APPENDIX I
Derivation and Calculation of the Hellas Crater Energy of Impact

The energy required to form a crater with a given diameter on Mars is less than the energy required to form the same crater on Earth, due the lower gravitational field on Mars [8]. The relationship between crater diameter and the gravity field for various impact energies has been determined from laboratory experiments to be:

$$\frac{E}{E_e} = \left(\frac{g}{g_e}\right)^{\frac{1}{8}} \qquad (1)$$

where E is the energy required to form a crater in a gravitational field, g, that has the same diameter as a crater that was created in the reference gravitational field, g_e, with an energy of E_e [8].

Therefore, in order to calculate the energy of impact for the Hellas basin on Mars, we first calculate the energy required to produce the same basin on Earth, and then scale this energy for the Mars gravitational field, based on Equation-1.

The energy of impact required to create a 2,300 km diameter Hellas-size crater on Earth can be calculated using the Schmidt-Holsapple crater scaling equation [9]:

$$E(D) = \left(\frac{0.84 \cdot D \cdot 1000}{1.8 \cdot \rho_t^{-0.33} \cdot g^{-0.22}} \cdot \frac{1}{\rho_p^{0.11} \cdot L_p^{\ 0.13}}\right)^{4.54} \qquad (2)$$

where:
E = Kinetic Energy of impact
D = Diameter of Crater (m)
Lp = Diameter of Projectile (m)
ρ_t = Earth Surface Density = 3000 kg/m^3
ρ_p = Projectile Density = 5980 kg/m^3 [10]
g = Earth Gravity = 9.807 m/sec^2

The diameter of the projectile (*Lp)* can be estimated using published data for crater diameters and impact diameters for Earth impacts at 17.8 km/sec [11], from which the following equation has been derived by curve-fitting the tabulated data:

$$L_p(d) = 4.5x10^{-5} \cdot d^2 + 0.0539 \cdot d - 0.077 \qquad (3)$$

where:
d = Diameter of crater (km)
$L_p(d)$ = Diameter of Projectile (km) as a function of crater diameter

Using equation-3 and d = 2300 km (Hellas Basin diameter) the diameter of the projectile (*Lp)* is calculated to be 227 km. This is the required projectile diameter for a basin the size of Hellas to be produced *on Earth*.

Therefore, using Equation-2 and a projectile diameter of 227 km, the energy of impact required to produce a Hellas-size Basin *on Earth* is calculated to be 6.02x10^{26} Joules.

The energy required to produce the Hellas Basin on Mars can now be calculated, using the gravity-scaling equation, Equation-1.

$$\frac{E_M}{6.02x10^{26} \cdot J} = \left(\frac{3.72 \cdot \frac{m}{s^2}}{9.807 \frac{m}{s^2}} \right)^{\frac{1}{8}} \qquad (4)$$

therefore, the energy required to produce the Hellas Basin on mars = E_M = 5.33x10^{26} Joules.