ISS and received a radiation exposure of up to 110.7 mGy. The authors concluded that, in general, nutrients and pharmaceuticals in the flight samples did not degrade any faster than the ground controls, and that long-term preservation is more challenging than mitigating the effects of radiation exposure. However, there was a reduction in potency of inflight pharmaceuticals that occurred before the labeled expiration date (Du B et al., 2011). Differences in intact vitamin concentrations due to duration of storage were observed for most foodstuffs (Zwart ST et al., 2009). The most striking changes in nutrients were a 50% decrease in folic acid and thiamin in tortillas, and a 15%-20% decrease in folic acid, vitamin K, and vitamin C in broccoli au gratin. Riboflavin, vitamin A and vitamin C decreased by 10% to 35%. In almonds, hexanal increased by 200% indicating lipid peroxidation, which may affect taste. With regard to taste, anecdotal reports from the astronauts suggest the taste of food changes during spaceflight (Lane et al., 2007). However, taste is largely influenced by smell, which can be affected by odors from different environmental and thermal systems in a spacecraft and compounded by body fluid shifts that cause nasal congestion. Scientists have found that the changes in food created by irradiation are minor compared to those created by cooking. The products created by cooking are so significant that consumers can smell and taste them, whereas detection of low concentration of radiolytic products induced by radiation exposure requires extremely sensitive laboratory equipment.

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Table 1. Simulated annual dosimetric quantities inside a Mars transfer vehicle in the interplanetary space from exposure to GCR at deep solar minimum and the resultant cancer risks for a 45-year old astronaut.

	D, mGy/y	*G*, mGy-Eq/y	*H*, mSv/y
Z=1	111.75	167.62	147.06
Z=2	43.58	108.94	173.90
Z=3-9	26.11	65.28	131.75
Z>9	24.66	61.65	432.41
Pion/EM	12.80	15.37	15.37
Total	218.90	418.86	900.49
	Cancer risks with 95% CI		
45-y Male	3.80%[0.93%, 8.92%]		
45-y Female	4.35%[0.88%, 10.02%]		

Table 2. Major components of daily diet allowance for astronauts (AILSS, 1969)

	Daily allowance	Chemical formula	MW
Carbohydrates	364 g	$C_6H_{12}O_6$	180 g/Mol
Fat	82 g	$C_{18}H_{34}O_2$	282 g/Mol
Protein	70 g	$C_{5.35}H_{9.85}O_{2.35}N_{1.25}S_{0.1}$	132.35 g/Mol
Calcium	0.8 g	Ca	40 g/Mol
Ascorbic Acid*	70 mg		
Niacin*	17 mg		
Iron*	10 mg		
Total mass	516.8 g		

*Neglected in the current analysis

Table 3a. Atomic parameters for dried food

	Z	A	Atomic Density, atoms/g	MW, g/Mol	ρ, g/cm^3
Carbon	6	12	2.35×10^{22}	180.6	0.26
Hydrogen	1	1	4.59×10^{22}		
Oxygen	8	16	1.63×10^{22}		
Nitrogen	7	14	7.70×10^{20}		
Sulfur	16	32	6.16×10^{19}		
Calcium	20	40	2.33×10^{19}		

Table 3b. Atomic parameters for frozen food (weight fraction of 49.5%/40.5%/10% for food/water/package)

	Z	A	Atomic Density, atoms/g	MW, g/Mol	ρ, g/cm^3
Carbon	6	12	1.65×10^{22}	30.88	0.414
Hydrogen	1	1	4.03×10^{22}		
Oxygen	8	16	2.23×10^{22}		
Nitrogen	7	14	3.94×10^{20}		
Sulfur	16	32	3.15×10^{19}		
Calcium	20	40	1.19×10^{19}		

Table 4. Input parameters and the mean hits on a small target area of water

Input parameters			Atomic interaction output results			
Ions at 1 GeV/u	*D*, Gy	Target area, μm^2	Fluence, $1/\mu m^2$	*L*, keV/μm	Mean number of hits per 100 μm^2	
					Track core only	With δ-rays (> 1 mGy)
p	0.335	100	9.40	0.22	939.75	1100.22
α	0.131		0.919	0.89	91.87	124.48
^{16}O	0.078		3.42×10^{-2}	14.24	3.42	9.38
^{56}Fe	0.074		3.07×10^{-3}	150.42	0.31	3.01

Table 5. Probability of a molecule being hit (for the calculations the molecule is represented by a sphere)

Ions at 1 GeV/u	*D*, Gy	Material	Mean hit frequency per mole	Mean hit frequency of a molecule
p	0.335	Dried food	9.18×10^{10}	1.52×10^{-13}
		Frozen food	2.10×10^{10}	3.49×10^{-14}
		Water	7.80×10^{9}	1.30×10^{-14}
α	0.131	Dried food	8.97×10^{9}	1.49×10^{-14}
		Frozen food	2.06×10^{9}	3.41×10^{-15}
		Water	7.63×10^{8}	1.27×10^{-15}
^{16}O	0.078	Dried food	3.34×10^{8}	5.55×10^{-16}
		Frozen food	7.65×10^{7}	1.27×10^{-16}
		Water	2.84×10^{7}	4.71×10^{-17}
^{56}Fe	0.074	Dried food	3.00×10^{7}	4.98×10^{-17}
		Frozen food	6.88×10^{6}	1.14×10^{-17}
		Water	2.55×10^{6}	4.24×10^{-18}

Table 6: Radiolytic species produced (nMol/L)

Input parameters				Results				
Ions at 1 GeV/u	*D*, Gy	Fluence, 1/μm^2	*L*, keV/μm	Concentration of molecules (nMol/L)				
				H.	.OH	H_2O_2	H_2	e^-_{aq}
P	0.335	9.40	0.22	33.0	188.1	3.7	10.6	146.7
α	0.131	0.919	0.89	12.1	69.3	1.3	3.9	53.9
^{16}O	0.078	3.42×10^{-2}	14.24	8.1	46.7	0.9	2.6	36.3
^{56}Fe	0.074	3.07×10^{-3}	150.42	7.4	42.3	0.8	2.4	34.5
Total	0.618	-	-	60.6	346.4	6.7	19.5	271.4

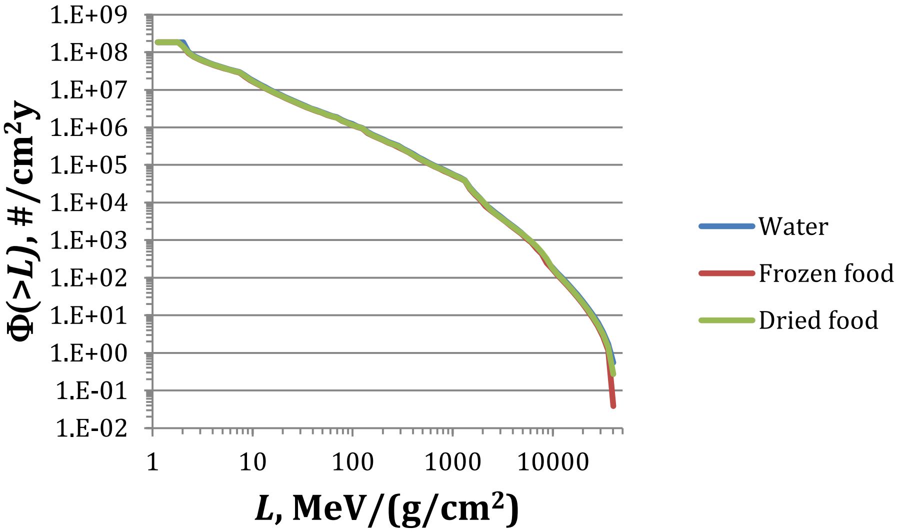

Figure 1a. LET distribution of integral particle fluence inside a Mars transfer vehicle for a 1-y interplanetary space.

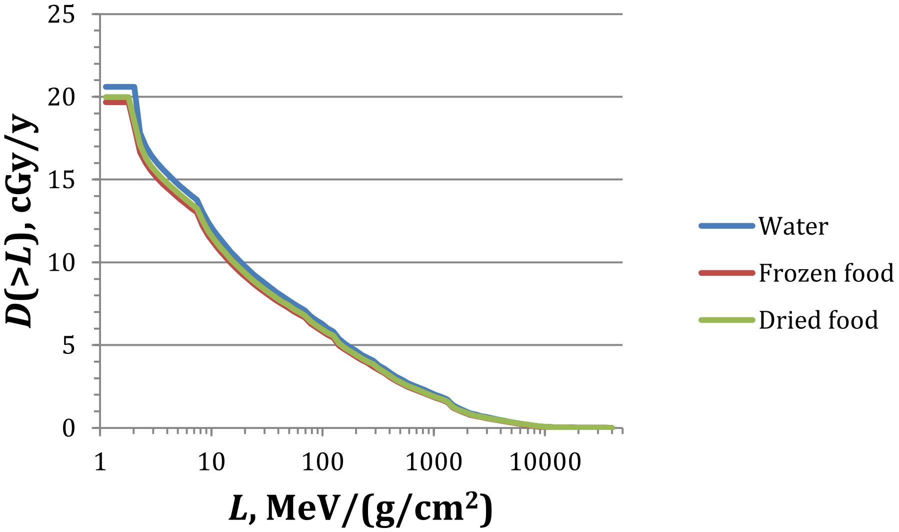

Figure 1b. LET distribution of integral dose inside a Mars transfer vehicle for a 1-y interplanetary space.

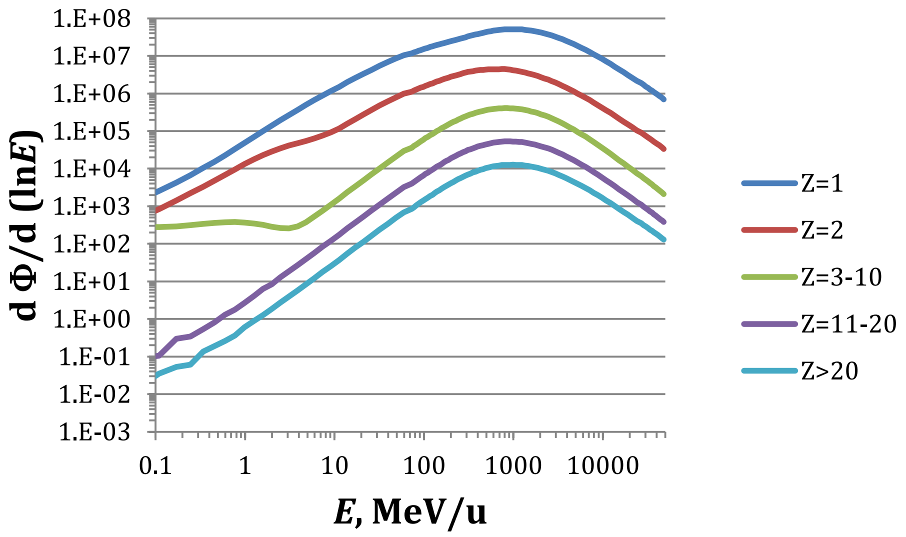

Figure 2a. Differential spectra of annual particle fluence per logarithmic interval of energy per nucleon on water inside a Mars transfer vehicle.

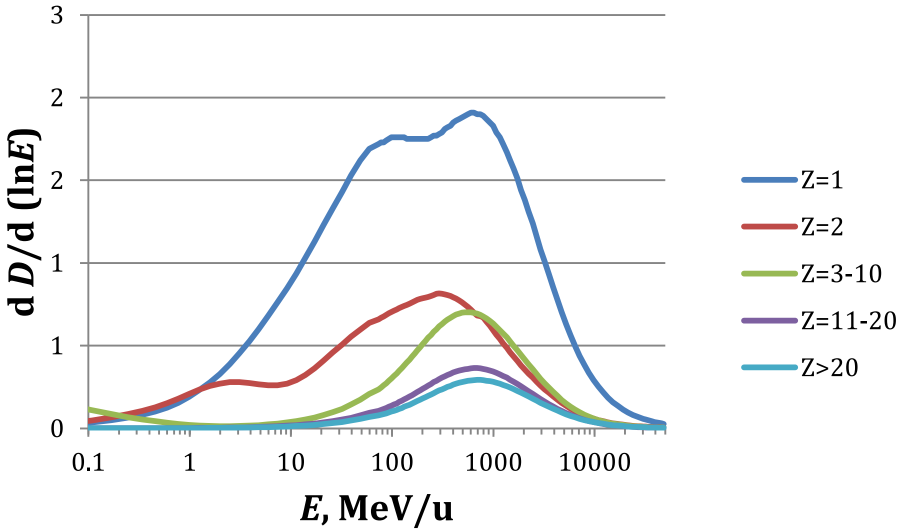

Figure 2b. Differential spectra of annual dose per logarithmic interval of energy per nucleon on water inside a Mars transfer vehicle.

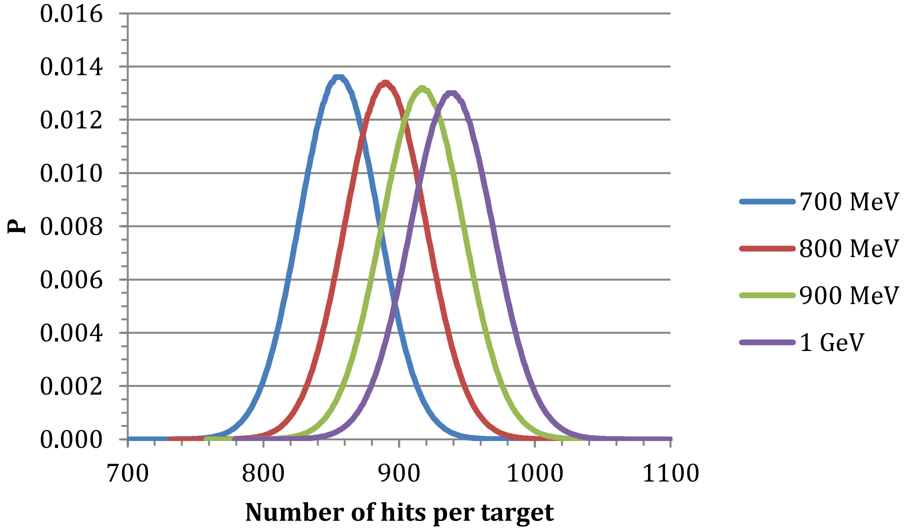

Figure 3. Probability density of number of hits by protons for target area of 100 μm^2 from exposure to 0.335 Gy of protons at various energies

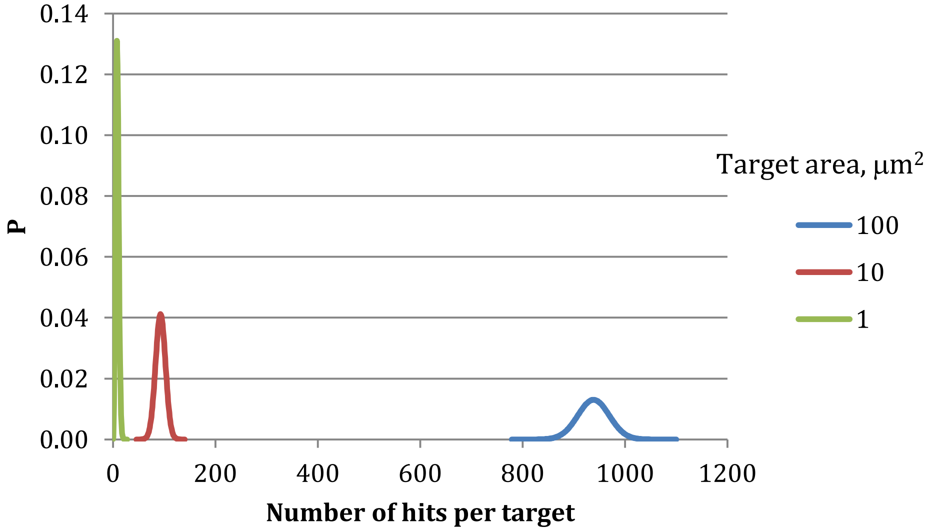

Figure 4. Probability density of number of hits by protons for various target areas from exposure to 0.335 Gy of protons at 1 GeV.