**RUSSIAN "FOBOS-GRUNT" MISSION. EXAMPLES OF SURFACE ROUGHNESS MODELS FOR PHOBOS.** E. V. Zabalueva[1], T. V. Shingareva[1], A. T. Basilevsky[1], V. P. Fedotov[2], E. G. Ruzskiy[2], [1]Vernadsky Institute, RAS (119991, Moscow, Kosygin Street, 19, Russian Federation, shingareva@geokhi.ru), [2]Lavochkin Association (141400, Khimki, Moscow province, Leningrad Highway, 24 Russian Federation, fedotov@laspace.ru)

**Introduction:** Models of surface roughness for Phobos in the areas of landing sites and along the spacecraft descent-and-approach paths have been worked out as a part of scientific support of the Russian sample return Fobos-Grunt mission [1]. As a basis for this work we used global numerical shape model of Phobos received as DAT file from Professor Peter Thomas, Cornell University, Itaca, USA. P. Thomas with coauthors have worked out the NSM in early 90's based on the Viking mission data [2]. This model designated as model **G** considered only those Phobos landforms (in particular, craters) whose diameters were larger than 2°×2°, that depending on latitude and longitude of the place correspond to 320 to 450 m. Planning of the spacecraft landing demands more detailed data on characteristics of the surface roughness in the landing area. So we have worked out models of surface roughness for Phobos of three detail levels based on direct and indirect data on the Phobos surface as well as on planetary analogies.

*The first detail level* of the surface roughness model (level **D1**) represents introducing into model **G** a real relief of craters with diameters 30–90 to 400 m and larger observed on the Viking Orbiter images and maps from the Atlas of Philip Stooke [3]. In the first area of landing and along the descent-and-approach paths between 10°N to 40°S and 10° to 260°W we have identified 943 craters. Diameter of the smallest identified crater is $d_{min}$= 0.4°, that is ~90 m, while diameter of the largest crater $d_{max}$= 14.6°, that is ~3200 m. In the second area of landing between 20°N to 20°S and 160° to 255°W we have identified 1634 craters. Diameter of the smallest identified crater is $d_{min}$= 0.14°, that is ~30 m, while diameter of the largest crater $d_{max}$= 7.7°, that is ~1540 m.

Depending on their preservation degree craters have been separated into three morphological classes: A, B, and C. Key morphometric parameter of these classes is depth/diameter ratio (D/H), which varies from 0.2 to 0.08. In addition to diameters and morphologic classes, phobosographic coordinates φ (latitude) and λ (longitude) of the crater centers have been determined. From the diameter values and depending on the distances from the crater centers the depths in various parts of the crater' interiors have been calculated. In these calculations we assumed that craters have no elevated rims and that the crater interior form is a spherical segment. Crosssection of the spherical segment was given as:

$$y(x)=r\ \{1/4k - k - \sqrt{(k+1/4k)^2 - (x/r)^2}\},$$

where $y(x)$ is the depth at the distance $x$ from the crater center, and $H/D=k$.

Working on **D1** detail model at first we have made linear interpolation of model **G** radius-vector values from knots of the grid 2°×2° into knots of more detail 0.1°×0.1° grid. Then mentioned above calculated values from crater profiles were put into the 0.1°×0.1° knot points. So the radius-vector in each knot of the 0.1°×0.1° grid is the sum of interpolated **G** model radius-vector and the increment Δρ1 from **D1** model.

*The second detail level* of the surface roughness model (level **D2**) was built by adding the 2°×2° tiles of the type relief-analog formed by the craters with diameters 20 to 50 m to the model **G** (together with previously added **D1** level). For the preparation of the type-relief tiles there was analyzed the high-resolution (1.5 m/px) Mars Global Surveyor image 55103. The craters with diameters 5–20 m could also be identified on this image, but they, as a rule, fall through the cells of the 0.1°×0.1° grid except the cases when they are located on the cell boundaries. The area of Phobos shown in this image is to the northeast of crater Stickney and is not a place of any considered Fobos-Grunt landing areas. But general morphology of this well imaged area is visually rather similar to that in the landing areas. So we used the data, which we acquired in the study of this area, as analogous characteristics for the surface roughness in the landing sites.

We have selected the 5°×5° subarea, which included characteristic landforms of the more detail relief: small craters, rock fragments, knobs. The subarea is located between 15° to 20°N and 10° to 15°W. Here there were identified 279 craters, rock fragments and knobs. Diameter of the smallest identified crater is $d_{min}$= 0.018°, that is ~4 m, while diameter of the largest crater $d_{max}$= 1.538°, that is ~340 m. Diameter of the smallest identified rock fragment is also $d_{min}$= 0.018°, that is ~4 m, while diameter of the largest rock fragment $d_{max}$= 0.098°, that is ~20 m. Within this subarea we have selected the 2°×2° fragment (15–17°N, 13–15°W) with most typical relief which was in turn selected as the tile for the model **D2**.

As the landing planning requires the surface roughness characteristics with linear sizes from 1–2 to 20–30 m (this is the *third detail level* – model **D3**), and the available data of real measurements on Phobos images do not cover this size range we have suggested for working out the **D3** model a version of the analog relief. We used as analogs characteristics of the relief the well-studied lunar surface. We did not use asteroid Eros as analog of surface roughness, although there are available images of this asteroid with centimeter-scale resolution, because lunar surface is almost as old as the Phobos surface [4] while surface of Eros is very young and this makes drastic differences in a number of surface characteristics. Besides, very peculiar characteristics of Eros surface are considered to be due to shake by a recent meteorite impact, which formed rather large new crater and destroyed part of preexisting small craters [5].

On the Moon as on Phobos in the considered size range the dominating landforms are craters. Many authors from representative studies had determined areal density of impact craters on the Moon, that is number of craters normalized per unit of surface area. So for building tiles of the analog relief for the **D3** model of Phobos surface roughness we used the cumulative size-frequency *N(D)* function [6, 7]: $N=10^{10.9}D^{-2}$, where $N$ – is cumulative number of craters with the diameter larger than $D$ (in meters) normalized to the area $10^6$ km$^2$. For Phobos the normalization area was reduced to 1 km$^2$, that changed the formula to $N=10^{4.9}D^{-2}$.

The range of crater diameters used for the model **D3** was 2 to 16 m. Using the above formula we have calculated the number of craters in each size interval for the area $2^o \times 2^o$ = 0.16 km$^2$. Then we built the model distribution of craters on the surface putting centers of craters to the coordinates determined with the generator of random numbers with distribution on the leg [0, 1]. To determine slopes, which are present in this crater distribution, we used data on percentages of craters belonging to classes A, B, and C characteristic for small craters in lunar maria [6]. We have slightly changed the percentages increasing role of the most dangerous for landing craters of class A. As a result the percentages we used was: A –7.5%, B – 7.5%, and C – 85%.

Figure 1 shows distribution of craters of different classes and sizes along the model area. Within this area were selected ten the $0.1^o \times 0.1^o$ subareas. They are different in relation to the danger for landing: ranging from those containing relatively large and steep-sloped craters of class A to those containing relatively small and gentle sloping craters of class C. For each of these subareas have been calculated elevations in the knot points with the $0.005^o$ steps along the latitude and longitude depending on distances of the knot points from centers of the nearest craters.

The data for model **D1** are given for the corresponding $2^o \times 2^o$ surface areas in the form of tables of radius-vector values in the knot points $0.1^o \times 0.1^o$ of the Phobos surface in kilometers, as a function of relative phobosographic coordinates (in degrees) along latitude $\varphi$ and longitude $\lambda$.

Radius-vector of the surface point in the model **D2** is determined by the sum of three terms: interpolated radius-vector from model **G**, increment of radius-vector from the **D1** model $\Delta\rho 1$, interpolated in the knot point in relation to reference ellipsoid, and increment of radius-vector from the **D2** model $\Delta\rho 2$.

Data for the **D3** model are given in the form of radius-vector increments tables in the knot points of $0.005^o \times 0.005^o$ grid of Phobos surface in kilometers as a function of relative coordinates (in degrees) along the latitude and longitude for each $0.1^o \times 0.1^o$ element of the **D2** model. So the received matrix of values of radius-vectors was member-by-member summed with the matrix of the model relief, determined with the 0.005° steps that is with the same resolution as the matrix of interpolated relief within the 0.1°×0.1° tile.

The resulted digital model of Phobos surface with variants of the type analog relief was synthesized by superposition of models **D2** and **D3** on the global model **G** refined at the expense of model **D1**.

**References:** [1] Marov M. Ya. et al. (2004) *Adv. Space Res., 33*, 2276–2280. [2] Simonelli D. P. et al. (1993) *Icarus, 103*, 49–61. [3] Stooke P. J. (2001) *Small Worlds Atlas,* CD-ROM. [4] Thomas P. and Veverka J. (1980) *Icarus, 41*, 365–380. [5] Thomas P. C. and Robinson M. S. (2005) *Nature Letters, 436*, 366–369. [6] Florensky K.P. et al. (1972) *Space Research XII. Akademie-Verlag, Berlin*, 107–121. [7] Quaide W. L. and Oberbeck V. R. (1969) *Earth Sci. Revs., 5,* No 4.

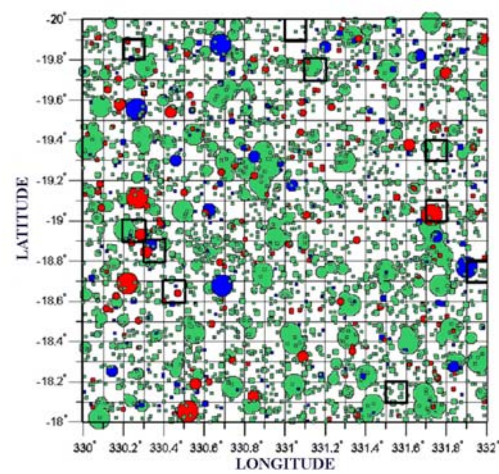


***Fig. 1.*** *The map of model distribution of craters of different classes within the 2×2$^o$ model area. Red shows crater of class A, blue – class B, and green – class C. Black outlined boxes show ten small areas with the type relief* ***D3****.*