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NOTES

FALLING SPHERE EXPERIMENT

INTRODUCTION

One of the major techniques used to determine upper atmospheric densi-
ies is to measure the acceleration on a known aerodynamic shape and
)mpute density with the help of the drag equation.

$$(1) \qquad a_d = \frac{C_D A \rho V^2}{2M}$$

iis same basic technique has been used to determine densities as diverse
; the surface ($\rho \approx 1$ Kg/m^3) and 250 km ($\rho \approx 1 \times 10^{-10}$ kg/m^3). As
:ght be expected the variety of shapes, mass to area ratios and velocities
:flects the extreme dynamic range. At one end of the spectrum we have
itellite data (velocities $\approx$ 6500 msec^{-1}) upper atmosphere sphere data,
'elocities $\approx$ 1500 msec^{-1}) surface data (velocities 30 msec^{-1}). For
iis discussion we will concentrate on those experiments which are used
i the 30 to 150 km region.

The flow regimes covered by the various systems are extremely broad;
goes from Mach No. 2 to hypersonic flow in the free molecular regime
continuum flow the Mach Numbers ranging from almost zero to supersonic.

In all versions of the experiment the principal source of uncertainty is the drag coefficient. For those who develop these systems to satisfy measuring requirements, these uncertainties are often two or three times the stated requirements.

In a recent NASA study (1) to select an operational system to be developed for sounding the atmosphere from 30 to 100 km, 1000 times a year, the falling sphere technique (radar tracked version) [2,3,4] was selected. The principal reason being that this type can be made to give soundings at a lower cost than any other density system. This passive system (radar tracked) is flown fairly routinely at rocket ranges in support of large rockets.

There are two accelerometer equipped versions used to sound up to 130 km.[5, 6] There is a "cannonball" which is essentially a low level satellite 145 km[7], and spheres which have been ejected by reentering vehicles. In addition there are other shapes [8] which are being evaluated to determine the density of Martian atmosphere. Above the altitude of interest for this course, the measurements of drag by satellites is by far the largest contribution to our knowledge of atmospheric density.