surface for almost two Mars years now. Spirit has found that the Gusev Crater does not contain sedimentary deposits from Ma'adim Valles as initially believed, but rather that basaltic materials cover the crater floor [51] and the Columbia Hill outcrops exhibit a variety of interesting water-related alteration minerals [53]. Opportunity has confirmed the orbital-based detection of coarse-grained gray hematite at Terra Meridiani [52], and it has explored the depths of several small to medium-sized craters, allowing extensive stratigraphic analyses of the sediments [20], [52]. The instrumentation on both rovers has allowed truly spectacular mineralogical studies to be completed and the geological understanding of two sites on Mars to be markedly improved, thus giving ground truth for several orbital missions' studies of the martian atmosphere, surface, and subsurface (see, e.g., [5], [10], [46], and [47]).

These two rovers have blazed trails for future ground-based missions as well. The experience gained from these missions, both from an engineering perspective and from a scientific perspective, will offer (or has offered) greater probabilities of success for the Phoenix Lander 2007, for the upcoming Mars Science Laboratory (MSL) 2009, and for Exomars 2013.[1] However, from a geological and mineralogical perspective, the impact of the current and past orbital missions may do more to assist the upcoming landed missions than the spatially limited observations from either Spirit or Opportunity. From the bird's-eye perspective, orbital scientific instruments, such as HiRISE, HRSC, MGS-TES, THEMIS, MOLA, MOC, PFS, GRS, MARSIS, SHARAD, OMEGA, and CRISM, have the capability to characterize and evaluate future landing sites. These orbital instruments have global mapping capabilities of sufficient resolution to have been critical in the selection of a safe and scientifically interesting landing site for the ice-prospecting operations of the Phoenix Lander 2007 [49]. Similar geomorphic and mineralogical studies of data acquired with instrumentation in Mars orbit are currently providing a wealth of interesting landing site options for the MSL 2009.

The CRISM imaging spectrometer has been acquiring data from its platform on the Mars Reconnaissance Orbiter (MRO) since September 2006 [31]–[33]. The data consist of as follows: 1) hyperspectral targeted observations with high spatial resolution ($\sim$18 m/pixel) and 544 spectral channels, and 2) multispectral mapping strips with lower spatial resolution ($\sim$200 m/pixel) and 72 spectral channels. The spectral coverage for both modes of observation is 0.362–3.920 μm. The data from both observing modes have been extremely valuable to the Mars exploration community in the selection of landing sites for the MSL [17], [44], particularly due to the capability of CRISM to identify minerals (i.e., phyllosilicates, sulfates, etc.) on the surface of Mars. The high spatial resolution of CRISM is particularly useful for the landing site evaluation. It should be stressed, however, that CRISM has other capabilities besides landing site selection, including the comprehensive spectral targeting and mapping of the entire planet in the near-infrared at significantly higher spatial resolution than before. This high spatial resolution in the near-infrared will allow for the detection of phyllosilicates, sulfates, and other minerals which contain H_2O,[2] among other minerals.

In order to quantitatively understand the data from any instrument, investigators need to account for variable observing conditions [1], [2], [19], [26], [37], [38], [41]. From Mars orbit, an instrument that acquires data at visible and near-infrared wavelengths encounters variable photometric angles (solar incidence angle and viewing angle), atmospheric conditions (surface pressure and dust and ice aerosol optical depths), and thermal conditions (surface temperature and surface slope). In this paper, we will describe the photometric, atmospheric, and thermal correction system, as first discussed by McGuire *et al.* [30], that is being used for converting the calibrated CRISM multispectral mapping I/F data [27], [31]–[33] to a true representation of the surface reflectance spectra. This basic pipeline may provide a useful recipe for similar correction pipelines for visible-to-infrared instrumentation that observes Mars, either from a rover, from Mars orbit, or from the Earth/Moon system. Furthermore, the visible-infrared instruments are common to many missions, and this pipeline could be generalized to other solar system targets. After accounting for variable observing conditions, mapping and data mining of both the atmosphere and surface of Mars (e.g., [4], [5], [7], [10], [11], [27], [36], [42], [46], and [47]) can begin in earnest, without concern for the distorting effects of changing surface geometries and atmosphere.[3] With proper correction, we can overlay or mosaic CRISM mapping image strips from different orbits at different times of the martian year of nearby locations, and the resulting digital map will have much reduced discontinuities between the different image strips. Such an endeavor will enhance our ability to accurately map [27] the surface properties of Mars and allow a more robust evaluation of future landing sites.

The I/F data from CRISM consist of the measured radiance-on-sensor I divided by the solar radiance F which is the solar irradiance (J) per steradian: $(F = J/\pi)$. The I/F data from CRISM are measured simultaneously for up to 544 different wavelengths from 0.362 to 3.92 μm, giving a spectrum in the visible to near-infrared which allows studies of both the minerals in the surface and the constituents in the martian atmosphere [31]–[33]. After the photometric, atmospheric, and thermal correction of CRISM multispectral I/F data, the resulting A_L data are the incidence-angle-corrected reflectance called "Lambertian albedo."[4] The retrieval of spectra of Lambert albedos allows the following: 1) the estimation of mineralogical

[1]According to recent press reports in October 2008 (i.e., http://news.yahoo.com/s/space/20081017/sc_space/europetodelaymarsrovermission), "European Space Agency (ESA) governments have tentatively agreed to delay the launch of the Exomars rover to 2016, as part of a broader effort to rein in project costs and seek deeper cooperation with NASA and the Russian space agency."

[2]H_2O ice has strong absorptions at 1.5 and 2.0 μm. When the mineral is not ice but, instead, contains H_2O either in a chemically bound or physically bound form (i.e., hydrated phyllosilicates and sulfates), then these absorptions at 1.5 and 2.0 μm are modulated and shifted to different wavelengths in the near infrared.

[3]The variable atmospheric conditions, which are corrected in this paper, include varying atmospheric CO_2 pressure and varying dust and ice aerosol optical depths. By correcting these major effects of the atmosphere, we can more readily assess more subtle atmospheric components of water vapor, carbon monoxide, oxygen/ozone, etc.

[4]Hereafter, we will often use the term "Lambert albedo" instead of "Lambertian albedo," for short.