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EXPERIMENT ON PENDULUM MOTION OF A BALLOON GONDOLA

BY

GUENTER R. RIEGLER

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NASA — GODDARD SPACE FLIGHT CENTER

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Abstract

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A camera on board a balloon gondola was aimed at the horizon in order to monitor the attitude of the gondola. An analysis of the film, which was exposed during one flight, provides evidence that no pendulum motion had occurred during the flight with amplitude larger than 0.5 degrees. This analysis, however, did indicate the presence of a significant rotational motion of the gondola, without apparent regularity as to speed and sense of rotation.

Author

Purpose of the Experiment:

In order to evaluate data from a telescope flown on a baloon gondola, it is necessary to have knowledge of any pendulum motion which the gondola might execute. The experiment described below was to provide such information.

Experimental Methods:

The motion of a system consisting of the balloon, ropes and the gondola can be approximated by that of a mathematical pendulum. With this assumption, it can be shown that it is impossible to detect pendulum motion by means of monitoring the motion of a secondary short pendulum relative to the first long one.

Among several alternative methods, optical sensing of the horizon was chosen. Images of the horizon display pendulum motion more clearly and over a longer period per day than, for example, images of the surface of the earth below the gondola or sky images would show.*

Infrared Film:

In order to reduce the image size of the haze layer above the horizon during the day, and to obtain some image of the horizon at night, infrared film was used.

However, the film showed no image of the horizon while the sun was far below the horizon, and the image size of the haze

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*The difference between "horizontal," as derived from the direction of a pendulum bob, and the tangent to the surface of the earth, will be neglected in what follows. The maximum difference during our balloon flight was approximately .1°.

layer (with the sun above the horizon) was still approximately 2.5°. This may be due to the low wavelength of the sensitivity peak of the film (Kodak HIR 430, peak around 850 mμ).

Exposure Times:

A wide range of exposure times was necessary to obtain proper exposure throughout the day. A chronometrically governed time-sequence mechanism operated the shutter of the camera so that 14 images were taken within every one minute cycle. The exposure times within each cycle ranged from 1/44 to 24 seconds. Images of stars were expected to appear on the film, expecially with the longer exposure times. However, due to the low sensitivity of the film (approximately 50 ASA) and the rotation of the gondola, no images of stars were found.

Camera and Lens:

The camera used was a 16mm D.B. Milliken movie camera which had a 400 foot-reel capacity, could be heated, and was pressure sealed. With a lens of 25.4mm focal length, the opening angle was 23.3° (zenith) by 16.7° (azimuth). At balloon altitude, which was approximately 40.2km., the horizon appeared 6.5° below the optical axis of the camera.

Results - Pendulum Motion:

An analysis of the exposed film shows that to within the error indicated (see page 5) no pendulum motion had occured during the course of the flight.

Three passages of the moon were recorded (on a total of 46 frames) approximately 2 hours before sunrise. The exact times could be found from the known rate at which pictures had been taken since launch, and from the variation of exposure time within each one-minute cycle. The known elevation of the moon agreed to within 0.5° with the position of the moon's image on the film.

Less than one hour before sunrise the image of the horizon was recorded as a sharp line. Exposure, due to light scattered through the atmosphere from below the horizon, varied in size and intensity with time and camera direction. The errors associated with the camera alignment and image definition determined the maximum amplitude of pendulum motion which might have occurred to approximately 0.2°.

The interpretation of daytime pictures was done under the assumption that the apparent size of the haze layer remained constant over periods of approximately one minute. It then appeared that there was no pendulum motion of more than 0.5° amplitude. This uncertainty is given mainly by the lack of definition of the upper end of the haze layer.

Results - Rotational Motion:

Information on the rotational motion of the gondola was obtained from images of the moon, of cloud banks while the sun was just below the horizon, of light scattered by dust particles on the camera window at sunrise, and of structures on the ground after sunrise. This motion corresponded to an angular speed of 0.2 - 0.03 revolutions

per minute. There was no apparent periodicity in the speed or the sense of rotation.

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History of the flight.

Dec. 6, 1965

MST (a.m.)		Pendulum motion	Rotational motion
1:08	Launch at Holloman AFB, N. M., lat. 33.2°N, long. 106°W.	-	-
1:09	During the next appr. 4 hours no images on film except for 3 passages of the moon.	-	-
3:51 4:02 4:08	Passage of the moon	none ±0.5°	either sense, max. speed 0.15 RPM
4:45	Balloon reached altitude 38.7 km	-	-
5:03	Horizon appears as sharp line with light scattered above	none ±0.2°	counterclock-wise, speed 0.06-0.12 RPM
appr. 6:	Haze layer above horizon. Size of haze layer appr. 2.5° (sun is above horizon)	none ±0.5°	either sense, speed 0.03 - 0.1 RPM
appr. 8:20	Ground structure can be resolved	none ±0.5°	either sense speed 0.05 - 0.2 RPM
12:02	Cut-down, Lat. 28.1°N Long. 84.4°W		

A 10.6×10^6 $(ft)^3$ Winzen balloon was used. The weight of the gondola was 395 lbs.