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TECHNICAL NOTE

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PROJECT ECHO— BORESIGHT CAMERAS FOR RECORDING ANTENNA POINTING ACCURACY

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SUMMARY

Motion picture cameras equipped with telephoto lenses were installed on the transmitting and receiving antennas at Holmdel, New Jersey. When the Echo satellite was visible, a camera obtained a photographic record of the pointing accuracy of the antenna. These data were then used to correlate variations of signal strength with deviations in antenna pointing angle.

PREFACE

The Project Echo communications experiment was a joint operation by the Goddard Space Flight Center of the National Aeronautics and Space Administration (NASA), the Jet Propulsion Laboratory (JPL), the Naval Research Laboratory (NRL), and the Bell Telephone Laboratories (BTL). The equipment described herein, although designed by BTL as part of its own research and development program, was operated in connection with Project Echo under Contract NASW-110 for NASA. Overall technical management of Project Echo was the responsibility of NASA's Goddard Space Flight Center.

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INTRODUCTION

The conventional method of evaluating the tracking performance of radar antennas has been to mount a camera-lens system on the antenna structure, thus providing an optical line-of-sight parallel to the radar beam. This system permits recording on motion picture film the radar pointing error whenever the object being tracked can be photographed. Camera instrumentation of this type was provided for both antennas (the 60-foot paraboloid transmitter and the 20-foot horn receiver) used by the Bell Telephone Laboratories (BTL) facility at Holmdel, New Jersey, in connection with Project Echo.

PHOTOGRAPHIC SYSTEM

The brightness of the Echo satellite was expected to be greater than that of a first-magnitude star. Experience in astronomical photography indicated that first-magnitude stars could be recorded on Tri-X negative film (Eastman Kodak No. 7233) with an exposure of 1/30 second and a lens aperture of f/3.5. Accordingly, it was decided to use a camera speed of four frames per second, which provided an exposure time of 1/8 second and at the same time afforded 16 minutes of continuous operation with the camera's 100-foot film capacity. The 16-mm film provided adequate photographic detail and was selected in preference to 35-mm in order to minimize film and processing costs, storage space, and equipment investment.

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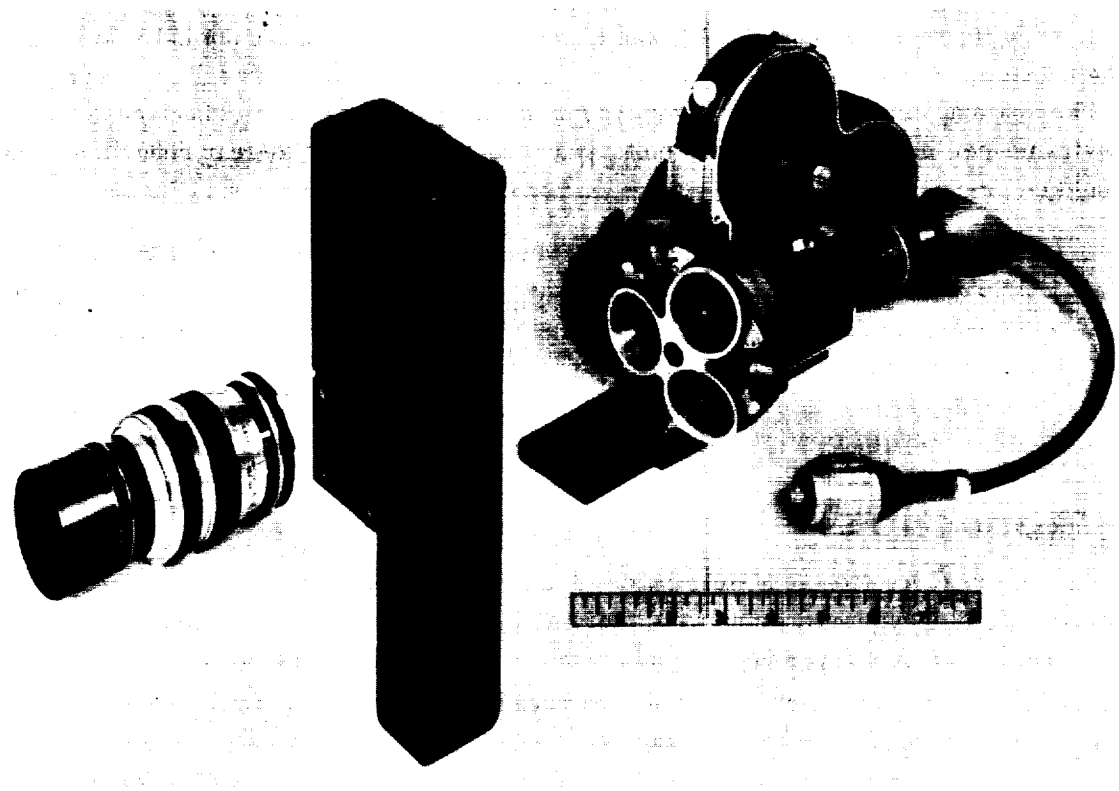

Figure 1 - Tracking camera

Figure 2 - Synchronous motor with gear reductions for 24, 8, 4 frames per second

The Arriflex 16-mm camera (Figure 1) was selected for Project Echo because the feature of through-the-lens viewing was desired for alignment of the optical system with the transmitting and receiving antennas. Also, this camera could have been equipped with a 400-foot magazine if a faster frame rate or longer tracking time had been desired. A 24-frame-per-second synchronous motor was ordered with special gear reductions that could be interchanged easily to provide four or eight frames per second (Figure 2).

The desired 3-degree field of view was obtained by using a 150-mm, f/3.5 Kilfitt lens. This field of view was large enough to keep the satellite image within the film frame during early tests when some tracking difficulties could be expected. The 150-mm lens provided enough magnification to permit reducing the data to the desired accuracy. The camera system was designed so that a 300-mm lens could be used, if desired in later tests, without modification.

A projected reticle was imaged on the film by using a beam splitter, as is shown in Figure 3. This time, in seconds, was recorded on the film by using a conventional telephone message register as a stepping counter. For optical alignment and time correlation, the reticle and message register were also visible through the eyepiece. The optics necessary to project these images on the film were assembled in a housing which replaced the standard lens-to-camera adaptor.

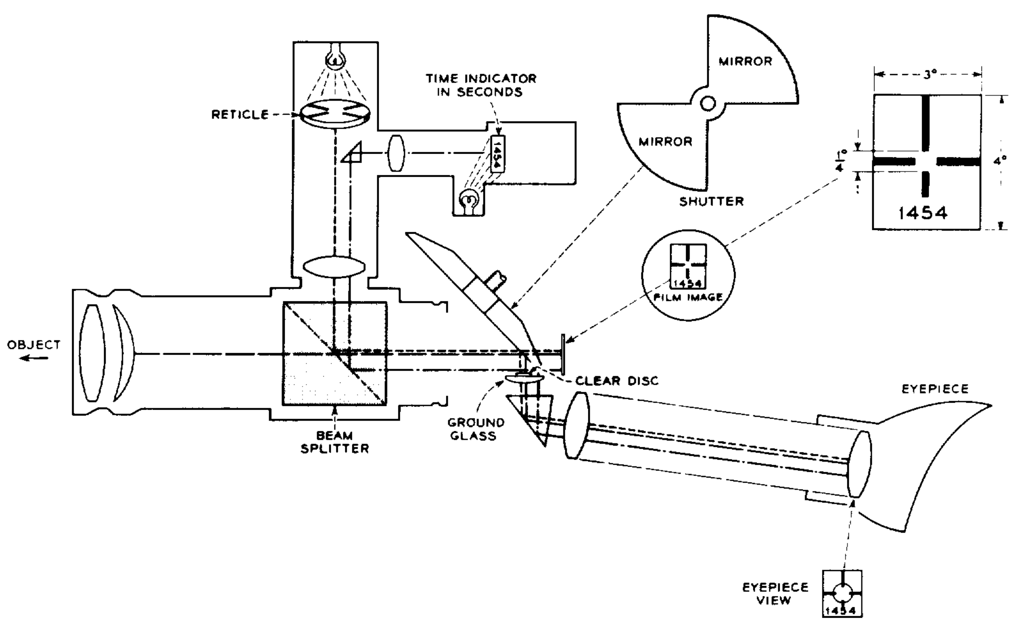

Figure 3 – Schematic of optical system

Figure 4 – Camera mounted on horn receiver

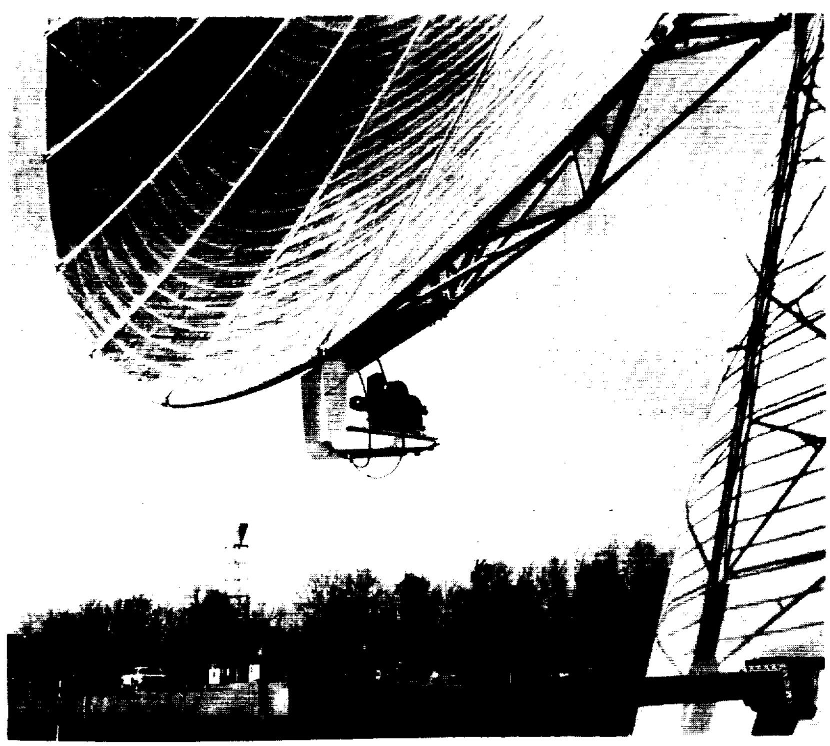

Figure 5 – Camera mounted on paraboloid transmitter

CAMERA MOUNTING, POWER SUPPLY, AND CONTROL

The cameras were mounted on the vertical center-line, just beyond the lower edge of the antenna apertures (Figures 4 and 5). This location placed the cameras about 8 feet above ground level when the antennas were pointed at the horizon, so that they could be loaded and checked for alignment. A special dovetailed mount was provided for the cameras to permit removal and replacement without disturbing the alignment. The base of this special mount was equipped with adjustments for alignment in elevation and azimuth. A weatherproof cover with a front opening was provided in case of inclement weather during operation.

Special 42-volt power supplies to operate the synchronous camera drive motors were mounted on the antennas adjacent to the cameras. The cameras could be operated at the antennas to facilitate loading of film and alignment, or they could be operated remotely from the main control console.

RESULTS

The enlarged view (Figure 6) of a single 16-mm frame of pass 70 shows the Echo satellite in the reticle opening. The opening is 0.15 degree, slightly less than the original design of 1/4 degree. The letter H at the end of the message register number indicates that the film came from the camera mounted on the horn antenna. From August 12, 1960, to March 15, 1961, a total of 6900 feet of film were exposed during 39 Echo satellite passes.

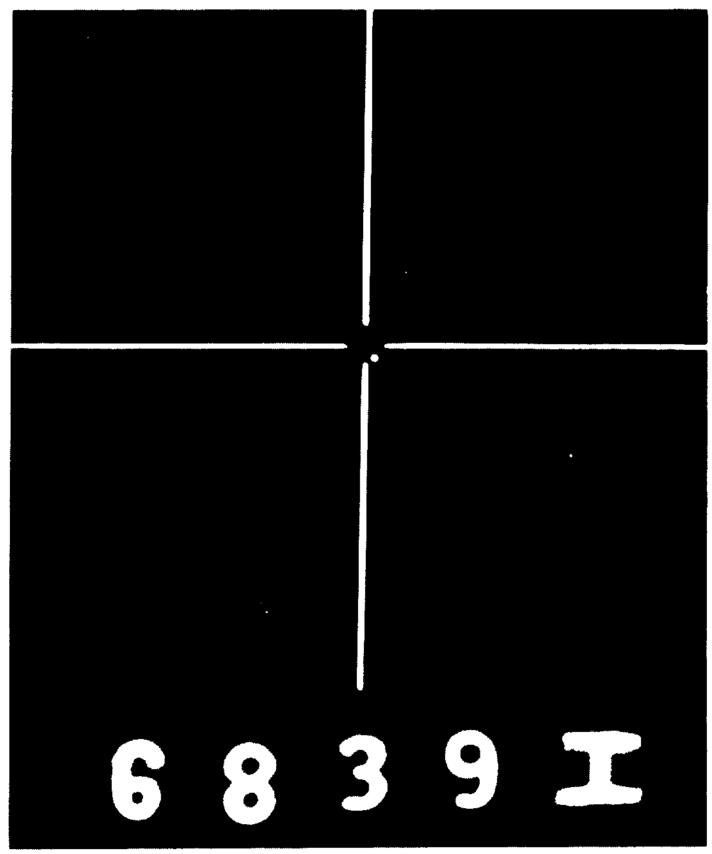

Figure 6 - Typical single 16-mm frame (pass 70, August 18, 1960)