by gas pressure. The starting and stopping of the motor must be precisely controlled. During the operation of the rocket motor the attitude control system is not able to control the orientation of the vehicle. Hence a set of vanes are mounted in the jet and controlled by an autopilot which uses gyroscopes for its reference directions.

Figure 15: The television system consists of two separate camera chains and transmitters. The two systems are as independent from each other as possible for increased reliability. The set of six cameras consists of two with one-inch focal length Fl lenses, and four three-inch focal length F2 lenses. The short focal length, wide angle images are focused on to vidicon tubes having sensitive areas of 0.44 x 0.44in. In the case of the two full scan cameras, the image is scanned by 1,100 lines. The P cameras scan 300 lines across an image 0.11 x 0.11 inches. The six cameras are orientated to give overlapping coverage with the P camera fields in the centre. Figure 16.

In operation, the vidicon image must be erased after being scanned. In the case of the F cameras, scanning and erasing each take 2.56 seconds. The partial scan cycle takes 0.2 seconds each. Pictures from the cameras are thus transmitted in turn, the F cameras on one and the P cameras on the other. The two 60 watt transmitters are diplexed into the high-gain antenna. The signals occupy band widths of 200 kc.

Another interesting problem to be solved is that of vehicle temperature control. in the vacuum of space, heat enters the spacecraft by radiation from the sun and leaves by radiating out to empty space. Hence temperature is established by the radiation properties of the surfaces of the vehicle. By proper coating of these surfaces, Ranger maintained temperatures within the range of 75° to 100° F. in all critical areas.

Another point of interest is that the launching rocket capability places a constraint on the total weight which can be sent to the moon. Therefore the design of the structure must be as efficient as possible. The Ranger spacecraft weighed 806 pounds and contained approximately 30,000 parts.

Ground-based elements which are needed during the flight are the tracking and telemetry receiving stations and the control centre. Each of the three stations in the network has the capability of sending commands to the spacecraft.

The control centre at Pasadena has the task of analyzing all the incoming data. The tracking data were analyzed by digital computers to determine the actual trajectory and the necessary corrections. The telemetry data were analyzed to determine the engineering performance of Ranger.

The most accurate tracking data were the doppler measurements. These were generally accurate to better than 0.01 cycle over a 60 second period. The equivalent accuracy in the radial velocity measurement is about .001 metres/sec. An example of doppler data is shown in the next figure, Figure 17. The solid lines indicate the calculated velocities during the midcourse manoeuvre; the actual measured data are shown as dots.

SOME RANGER RESULTS

The principal result of the Ranger flight is, of course, the series of close-up photographs. However, a great deal of additional data was obtained from study of spacecraft telemetry and the analysis of the actual trajectory.