A PRELIMINARY STUDY OF UNIDENTIFIED TARGETS OBSERVED ON AIR TRAFFIC CONTROL RADARS

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The Air Navigation Development Board (ANDB) was established by the Departments of Defense and Commerce in 1948 to carry out a unified development program aimed at meeting the stated operational requirements of the common military/civil air navigation and traffic control system. This project, sponsored and financed by the ANDB is a part of that program. The ANDB is located within the administrative framework of the Civil Aeronautics Administration for housekeeping purposes only. Persons desiring to communicate with ANDB should address the Executive Secretary, Air Navigation Development Board, Civil Aeronautics Administration, W-9, Washington 25, D. C.

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SUMMARY

This report describes the investigation of a type of unidentified moving target which has been observed recently in considerable numbers on the viewing screens of air traffic control radar equipment operated by the Civil Aeronautics Administration. This investigation was conducted by means of interviews with personnel concerned, by study and correlation of official records, and by firsthand observation of numerous targets on the Washington Microwave-Early-Warning (MEW) radar and on the Indianapolis ASR-2 radar.

It was determined that targets which are known to operating personnel by various terminologies such as "ghosts," "angels," or "pixies" do not represent new phenomena; nor are they peculiar to the Washington area. Correlation of controllers' reports with United States Weather Bureau records indicated that a surface temperature inversion was almost always noted when such targets appeared on the radar.

Firsthand observation in the tracking and subsequent motion analysis of 80 of these unidentified targets indicated that a large number of these were actually secondary reflections of the radar beam. Apparently these reflections were produced by isolated refracting areas which traveled with the wind at or near the temperature inversion levels.

Although the exact size, shape, and composition of these isolated areas are not known, it is believed that they may be atmospheric eddies produced by a shearing action of dissimilar air strata. It appears possible that such eddies may refract and focus the radar energy with a lens effect to produce small concentrations of ground return with sufficient intensity to show up on the radar display. It is also believed that the correlation of the appearance of these radar targets with visual reports of so-called "flying saucers" is due to the strong probability that both effects are caused primarily by abrupt temperature inversions.

Such radar targets are usually easy to recognize because of their generally weak return and slow ground speed. Unfortunately, radar returns from small helicopters sometimes present these same characteristics. Spurious targets of this type can become a nuisance under busy traffic conditions, particularly in localities where helicopter operations are prevalent.

INTRODUCTION

Closely related to a recent flood of visual reports of flying saucers, the sighting of scores of unidentified targets on the Washington Air Route Traffic Control Center (ARTC) radar aroused much publicity and speculation regarding the origin, composition, and import of these objects. Concerned with the possible detrimental effects of this situation on the control of air traffic, the Air Navigation Development Board requested the Technical Development and Evaluation Center of the CAA to investigate the problem.

The specific objectives of this study were:

1. To find out as much as possible about the nature of the targets themselves.
2. To determine whether this problem is new and peculiar to the Washington area or whether it had occurred previously at Washington and at other CAA radar locations.
3. To determine the effect of this problem on the control of air traffic.
4. To determine what changes should be made in the radar development program in order to cope with the situation.

OFFICIAL RECORDS

As one of the first steps in this study, all records of these phenomena reported in the logs of the Washington ARTC Center were tabulated. The tabulation, given as Table I of this report, was taken to the Analysis Section of the United States Weather Bureau where it was correlated with meteorological data for the periods involved. It was then discovered that a temperature inversion had been indicated in almost every instance when the unidentified radar targets or visual objects had been reported. Weather analysts were asked whether any unusual weather conditions had prevailed over the Washington area during the period covering the occurrences of large numbers of the unidentified radar targets. Their report may be condensed as follows:

Monthly Weather Summary, July 1952.

The heat wave that broke records in the eastern portion of the United States during the month of June continued on through July, becoming intensified during the latter part of the month. July weather maps were characterized by a well-developed Bermuda high

TABLE I

TABULATION OF UNIDENTIFIED RADAR TARGETS AND VISUAL OBJECTS REPORTED TO WASHINGTON ARTC CENTER MAY 23 TO AUGUST 16, 1952

Date 1952	Time EST	Number Targets	Radar Contact			Visual Contact	Color	Location	Altitude MSL (feet)	Reported By	Radiosonde Observations		Remarks
			DCA CTR	DCA TWR	ADW APC						Temperature Lapse Rate	Humidity	
5-23	2000 to 0000	Estimated 50	x					DCA Terminal Area		Center	Inversions: 2° from 700 to 1500 ft., 1° from 9600 to 10,000 ft., otherwise normal	Normal	Speed 20 to 35 miles per hour. Followed curved course from 15 miles south of Arcola over Manassas, La Plata, and McLean.
7-10	Not Available	1				x		Quantico	2000	National 42	Not available for locality	Not available for locality	No details available.
7-13	0300	1				x	Blue-White	60 Miles Southwest DCA	11,000	Capt. Bruen National	DCA: Surface inversion 6° below 1000 ft.	DCA: Low, below measuring limits at 11,000 ft.	Came up to altitude of aircraft, hovered 2 miles to left of northbound aircraft. Pilot turned on all lights. Ball of light took off, going up and away.
7-14	2112	6				x	Red	Vicinity Langley Field	1000 to 2000	Pan-American Ferry 901	Norfolk: Superadiabatic lapse rate around 9000 ft. DCA: Surface inversion 2°	Norfolk: High, but fell off at 6000 ft. DCA: Sharp fall at 6000 ft.	Estimated speed 1000 miles per hour, heading northeast with sudden change to west-southwest.
7-19	2340	8	x	x				East and South ADW		Center	DCA: Surface inversion 3° isothermal between 8000 and 10,000 ft.	DCA: Above 10,000 ft. dropped, then increased slightly, dropping again at 15,000 ft.	Fair to weak targets, speed 100 to 130 miles per hour.
7-20	0100	7				x		DCA to Martinsburg		Capital 807	DCA: Surface inversion 3° isothermal between 8000 and 10,000 ft.	DCA: Above 10,000 ft. dropped, then increased slightly, dropping again at 15,000 ft.	Lights moved rapidly up, down, and horizontally. Also hovered.
7-20	Early Morning	1				x	Orange	Over ADW		USAF Personnel	DCA: Surface inversion 3° isothermal between 8000 and 10,000 ft.	DCA: Above 10,000 ft. dropped, then increased slightly, dropping again at 15,000 ft.	No details available.
7-20	0000 to 0540	Many	x					DCA Terminal Area		Center	DCA: Surface inversion 3° isothermal between 8000 and 10,000 ft.	DCA: Above 10,000 ft. dropped, then increased slightly, dropping again at 15,000 ft.	Radar checked, found all right. Targets moved at random. Maximum 10 at one time.
7-20	0300	1	x	x		x		DCA Terminal Area		Capital 610	DCA: Surface inversion 3° isothermal between 8000 and 10,000 ft.	DCA: Above 10,000 ft. dropped, then increased slightly, dropping again at 15,000 ft.	Light and radar target appeared to follow aircraft from vicinity of Herndon to 4 miles west of DCA airport.
7-23	0000 to 0800	Many	x					DCA Terminal Area		Center	DCA: Surface inversion 3° normal lapse rate above	DCA: Sharp decrease at 10,000 ft.	Movement generally southeast at 35 to 40 miles per hour, sometimes in pairs and threes. Mostly weak, occasionally strong.
7-26	2030	8	x	x				DCA Terminal Area		Center	DCA: Surface inversion 1° otherwise normal	DCA: Fell below measuring limits at 8000 ft.	Tower saw few targets, only one moving fast. Center noted other targets at 2200 EST.
7-27	1930	1				x	Dark	Riverdale		Lt. Wales (ADW)	DCA: Slight inversion at 1500 ft., small inversion at 18,000 ft.	DCA: High to 12,000 ft., fell off somewhat, sharp rise at 18,000 ft.	Small circular object, edge occasionally visible. No noise, speed est. at 50 to 60 miles per hour. Oscillating rolling motion moving northeast. Clouds moving southeast. Entered base of clouds.
7-27	2030	1				x		Greenbelt		Local Citizen	DCA: Slight inversion at 1500 ft., small inversion at 18,000 ft.	DCA: High to 12,000 ft., fell off somewhat, sharp rise at 18,000 ft.	Brilliant light, tremendous speed.
7-27	2112	2				x		10 Miles East Tyrone, Pa.		American 516	Not available for locality	Not available for locality	Vicinity thunderstorm. Darting around edges. Left no trail.
7-27	2040	1				x		Lynchburg, Va.		Local Citizen	Not available for locality	Not available for locality	Low, unsteady flight, moving north to south. Left no trail.
7-27	2200	1				x	Yellow	ADW	40,000 to 50,000 (est.)	Maj. Turlin	DCA: Slight inversion at 1500 ft., small inversion at 18,000 ft.	DCA: High to 12,000 ft., fell off somewhat, sharp rise at 18,000 ft.	Moved slowly, stopped, flickered, moved in arc.
7-27	2318	2		x				DCA Terminal Area		DCA Tower	DCA: Surface inversion 4°, steep lapse rate to 10,000 ft.	DCA: High at 10,000 ft., slow fall to 15,000 ft., fast fall above 15,000 ft.	Tracked on north-northeast heading from 6 miles south-southwest of antenna to antenna site at speed of 25 miles per hour.
7-28	003C	1				x		City of Washington		Local Citizens	DCA: Surface inversion 4°, steep lapse rate to 10,000 ft.	DCA: High at 10,000 ft., slow fall to 15,000 ft., fast fall above 15,000 ft.	Many sightings.
7-29	0130 to 0500	Many	x					DCA Terminal Area		Center	DCA: Surface inversion 4°, steep lapse rate to 10,000 ft.	DCA: High at 10,000 ft., slow fall to 15,000 ft., fast fall above 15,000 ft.	Movement from Herndon to Andrews, southeast heading, in belt 15 miles wide.
7-29	1230 to 1500	Many	x					DCA Terminal Area		Center	DCA: Steep lapse rate to 2000 ft., inversion 500 ft. thick to 2500 ft.	DCA: High to 5000 ft., sharp fall, then increasing to 100 per cent at 9000 ft.	No details available.
7-29	1500	3				x	White	10 Miles Southeast ADW		Bolling Field Pilot	DCA: Steep lapse rate to 2000 ft., inversion 500 ft. thick to 2500 ft.	DCA: High to 5000 ft., sharp fall, then increasing to 100 per cent at 9000 ft.	Round white objects.

TABLE I (Continued)

Date 1952	Time EST	Number Targets	Radar Contact DCA CTR			Visual Contact	Color	Location	Altitude MSL (feet)	Reported By	Radiosonde Observations Temperature Lapse Rate		Remarks
			DCA CTR	DCA TWR	ADW APC						Temperature Lapse Rate	Humidity	
7-30	2258	1				x		City of Washington		Local Citizen	Not available	Not available	Oblong light. Note: may have been light from airport ceilometer.
7-31	0810	1				x		25 Miles North Savage, Md.		Local Citizen	Not available for locality	Not available for locality	Ball of fire with tail. Shot upwards.
8-3	2000	1				x	Blue-White	50 Miles South DCA	19,000	Capital 982	DCA: Small surface inversion isothermal at 11,000 ft., small inversion at 14,000 ft.	DCA: Decreasing to very dry at 14,000 ft.	Moving southeast.
8-5	1600 to 0000	Some			x			DCA Terminal Area		ADW Approach Control	DCA: Small surface inversion	DCA: High throughout	No details available.
8-6	0000 to 0800	Many	x					DCA Terminal Area		Center	DCA: Small surface inversion	DCA: High throughout	Moving east to southeast at average speed of 38 miles per hour. First appeared 20 to 25 miles west of DCA. Winds to 20,000 ft. averaged 18 to 20 knots.
8-8	1400	3		x				DCA Terminal Area		DCA Tower	DCA: Normal	DCA: High throughout	Class 4 targets, speed 60 miles per hour, tracked from 18 miles north of DCA to 3 miles north of DCA.
8-9	2210	2	x	x				DCA Terminal Area		Center	DCA: Normal	DCA: High, decreasing to below measuring limits at 17,000 ft.	Heading east.
8-13	2100	1			x		Blue-White	City of Washington		Local Citizen	DCA: Surface inversion below 2000 ft., another between 8000 and 9000 ft.	DCA: High at surface, low above upper inversion, otherwise below limits	Moving in arc high overhead.
8-13	1958 to 0030	68	x					DCA Terminal Area		Center	DCA: Surface inversion below 2000 ft., another between 8000 and 9000 ft.	DCA: High at surface, low above upper inversion, otherwise below limits	Targets plotted on southeast and south headings at 24 to 59 knots. Most targets within 10 miles of radar antenna.
8-14	1956	1	x					15 Miles West DCA		Center	DCA: Surface inversion 6°, upper inversions at 13,500 and 15,000 ft.	DCA: High, decreasing sharply at 14,000 ft.	Target plotted on east-southeast heading, speed 53 knots, curved path.
8-14	2055	1			x			1 1/2 Miles Southwest ADW		ADW Weather	DCA: Surface inversion 6°, upper inversions at 13,500 and 15,000 ft.	DCA: High, decreasing sharply at 14,000 ft.	Slow-moving target.
8-15	2213 to 2244	5	x					DCA Terminal Area		Center	DCA: Surface inversion to 400 ft., isothermal to 1100 ft.	DCA: High, with sharp fluctuations between 16,000 and 23,000 ft.	Targets plotted on north to east-northeast headings, speed 28 to 45 knots.
8-16	0000 to 0450	7	x					DCA Terminal Area		Center	DCA: Surface inversion to 400 ft., isothermal to 1100 ft.	DCA: High, with sharp fluctuations between 16,000 and 23,000 ft.	Targets plotted on west-northwest to north-northwest headings, speed 21 to 43 knots.

LEGEND

ADW = Andrews Air Force Ba' e
APC = Approach Control
CTR = Center
DCA = Washington
EST = Eastern standard time
est. = Estimated
MSL = Mean sea level
TWR = Tower

pressure area which remained in the vicinity of the southeastern coast line during the entire period. This high pressure area was responsible for an anticyclonic (clockwise) circulation of air over the eastern United States, a movement which continued during the month. This flow brought warm, moist air up from the Gulf of Mexico. The warm air mass usually extended up to about 10,000 feet. At higher levels the flow was from the west-southwest, and this continental air mass from the southwestern desert and drought area was hot and dry. Stagnation and heating of the air over the eastern United States was further increased because of an extremely strong band of westerly winds along the northern United States border, winds which prevented cold Canadian air masses from pushing south. Cyclonic activity was confined mostly to the area north of this band of westerly winds. There was a notable lack of thunderstorm activity in the Washington area. Physicists at the Naval Observatory reported that the amount of electrification in the air was very low.

The foregoing analysis indicated that the lack of cloud cover promoted solar heating in the daytime and rapid radiation cooling of the surface at night. This combination, with the prevailing light winds, was unusually conducive to the formation of temperature inversions during the hours of darkness.

Since the visual reports of flying saucers indicated that the observed lights spanned the same color range as the aurora borealis and since auroral effects closely follow sunspot activity, personnel of the Naval Observatory were consulted in order to determine whether any unusual sunspot activity had occurred during the period in question. They reported that there had been no unusual activity of this nature.

Reports from Other Locations.

The Washington ARTC Center is the only one equipped with air route surveillance radar. However, several CAA control towers are equipped with airport surveillance radar, Type ASR-1. A survey of these locations produced the following results:

ATLANTA, Municipal Airport. No unidentified targets of this nature have been reported.

BOSTON, Logan Field. Unidentified targets have been noticed on rare occasions. One slow-moving target was observed during instrument flying weather conditions about August 1, 1952. No interference with traffic has been caused by this problem.

CHICAGO, Midway Airport. Unidentified targets have been seen on many occasions, particularly when temperature inversions have been in effect and low smoke hung over the city. They are usually given as traffic information to other aircraft and occasionally form a nuisance problem, since there is a considerable helicopter activity at and around the airport.

CLEVELAND, Municipal Airport. Unidentified radar targets have been observed many times. The chief controller reported that on a recent occasion such targets moving slowly from west to east showed up in all portions of the scope face.

MINNEAPOLIS, International Airport. No targets of this nature have been reported.

NEW YORK, New York International Airport. No targets of this nature have been reported.

La Guardia Airport. Only one such instance was reported. At the time it was thought to be due to difficulties within the radar itself.

WASHINGTON, National Airport. Targets of this nature have been observed occasionally over a long period. Recent occasions are logged in Table I of this report.

HISTORICAL REFERENCES

The history of radar abounds with reports of strange echoes received from supposedly clear skies. Early observers suspected birds or stray weather balloons, but these were eliminated by visual checks. Conjecture that clouds of insects were responsible was also eliminated when such echoes were obtained in the dead of winter. Some connection with the weather was suspected after it was noted that echoes of this type became more numerous on summer nights under calm conditions. Additional evidence indicated that many of these echoes originated in the fine structures of the dielectric (refracting) layers of air-mass boundaries and in regions of air turbulence. Some of the sharpest echoes involved surfaces of pronounced transitions of the water-vapor content of the air. The bibliography at the end of this report contains numerous detailed references to these general phenomena.

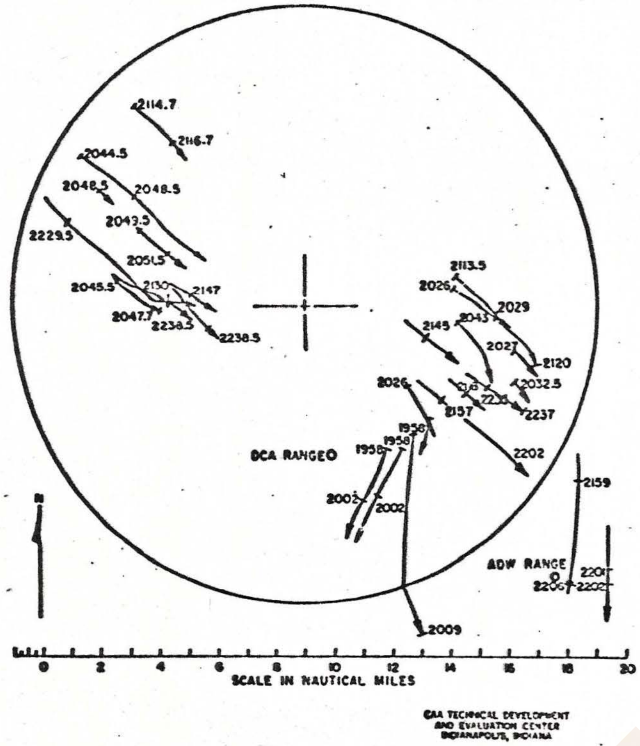

Fig. 1 Track Plots of Unidentified Targets, Washington MEW Radar, 1958 to 2242 EST, August 13, 1952

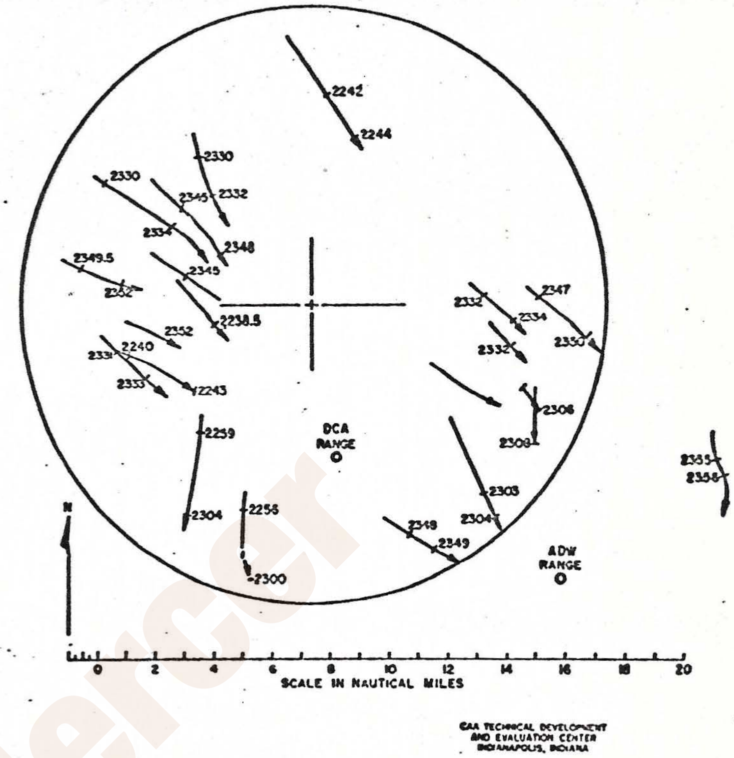

Fig. 2 Track Plots of Unidentified Targets, Washington MEW Radar, 2242 to 2352 EST, August 13, 1952

WASHINGTON OBSERVATIONS

August 13-14, 1952.

The observation period started at 1830 Eastern standard time (EST) on the evening of August 13. At the beginning of this period, the moving target indicator was gated to cancel out ground returns up to a range of 10 nautical miles. Beyond this range the scope was clear except for a few permanent echoes that were visible.

Suddenly, at approximately 1957 EST, a group of seven strong stationary targets became visible in an area about 15 miles north-northeast of the radar antenna. During the next two or three antenna revolutions, the area on the scope between Washington and Baltimore became heavily sprinkled with stationary targets in a belt about 6 miles wide. A group of additional targets became visible in an area approximately 10 to 15 miles south of the radar antenna. This was evidence of the beginning of a temperature inversion.

Within the next minute, at approximately 1958 EST, four unidentified moving targets showed up 5 miles southeast of the radar antenna and moved in a southerly direction away from it. When the radar beam was switched from high to low, the targets disappeared. The beam was switched back to high, and the targets returned.

Targets were uniformly small and usually had a weak, fuzzy appearance. However, the target intensity varied from sweep to sweep. Occasionally one or two very strong returns would be received in succession, followed by almost total blanking.

For the next four and one-half hours, many unidentified targets were carefully plotted with a grease pencil on the face of the Type VG scope. The time for each was entered on these plots in order to calculate ground speeds. To secure a permanent record, time data and track plots were transferred from the scope face to a sheet of frosted acetate. These plots are reproduced in Figs. 1, 2, and 3. The distribution of target ranges is shown in Fig. 4. The average distance that any target was tracked continuously was approximately 2.1 nautical miles.

The observation period was discontinued at 0030 EST on August 14, and steps were taken to secure all available meteorological data relevant to the observation period. The local radiosonde observation

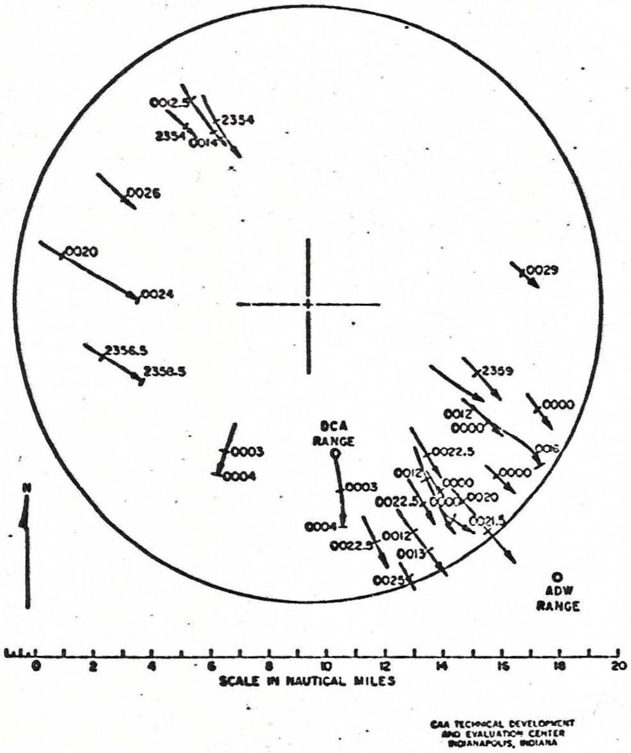

Fig. 3 Track Plots of Unidentified Targets, Washington MEW Radar, 2353 to 0029 EST, August 13-14, 1952

which was taken near the midpoint of the observation period, at 2200 EST on August 13, is reproduced in Fig. 5. Winds aloft, as observed at the same time, are listed in Table II.

August 15-16, 1952.

On the night of August 15-16, additional track plots were obtained by Washington ARTC Center personnel. During this period, the radar was operating on the high beam with the moving target indicator gated to 12 miles. The same stationary targets in the Washington-Baltimore belt and in an area 10 to 15 miles south of the radar antenna were visible again on the scope face.

Track plots for this period are shown in Figs. 6 and 7. The local radiosonde observation taken at 2200 EST on August 15 is reproduced in Fig. 8. Winds aloft, as observed at the same time, are listed in Table III.

ANALYSIS OF WASHINGTON DATA

It will be noted from Table I that many more unidentified targets are picked up by the Washington ARTC Center than by the Washington Airport Traffic Control Tower. This may be explained by the fact that the center is equipped with a MEW radar, while the tower is equipped with an airport surveillance radar, Type ASR-1. The most significant differences between the two types of equipment are listed in the following:

1. The peak power of the MEW is 3 decibels (db) higher than the ASR-1.
2. The average power of the MEW is 6 db higher than the average power of the ASR-1.
3. The MEW has a higher elevation angle coverage.
4. The MEW elicits approximately twice as many hits per scan per target since the scan rate of the MEW is 6 revolutions per

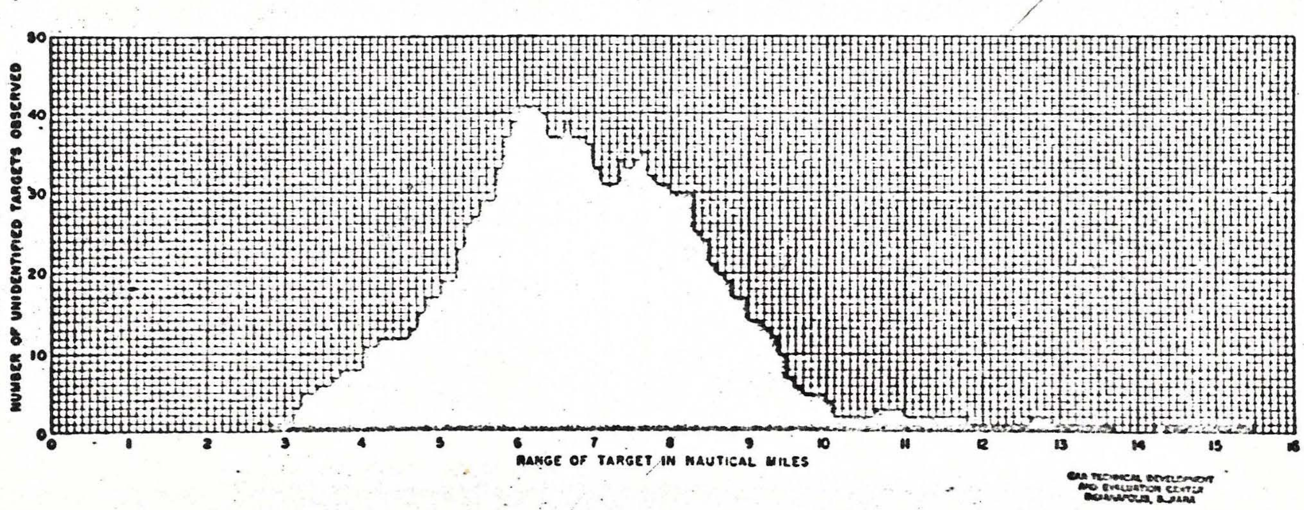

Fig. 4 Distribution of Target Ranges, Washington MEW Radar, August 13-14, 1952 Observation

minute (rpm). Additional specifications of these radars are listed in Table IV.

The almost simultaneous appearance of the first moving targets with the ground returns, signifying the beginning of the temperature inversion, suggested that the target display was perhaps caused by some effects existing in or near the inversion layers.

It will be noted in Figs. 1, 2, and 3 that all targets observed in the first period were moving from the north or northwest. In Fig. 6 all targets were moving from the south or southwest, and in Fig. 7 all were moving from the west or northwest. The definite directional trend in each case eliminated the possibility that the unidentified targets were surface vehicles such as trains, trucks, automobiles, or boats. Had this been the case, some vehicles would have been moving in the reverse directions. In each case, target directions corresponded with the wind

TABLE II

WINDS ALOFT
WASHINGTON (SILVER HILL)
2200 EST August 13, 1952

Altitude (MSL)	Direction (Degrees)	Velocity (Knots)
Surface	Calm	0
1000	Calm	0
2000	350	12
3000	340	12
4000	320	14
5000	320	16
6000	300	18
7000	300	20
8000	310	20
9000	310	22
10000	300	26
11000	290	28
12000	290	29
13000	300	30
14000	300	28
15000	290	29
16000	300	29
17000	300	29
18000	300	30
19000	300	32
20000	300	38
21000	290	38
22000	280	43
23000	280	48
24000	280	50
25000	270	52
26000	280	57
27000	270	61
28000	270	54
29000	270	55
30000	280	62
31000	270	63
32000	280	73
33000	280	84

TABLE III

WINDS ALOFT
WASHINGTON (SILVER HILL)
2200 EST August 15, 1952

Altitude (MSL)	Direction (Degrees)	Velocity (Knots)
Surface	170	5
1000	180	24
2000	190	26
3000	210	24
4000	210	23
5000	220	20
6000	220	16
7000	220	18
8000	220	17
9000	220	13
10000	240	12
11000	270	11
12000	270	13
13000	260	17
14000	260	21
15000	260	25
16000	270	25
17000	270	23
18000	270	22
19000	270	21
20000	260	20
21000	270	22
22000	280	24
23000	290	26
24000	280	26
25000	290	26
26000	300	30
27000	300	34
28000	300	38
29000	290	38
30000	290	36
31000	300	35
32000	300	35
33000	310	34
34000	310	40
35000	300	47
36000	300	49
37000	300	50
38000	300	48
39000	310	42
40000	320	38
41000	300	43
42000	300	53
43000	300	67
44000	310	69
45000	310	60

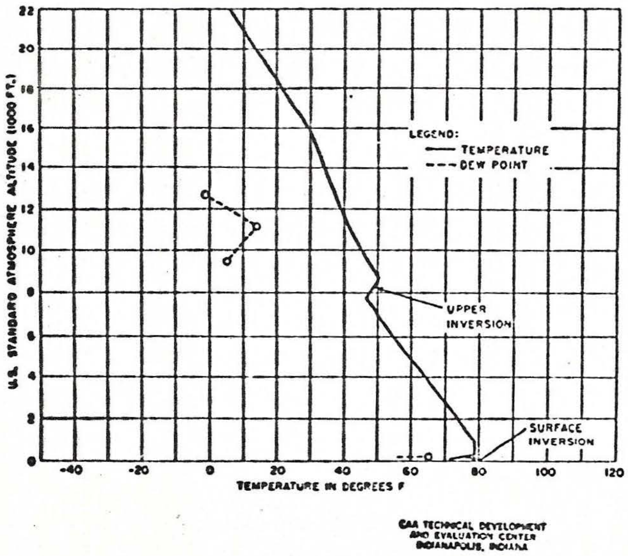

Fig. 5 Radiosonde Observation, Silver Hill, Washington, D. C., 2300 EST, August 13, 1952

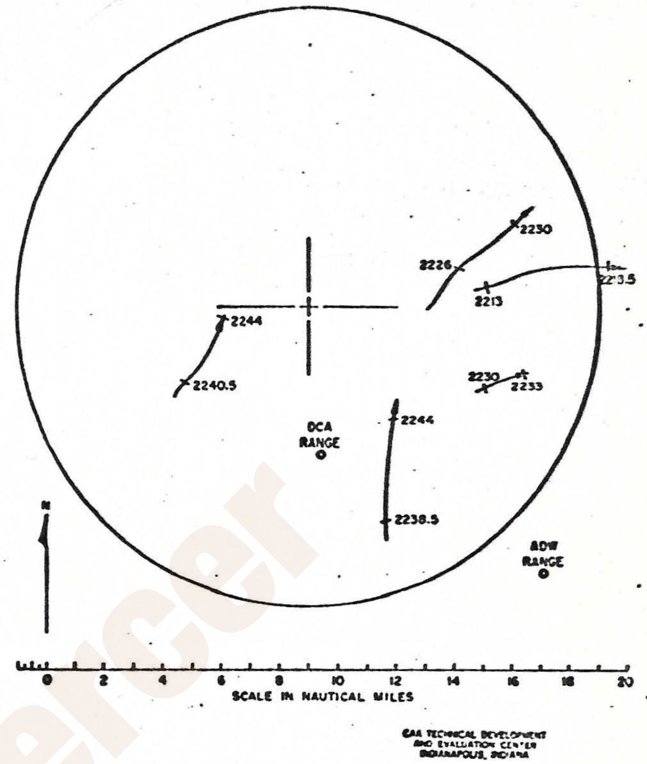

Fig. 6 Track Plots of Unidentified Targets, Washington MEW Radar, 2213 to 2244 EST, August 15, 1952

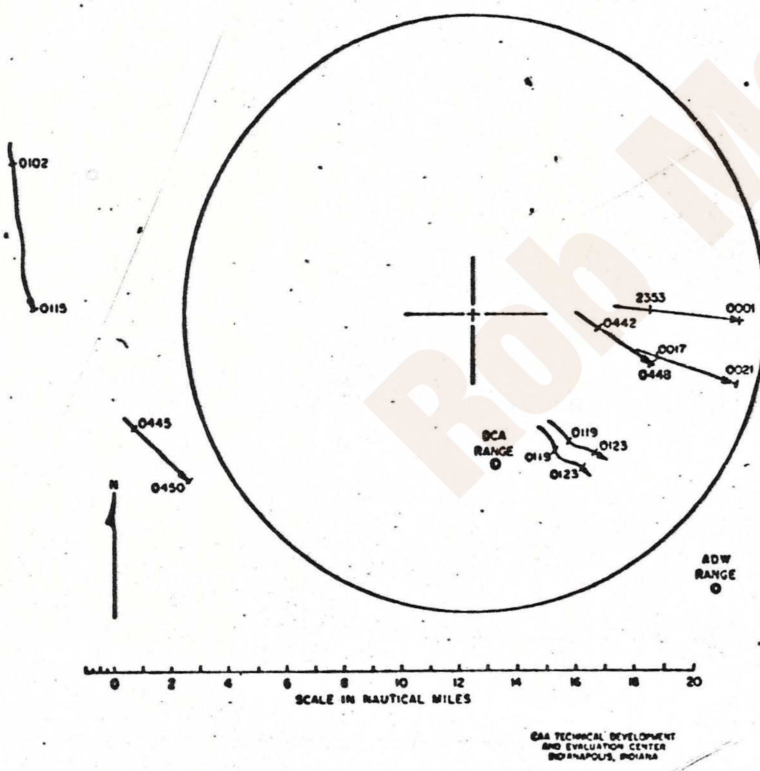

Fig. 7 Track Plots of Unidentified Targets, Washington MEW Radar, 2253 to 0450 EST, August 15-16, 1952

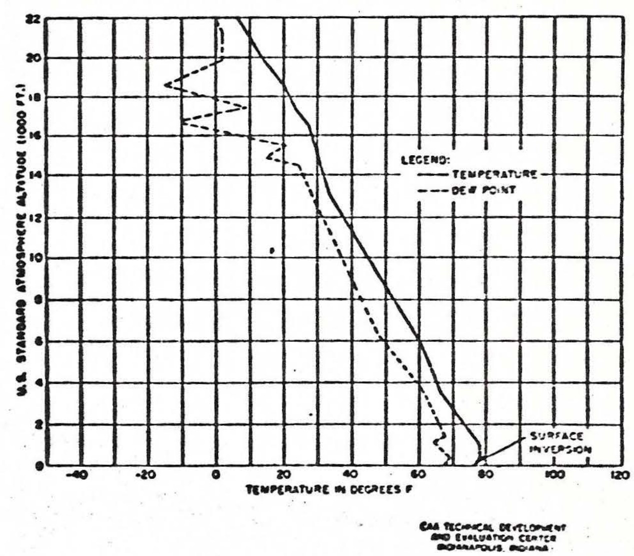

Fig. 8 Radiosonde Observation, Silver Hill, Washington, D. C., 2200 EST, August 15, 1952

directions reported aloft. This fact suggested that whatever was producing the targets was being carried by the wind.

The next step of the analysis was to determine, if possible, the altitude of the objects which produced the radar targets. Since the radar actually measures slant range which could in some cases be almost directly overhead from the high-beam MEW antenna, the minimum range of each target was used to determine the absolute maximum altitude of the object producing the target.

TABLE IV

RADAR EQUIPMENT CHARACTERISTICS

	Tower Radar	Center Radar
Type	ASR-1	MEW
Frequency	S-band	S-band
Pulse-repetition frequency	1,000	900
Pulse rate	0.5 microsecond	1 microsecond
Vertical coverage	6,000 feet at 6 miles	12,000 feet at 3 miles
Scan Rate	28 per minute	6 per minute
Display scopes	12DP7	12DP7 and VG2
Power output	200 kilowatts	400 kilowatts

For example, a target which came within five nautical miles of the radar antenna could not be above an altitude of five nautical miles, or 30,400 feet. With the use of the slant-range principle, the absolute maximum altitude of each target was determined and is listed in Table V. When attempting later to determine the probable altitude of each target by studying the winds aloft, it was useful to have these maximum altitude figures to eliminate the necessity for consideration of higher-altitude levels.

Since winds aloft can vary considerably during the period of a few hours, it was decided to use in this analysis only data on targets which were under observation during the periods from one hour before to one hour after the observations of the local winds aloft. These targets are listed in Table V.

During the observation period on the night of August 13-14, all targets on a southerly heading had ground speeds of at least 24 knots. The only reported winds with a southerly heading had a velocity of only 12 knots. These were winds at the 2,000- and 3,000-foot levels. Targets on a southeasterly heading had a speed range of 32 to 48 knots. However, the only winds on this heading were from 14 knots at 4,000 feet to 38 knots at 20,000 feet.

During the August 15-16 observations, targets on a north or northeasterly heading had speeds of 35 to 42 knots. The only reported winds moving in this direction ranged between 5 and 26 knots from the surface up to 9,000 feet. Targets on easterly headings had speeds from 22 to 45 knots. The only reported winds moving in this direction had speeds of from 10 to 24 knots between 10,000 and 25,000 feet.

In Figs. 9 and 10, the directions and velocities of the winds aloft are plotted on a polar projection diagram together with the directions and velocities of the observed targets. Agreement between the directions of the winds and the directions of the targets is apparent.

One of the theoretically possible causes of the unidentified targets was the delayed-pulse or second-time-around effect inherent in the radar method of time measurement. With a second-time-around effect, objects beyond the normal sweep range of a radar can be displayed on the scope because of reception of an echo pulse elicited not by the transmitted pulse which triggers the range sweep but by the preceding transmitted pulse. The apparent velocity of the target on the radar is no greater than and normally less than the velocity of the object producing the return. The heading of the radar target would not necessarily be parallel to the heading of the object unless the object was on a course radial to the radar antenna. These effects are illustrated in Fig. 11.

If we assume then that an object producing a second-time-around radar target was being carried by the wind, the apparent velocity of the target would be no greater than the wind velocity. However, the analysis of the targets listed in Table V showed that

TABLE V

MOVEMENT DATA ON TARGETS TRACKED WITHIN ONE HOUR FROM START OF OBSERVATIONS OF WINDS ALOFT

Date Aug. 1952	Starting Time EST	Direction (Degrees)	Target Speed (Knots)	Reflector Speed (1/2 Target Speed)	Absolute Maximum Altitude (Based on Minimum Slant Range	Probable Altitude (Based on Winds Aloft)
13	2159	005	28	14	63000	2000
	2201	360	24	12	75000	2000
	2229	310	33	16.5	23000	8000
	2240	300	46	23	30000	9000
	2242	325	48	24	33000	9000
	2259	010	31	15.5	31000	2000
	2303	330	42	21	36000	8000
	2330	340	39	19.5	23000	5000
	2330	305	39	19.5	24000	8000
	2331	315	39	19.5	35000	8000
	2332	315	36	18	23000	8000
	2345	310	38	19	19000	8000
	2347	310	42	21	43000	8000
	2349	290	39	19.5	35000	7000
	2356	300	42	21	37000	7000
	2355	350	36	18	83000	2000
15	2213	260	45	22.5	34000	14000
	2226	225	35	17.5	24000	900
	2230	250	28	14	37000	10500
	2238	185	36	18	29000	900
	2240	210	42	21	18000	4500
	2353	275	23	11.5	29000	10500*

*This target could also have been a direct radar return from an object floating with the wind at 15000 to 17000 feet mean sea level.

they were actually moving at speeds approximately double the wind velocities reported for the directions involved. This fact eliminated the possibility that the targets were being produced by the second-time-around effect.

When the target velocities plotted in Figs. 9 and 10 were halved, those plotted points clustered very closely around the wind plots. Further investigation of the doubled-speed effect indicated that this effect could be produced if the original radar beam were reflected downward to give a ground return, as shown in Fig. 12. If we assume that some sort of horizontal reflector was present aloft and that the angle of reflection equalled the angle of incidence of the radar beam, any horizontal movement of the reflector would produce a movement twice as great in the image being received on the radar scope. Furthermore, the apparent motion of the image would be parallel to the motion of the reflector, as illustrated in Fig. 13.

When the observed target velocities were divided by two, the target motions corresponded closely to the reported wind directions and velocities at certain altitude levels. In nearly all of these cases the altitude levels, which are listed as probable altitudes in Table V, were at or adjacent to the temperature inversion levels.

With only one exception, no targets were seen moving at the speed and heading of the reported wind at any altitude. This suggested that the reflecting areas, which were capable of bending the radar beam, were nevertheless not of sufficient density to produce direct returns on the radar scope. Thus, it appeared likely that the reflection effect was being produced by the atmosphere itself. If this were the case, it would probably be a refraction rather than a reflection which was involved. This effect is shown in Fig. 14.

The uniformly small size of the observed targets as well as the relatively low frequency of their occurrences suggested that the conditions producing this effect were extremely localized and decidedly critical. Although the exact nature of the discontinuity

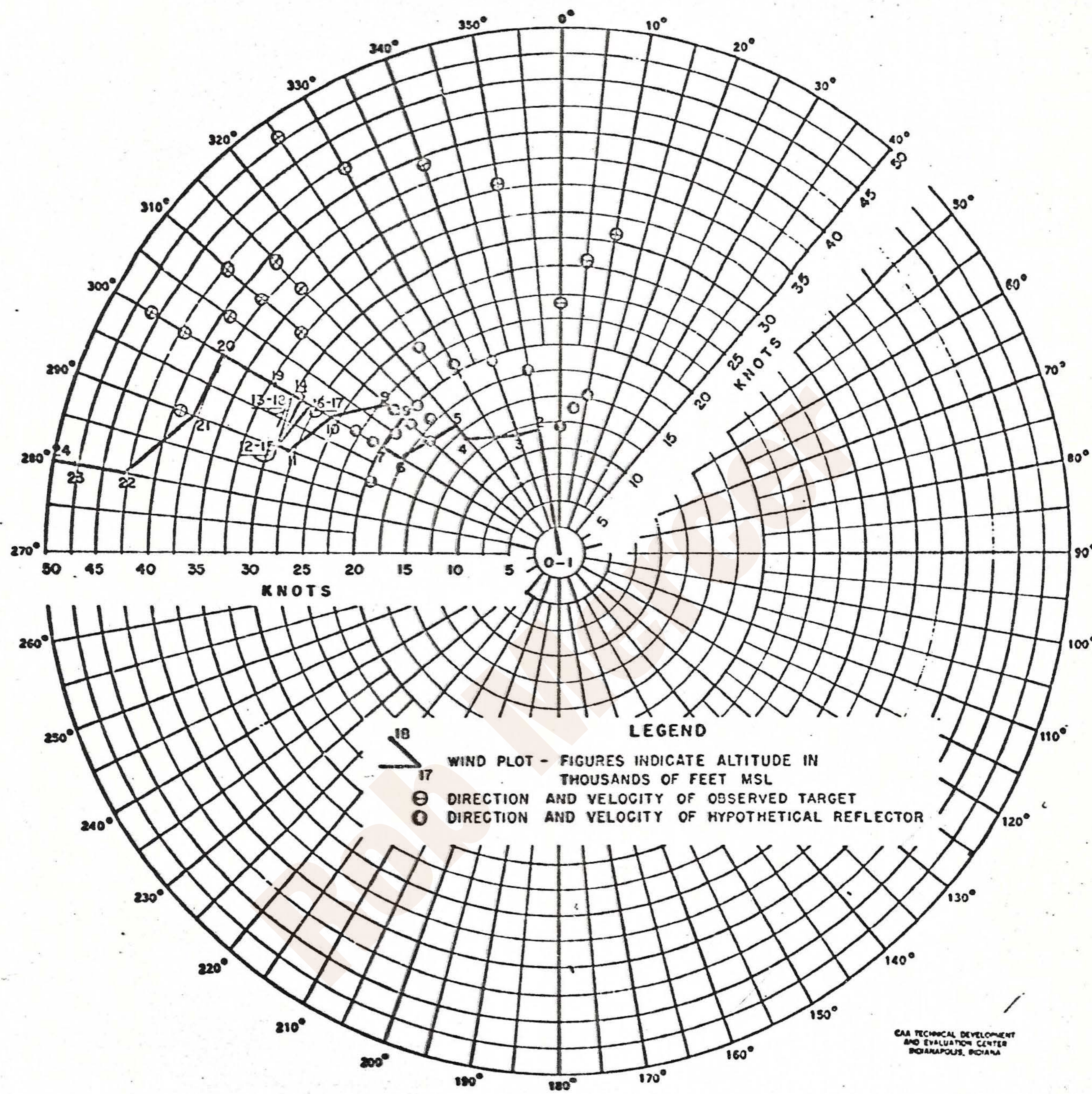

Fig. 9 Comparison Between Winds Aloft and Target Data, August 13, 1952 Observation

is not known, one possible explanation might be that it is an eddy in the atmosphere. Such eddies may be produced by the shearing effect of dissimilar air masses moving at different speeds and headings at or near the inversion boundary. They might under certain conditions produce bulges in the inversion layer, concentrating and directing the radar energy with a lens effect to produce a return signal strong enough to show up on the radar scope. The relatively short paths of some of the radar targets before their fade-out might be attributed to the dissipation of these eddies in the stratified air mass.

Intermediate speed checks on numerous targets indicated that individual velocities remained quite steady during the observation period. It became possible to predict with accuracy the progress of specific targets from minute to minute. There was no evidence of hovering or of sudden increases in speed by any target. It is believed that previous reports of sudden accelerations of targets to supersonic velocities were due to

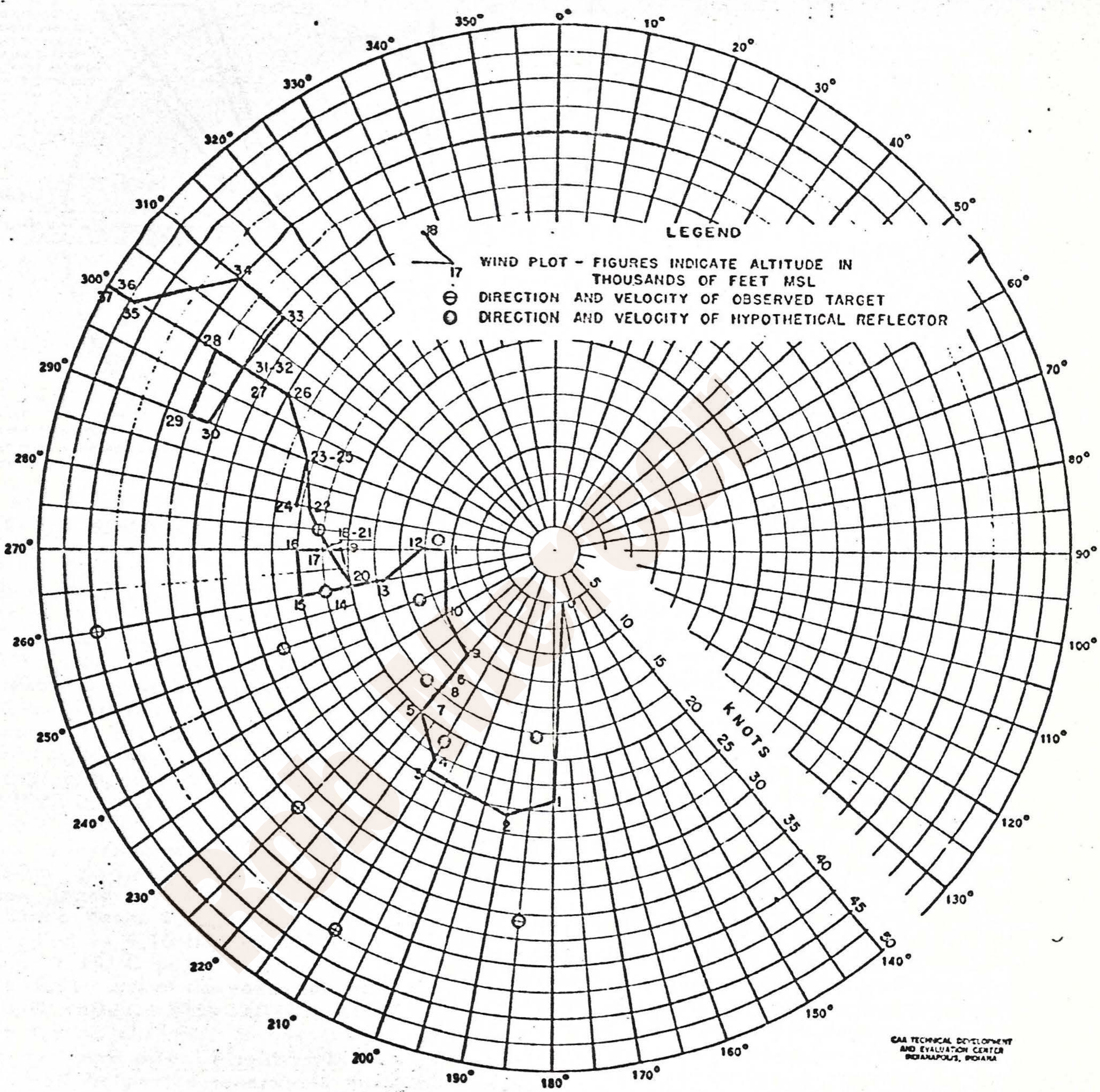

Fig. 10 Comparison Between Winds Aloft and Target Data, August 15, 1952 Observation

a controller's transfer of identity from a faded target to another target which was just appearing on a different section of the scope.

It would be unwise to assume that all unidentified slow-moving radar targets are caused by refraction of radar energy. Small rain clouds produce much the same appearance on the scope. Other targets could be direct returns from bird formations, balloons, or debris carried aloft by convection or tornadoes. It has recently been reported that more than 4,000 balloons are released in the United States every day by Government and civilian research organizations.[1] A recent analysis of more than 1,000 visual reports of unidentified flying objects by the Air Technical Intelligence Center at Wright-Patterson Air Force Base indicates that

[1] "Many Potential 'Saucers,'" Science News Letter, Vol. 62, No. 7, Aug. 16, 1952, p. 106.

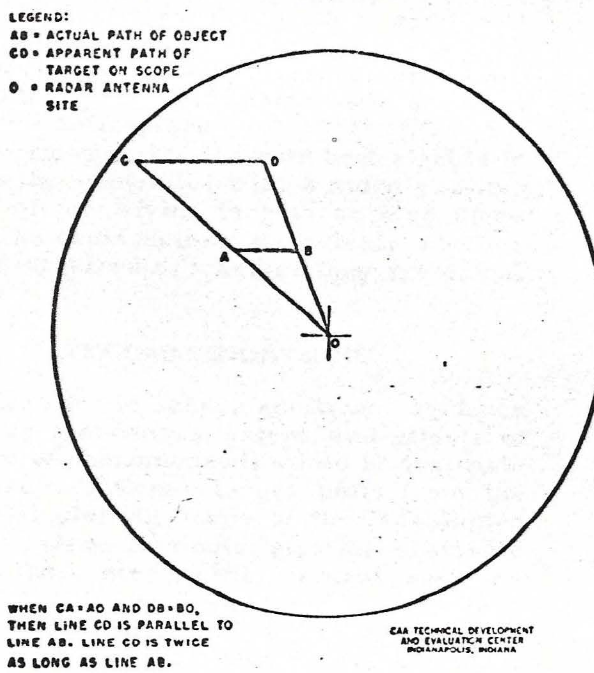

Fig. 13 Plan View of Reflection Effect

Aircraft targets showed sharp rise and decay times as well as relatively constant shape and amplitude. The unidentified targets showed gradual rise and decay times; amplitude and shape showed wide variations, which resulted in a random interlaced signal envelope similar to that returned by rain and cloud formations. These target characteristics are sketched in Fig. 15.

ANALYSIS OF SUPPLEMENTARY OBSERVATIONS

The reduced target returns from the L-band radar indicated that the reflecting areas are formed by atmospheric disturbances or discontinuities rather than by some form of ionization. If the cause were ionization, it would be expected that the lower frequency of the L-band equipment would increase the susceptibility of the radar energy to reflection or refraction effects. An example of this trend is that of ionospheric layers which produce no appreciable reflection of ultra-high-frequency energy but cause strong skip propagation of the lower radio frequencies.

EFFECT ON AIR TRAFFIC CONTROL OPERATIONS

The generally weak and fuzzy appearance as well as the slow speed of spurious radar targets usually enable them to be

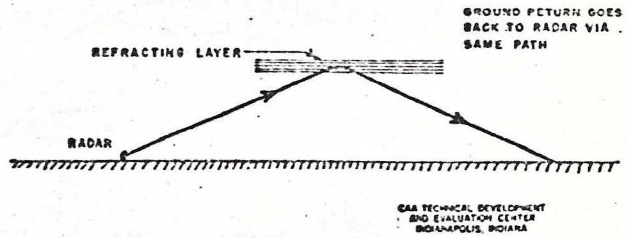

Fig. 14 Refraction of Radar Beam

recognized as such by experienced radar controllers. Normally these targets have but little effect on traffic control, because they occupy very little space in relation to the entire scope area and their progress on course is very slow. The most dangerous possibility from the traffic control standpoint is the chance that one of these targets might be a helicopter.

If their course will not collide with that of an aircraft target, such targets are generally disregarded. If the course will collide with an aircraft target, some control action is indicated because of the helicopter hazard. In such cases, prudent controllers will give traffic information to pilots regarding the unidentified target, particularly at night under visual flight rule conditions. Where a collision course is involved, pilots would rather be warned about a spurious target than not be warned about a legitimate one.

At the present time, very little instrument flying is done by helicopters. Therefore, unidentified targets of this type are not usually given as traffic information to pilots known to be operating on instruments.

CONCLUSIONS

1. It is believed that most of the unidentified targets observed on the Washington MEW radar during the period beginning on the night of August 13, 1952 and the period beginning on the night of August 15, 1952 were ground returns caused by reflection phenomena closely connected with the temperature inversions in the lower atmosphere.

2. Unidentified radar targets of the type described in this report have been noticed since the early days of radar. Unusual weather conditions prevailing in the Washington area during the summer of 1952 were exceptionally conducive to the formation of these phenomena.

3. Present evidence indicates that the appearance of unidentified targets of this nature on radar scopes has but little effect on the control of air traffic. At its worst, it forms a nuisance by cluttering the scope

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