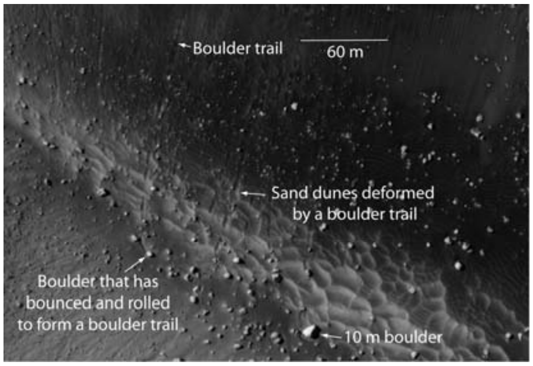

The InSight seismometer (SEIS) will measure vibrations caused by distant meteor impacts and 'marsquakes'. Scientists measure these impacts in three ways: By their energy in Joules, by their frequency in impacts per year, and by their magnitude on a Richter-like 'M' scale.

It is estimated that M=5.6 impacts deliver about 2×10^{17} Joules of energy, and occur about once each year. This amount of impact energy is equal to 48 million tons (48 megatons) of TNT!

The image above was taken by the Mars Reconnaissance Orbiter and shows boulders dislodged by marsquakes near the region known as Cerberus Fossae. Tracks made by the rolling boulders can be easily seen in the sand dunes.

Problem 1 – On Mars, scientists have predicted that there will be 100 events per year with M=3.5, 10 events per year with M=4.5 and 1 event per year with M=5.5. If an M=4.5 quake is 10 times more violent than an M=3.5 quake, write a mathematical formula that gives the impact rate, R, as a function of the quake severity, M.

Problem 2 – An impact with M=5.0 is strong enough that if it occurred closer than 100 km from the InSight seismometer, it would overpower the sensors and not be recorded accurately; a condition called data saturation. How long would scientists have to wait for such an impact to occur? (The radius of Mars is 3,376 km).

Problem 3 – For what magnitude of marsquake, M, would you expect to detect one event within 100km of the InSight seismometer?

Problem 4 – If an M=5.6 delivers 2.0×10^{17} Joules of energy, and M=4.6 delivers 30x less energy, about how many tons of TNT will the earthquake described in Problem 3 deliver?

Problem 1 – On Mars, scientists have predicted that there will be 100 events per year with M=3.5, 10 events per year with M=4.5 and 1 event per year with M=5.5. If an M=4.5 quake is 10 times more violent than an M=3.5 quake, write a mathematical formula that gives the impact rate, R, as a function of the quake severity, M.

Answer: $R(M) = 100 \times 10^{(3.5-M)}$

Problem 2 – An impact with M=5.0 is strong enough that if it occurred closer than 100 km from the InSight seismometer, it would overpower the sensors and not be recorded. How long would scientists have to wait for such an impact to occur? (The radius of Mars is 3,376 km).

Answer: For M=5.5, the rate is once per year over the entire planet. The surface area of Mars is $4 \times 3.141 \times (3376)^2 = 1.4 \times 10^8$ km^2, and the area of the zone near the seismometer is $3.141 \times (100\text{km})^2 = 3.1 \times 10^4$ km^2. The ratio of the areas is about 1/4500, so the rate of impacts inside the InSight zone is 1/4500 per year or an average of 4500 years between impacts.

Problem 3 – For what magnitude of marsquake, M, would you expect to detect one event within 100km of the InSight seismometer?

Answer: The ratio of the martian surface area to the area inside 100km is 1/4500. We need 4500 events per year over all of Mars in order to get 1 event inside our detection zone. From our rate function:

4500 = 100 x 10(3.5-M)

Solving for M we get 45 = 10(3.5-M)
Taking Log10 on both sides we get Log10(45) = 3.5-M
Then 1.6 = 3.5-M
And so M = 3.5-1.6 **M = 1.9**

Problem 4 – If an M=5.6 delivers 2.0×10^{17} Joules of energy, and M=4.6 delivers 30x less energy, about how many tons of TNT will the earthquake described in Problem 3 deliver?

Answer: 2×10^{17} Joules equals 48 megatons, so we use that unit directly.
The difference between M=5.6 and M=1.9 is 3.7. Rounding this to 4.0, we have $30^{4.0}$ = 810,000 times less energy, so 48,000,000/810,000 = 59 tons of TNT.