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The Use of High Temperature Superconductors to Levitate Lunar Telescope

by

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The Use of High Temperature Superconductors to Levitate Lunar Telescope

One project made nearly impossible from either ground-based or low-Earth orbit observational platforms is the search for extrasolar planetary systems. One reason for this is atmospheric scintillation. This causes the object being viewed to appear to shift, thus creating a fuzzy image. What is needed is a lunar observational site. From the moon, the detection of a Jupiter sized planet will be more feasible. Indeed, earth-like planets may well be in the range of lunar telescopic systems. An observation site on the moon would also be used to describe the prevalence of other planetary systems and to study their atmospheric compositions. In combination with a study of pre-planetary disks, this information would enable us to know more about our own solar system[1].

The moon has been chosen as an observational site because of its numerous advantages over the Earth and low-Earth orbits. The lunar atmosphere is, for example, virtually an ultra-high vacuum. This would enable telescopes to be used to their full spectral power. The low density atmosphere also means no wind. Along with the moon's low gravity, this means that structures (both telescope and housing) can be made of extremely lightweight construction with attention only to static thermal loads. Also, since the moon has a slow rotation period, observation times will be longer (indefinite times for polar sites). The sky above the lunar surface is both dark and cold. The darkness of the sky is a result of the absence of air glow. Thus, deep observations may be made even in daylight (with proper shading of the telescopes). The coldness reduces or eliminates the need for cyrogens to cool optical components[2,3]. It is this attribute that forms the basis for a lunar telescope as designed by Dr. Peter Chen (Code 684.9).

My job this summer was to assist in the construction of a mirror model of this telescope. The mirror is of a simple construction making use of high temperature superconductors and electromagnets to levitate, point, and move the mirror. The feasiblity of this type mirror lies in the fact that temperatures on the moon are low enough to allow superconductors to become fully conducting without the need for additional cyrogens. In addition, the low gravity of the moon makes it possible to obtain a rigid reflecting mirror without a massive support system.

The mirror itself has not been made yet. The model will be made by a replication process using a glass lens as a mandrel. A thin layer of gold will be deposited as the reflecting surface. A layer of graphite epoxy will then be applied as a lightweight rigid backing. The mirror will be attached to an annular support frame to which the superconductors will be fixed. The material for the support ring has not been determined yet. There are several candidates being considered, all of which are low-density, rigid (in space) materials. These include aluminum metal-matrix composites, polystyrenes (for example, styrofoam), and polyurethanes.

The entire structure will then be suspended above electromagnets. By varying the current going through each electromagnet, the height and orientation of the mirror can be adjusted. As an alternative to placing superconductors above the electromagnets, it may be possible to coat the back of the mirror with a magnetic thinfilm and suspend the construction above superconductors.

In preparation for the use of superconductors to lift the mirror, I observed the levitation of several Y-Ba-Cu-O superconductors with the use of a small permanent magnet and liquid nitrogen (to cool the superconductor). Levitation is the result of the Meissner effect which is the expulsion of magnetic field lines by a superconducting material. I then ground down two superconductors to measure differences in levitation properties with respect to thickness. This was done by placing the superconductors, including one of original thickness (4mm), above a large magnet. One superconductor was ground to approximately 2mm; the other to about 1mm. From these experiments, I found that, when levitating a small magnet above a superconductor, levitation height increased with thickness. When suspending a superconductor above a magnet, however, levitation height decreased with thickness.

In the next stage, I experimented with different configurations of superconductors, magnets and variable magnetic fields After some research[4,5], it was found that if an electromagnet (a solenoid connected to a DC power supply in this case) were to be placed above the permanent magnet (in turn suspended above the superconductor), the levitated height of the magnet could be increased. This increase in height was due to the attractive force from the electromagnet adding to the repulsive force from the superconductor. It was determined that the range of vertical motion produced in this manner was finite. There exists a point (maximum height) at which the flux lines snap and the magnet is pulled toward the electromagnet.

Continuing with this line of experimentation, I attached two cylindrical magnets to either end of a split tongue depressor (approximately 4.32g) by means of an epoxy resin and tape. Three superconductors were used in each of two petri dishes in order to permit the depressor to clear the edges of the dishes. It was found that when one end of the construction was further lifted under the electromagnet, used in the single magnet experiment, the other end remained fixed in place. This helped confirm the stability of the suspended object.

I then proceeded to add ever increasing weight to the construction in anticipation of what would be required to lift the model mirror (calculated to be approximatley 14.2g). By increasing the amount of current flowing through the solenoid, and by lowering the height of the solenoid over the end of the depressor, I was able to maintain levitation to a weight of 10.52g. At this point, I noticed a slight levitation; however, the electromagnet was so low over the construction as to severly limit any vertical movement that may have been possible.

In conclusion, it is believed that with a construction of four magnets suspended over four bulk superconductors (or vice versa) there should be no problems lifting the model mirror and stabilizing it at different positions. It may be necessary to increase the size and quality of the superconductors and/or magnets in order to achieve this.

References

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5. T. Takamori, J. J. Boland, and D. B. Dove, Rev. Sci. Instrum. **61(7)**, pp. 1984-1986 (1990).

Viewgraphs

* Objective summary
* Table of lunar advantages
* Basic mirror design
* Levitated construction without electromagnet
* Levitated construction with electromagnet
* Table of experimental results

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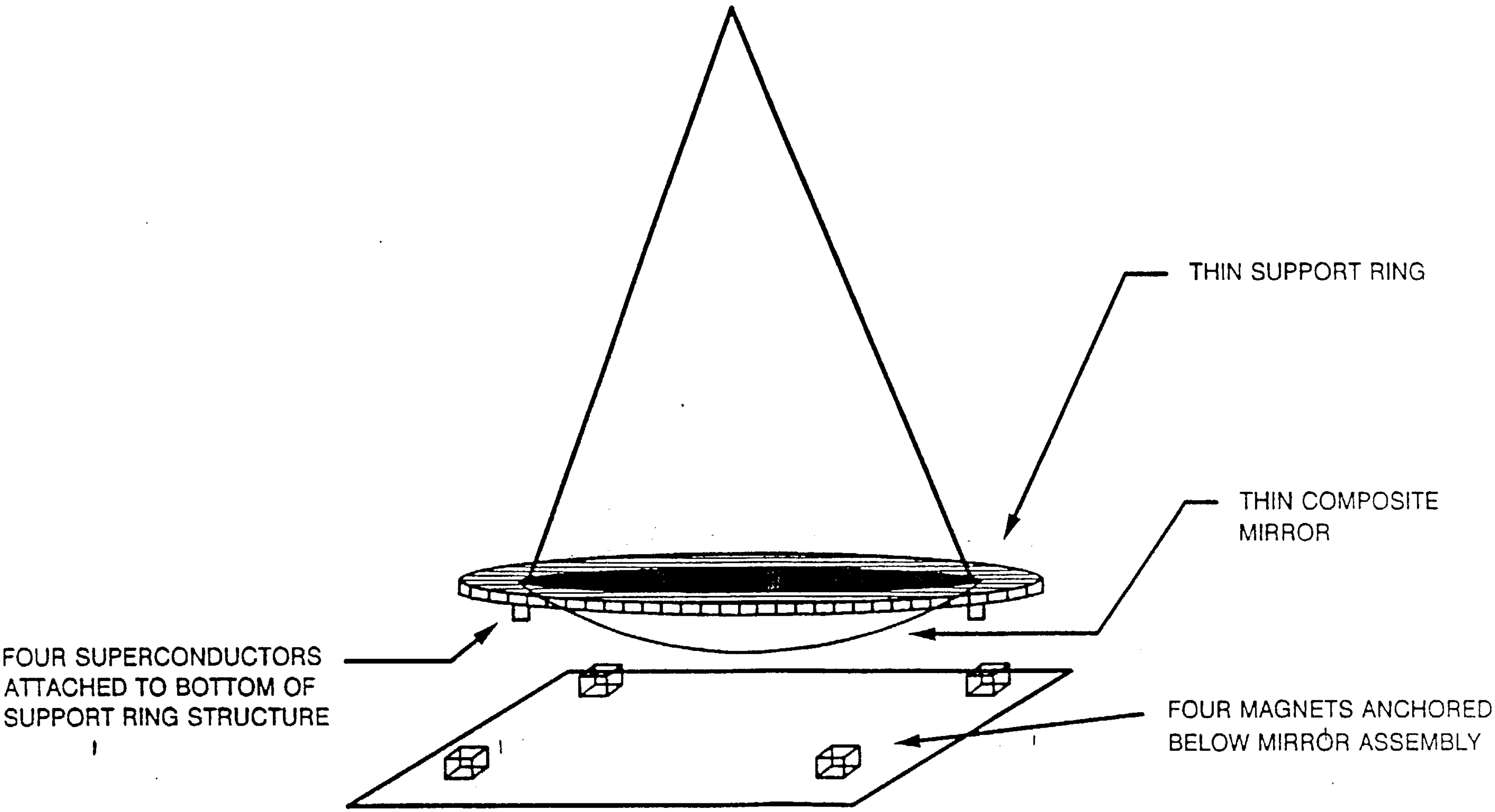
Objective To assist in the construction of a lunar telescope mirror model by conducting research on composite materials and other lightweight, rigid materials, and by determining how much weight can be levitated by available superconductors.

BASIC DESIGN
MEISSNER EFFECT TELESCOPE PRIMARY MIRROR



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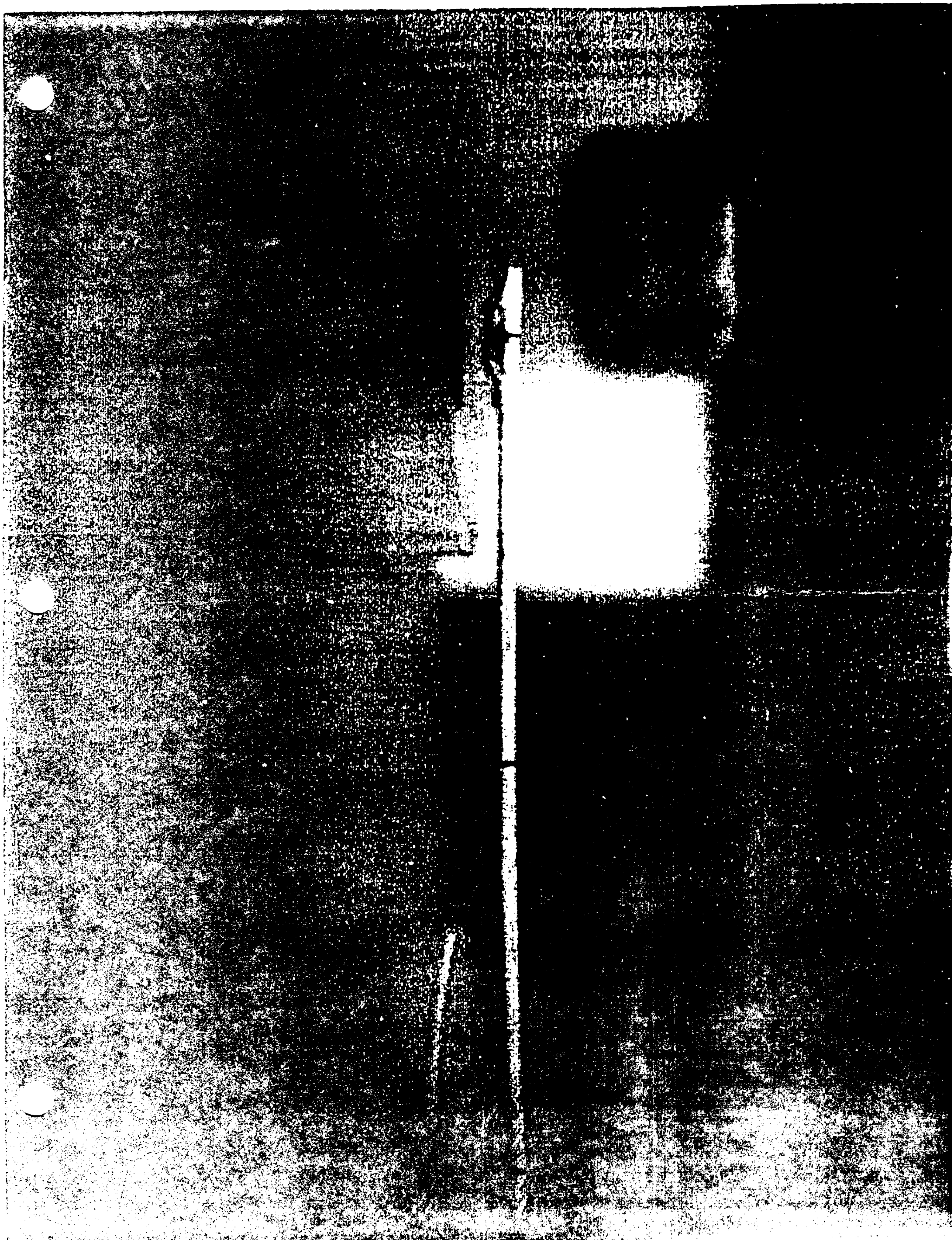
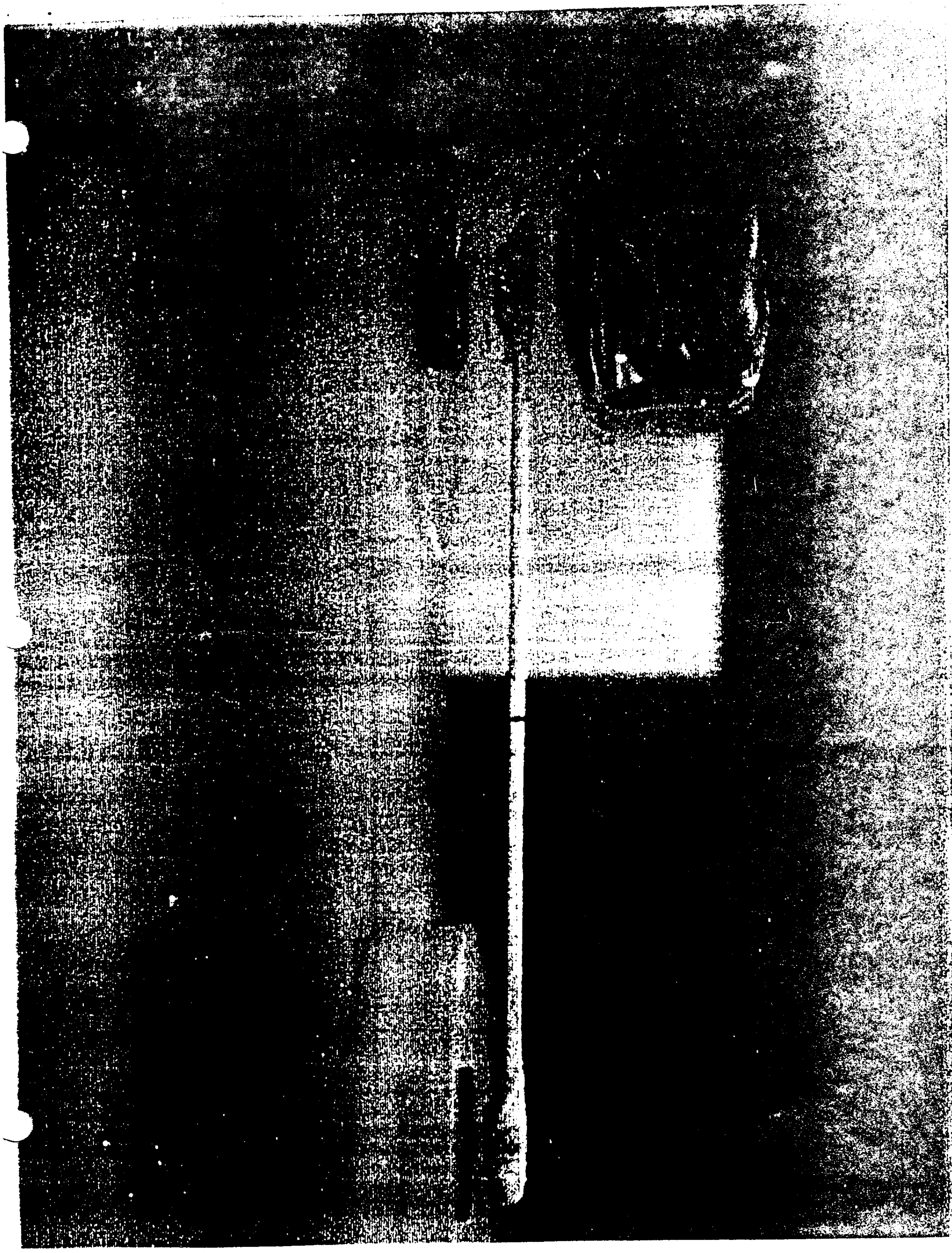
Advantages of the Moon as an Observational Site

* ultra-high vacuum	telescopes can be used to their full spatial resolving power
* dark sky	virtually free from air glow; from any site, the Earth appears fixed; with proper shading, deep sky observations can be made
* cold sky	reduce or eliminate need for cyrogens
* low gravity	structures much lighter and of less expensive construction; debris falls to surface rather than floating
* lunar farside	ideal for limiting sensitivity (site which never sees Earth in the sky)
* absence of wind	structures built with attention only to static thermal loads
* proximity to Earth	round-trip communication times < 3 seconds
* room	for laying out systems of instruments
* raw material	virtually inexhaustible supply of many essential materials





Mass (g)	Height (mm)			Current (A)
	Magnet above s.c. w/o electromag.	Magnet above s.c. w/electromag.	electromag. above s.c. (from vertical center)	
4.32	3.5	8.0	28	.45
6.34	1.5	5.75	26	.55
7.72	1.0	4.0	21	.56
10.52	0.0	.05	18.5	.60