

TARGET BALLOON METEOROLOGY

I. INTRODUCTION

Although balloons are generally assumed to be subject only to the capacities of the atmosphere, they may be utilized to overfly designated targets. The Air Force Geophysics Laboratory (AFGL, AFSC) has periodically engaged in the activity since 1955, with some 250 flights, principally in the vicinity of White Sands Missile Range (WSMR), New Mexico. As early as 1949, the Navy, with AFGL support, dropped a missile from a target balloon above WSMR.

The balloons referred to here, are almost all plastic, constant level cells, flown primarily by AFGL and NCAR. They may handle payloads in excess of five tons, (4545KG), and attain with smaller loads, altitudes in excess of 50 kilometers. An example of a medium sized model, some two million cubic feet (56,634 cubic meters) is shown in figure 1. Not the complex assortment of payloads which can be handled.

The usefulness of this aerostate in its role as a targeting device is exemplified in drop tests of nose cones, ejection seats, etc. Some of the more important programs have included the discoverer, Biosatellite and Samos nose cones, the Convair B-58 ejections seats, the Goodyear balute the Viking and Pioneer Venus recovery systems. Some nose cones have even been driven to altitudes above the balloon with rocket engines, for more valid reentry tests. Some have been powered during the drop phase. There were numerous flights where the balloon itself served as a target for guided missiles. In one series, a small target rocket was fired horizontally from the balloon.

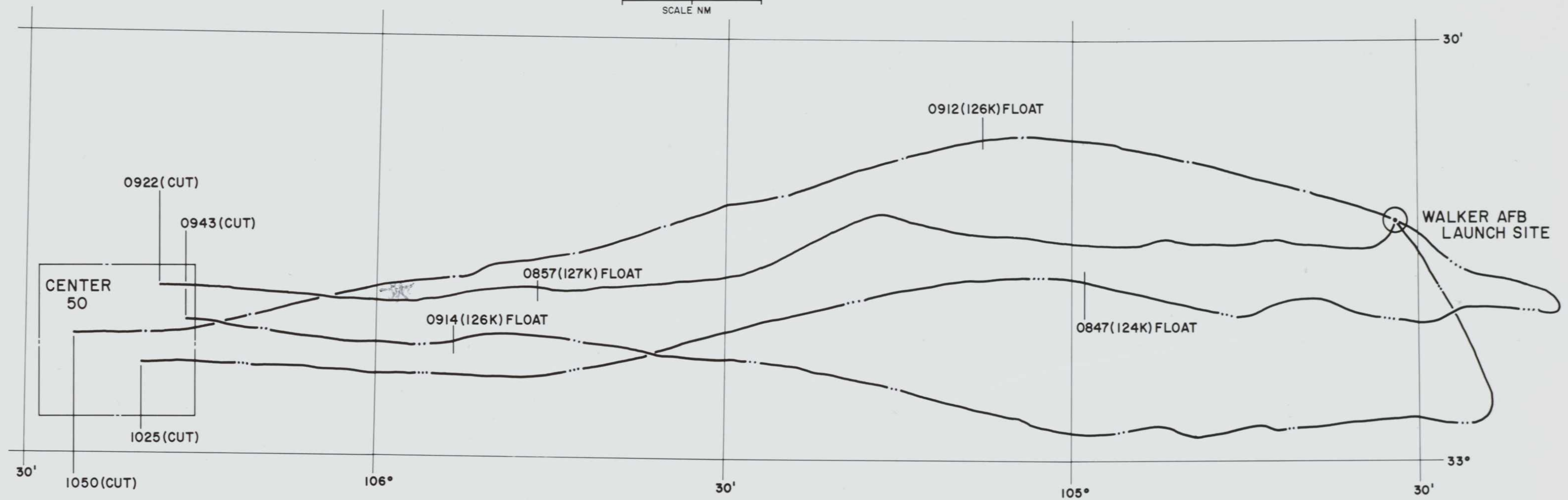
Most of these missions required a drop or rendezvous at a designated altitude, time and position over a network of impact areas on the WSMR. Some concept of the scale of the operation illustrates 4 target flight trajectories from a launch point 90 nautical miles (167km) upwind of the target area. Float altitudes were 125 to 128K (38 to 39 km). Consistency of the high stratosphere summer easterlies aided in forecast accuracy.

Accuracy of AFGL target balloon missions over WSMR is summarized in the following tables. The data covers the period from summer 1956 to December 1976.

<u>Nautical Miles from Target Center</u>	<u>%</u>	<u>Accumulative %</u>
0-2	19	
3-5	39	58
6-10	26	84

PEPP TRAJECTORIES

0 5 10
SCALE NM

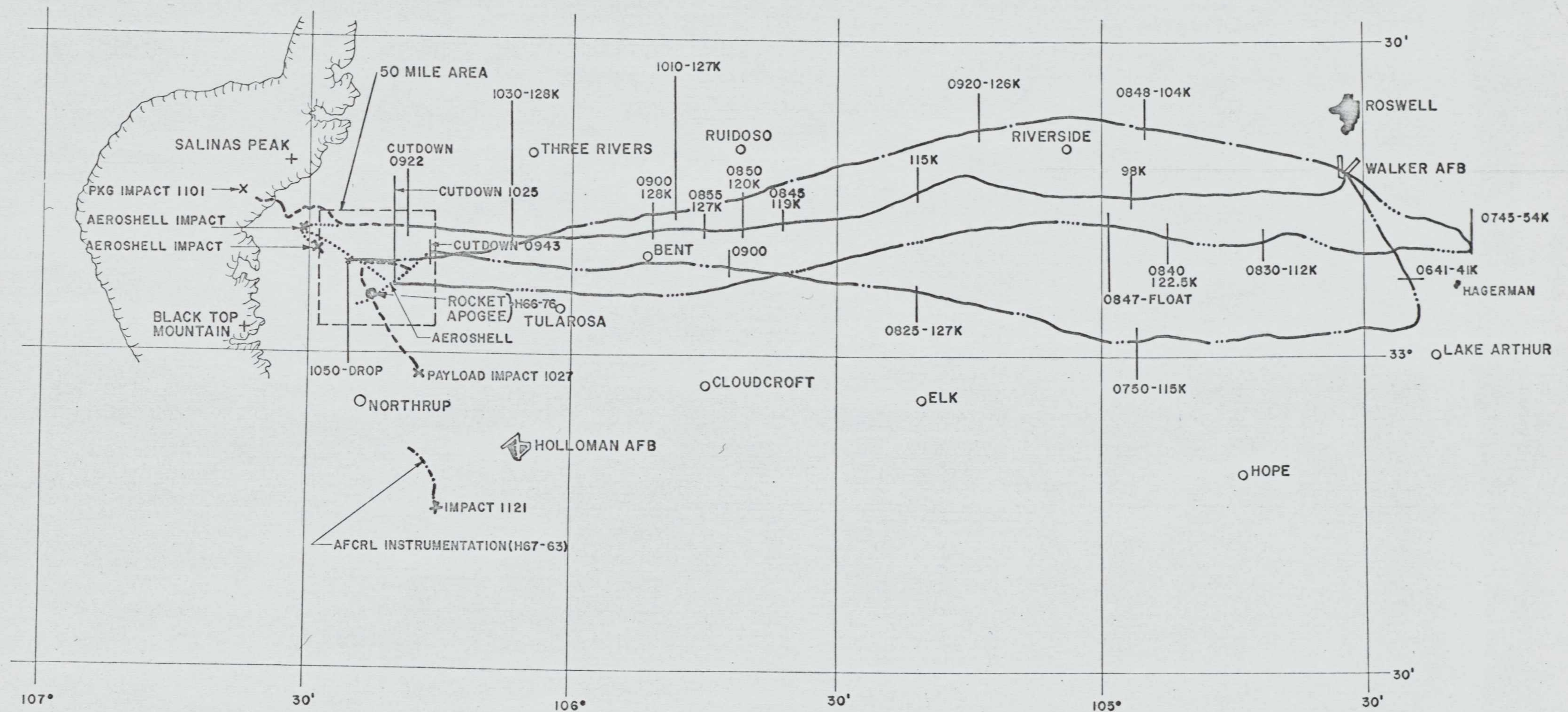


○ HOLLOMAN AFB

LEGEND

- H66-76 30 AUG 66
LAUNCH 0717 MST
- H67-60 28 JUL 67
LAUNCH 0628.5 MDT
- H67-63 15 AUG 67
LAUNCH 0609 MDT
- H67-65 22 AUG 67
LAUNCH 0702 MDT

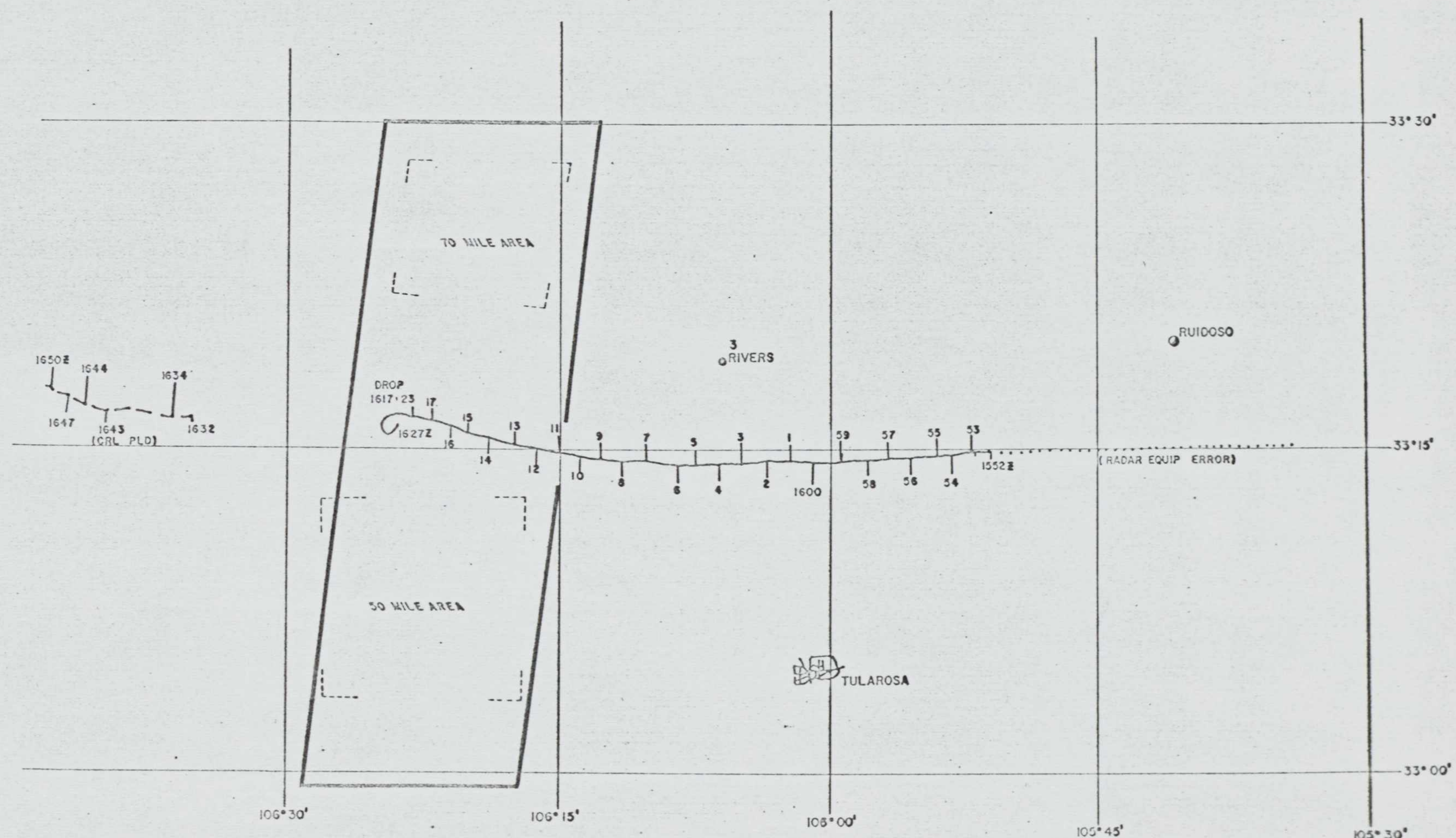
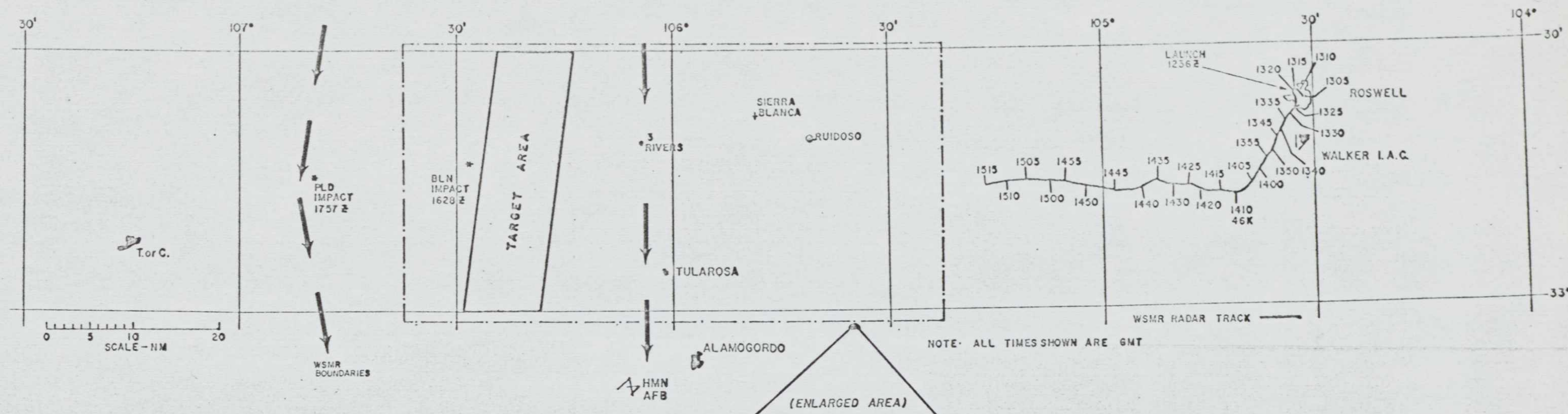
PEPP TRAJECTORIES



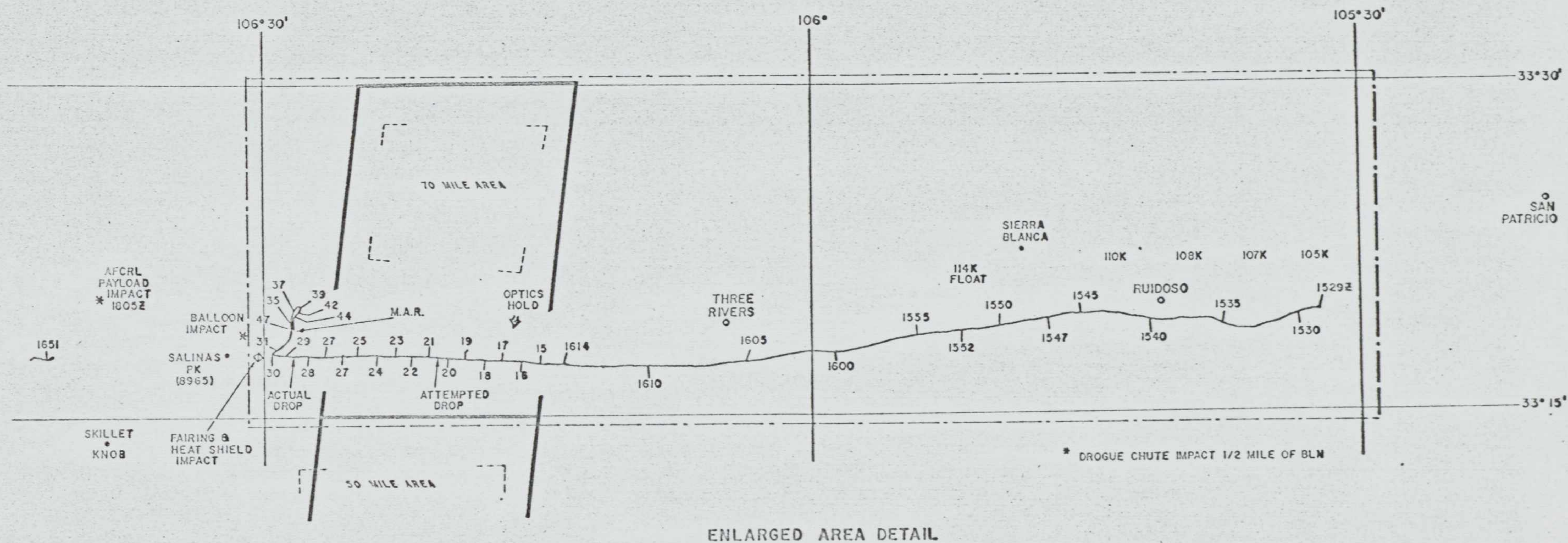
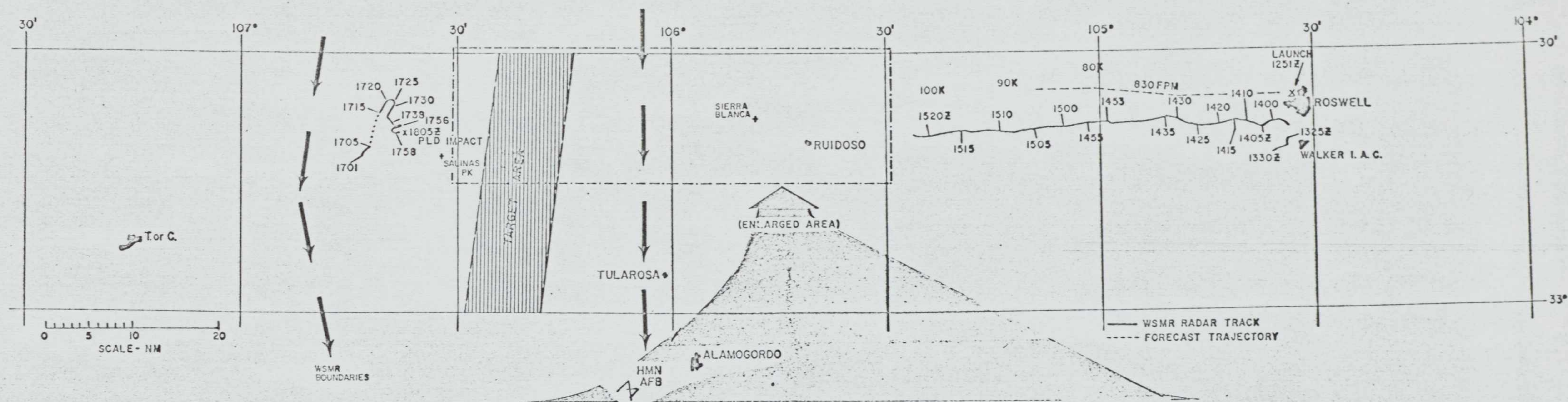
LEGEND

- H67-60 28 JULY 67
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TRAJECTORY FLT. NO. H70-45 30 JULY 70

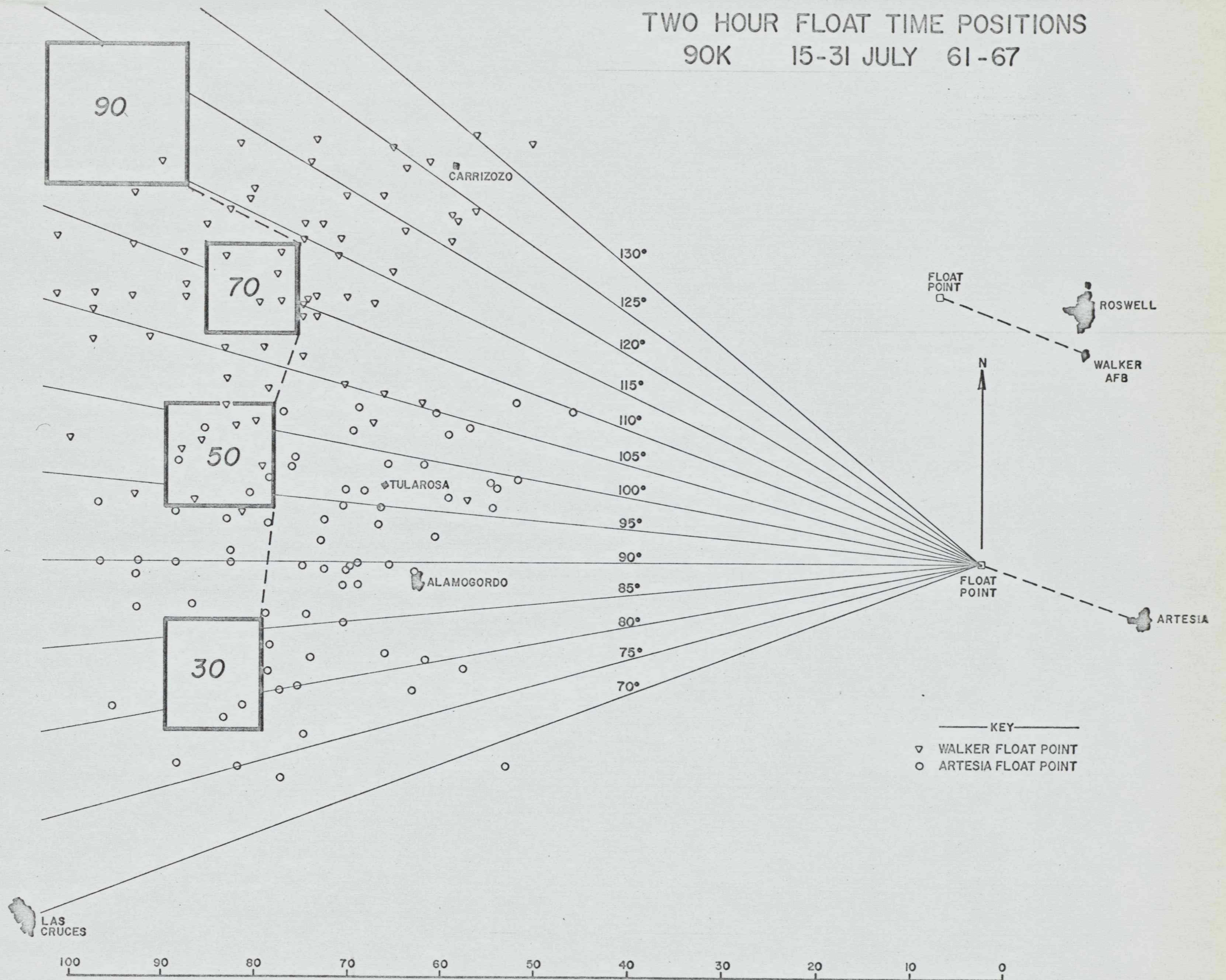


TRAJECTORY FLT. NO. H70-40 13 JULY 70



TWO HOUR FLOAT TIME POSITIONS

90K 15-31 JULY 61-67





<u>Nautical Miles from Target Center</u>	<u>%</u>	<u>Accumulative %</u>
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11-15	11	95
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15+	5	100 (172 cases)
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Target Time Error

<u>Minutes</u>	<u>%</u>	<u>Accumulative Percent</u>
0-5	39	72
6-15	33	84
16-30	12	100 (215 cases)
30+	16	

The record is quite impressive, but the population does include a wide range of altitudes (40 to 120K, 12 to 40KM) with both fixed and adjustable launch sites. Some targets accuracies are shown in Figure 2.

In addition to attaining target drop areas over WSMR, cities were chosen as overfly targets several times. Other experiences saw the balloon intercepting, (in the X-Y plane) ground vehicles carrying optical targets.

2. BASIC MISSIONS PROCEDURES

(1) At least six to eight months in advance of the desired launch date, target areas and drop altitudes are agreed upon. The advance decision is needed to make launch site arrangements and for general coordination, particularly with the Missile Range.

(2) Shortly afterwards, a climatological analysis is performed and launch sites are selected. Logistics of preparing large, complicated payloads usually require a single site. This limits the number of "go days" but does simplify most of the other problems associated with remote operations.

(3) On launch minus one day, a nominal launch time is selected, based on the fixed target time, and the forecast trajectory.

(4) The flight is launched at an adjusted time, finely tuned to the most update forecast trajectory.

(5) The trajectory is corrected during flight, if necessary, by varying the ascent rate in significant strata, via command ballasting and valving of the balloon.

(6) Target achieved, but the remaining balloon control instrumentation (assuming a drop of the experiment) may still have to be flown on the balloon to a favorable recovery area.

TARGET ACCURACIES

CREH JULY '56 to MARCH '70

ΔT (minutes) from
Scheduled Intercept

%

Accumulative
%

0 - 5

37

37

6 - 15

33

70

16 - 30

12

82

> 30

18

100

211 Cases, 1 to 5 hours Flight Time

3. CLIMATOLOGY AND STRATEGY

As noted earlier, a climatological analysis is required for selection of launch sites, and also the optimum launch date bracket. Some useful rules of thumb for both the climatological procedures and flight strategy are listed below.

(1) A launch site or sites should be selected, which minimizes the float segment of the trajectory. The float altitude is usually in the stratosphere and the stratospheric winds, responsible for most of the climb out segment, can be forecast accurately. There are no facsimile chart forecasts available above 100 millibars, (53K, 16KM), and above 10 millibars (102K, 31KM) even raw data becomes sparse. Moreover, forecast errors at some climb out altitudes are often neutralized by compensating errors at other levels.

(2) The easterlies in the summer stratosphere are much more persistent than any other seasonal wind regime, and should be a preference if a significant float phase is necessary

(3) Rarely depend upon light winds near or at float (less than 15 knots, 8Mps) to drive into a target area. Highly sensitive to diurnal changes, gravity waves and terrain effects, this flow is precariously variable. Plan to be inside the target area when float altitude is attained, in this case. Make up the distance by utilizing the strongest winds below float altitude which have a favorable directional bias toward the target. This technique will be discussed under "In Flight Procedures".

If driving winds less than 15 knots have to be accepted, excess ballast should be carried in order to maneuver for the best steering altitude. Inevitably there will be altitudes of calm which can be used to "park" the system just upwind of the target area. Thus, one can launch about two or three hours earlier than the nominal trajectory indicates, in order to finely adjust the drop time. The wind flow selection can be calibrated by rising to float immediately, and checking all the levels, preferably with a real time trajectory plot. Then one descends to the best driving level, drifting to the upwind side of the target area and rising to a relatively calm level, to stall for optimum target rendezvous time.

(4) The optimum position for reaching float is on the upwind side of your target area. There may be target time slides for telemetry, ground optics, clouds, etc. With 25 knots, (13mps) or more, the balloon will rapidly drift out from the center of the area with any kind of slide

During early summer and early fall, climb out winds are westerly, and float winds easterly, so you actually want to reach float on the target side downwind from the climbout.

(5) Since most balloon target missions require relatively clear skies, tropospheric wind climatology should be selected for clear to scattered cases, only. One will generally see, therefore a percentage increase in climbouts towards the south, when compared to climatology which disregards cloud coverage.

(6) Rather than use conventional integrated monthly upper wind data for constructing trajectory climatology charts, plot discrete trajectories by date for each month. Many months display a marked drift throughout the period, and one or two specific weeks can be flagged as most desirable.

(7) Mountain ranges usually generate trajectory deflections even in the stratosphere, whatever that mechanism may be. These "bank shots" should be calibrated, possibly with small pathfinder balloons, prior to the mission.

The deflections can be consistent in crossing a given range, and a calibration series with pathfinders, one year prior might be worthwhile.

The tropospheric winds see an enhancement of any north-south component on the upwind side of the range. The lighter the winds, the greater the deflection. Light summer stratosphere easterlys can break down into closed circulation on the upwind side. A cloud undercast appears to modify these patterns.

(8) If the opportunity exists, load up the balloon with ballast, so that it will float initially at least 2000 feet (.6KM) below the specified altitude. There can be substantial wind shear even in 500 foot slices. If some duration at float is required to attain the target, one then evaluated the initial, lower float as to desirability. If favorable, and prior data indicated more advantageous winds above, then perform the same evaluation in 500 or 1000 foot steps. The remaining ballast can be dropped before target time.

Sometimes, this procedure is complicated by the fact the experiments desire maximum balloon stability at target time, which means no ballasting for some prior time increment. But with summer float winds, particularly, the float segment may be long enough to employ this strategy.

(9) If minimum cloud coverage at target time is an especially firm requirement, then the launch time should be moved up. Most launches are set for sunrise, when surface winds are lightest. Balloon layout might be set for on hour after morning twilight. During the night, save in the case of a bright moon, cloud coverage observations can be marginal. At sunrise, there are frequent mysterious quantum jumps in the coverage. This can be a trap, if the balloon is committed prior to day break. So one wants a good look at the twilight observations, which are especially sensitive in the flat lighting, before committing the balloon. The latter step can be an expensive one, if a 500 foot wafer thin envelope has to be placed back into the box.

If the season sees prolonged surface wind calms in the morning, it becomes advisable to move all the schedules ahead even more so. In that way, one can obtain a feel for diurnal reactions of the cloud coverage.

(10) Abort contingencies should be discussed in great detail, long before the actual flight day. Sometimes, even partial data can be obtained at some lower altitude, if a target overshoot is forthcoming.

The definition of the drop altitude measurement should also be discussed very early in the planning. It could be pressure, density or radar (geometric) altitude. The first two may be geometric or geopotential, in relation to the Standard Atmosphere. Radar heights, particularly can be substantially different from density height in the high stratosphere. There are marked diurnal variations which should be studied via climatology, balloon floats on a constant density surface. This problem is discussed in more detail in a AFGL report by Mr Gildenberg (Oct 66 see part B this book)

(11) For climatological selection of the launch site, any number of statistical approaches can be utilized. One such example is seen in Figure 3.

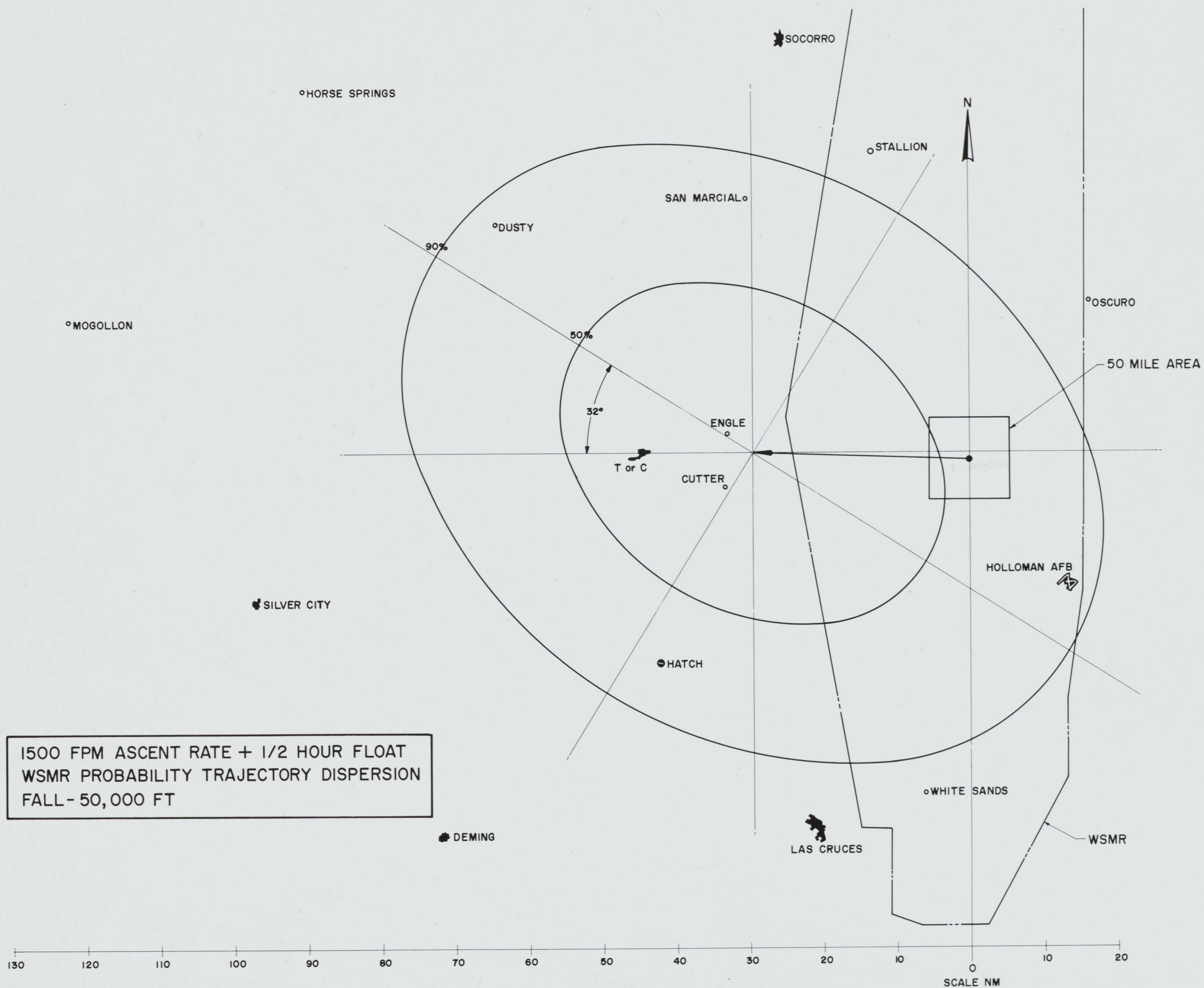
Here, the center of the target is employed as the starting point for the mean vector. The endpoint which would be the optimum launch site is at the center of probability ellipses for 50 and 90%. These help to visualize the scatter.

4. FORECASTING PROCEDURES

This report is concerned primarily with the balloon trajectory, but launch surface winds and clouds are also important factors. At a remote site these elements are best handled by seeking advice from local forecasters and by taking special pibal data for a week prior to launch day, during pertinent hours.

The climb out trajectory forecast can be approached in two ways, basically. The first, is to forecast wind flow for 5,000 foot (1.5KM) levels from surface to float altitude. Weather facsimile charts are also available for these levels. Above 200mb, only 50mb (67K, 20KM) and 30mb (78K, 24KM)

Figure 3
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analysis charts are available on AFX 109 facsimile circuit. There are no forecasts, provided at these levels. Therefore 5K (1.5Km) maps should be hand plotted for continuity.

For the tropospheric wind forecasts, the national facsimile forecast charts are the starting point. Since the raw data they are based upon is only generated twice a day, however, a few local radiosonde runs should be employed in order to find tune the forecasts. The drift of overhead clouds can also be used as a rough update guide.

In a typical target balloon mission, the first point of no-return is met at 0300LST, when the balloon is taken out of the box. By this time, in the Southwestern U.S., the standard data is already ten hours old. Therefore, one would want at least two launch site radiosonde runs to discern the interim history of upper air systems. Then, eyeballing wind, temperature and height drift, one forecasts for each of the levels, modifying the facsimile or teletype forecasts accordingly.

An alternate procedure is to largely ignore discrete layers, and if affordable, take a larger number of special radiosonde runs at the launch site. What one required then, is only the elevation angle, azimuth angle and elapsed minutes for the millibar equivalent of the target balloon float altitude. This entails no reduction for the radiosonde crew, and they can provide the information immediately, turning around to launch the next run. The target balloon meteorologists then convert the reading to a x-y position on a map, after adjusting the range for the difference in ascent rates between radiosonde and target balloons. One must also correct the elevation angle for curvature and refraction in computing distance out. Endpoints are plotted for consecutive runs on the same map, identified by time. The strategy then, is to visually gauge the drift of these points, extrapolating (and not necessarily linearly) the position for the launch time of the target balloon.

This procedure is very fast, and could be used by people with limited meteorological experience. But one can better rationalize the drift of these end points, if you knew the history of the prevailing tropospheric systems. Best procedure is to integrate these two techniques. One forecasts for the 5K slices from the 00Z data maps, usually the last to come in over weather circuits before the target balloon launch. A trajectory is constructed from these layers, and the endpoint plotted on the map for the first position in the drift calibration. This is followed up by successively plotting on-site special radiosonde runs. Now, having analyzed complete charts, one has a feel for the mechanisms steering the drift of the integrated trajectory.

If the stratosphere winds are light and or conservative, time can be saved and perhaps more frequent samples taken by using high ascent rates on the radiosonde balloons, to sample only the more dynamic tropospheric flow. You then add on the stratosphere segment taken from the forecast or the first run.

After the last scheduled on-site run is plotted, a final complete (5K segments) forecast trajectory is constructed, modifying the initial forecast on the basis of the observed time drift. This trajectory should be layed out on the same map where the plot of the target balloon will be maintained. In this way, any deviation from forecast can be monitored, and updated forecasts for the intercept provided.

The (nominally) stratospheric float wind is an independent problem, for the most part. (Occasionally a strong winter trough appears to hold it's configuration even through 10mb). One can monitor the 50 and 30mb AFX109 charts for major system locations and movements, but these are transmitted 11 or more hours after sampling time, which makes them useful only as a guide.

It is most useful to maintain a cross sectional map for the altitude slice for 10K on either side of the float altitude. Besides wind vectors, it should include heights and temperatures at the standard levels. This chart should be initiated about ten days prior to the scheduled flight, and include all the teletype data plus special runs. It will provide at least, the prevailing range of activity of the float winds, and usually some drift. The temperatures may be more sensitive than the heights. In the winter months particularly, one should watch for jets working there way down rom the higher stratosphere. The chart is also very useful for illuminating diurnal variations, which are more marked in the stratosphere.

Since 10mb comes close to being a mean altitude for plastic balloon flights, that complete map should also be plotted for 10 days prior to the mission. If neither the 10mb (sometimes a 7mb map is possible) map or cross section seem to indicate any systematic trend then one should use the latest local float wind as is. Preferably it should be sampled in the impact area, in addition to the launch area, if the float segment is to be sufficiently lengthy to cross over changing terrain. Another strategy is to use small, lightly loaded plastic constant level balloons as pathfinders. The basic concept is straightforward, but there are limitations. The smaller cells are more likely to lose altitude, if they are launched the night of the mission; they require accurate altitude measurement to assure they are at the scheduled target balloon height, and they require extra manhours to launch and monitor. To maintain a track all the way to the target area, may demand more than a simple radiosonde package, so the on-board instrumentation becomes more complicated. This would dictate a recovery operation, and accumulating manhours. Pathfinders are perhaps best used a year prior to the exercise, to calibrate terrain deflections, etc. or, if the target date is in mid-season, they could be launched in a series, the week prior. If no significant float segment is necessary, the launch site radiosonde runs serve as pathfinders, in effect.

5. IN-FLIGHT PROCEDURES

Ascent profile modifications may be necessary to achieve the target. These are effected via command control of an apex valve and ballast. The unaltered performance sees an ascent rate of 1000 ± 200 fpm (304 ± 60 mps) to the tropopause, and a decrease of 100 to 300 fpm in the stratosphere, depending upon the sun angle. With command control, however, the rate in a

given slice can be decelerated to 200 fpm (60 mps). Rates below that are marginal because thermodynamic excursions can actually cause a slight drop and the ensuing intake of air, requires more ballast to resume ascent. But this capability can be very useful in modifying the trajectory to one's needs. Consider this wind profile, for instance.

10-20K	260-15 knots
20-30K	260-25
40K	280-45
50K	295-60
60K	290-30
70-100K	270-25

If a natural ascent rate were steering the balloon too far to the north, the trajectory could be corrected by decelerating the system in the 40 to 60K region. This may be generally planned prior to the launch, and the "flown" by ear" during the mission. Deceleration is commenced at 40K, and varied accordingly watching the actual (hopefully, real time) ground plot. If the actual winds at 50K are even steeper than forecast, one might want to hold it there longer, and forget about the 60K prop. You concentrate on the slice that steers real time for target center, and then ballast rigerously above that. Since the forecasting art is probably only sufficient to attain the general target area, very precision targeting depends upon this command capability, combined with a reliable, accurate real time capability, such as missile range radar.

It was previously mentioned that light float winds should not be relied on as a driving mechanism for attaining the target. Below is an example of a wind profile which can be utilized to solve this problem.

10-20K	230-10 Knots
20-30K	250-15
30K	260-20
40K	270-45
50K	270-70
60K	270-20
70-100K	270-05-10

If the target area were 50 n.m. (90Km) due east, it may never be attained with a standard ascent profile, float winds being light and variable for practical purposes. But decelerating to 250 fpm in the 40 to 50K region will easily make up the distance. The extra time spent here should be accounted for in adjusting the launch time. Sufficient on-board ballast must also be available to resume a nominal ascent rate after the driving period.

If timing is very critical then it is best to fly in the seasons when the low stratospheric winds are very light. If the nominal 100K is the drop altitude, one can launch an hour early, in the calmest winds below 100K, and then up the last 20-30K with a high ascent rate. The timing in transversing this smaller ^{slice} will be much more accurately forecast than for the overall ascent.

The minimum wind area will usually be even lighter than indicated by the radiosonde data, which tends to smooth minimum and maximum winds. This is seen on figure 4., where both radiosonde and accurate missile radar tracked the same balloon through a minimum wind slice. Moreover, a balloon in a light wind field, which is almost floating, will not track a straight line, with the trajectory vector thus being lighter than the instantaneous sample registered by the radiosonde.

The technique may also be used spontaneously if a hold were called during the ascent.

In certain months there are both easterly and westerly winds in the stratosphere. If these winds are phased close to 180 degree, then there are opportunities for spectacular targeting. In October 1961, a single target area over WSMR was achieved twice on the same day, 9 hours apart, with the same balloon. During a large part of the interim period, the flight was parked over the mountains upwind of the target area, to avoid missile operations.

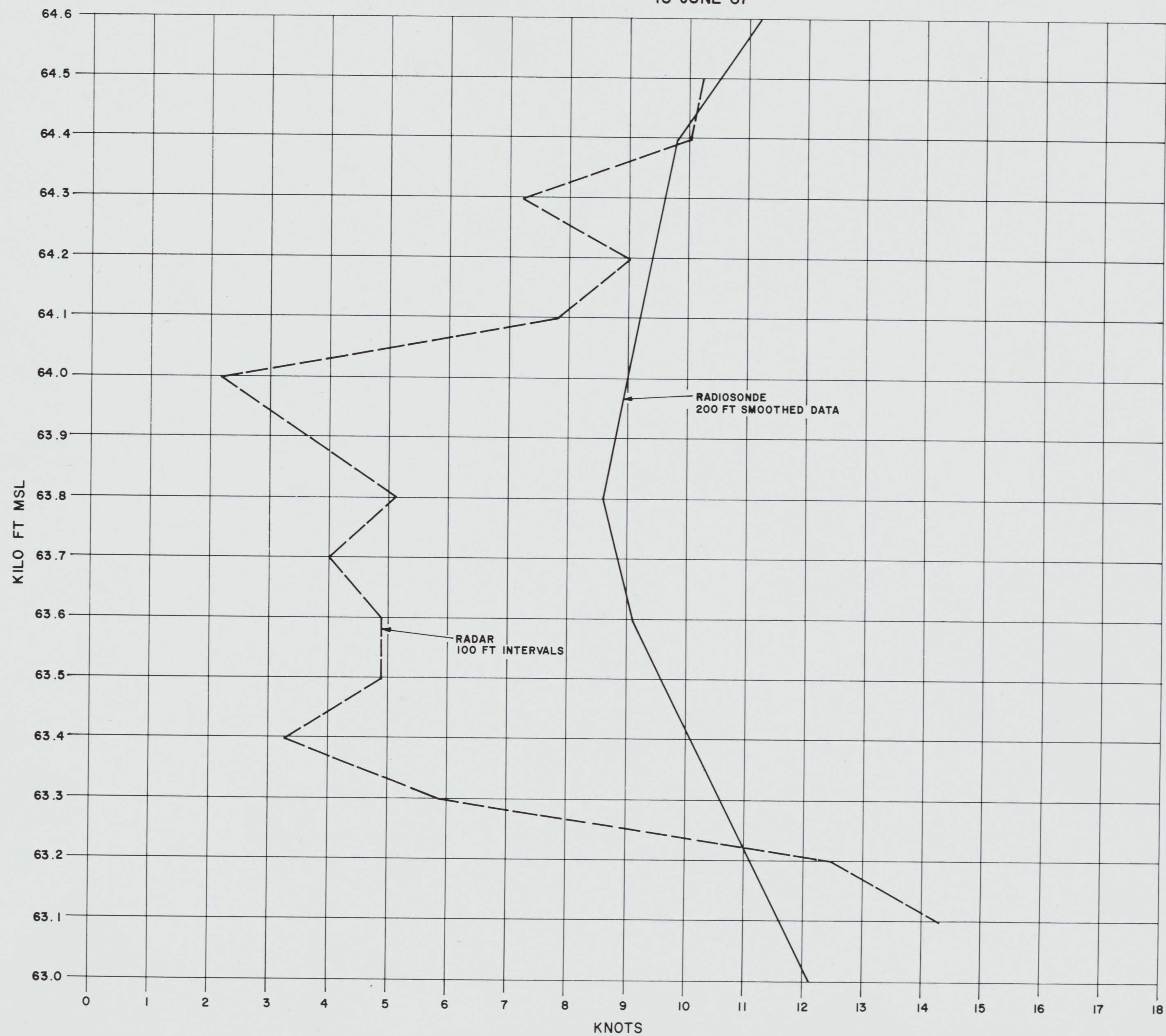
Most of the other activities during the mission are primarily performed by inputting data into a computer. There is not sufficient time for manual computations. Even the balloon control should be performed by computer, but that is a subject in itself. Ideally, the forecast trajectory should be in memory, and as each actual 5K position is reported, the intercept time and position updated on a printout. There are generally a number of objects being dropped by parachute during a drop, and these various parachute drifts, could also be automatically updated at the same time. Getting closer to drop time, the computer program should provide both positions and impacts for 10 minute increments for the next hour. Position sample times for such computer forecasts should not be less than 5 minutes in most cases to smooth out wind variability.

6. POTENTIAL AND FUTURE

Target ballooning thus far, has been performed in a relatively casual way, as the need arises, and with no formal development. Reliability has proved more than adequate, but requirements generally hold close to the limits of experience.

Vehicle applications are not a concern of this report, but conceivably there could be important new applications if the current target accuracy could be maintained over much greater distances. On one program, a target 460 nautical miles (852 Km.) downwind was nominated as a desirable but not mandatory goal. In the driving process, the balloon altitude was varied from the top of the tropopause to above 25 Km. But it did finally pass within 10 nm of the target, 28 hours after launch, and with a 4 ton (3636 Kg.) payload. This kind of capability would be even more valuable, if stratospheric minimum wind field existed, so that the vehicle could be hovered after arriving at the target.

MINIMUM WIND FIELD, ON-BOARD RADIOSONDE VS DIGITAL FPS-16 DATA
13 JUNE 67



To evaluate potentialities, a series of tests would be needed at varying ranges. Without an active payload on-board, the balloons could be relatively small and inexpensive. From the experience garnered thus far, it would appear that the key elements needed to extend capability are climatology, balloon control and real time tracking.

Very thorough climatology is required, in order to assure that the mission is flown at the right time and place, with sufficient degrees of freedom, in terms of vertical wind shear.

Balloon control is an entire art of itself, slowly improving from accumulated experience better command instrumentation and computer facilities. Ballasting efficiency and apex valve reliability are the two components from this field which primarily effect targeting operations.

No matter how superb the control or the meteorology, the target cannot be positioned with pinpoint accuracy unless the actual ground plot and drift is continuously and accurately displayed. For WSMR drop missions, powerful missile tracking radars with on-board transponders, and plotting boards in the balloon control center, provide an excellent capability. But this facility cannot be extended beyond roughly 200 n.m. (360 Km.) Satellite navigation systems probably offer the best hope for optimization. More computer processing with perhaps CRT map displays integrated with current systems such as Locate or the AFGL VOR package would be helpful. Computer trajectory extrapolations are also very important.

Pathfinder balloon technology could also be improved with thinner filmed and thus smaller cells, plus improved but cheaper tracking techniques.

Basic target balloon trajectory forecasting would benefit substantially from new state of the art wind sampling techniques as much as anything. Laser soundings might eventually offer a solution, with continuous sampling of winds aloft. If this kind of data were fed into an on-board computer which in turn controlled ballasting and valving functions, then one would in effect have a target drone balloon.

<u>Period</u>	<u>A</u>	<u>B</u>
1-15 June	48	23
16-30 June	79	36
1-15 July	84	44
16-31 July	98	58
1-15 August	86	60
16-31 August	77	50

A - Percent chance of overflying an Acceptable Part* of WSMR at 120Kft after launch from Roswell Municipal.

B - Percent chance of not overflying Roswell (including RIAC) below 20Kft MSL and of overflying an Acceptable Part * of WSMR at 120Kft after launch from Roswell Municipal.

*Acceptable Part = Crossing 106°16' W between 75,000 feet south of the northern boundary of WSMR (viz., 33°36.9'N) & a point 200,000 feet to the south (viz., 33°04.0'N).

NOTE: Ascent rates used for both A and B are: Surface - 30Kft., 1200 fpm; 30-50 Kft., 1575 fpm; 50-100Kft., 1100 fpm; 100-120Kft., 760 fpm.

800 fpm to 110K ft

<u>Period</u>	<u>Cases</u>	Roswell Municipal		Walker AFB	
		<u>On Target</u>	<u>Target $\pm$ 5 nm</u>	<u>On Target</u>	<u>Target $\pm$ 5 nm</u>
1 - 15 Jul	38	39	58	58	68
16 - 31 Jul	43	65	74	81	88
1 - 15 Aug	45	47	62	53	71
16 - 31 Aug	41	49	63	59	68

800 fpm to 50K ft, then
600 fpm from 50-110K ft

1 - 15 Jul	38	42	58	61	71
16 - 31 Jul	43	65	74	84	91
1 - 15 Aug	45	44	62	56	73
16 - 31 Aug	41	49	63	59	71

"On Target" is defined as a flight that reaches the meridian of the eastern boundary of the 50 Mile Area on WSMR (106°16'W) between the latitude of Wood (33°29'30"N) and the southern boundary of the 50 Mile Area (33°03'30"N).

WSMR FLOAT WINDS (E-W, KNOTS)

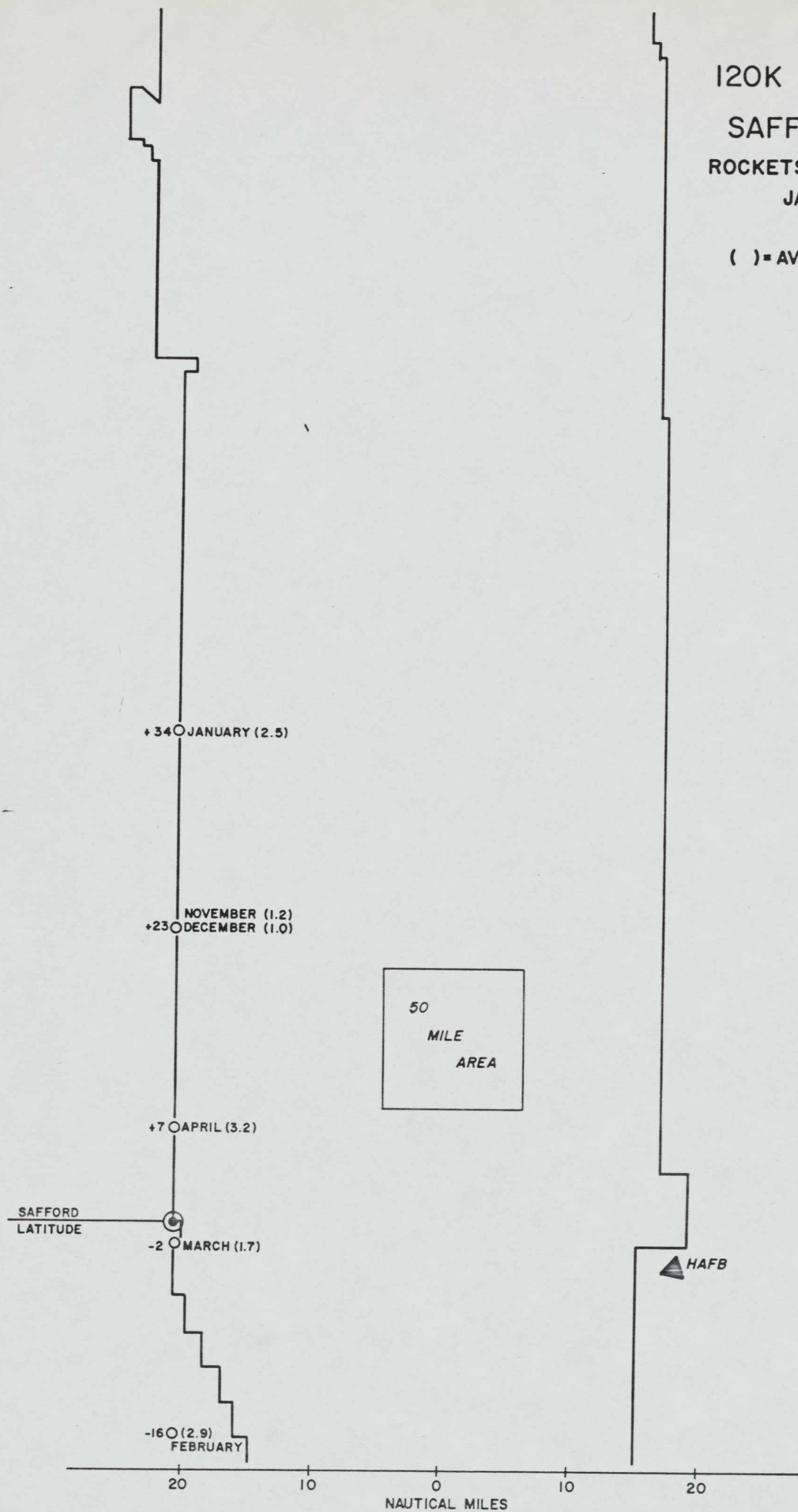
Km	<u>MSL</u>	<u>J</u>	<u>F</u>	<u>M</u>	<u>A</u>	<u>M</u>	<u>J</u>	<u>J</u>	<u>A</u>	<u>S</u>	<u>O</u>	<u>N</u>	<u>D</u>
	Ft												
18	60	28	20	22	24	14	-2	-14	-10	2	8	20	26
21	70	12	10	10	4	-4	-14	-24	-20	-10	2	8	14
24	80	8	8	10	0	-6	-18	-30	-28	-14	2	12	14
27	90	8	10	14	4	-4	-20	-34	-32	-16	6	20	24
30	100	12	14	18	12	-2	-26	-40	-36	-16	10	42	42
33	110	26	24	28	22	0	-28	-44	-40	-14	20	56	64
36	120	40	34	40	36	0	-34	-50	-42	-14	28	74	84
39	130	46	44	28	36	-8	-44	-60	-48	-16	36	86	98

100Kft DAY-NIGHT VARIATIONS WSMR

	<u>DAY</u>	<u>NIGHT</u>
Winter	262/30	265/25
Spring	256/15	267/11
Summer	098/32	087/30
Fall	249/11	269/11

120K WSMR INTERCEPTS
FROM
SAFFORD, ARIZ. AIRPORT
ROCKETSONDE, RADIOSONDE DATA
JAN 1960 - DEC 1969
1000 FPM

() = AVERAGE FLOAT HOURS



PERCENTAGE OF HITS & NO. OF CASES

JAN	54.12	85
FEB	31.31	99
MAR	50.46	109
APR	56.57	99
NOV	67.70	127
DEC	69.14	94

