




# Space Radiation and *Fox* Satellites



AMSAT Engineering  
2011 Space Symposium





# Space Radiation



- What is it?
- Why do we care?
- What can we do about it?

Information provided by WA4SCA



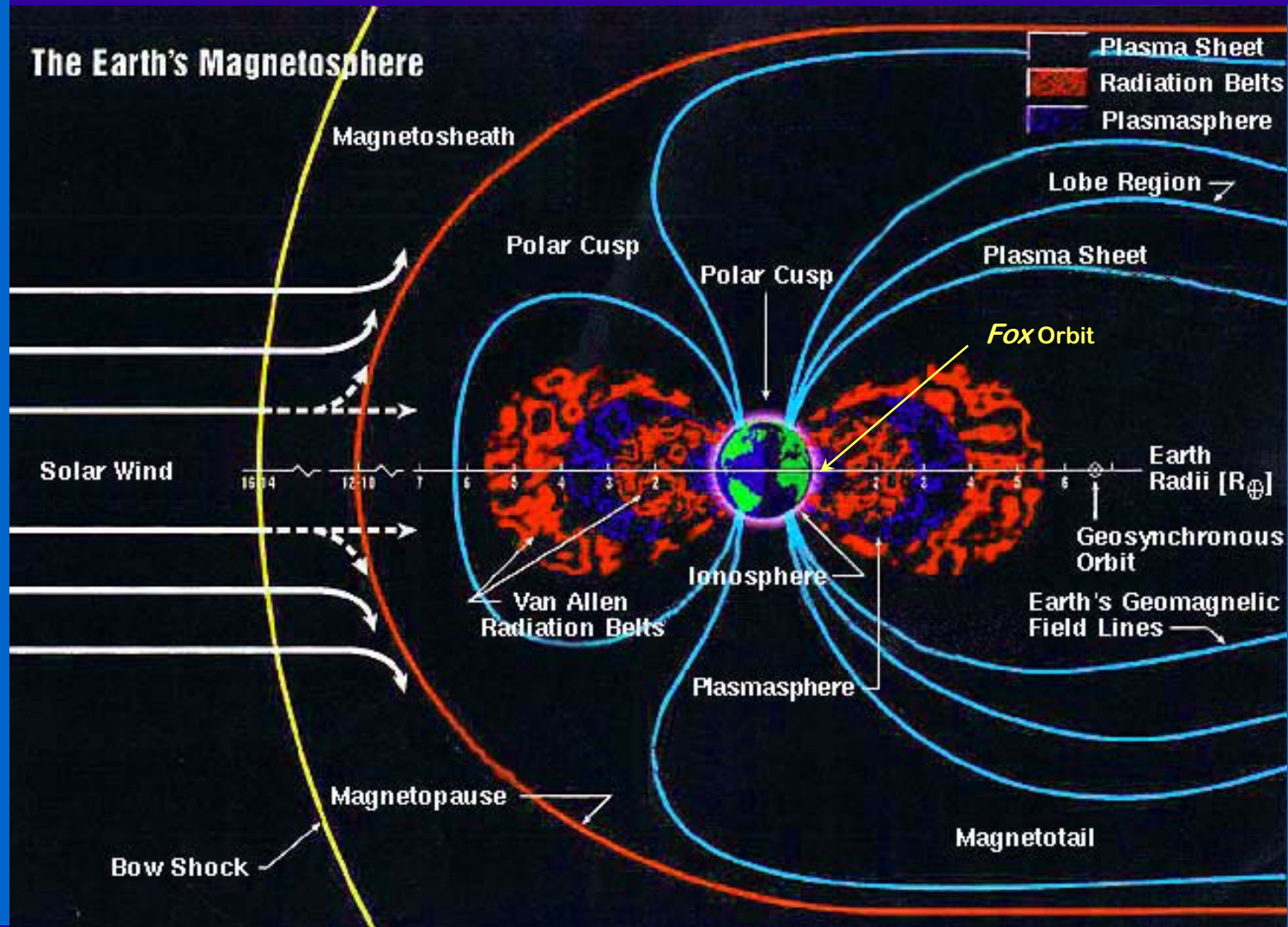
# Space Radiation



Type	Source	Composition
Trapped Particles in Van Allen Belts	Solar Wind	High Energy Protons (+ Anti-protons!) High Energy Electrons Bremsstrahlung (X-Rays)
Galactic Cosmic Radiation	Cosmic Rays	Hydrogen to Uranium Nuclei Low Flux, but Very High Energies
Solar Particle Events	Solar Flares and Coronal Mass Ejections	Energetic Electrons, Protons, Alpha Particles

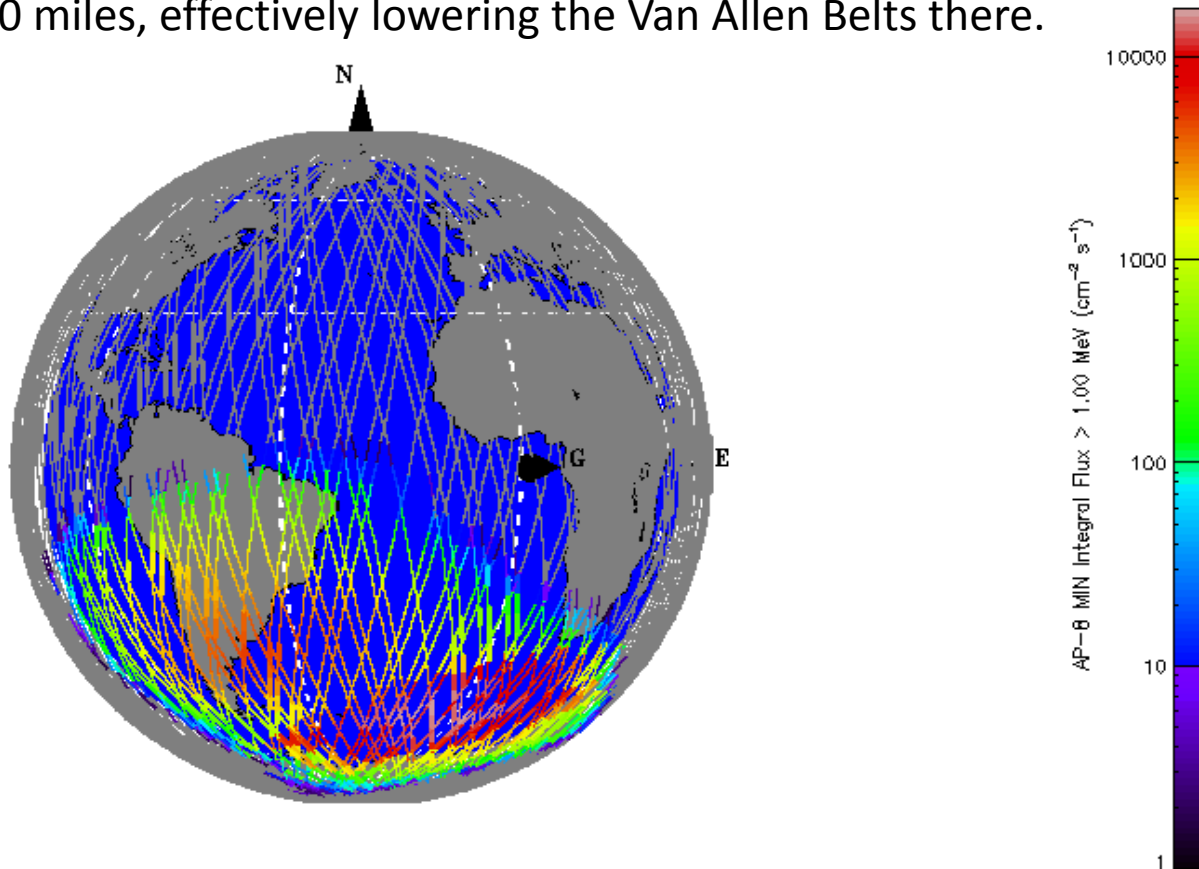
Lower energy particles cause cumulative damage. Higher energy particles cause Single Event Upsets. All can impact electronics. Comprehensive component testing is complicated and expensive.

# Space Radiation Model



# South Atlantic Anomaly

- Caused by the Earth's magnetic field being displaced about 280 miles, effectively lowering the Van Allen Belts there.



- The major source of radiation for *Fox* satellites

# Calculated Total Radiation Dose



Satellite	Altitude (km)	Inclination (degrees)	kRAD/year (50% confidence)	kRAD/year (98% confidence)
ARISSat-1	350	52	1	7
<i>Fox-1</i>	650	98	7	62
<i>Fox-2, AO-51</i>	800	98	11	99
AO-7	1500	101	90	450
Geosynch	35786	0	2120	15500

Data from ESA SPENVIS



# Radiation Effects on Components



- Transient errors
- Logic and memory stuck-bit errors
- CMOS latchup
- Electrical leakage in insulators
- Parameter drift
- Gate rupture of MOS devices



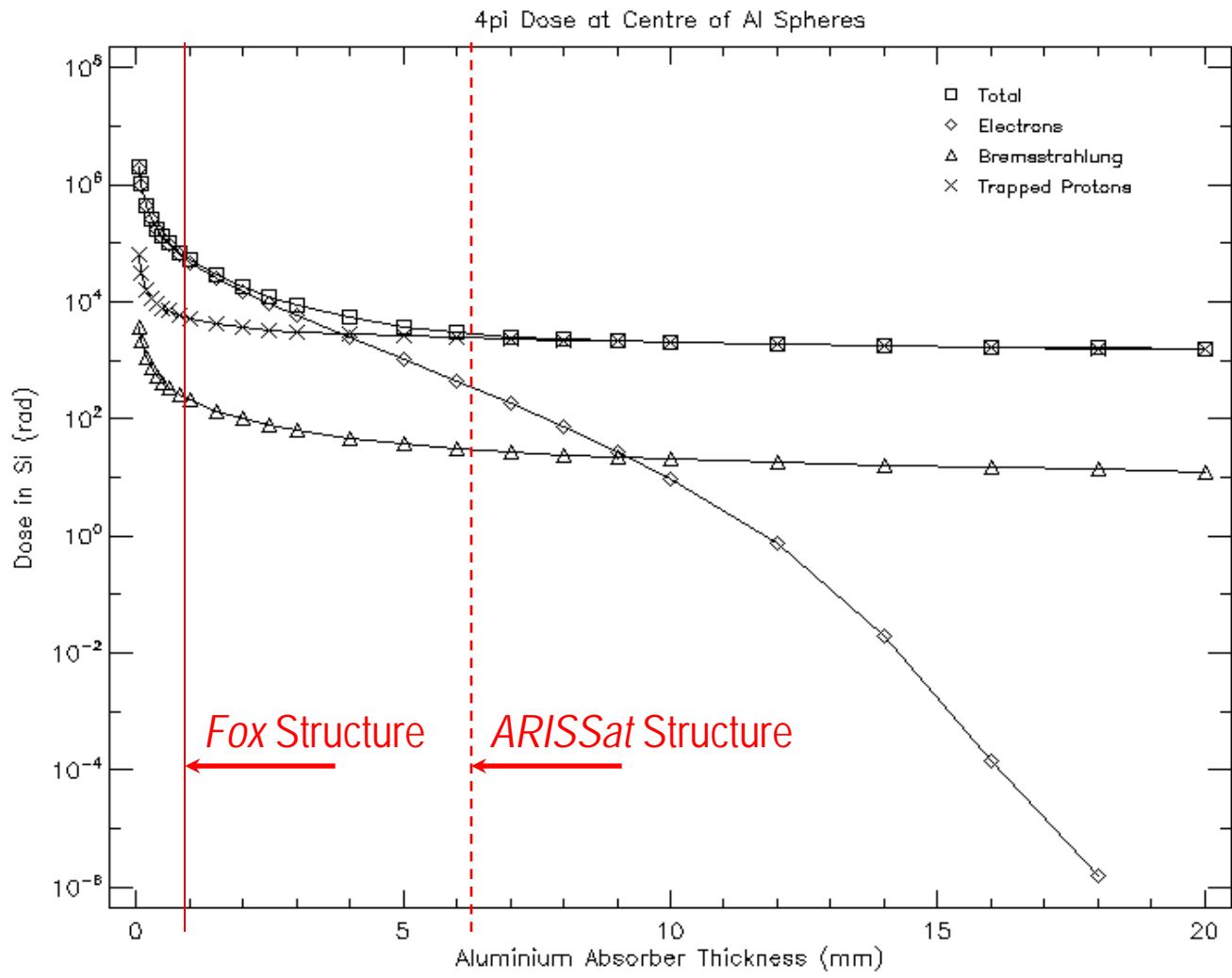
# Example Component Lifetimes



Component	Typical Failure Dose kRAD(Si)	650 km Orbit Years (50% conf)	650 km Orbit Months (98% conf)
INTEL 80386	7.5	1	1
MAX724 DC/DC	20	3	4
2N2222 Transistor	30	4	6
AD574 12-Bit ADC	30	4	6
TI OMAP5912	35	5	8
U310 JFET	50	7	10
Hitachi EEPROM	>100	>14	>24
Rad-Hard component	>100	>14	>24



# Aluminum Shielding Effectiveness





# *Fox-1* Mitigation Strategy



- Component shielding
- CMOS latch-up protection circuitry
- Limited use of Rad-hard/tolerant parts
- CPU failure tolerant (not mission critical)
- Analog hardware transponder





# *Fox-2* Radiation Issues



- SDX requires powerful CPU
- CPU is mission critical
- Need confidence that CPU will survive
- Rad-Hard CPU - very expensive
- CubeSat constraints
  - Power
  - Volume
  - 3 lb weight limit



# *Fox-2* Radiation Strategy



- Rad-tested COTS parts - published papers
- Radiation testing of desirable components
- Rad-tolerant FPGAs
- Radiation tolerance at the circuit card level
  - Redundancy
  - Error Correction
  - Event Recovery



Any Questions?



AMSAT Fox



Thank You

