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NAVY DEPARTMENT

Preliminary Report on Tests
of Reflecting Material as a
Radar Countermeasure

Naval Research Laboratory
Anacostia Station
Washington, D. C.

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ABSTRACT

Tests were made on radar echoes from Window at the Naval Research Laboratory Chesapeake Bay Station on March 8 and 9, 1943. Observations were made on five radar equipments: CXBQ (3.2 cm), Mark X (10 cm), FD (700 mc), CXAZ (400 mc), and Japanese (100 mc). Motion picture records were taken on all except the Japanese radar.

The Window (10" x 10" paper-backed aluminum weighing 18 oz. per 100 sheets) was dropped from the tunnel hatch of a PBV, at altitudes of 5000 and 10,000 ft. Good echoes were obtained on all radars except the Japanese. Five hundred sheets gave an echo about equal to that from the PBV head-on on FD and CXAZ, but only about 1/2 of the PBV echo on CXBQ and Mark X. The Window echoes decreased in relative intensity only slowly, persisting for about 10 minutes. Useful confusion lasted for about 5 minutes. Rate of fall was 3-4 minutes per 1000 feet.

Wind direction and velocity at various altitudes were determined just prior to the tests by plotting the course of a pilot balloon. This information was used to determine the point where the Window should be dropped in order that the sheets land in Chesapeake Bay. Prior to tests in which actual reflecting material was used, tests were made using paper sheets of two different weights as "dummy" Window, both to study ejection technique and to determine the degree of control that could be attained over the position at which the material fell. The progress of the sheets (both paper and Window) was followed by the plane, and was also observed by the Laboratory's patrol boat Navajo. All sheets landed in the Bay, and the Window sank within a few seconds; the paper sank after a slightly longer period.

Subsequent to the completion of this preliminary report, further tests of Window will be made, including more complete study of methods of ejection.

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I. INTRODUCTION

- 1-1. The work on this problem was authorized by the Bureau of Ships letter of 5 February 1943, S-S67-5(920-2), Serial No. 3740 (NRL File S-S67/36/RCM, Serial 002-6-4). This letter authorized the tests under problem CMLS on priority AA, and requested that a preliminary report be furnished to the Bureau within 30 days, and that the problem be completed within 60 days.
- 1-2. In the above letter it was requested that this laboratory conduct tests on various reflectors which may be ejected from aircraft to determine the effectiveness of such reflectors as a radar countermeasure in various frequency ranges. Reflecting material used in this way has been designated as "Window" by the British, and this term will be used in this report in referring to the reflecting material.
- 1-3. It was further requested that tests be made to discover feasible and effective methods of ejecting the reflecting material from aircraft.

II. DESCRIPTION OF EXPERIMENTS

2-1. Preliminary Tests with Paper

- 2-1-1. In order to maintain security on Window, preliminary experiments using paper were conducted to obtain experience in control of the area in which the sheets landed. Wind data were obtained from the Naval Air Station, Anacostia, prior to each dropping test. In addition, observations of the path of a free balloon released from the Chesapeake Bay Station were made shortly before each flight schedule. Using the data on wind direction and velocity at various altitudes obtained in this manner, together with an approximate figure for rate of fall, a point where the paper should be released was determined such that all should safely land in Chesapeake Bay. The plane was instructed accordingly (all information passed between plane and ground stations was coded). After dropping the paper, the plane would circle over the "cloud" and observe its course. In addition, the Laboratory's patrol boat Navajo made observations of where the sheets landed, the approximate spread, and length of time required before all sheets sank. As an additional measure of security, the paper bore a "BUY WAR BONDS" imprint.
- 2-1-2. The experiments with paper were made at altitudes from 1000 ft. to 10,000 ft., with various quantities per bundle, and with paper stock (10" x 10") of two different weights (10-1/2 lbs. per 1000 sheets and

32 lbs. per 1000 sheets). In all cases, without exception, the control of the landing area was very good, all of the sheets falling well within the Bay, and sinking within about five minutes. The tests with paper were made on four days.

2-2. Tests with Window

2-2-1. The tests using Window were made on March 8 and 9, 1943. Five radar equipments were used for observation, as listed in the following table:

<u>Radar Equipment</u>	<u>Frequency Mc</u>	<u>Pulse Length Microseconds</u>	<u>Pulse Frequency</u>	<u>Pulse Power, Kw</u>
CXBQ	9400	3/4	900	5
Mark X	3000	1	3600	10-15
FD	700	2	1640	50
CXAZ	400	1	700	150
Japanese	100	20	1000	5

All radars used Type A scopes for the tests. The antennae of all except the Japanese were controllable in both azimuth and elevation, the Japanese antenna having only azimuth control. The FD antenna was mounted on a Mark 37 director used for fire control studies. This radar and director were connected to a Mark I computer, which transmitted bearing, elevation, and range information, as well as other elements not needed for the Window tests, to a control dial box by means of synchros. The readings of the bearing and elevation dials were called over to the CXAZ operator, who set his antenna controls accordingly.

2-2-2. The CXBQ antenna (twin 18" parabolas) was readily manned by a single operator, who kept the antenna trained on the target by sighting through a telescope mounted on the antenna. The Mark X antenna was carried on a mount manned by two operators.

2-2-3. Motion picture cameras were set up to photograph the A scopes of each of the radars except the Japanese. An additional camera was arranged to photograph the dials showing bearing, elevation, and range of the FD, in order to record position of target for each run. Communication was set up between each radar station and a central control point in the radio communications center, so that all cameras could be signalled to start simultaneously by the engineer in charge of the tests (hereafter referred to as "control engineer").

2-2-4. The plane used for the Window tests was a Navy PBY-5A. The Window was ejected through the tunnel hatch of the

plane by an NRL engineer, who also made observations of the subsequent behavior of the material. Through pre-arranged code, the control engineer notified the plane of the altitude and location where the material should be released, and the number of sheets to be released. When the plane reached the designated location and altitude, the control engineer was so informed by radio. The radar operators, who had been notified of the position of the plane, were then contacted and reported when they were "on the plane." When all radars were "on", the plane was told to "go ahead." Thereupon, the pilot went into his "run", giving pre-arranged signals 20 seconds and 10 seconds before release, and a "mark" signal when the Window was ejected. Upon receiving the 10-second warning signal, the control engineer instructed the cameramen to start cameras, and gave an additional signal at the time of release. This last signal was given for the purpose of notifying the antenna pointing operators that they should thereafter track the Window, rather than the plane. Twenty-five to thirty seconds after the cameras were started, a "cease run" signal was given to stop the cameras, since this represented the maximum time the cameras would run without rewinding.

- 2-2-5. During the fall of the material, additional camera shots were taken, at intervals of two to three minutes. For some of these shots the plane made a pre-arranged run toward the station just over the cloud, in order to allow comparison of the relative magnitudes of the echoes from the plane and the Window cloud. Similar arrangements to those described above were made to synchronize the operation of the cameras with the run of the plane.
- 2-2-6. For most of the runs, only a single bundle was dropped. For two of the runs, however, three bundles were dropped in succession; for one of these tests, the bundles were released in rapid succession (about one-second intervals), while for the other they were spaced about five seconds apart.
- 2-2-7. The speed of the plane was about 100 knots, or about 60 yards per second.

III. DATA OBTAINED

- 3-1. The data describing the various tests which were made are assembled in Table II. The results of each test are contained in the film records, supplemented by reports on visual observations. These results can be summarized as follows:

- 3-2. On Test Run 1, the Window was ejected from the plane prematurely, so that adequate preparation for following the target with radar had not been made, and the planned sequence of pictures was not taken on this run. On Runs 2 and 3 the same quantity of Window (200 sheets) was used, and echoes observed on all equipments except the Jap Radar (100); on this latter equipment the operator thought that some echo from the Window may have been present just after the time of ejection, but was not sure of this because of the long pulse length used (20 microseconds); the echo from the plane obscured any echo that may have been momentarily present from the Window. This observation was also true of subsequent tests with larger quantities of Window.
- 3-3. The other operators reported echo strengths comparable to that from the plane (Navy PBV), especially for the first minute or two after ejection. As the Window dispersed the echo from it grew progressively weaker. The FD operator reported considerable confusion between the plane echo and that from the Window existed when the two were at the same range; the CXBQ and Mark X operators, however, stated that it was possible to follow the plane without appreciable difficulty as it passed close by the Window, due to the fact that the plane echo was about twice as strong.
- 3-4. When 500 sheets of Window were ejected, the resulting echoes on FD and CXAZ were definitely as strong as those from the plane, and occasionally stronger. All operators noted that as the plane approached from beyond the cloud of Window, its echo was usually about the same amplitude until it had passed the cloud; thereupon the plane echo usually rose to saturation.
- 3-5. On Test Run #5, the separate batches of material merged to a single echo on all sets except the CXBQ which showed a slight splitting of the echoes at first. Within five minutes inter-diffusion had taken place, both in altitude and laterally.
- 3-6. The observer in the plane reported behavior of the material was erratic from one run to the next, and seemed to depend on local wind conditions. Sometimes the spread was greater laterally than vertically, and sometimes vice versa. The sheets stayed in a fairly close cluster for about 15 seconds or more before spreading out to any large extent.
- 3-7. On Test Run #7, the three separate echoes were distinct for a considerable time (4 to 5 minutes) on the CXBQ and Mark X, and were slightly less distinct on CXAZ, but were merged into a single broad echo on the FD. Complete inter-diffusion had occurred after about 15 minutes. On the FD the echo on this run was about twice as strong as the noise after about 9 minutes, and had spread out so that it covered a section of the indicator sweep equal to about 2500 yards. When first ejected the Window on this run had a range depth of about 1000 yards on the FD.

- 3-8. On some of the runs the Mark X and CXBQ were unable to stay on target for the following reasons: (a) target angle of elevation too great, (b) range too great, (c) lack of adequate optical equipment. The material was released generally from a point about 2 miles (horizontal distance) away.
- 3-9. To illustrate the results more vividly, selected extracts of the film records are reproduced on Plates 1 to 8. It is planned to assemble the film records into a composite motion picture.

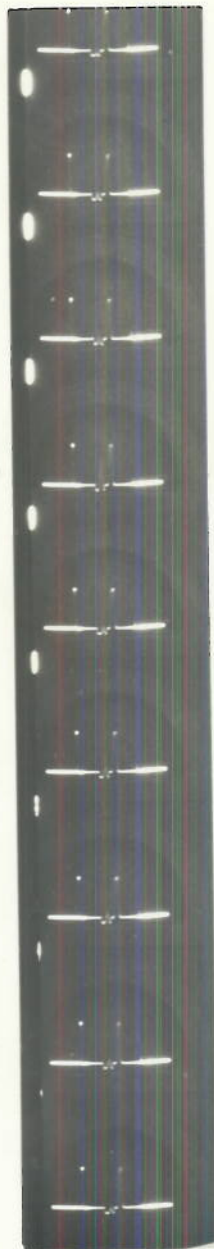
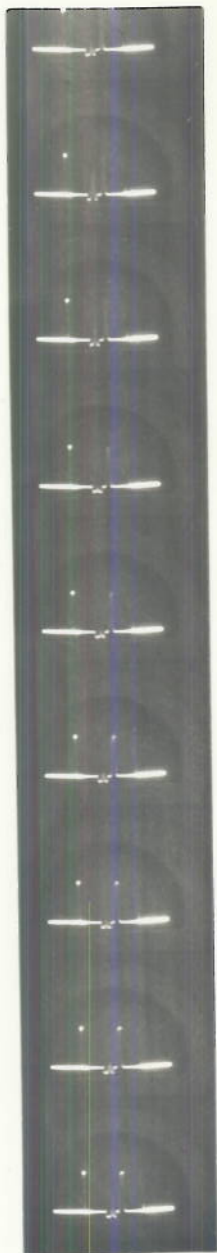
IV. CONCLUSIONS

- 4-1. From the results of the preliminary experiments carried out thus far, it is quite evident that Window can cause radar confusion when dropped in sufficient quantities. When the plane was within the range of the Window cloud, it was not possible to distinguish one echo from the other as long as their amplitudes were comparable. Five hundred 10" x 10" sheets appear to give an echo on 700 Mc equal to that from a PBV approaching head-on. The results on 400 Mc were not very satisfactory, due to difficulties experienced with the equipment, but they appear to be similar to those obtained on 700 Mc. On 10 cm and 3 cm, 500 10" x 10" sheets gave an echo of about one-half the amplitude of echo from a PBV head-on.
- 4-2. The echoes received from isolated clouds of Window appear very much like that from a plane. The echo decreases in intensity gradually as the cloud disperses. The "useful" time of a Window cloud appears to be about 5 minutes. Rate of fall varied somewhat, being between 3 and 4 minutes per 1000 feet.
- 4-3. Echoes from Window are distinguishable from plane echoes principally because of their lack of rapid change of range. For this reason, a plane echo can be followed through Window which is bunched so as to give distinct separate echoes. This was very clearly brought out by the last run made. It appears desirable, therefore, to space the batches of Window by somewhat less than the range resolution of the radar being jammed.

TESTS OF "WINDOW" at Chesapeake Bay Annex, March 8 and 9, 1943

Test Run Number	Altitude at Ejection	Quantity (No. of Sheets)	Time of Ejection	Starting Time of Camera Run	Range, Bearing, Degrees	Elevation	Remarks on Camera Run
1-1	5000 ft.	200	1330	1330 ?	4700 115°	14°	FD Camera only
1-2				1338	6600 122°	7°	
2-1	5000	200	1348	1348	4000 90°	21°	Camera started about 10 sec. before ejection
2-2				1350	3500 101°	19°	Pictures show Window without plane
2-3				1352	4400 110°	14°	Plane flew "thru" target, closing range
2-4				1354	8700 110°	7°	Same as 2-2
3-1	10000	200	1437	1437	5400 88°	33°	Film stuck on FD camera
3-2				1441	9300 98°	17°	CXAZ had circuit failure FD trouble cleared
3-3				1446	15000 98°	7°	Results O.K. on FD only
4-1	10000	500	1506	1506	4000 92°	48°	CXBQ not on target
4-2				1508	5200 98°	29°	Same as 2-2. CXBQ O.K.
4-3				1511	7800 102°	18°	Same as 2-3. CXBQ O.K.
4-4				1516	12400 106°	14°	Same as 2-2.
5-1	10000	400,	1548	1548	5200 76°	35°	"Window" ejected
5-2		400,		1550	6200 85°	23°	Same as 2-2
5-3		300 in rapid succession		1553	9300 92°	15°	Same as 2-3
5-4				1601	16600 107°	6°	CXBQ and Mk. X lost target
5-A	5000	200	1358	---	---	---	No pictures made. Trial Run, March 9 Time of fall about 19 minutes
6-1	10000	500	1442	1442 +	5400 102°	32°	Cameras started few sec. after release
6-2				1445	7900 97°	20°	Same as 2-3
6-3				1446	8600 95°	17°	Same as 2-2
6-4				1450	11200 91°	14°	Same as 2-3
7-1	10000	500,	1534-1/2	1534-1/2	5900 123°	30°	Cameras started just before ejection
7-2		500,		1538	7500 110°	22°	Same as 2-3
7-3		500 - at 5 sec. intervals		1541	9500 101°	15°	Same as 2-3, but plane going out instead of closing range.
7-4				1544	11000 98°	12°	

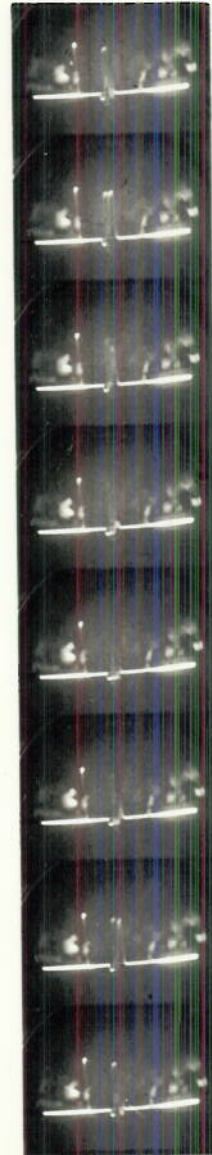
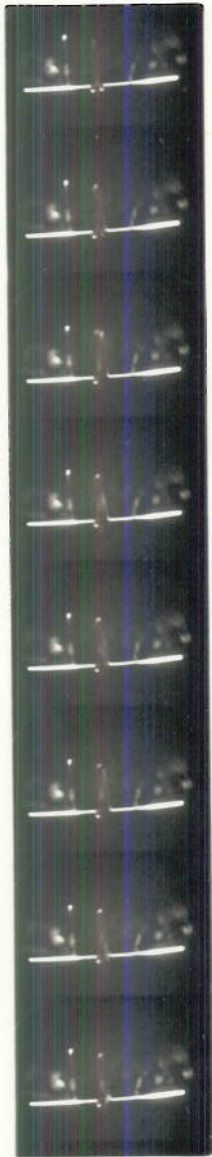
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FD -- Test Run #3-2: (200 sheets - 2 minutes after ejection)
Plane echo is to right of Window echo; latter in range
notch. Amplitudes occasionally equal, but plane echo
usually stronger. Range 9,300 Yds.; Bearing 98°;
Elevation 17°.

PLATE I

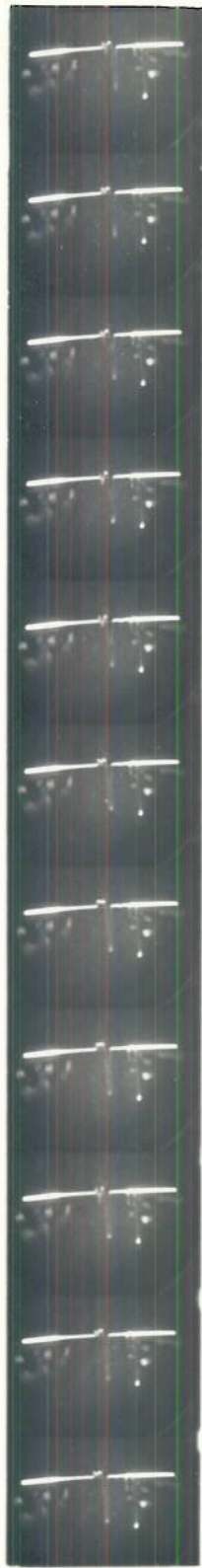
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FD -- Test Run #6-1: (500 sheets, just after ejection)
Plane and Window echoes both seen in range notch (plane
echo is at left of Window echo). Range 5,400 yds.;
Bearing 102°; Elevation 32°.

PLATE 2

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FD -- Test Run #6-2: (2 minutes after ejection) Plane and Window echoes both shown; plane, at closer range, is the stronger echo (on left edge of range notch; Window echo in notch). Range 7,900 yds.; Bearing 97°; Elevation 20°.

PLATE 3

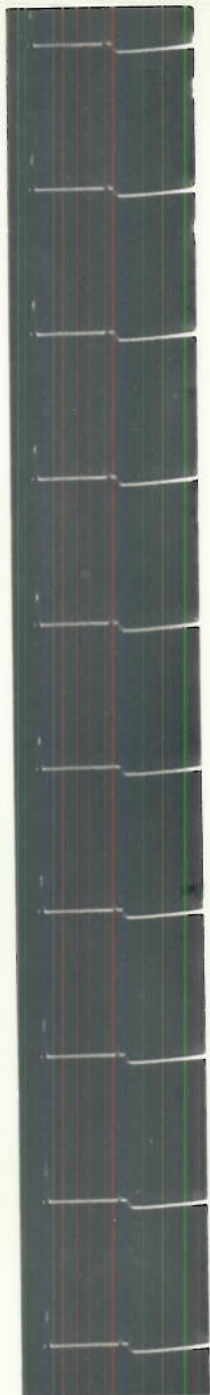
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FD -- Test Run #6-4: (8 minutes after ejection). Plane echo in center of notch, Window echo on right edge of notch. Plane echo stronger most of the time, but echoes occasionally of equal amplitude. Range 11,200 yds.; Bearing 91° ; Elevation 14° .

PLATE 4

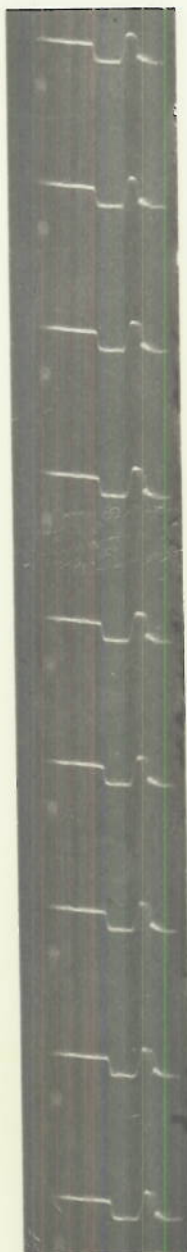
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Mark 10 - Test Run #4-1: (500 sheets from 10,000 ft.) Window
echo on step, plane echo to left (at closer range)
just after ejection. Range 4,000 yds.; Bearing 92° ;
Elevation 48° .

PLATE 5

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CYBQ -- Test Run #7-1 (a): Plane and Window echoes immediately after ejection of first batch of 500 sheets (altitude 10,000 ft.). Plane was approaching station; Window echo just beginning to appear to right of plane. Range 5,900 yds.; Bearing 123°; Elevation 30°.

PLATE 6

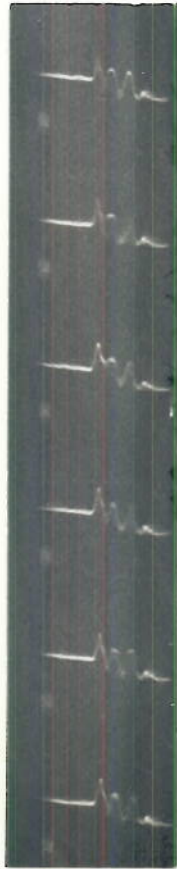
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CXBQ -- Test Run #7-1 (b): Taken just after plane had ejected
third batch of 500 sheets; echoes from first two batches
and plane echo all present - plane echo farthest to left.

PLATE 7

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CXBQ -- Test Run #7-1 (c): Shortly after ejection of third batch --
echoes from all three batches plus plane echo (latter just
to left of range step).



CXBQ -- Test Run #7-2: 3 minutes after ejection of three batches of 500 sheets each. Plane is at approximately same range as Window; its echo is the strongest, but is "mixed in" with the Window echo. Resulting picture is somewhat confused, although operators reported plane could be distinguished with little or no difficulty. Range 7,500 yds.; Bearing 110°; Elevation 22°.

PLATE 9

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