Science and Astrobiology from the Moon or near Moon. N.J. Woolf[1], J.F. Kasting.[2],and M. Mumma [3] ([1]NASA Astrobiology Institute, Steward Observatory, University of Arizona, Tucson AZ 85721, nwoolf@as.arizona.edu[2] NAI. Penn. State University, [3] NAI Goddard Space Flight Center.

Introduction

We suggest that a small telescope, or pair of telescopes, be placed on or near the Moon and used to make observations of the Earth.in the visible/near-infrared and in the thermal-infrared. The observations will be useful to both Astrobiology and to NASA's Earth Sciences program.

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II Motivation

Two communities will be very interested in Earth observations from the Moon. The first is Earth Science. A recent National Academy study points out that the current aging and dying Earth observing satellites contrasts with increased interest in observations of the Earth relevant to climate change. Earth scientists look to the first Earth observations from the Moon or from near the Moon to provide an extended lifetime for Earth observations. They also look for them to provide a global calibration of photometric observations of current satellites to a precision of 0.1%. Current satellite data suffer from observing adjacent areas of the Earth from different orbits (observation times) and different Earth-Sun phase angles. Earth Sciences also needs calorimetric observations of Earth that cover the range from 2000A to 100 microns.

The second community is Astrobiology. Current concepts for observing extrasolar planets suffer from a lack of a capability to observe water in the liquid phase. Two types of observation give some hope of being able to do this. The first is to search for the specular reflection from oceans. This is broadened by waves into a bright patch some 15x15 degrees in latitude and longitude that is polarized, and that shows up prominently in observations made in crescent phases. The second possibility is that light reflected from clouds, too, is polarized, with a phase angle dependence that is characteristic of the refractive index of the liquid.

Observation of either or both of these phenomena may be possible. However, observation of the Earth as a single pixel requires that the observation be made from many Earth diameters away. The nearest sites that provide this opportunity are the lunar surface, lunar orbit, or Earth-Moon L1. A further problem is the variable cloud cover of Earth, which is very difficult to model. Therefore, the preferred method of studying this is to observe the Earth for an extended period of time, during which both single pixel observations and imaging observations are obtained. The images are required to ground truth the single pixel observations. Because imaging observations could satisfy Earth Science needs, there is a useful synergy in planning these observations together.

There is also an Astrobiology interest in observing the Earth, and taking spectra, at a variety of phase angles. Atmospheric scattering is strongly phase angle dependent, and surface features are likely to show far better at some phase angles. However, current integrated spectra are only available from earthshine, which is limited to phases close to full Earth.

III The Moon versus Earth-Sun L1

The mission concepts for TRIANA and DISCOVR were for an Earth observing satellite at Earth-Sun L1, roughly 4 times further from Earth than is the Moon. Thus, for any given angular resolution on Earth, cameras at Earth-Sun L1 would need to be about 60 times greater in volume and weight. They would also require 4 times better pointing accuracy. Furthermore, they would look at the Earth from a single (daytime) angle, so that any changes in the nighttime earth would go unnoticed. Lunar observations return to the same phase of Earth each lunation; hence, there would be long-term time series of images available for comparison with any prior phase of observation. Earth-Sun L1 does have the advantage that it is a good site for observing the Sun and the solar wind; however, solar calorimetry can be performed more readily from near-Earth orbit. Another possibility for the Moon is thermal imaging (uncooled detector array). For Earth-Sun L1, any appreciable angular resolution at thermal wavelengths requires a large camera. However, from the vicinity of the Moon, filling the currently available uncooled array cameras can make Earth images with a ~1 inch objective.

The Moon offers three very different sites from which to make observations. The first is the lunar surface, where a telescope could be set in place either by humans or by an unmanned lander. The advantage of making observations from the lunar surface sooner, rather than later, is that one can learn about the potential problems of making such lunar observations from a very small device. This may prove useful in designing instruments to be used for other purposes. The disadvantage of being on the surface is that if lunar dust prevents observations after some time, and if human repair is not possible, then the goal of learning about climate change would be compromised. The second possibility is that observations could be made from an add-on package to a lunar satellite that also served another purpose. The pointing requirements for observing Earth are resolution dependent: for 100-km to 10-km resolution they are ~+/- 24 arc seconds to 2.4 arc seconds. This is not unreasonable for a satellite performing lunar imaging. The third possibility is that a message relay satellite might well be placed at Earth-Moon L1. Such a site could also permit piggy-back observations.

IV Speed of initiation versus performance

Whereas the astrobiology observations can be made with very small equipment – low resolution spectrometers and polarimeters – the Earth Science observations will need to balance the desire to make early observations against the desire to obtain high-resolution images of Earth in a number of spectral bands, along with the need to test methods of calibration, etc. In the long run, Earth Scientists would like to have sensitive and powerful observing devices with many spectral bands (see the Triana and DISCOVR web sites). However, it would also be valuable to start making observations early, even if those observations were necessarily more restricted.

Astrobiologists, too, would like to make observations in the near future. Already, Discovery proposals have been submitted (though not selected) for extrasolar planet spectral observations. None of the devices were planned to include polarimetry. None of the devices could be planned around the possible advantages of observing planets at various phase angles. Thus, devices are being planned at the present time that may not be optimum for studying extrasolar planets. The sooner Earth observations are initiated from the Moon's vicinity, the better. This work will serve current and future needs. There is need for a joint Earth Science-Astrobiology study that weighs these options together with the possibilities for an early start. An optimal program might be one that starts early and that then evolves to more powerful future instruments once the advantages/disadvantages of a lunar observatory have been established.

In like manner, astrobiologists would be interested in sharing the opportunity to make more detailed observations. A sequence of observations from the Moon that reveals the Earth at sequences of times of day, and that expands into seasons, is one ideally suited to observations of life processes on Earth. Observation of seasonal changes of CO_2 already show that observation of biogenic gases varying with time could be interesting, but would likely require high resolution spectrometers associated with angular resolution.