

UNCLASSIFIED

AD NUMBER
AD346383
CLASSIFICATION CHANGES
TO: unclassified
FROM: confidential
LIMITATION CHANGES
TO: Approved for public release, distribution unlimited
FROM: Controlling DoD Organization: Director, U.S. Naval Research Laboratory, Washington, DC.
AUTHORITY
NRL ltr dtd 17 Sep 2007; NRL ltr dtd 17 Sep 2007

THIS PAGE IS UNCLASSIFIED

UNCLASSIFIED

AD NUMBER
AD346383
CLASSIFICATION CHANGES
TO
confidential
FROM
secret
AUTHORITY
30 Nov 1975, DoDD 5200.10

THIS PAGE IS UNCLASSIFIED

AD 346383L

DEFENSE DOCUMENTATION CENTER

FOR

SCIENTIFIC AND TECHNICAL INFORMATION

CAMERON STATION, ALEXANDRIA, VIRGINIA



NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

NOTICE:

THIS DOCUMENT CONTAINS INFORMATION
AFFECTING THE NATIONAL DEFENSE OF
THE UNITED STATES WITHIN THE MEAN-
ING OF THE ESPIONAGE LAWS, TITLE 18,
U.S.C., SECTIONS 793 and 794. THE
TRANSMISSION OR THE REVELATION OF
ITS CONTENTS IN ANY MANNER TO AN
UNAUTHORIZED PERSON IS PROHIBITED
BY LAW.

RET

SECRET

NRL Report 6015
Copy No. 78

346383

HF RADAR ECHOES AND REFRACTION EFFECTS DUE TO WATER AND PROPELLANT RELEASES IN THE IONOSPHERE

[UNCLASSIFIED TITLE]

J. M. Headrick, S. R. Curley, J. L. Ahearn,
J. R. Davis, and E. W. Ward

Radar Techniques Branch
Radar Division

November 22, 1963



U S NAVAL RESEARCH LABORATORY
Washington D C

RET

SECRET

346383L

CATALOGED BY DDC

AS AD NO. 1

See also with COMINT 6510-100
This report is classified as CONFIDENTIAL
by direction

SECRET

SECURITY

This document contains information affecting the national defense of the United States within the meaning of the Espionage Laws, Title 18, U.S.C., Sections 793 and 794. The transmission or revelation of its contents in any manner to an unauthorized person is prohibited by law.

SECRET

SECRET

CONTENTS

Abstract	ii
Problem Status	ii
Authorization	ii
INTRODUCTION	1
DISCUSSION OF MISSILE RELEASE- ASSOCIATED PHENOMENA	2
AMR Test 2508 - Atlas (E)	2
AMR Test 0811 - Jupiter	4
AMR Test 5051 - Saturn (SA-3)	6
PMR Test 291201 - Thor-Agena	10
CONCLUSION	13
REFERENCES	13

SECRET

ABSTRACT
[Unclassified]

High-frequency radar observations of non-igniting rockets traversing the ionosphere often yield large range-discrete echoes and ionospheric path perturbations during periods in which the venting of fuel components or fluid ballast takes place. A study of several missile launchings during which such releases occurred has been conducted, and an analysis of the experimental data which takes into account the propagation conditions surrounding each launching is presented.

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
MIPR (30-602)-63-2929, 2928, 2995
RF001-02-41-4007

Manuscript submitted September 16, 1963.

SECRET

SECRET

HF RADAR ECHOES AND REFRACTION EFFECTS DUE TO WATER AND PROPELLANT RELEASES IN THE IONOSPHERE [Unclassified Title]

INTRODUCTION

High-frequency radar observations of missiles traversing the ionosphere often exhibit brief, large echo cross sections during periods in which the rocket engines reportedly are not burning. The appearance of these unexpectedly large echo cross sections commonly occurs during staging or immediately following engine cutoff. It is the purpose of this report to present evidence of the occurrence of ionospheric perturbations and strong hf radar echoes during periods in which there is a reasonable certainty that rocket motors are not burning.

The study was conducted with the NRL Madre radar, a coherent pulse-doppler system possessing receiver rejection filters matched to the usual spectrum of the earth's backscatter. The overall characteristics of the Madre radar are more thoroughly described elsewhere (1-8); a brief review of qualities pertinent to the ensuing discussion follows.

The coherent pulse-doppler system utilizes a comb-filter rejection technique to eliminate the strong earth backscatter signal immediately adjacent to both the center frequency and the pulse repetition frequency (prf) lines. The system possesses a receiver transfer function as shown in Fig. 1(a). Notches are placed within the receiver bandwidth upon the radar carrier frequency and upon each prf sideband. Figure 1(b) shows a detailed sketch of one such rejection notch used in the Madre radar. It can easily be seen that backscatter-associated clutter-to-signal ratios approaching 70 db may be accommodated.

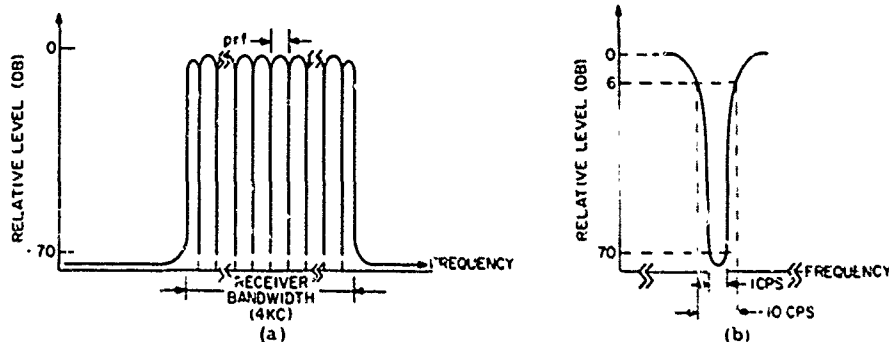


Fig. 1 - (a) Transfer function of Madre receiver utilizing
(b) comb rejection filters

Later in the receiver system the target signal is converted to a zero-frequency intermediate frequency by the use of a synchronous detector. Two forms of spectrum analysis then are possible. One of these two analysis processes is illustrated in Fig. 2. The zero-frequency i-f signal is range-gated to exclude the effects of undesired targets, passed through a second comb filter which provides an additional 50 db of backscatter rejection,

SECRET

and spectrum-analyzed with the aid of a Kay Sonograph. The resultant is a doppler-intensity-time plot of the echo spectrum, with doppler frequency appearing on the ordinate, time on the abscissa, and signal amplitude appearing as the degree of shading (intensity) on the plot. Due to the inherent limitations of a pulse-doppler radar, doppler-shifted traces appear about the prf-induced lines as well as about the center frequency, and hence doppler frequency is unambiguous only insofar as it remains below one-half the prf. The spectrum analysis provides a doppler resolution of 3 cps. The second form of spectrum analysis utilizes a rotating magnetic drum upon which short samples of the coherent echoes are stored and read off sequentially after a 20-second storage period, providing a continually updated time-compressed presentation of the previous 20 seconds of received information. This presentation appears as a range-doppler-intensity plot, with doppler on the ordinate, range on the abscissa, and amplitude appearing as intensity. Both types of spectrum analysis are presented in the following discussion.



Fig. 2 - Block diagram of a spectrum-analysis system used with Madre radar

DISCUSSION OF MISSILE RELEASE-ASSOCIATED PHENOMENA

During the period from October 1960, until November 1962, four missile launches were carried out at the Atlantic Missile Range (AMR) and the Pacific Missile Range (PMR) which gave rise to path-perturbations and strong hf radar echoes at times when no rocket motors were burning, but when known venting of oxidant or release of fluid ballast was occurring. Upon occasion these path perturbations and radar echoes took on a marked resemblance to the type of effect normally associated with burning rocket motors. The effects detected by the Madre system during each of the four launches are discussed below.

AMR Test 2506 - Atlas (E)

T_0 : 3:15:34 p.m. EDT, 11 Oct. 1960

Frequency: 26.6 Mc

Pulse repetition rate: 180 pps

Pulse duration: 250 μ sec

Radiated power: 1.5 kw (average)

Antenna gain: 14 db over an isotrope

Postflight data indicates that the sustainer engine cut off 150 seconds after liftoff and that the vehicle itself exploded 5 seconds later. At this time, 155 seconds after liftoff, the vehicle was at an altitude of 112 km and traveling at 1.5 km/sec. Assuming that the remaining tankage and propellant followed a ballistic trajectory, these should have reached an altitude of 180 km at $T_0 + 240$ seconds and should have continued upward to an apogee of 211 km.

The illumination geometry, determined from observation of ground backscatter, and the missile's trajectory are sketched in Fig. 3. This illustration indicates that the ballistic path of the remnants was visible to the Madre radar for altitudes above 180 km.

Figure 4(a) shows the effects of a path perturbation which began at $T_0 + 240$ seconds, the time at which propagation conditions indicate that the missile remnants entered the Madre antenna beam. This illustration is a spectrogram of earth backscatter returns

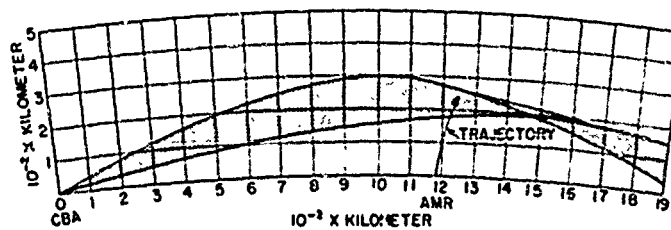


Fig. 3 - Illumination geometry and missile trajectory for AMR Test 2508

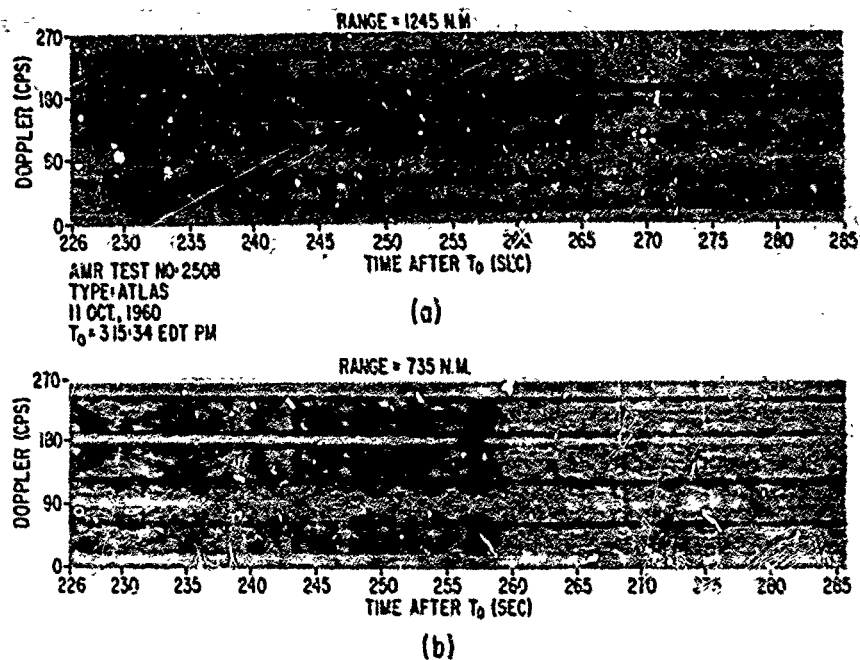


Fig. 4 - Doppler-intensity-time records of (a) path perturbation and (b) diffuse echo associated with exploding missile of AMR Test 2508

driven outside the clutter rejection filters by the path perturbation. Backscatter is driven 20 cps from the 180 cps line at $T_0 + 240$ seconds and gradually relaxes to normal over a period approaching one minute. This perturbation was quite similar to the type produced by a missile actually burning through the F-region. Figure 4(b) shows a reflection at $T_0 + 256$ seconds which exhibits discreteness in range and diffusion in doppler. This reflection lasts approximately 2 seconds and presumably represents an echo from a charge gradient moving up through the ionosphere at the approximate range of the ballistic missile fragments.

AMR Test 0811 - Jupiter

T_0 : 1:17:53 p.m. EDT, 18 Apr. 1962

Frequency: 15.595 Mc

Pulse repetition rate: 180 pps

Pulse duration: 200 μ sec

Power: 75 kw (average)

Antenna gain: 11 db over an isotrope

In this flight all missile functions were normal until $T_0 + 153$ seconds. At that time fuel depletion was reached due to an excessively fuel-rich propellant mixture, and normal guidance cutoff was not achieved. Oxygen venting is certain to have continued until the supply was exhausted (or until $T_0 + 522$ seconds when the guidance computer initiated cutoff procedures). Backscatter coverage ran from 760 to 1250 naut mi in range with a strong peak at 810 naut mi. The coverage suggested by this backscatter distribution is sketched in Fig. 5.

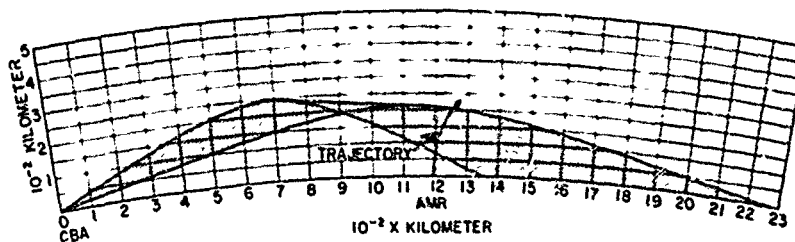


Fig. 5 - Illumination geometry as indicated by backscatter observations at the Madre site, and missile trajectory for AMR Test 0811

Figure 6 is the range-gated doppler-intensity-time record. The first reflections occurred at $T_0 + 162$ seconds when the missile was at an altitude of 131 km. It is worthy of note that the backscatter observations represented in Fig. 5 indicate that the burning rocket actually entered the beam of the Madre antenna when it achieved an altitude of 70 km at $T_0 + 130$ seconds. No reflection or path perturbation was detected, however, until $T_0 + 162$ seconds, 9 seconds after the fuel was depleted. The character of the effect evident at $T_0 + 162$ seconds was similar to that associated with a burning rocket traversing the E-layer. This reflection continued until $T_0 + 190$ seconds when the missile had achieved an estimated altitude of 200 km. The slope of the doppler envelope apparent near the start

of the signature corresponds roughly to that of the expected missile doppler. The abrupt disappearance of the target at $T_0 + 190$ seconds probably was due to the missile's exit from the radar-illuminated region. The slowly shifting doppler lines near 180 cps are due to aircraft echoes from the range interval under examination.

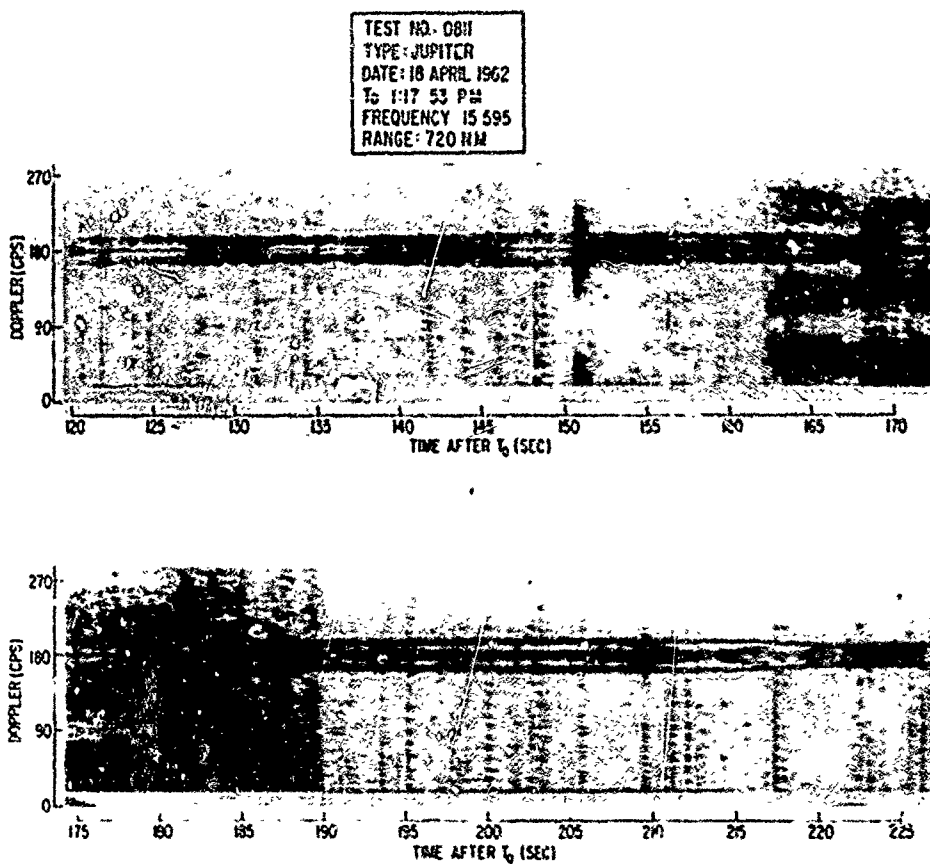


Fig. 6 - Doppler-intensity-time record of diffuse echo due to oxygen venting associated with AMR Test 0811

AMR Test 5051 - Saturn (SA-3)

T_0 : 12:45:02 p.m. EST, 16 Nov. 1962

Frequency: 18.036 Mc

Pulse repetition rate: 90 pps

Power: 75 kw (average)

Pulse duration: 300 . sec

Antenna gain: 12 db over an isotrope

The illumination suggested by backscatter coverage is sketched in Fig. 7. This vehicle was ballistic above 100 km. At $T_0 + 292$ seconds, when the missile reached its apogee of 167 km, 192,528 pounds of water were released into the ionosphere.

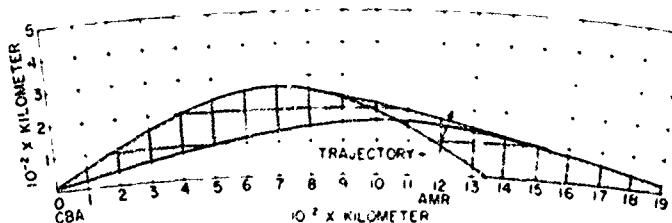


Fig. 7 - Illumination geometry as indicated by backscatter observations at the Madre site, and missile trajectory for AMR Test 5051

Figure 8 is a doppler-intensity-time presentation of echoes from a range gate centered on the missile itself. A large reflection may be seen in this illustration beginning precisely at $T_0 + 292$ seconds, the exact time of the water release. This reflection persisted until $T_0 + 365$ seconds and at its peak displayed an echo cross section of $4 \cdot 10^8$ square meters.

Figure 9 is a doppler-intensity-time presentation of echoes from a range gate centered on the backscatter returns from a one-hop distance at which ionospheric reflection would have occurred in the region in which the ionospheric perturbation took place. An ionospheric perturbation is seen to have begun in Fig. 9 at the water-release time. This perturbation moved rapidly through a distance of 140 naut mi toward the radar site and achieved a maximum doppler spread of 18 cps about the 90 pps line. Its duration was approximately 4 minutes.

Figure 10 shows the conventional Madre analysis of the water-release reflections. The doppler frequency scale is on the left, running from 0 to 45 cps. Approximate range is given on the top horizontal scale running from 450 to 900 naut mi. Time after launch is indicated on the counter in minutes and seconds. The echo starts with the available doppler frequencies filled, its maximum doppler decreases with time and occupies about 20 cps at the time of the echo's disappearance.

SECRET

NAVAL RESEARCH LABORATORY

7

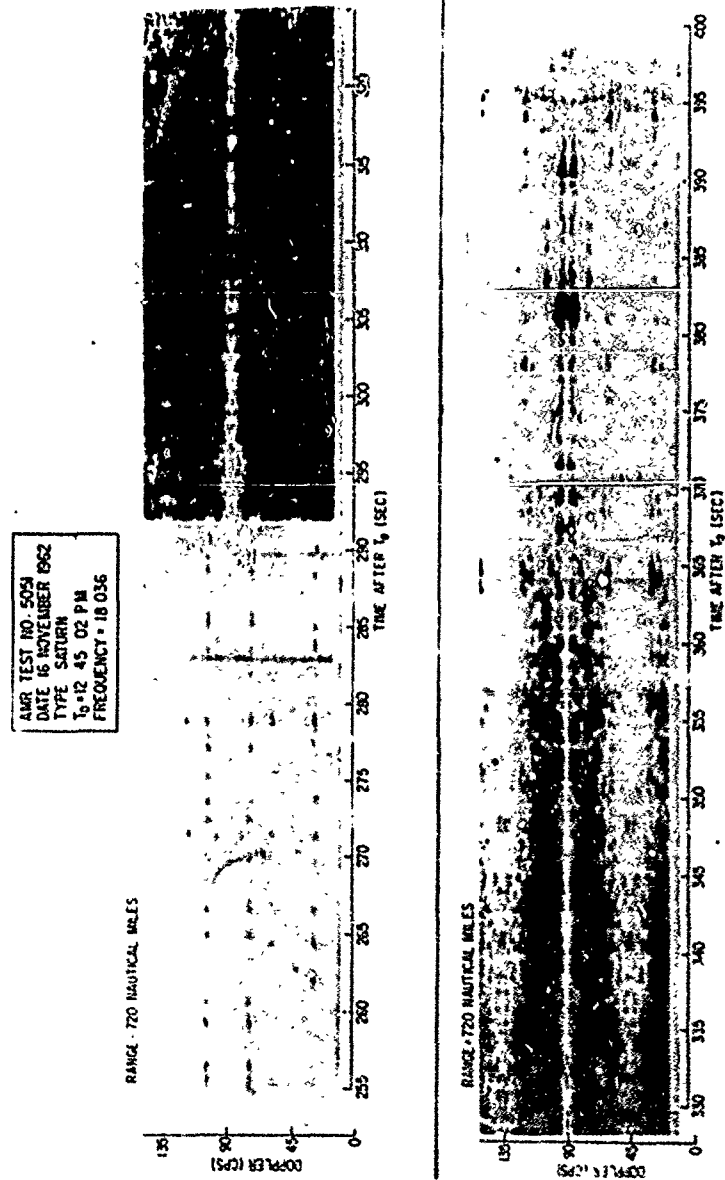


Fig. 8 - Doppler-intensity-time record of diffuse echo due to water release associated with AMR Test 5054, range gate centered on missile

SECRET

SECRET

NAVAL RESEARCH LABORATORY

9

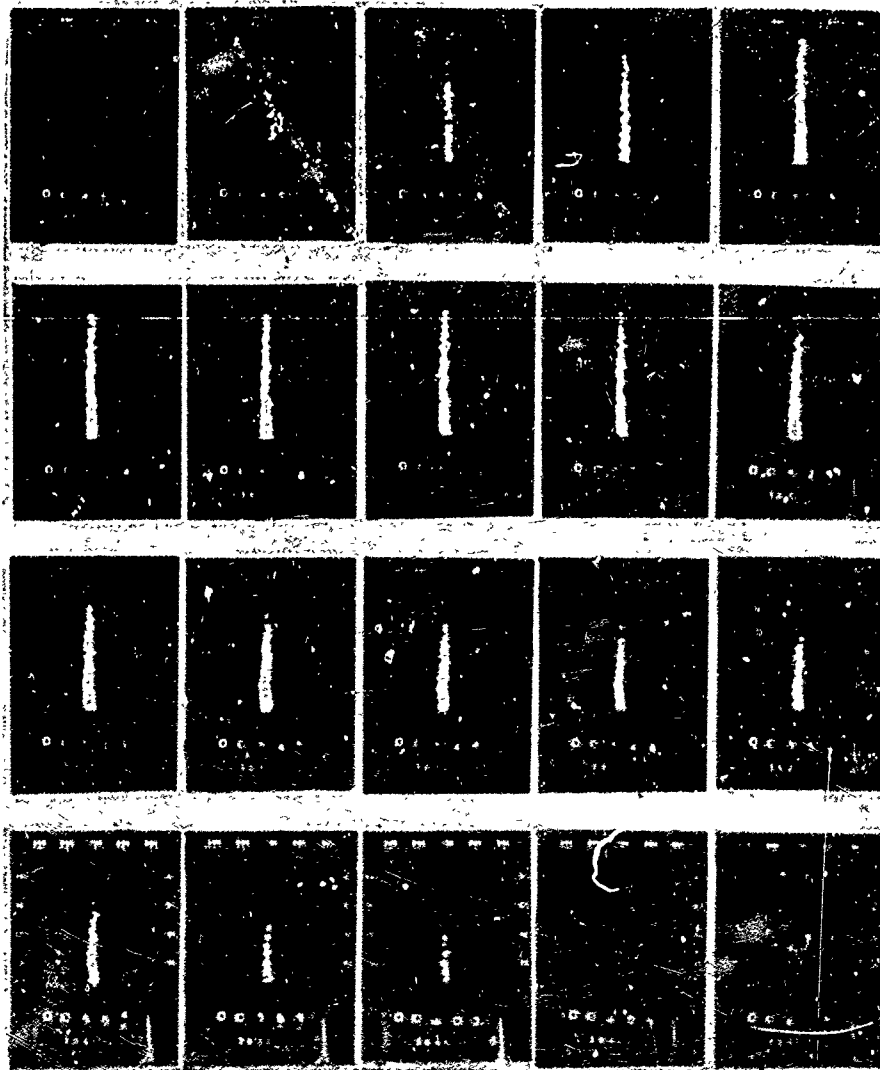


Fig. 10 - Conventional Madre record of doppler-intensity-range for the diffuse echo due to water release associated with AMR Test 5051

SECRET

PMR Test 291201 - Thor-Agena

T_0 : 12:13:39 p.m. EST, 26 Oct. 1962
 Frequency: 18,036 Mc
 Pulse repetition rate: 90 pps
 Pulse duration: 300 μ sec
 Power: 75 kw (average)
 Antenna gain: 12 db over an isotrope

In this test, propellant depletion was allowed to determine first-stage thrust termination. Stanford Research Institutes furnished information indicating that 10 pounds of liquid oxygen remained at main engine cutoff (MECO) and it appears likely that this excess oxidizer was vented. Although ten pounds of liquid oxygen seems a small quantity, a well-defined reflection typical of rocket exhausts and releases was noted.

Backscatter distribution and ionosonde data indicate an illumination geometry as sketched in Fig. 11. Signals from a transponder at Point Arguello showed only two-hop coverage of the launch site.

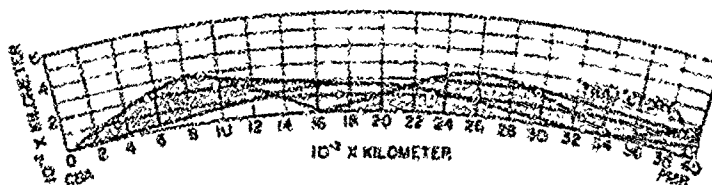


Fig. 11 - Illumination geometry, as indicated by backscatter distribution and ionosonde data, and missile trajectory for PMR Test 291201

Figure 12 shows the conventional Maf's display. The 45-cps available doppler is scaled on the left side of each picture. Range intervals for which the receiver was unblanked were 350-800, 1250-1700, and 2150-2650 naut mi, and in these superimposed 450-naut-mi intervals, the range runs from left to right along the abscissa. The time after launch is given in minutes and seconds on the counter below each frame. Numerous meteor trail returns appearing on the photographs at low doppler frequencies partially obscured the display throughout the test. The echo in the pictures taken at 002:48, 002:52, 002:56, and 003:00 minutes, appearing at about the center of the range display and having a continuum of dopplers up to 23 or 30 cps, had the characteristics typical of a missile exhaust. This echo's slant range was 2350 naut mi, about 85 naut mi farther than that of the transponder.

A range-gated doppler-intensity-time analysis of the event is shown in Fig. 13. The target, which shows on this display from $T_0 + 160$ to $T_0 + 180$ seconds, did indeed have the character of an exhaust or release. No echo was seen during Agena burn period, and it is doubtful that illumination of the missile was obtained during that period.

SECRET

NAVAL RESEARCH LABORATORY

11

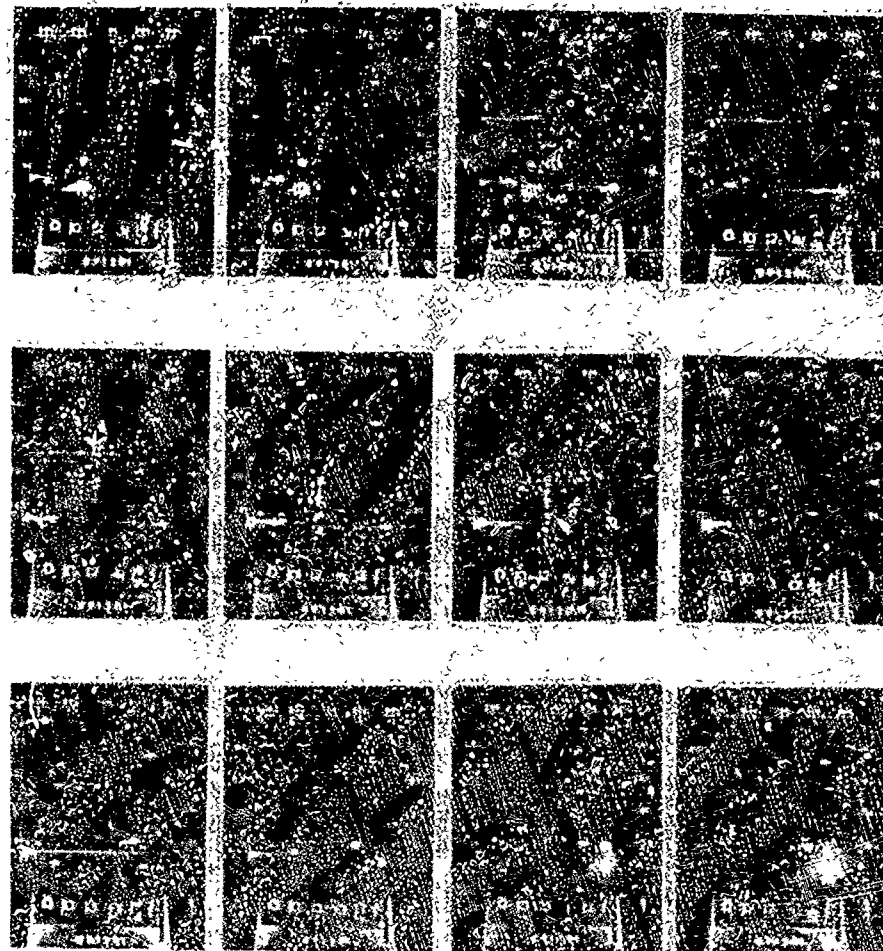
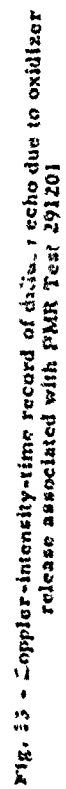


Fig. 12 - Conventional Madre record of doppler-intensity-range for the diffuse echo due to condenser release associated with PMR Test 291201

SECRET



CONCLUSION

During each of these four missile launches the Madre facility was able to detect hf radar echoes at the approximate range of the vehicle at a time when its rocket motor was not burning. In three cases the missile itself had achieved E-layer altitude when the effects set in, and in all four events the character of the echoes bore a close resemblance to the effects normally associated with burning rockets traversing the ionosphere. In two cases an ionospheric path perturbation, usually detected when a burning rocket passes through the F-layer, was discerned when nonburning debris approached F-layer height.

REFERENCES

1. Page, E.M., "Storage Radar," NRL Report 3532 (Confidential Report, Unclassified Title), Oct. 1949
2. Page, R.M., and George, S.F., "Magnetic Drum Storage Applied to Surveillance Radar," NRL Report 4878 (Confidential Report Unclassified Title), Jan. 1957
3. Wyman, F.E., and Zettle, E.N., "Magnetic Drum Storage Correlation Radar," NRL Report 5023 (Secret Report, Unclassified Title), Nov. 1957
4. Headrick, J.M., Navid, B.N., Ahearn, J.L., Curley, S.R., Utley, F.H., Headrick, W.C., and Zettle, E.N., "A Madre ICBM Detection," NRL Memo Report 1251 (Secret Report, Unclassified Title), Dec. 1961
5. Headrick, J.M., Curley, S.R., Ahearn, J.L., Headrick, W.C., and Utley, F.H., "Madre Evaluation," NRL Memo Report 1287 (Secret Report, Unclassified Title), Jan. 1962
6. Headrick, J.M., Curley, S.R., Thorp, M.E., Ahearn, J.L., Utley, F.H., Headrick, W.C., and Rohlf, D.C., "Madre Evaluation Report III," NRL Memo Report 1316 (Secret Report, Unclassified Title), Feb. 1962
7. Headrick, J.M., Ahearn, J.L., Curley, S.R., Ward, E.W., Utley, F.H., and Headrick, W.C., "Madre Evaluation Report IV," NRL Report 5811 (Secret Report, Unclassified Title), June 1962
8. McGeogh, J.E., Jensen, G.K., and Uniacke, C.L., "A 100-KC Quartz Crystal Comb Rejection Filter," NRL Report 5589 (Confidential Report, Unclassified Title), Feb. 1961

SECRET

DISTRIBUTION

	<u>Copy No.</u>
Dir., Advanced Research Projects Agency, Wash. 25, D.C. Attn: Mr. A. Van Every	1-4
Dir., Weapons Systems Evaluation Group, Rm. 1E880, Pentagon Attn: Mrs. Sjogven (2 cys.)	5-6
NBS, U.S. Dept. of Commerce, Boulder, Colo. Attn: Mr. L. E. Tveten	7
Dir., National Security Agency, Fort George G. Meade, Md. Attn: C3/TDL	8
CO, USNOTU, Patrick AFB, Fla. Attn: CDR R. E. Colopy	9
Dir., USNEL, San Diego 52, Calif. Attn: Tech. Library (2 cys.)	10-11
ONR Attn: Code 427	12
463	13
418	14
CNO Attn: Code Op-92 (4 cys.)	15-18
Oo-30	19
Op-70	20
Op-07T	21
Op-03EG (2 cys.)	22-23
Chief, BuShips, Dept. of the Navy, Wash. 25, D.C.	24
Research & Technical Div., Hdqs., Air Force Systems Command, Bolling AFB, Wash. 25, D.C. Attn: LTCOL R. M. Cosel	25
USNOTS, China Lake, Calif. Attn: Tech. Library	26
USNPGS, Monterey, Calif. Attn: Tech. Library	27
USNADC, Johnsville, Pa. Attn: Tech. Library	28
OCSigO Attn: Ch., Res. & Dev. Div.	29

SECRET

SECRET

NAVAL RESEARCH LABORATORY

15

DISTRIBUTION (Cont'd)

Copy No.

USAEIRD, Ft. Monmouth, N.J. Attn: USAEIRD Liaison Office (3 cys.)	30-32
Dir., Special Projects Div., Dept. of the Navy, Wash. 25, D.C.	33
Dir., Defense Research & Engr., Dept. of Defense, Wash. 25, D.C. Attn: Air Defense (2 cys.)	34-35
CO, USNATC, Patuxent River, NAS, Patuxent River, Md. Attn: Mr. D. Decker Electronics Test Div.	36 37
CO, USNOL, Corona, Calif. Attn: Mr. V. Hildebrand	38
CDR, Naval Missile Center, Point Mugu, Calif. Attn: Tech. Library, Code NO3022	39
CO, US Army Signal Radio Propagation Agency, Ft. Monmouth, N.J. Attn: SIGRP-A	40
CG, Picatinny Arsenal, Tech. Res. Sec., AAWL, Dover, N.J. Attn: Dr. Davis	41
Hdqs., US Army Liaison Grp., Project Michigan, Univ. of Mich., P.O. Box 618, Ann Arbor, Mich. Attn: Chief, Administration (BAMIRAC)	42
Office Director of Defense (R&E), Pentagon Attn: Mr. J. J. Donovan, Office of Electronics, Rm. 301033 Technical Library Branch (2 cys.)	43 44-45
CO, US Army Signal Electronic Research Unit, P.O. Box 205, Mountain View, Calif.	46
Office, Chief of Ordnance, Dept. of the Army, Wash. 25, D.C. Attn: ORDTX, Dr. C. M. Hudson	47
Hdqs., USAF, Office Asst, Chief of Staff Intelligence, Wash. 25, D.C. Attn: MAJ A. T. Miller	48
Hdqs., USAFCRC, Hanscom Field, Bedford, Mass. Attn: CRRK, Dr. Philip Newman CRRK, Mr. Wm. F. Ring MAJ Scott Sterling CRTOTT-2	49 50 51 52
CDR, RADC, Griffiss AFB, Rome, New York Attn: RALTT (Mr. F. Bradley) RCLTS (Mr. T. Maggio)	53 54

SECRET

DISTRIBUTION (Cont'd)

Copy No.

CDR, Air Technical Intelligence Center, USAF, Wright-Patterson AFB, Dayton, Ohio	55
Attn: Dr. P. J. Overbe	56
Mr. Goff	57
ASAPRD-Distr.	
Hdqs., USAF, Dept. of the AF, Office for Atomic Energy DCS/O, Wash. 25, D.C.	58
Hdqs., USAF, Dept. of the Air Force, Wash. 25, D.C.	
Attn: LTCOL K. Baker, AFRDP-A	59
CDR, Air Force Office of Scientific Research, Wash. 25, D.C.	
Attn: Code SRY	60
CDR, Air Force Ballistic Missile Div., Air Force Unit P.O., Los Angeles 45, Calif.	61
Hdqs., Offutt AFB, Nebraska	
Attn: Strategic Air Command	62
Hdqs., North American Air Defense Command, Ent AFB, Colo. Springs, Colo.	
Attn: NELC (Advanced Projects Grp.)	63
Electr. Physics Labs., ACF Electronics Div., 3355 - 52nd Ave., Hyattsville, Md.	
Attn: Mr. W. T. Kneiss	64
Stanford Electronics Lab., Stanford Univ., Stanford, Calif.	
Attn: Dr. O. G. Villard	65
Raytheon Mfg. Co., Wayland Lab., Waltham, Mass.	
Attn: Mr. D. A. Hedlund	66
General Electric Co., Court St., Syracuse, N.Y.	
Attn: Dr. G. H. Millman	67
Lockheed Aircraft Corp., Calif. Div., Burbank, Calif.	
Attn: Mr. R. A. Bailey	68
Pilotless Aircraft Div., Boeing Airplane Co., Seattle 24, Wash.	
Attn: Mr. F. S. Holmar	69
The Martin-Marietta Co., Baltimore 3, Md.	
Attn: Dr. D. M. Sukhia	70
RCA, Aerospace Communications & Controls Div., Burlington, Mass.	
Attn: Mr. J. Robinovitz	71

SECRET

DISTRIBUTION (Cont'd)

	<u>Copy No.</u>
MIT, Lincoln Labs., Box 73, Lexington 73, Mass. Attn: Dr. J. H. Chisholm	72
Mr. Melvin Stone	73
The Rand Corp., 1700 Main St., Santa Monica, Calif. Attn: Dr. Cullen Crain	74
DDC, Arlington, Va. Attn: TIPDR (20 cys.)	75-94
Bendix Systems Div., The Bendix Corp., 3300 Plymouth Road, Ann Arbor, Mich. Attn: Mr. C. M. Shear, Assoc. Dir. of Engr.	95
Smyth Research Associates, 3555 Aero Court, San Diego 11, Calif. Attn: Mr. Steven Weisbrod	96
CDR, Electronic Systems Div., Hanscom Field, Bedford, Mass. Attn: Mr. Harry Byram, ESRDT	97
CONVAIR, Div. of General Dynamics, 3165 Pacific Coast Highway, San Diego 12, Calif. Attn: Dr. Bond	98
Stanford Research Inst., Menlo Park, Calif. Attn: Mr. R. Leadabrand	99
Mr. L. T. Dolphin, Jr.	100
Thompson Ramo-Wooldridge, Inc., Box 90534, Airport Station, Los Angeles, Calif. Attn: Tech. Info. Services	101
APL/JHU, 8621 Ga. Ave., Silver Spring, Md. Attn: Mr. G. L. Seitelstad (NavOrd 7386)	102
Chief, Army Security Agency, Arlington Hall Sta., Arlington 12, Va.	103
Aircraft Instruments Laboratory, Melville, L.I., N.Y. Attn: Mr. Scott Hall	104
CIC, Ent AFB, Colorado Springs, Colo. Attn: LTCOL M. R. Cripe, Hq. NORAD, NPSD-R (NPD-A, Box 42)	105
US Army Ordnance Missile Command, Redstone Arsenal, Ala. Attn: Mr. James E. Norman	106
Diamond Ordnance Fuze Labs., Ordnance Corps, Wash. 25, D.C. Attn: Mr. Pervy Griffen	107

DISTRIBUTION (Cont'd)

	<u>Copy No.</u>
Institute for Defense Analyses, 1666 Conn. Ave., N.W., Wash., D.C. Attn: Dr. Nils L. Muench	108
Westinghouse Electric Corp., Defense Center-Baltimore, Technical Info. Center, P.O. Box 1693, Baltimore 3, Md.	109
Systems Branch, U.S. Army Scientific Liaison & Advisory Grp., P.O. Box 7157, Apex Sta., Wash. 4, D.C. Attn: Mr. Richard A. Krueger	110
Aero Geo Astro Corp., P.O. Box 1082, Edsall & Lincoln Rds., Alexandria, Va. Attn: Technical Library	111
Dir., DASA Data Center, P.O. Drawer QQ, Santa Barbara, Calif.	112
Dir., Marshall Space Flight Center, Huntsville, Alabama Attn: Mr. J. B. Dozier M-RP-P	113

SECRET

UNCLASSIFIED

Naval Research Laboratory, Report 6015 (SECRET).
 HF RADAR ECHOES AND REFRACTION EFFECTS
 DUE TO WATER AND PROPELLANT RELEASES IN
 THE IONOSPHERE [Unclassified Title], by J. M.
 Headrick, S. R. Curley, J. L. Ahearn, J. R. Davis,
 and E. W. Ward. 18 pp. and figs. November 22, 1963.

High-frequency radar observations of nonburning
 rockets traversing the ionosphere often yield large
 range-discrete echoes and ionospheric path pertur-
 bations during periods in which the venting of fuel
 components or fluid ballast takes place. A study of
 several missile launchings during which such releases
 occurred has been conducted, and an analysis of the
 experimental data which takes into account the prop-
 agation conditions surrounding each launching is
 presented. [Unclassified Abstract]

UNCLASSIFIED

1. Radar echo areas - Anal.
2. Guided missiles - Launching - Radar anal.
3. Ionosphere - Reflective effects
4. Radar signals - Reflection
5. Headrick, J. M.
6. Curley, S. R.
7. Ahearn, J. L.
8. Davis, J. R.
9. Ward, E. W.

UNCLASSIFIED

Naval Research Laboratory, Report 6015 (SECRET).
 HF RADAR ECHOES AND REFRACTION EFFECTS
 DUE TO WATER AND PROPELLANT RELEASES IN
 THE IONOSPHERE [Unclassified Title], by J. M.
 Headrick, S. R. Curley, J. L. Ahearn, J. R. Davis,
 and E. W. Ward. 18 pp. and figs. November 22, 1963.

High-frequency radar observations of nonburning
 rockets traversing the ionosphere often yield large
 range-discrete echoes and ionospheric path pertur-
 bations during periods in which the venting of fuel
 components or fluid ballast takes place. A study of
 several missile launchings during which such releases
 occurred has been conducted, and an analysis of the
 experimental data which takes into account the prop-
 agation conditions surrounding each launching is
 presented. [Unclassified Abstract]

UNCLASSIFIED

1. Radar echo areas - Anal.
2. Guided missiles - Launching - Radar anal.
3. Ionosphere - Reflective effects
4. Radar signals - Reflection
5. Headrick, J. M.
6. Curley, S. R.
7. Ahearn, J. L.
8. Davis, J. R.
9. Ward, E. W.

UNCLASSIFIED

Naval Research Laboratory, Report 6015 (SECRET).
 HF RADAR ECHOES AND REFRACTION EFFECTS
 DUE TO WATER AND PROPELLANT RELEASES IN
 THE IONOSPHERE [Unclassified Title], by J. M.
 Headrick, S. R. Curley, J. L. Ahearn, J. R. Davis,
 and E. W. Ward. 18 pp. and figs. November 22, 1963.

High-frequency radar observations of nonburning
 rockets traversing the ionosphere often yield large
 range-discrete echoes and ionospheric path pertur-
 bations during periods in which the venting of fuel
 components or fluid ballast takes place. A study of
 several missile launchings during which such releases
 occurred has been conducted, and an analysis of the
 experimental data which takes into account the prop-
 agation conditions surrounding each launching is
 presented. [Unclassified Abstract]

UNCLASSIFIED

1. Radar echo areas - Anal.
2. Guided missiles - Launching - Radar anal.
3. Ionosphere - Reflective effects
4. Radar signals - Reflection
5. Headrick, J. M.
6. Curley, S. R.
7. Ahearn, J. L.
8. Davis, J. R.
9. Ward, E. W.

UNCLASSIFIED

Naval Research Laboratory, Report 6015 (SECRET).
 HF RADAR ECHOES AND REFRACTION EFFECTS
 DUE TO WATER AND PROPELLANT RELEASES IN
 THE IONOSPHERE [Unclassified Title], by J. M.
 Headrick, S. R. Curley, J. L. Ahearn, J. R. Davis,
 and E. W. Ward. 18 pp. and figs. November 22, 1963.

High-frequency radar observations of nonburning
 rockets traversing the ionosphere often yield large
 range-discrete echoes and ionospheric path pertur-
 bations during periods in which the venting of fuel
 components or fluid ballast takes place. A study of
 several missile launchings during which such releases
 occurred has been conducted, and an analysis of the
 experimental data which takes into account the prop-
 agation conditions surrounding each launching is
 presented. [Unclassified Abstract]

UNCLASSIFIED

1. Radar echo areas - Anal.
2. Guided missiles - Launching - Radar anal.
3. Ionosphere - Reflective effects
4. Radar signals - Reflection
5. Headrick, J. M.
6. Curley, S. R.
7. Ahearn, J. L.
8. Davis, J. R.
9. Ward, E. W.

Naval Research Laboratory

Technical Library

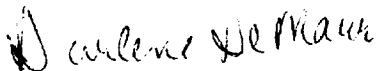
Research Reports & Bibliography Unit

To: Larry Downing, DTIC
From: Darlene DeMarr, Code 5596.3
Date: 9/17/2007
Subject: Change in Classification & Distribution Statement

Please change the classifications & distribution statement on the following documents to
Unclassified/Unlimited Distribution:

ADC954564 (NRL-3703-PT-1)	Declassified with no restrictions 9/11/1996
AD0348828 (NRL-6066)	Declassified with no restrictions 9/30/1996
AD0348901 (NRL-6037)	Declassified with no restrictions 12/3/1996
AD0352827 (NRL-6117)	Declassified with no restrictions 1/25/1996
AD0361630 (NRL-6247)	Declassified with no restrictions 1/7/1997
AD0377010 (NRL-6476)	Declassified with no restrictions 1/29/1997
AD0377011 (NRL-6485)	Declassified with no restrictions 1/29/1997
AD0377242 (NRL-6479)	Declassified with no restrictions 1/29/1997
AD0379058 (NRL-6508)	Declassified with no restrictions 1/29/1997
AD0379893 (NRL-6507)	Declassified with no restrictions 1/29/1997
AD0346383 (NRL-6015)	Declassified with no restrictions 1/29/1997
AD0349268 (NRL-6079)	Declassified with no restrictions 1/29/1997
AD0355651 (NRL-6198)	Declassified with no restrictions 1/29/1997
AD0368068 (NRL-6371)	Declassified with no restrictions 1/29/1997

Thank you,



Darlene DeMarr
(202) 767-7381
demarr@nrl.navy.mil