MARS ORBIT DUST EXPERIMENT (MODEX) FOR FUTURE MARS ORBITER. J. P. Pabari[1], P. J. Bhalodi[2] and D. K. Patel[3], [1]Physical Research Laboratory, Navrangpura, Ahmedabad-380009, INDIA. Email: jayesh@prl.res.in, [2]AITS, Rajkot-360005, INDIA, [3]SALITER, Ahmedabad-380060, INDIA.

Introduction: Active dust devils, playing key role in background dust opacity on Mars, were observed with fluxes [1] of greater than 10^{11} particles m^{-2} s^{-1}. Second dust source is ejecta caused by impacts on Moons. Third possible source is by levitation of particles from the Moons, which have velocity larger than the escape velocity. Escaping dust is predicted to form dust rings within orbits of Moons and therefore, also around the Mars. However, no such rings have been detected to the present day [2]. Width and height of the dust torus are ~5 Mars radii [3]. The other contributing particles could be interplanetary and interstellar in nature. A Mars Dust Counter (MDC) on Nozomi [4] has detected ~100 particles, several of interplanetary, during cruise phase. Lee et al. [5] have proposed a PADME mission, having a dust experiment. Andersson et al. [6] have reported observations of dust at altitudes ~150-1000 km by the LPW on MAVEN. A dedicated dust instrument on future Mars orbiter may be helpful to understand the source of high altitude martian dust.

Scientific Objectives of MODEX: To study origin, abundance, distribution and seasonal variation of Martian dust, a Mars Orbit Dust Experiment (MODEX) is proposed for future orbiter to Mars. The secondary objective of the MODEX is to measure the Interplanetary Dust Particles (IDPs) during the cruise phase for understanding the dynamical evolution. The MODEX targets three types of observations, viz., (a) Martian Atmospheric Dust Measurement, (b) Martian Ring/Torus Dust Measurement (and verify the existing hypothesis of dust ring/torus) during initial orbits and (c) IDP Measurement during the cruise phase.

MODEX Detector Design: Whenever a hyper velocity dust particle makes an impact on a metal (gold) target dust detector, impact plasma is generated. The plasma electrons and ions are separated using positively and negatively biased electrode plates, respectively. A neutral channel is also added to differentiate the impact charge from the noise. The charge pulses are processed to arrive at velocity and mass of the particles. A snapshot of the detector box is shown in Figure 1 while the preliminary design of MODEX is shown in Figure 2. To derive the velocity and mass of impacting dust particles, Igenbergs et al. [4] have used the rise time (t) and maximum charge (Q) of impact pulse for the MDC

$$t = c_g \, v^{\eta} \quad (1)$$

and

$$\pm \, Q/m = c_r \, v^{\beta} \quad (2)$$

respevtively. In the above, c_g, c_r, η and β are constants to be determined by calibration experiments [7].

Another scientific interest is the number density n, which is proportional to the impact rate $\Delta N/\Delta t$ recorded by the dust instrument, and the relation between both quantities is given by Kruger et al. [8]

$$n = \frac{\Delta N}{\Delta t} \frac{1}{v \, A_s\,(\psi)} \quad (3)$$

where $A_s\,(\psi)$ is the sensor area (function of angle ψ with respect to spacecraft spin axis) and v is the grain impact speed. Initial specified mass and size of the MODEX under development are ~1.5 kg and ~ 150 mm × 150 mm × 200 mm, respectively.

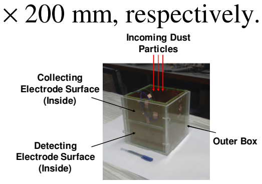

Figure 1: Snapshot of a prototype detector

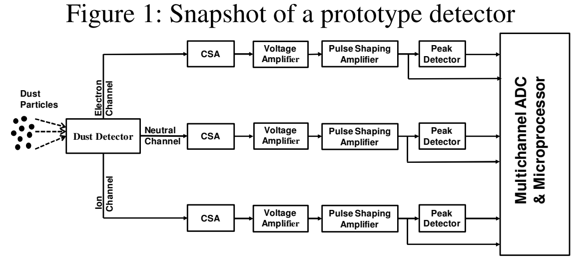

Figure 2: Preliminary design of MODEX

Estimation of Parameters: Due to continuous bombardment of micrometeorites on Moons of Mars, the secondary ejecta comes out and may escape. Particles with velocity between escape velocity and orbital speed can form dust belt around the Mars. Such particles have their own inclination (orbit angle with respect to the reference plane) and eccentricity (measure of orbit shape deviation from the circular one) in the orbit [9]. The random velocity (v_{ra}) of dust particles in the belt is given by Safronov [10] as

$$v_{ra} = (a\,n) \sqrt{\left(\frac{5}{8}\right) \bar{e}^2 + \bar{\imath}^2} \quad (4)$$

where $\bar{\imath}$ is the mean inclination, $\bar{e}$ is the mean eccentricity and (a n) is orbital velocity of the Mars. The orbital velocity of the Mars is known to be 24 km/s [11]. The particle inclination is 3° to 28°, while the eccentricity is 0 to 0.6 for particles ejected from both, the Phobos and Deimos [9], with the particle mass from 10^{-7} to 10^{-11} kg (equivalent to size ~10 µm to 200 µm). We have computed the particle velocity using Eq. (4) and results are shown in Figure 3, which show that expected velocity of the particles around the Mars may be up to 20 km/s.

Moreover, impact rate of the particles is 0.001 to 0.01 Hits per second for spacecraft altitude from ~150 km to 1000 km [6]. Using the computed velocity and Eq. (3), we have estimated the number density whose results are shown in Figure 4. The MAVEN has a cube shaped primary structure of 2.3 m × 2.3 m × 2 m high [12], which is considered for the computation of density. Results in Figure 4 shows that the expected dust number density is ~10^{-3} to 10^{-6} #/m^3.

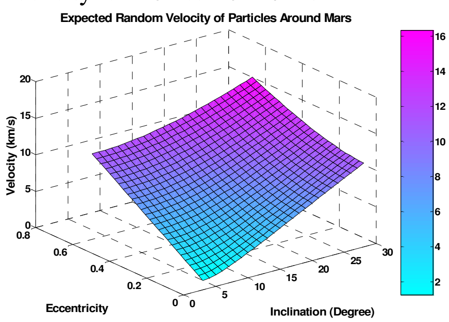

Figure 3: Expected particle velocity around the Mars

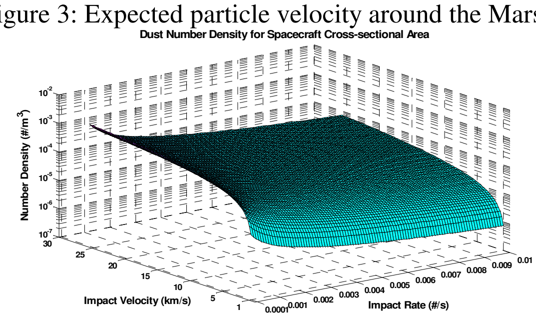

Figure 4: Expected countable number density by MAVEN size detector

In addition, lifetime of dust from the Moons have been simulated using the particle velocity and volume of dust toroid (V), from the equation [9]

$$\tau_s = \frac{8\, v_{ra}\, V}{5\,\pi\, R_s^{\,2}\, (v_{ra}^{\,2} + v_e^{\,2})} \qquad (5)$$

where R_s is satellite radius and v_e is satellite escape velocity. The volume for Phobos case is 4.3×10^{19} m^3 to 1.2×10^{20} m^3 while volume for Deimos case is 1×10^{20} m^3 to 1.2×10^{22} m^3 [9] for particles with mass 10^{-7} kg to 10^{-11} kg. The results are depicted in Figure 5 and Figure 6 which show that the dust lifetime is a few Earth years for the particles from Phobos and a few thousand Earth years for the particles from Deimos. All estimated paramters in this work are summarized in Table 1.

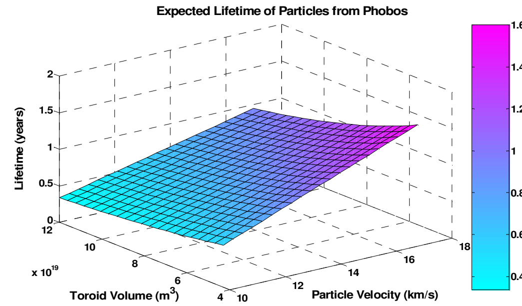

Figure 5: Lifetime of particles coming from Phobos

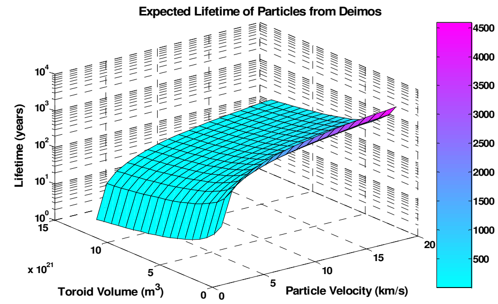

Figure 6: Lifetime of particles coming from Deimos

Table 1: Summary of estimated parameters

Parameter	Value
Size	10 to 200 µm
Mass	10^{-7} to 10^{-11} kg
Random Velocity of Particle	1 to 17 km/s
Particle Number Density	10^{-3} to 10^{-6} #/m^3
Lifetime of Dust Particle	0.4 to 4500 years

Summary and Implications: A MODEX is proposed for future Mars orbiter to measure the Martian dust. Modelling results show existence of dust around the Mars at orbital altitudes, which is consistent with the results from MAVEN. The study of planetary dust can enhance understanding about a planetary system and dust production functions. The atmospheric chemistry may be affected due to presence of dust.

References: [1] Metzger S. M. et al. (1999) GRL, 26, 2781-2784. [2] Oberst et al. (2014) PSS, 102, 1. [3] Krivov A. V. and Hamilton D. P. (1997) Icarus, 128, 335-353. [4] Igenbergs E. et al. (1998) EPS, 50, 241-245. [5] Lee P. et al. (2014) 45th LPSC, 2288. [6] Andersson et al. (2015) Science, 350, aad0398-1-3. [7] Igenbergs E. et al. (1996) 20th ISSTS, 1222-1229. [8] Kruger H. et al. (2009) Icarus, 203, 198-213. [9] Ishimoto H. (1996) Icarus, 122, 153-165. [10] Safronov V. S. (1969) Nauka Press, Moscow. [11] Online (2016), http://nssdc.gsfc.nasa.gov/. [12] Online (2016), http://www.nasa.gov/.