NASA TECHNICAL NOTE

NASA TN D-8172

NASA TN D-8172

A GLOBAL SEARCH AND RESCUE CONCEPT USING SYNTHETIC APERTURE RADAR AND PASSIVE USER TARGETS

W. E. Sivertson, Jr.

Langley Research Center
Hampton, Va. 23665

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • APRIL 1976

1. Report No. NASA TN D-8172	2. Government Accession No.
3. Recipient's Catalog No.	
4. Title and Subtitle A GLOBAL SEARCH AND RESCUE CONCEPT USING SYNTHETIC APERTURE RADAR AND PASSIVE USER TARGETS	5. Report Date April 1976
	6. Performing Organization Code
7. Author(s) W. E. Sivertson, Jr.	8. Performing Organization Report No. L-10259
	10. Work Unit No. 645-25-05-01
9. Performing Organization Name and Address NASA Langley Research Center Hampton, Va. 23665	11. Contract or Grant No.
	13. Type of Report and Period Covered Technical Note
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546	14. Sponsoring Agency Code
15. Supplementary Notes	

16. Abstract

A terrestrial search and rescue concept is defined embodying the use of passive radio-frequency (RF) reflectors in conjunction with an orbiting synthetic aperture radar to detect, identify, and locate users. An airborne radar test was conducted to evaluate the basic concept. In this test simple corner-reflector targets were successfully imaged. Results from this investigation were positive and indicate that the concept can be used to investigate new approaches focused on the development of a global search and rescue system.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Search and rescue Synthetic aperture radar Passive reflectors Earth orbit Shuttle experiment Terrestrial users	Unclassified – Unlimited Subject Category 32

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	29	$3.75

*For sale by the National Technical Information Service, Springfield, Virginia 22161

A GLOBAL SEARCH AND RESCUE CONCEPT USING SYNTHETIC APERTURE RADAR AND PASSIVE USER TARGETS

W. E. Sivertson, Jr.
Langley Research Center

SUMMARY

This report defines a search and rescue concept that embodies the use of passive radiofrequency (RF) reflectors in conjunction with an imaging synthetic aperture radar to detect, identify, and locate Earth users in distress. The radar would operate in low Earth orbit to provide global coverage and would operate within a 1- to 10-GHz frequency range to provide day or night and all-weather operational capability.

An airborne radar test was conducted to aid in evaluating the basic concept. Simultaneous, horizontal and vertical polarization images were obtained, using both X- and L-band radars, of a number of corner-reflector targets positioned in specific geometric configurations. Evaluation was made relative to reflector image brightness and position location. Results from this investigation indicate that synthetic aperture radar can be used to detect, identify, and locate simple, passive ground-positioned RF reflectors; this capability can be used to investigate new search and rescue concepts focused on developing a global search and rescue system.

INTRODUCTION

A significant search and rescue operation is maintained throughout the world, and future needs for this service are likely to increase as travel, trade, and transportation industries expand. As this service expands, it will continue to require the expenditure of considerable manmade and natural resources. Furthermore, the increasing size of the operation will expand the risks to rescue personnel. The development of a low-cost, low-risk search and rescue system tailored to meet these future needs should be a high-priority endeavor.

Although current search and rescue efforts are extensive and are executed with dedication and diligence, current techniques employed are inadequate and piecemeal. There is no single system accessible to users (aircraft, marine vessels, surface vehicles, or individuals) engaged in penetrating potentially alien environments. A user in distress cannot, on demand, initiate a search and rescue operation. Search and rescue need is presently signaled by secondary inputs: someone notices that a prescribed flight or float plan has not been maintained, or simply someone, somewhere, suspects that individuals are missing or have failed to appear after a period of time. Frequently days have passed before the need for a search and rescue operation is known. Even the emergency location transmitters (ELT) (required as of 1973 by law on all aircraft of U.S. origin) are monitored, if operating properly, only on a random basis. Detections of reported distress are made by chance and, after a case of distress has been detected, location is not always achieved. In brief, current search and rescue capability is inadequate in three broad areas: (1) the timely detection of an emergency, (2) the location of a distress site, and (3) assessment of needed rescue procedure and identification of the shortest path to rescue sites in remote areas.

This report considers a new search and rescue concept and presents the results of an aircraft flight test which was conducted to investigate the feasibility of the concept. This concept was originated at the Langley Research Center (ref. 1) and is being pursued to develop an improved search and rescue capability in the three areas previously listed. The concept is amenable to standardization. It defines a system for providing a total global search and rescue service under all-weather, day or night conditions. User equipment consists of passive radiofrequency (RF) reflectors. Active search hardware in the system consists of a synthetic aperture radar capable of rendering, through signal processing, a visible image of the geometric distribution relative to the electromagnetic scattering properties of objects or "targets" under radar observation. The image is formed with electromagnetic waves of much longer wavelength than those used for conventional optical imaging. A discussion of synthetic aperture radar can be found in reference 2.

An aircraft flight was conducted on October 12, 1973, to collect image data used to evaluate the basic search and rescue concept. The test objectives were to demonstrate and evaluate cooperative RF passive target detection and identification by using airborne synthetic aperture radars. This test was conducted by the Langley Research Center and was simultaneously executed with other airborne imaging radar tests conducted by the John F. Kennedy Space Center (refs. 3 and 4). Radars used were developed by the Environmental Research Institute of Michigan (ERIM) and operated under contract to the National Aeronautics and Space Administration (NASA).

SYMBOLS

A_e	effective aperture area of receiving antenna, meters^2
a	Luneberg lens radius, meters
D_h	antenna physical aperture length (horizontal), meters

F_1	radar signal recording (assigned center frequency 1)
F_2	radar signal recording (assigned center frequency 2)
F_3	radar signal recording (assigned center frequency 3)
ℓ	trihedral corner-reflector edge length, meters
N_o	additive noise constant spectral density, watts per hertz
P_{av}	average radiated power, watts
R	slant range, meters
SNR	signal-to-noise power ratio
v	relative velocity of radar carrying vehicle, meters per second
x,y	measured distance along orthogonal two-dimensional image axes
λ	radar wavelength, meters
σ	target radar cross section, meters^2
σ_c	radar cross section of circular trihedral corner reflector, meters^2
σ_L	radar cross section of Luneberg lens, meters^2
σ_T	radar cross section of triangular trihedral corner reflector, meters^2

BASIC CONCEPT

The basic concept (fig. 1) embodies the use of passive RF reflectors in conjunction with an imaging or side-looking radar (synthetic aperture radar) to detect, identify, and locate the position of users exposed to emergency situations which may require search and rescue. Passive RF reflectors could be carried as standard emergency equipment by aircraft, ships, small boats, terrestrial vehicles, and individuals. The reflectors would be deployed in emergency situations to mark a distress site and to provide a radar target for subsequent detection and use in implementing search and rescue operations. The deployed target is detected and identified and the position is located by an Earth pointing, Earth orbiting, synthetic aperture radar maintaining a global scan. The radar provides an image in which the distress target and distress site are visible. In this way, surrounding terrain is mapped and can be analyzed to determine useful and practical ingress and egress routes as an aid in implementing rescue. The radar is operated within the 1- to 10-GHz frequency range. This frequency range is within a radiofrequency window and in a frequency region of low RF background noise (fig. 2); it provides for day or night and all-weather operational search capability.

In an operational system, a satellite system would be maintained in a polar Earth orbit. The satellites would be equipped with a synthetic aperture radar and a communication system and would be operated in a search mode throughout successive flight passes over the global surface. Upon the detection of a user's distress target, image data would be generated and transmitted to a rescue operations control center where it would be used to initiate rescue operations. Distress targets would be carried by users and would be deployed in emergencies either by automatic and/or by manual means. Targets would be designed to provide large radar backscatter cross sections over a wide range of aspect angles.

In the basic concept, the radar system functions to perform the tasks of target detection, identification, and location. Detection is achieved in the orbiting radar by insuring that for a given transmitter power, the user target has a radar cross section which provides a return signal with an energy level above the additive white and/or Gaussian noise levels. This signal-to-noise relationship relative to detection is shown here in Harger's expression for signal-to-noise ratio (section 3.6 of ref. 2):

$$\mathrm{SNR} = \frac{A_e^{2}}{4\pi\lambda R^{3} v D_h}\left(\frac{P_{av}}{N_o}\right)\sigma \tag{1}$$

From equation (1), the radar cross section required for detection of a given reflector target is a function of reflector geometry, radar frequency and average power, antenna aperture size, radar signal-to-noise ratio, radar vehicle velocity, additive noise, and range. The Luneberg lens (with reflecting cap) and the corner reflector both appear to be suitable targets for use in developing the basic search and rescue concept. Small physical targets exhibit relatively high radar cross-section σ values that are essentially independent of aspect-angle variations (relative orientation). Maximum cross-section expressions (ref. 5) for these reflector types are:

the Luneberg lens,

$$\sigma_L = \frac{4\pi^3 a^4}{\lambda^2} \tag{2}$$

the circular trihedral corner reflector,

$$\sigma_c = \frac{15.6\ell^4}{\lambda^2} \tag{3}$$

and the triangular trihedral corner reflector

$$\sigma_T = \frac{4\pi\ell^4}{3\lambda^2} \tag{4}$$

By working from equations (1) to (4), Luneberg lens and corner-reflector sizes have been calculated for shuttle orbits and are shown as a function of radar average power and orbital altitude in figure 3. The data in this figure are calculated by assuming a signal-to-noise power ratio of unity, an antenna physical aperture length (along track direction) of 9 m, and a radar wavelength of 0.03 m. As these data show, target size can be relatively small and should present no major user hardware inconvenience. For a power level of 125 W (which is within the current state of the art), the theoretical corner-reflector edge dimension is between 23 cm and 31 cm for the range of altitude shown.

The basic concept allows the use of a number of RF reflector types, but the corner reflector is attractive for use as a search and rescue target. It is simple, effective, convenient to store and deploy, and low in cost. One interesting configuration can be fabricated from two basic components (fig. 4): a mylar-saran (or similar nonconducting material) sphere and an internal array of corner reflectors. The reflectors are aluminized mylar disks arranged into orthogonal planes and attached internally to the sphere. For deployment, the sphere is inflated with helium or hydrogen gas and is tethered by a line anchored at the distress site (illustrated in fig. 4). This tethering places the target above local obstructions and provides a clear RF field of view for radar detection. In windy conditions it may be beneficial to tether more than one target on a line to compensate for target motion.

Target deployment can be achieved in a number of ways depending on user needs. In general, these needs would translate into two basic deployment packages: a manual launch canister and a rocket launcher. Each configuration would include an RF reflector, an inflation device, a release mechanism, a tether line, a propulsion unit, and a packing and storage container. Specific targets would be selected and configured, packaged, and deployed as dictated by predetermined user class and expected operational constraints. For example, the target package for explorers and sportsmen would be simplified in comparison with the package designed for commercial airliners or large ships.

The following discussion offers a few examples which explore the basic concept and its practical applications. Once the system achieves target detection, it must be capable of uniquely identifying the detected signal within a processed image as a signal representing a search and rescue distress situation. Three identification approaches appear to be applicable.

One approach uses a single orbiting radar in conjunction with multiple targets. In this case (left-hand side of fig. 5), multiple targets are arranged in a known geometric configuration. An L-pattern is shown, but other configurations such as a linear, circular, or square array could be used. Target spacing would be maintained at one to five times the radar spatial resolution, and the pattern would appear in the radar image for use in recognition and identification.

A second technique is depicted on the right-hand side of figure 5. In this case, multiple radars (two or three) would be operated at different transmission frequencies (X- and L- or X-, L-, and Ku-bands), would transmit at a single polarization (horizontal), and would receive both vertical and horizontal polarizations. A preselected set of frequencies (F_1, F_2, and F_3) and polarizations would be processed to generate three images. Different color filters and intensity levels would be assigned to each image and a composite (superimposed) image would be generated. In this way, false color enhancement is used to aid in target discrimination.

A third technique would employ a matched spatial filter (ref. 6, ch. 7). By using this technique (fig. 6), a single radar image is suitably recorded on film and is used as the input object in an optical processor. Coherent plane wave illumination is then used to transform the spatial variations of the radar image into its Fourier spectrum through a transform lens. Autocorrelation of the object spectrum with a stored matched filter of appropriate design may then be accomplished by performing a second Fourier transform of the light transmitted by the matched filter. At those points where correlation between the object spectrum and matched filter exist, a bright image spot providing the desired target identification is formed.

Once a target has been detected and identified, its position (longitude and latitude) can be determined from one of two basic measurements. One simple method would measure target reflector image position, within the total radar image, relative to any known ground reference point or points (deliberate manmade grid network targets or natural landmark imaged features) appearing in the total radar image. Then, when image scale factors and geographical position of the reference features are known, target location could be calculated. A second method would measure search and rescue target image coordinates within the total radar image relative to a fixed image frame coordinate position. This image coordinate can then be translated into Earth surface longitude and latitude as a function of radar geometry and orbital position (ephemeris data) at the time the radar image was recorded. The radar image is used to locate the position of the target; in addition, the target is imaged together with the natural localized terrain in which it is embedded. In this way, the target, as well as a visible real-time map of the terrain around the target, is displayed. From this image, ingress and egress paths can be identified and used to plan, initiate, and execute the complete rescue operation.

AIRCRAFT FLIGHT TEST

Flight-Test Objectives

An aircraft flight test was conducted on October 12, 1973, to collect image data in order to evaluate the basic search and rescue concept. The objectives of the test were to demonstrate and evaluate cooperative RF passive target detection and identification by use of airborne synthetic aperture radars. Radars used for the testing were developed and operated by the ERIM under contract to NASA.

Radars and Test Flight

An ERIM C-46 aircraft equipped with an X-band and L-band radar system was used for the data-gathering flight. A multiplexing design was employed to provide a synthetic aperture side-looking radar that imaged the terrain simultaneously with X-band (9.3-GHz center frequency) and L-band (1.165-GHz center frequency) radar frequencies (ref. 7). Average transmitter power for the X- and L-band radars was 10 and 200 W, respectively. Each channel used horizontal polarization for transmission and simultaneously received horizontal (H) and vertical (V) polarization energy reflected to the transmitting antenna. This polarization provided the capabilities for the simultaneous recording of four channels of radar imagery: H-H and H-V at the X-band; H-H and H-V at the L-band.

On the image-gathering flight, adverse weather imposed an early termination of flight activity immediately following a single pass over the target area. During data taking, the aircraft was flown at 1980 m above mean sea level. Slant range to the near edge of the ground swath was 4025 m. Near-range depression angle (measured from the horizon downward) was 30°, and far-range depression angle was 12°. Imaged length on the ground was 25.75 km. Slant-range swath width was 5490 m. Aircraft flight direction (true azimuth) was 356°, and radar look direction (true azimuth) was 86°. Radar resolution was approximately 10 m by 10 m. An LTN-51 inertial navigation system was used to maintain aircraft heading during data-gathering periods of the flight.

Reflectors and Ground Site

Inflatable circular trihedral corner reflectors and rigid triangular trihedral corner reflectors were designed, fabricated, and placed by Langley Research Center personnel on Merritt Island, Florida, in the area shown in figure 7. The reflectors were designed to provide radar data for use in determining relative calibration and in evaluating reflector characteristics relative to their identification and location.

These targets were located along the unified S-band tracking station entrance road. The ground targets were located in the northeastern corner of the outer extremity (far-range edge) of the imaged ground swath (along unified S-band tracking site road). The unified S-band road is oriented in a north-south direction. Marsh areas and wooded sections flank the east and west sides of this test site road. The roadbed is bounded by broad sloping shoulders which are separated from the marsh area by wide water-filled drainage canals. Representative target installation is shown in the cross section in figure 8.

Rigid corner reflectors used for this test varied in radar cross section as shown in table I. A representative reflector installation setup is shown in figure 9. Spacing between reflectors was selected to equal radar minimum resolution. In the discussion that follows, all individual reflectors are alphabetically keyed to figure 7. Individual reflectors within each of two L-pattern groups are A, B, and C at the X-band, and reflectors D, E, and F at the L-band. The L-shaped pattern was selected to demonstrate the ability to identify targets by the use of a unique, predetermined geometrical configuration. Four rigid reflectors (G, H, I, and J) were arranged in a straight line with the spacing between successive reflectors varied as a product of radar resolution. This arrangement was selected to provide data for assessing the uniqueness of the pattern for use in target identification and to evaluate the effects of target spacing as a function of radar resolution. Four rigid reflectors (K, L, M, and N) were arranged in a two-segmented offset line. Spacing between these reflectors was maintained at three times the radar minimum resolution. This arrangement was selected to provide relative calibration data (relative image intensity plotted against reflector cross section). Spacing between adjacent rigid target groups was maintained at approximately 53 m.

In addition to the rigid reflectors, two inflatable reflectors were spaced 53 m apart along a straight line. As explained earlier, these targets (fig. 10) consisted of an array of corner reflectors internal to an inflatable sphere. The sphere was 63.5 cm in diameter, was inflated with helium, and was tethered with a monofilament line 10 cm above a ground stake. Adverse weather during the flight (passage of a fast moving front with high surface winds and heavy rains) contributed to the loss of one of these targets, but the second target T remained in position and was successfully imaged.

Only the three targets D, E, and F were designed to have radar cross sections large enough to be detected reliably by the L-band radar. As expected, the manmade L-band reflectors did not provide intense signal returns for the H-V (cross polarization) case. However, the natural reflectors (marsh grass and other vegetation) did provide reasonable signal intensities in both the H-H and H-V cases. This phenomenon (low-level cross polarization returns from manmade targets as opposed to those from natural targets) is being evaluated using difference signal processing to aid in the isolation of unique search and rescue target identification processing algorithms.

Radar Images

Both horizontally and vertically polarized X-band and L-band images were obtained from the test flight. Representative X-band images are shown in figure 11. These images are isolated, localized magnifications of the specific test area of interest for this report. The resolution of the radar imagery shown is approximately 10 m in both azimuth and range directions. Resolution is defined as the half-power width of the main lobe of diffraction-limited image components. Random variations in X-band antenna alinement during the flight resulted in unwanted antenna-gain variations along the line of sight. This variation in gain accounts for the randomly positioned, dark intensity bands running across the image from near range to far range in the X-band imagery. The ERIM has recently completed work on the system to prevent this unwanted antenna misalinement in future flights.

All the reflectors making up the target groups were designed to respond (adequate radar cross sections) at the X-band frequency. Differences between parallel and cross-polarization images are displayed in figure 11. The H-H (parallel polarization) case imaged all reflectors, whereas the H-V (cross polarization) case clearly indicates the degradation of manmade target response relative to return-signal cross polarization of the transmitted signal. Extensive digital processing work is in progress to capitalize on this phemonenon in order to develop identification processing algorithms with the potential for use in automating an operational search and rescue system. It should be noted that the aircraft flight line was displaced approximately 3.2 km west from the planned flight line and the imagery obtained from this flight places the test targets in the far-range area of the ground swath. This far-range position resulted in a degradation in range resolution because a range gate return-signal cutoff occurred before the return signal was allowed to be integrated in time over the full chirp pulse period. This undesirable circumstance, however, did not adversely impair the usefulness of results from the test, and meaningful relative intensity measurements were achieved.

Image Processing

Radar signal film for each group of target reflectors was processed by using the ERIM optical processor and microdensitometer setup shown in figure 12. Representative results from this processing are shown in figure 13. In the latter figure, reflector letters are keyed to figure 7 and relative intensity amplitude is plotted against linear distance (position) scanned along a true azimuth line of 355° passing through the center of each target image.

Boresight alinement between the rigid reflectors and the radar was misalined during the flight by a 3° offset in elevation and a 1° offset in the range look direction. This off-boresight alinement deviation presented no significant disadvantage, and near maximum reflector performance was obtained. No specific maintenance of boresight alinement was attempted for the inflatable reflector. This unit was tethered and free to rotate about the vertical. As a result of this freedom, range alinement during this test cannot be specified. Although the balloon target is difficult to detect in the photographic data reproduced for this report, the radar signal film when viewed in the optical processor did show an image, and low-level densitometer response did occur at a position corresponding to the balloon location.

Analysis of Data

Absolute synthetic aperture radar calibration is not currently a demonstrated technology. Although absolute image intensity values cannot be correlated to individual target (reflector) brightness levels within the images, relative brightness levels can be measured for each reflector. These data are shown in table I as relative radar image brightness in decibels. Maximum image density (black) was selected as a 0-dB reference level, and all reflector maximum intensity peaks were measured from densitometer pen recordings. The 1185-m^2 target (reflector N) was selected as a reference for calculating difference-brightness (Δ brightness) values. Theoretical values were calculated by assuming film image brightness to be a function of a constant multiplied by the target radar cross section. This relationship assumes that all system parameters are fixed and that only reflector radar cross section or target size affects return-signal strength (eq. (1)) and thus image brightness. Therefore, theoretical Δ brightness in decibels is:

$$\Delta \text{ brightness} = 10 \log \frac{\sigma_N}{\sigma_x} \tag{5}$$

where

σ_N radar cross section of 1185-m^2 reflector

σ_x radar cross section of x-m^2 reflector

Actual test result Δ brightness is the difference between individual reflector relative radar image-brightness values and the 1185-m^2 reflector brightness. Results from table I are shown in the bar graph of figure 14. As can be seen, overall reflector signal response is detectable both from densitometer and from visual scanning of the radar image. Also, target groups (geometrical configurations) provide a simple means for identifying specific locations of interest. The L-pattern, variable straight-line spacing, and variable target cross section and offset spacing resulted in uniquely identifiable imaged target groups. Differences between theoretical and actual values are relatively small and involve radar boresight and reflector axes misalinement, radar antenna motion during imaging, off-orthogonality between reflector surfaces, and other system variables.

Distance measurements are summarized in table II. Densitometer scans were made on along track (north-south unified S-band road) lines, and target separation distances were measured between individual target intensity-response peaks. Minimum spacing between targets was maintained at 10 m. Highest percentage differences (relative to field installation distances) in distance measurements are associated with G to H and H to I reflector spacings and with M to N and G to I spacings (fig. 7). In the cases of G to H, H to I, and G to I, significant antenna motion during imaging occurred. In the case of M to N, target radar cross sections were large and peak response curves were nonsymmetrical with relatively large side-lobe signal levels.

Discussion of Test Results

The airborne test indicates that relatively small, low-cost, simple, passive targets (corner reflectors on the order of 176 m^2 in radar cross section) can be detected by synthetic aperture radar of reasonable transmitter power relative to natural terrain which is characteristic of many remote areas of the world. This test result and the analytical data summarized in figure 3 in this report make it reasonable to expect that a 63.5-cm-diameter (minimum size) inflatable, circular trihedral corner-reflector array could be detected by a 125-W (average transmitter power) synthetic aperture radar operating with a 60° depression angle from a 370-km Earth orbit.

Corner reflectors can be uniquely identified as distress targets when grouped into a known geometric pattern. An L-pattern array, a straight-line variable spacing array, and an offset line array have been demonstrated successfully. In each configuration, minimum geometric spacing of individual targets was effective when the spacing was maintained slightly larger than the minimum spatial resolution of the radar system.

Corner-reflector synthetic aperture radar returns are sensitive to transmitted signal polarization and frequency. This sensitivity can be used to discriminate manmade targets relative to natural background and can provide a means for search and rescue target identification and terrain assessment. Relative target position can be measured within a given image, and local terrain can be evaluated to define access routes for target sites.

CONCLUDING REMARKS

A new concept employing synthetic aperture radar in conjunction with passive radio-frequency (RF) user reflector targets has been defined. The concept is being explored to acquire the knowledge needed to specify a future all-weather, day or night, global search and rescue system. The basic concept was conceived to meet user needs, that is, to provide simple, low-cost user search and rescue hardware and the assurance of a full-time, systematic search for this hardware whenever required.

Results from an airborne test have demonstrated that relatively small reflector targets positioned in natural terrain, characteristic of many remote areas of the world, can be detected and identified using synthetic aperture radar. Corner-reflector synthetic aperture radar returns were shown to be sensitive to transmitted signal polarization and frequency; the result was the postulation of three passive target identification approaches that merit further study.

Study of the basic concept and evaluation of results obtained from the aircraft flight test indicate that a multiple-frequency, dual-polarization, day or night global search and rescue system is feasible. Work is proceeding with plans leading to a shuttle low attitude Earth-orbit test and demonstration flight in the early 1980's.

Langley Research Center
National Aeronautics and Space Administration
Hampton, Va. 23665
March 4, 1976

REFERENCES

1. Staff of Shuttle Experiments Office: Study of Shuttle-Compatible Advanced Technology Laboratory (ATL). NASA TM X-2813, 1973.

2. Harger, Robert O.: Synthetic Aperture Radar Systems Theory and Design. Academic Press, Inc., c.1970.

3. Drake, Ben; Shuchman, Robert A.; Bryan, M. Leonard; Larson, Richard W.; Liskow, Charles L.; and Rendleman, Robert A.: The Application of Airborne Imaging Radars (L- and X-Band) to Earth Resources Problems. NASA CR-139385-1, 1973.

4. Drake, Ben; Bryan, M. Leonard; Inslow, Charles L.; Schuchman, Robert A.; Larson, Richard W.; and Rendleman, Robert A.: The Application of Airborne Imaging Radars (L- and X-Band) to Earth Resources Problems. NASA CR-139385-2, 1974.

5. Ruck, George T.; Barrick, Donald E.; Stuart, William D.; and Krichbaum, Clarence K.: Radar Cross Section Handbook. Volume I, Plenum Press, Inc., c.1970.

6. Goodman, Joseph W.: Introduction to Fourier Optics. McGraw-Hill Book Co., Inc., c.1968.

7. Rawson, R.; and Smith, F.: Four Channel Simultaneous X-L Band Imaging SAR Radar. Proceedings of Ninth International Symposium on Remote Sensing of Environment, Volume I, Environ. Res. Inst. of Mich., Apr. 1974, pp. 251-270.

TABLE I. - SEARCH AND RESCUE AIRCRAFT TEST IMAGE-BRIGHTNESS DATA

[Average 176-m^2 target image brightness, 24.85]

Reflector		Theoretical radar cross section, m^2		Relative radar image brightness, dB[a]	Δ brightness, dB (X-band targets)[b]	
Identification letter	Edge dimension, cm	X-band, 9.3 GHz	L-band, 1.165 GHz		Theoretical	Test results
A	45.7	176	---	24.5	8.3	8.1
B	45.7	176	---	27.5	8.3	5.1
C	45.7	176	---	25.0	8.3	7.6
D	111.8	---	99	37.6	---	---
E	111.8	---	99	33.3	---	---
F	111.8	---	99	28.5	---	---
G	45.7	176	---	24.7	8.3	7.9
H	45.7	176	---	24.1	8.3	8.5
I	45.7	176	---	24.8	8.3	7.8
J	45.7	176	---	19.7	8.3	12.9
K	25.4	17	---	20.5	18.5	12.1
L	45.7	176	---	28.5	8.3	4.1
M	63.5	655	---	30.6	2.6	2.0
N	73.7	1185	---	32.6	0	---
T	31.8	152	---	17.8	8.9	14.8

[a]Maximum image density (black), 0 dB.

[b]Relative to 1185-m^2 target image brightness.

TABLE II.- SEARCH AND RESCUE AIRCRAFT TEST TARGET SEPARATION DATA

Targets	Distance between targets, m		Difference, m (actual separation minus image measured separation)	Percent difference (actual separation minus image measured separation)
	Field installation (actual separation)	Radar image densitometer data plots (measured separation)		
A-B	10	---	---	----
B-C	10	9.0	1.0	10.0
D-E	30	---	---	----
E-F	30	28.0	2.0	6.7
G-H	10	8.0	2.0	20.0
H-I	20	16.9	3.1	15.5
I-J	40	41.0	-1.0	2.5
K-L	30	28.0	2.0	6.67
M-N	30	27.5	2.5	8.33
G-I	30	24.9	5.1	17.0
H-J	60	57.9	2.1	3.5
G-J	70	65.9	4.1	5.8

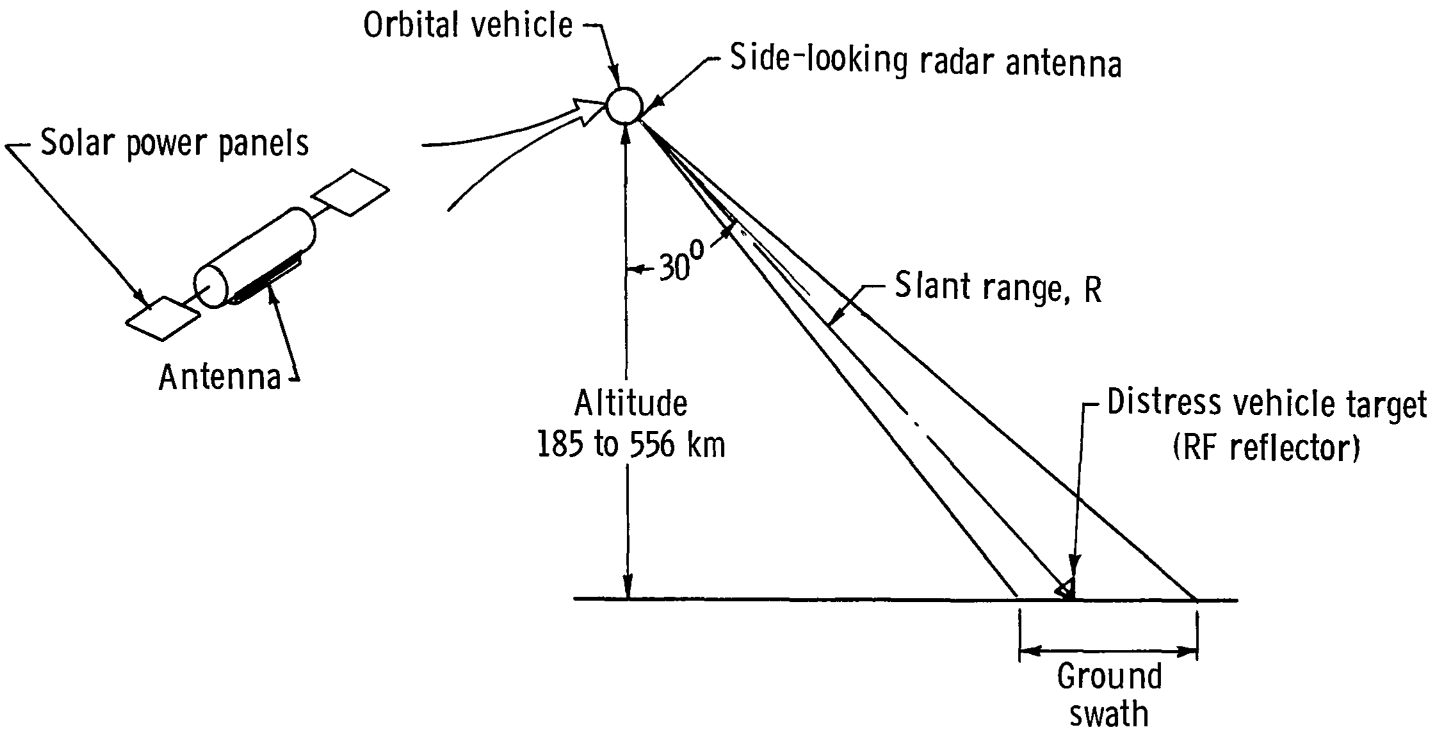


Figure 1.- Global search and rescue basic concept.

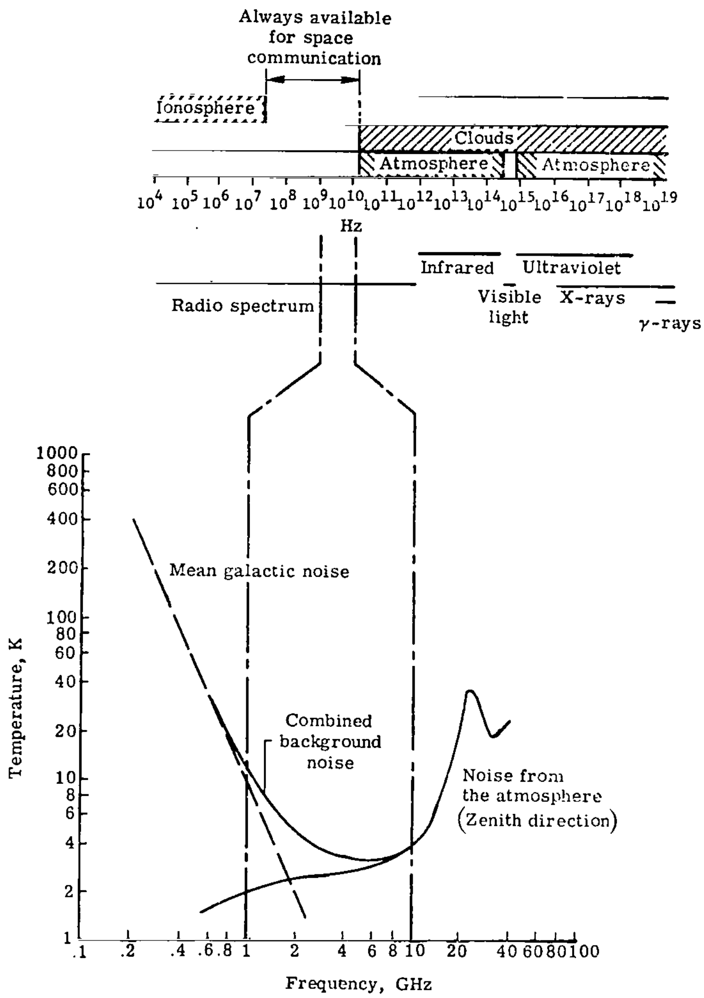


Figure 2.- Global search and rescue frequency window.

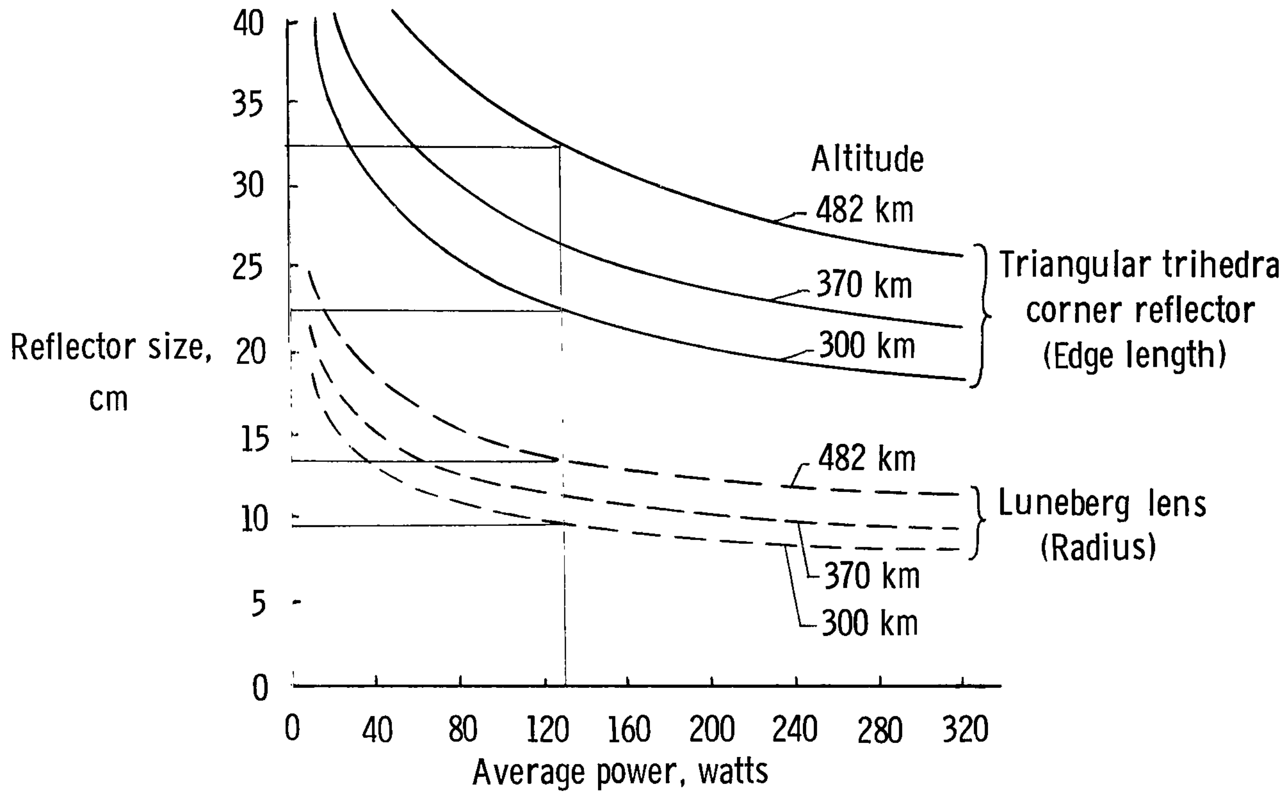


Figure 3.- Reflector size plotted against average radiated power.

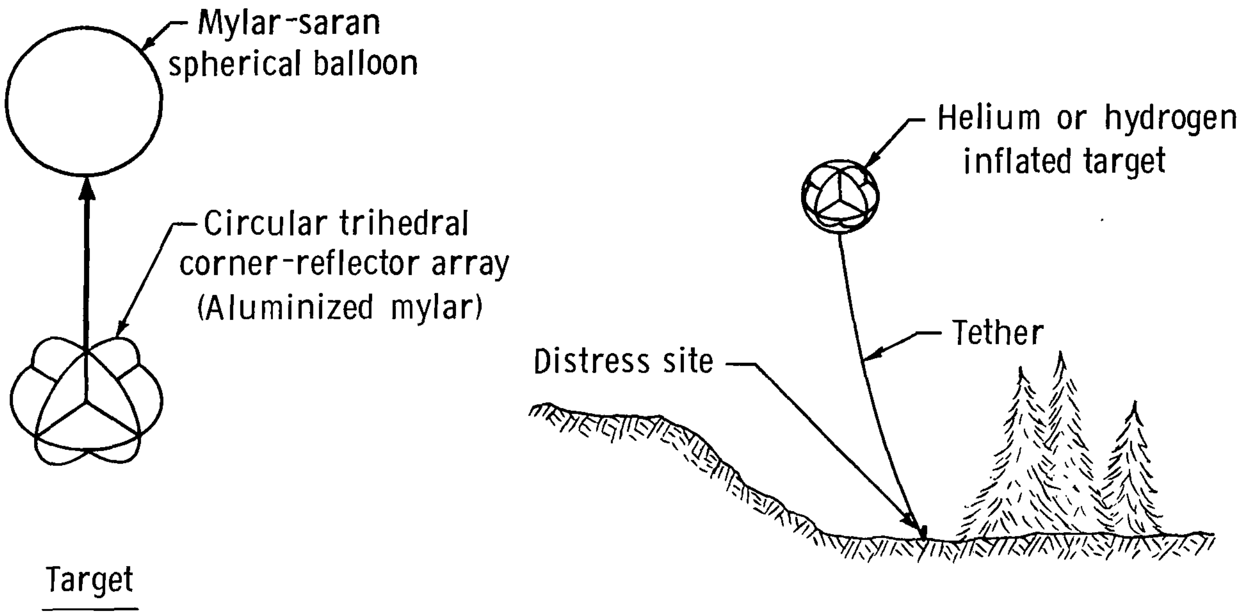


Figure 4.- Search and rescue reflector target concept.

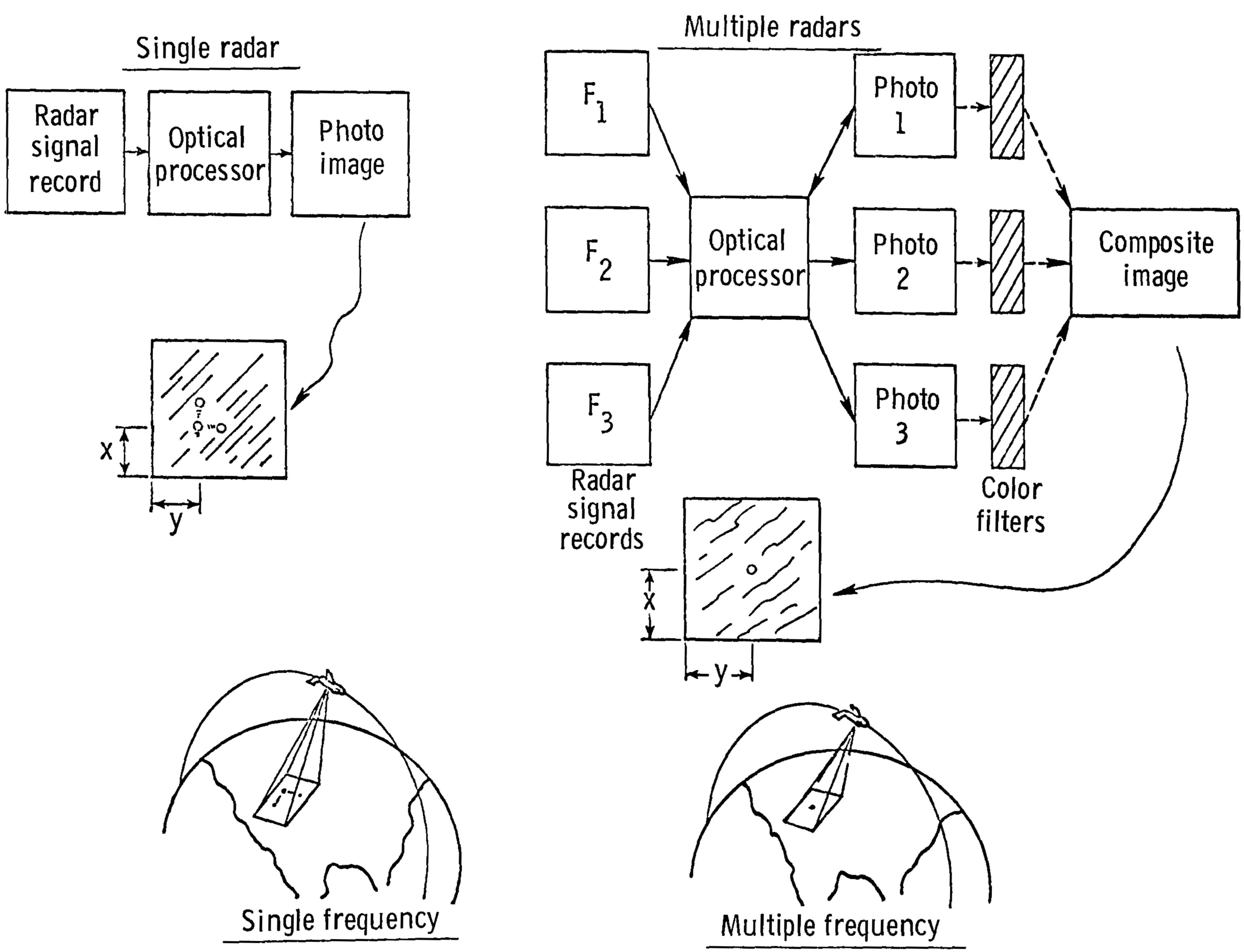


Figure 5. - Search and rescue target identification approaches.

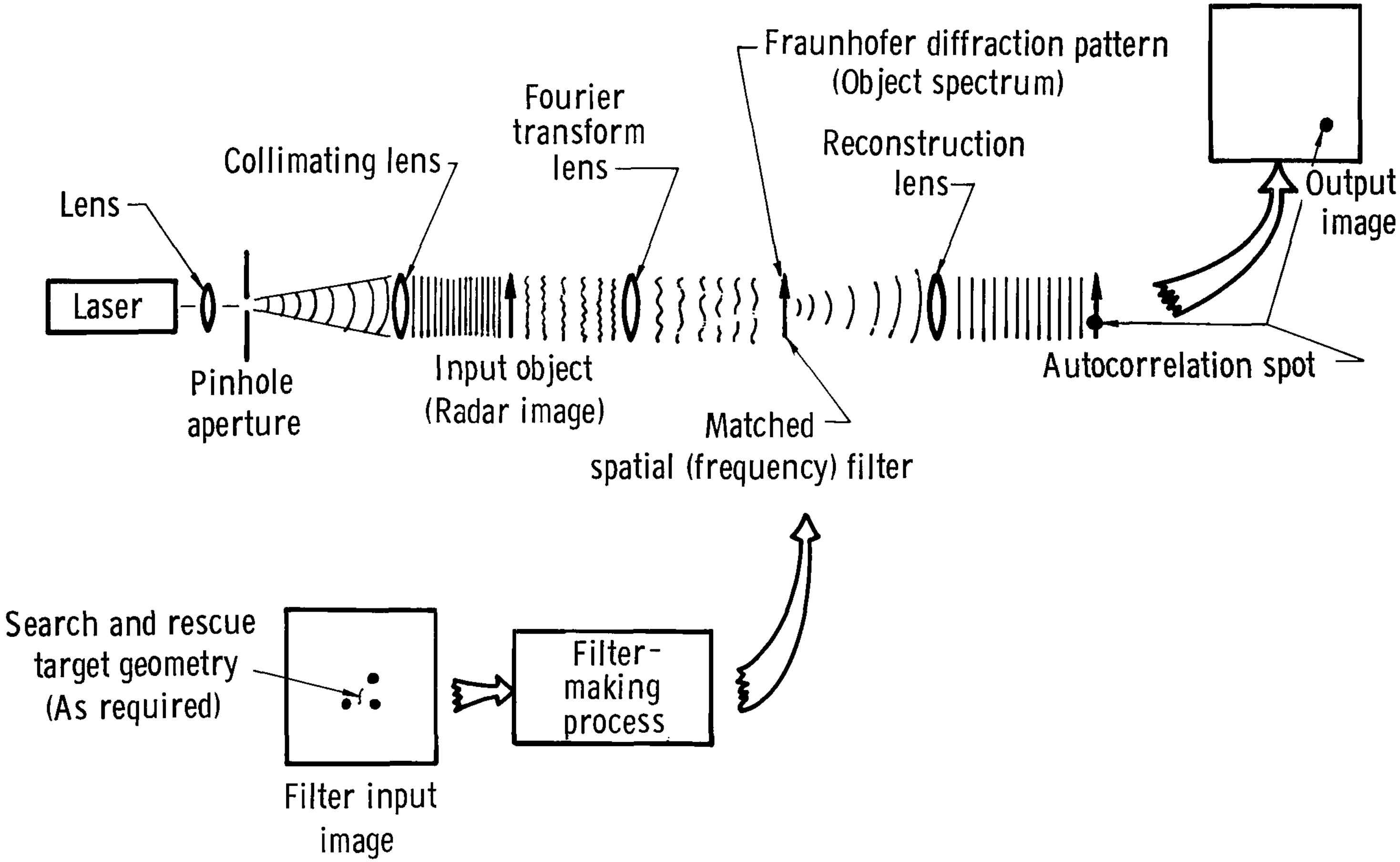


Figure 6.- Matched spatial filter distress target identification processing.

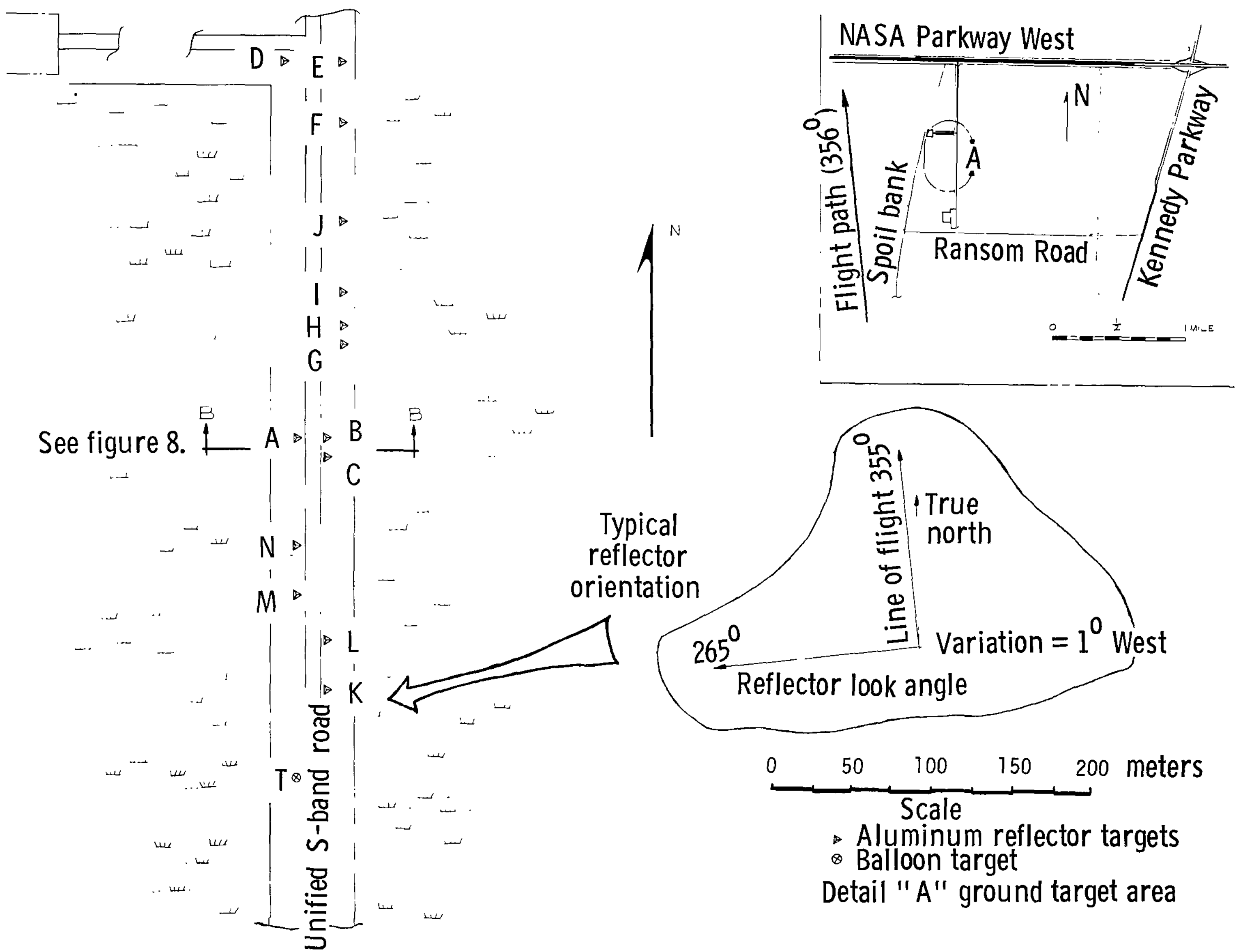


Figure 7.- Aircraft test ground target layout, Merritt Island, Florida. (Capital letters designate targets.)

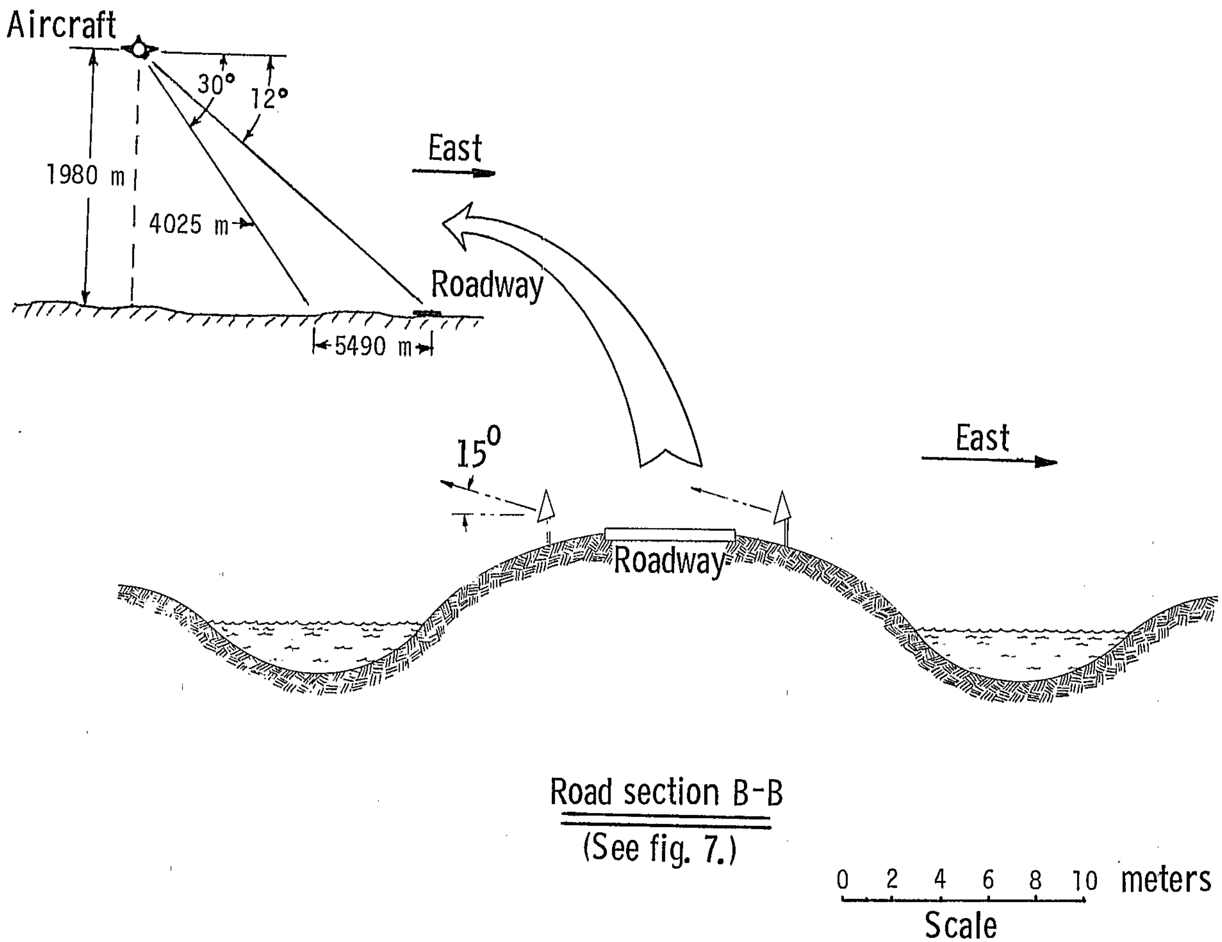
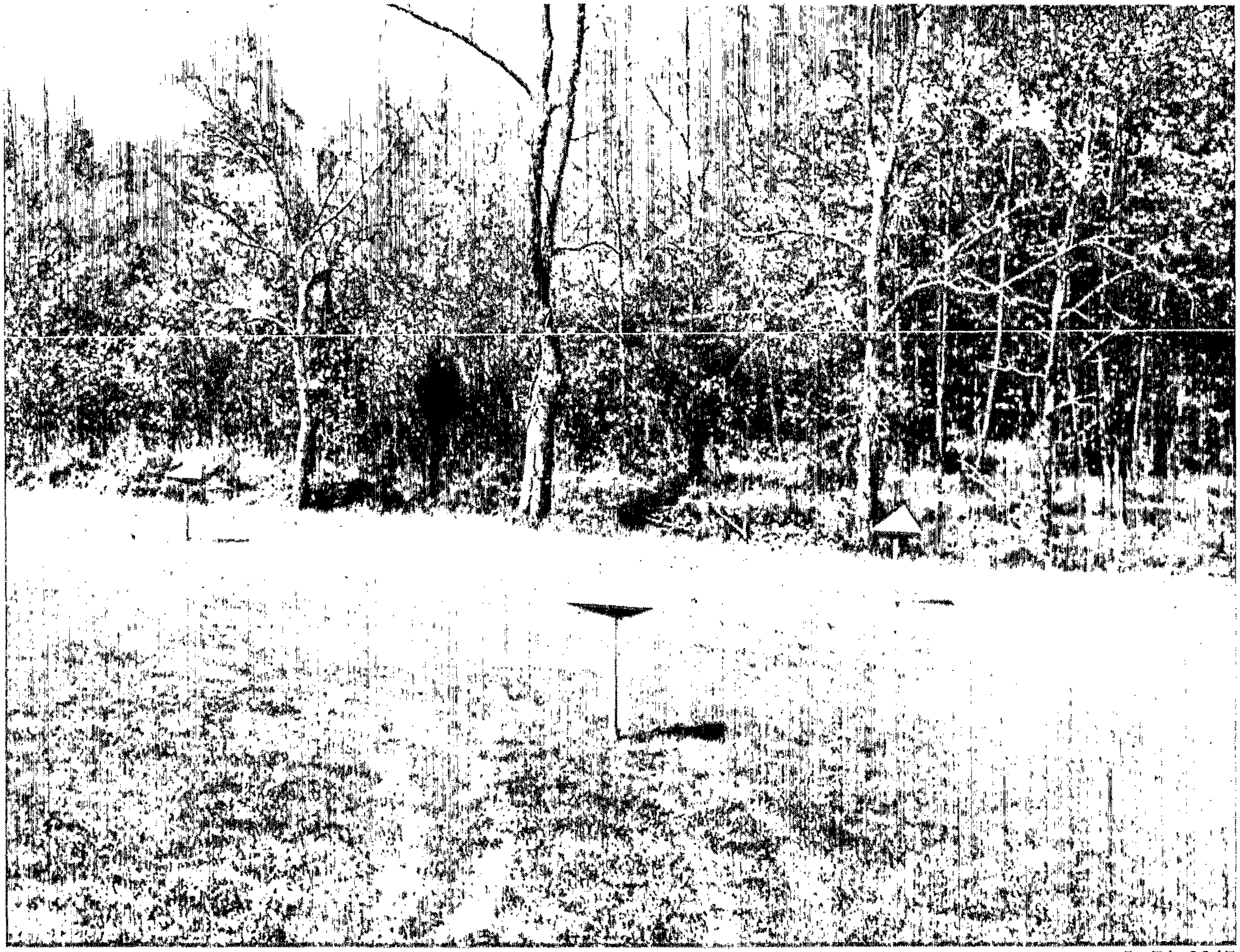
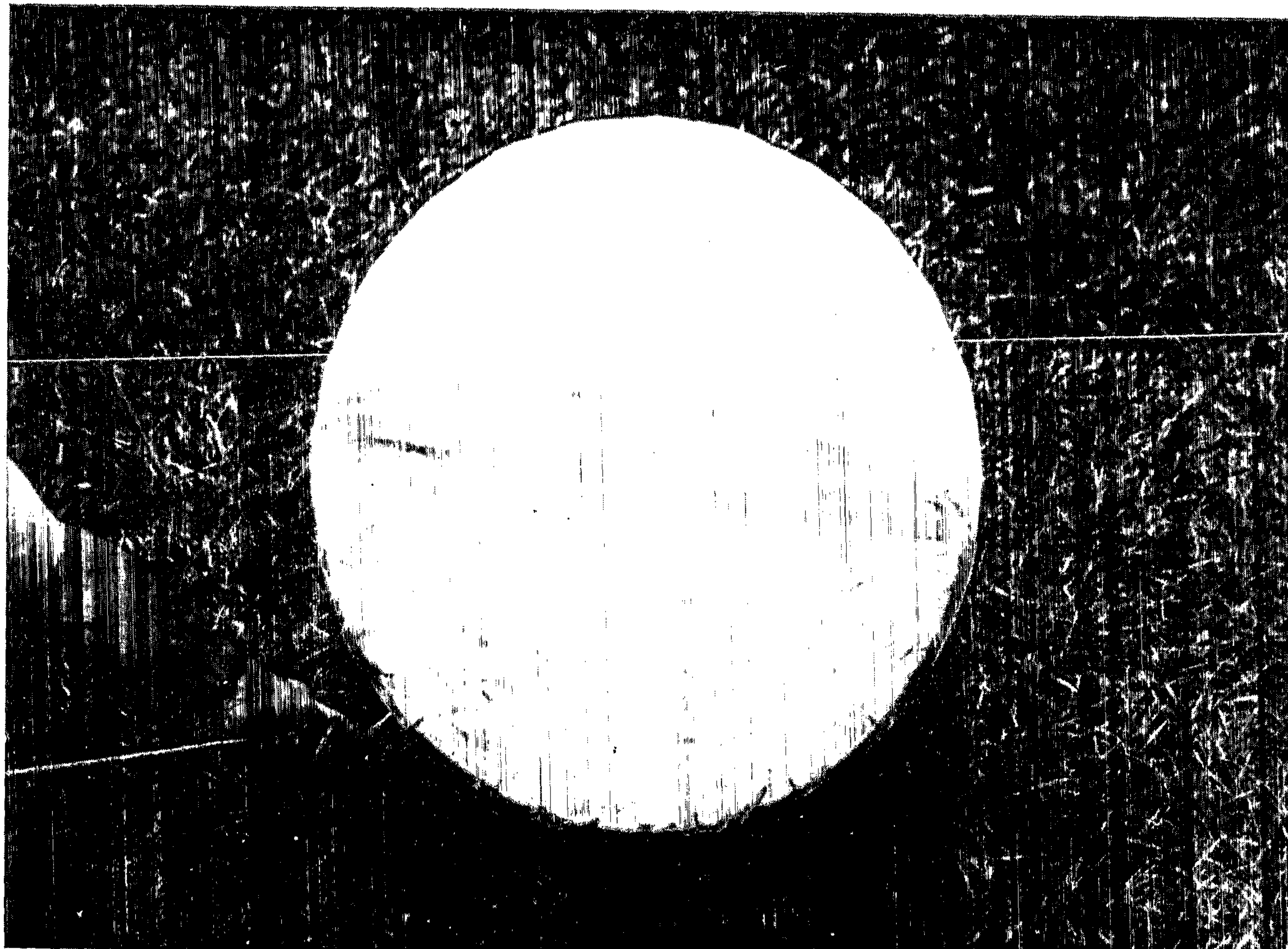


Figure 8. - Aircraft test representative target installation cross section.



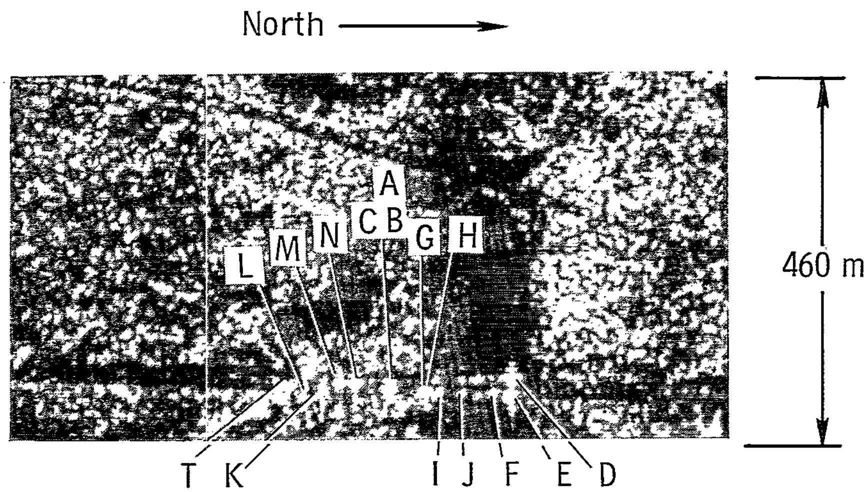
L-74-2317

Figure 9.- Aircraft test representative reflector installation.

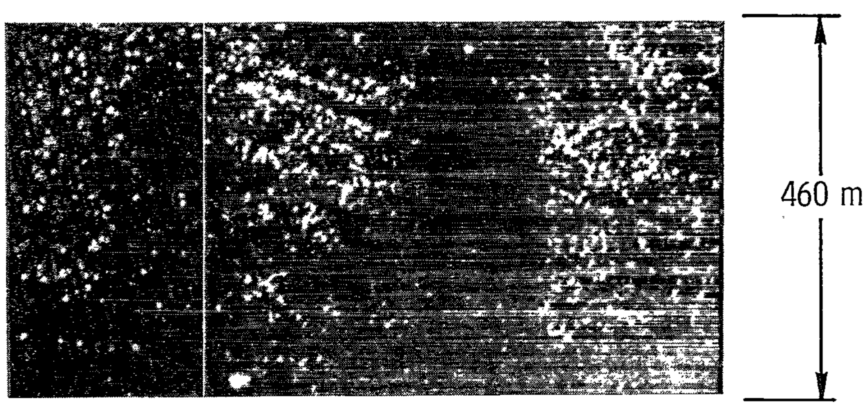


L-74-5877

Figure 10.- Aircraft test inflatable reflector target.



X-Band
Parallel polarization



X-Band
Cross polarization

L-76-120

Figure 11.- Typical aircraft test radar images. (Capital letters designate targets.)

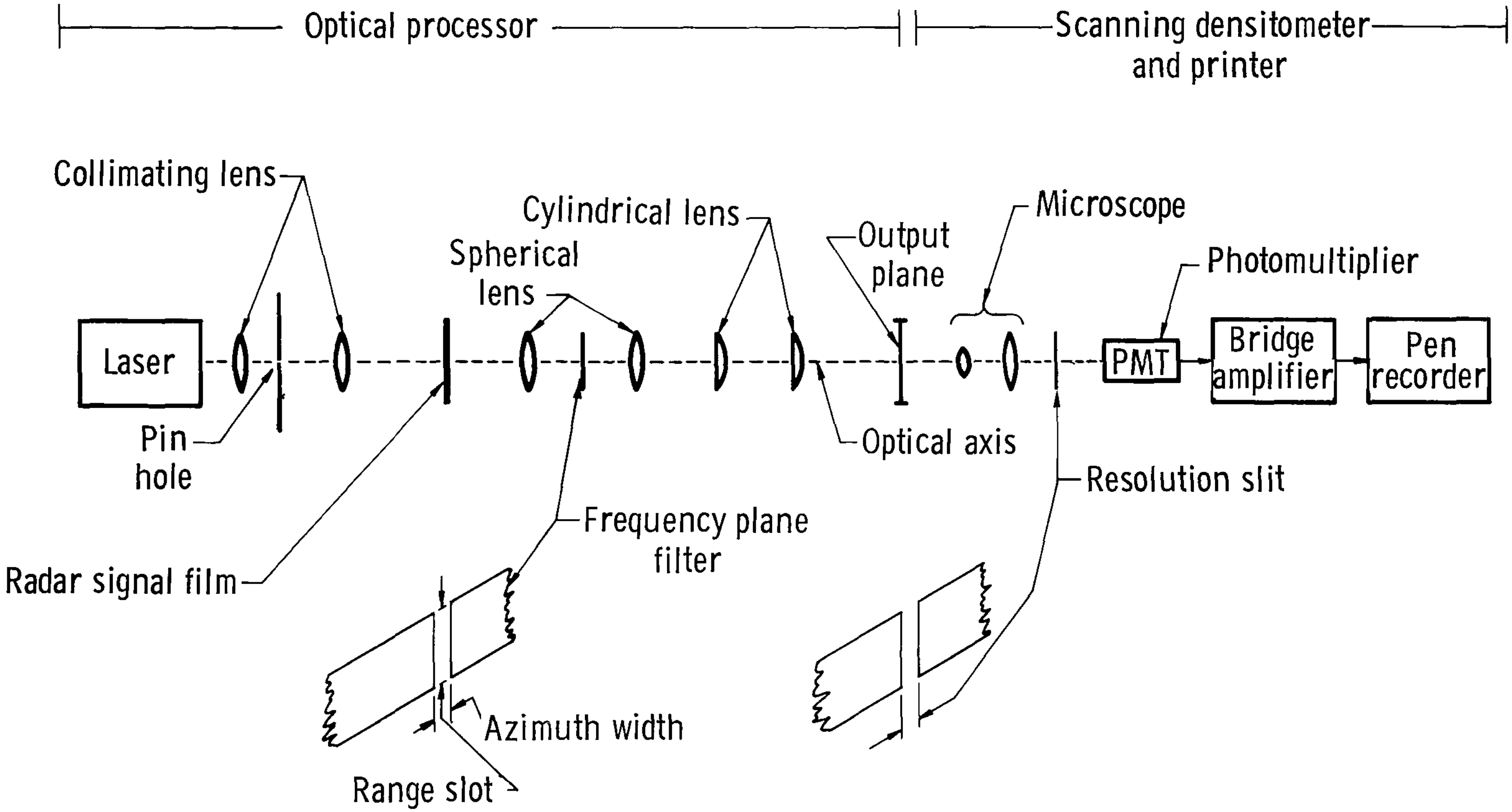


Figure 12.- Aircraft test image optical processing setup.

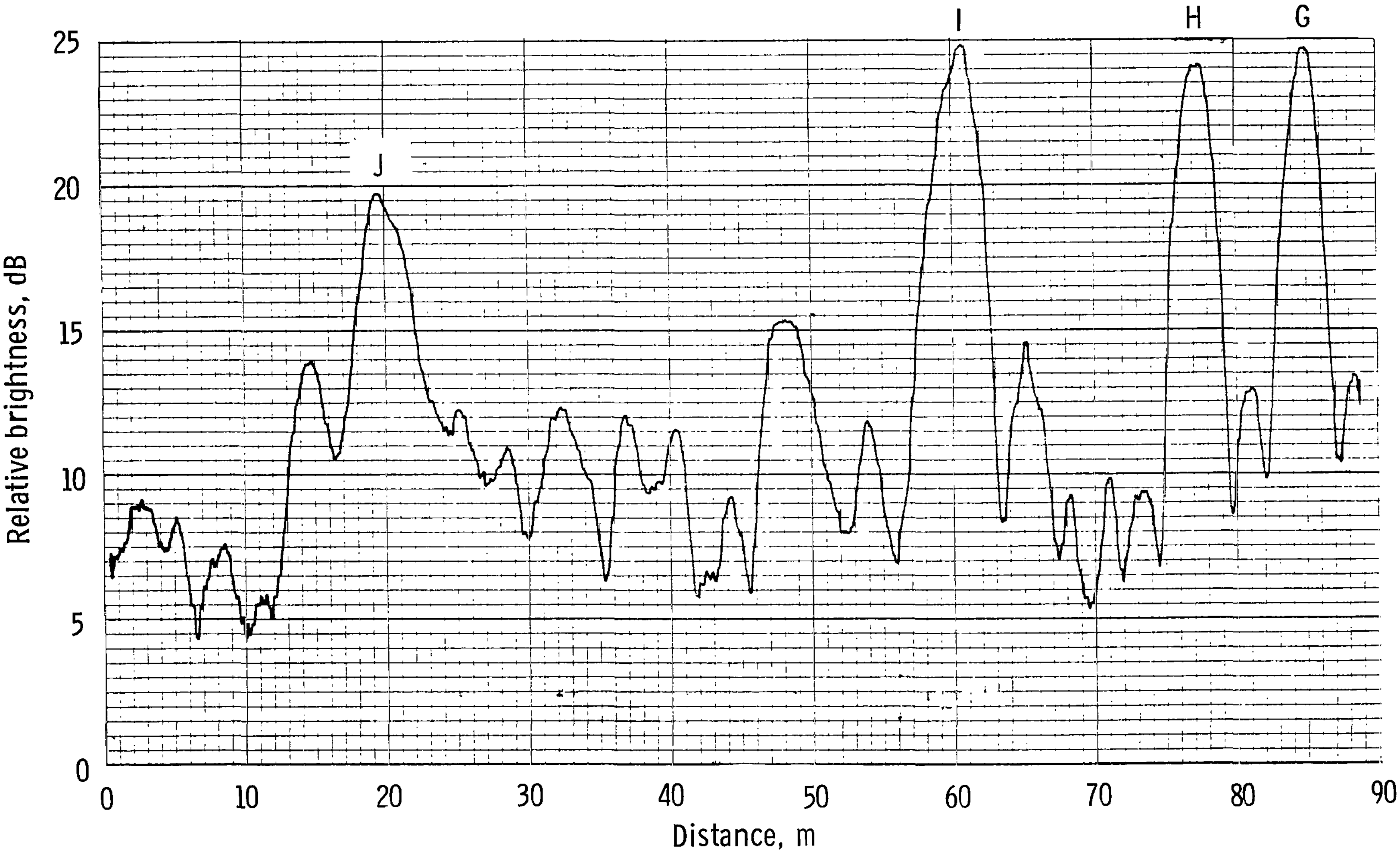


Figure 13. - Aircraft test processed image data representative relative target brightness.

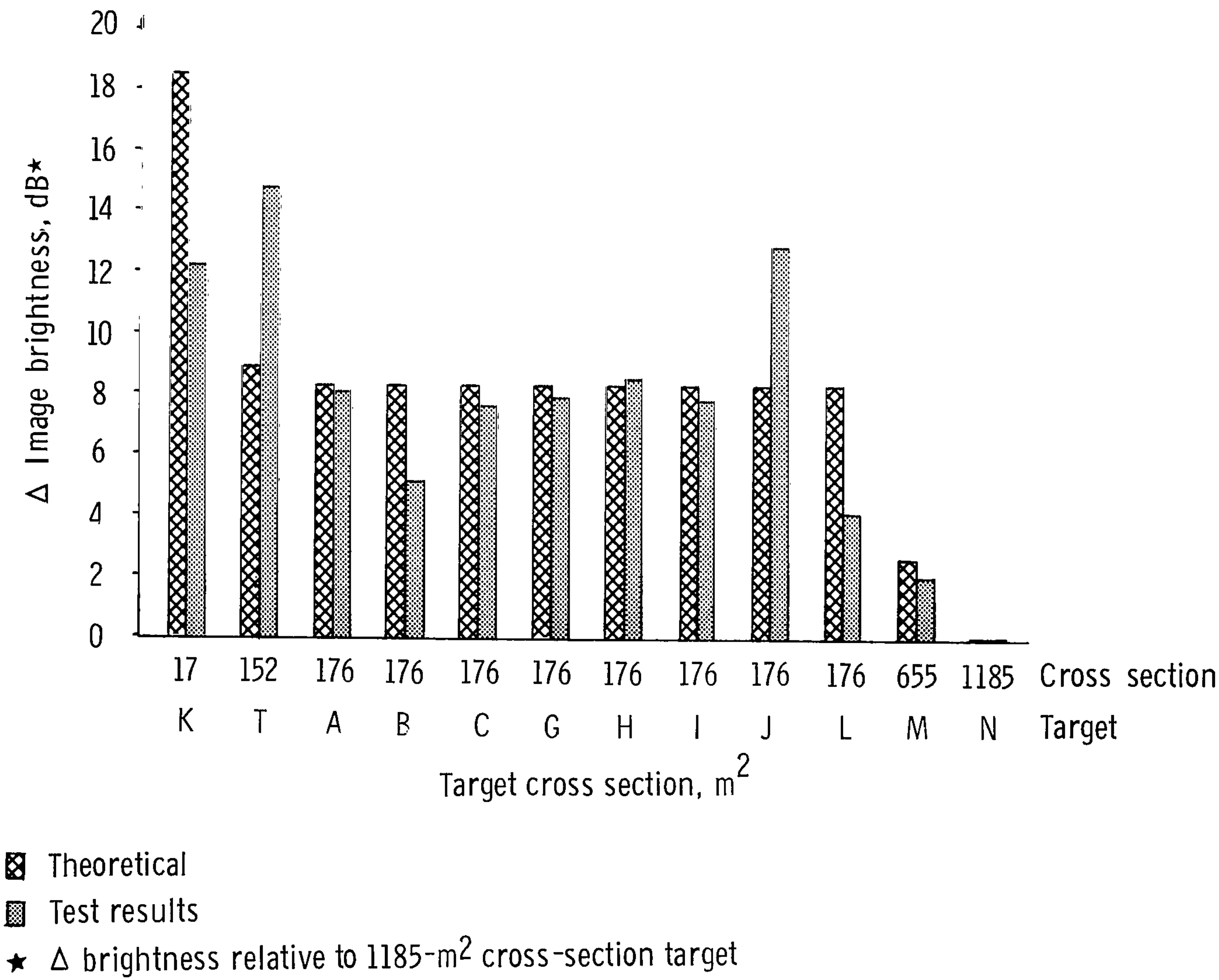


Figure 14.- Aircraft test Δ image brightness plotted against radar target cross section.

NASA-Langley, 1976 L-10259

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons. Also includes conference proceedings with either limited or unlimited distribution.

CONTRACTOR REPORTS: Scientific and technical information generated under a NASA contract or grant and considered an important contribution to existing knowledge.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities. Publications include final reports of major projects, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

TECHNOLOGY UTILIZATION PUBLICATIONS: Information on technology used by NASA that may be of particular interest in commercial and other non-aerospace applications. Publications include Tech Briefs, Technology Utilization Reports and Technology Surveys.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION OFFICE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. 20546