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A MADRE EVALUATION REPORT V

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ABSTRACT

The four-stage Trailblazer IIa was launched from Wallops Island for the purpose of studying phenomena associated with the high speed reentry bodies. The Madre radar observed portions of the trajectories of all four stages. The first stage was observed throughout the most of its flight. The second stage was observed on the way up until it left the antenna pattern and again on the way down when it reappeared in the antenna pattern. The other two stages were observed just prior to and during reentry.

PROBLEM STATUS

This is an interim report on one phase of the problem; work is continuing on this and other phases.

AUTHORIZATION

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DETECTION AND ANALYSIS OF TRAILBLAZER IIA

Madre is a high frequency coherent doppler radar located at the Chesapeake Bay Annex of the Naval Research Laboratory. It has been in operation for several months and is normally used for over-the-horizon detection of aircraft and rocket powered launches on the Atlantic and Pacific Missile Ranges. Details of the operation of Madre can be found in a number of reports. One of these is NRL Memo Report 1251, 1 December 1961, "A Madre Evaluation Report," J. M. Headrick, et al.

Recently Madre has been used a number of times for direct observation of launches of interest from Wallops Island, Virginia. The launch site is approximately 70 naut mi. from the Madre site. The Trailblazer IIa was such a launch.

The Madre parameters for the test were as follows:

Power Radiated	100 kw average
Frequency	26.6 Mc
Repetition Rate	180 pps
Pulse Length	350 μs
Antenna Gain	15 db one way
Antenna Direction	142^0

The Trailblazer rocket vehicle is a unique research tool which has been developed to study the physical phenomena which occur during reentry of high speed objects into the earth's atmosphere. Trailblazer IIa consisted of four stages. Two of the stages, namely a Castor engine and a Lance engine, were used to propel the vehicle upward, and the other two stages were used to fire the payload downward to provide a high speed reentry body. The high speed reentry body is a metal sphere with a 15-inch diameter. The design reentry speed is about 14,000 knots.

The vehicle was launched from Wallops Island on 14 December 1961 at 2:09:48 a.m. EST. The Madre radar observed portions of the trajectories of all four stages. The first stage was observed through most of its trajectory. The second stage was observed on the way up until it went out of the antenna pattern and again on the way down when it reentered the antenna pattern. The other two stages were observed just prior to and during reentry.

Complete trajectory post flight data has not been available, therefore Fig. 1 is a representation of the trajectories as reconstructed from Madre data. The broken lines represent the lobes in the vertical antenna pattern. The power in the fifth lobe is down by about 3 db and falls away rapidly with increases in vertical angle. This means that the second, third and fourth stages were not observed during large portions of their trajectories. In reconstructing the observed portions of the trajectories, the slant ranges were measured directly, the heights were calculated from the antenna lobe structure and the timing was taken from WWV. In reconstructing the unobserved portions of the trajectories, a parabolic path was assumed for the second stage. This was not the most accurate choice since the Madre radar was not in the plane of the trajectory, but it was made for simplicity.

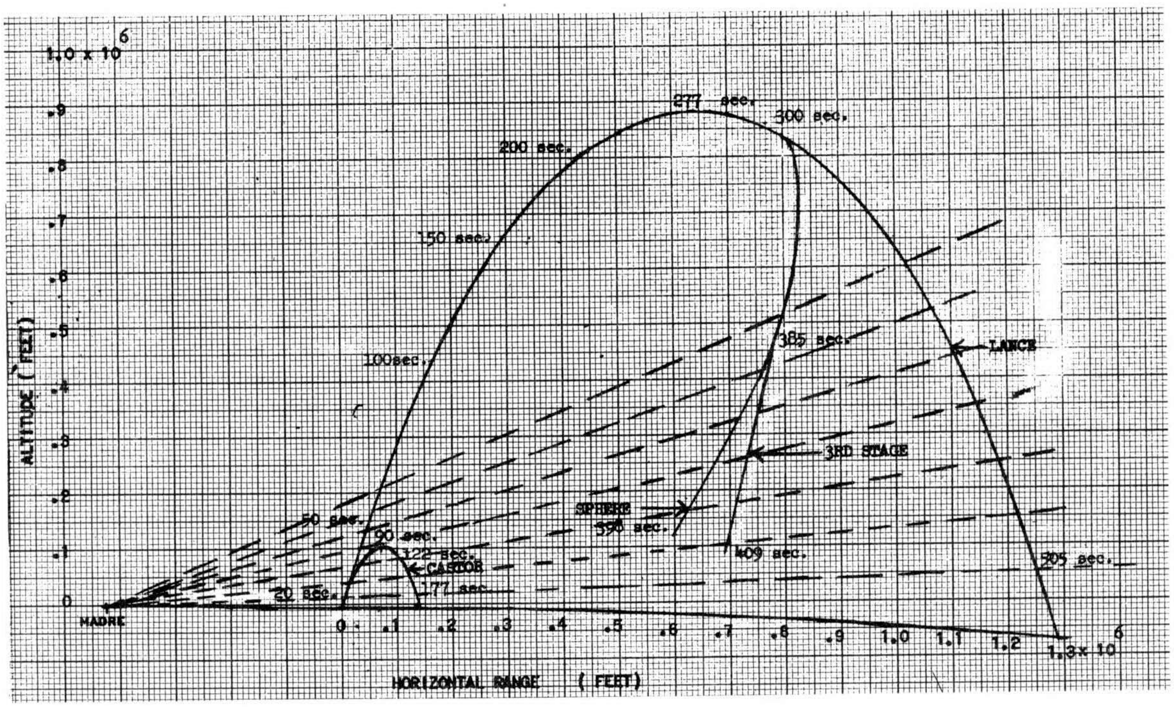

Fig. 1 - Trajectory geometry reconstructed from Madre data. Note the curved Earth.

Velocity calculations from this path would be inaccurate. Apogee was obtained from post-flight data supplied by Lincoln Laboratories, as was the times of the third and fourth stage ignitions. Air resistance was neglected.

For the purpose of understanding the remaining figures some details of the Madre receiving system will be given here. The receiver converts the received signals to a zero or near zero IF and these signals are passed through a set of comb filters which reject the ordinary backscatter clutter by rejecting the repetition rate frequency and all of its harmonics plus a few cycles on either side of these frequencies. The doppler frequency from each target will appear around zero frequency and around the repetition rate frequency and its harmonics. The recede and approach dopplers were not resolved for this test, although it can be done easily. Therefore, around zero frequency and 180 cps both recede and approach dopplers will appear. For example, in Figs. 2 and 3, there appears the approach doppler associated with zero frequency and the recede doppler associated with 180 cps. The data presented here were taken from the output of the comb filters and recorded on magnetic tape. A Kay Vibralyzer was then used to spectrum analyze the tape.

The Madre radar also employs a real time analysis system which was in operation during this test. The display of this analysis does not give a detailed time history and since they would not add substantially to the results presented here those data will not be presented.

Figures 2a, 2b, 3a and 3b are the complete records of the doppler versus time information that were obtained during the test. The thick black line near 180 cps is the doppler frequency of a local aircraft. The 60 cps lines associated with zero cps and 180 cps can be seen and they are caused by equipment. A number of very high acceleration targets will be noted throughout the spectrum-time record. These returns whose doppler changes by 90 cps in a second or so are from meteor entry ionization. The regular fading of the target is due to its presence in an antenna null. Details of the vertical antenna pattern have been published in NRL Memo Report 1316 of 1 February 1962, "A Madre Evaluation Report III (U)," J. M. Headrick, et al.

In Fig. 2a, the target is first detected at about T_0+10 seconds or 10 seconds after launch. Castor burnout, separation and Lance ignition were designed to occur at about T_0+35 seconds. The record shows a target acquiring more acceleration from about T_0+35 to about T_0+40 seconds. Lance burnout was designed to occur at about T_0+42 seconds. At about this time both the Castor and the Lance appear on the record. The Lance doppler is the weak signal that starts at about 30 cps at 42 seconds. It passes into an antenna null at T_0+43 seconds, emerges at T_0+45 seconds at about 60 cps, passes into another null from which it emerges at T_0+55 seconds and finally into another null from which it emerges at T_0+58 seconds and near 90 cps. It finally disappears at about T_0+62 seconds. This weak signal is more evident if the record is observed at grazing angle. The rest of the record from T_0+42 seconds to T_0+188 seconds shows the doppler associated with the ballistic trajectory of the first stage Castor at which time it drops out of the antenna pattern.

Figures 3a and 3b are the record of the other three stages on their return to earth. At about T_0+395 seconds, a weak skin track of the high velocity sphere appears and is followed by the enhancement due to reentry ionization from T_0+398 seconds to T_0+402 seconds. The slant range to this target was 170 naut mi.

At about T_0+404 seconds the skin track from the next to last stage appears and the reentry enhancement occurs at T_0+409 seconds. The slant range to this target was about 182 naut mi.

At about T_0+488 seconds the skin track from the Lance appears, decelerates and finally disappears at about 513 seconds. The slant range to this target was 270 naut mi.

Although this is the first report of a Trailblazer detection from the Madre site at the Chesapeake Bay Annex, other Trailblazer detections have been accomplished by a back-scatter radar from NRL, Washington, D. C. site. A summary of these may be found in NRL Memo Report 1176 of 1 June 1961, "High Frequency Radar Observations Made on Trailblazer 1g," S. R. Curley, et al. Some conclusions reached in this earlier report may have to be changed in the light of new data presented in this report.

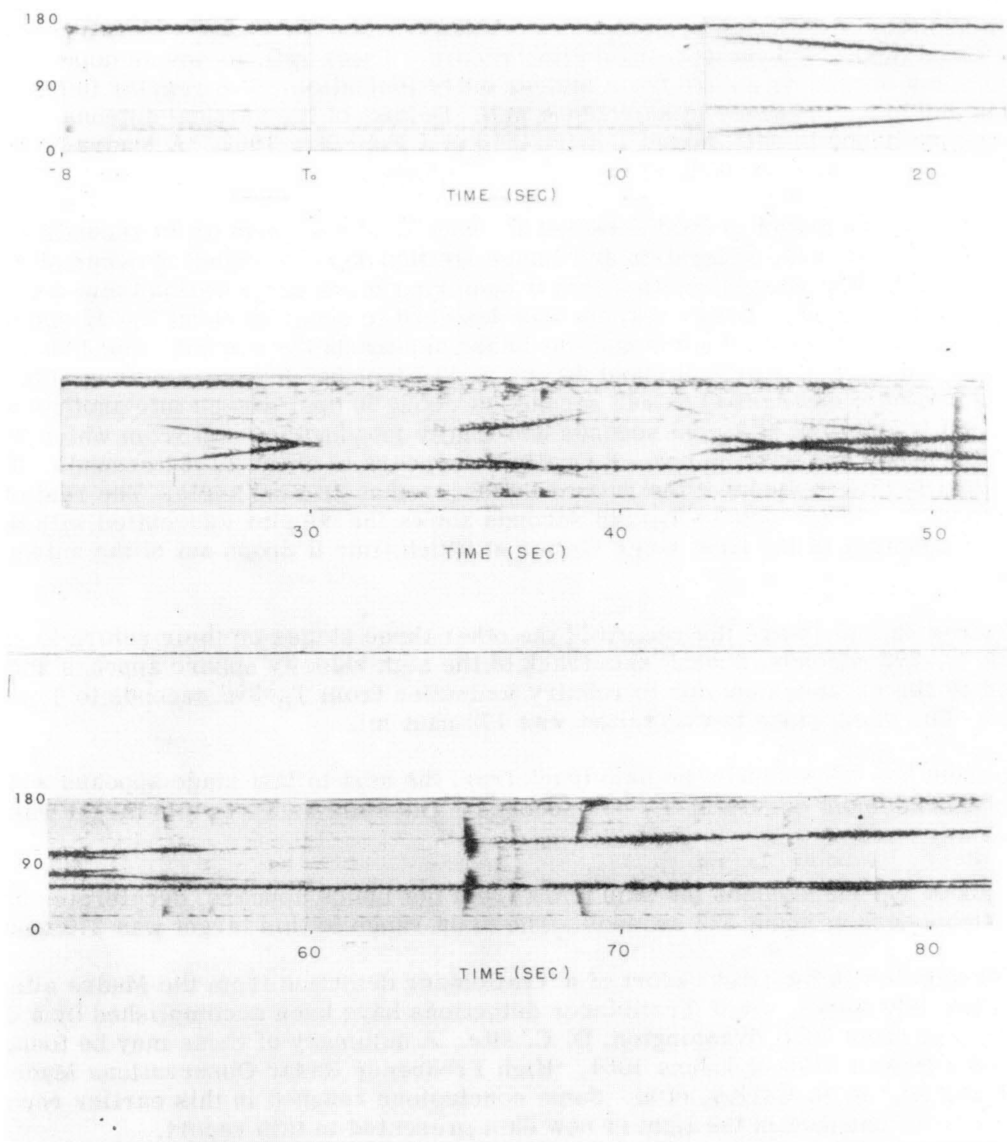

Fig. 2a - Doppler frequency versus time record for the launch phase. The ordinate represents time in seconds after launch time [T_o].

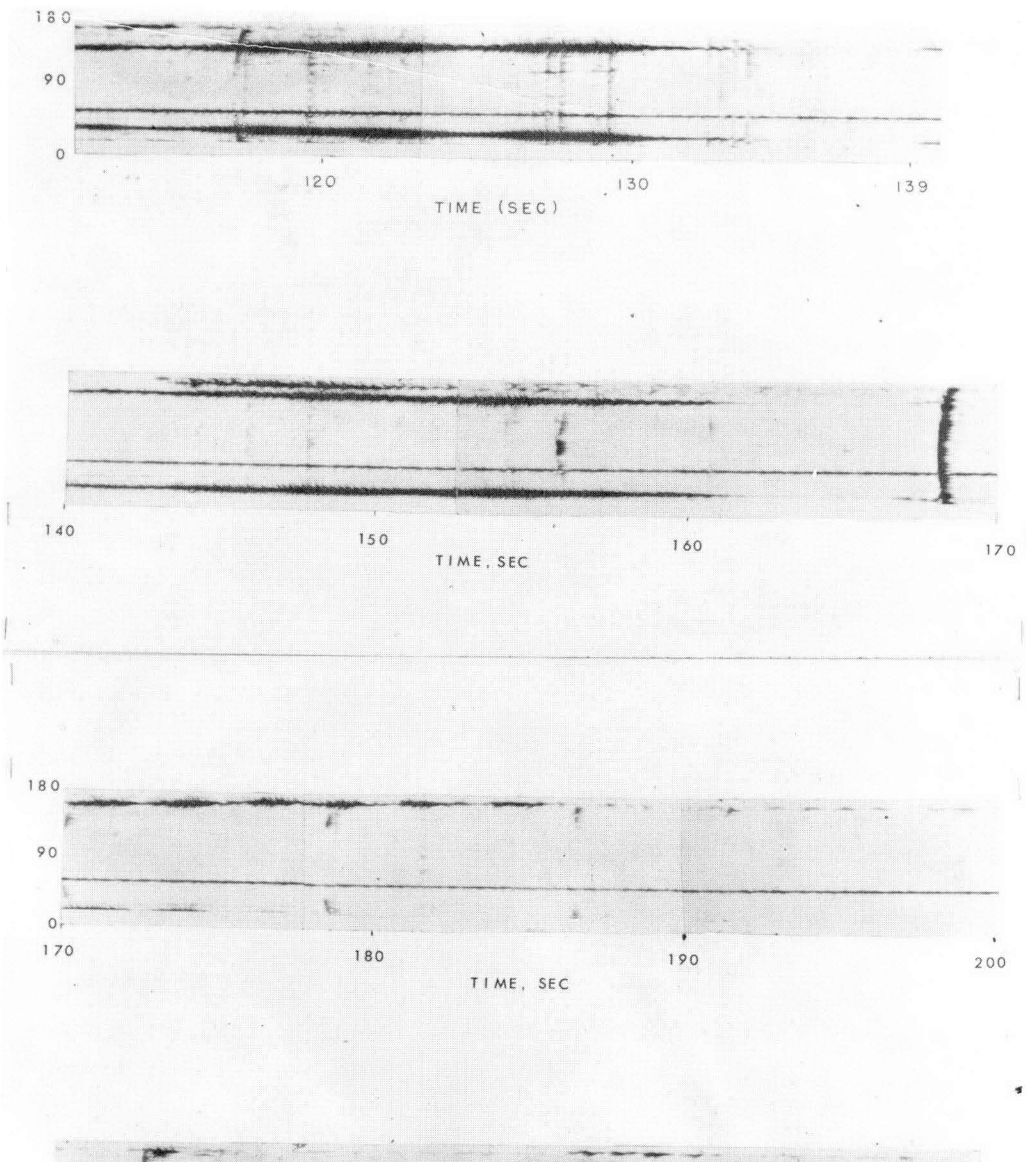

Figure 2b. Continuation of 2a.

Fig. 2b - Doppler frequency versus time record for the launch phase. The ordinate represents time in seconds after launch time [T_o].

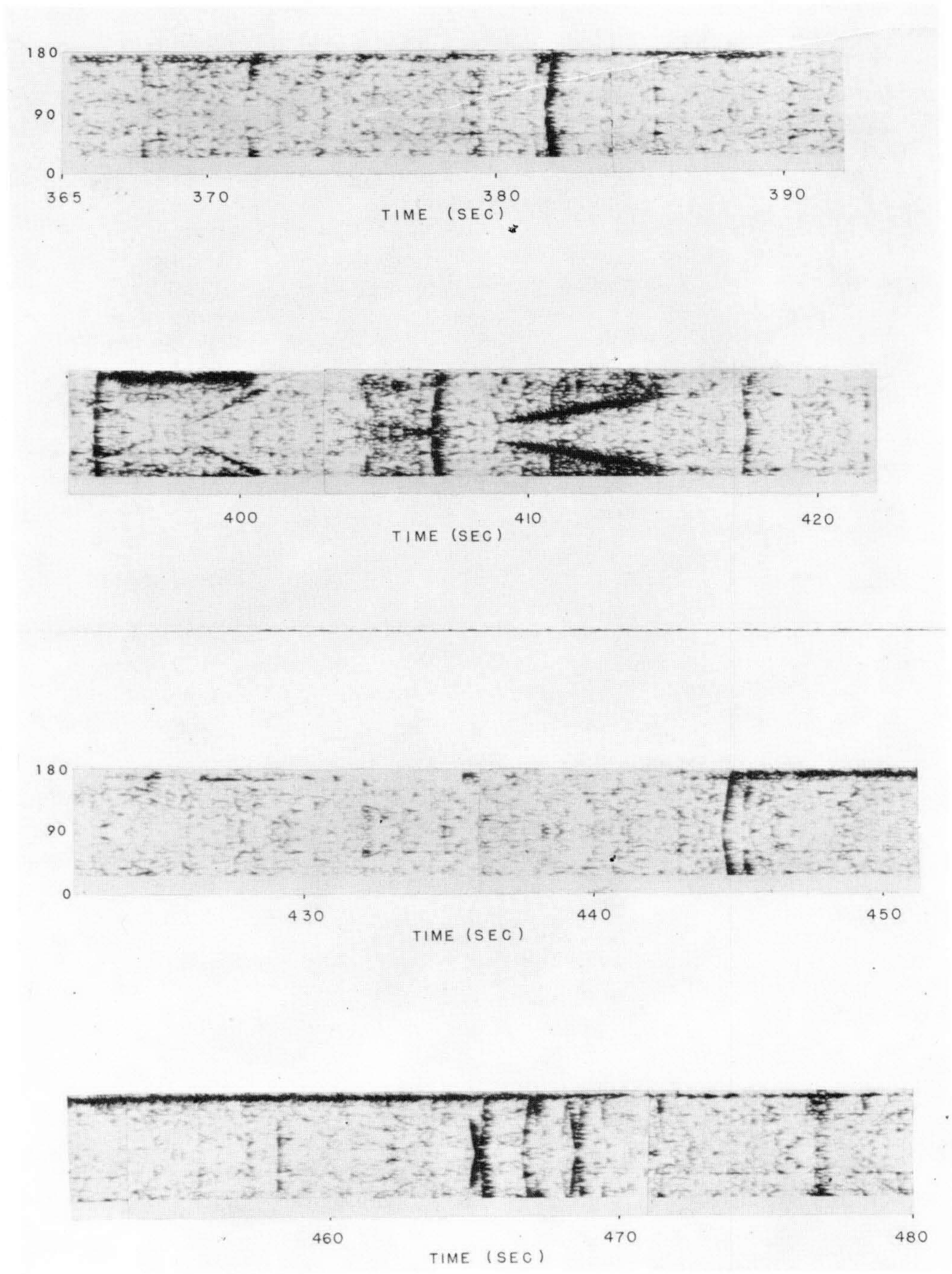

Fig. 3a - Doppler frequency versus time record for the reentry phase.

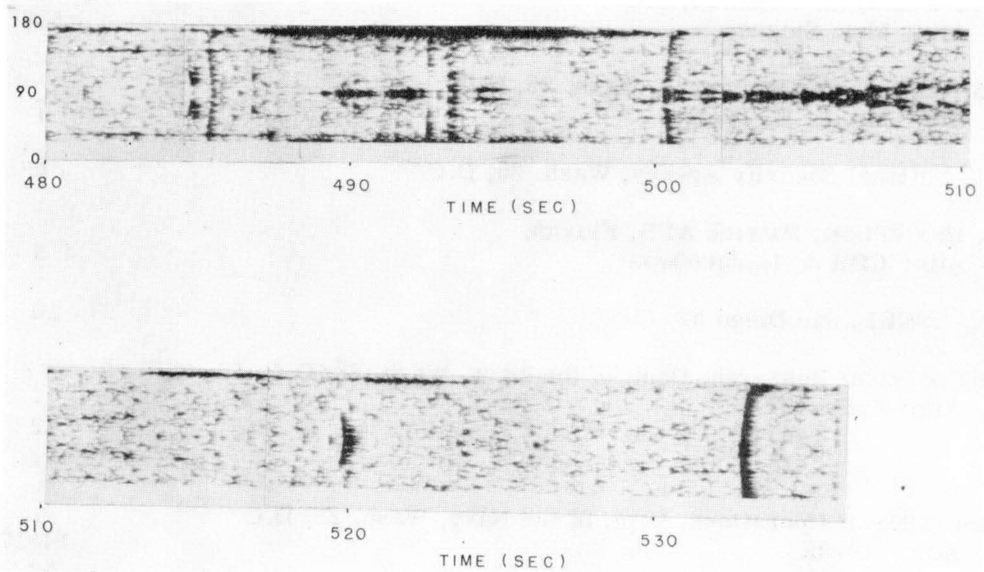

Fig. 3b - Doppler frequency versus time record for the reentry phase.

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