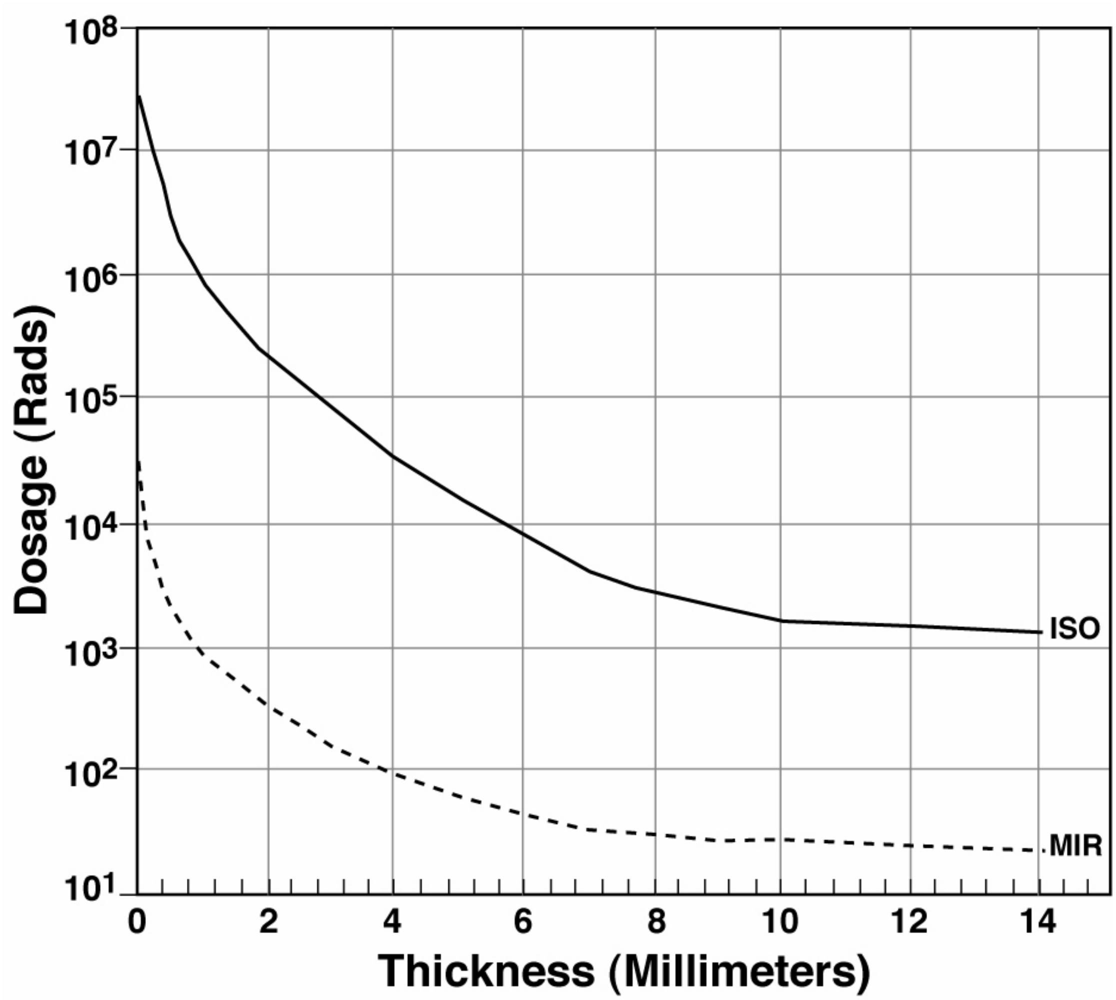
Introduction to Radiation Shielding



Satellites are designed to withstand many forms of radiation in the harsh environment of space. The above graph shows how the total life time radiation dosage inside a spacecraft changes as the amount of aluminum shielding increases. The data comes from the former MIR space station and the research satellite ISO. The sensitive instruments and electronic systems operate inside the satellite shell and are protected from harmful dosages of radiation by the shielding provided by the spacecraft walls.

Problem 1: You want to design a new satellite to replace the ISO satellite and to last 8 years in orbit, but it can only continue to work normally if it accumulates no more that 75,000 Rads of radiation during that time. Using the curve for ISO, how thick do the satellite walls have to be to insure this?

Problem 2: The International Space Station has the same orbit as the MIR. An astronaut will spend about 100 hours in space to assemble the station. If the equivalent shielding of her spacesuit is 1.0 mm of aluminum, how large of a dosage will she receive during this time? How does it compare to the 0.4 Rads she would receive if she stayed on the ground?

Problem 3: A cubical satellite has sides 1 meter across, and the density of the aluminum is 2.7 g/cc. How much mass, in kilograms, will the satellite have with 4 mm-thick walls? 12 mm-thick walls? If the launch cost is $15,000 per kilogram, how much extra will it cost to launch the heavier, and better-shielded, satellite?

Answer Key:

Problem 1: You want to design a new satellite to replace the ISO satellite and to last 8 years in orbit, but it can only continue to work normally if it accumulates no more that 75,000 Rads of radiation during that time. Using the curve for ISO, how thick do the satellite walls have to be to insure this?

Answer: The annual dosage would be 75,000 rads/8 years = 9,375 rads/year. From the ISO curve, this level of radiation would occur with about 5.5 millimeters of aluminum shielding.

Problem 2: The International Space Station has the same orbit as the MIR. An astronaut will spend about 100 hours in space to assemble the station. If the equivalent shielding of her spacesuit is 0.5 mm of aluminum, how large of a dosage will she receive during this time? How does it compare to the 0.4 Rads she would receive if she stayed on the ground?

Answer: The graph shows that for 0.5 millimeters equivalent spacesuit thickness and a MIR orbit, the annual dosage is 800 Rads. But she will only spend 100 hours in space. There are 8760 hours in a year, so her actual dosage would be about 800 Rads/yr x (100 hrs/8760 hrs/yr) = 9.1 Rads. This is about 9.1/0.4 = 23 times the dosage she would get on the ground in one year..or equal to 23 years worth of dosage on the ground.

Problem 3: A cubical satellite has sides 1 meter across, and the density of the aluminum is 2.7 grame per cubic centimeter. How much mass, in kilograms, will the satellite have with 4 mm-thick walls? 12 mm-thick walls? If the launch cost is $15,000 per kilogram, how much extra will it cost to launch the heavier, and better-shielded, satellite?

Answer: A) A cube consists of six sides. Each side has a volume of 1 meter x 1 meter x 4 millimeters, which in centimeters is = 100 x 100 x 0.4 = 4000 cubic centimeters. The density of aluminum is 2.7 grams/cubic centimeter, so the mass of one side of the cube will be 2.7 x 4000 = 10,800 grams or 10.8 kilograms. The entire satellite will have a mass of 6 x 10.8 kilograms or 64.8 kilograms.

B) With 12-millimeter walls, the mass will be 100x100x1.2 x 2.7/1000 = 32.4 kilograms.
C) The extra launch cost would be (32.4 - 10.8)x $15,000/kg = $324,000