Introduction: The future human exploration and habitation of the Moon may significantly impact the density, structure and chemical composition of the Moon’s atmosphere resulting in the first case of the inadvertent terraforming of another world. In order to accurately assess the impact of human exploration and habitation, we must begin to quantify the state of the Moon’s atmosphere prior to human presence and then continue to monitor the atmosphere on a routine basis as human exploration and habitation progress. The monitoring of the Moon’s atmosphere should begin as soon as possible, as early as the first robotic missions and continue with human landings.

The Moon’s Atmosphere: The total mass of the very thin atmosphere of the Moon is about $10^7$ g (about 100 tons) and the natural rate of supply of gases to the atmosphere is on the order of $10$ g s$^{-1}$ [1]. Due to its very low mass, the atmosphere of the Moon is very susceptible to impact by activities associated with human presence and exploration. Each Apollo landing mission deposited rocket exhaust and spacecraft effluents totaling about 0.2 lunar atmosphere masses [2,3].

The lunar atmosphere is optically thin to both incoming solar photons and charged particles, and hence, the atmospheric escape time is very short [1]. However, it has been shown [2,3] that as the number density of the lunar atmosphere increases, the exobase eventually rises above the surface and shields the atmosphere beneath it from escape. As the density of the atmosphere increases as a result of human activities, the dominant atmospheric loss process changes from photoionization loss to thermal escape loss accompanied by a significant increase in characteristic escape time [1]. For a gaseous injection rates of $6 \times 10^4$ g s$^{-1}$, corresponding to a total atmospheric mass greater than about $10^{11}$ g, or roughly $10^4$ the present lunar atmospheric mass, the atmospheric escape time increases from tens of days to hundreds of years [2,3].

The very tenuous atmosphere of the Moon is naturally produced by several different processes, including photon and charged particle sputtering, meteoric impact, solar wind surface impact and release from the surface and outgassing of species, such as water vapor and several radiogenic decay products from the regolith and interior [1].

Measurement Strategy: Prior to the start of human landings, we must begin to quantify the sources and sinks that control the natural state of the atmosphere of the Moon. Questions to address include:

1. What are the chemical composition and flux of solar wind particles impacting the lunar regolith that is both a source and sink of atmospheric gases? How do the solar wind composition and flux vary over the solar cycle?

2. What are the chemical composition and outward flux of outgassed gaseous species emanating from the lunar regolith? How do the composition and flux vary with geographical location and terrain type?

An autonomous lunar atmosphere measurement system to address these questions may contain the following instrumentation:

1. An upward-viewing mass spectrometer and ion detector located on the lunar surface to measure the composition and outward flux of solar wind particles impacting the surface of Moon.

2. A mass spectrometer and/or gas chromatograph housed in a closed flux box with open bottom in contact with surface of Moon. Outgassed species from lunar regolith will build up in the flux box as a function of time and will be measured by the mass spectrometer and/or gas chromatograph. The rate of increase of species as a function of time in the flux box will be used to calculate the gaseous fluxes emanating from the regolith and interior. The closed flux box technique is a standard technique used in studies of the
production and outgassing of species in the Earth’s atmosphere [5, 6, 7].

The measurements of the density, structure and chemical composition of the Moon’s atmosphere outlined here will provide the baseline measurements needed to better understand and quantify the processes that control the natural production and loss of the Moon’s “pristine” atmosphere prior to human exploration. Continued measurements will provide the baseline needed to quantify the impact of human presence on the lunar atmosphere. As we begin the human exploration of the Moon, we will begin the inadvertent terraforming of another world. It is critical to understand and quantify the impact of the human presence and human activities on the atmosphere of the Moon before the terraforming of the Moon’s atmosphere becomes a reality.