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MADRE EVALUATION

(Unclassified Title)

J. M. Headrick, S. R. Curley,
J. L. Ahearn, Jr., W. C. Headrick,
and F. H. Utley

RADAR DIVISION

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(7) THE DETECTION OF A POWERED MISSILE'S TRANSIT OF THE IONOSPHERE

(AMR TEST 5462) (S). (8)

(SECRET)

(10) J. M. Headrick, S. R. Curley,
J. L. Ahearn, Jr., W. C. Headrick
[redacted] F. H. Utley
Radar Techniques Branch

Radar Division

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ABSTRACT

(Secret)

The launch of an Atlas vehicle, AMR Test 5462, was monitored with the Madre system from the Chesapeake Bay Annex. Detection was accomplished via an over-the-horizon mode of propagation. Both real time and post flight analysis assess the ~~10^4~~ 10,000 square meters target return to be a typical ICBM launch signature.

PROBLEM STATUS

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

AUTHORIZATION

NRL Problem R02-23
Project RF 001-02-41-4007

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MADRE EVALUATION
(UNCLASSIFIED TITLE)

THE DETECTION OF A POWERED MISSILE'S TRANSIT
OF THE IONOSPHERE
(AMR TEST 5462)
(SECRET)

The Radar Techniques Branch of the Naval Research Laboratory has a long term investigative program on radar signal processing methods. The Madre radar is one of the developments in this program. This coherent doppler radar is a research system designed to demonstrate the feasibility of aircraft and missile detection and tracking via an ionospheric path. As a research system, the radar is in an almost continuous state of change, however, there are some basic attributes:

1. The received signals are sampled and packed by magnetic drum storage giving a time compression of about 83000 to one. The process gives a continuous capability of readout in each 1/180 second of the past 20 seconds of information.

2. Clutter rejection filters are applied prior to signal storage. These filters are matched to the usual earth's backscatter spectrum. Clutter to signal ratios in excess of 70 db can be accommodated.

In this report, some of the results of observing AMR Test 5462 (Atlas) are described. The primary goal of obtaining low altitude skin track and determining trajectory parameters was not attained due in part to insufficient illumination. However, the test results give a fairly typical example of the ICBM launch signature.

The Madre system at the NRL Chesapeake Bay Annex was operated on 16.16 mc, radiating 60 KW average power from a 15 db over an isotrope antenna directed at 185°. A 500 μsec pulse at a 90 pps rate was employed, and the receiver was gated such that ranges of 450 to 900 naut. mi. from each pulse were available for analysis and display. Signal processing of the drum recording was simple spectrum analysis of the past (stored) 20 seconds of received signals versus range. The resolution bandwidth was 1/3 cps. This analysis was displayed in real time as a doppler or range rate versus range plot in each two second period. In addition the clutter filtered signal channel was recorded on magnetic tape and a spectrum versus time analysis made from a playback. The resolution bandwidth for this latter analysis was about 3 cps.

At the time of missile launch, the one hop backscatter reception ran continuously from 800 to 2000 naut. mi. slant range. The ionosphere's true height was estimated to be 200 kilometers. In Fig. 1 the missile trajectory is given on a height versus ground range plot. Distances are given in kilometers. Times after launch are noted along the track. The limiting rays by which the region was illuminated are sketched on the plot. The lower ray is an estimate of the limiting line of sight path. The upper ray approximates the highest angle energy that is reflected from the ionosphere. If the diagram furnishes a fair representation of existing conditions, the missile

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first came in view at T+150 when it was 90 KM above the earth and remained illuminated until shielded by the ionosphere. Direct viewing became possible at about T+190.

In Fig. 2 a series of Madre analysis displays are shown. The time after missile launch is noted in the upper left corner of each display. This refers to the time the picture was taken. The display is a spectrum analysis of the prior 20 seconds of stored information, and thus signals are somewhat smoothed in time. Approximately 450 naut. mi. of range is given along the horizontal; with the receiver gating employed, the viewed, overlayed range intervals are 450-900 naut. mi., 1350-1800 naut. mi., etc. Some inadvertent time delays caused the pictured displays to have an unorthodox range distribution. This distribution is given in the following table.

Abscissa Marking	0	100	200	300	400	450
Nautical miles, first overlayed range interval	500	600	700	800	900 450	500
Nautical miles, second overlayed range interval	1400	1500	1600	1700	1800 1350	1400
Nautical miles, third overlayed range interval	2300	2400	2500	2600	2700 2250	2300

The vertical scale covers 45 cps of doppler (approach and recede overlayed) with 0.5 on the scale corresponding to zero doppler. The 45 cps line is at about 9.5 on the vertical scale. The first picture (T+156) is almost free of missile returns. At 9.3 and 5.3 on the vertical scale the faint horizontal lines plus target-like manifestations at 360, 5.3 and 360, 9.3 are spurious signals generated by a lack of symmetry in the signal sampling. The group of signals at various ranges and at 6.3 on the vertical scale are due to undesired 60 cps hum in the radar. The target at 390, 2 thus was a return from 890 naut. mi. with a 10 cps doppler (180 knots) and was an echo from either an aircraft or a meteor trail. This display at T+156 is a fairly representative Madre-eye view of the world; there was one exception, the first missile returns are starting at the top of the screen and 220 on the abscissa. At T+162 the missile returns are more in evidence. By T+170 the missile returns have practically filled the available 45 cps doppler at 220 on the horizontal (720 naut. mi. range) and are intense. The returns persist through T+225, but are fading at T+235 and have disappeared at T+245. The returns from the missile region were spectacular, and the echoing cross section is estimated as greater than 10^4 square meters. The system sensitivity was such that missile skin echoes seemed possible, however, the intense and doppler diffuse reflections from the charge gradient surrounding the exhaust effectively prevented any skin tracking. An additional missile manifestation is present in the pictures of Fig. 2; this is the "flutter" (backscatter that comes around the rejection filter nulls due to the missile perturbed ionosphere). The first patch appears in the picture of T+215 at 0, 2 and at T+225 has spread from 0, 0.5 to 0, 4. This patch of backscatter which is only partially seen due to the gating must have a range of either 1400 naut. mi. or 2300 naut. mi. Based on past missile observations this flutter is identified as that associated with the lower angle rays which have an approach doppler. At T+215 another patch of flutter is starting at 420, 1. This flutter builds up with time until the 45 cps available doppler display is filled at T+245. Again the gating chops off part of the flutter presentation. Based on prior experience this latter example of flutter is considered to have a range of 1370 naut. mi., to be associated with the higher angle rays by which backscatter was received, and to have a recede doppler. The amplitude is certainly quite large, and the perturbed path existed strongly for several minutes.

A spectrum analysis of the clutter filtered zero frequency IF signal channel reveals a more detailed time structure than the Madre analysis as employed for Test 5462. The echoes from the charge gradient surrounding the exhaust were analyzed and the results are presented in Figs. 3A and 3B. Doppler spectrum is given on the ordinate, time after launch on the abscissa, and intensity of the record is proportional to signal strength. For the analysis a 50 naut. mi. range gate centered on 710 naut. mi. was used. To be explicit, the data and the nature of the spectrum analysis can be detailed. The data are the receiver zero frequency IF or coherent bi-polar video signals; zero and near zero frequencies have been eliminated by filter rejection notches placed upon the carrier frequency and the sidebands at carrier ± 90 cps, ± 180 cps, ± 360 cps, etc. Thus, echoes from a constant relative velocity target would be in the form of a sequence of pulses at a near 90 pps rate and with the pulse train envelope having the doppler frequency. The spectrum analysis is the result of passing the signal data through a 3 cps bandwidth filter. The analysis filter has been placed on all frequencies between 30 cps and 120 cps in the case of this test. As an example of results, a constant velocity target with a 30 cps doppler would show as a straight horizontal line at 30 cps, at 90-30 = 60 cps, and at 90+30 = 120 cps. Of course all of the available doppler information is contained in the first 45 cps; however, the redundancy is sometimes helpful in picking out echo structure. As was mentioned earlier there was considerable undesired 60 cps hum in the system at the time of the test; this hum appears as a strong double target with a 60 cps doppler. These hum lines can be seen at 0+60, 90±60, and 180-60 cps or at 30, 60, and 120 cps. Now, in Figs. 3A and 3B, times are shown starting at T+0 and running continuously through T+295 sec. The missile region big echoes consist of a strong burst at T+157, again at T+160, and a lighter burst at T+164. At T+167 strong returns start and by T+178 they have faded to a low level. At T+182 another short lived intense burst occurs, and at T+194 strong returns are developing that terminate abruptly at T+230. It can be noted that the 45 cps available doppler spread was filled such that no preferred frequencies were evident. However, in other tests, especially where a higher pulse rate was employed, a concentration of energy near the missile doppler has been noted. Close examination of Figs. 3A and 3B suggests that some low level missile effects started as soon as T+120 and persisted until T+250.

The large scale missile effects observed during this test are typical in NRL experience. That is, when the F region of the ionosphere is refracting the radar rays to the earth, two missile signature effects occur in this time order; (1) reflections from the exhaust boundary and (2) flutter perturbations in the backscatter. Powered ICBM transit of the ionosphere invariably yields such a signature when illumination is as given above; although not thoroughly tested, it seems clear that this signature should be recognizable in the second hop region. Of course, there are more facets to the signature than have been outlined herein, and the Madre system analysis and presentation is not optimized for this type of signature recognition. However, for the problem of determining that a missile has been launched with conditions similar to those on this test (AMR 5462), it can be stated that transit of the ionosphere by a powered ICBM creates a unique, recognizable signature when properly illuminated. The signature is readily distinguished from natural phenomenon, with the possible exception of an occasional auroral manifestation. The area of ignorance is in how well can a large region of the earth be properly illuminated and in how can deficiencies in coverage be recognized.

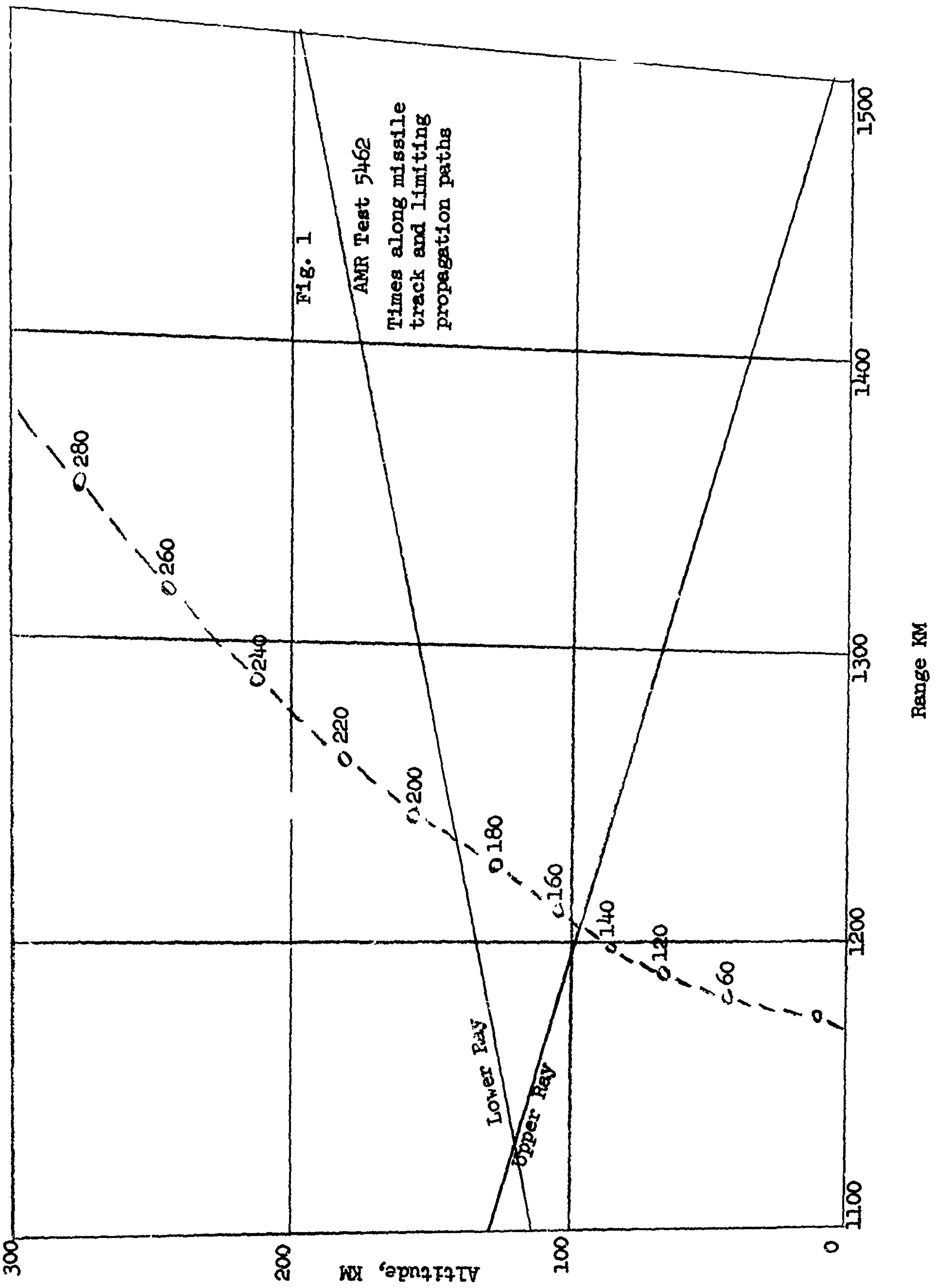
Fig. 1
AMR Test 5462
Times along missile track and limiting propagation paths
Lower Ray
Upper Ray
280
260
240
220
200
180
160
140
120
60
Range KM
1100
1200
1300
1400
1500
Altitude, KM
300
200
100
0

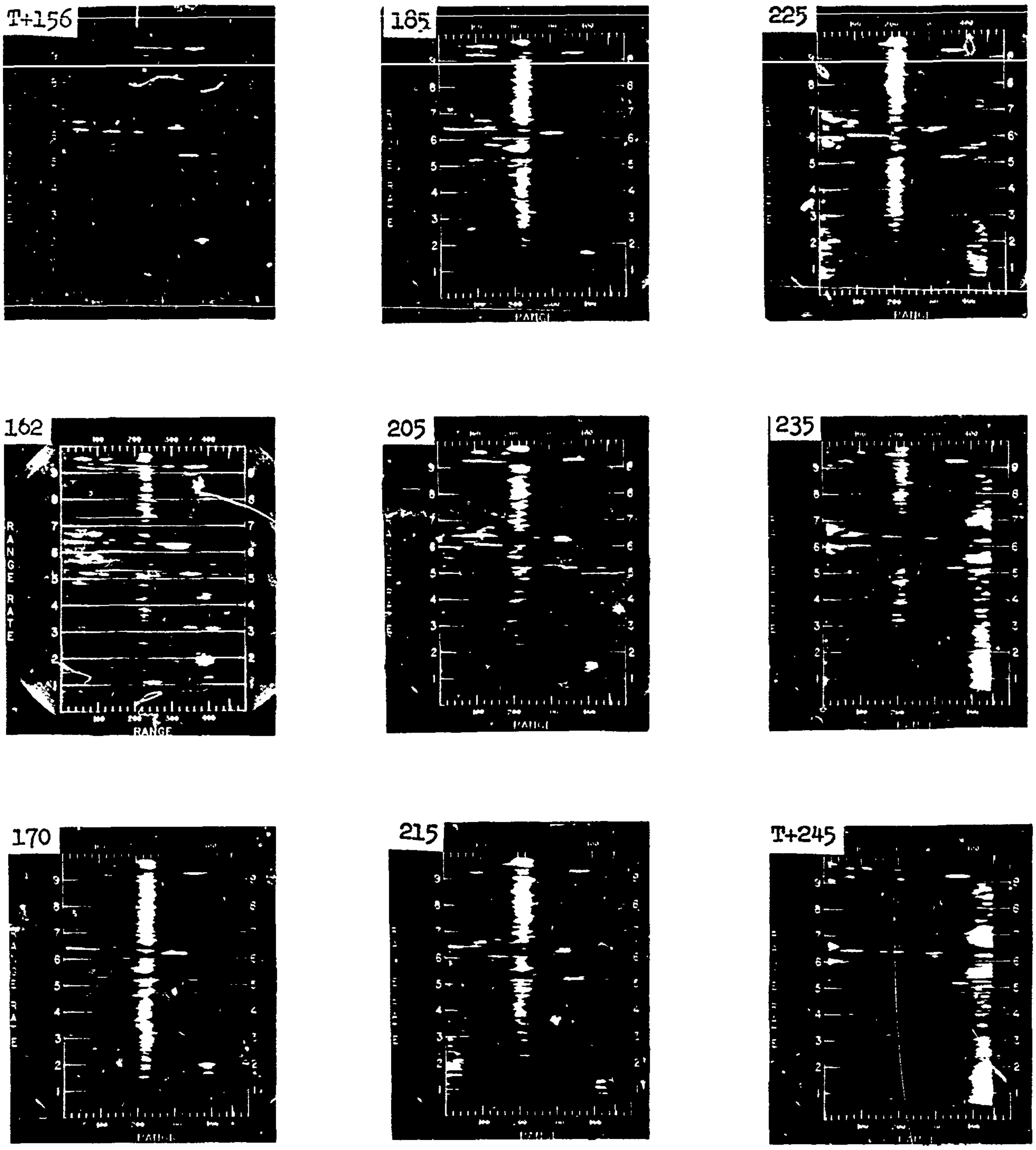

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Fig. 2 - Test 5462. Doppler versus range for indicated seconds after launch. Abscissa displays approximately 450 to 900 NM; 200 on the scale corresponds to a range of 700 NM. Ordinate displays 0 to 45 cps. 0.5 on the scale corresponds to 0 doppler and 9.5 corresponds to 45 cps.

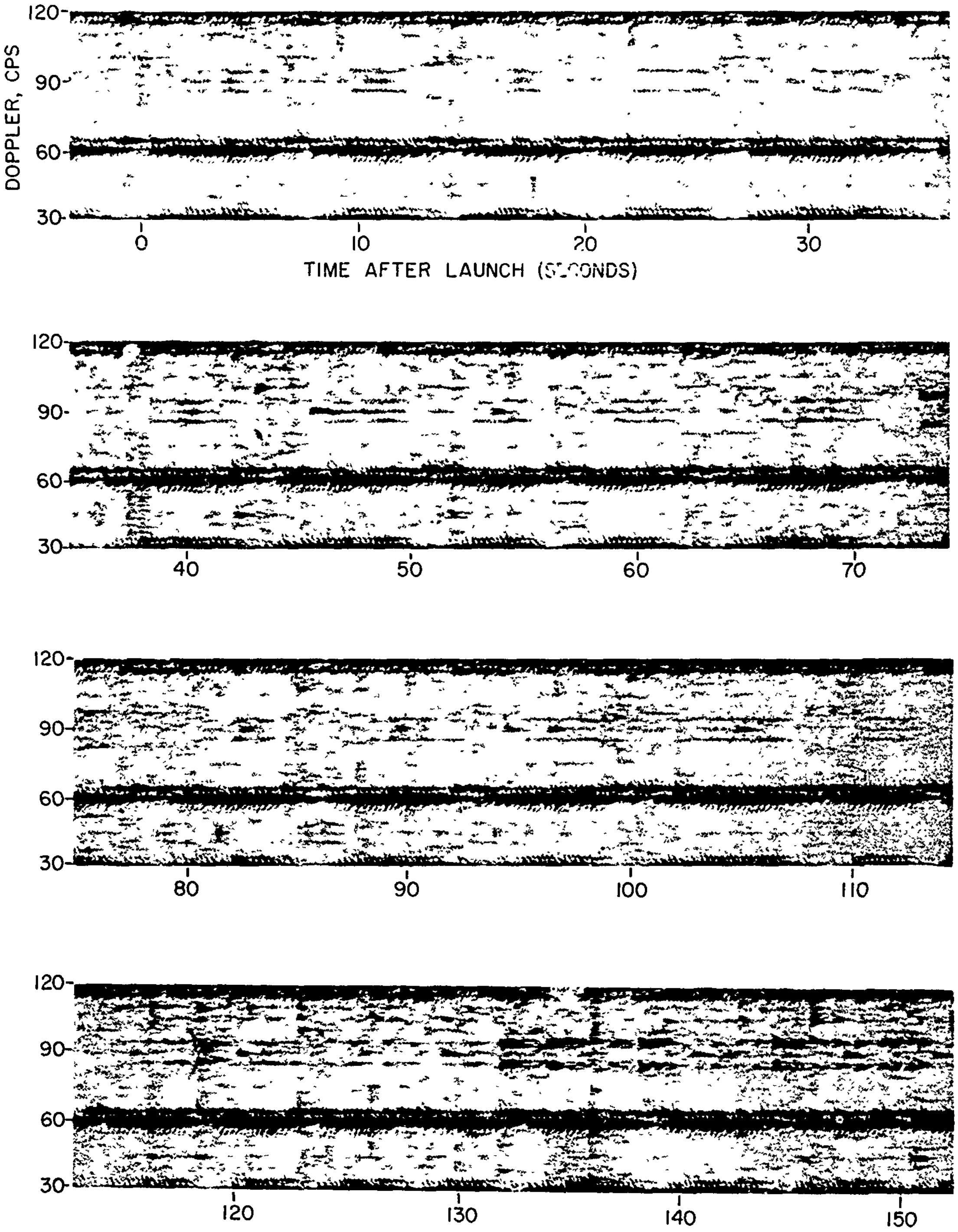

Fig. 3A - A doppler spectrum intensity versus time after launch plot

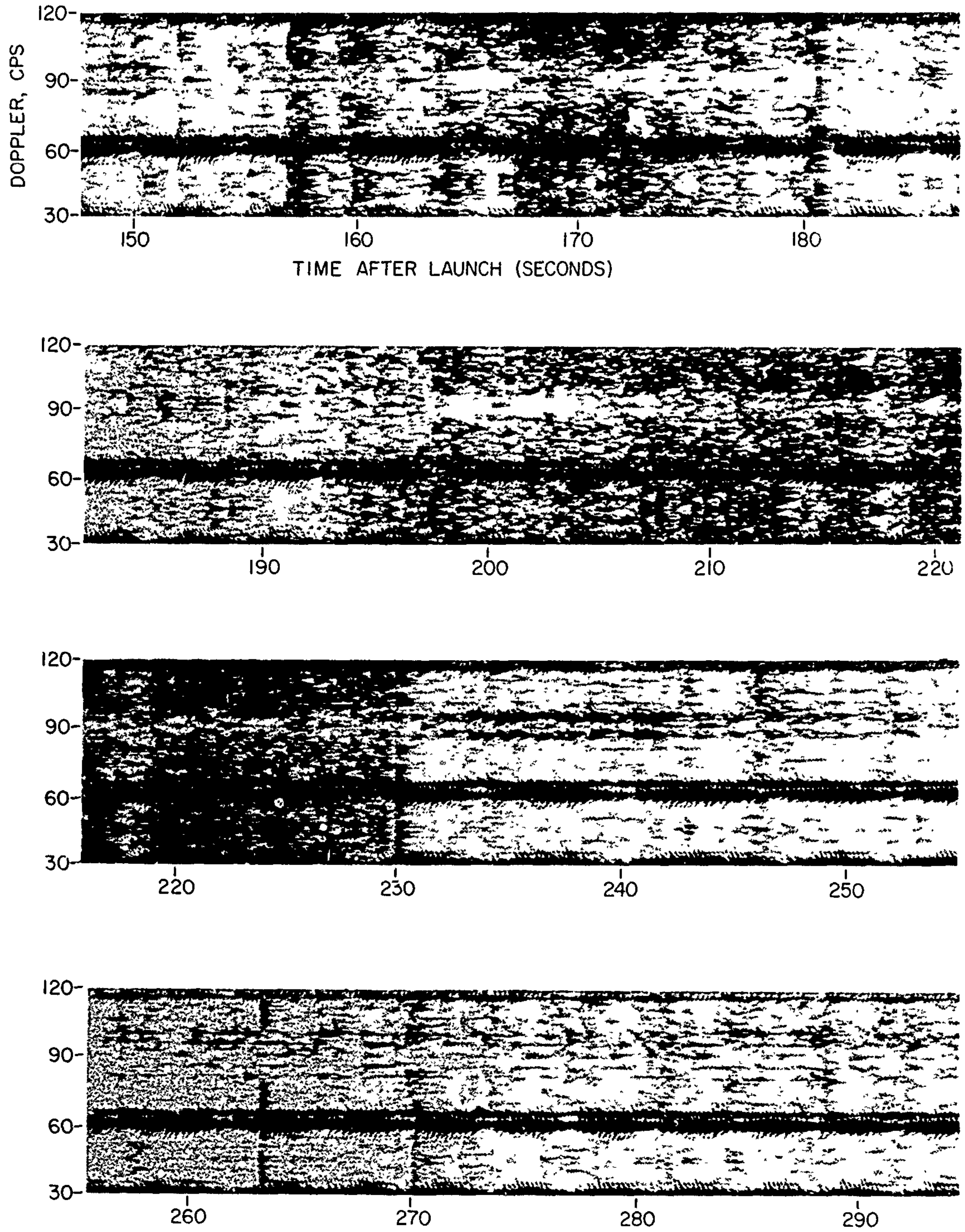

Fig. 3B - A doppler spectrum intensity versus time after launch plot

MEMORANDUM

20 February 1997

Subj: Document Declassification

Ref: (1) Code 5309 Memorandum of 29 Jan. 1997
(2) Distribution Statements for Technical Publications NRL/PU/5230-95-293

Encl: (a) Code 5309 Memorandum of 29 Jan. 1997
(b) List of old Code 5320 Reports
(c) List of old Code 5320 Memorandum Reports

1. In Enclosure (a) it was recommended that the following reports be declassified, four reports have been added to the original list:

Formal: 5589, 5811, 5824, 5825, 5849, 5862, 5875, 5881, 5903, 5962, 6015, 6079, 6148, 6198, 6272, 6371, 6476, 6479, 6485, 6507, 6508, 6568, 6590, 6611, 6731, 6866, 7044, 7051, 7059, 7350, 7428, 7500, 7638, 7655. Add 7684, 7692.

Memo: 1251, 1287, 1316, 1422, [redacted], 1500, 1527, 1537, 1540, 1567, 1637, 1647, 1727, 1758, 1787, 1789, 1790, 1811, 1817, 1823, 1885, 1939, 1981, 2135, 2624, 2701, 2645, 2721, 2722, 2723, 2766. Add 2265, 2715.

The recommended distribution statement for the these reports is: **Approved for public release; distribution is unlimited.**

2. The above reports are included in the listings of enclosures (b) and (c) and were selected because of familiarity with the contents. The rest of these documents very likely should receive the same treatment.

J. M. Headrick
J. M. Headrick
Code 5309

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