VIII. Optical Tracking of Rockets

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1. Purpose and Role

The functions of the camera observation groups are important for tracking the flight conditions of a rocket by camera and 15X binoculars, for ascertaining rocket altitudes relative to time, horizontal range and flame-out (brennschluss), moment of release, ignition and burn-out of the main rocket and for finding the correct flight trajectory different than the anticipated ballistic trajectory determined by calculations, or when accidents occur to a rocket due to some influence. In this manner, the camera observation groups have performed many functions using different kinds of optical tracking equipment for the purpose of accurately determining flight conditions after launching and during first stage firing.

They have used high speed films to make analyses of all phenomena occurring from the time of ignition to the moment of separation from the launcher. Moreover, the camera observation groups determine wind velocity and wind direction in the upper atmosphere by balloon tracking. This method yields fruitful data for analyzing the results of observing wind and air temperature in the upper atmosphere.

2. Optical Tracking Equipment

The following equipment is used in the optical rocket tracking system.

1) A 15X Manually Operated Tracking System (at the south observation point). This system principal consists of a 35mm Mitchell camera with a Canon 300mm extra long range lens attachment which, when the weather conditions are favorable, makes tracking possible up to about 50 or 60 km. In order to find 0 firing time, the flash ignition for a camera set up in front of the launching point is photographed in the camera presentation. When tracking rocket flight conditions, indications of angle of elevation, angle of train and time scale are indicated at one place, and while this scale is recorded by a 16mm movie camera, the rocket flight conditions are photographed by long range lens. Moreover, the time axis reports simultaneously the time marks made by neon lamps on the film edges of a 35mm movie camera and a 16mm calibrated camera.

2) 15X Manually Operated Tracking System (at the central observation point).

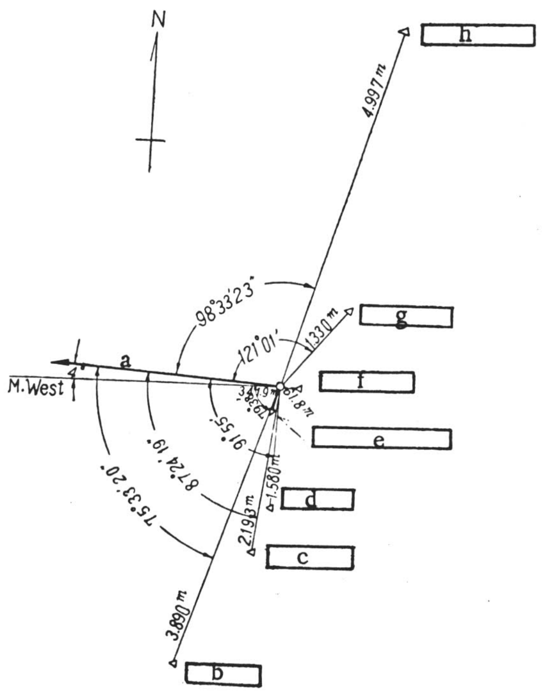
The equipment here is the same as that of the south observation point, but a 250mm focal range lens is used. The important function of the central observation point is to find the angle of deflection which is indispensable in analyzing flight trajectories. Moreover, the same type of tracking equipment is installed and used at the east and north observation points.

3) 35mm Bell and Howell Camera

This camera has a 250mm lens attached and tracks rocket flight conditions. It is used to find qualitative values. The drive is by synchronous motor, the crankspeed is 24 comas/sec and exposure time for 1 coma is 1/500 to 1/1000 seconds.

4) 16mm Fastex High Speed Camera

The maximum crankspeed of this camera is about 8000 comas per second. It photographs the conditions when the rocket leaves the launcher



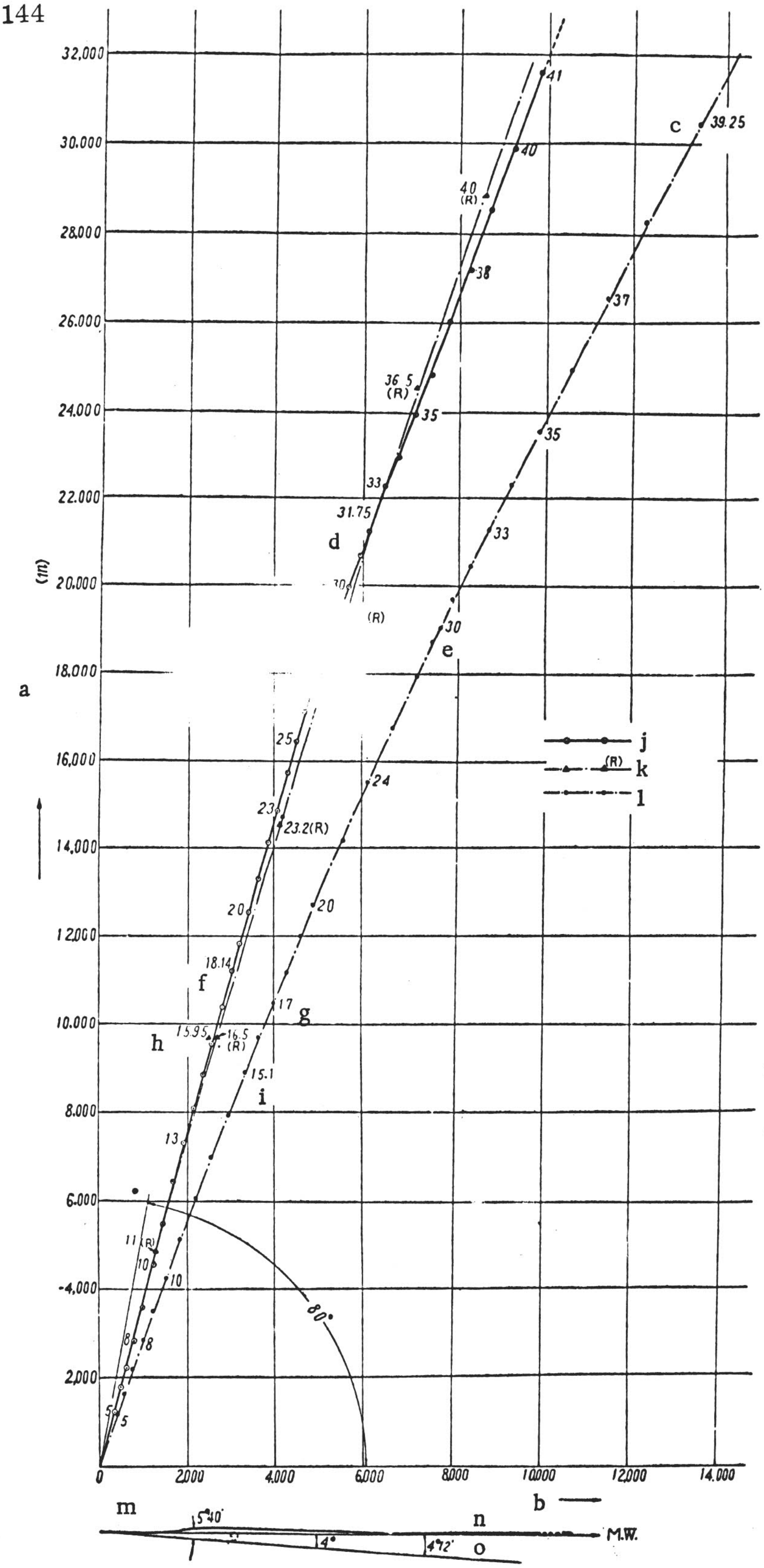
Legend:
- a. launch direction
- b. South observation point (Uemura Laboratory)
- c. Omiya observation point (Maruyasu Laboratory) Aerial camera Aerial camera H = 46.2m.
- d. East observation point (Maruyasu laboratory) H = 60.5m
- e. High speed camera observation point (Uemura laboratory)
- f. Center observation point (Uemura laboratory)
- g. Taminoyama observation point H = 111.7m (laboratories of Itogawa and Maruyasu)
- h. North observation point (Shimohama) (radar group, Maruyasu lab)

Figure 1. Diagram of Distribution of Tracking Camera Equipment.

at 1,000 to 2,000 comas per second, and by analyzing the film, we find the flight characteristics of the rocket. We were able to obtain good results using color film for the K-8-2 and K-8-4.

5) D-20 and Focal Range 75cm Aerial Photography Camera.

These are used chiefly for taking photographs of the flight paths of



a altitude

b horizontal range

c main burn-out

d main ignition

e main ignition

f booster separation

g booster separation

h booster burn-out

i booster burn-out

j measured value

k radar determined

l calculated value

m flight in horizontal

n flight direction

o launching direction

Figure 2. Flight Trajectory of the K8-3.

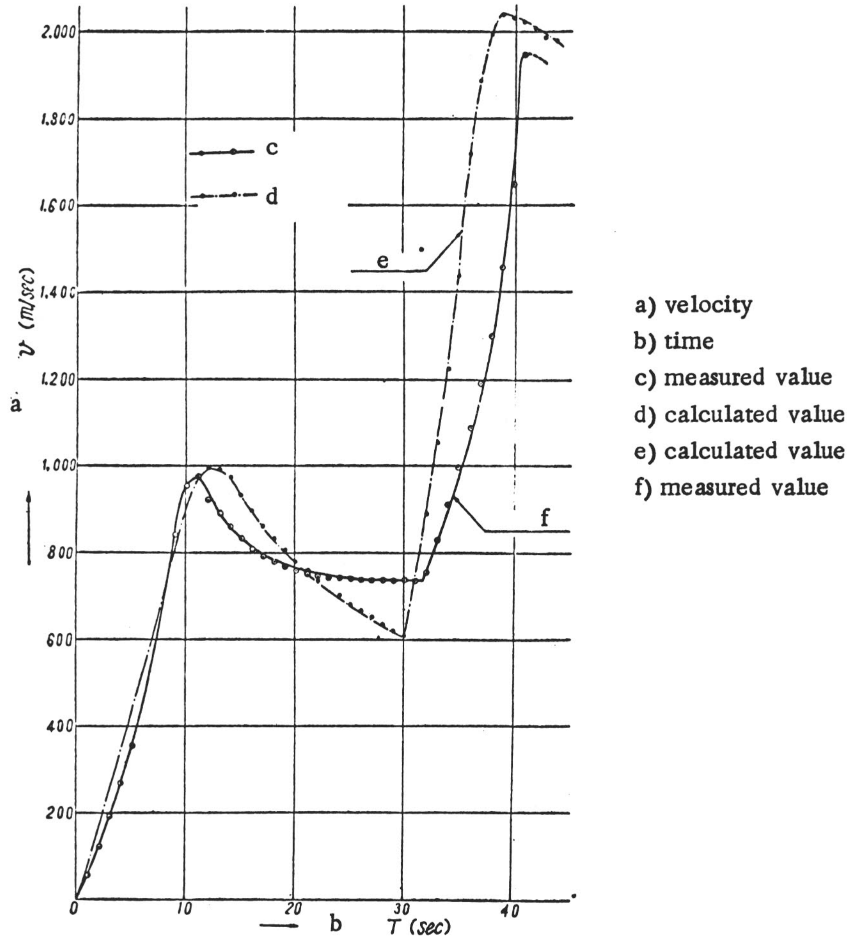


Figure 3. K-8-3 velocity-time.

rockets at night. The lens is Topogon, focal range 20cm, f = 5.6 and the film used is Kodak SuperXX aerographic Film.

6) Rocket-Borne Camera

In the flight tests of the BABY R-1 and R-3 in November 1955, we first used a rocket-borne camera, made a successful recovery at sea, and we were able to obtain valuable films containing photographs taken in the air. Our purposes in loading a camera on a rocket were: 1) to obtain data for the analysis of rocket movements by photographing the external world, 2) to obtain aerial photographs from the upper atmosphere at altitudes inaccessible by plane, 3) to record on film the scale indications of all equipment installed in the rocket, 4) to photograph living conditions when animals are carried. However, the rocket borne cameras carried in the BABY-R rockets were used only for the objectives in 1).

3. Tracking and Analysis

Tracking operations are generally carried out at each observation point shown in Figure 1, using the above optical tracking equipment.

1) Analysis of Flight Trajectory

We obtain flight trajectory information by analyzing the results of tracking photographs at each observation point (south, central and east) in Shimohama. For example, the trajectory and velocity of the K-8-3 which was flight-tested on September 22, 1960 are shown in Figures 2 and 3. From these results the rocket flight angles were greater than the calculated values and agree with the values determined by radar.

2) Method of Analysis by High Speed Camera

In order to find flight characteristics at the time a rocket leaves the launcher, we analyzed the movie film, obtained the displacement-time characteristics, and obtained the velocity-time characteristics by differentiating these graphically. For example, Figures 4 to 7 indicate the results of analyses of the K-6H-1 flight tests on September 26, 1960.

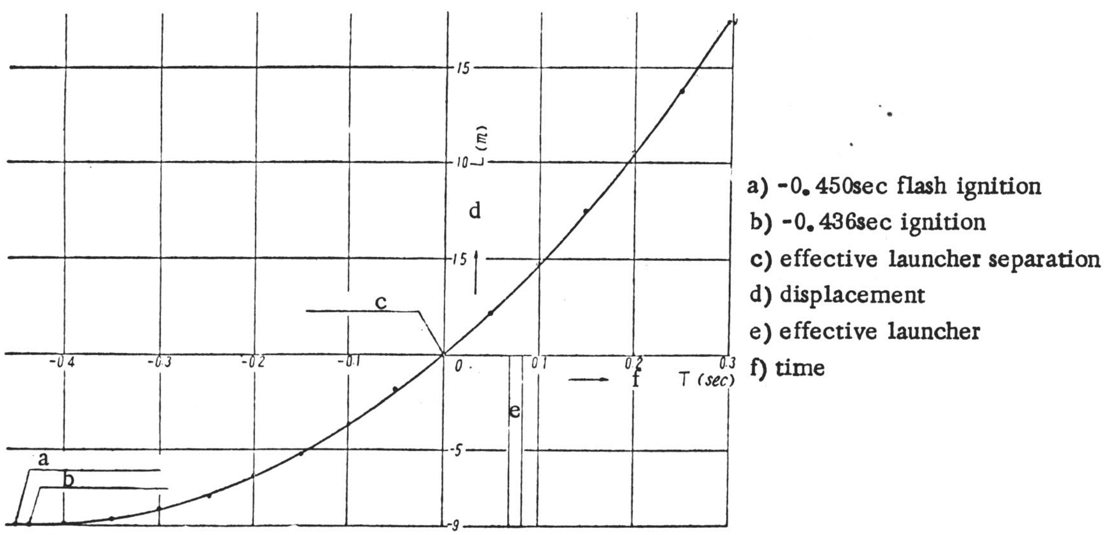
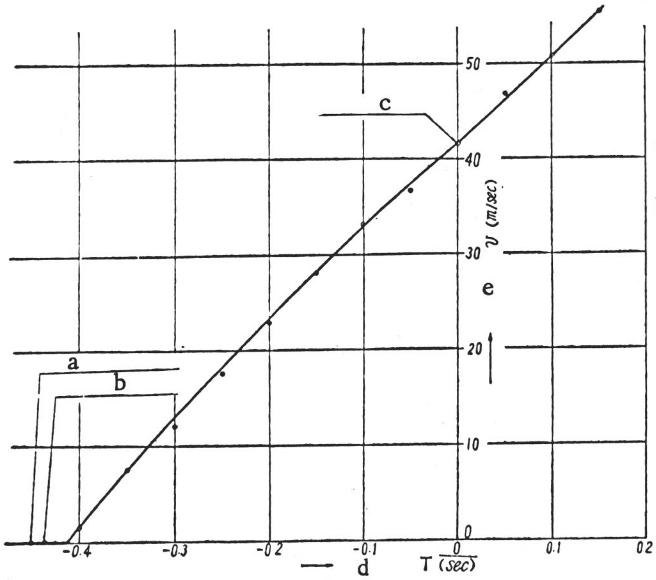


Figure 4. Results of Fastax Analysis of K-6H-1 displacement-time.

3) Analysis of Photographs Taken by Aerial Camera.

Photograph 8 [sic] is a photograph of the trajectory and a section of it obtained by observation with an aerial camera. According to it, we discovered that unusual motion occurred. Just before burn-out of the main rocket engine it shook cross-wise, and there was considerable deviation from the trajectory.



a) -0.450sec flash ignition

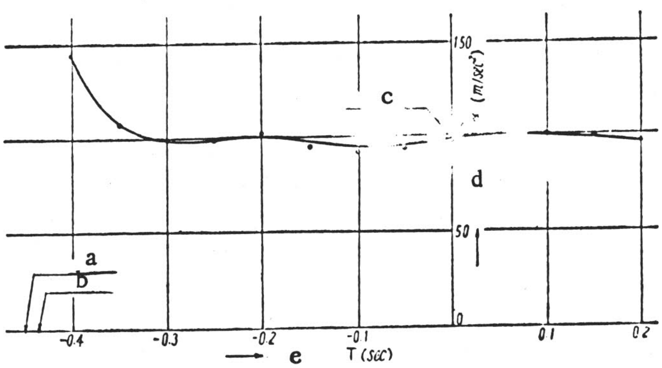
b) -0.436sec ignitor ignition

c) effective launcher separation

d) time

e) velocity

Figure 5. Results of Fastax Analysis of K-6H-1 velocity-time.



a) flash ignition

b) igniter ignition

c) effective launcher separation

d) acceleration

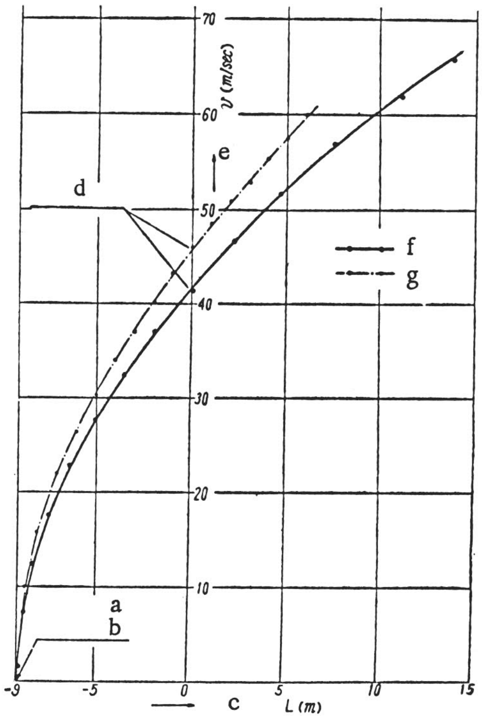
e) time

Figure 6. Results of Fastax Analysis of K-6H-1 Acceleration-Time.

4. Conclusions Regarding Analysis Results of Optical Observation

Optical observation played a role in almost every rocket experiment since the PENCIL rocket in the Spring of 1955, and provided valuable data for the analysis of rocket flight trajectories and all other phenomena. Since the above systems were carried out with limited funds and at the present stage, where rocket capability has improved, there are many things which have not satisfied our ideas, there are many points which must be discussed regarding future improvements and sounding methods.

Considering that optical observation plays a very important role, and that the flight altitudes and velocities of future rockets will be



a) flash ignition

b) igniter ignition

c) displacement

d) effective launcher separation

e) velocity

f) measured value

g) calculated value

Figure 7. Results of Fastax Analysis of K-6H-1 Velocity-Displacement.

increased, it is hoped from this standpoint that basic improvements will be made on equipment especially. The main feature of optical tracking is the recording of flight conditions by photography. It is extremely effective for a detailed analysis of phenomena. The Camera Observation Groups are under the supervision of The Maruyasu and Uemura Laboratories; the east and the north observation points under the Maruyasu Laboratory and the south and center high speed camera observation points are under the supervision of the Uemura Laboratory.

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