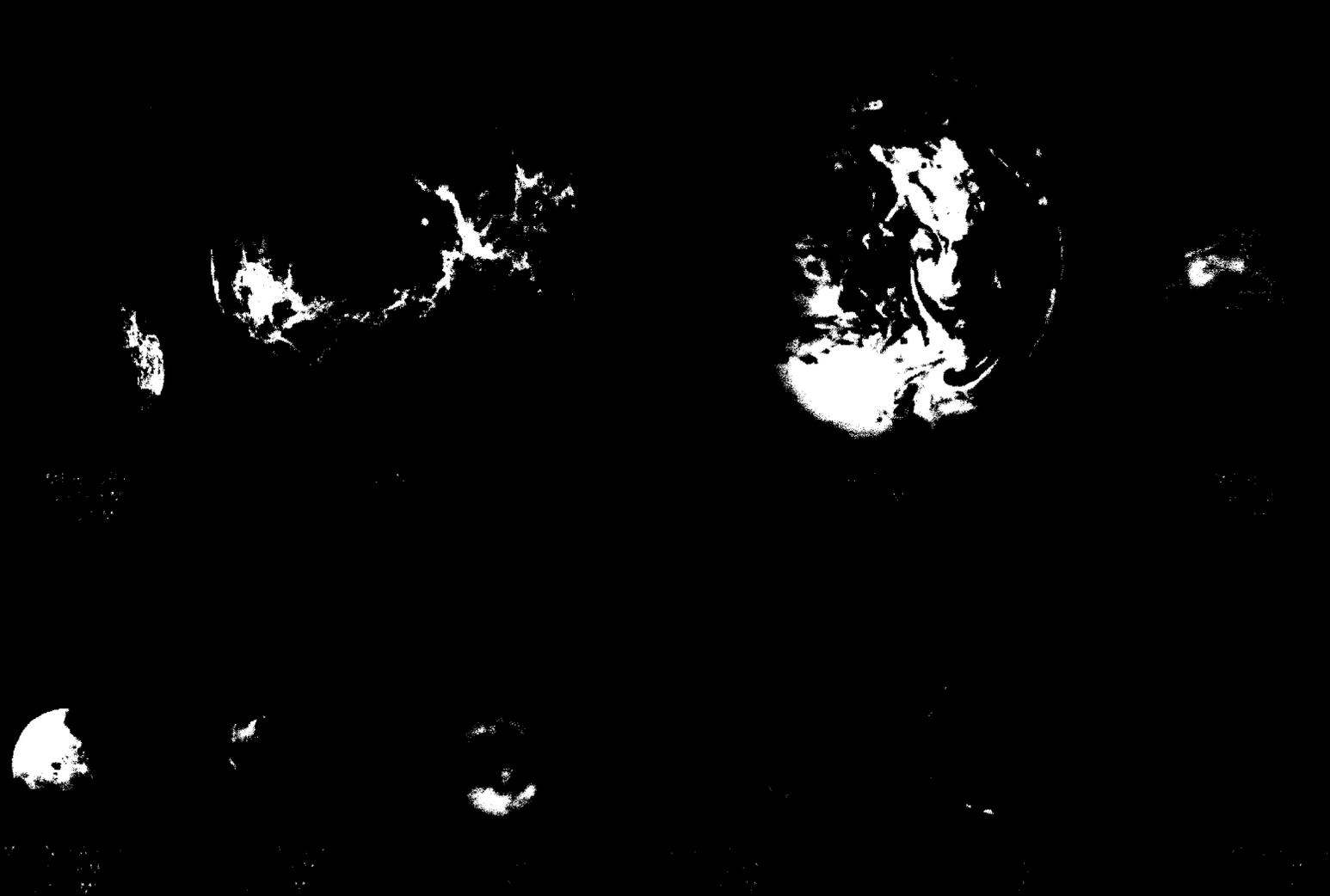
JPL

Key Questions:

- Is there an ocean of liquid water beneath Europa's ice?
- Are there places where the ice is thin or where water reaches the surface?
- Could the Europa environment support pre-biotic chemical processes?



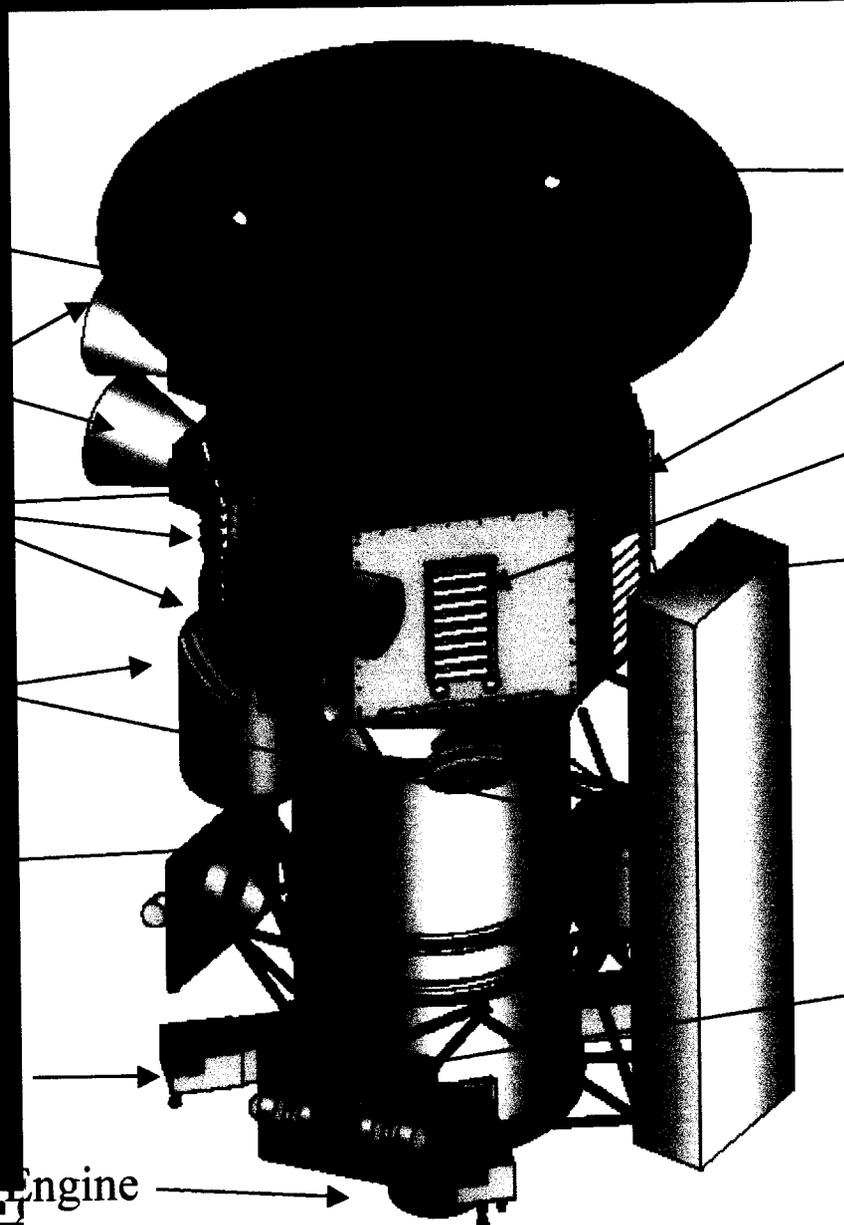
Exploration of Moons and Planets





Spacecraft Survivability





Engine



JPL







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Europa Mission Technical Challenges



- Drivers of cost and complexity for the Europa Orbiter Mission:
 - Radioisotope power source
 - High launch and trajectory energy requirements
 - Radiation environment at Jupiter and Europa
- All lead to requirements for radiation tolerance, low mass, power, volume designs

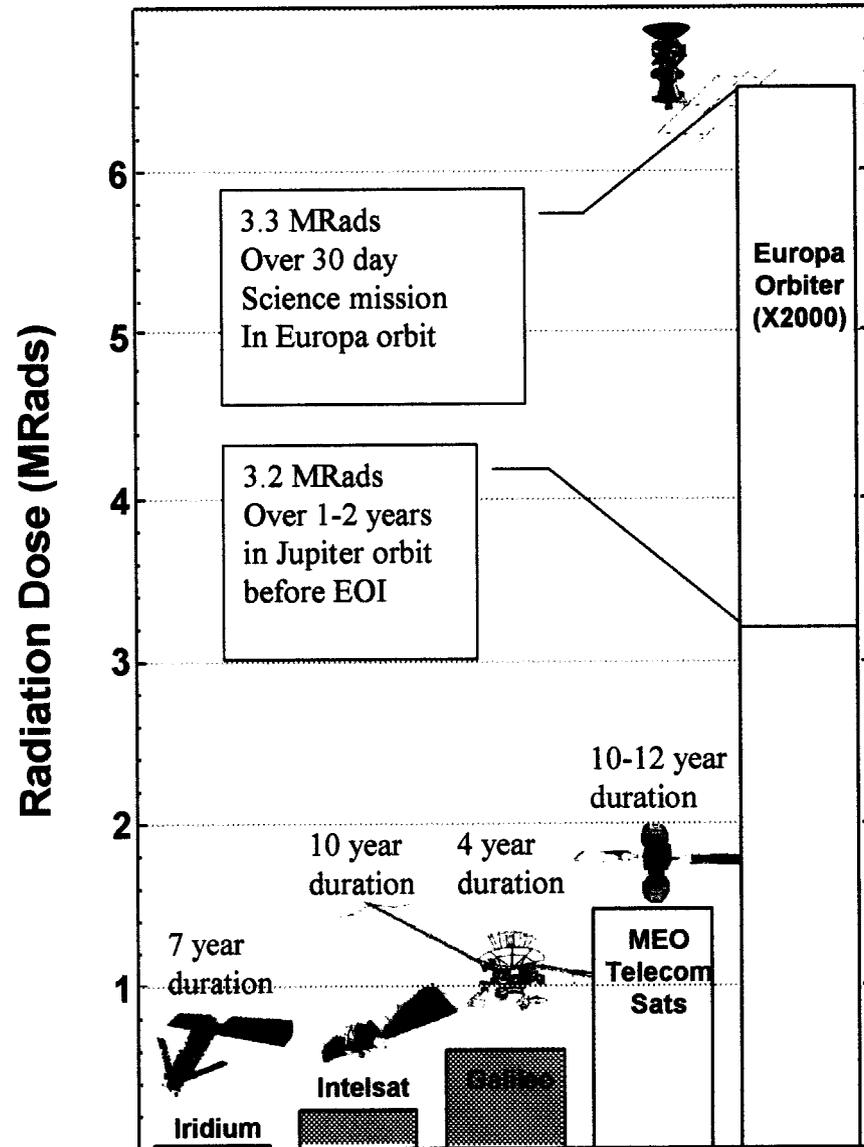


Radiation environment biggest challenge



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Europa Radiation Environment



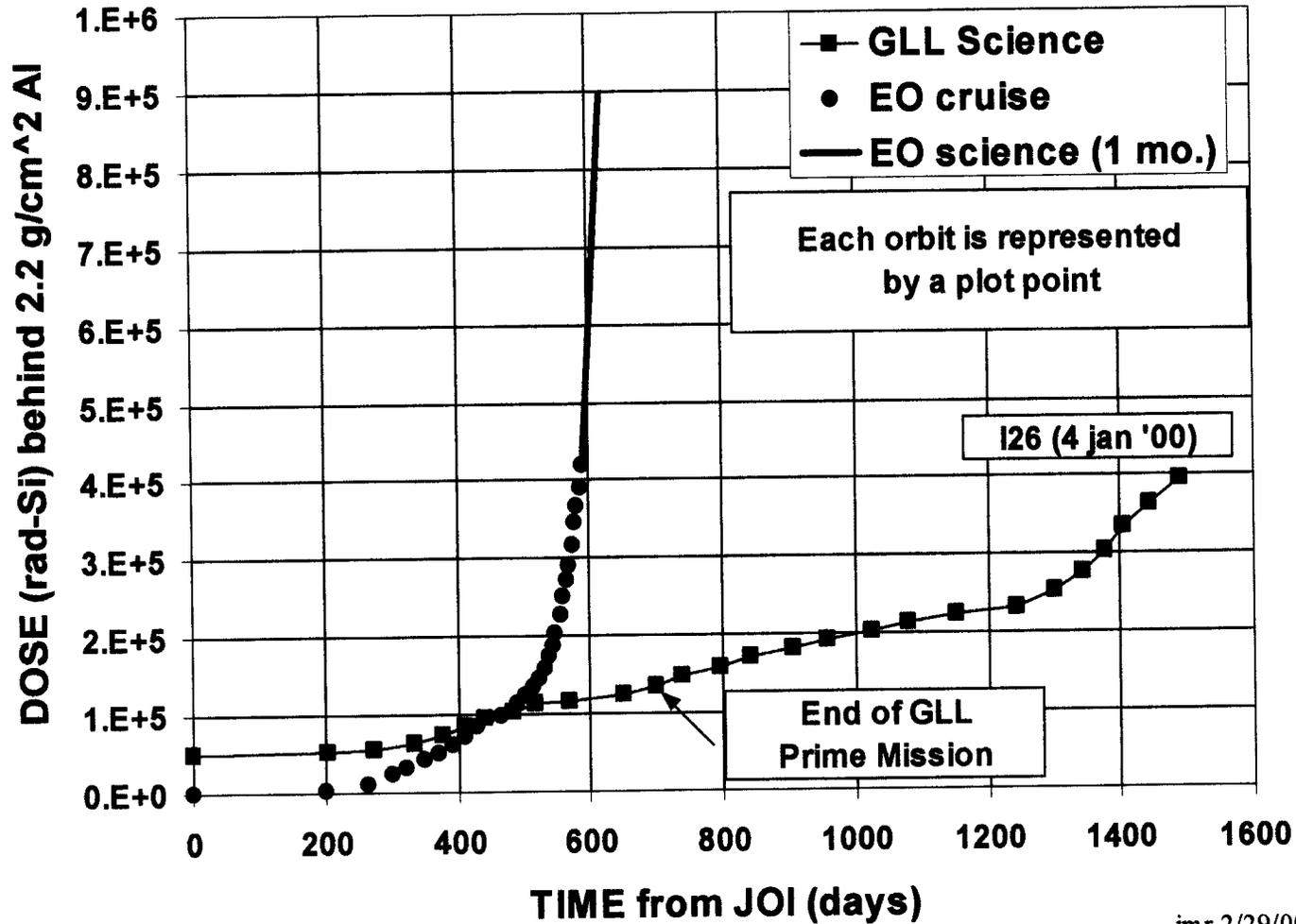
- The Europa Orbiter total dose environment is harsh compared to current experience
 - At Europa an astronaut inside an EVA suit receives a lethal dose every 12 minutes
- The Europa Orbiter must operate with high reliability during the 30 day mission
 - Science objectives
 - Achieve quarantine orbit
- Impact
 - High technology, high risk, high cost electronics development (X2000) to reduce risk
 - Total shielding = 39 kg



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Galileo and Europa Orbiter Missions: Radiation Profile.



jmr 2/29/00



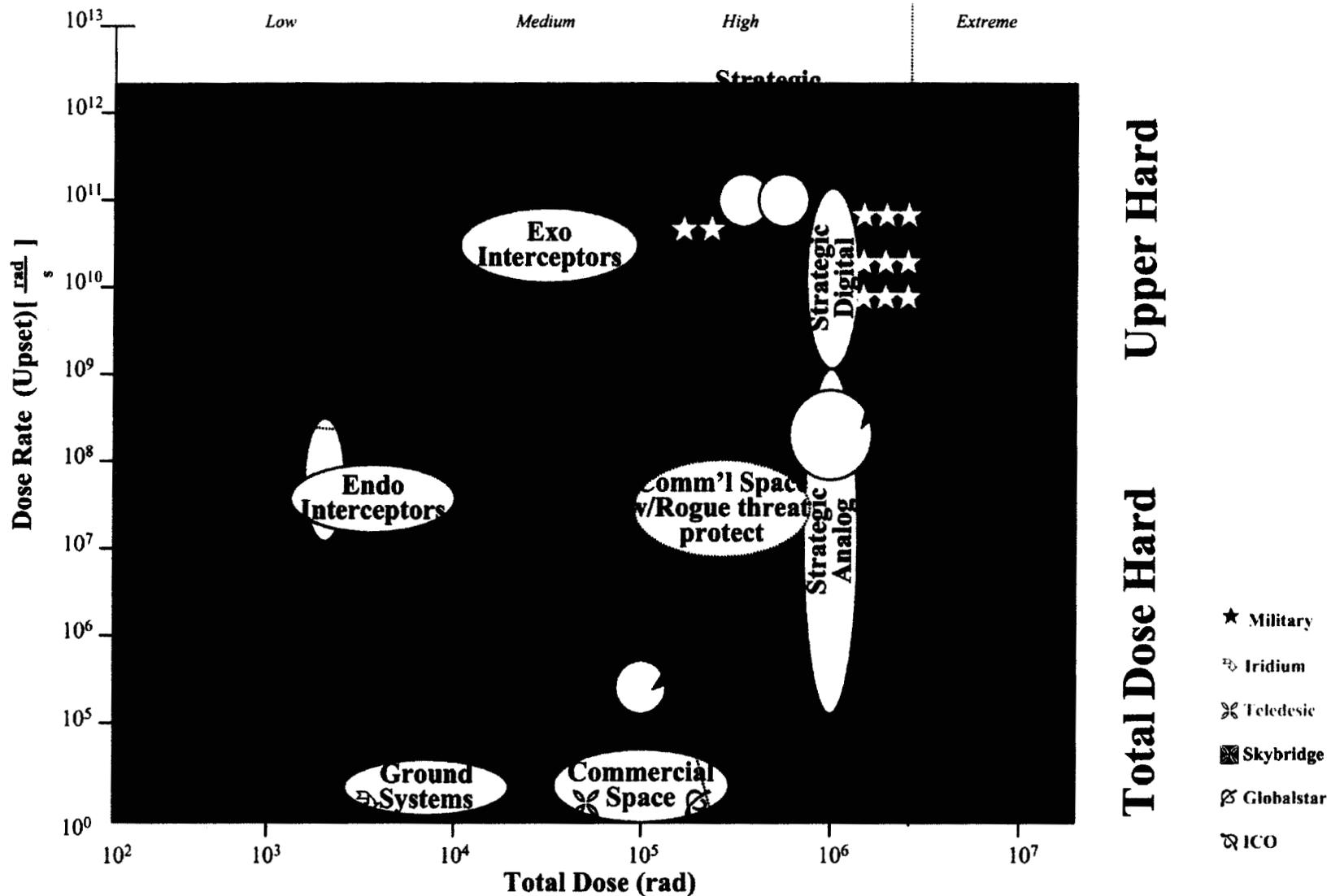
Why Worry About Radiation?

- Studies show that satellite systems can be adversely affected in their expected lifetime should radiation be encountered outside their design limits
 - Teledesic, 60 kRads, 10 years – reduces to 2 months
 - Iridium, 7 kRads, 6 years – reduces to 3 weeks



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Process Capabilities





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Memory System for Europa Orbiter Top level Rqmts.



- **2 Gb of Non-Volatile Data Storage, not including EDAC**
- **No Loss in Performance from 50 kRads Environment**
- **Uncorrectable Data Error Rate Less Than 10^{-10} Bit Errors/Day**
- **No Loss In Performance Due To A Single Failure In The Memory System, A Processor Node, Or The Data Bus**



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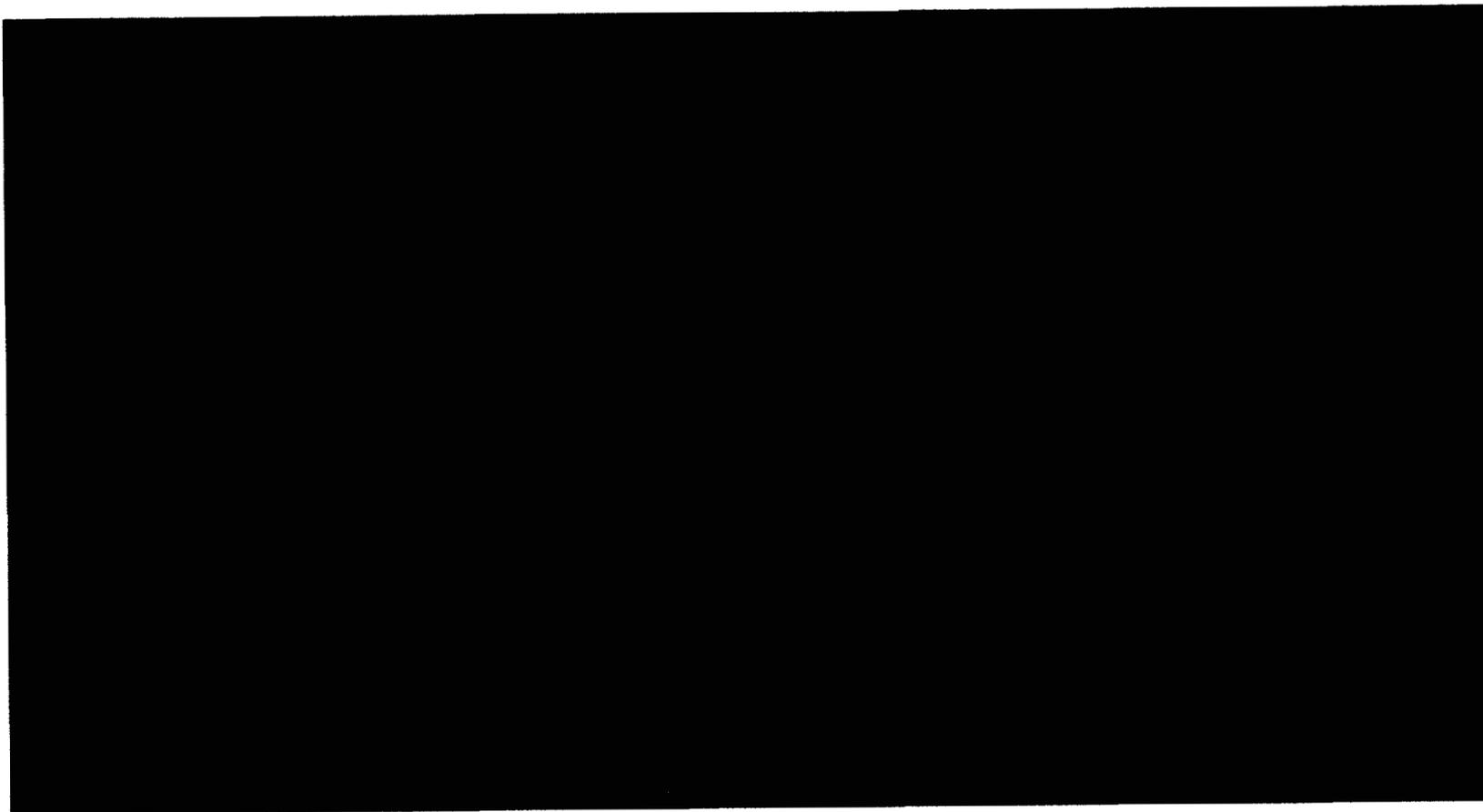
EXAMINED TECHNOLOGIES



- FLASH
- EEPROM
- SDRAM (SYNCHRONOUS DRAM)
- SRAM (STATIC RAM)
- DISK DRIVES
- CHALCOGENIDE
- MRAM
- FERROELECTRIC



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Memory options becoming limited



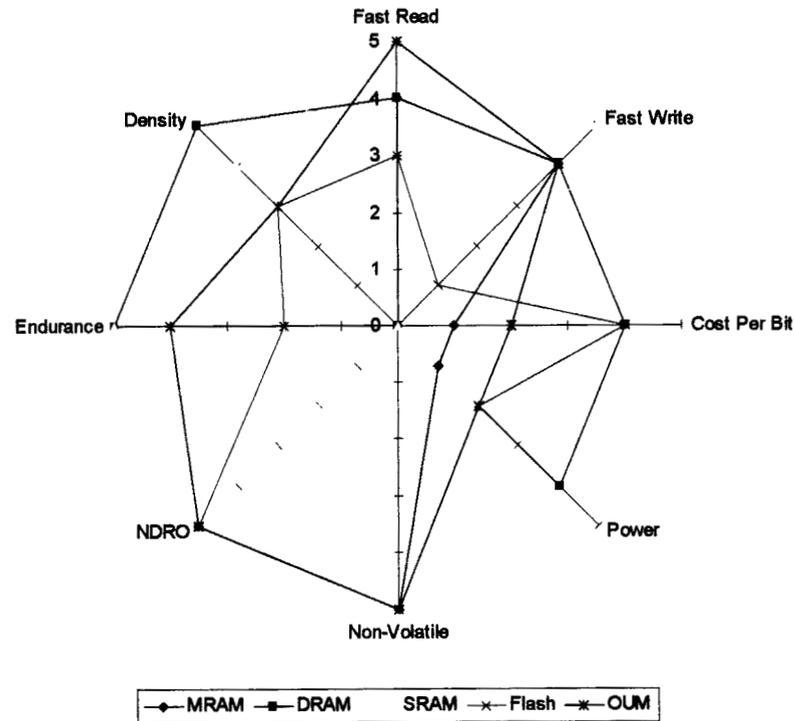


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Key Memory Attributes

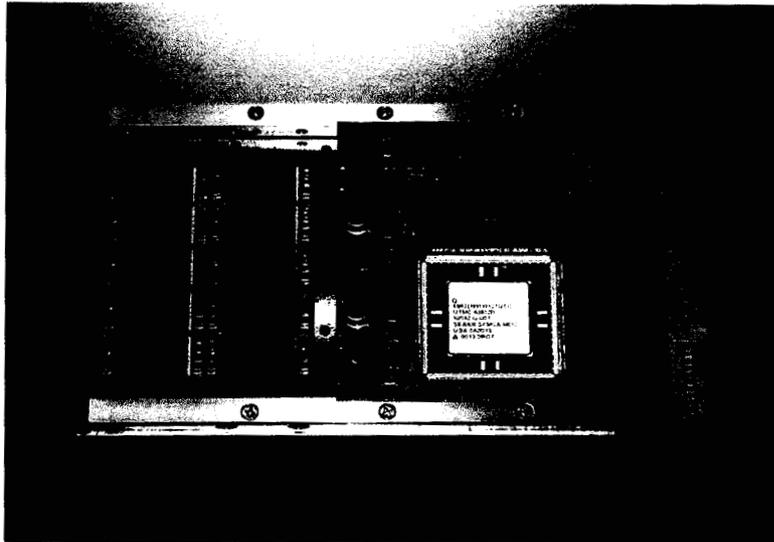


Comparative Memory Technologies

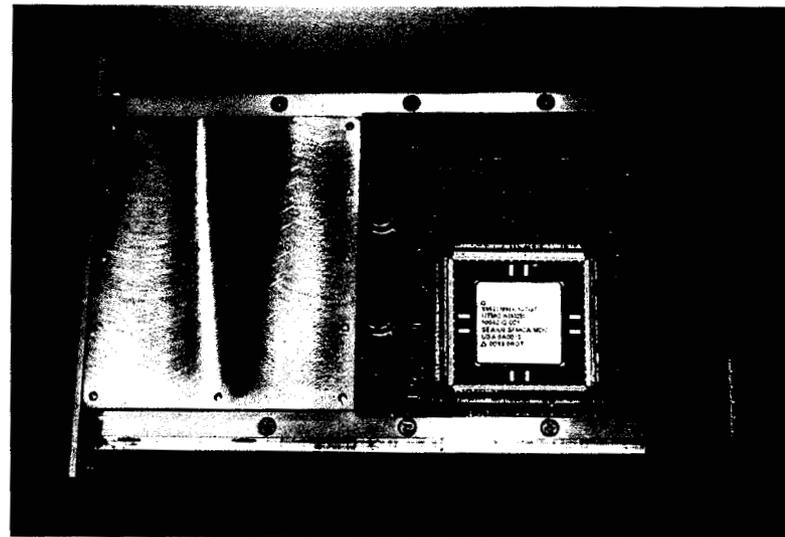




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without Clamshell



with Clamshell



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A Better Solution Exists!



- This solution is not elegant and results in lost science.
- This solution uses Tungsten and Copper to hide from the real problem: that commercial designs do not take into account the effects of radiation
- The effects of radiation are everywhere – the problems caused by is only a matter of degrees.



- IEEE now sponsors the JPL Non-Volatile Memory Technology Symposium
 - Two have been held to date: 2000 and 2001.
- NVMTS2002 will be held, November 5 & 6, Honolulu
 - See <http://nvm.jpl.nasa.gov> for more information