IMAGING OF THE OUTER PLANETS AND SATELLITES*

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Abstract. Imaging is the most widely applicable single means of exploring the outer planets and their satellites and also complements other planet-oriented instruments. Imaging generally is more effectively carried out from a three-axis stabilized spacecraft than from a spinning one.

Both specific experimental and broader exploratory goals must be recognized. Photography of Jupiter from terrestrial telescopes has revealed features which were neither predictable or predicted. Close-up imaging from fly-bys and orbiters affords the opportunity for discovery of atmospheric phenomena on the outer planets forever beyond the reach of terrestrial laboratories and intuition. On the other hand, a large number of specific applications of close-up imaging to study the giant planets are suggested by experience in photography from Earth and Mars orbit, and by ground-based telescopic studies of Jupiter and Saturn. Photographic observations of horizontal and vertical cloud structure at both global and finer scale, and motions and other time changes, will be essential for the study of atmospheric circulation. Size and composition of cloud particles also is a credible objective of fly-by and orbiter missions carrying both imaging and photo-polarimeter experiments.

The satellites of the outer planets actually constitute three distinct classes: lunar-sized objects, asteroidal-sized objects, and particulate rings. Imaging promises to be the primary observational tool for each category with results that could impact scientific thinking in the late 70's and 80's as significantly as has close-up photography of Mars and the Moon in the last 10 yr.

Finally, it should be recognized that photography occupies a unique role in the interaction between science and the popular mind. This popular, educational aspect of imaging constitutes a unique aspect of 20th Century culture. Imaging therefore is not only a primary basis for scientific discovery in the exploration of the outer planets, but an important human endeavor of enduring significance.

1. Introduction

The purpose of this paper is twofold: First, to illustrate how imaging can be used as a part of scientific experimentation, and especially to illustrate proposed imaging experiments for the outer planets and their satellites. Second, to show that imaging yields highly communicable results having not only scientific significance but broad intellectual and cultural meaning as well. Thus, it is argued that both for scientific and cultural reasons imaging should play a major role in the exploration of the outer solar system. In the following, we first briefly review the scientific, technological, and systems background for imaging experiments, then proceed to separate sections concerned with imaging of: (1) the giant planets, and (2) their satellites.

1.1. TECHNICAL ALTERNATIVES

There are many ways to gather data about the outer planets, including flybys, orbiters, and entry probes. Among the flybys, there are the possibilities of one-two-three – and even four – planet missions. The uniqueness of the 1976–79 opportunities for comparative studies of the outer planets is well established in other papers in this issue, as is the fact that the early eighties offer a favorable time for Jupiter orbiters. Needless to

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say, there are many trajectory constraints on multiplanet missions. In addition, environmental factors including the radiation belts of Jupiter, the rings of Saturn, and possibly the asteroid belt must be taken into consideration. As always, some kinds of technological evolution will be involved going from simpler systems to more complex ones as time goes on. Hence, it can be difficult to discuss a proposed scientific experiment in the context of such a variety of possible missions, spacecraft, and resources.

Yet, an important aspect of imaging is that it can contribute to virtually any orbiter or flyby mission to any of the planets or satellites, and with almost any trajectory likely to be considered. Hardly any other scientific experiment has such widespread applicability. In addition, imaging is not dependent upon a priori knowledge of the nature of the targets, or even on what will prove to be the most exciting questions. Most importantly for related investigations, imaging provides the map base for other experiments, a point well illustrated by the Mariner 9 orbiter mission in which spectral and radiometric instruments required a visible map of the surface to plot their own data for analysis. Imaging occupies a unique role in its importance to the other instruments involved in remotely exploring the surface or atmosphere of a planetary body.

The particular hardware and data return systems, and their associated cost and complexity, will vary greatly from mission to mission depending on the resources available, the particular scientific priorities of the mission under consideration, and results of previous missions. The hardware and system implications of imaging are presented in general terms in Murray and Davies (1970) and Davies and Murray (1971), and specifically for outer planet missions in Belton et al. (1972). Here it is sufficient to note that within weights ranging from perhaps 30 lb to 100 lb, within dollar amounts ranging from perhaps 4 to 20 million dollars, and for communication rates ranging from several hundred to several hundred thousand bits per second, a wide range of imaging experiments is possible.

It is important to note that high resolution imaging of planetary and satellite targets is much more effectively carried out from a stabilized platform than from a spinning spacecraft. The spinning motion intrinsically degrades angular resolution because of the brief dwell time for each resolution element. Difficulties in geometric reconstruction of the scanned data may also be encountered, especially where there is significant planet-spacecraft motion. In addition, the stabilized spacecraft normally includes greater data handling capability and greater total data return capability. Also, appropriate frame cameras already have been developed for, and flown on, planetary missions. More limited imaging experiments, especially for low resolution investigation of planetary atmospheres, are practical as well from a spinning orbiter using either point scan or line scan techniques. Higher performance with spinning flybys and orbiters is also possible, in principle, through use of the spin/panoramic concept (Davies and Murray, 1971). However, a significant new development effort would be required for planetary application of this camera concept.

1.2. Planets vs. Satellites

In considering the large number of objects beyond the orbit of Mars that will be