

Aerial Imaging System Design Considerations

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When exploring a new planetary surface *in situ*, one challenge is to quickly survey and select the sites of interest. Coverage of a large area is warranted, and close up imaging ($\sim 5 - 10$ cm resolution) is desired. This essential mid-range, 50 – 1000-m altitude perspective is required to obtain details of surface features/topography, particularly to identify hazards and slopes for a successful mission. For a planet with an atmosphere, such as Mars, flyers carrying miniature cameras can provide this larger-scale visibility at the required spatial resolution within the context of orbiter and/or descent imaging. A telecomm relay link of sufficient bandwidth to support high-quality imaging is facilitated if the communication range is kept small (<10 km) and the relay base is always available.

The design of such a miniature aerial camera is driven by the spatial resolution and areal coverage requirements as well as by the flight characteristics of the aircraft. Payload mass limitations will restrict the size of the optics used, which constrains the spatial resolution that can be achieved. Modern miniaturized detector heads use less than one Watt of power and have masses on the order of 250 gm or less potentially leaving the optics as the major mass component of such an aerial camera. Optics masses larger than ~ 2 kg are probably not feasible to fly. Optics speeds of $f/8$ or faster are needed to provide diffraction-limited imaging performance with the typical $10\text{-}\mu\text{m}$ pixel dimensions of modern solid-state detectors. The optics focal length is determined by the spatial resolution desired and the flying altitude of the aircraft.

Keeping image smear to <1 pixel is necessary to yield good quality imagery. Without using complex active pointing systems or special time-delay-integration (TDI) scene tracking on the detector, exposure times will be limited so as to freeze the relative motion between the aircraft and the ground. Spectral filter bandpasses must be broad enough and exposure times must be long enough to provide adequate image signal-to-noise ratios (50 or better) but short enough to keep smear to less than one pixel given the aircraft's ground speed. Figures 1 and 2 present some of the parameter trades that need to be considered in designing such an aerial imaging system for use at Mars. Slow aircraft relative ground speeds and low flight altitudes make achieving a given ground pixel scale possible with smaller optical systems. For a representative 5-cm ground pixel scale, unsmearred clear-filter imaging of Mars with an $f/8$ optic requires a ground speed slower than about 100 m/s. Faster ground speeds would require larger optical systems. For a typical flight altitude of 500 m, the required optics would have a mass of about 0.2 kg. This design supports imaging only through a broadband clear filter. Narrower spectral filters would require faster, more massive (by roughly a factor of 8) optics. Use of a detector with TDI capability could allow use of a smaller optic but requires achieving a very stable, well-known flight path and aircraft attitude.

Imaging data rates are typically high and are driven by the aircraft ground speed and the desired ground pixel scale. Imagery from a 1024-pixel-wide detector encoded to 12 bits will generate data at a rate of 12000 bits/s times the number of ground-pixel scales traveled per second by the aircraft. For our representative case of a 5-cm ground pixel scale and a flight speed of 100 m/s, the output data rate for contiguous imaging along a strip would be about 24 Mbps.

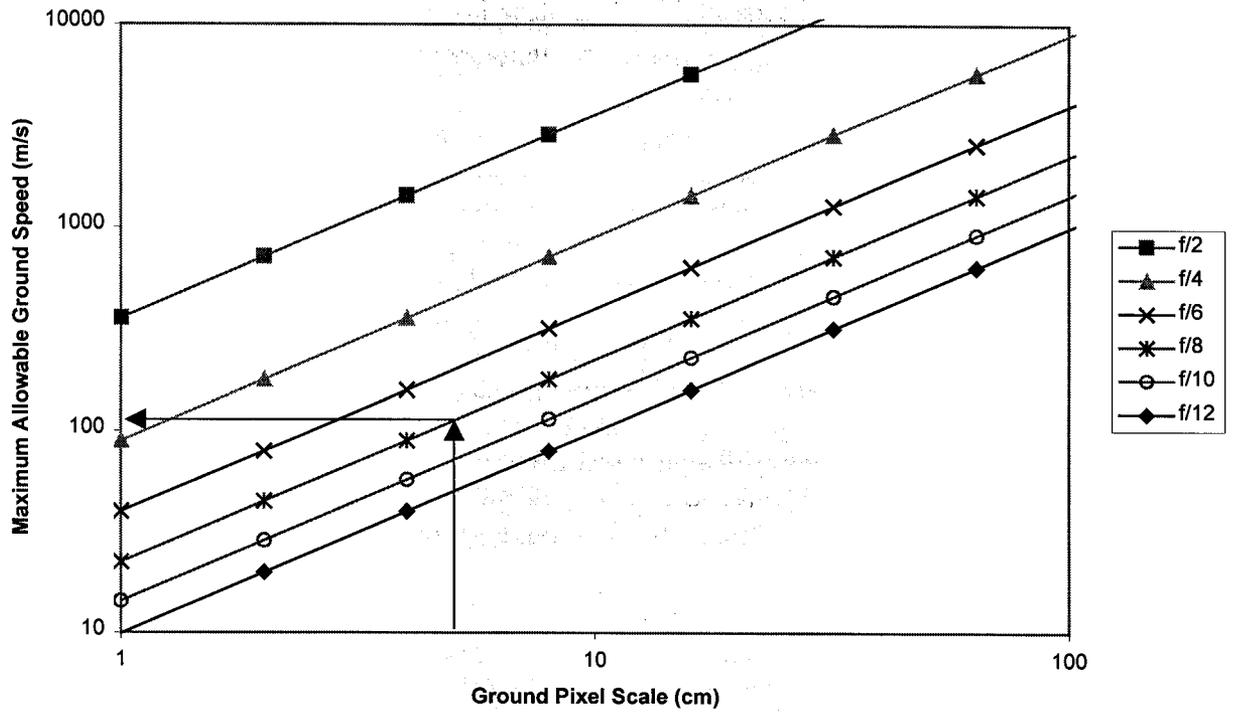


Figure 1: Maximum Allowable Ground Speed for Unsmearred Aerial Clear-filter Imaging of Mars at SNR = 50 for Various Optics Speeds

Altitude x
Ground Speed

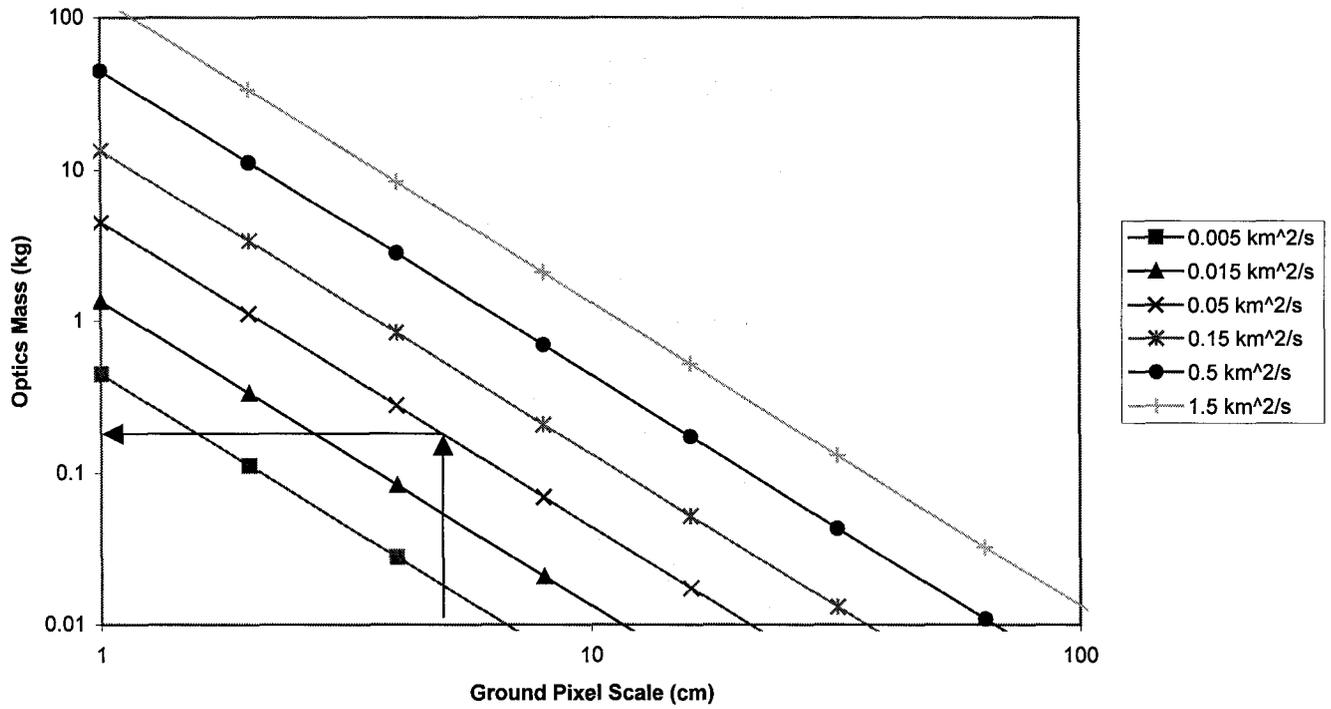


Figure 2: Approximate Optics Mass for Unsmearred Mars Clear-filter Aerial Imaging at SNR = 50

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