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THE ORBITAL RECOVERY PROBLEM

PART II - APPLICATION OF ANALYSIS TECHNIQUE TO SELECTION OF RECOVERY SITES FOR RETURN FROM LOW CIRCULAR ORBITS

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CONTENTS

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SUMMARY

The problem of return from a circular orbit at an altitude of 150 nautical miles to land recovery sites is treated from two viewpoints: First, the recall capability for return of several classes of entry vehicles with lateral-range capabilities of 210 to 3000 nautical miles to three sites located in the American quadrant of the Northern Hemisphere is defined. The effect of the addition of one optimally located emergency site to a network of three prime sites is also determined. It is shown that a capability of return to the continental United States once per orbit will require a vehicle with a lateral-range capability of about 3000 nautical miles (a lift-drag ratio L/D of approximately 2.4). The addition of one optimally located emergency site reduces this "quick-return" lateral-range requirement to 1000 to 1500 nautical miles (L/D $\approx$ 1.25 to 1.6).

Second, the minimum number of recovery sites necessary to support return to earth once per orbit (quick return) are defined for vehicle lateral-range capabilities of 270 to 3000 nautical miles, orbital inclinations of 30°, 45°, 60°, 75°, 90°, and all orbital inclinations in the range of 30° to 90°, and recovery sites with existing runways at least 8000 feet in length at which military and/or civilian aircraft of the United States are currently permitted to land. It is shown that only small reductions in the number of required sites in a minimum-site recovery network (for return from a given orbit with an inclination in the range of 30° to 90°) can be obtained by increasing the lateral-range capability of the vehicle beyond the following values:

(a) 1000 nautical miles (L/D $\approx$ 1.25) for prime recovery network

(b) 2000 nautical miles (L/D $\approx$ 1.8) for prime plus weather-alternate recovery networks

(c) 2500 to 3000 nautical miles (L/D $\approx$ 2.2 to 2.4) for prime plus daylight-alternate recovery networks

It is also shown that a single recovery network of two to seven sites (depending on weather or daylight requirements) will support quick return from all orbits with an

inclination in the range of 30^{o} to 90^{o} for an entry vehicle with a lateral-range capability of 2500 to 3000 nautical miles ($L/D \approx 2.2$ to 2.4).

Finally, the return of spacecraft with a vertical-landing capability to large recovery areas is considered. It is shown that large recovery areas allow only small reductions in lateral-range requirements when compared with the careful selection of a few point recovery sites.

INTRODUCTION

The determination of recall opportunities and lateral-range requirements for return from space to a large number of recovery sites has heretofore been a lengthy task. Part I of this study on "The Orbital Recovery Problem" (ref. 1) presented a technique of analysis with which the return opportunities and lateral-range requirements may be rapidly obtained for a large number of constraints. It is the purpose of the present report, Part II, to apply the analysis technique of Part I to the selection of recovery sites for return from space of many classes of entry vehicles.

In the discussion presented herein, two aspects of the application of the technique are considered separately. First, in the subsection "Capability for Return to Prime Recovery Networks," the problem is treated in terms of the recall capability (number of orbits per day during which recovery can be accomplished) of a given class of vehicle for return to a recovery network consisting of not more than three sites located in the American quadrant of the Northern Hemisphere. It is obviously desirable to locate within the United States as many sites of a multiple-site network as possible. Thus, the emphasis is placed on a recovery network consisting of three sites in the continental United States; however, for comparative purposes, other networks are considered which are located outside the United States but still within the American quadrant of the Northern Hemisphere. In addition, the increased recall capability available by the careful selection of a single emergency site located outside the American quadrant is demonstrated. The ranges of variables considered are vehicle lateral-range capabilities of 210 to 3000 nautical miles and orbital inclinations of 30^{o}, 45^{o}, 60^{o}, 75^{o} and 90^{o}.

In the subsection of the discussion entitled "Minimum Number of Recovery Sites," the minimum number of sites necessary to support return once per orbit (quick return) are determined for vehicles possessing lateral-range capabilities of 270 to 3000 nautical miles. (Note that the minimum range considered was increased to 270 nautical miles in this section so that the determination of a minimum number of sites would be feasible.) Orbit inclinations of 30^{o}, 45^{o}, 60^{o}, 75^{o}, and 90^{o} and all orbit inclinations in the range of 30^{o} to 90^{o} are considered. Also included are the number of sites necessary to offer a choice between return to a prime or a weather-alternate site and return to a prime or a daylight-alternate site during each orbit.

Return to large recovery areas is discussed in an appendix by Paul F. Holloway, E. Brian Pritchard, and Helen S. Creekmore.

This paper should allow some insight into the needs, in terms of lateral-range capabilities, of future entry vehicles.

SYMBOLS

D	drag
L	lift
n	orbit number
t	time
Δt_r	time interval between consecutive return opportunities
α	inclination of orbital plane with respect to earth equatorial plane
λ	latitude
λ'	lateral-range angle (latitude of recovery site referred to orbital plane) measured in degrees of earth surface arc (1^{o} = 60 n. mi.)
θ	longitude
τ_s	period of spacecraft in its orbit

Subscripts:

hyp	hypersonic
max	maximum
req	required

ASSUMPTIONS AND CONSTRAINTS

General Assumptions and Constraints

In the selection of recovery sites, the following general assumptions and constraints are imposed throughout this report:

Site selection.- Sites considered are restricted whenever possible to prepared airstrips with runways at least 8000 feet long at which aircraft (commercial and/or military) of the United States are currently permitted to land. In any recovery network considered, at least one site is required to lie within the continental United States.

The restriction of sites to prepared airstrips whenever possible does not dictate the mode of landing. The accessibility results presented are equally applicable to vehicles making an essentially vertical touchdown and to vehicles landing in a conventional horizontal maneuver.

Orbital altitude.- For the purposes of this study, the spacecraft is considered to be in a circular orbit at an orbital altitude of 150 nautical miles. This altitude was chosen so that the spacecraft would be in its original position with respect to the earth at the end of a 24-hour period. The results obtained, however, are generally applicable to other altitudes (with $\tau_S \approx 1.5$ hours) as well as to elliptic orbits with small eccentricities.

Spacecraft motion.- The spacecraft is assumed to move in a west-east direction and to complete 16 revolutions on its orbit daily.

Orbital inclination.- The results presented herein are equally applicable to both positive and negative orbital inclinations. For this reason, the results of this report are presented in terms of the absolute value of orbit inclination $|\alpha|$.

Nominal prime site.- Within each recovery network, a nominal prime recovery site is selected to which scheduled returns might be made. This site is always restricted to the continental United States (excluding Alaska).

Initial orientation.- The initial orientation simply orients the vehicle in its orbit at some reference time relative to a particular orientation of the earth in its rotation about its axis. (This orientation is chosen to maximize the opportunities for return to the nominal prime site.) The initial orientation may be considered as the injection of the spacecraft into its orbit at a particular point and time. For an actual mission, of course, it would be necessary either to use this orientation time as a mission constraint or else to determine a recovery network for the actual injection conditions.

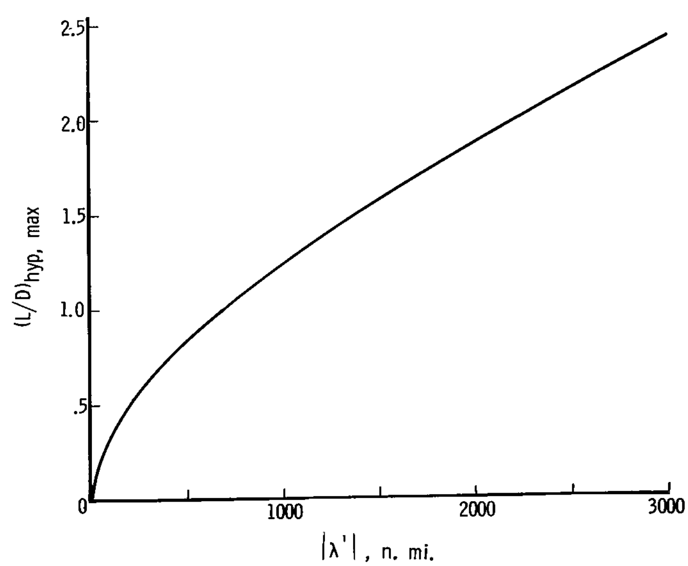


Figure 1.- Lateral range obtainable by aerodynamic maneuvering.

Lateral range.- No consideration has been given to the type of maneuver utilized to obtain the lateral-range capabilities considered. Therefore, the results are equally applicable to vehicles which obtain lateral range by aerodynamic maneuvering, propulsion, or combinations of the two. For reference purposes, the variation of lateral range with L/D for purely aerodynamic maneuvering is shown in figure 1. (See ref. 2.)

Optimum site location.- The term optimum, when applied to the location of a recovery site, denotes that the site is selected at the location in accordance with the other constraints which will provide the maximum return opportunities possible with the lateral-range capability being considered. Ideally, the latitude of the site would be given by (see appendix B of ref. 2):

$$|\lambda| = |\alpha| - |\lambda'| \tag{1}$$

with the following restrictions:

If $|\alpha| - |\lambda'|$ is negative, an equatorial site should be used.

If $|\lambda'| \geqq 90^{\circ} - |\alpha|$, a polar site should be used.

As an example, a semiballistic vehicle with a lift-drag ratio of 0.5 has a lateral-range capability of 210 nautical miles or 3.5° of earth surface arc. Therefore, for return from a 30° orbit, equation (1) would dictate that the latitude of the recovery network be 26.5°.

It must be stressed here that the definition of optimum recovery site used herein differs significantly from the definition used in reference 2. In reference 2, the optimum location of recovery sites was defined for a particular recovery network consisting of a specific number of sites and the resulting lateral-range requirements were then specified. In this report, the lateral-range capability is specified initially and then the location of the sites is determined.

The particular assumptions and constraints applied in each of the main sections of this report are presented in the following section.

Capability for Return to Prime Recovery Networks

In this section of the report, the recall opportunities of vehicles possessing lateral-range capabilities of 210, 500, 1000, 1500, 2000, 2500, and 3000 nautical miles are defined for return to prime recovery networks from orbits inclined 30°, 45°, 60°, 75°, and 90°. The increased recall capabilities obtainable by careful selection of an emergency recovery site are also defined. The general constraints on prime and emergency sites are as follows:

The prime recovery sites are defined in this subsection as those sites located within the American quadrant of the Northern Hemisphere (i.e., all of North America is considered and some parts of northern South America). A maximum of three prime sites has been considered within the network.

The emergency site is the site within each recovery network located outside the American quadrant of the Northern Hemisphere. In any network, only one emergency site is considered.

In order to illustrate the effects of a variation in the recovery-network location on the recall capability of specific classes of spacecraft, three separate constraints on the site location are imposed in the selection of the prime recovery networks. These constraints are:

(1) That all recovery sites within the prime recovery network be located by the lateral-range capability of a semiballistic ($\lambda' = 210$ nautical miles) spacecraft. (Note that, by use of this constraint, it was possible to obtain information on the increased recall capability obtainable by increasing the lateral-range capability of the spacecraft to reach a network of recovery sites initially designated to support return of the semiballistic class of spacecraft.)

(2) That all recovery sites within the prime recovery network be located by the particular lateral-range capability considered.

(3) That all recovery sites within the prime recovery network be located at the optimum location within the bounds of the continental United States.

Emergency sites were always selected by the lateral-range capability considered, regardless of the constraint on the prime recovery network.

The consideration of constraint (1) for $\alpha = 75^\circ$ and 90° and of constraint (2) for $\alpha = 90^\circ$ has been omitted because of the high latitudes of the recovery sites dictated under these constraints.

Table I shows the latitude, longitude, and preparedness of the sites used to obtain the results. Also indicated are the orbits in which the spacecraft can return to the sites. The site chosen as the nominal prime recovery site is indicated in the tables by an asterisk. Discussion of these results is presented in subsequent sections of this report.

Selection of Minimum Number of Recovery Sites

In this subsection, the minimum number of recovery sites necessary to support return once per orbit for vehicles possessing lateral-range capabilities of 270 to 3000 nautical miles are defined for return from orbit inclinations of 30°, 45°, 60°, 75°, and 90°, and all orbit inclinations in the range of 30° to 90°.

The minimum number of recovery sites has been determined for the provision of a prime recovery network (return opportunity once per orbit), a prime plus a weather-alternate recovery network (return opportunity once per orbit to either a prime site or a second site qualifying as a weather alternate), and a prime plus a daylight-alternate recovery network (return opportunity once per orbit to at least two sites which are mutual daylight alternates). The recovery networks were selected under the following constraints:

Prime recovery sites: At least one site within the network of prime recovery sites is required to lie within the continental United States.

Weather-alternate recovery sites: Weather-alternate recovery sites are required to be located at least 30° of earth surface arc (1800 nautical miles) from the prime site. It is pointed out in reference 3 that the provision of weather-alternate recovery sites can be extremely important, that is, the return of spacecraft from orbital missions in the future may not necessarily be under ideal weather conditions such as have been required for the X-15 flights. Therefore, in this report, a minimum of 1800 nautical miles between weather-alternate sites has been required to minimize the possibility of these sites being covered by the same weather front.

Daylight-alternate recovery sites: Since the geometry of the earth seldom permits a pairing of sites which are optimum daylight alternates, the sites were selected so that a daylight alternate would be available during all the orbits. The reader is reminded here that a daylight-alternate recovery site is, of necessity, also an ideal weather alternate.

It should be noted that the restriction on selection of daylight-alternate sites is an extremely rigid one. Therefore, the number of sites necessary to meet this constraint may be relatively large for a given vehicle. This number of sites is both necessary and sufficient to insure that a daylight alternate is available for the prime site during each orbit without imposing any exact restriction on the time of day at which injection into orbit occurs. To illustrate the application of the constraint on the selection of daylight-alternate sites, consider prime site A to which a vehicle with a lateral-range capability of 1000 nautical miles can return during orbits 1, 2, 3, and 4. Let there exist also sites B and C to which this vehicle can return during these orbits. Suppose further that site B can be a daylight alternate to site A only during the first and second orbits. Similarly, suppose that site C can only be a daylight alternate to site A during the third and fourth orbits. Hence, even though the vehicle can reach either site B or site C during each of orbits 1, 2, 3, and 4, both sites are necessary within the daylight recovery network. A second possibility, if no single daylight-alternate site to the prime site exists, is to select a pair (or pairs) of sites which are themselves optimum daylight alternates and to which the vehicle can return during these orbits.

The philosophy behind the location and selection of the minimum number of sites was to place full emphasis on the prime recovery network. That is, the prime sites have been selected to determine the true minimum number of sites necessary without regard to the additional provision of weather or daylight alternates. Therefore, the numbers of sites necessary to provide weather or daylight alternates are determined for the particular prime recovery network previously selected. This means that, if the initially determined prime reco y network could be altered in location without increasing the number of sites to allow a reduction in either the number of weather- or daylight-alternate sites required, then this revision was made (except when this revision required a reduction of the number of prime sites located within the United States). If, however, a reduction in the total number of recovery sites for the provision of weather and/or daylight alternates could be accomplished only through a revision requiring an increase in the number of prime recovery sites, then no change was made. An illustration of this type of consideration is given in the section entitled "Discussion of Results."

Site selection: The sites used in this section of the study are restricted to those in a proposed list of acceptable sites (table II). The sites listed in table II are those which were found necessary in this investigation and were obtained from a listing of 862 acceptable recovery sites. (See ref. 4.) However, during the selection of the recovery networks, each of the 862 sites was considered. The particular combination of sites chosen is not necessarily the only combination which would suffice. However, there should be no combination which yields a lesser number of sites as long as the sites are restricted to the list of acceptable sites (table II).

The difficulties of selecting daylight alternates have occasionally dictated the use of unlisted and/or unprepared sites for the lower lateral-range capabilities considered. Those networks which include unlisted sites are indicated in table III. The unprepared sites considered were Easter Island (Chile); the Kerguelen Islands (France); Columbo, Ceylon; and Capetown, Republic of South Africa.

DISCUSSION OF RESULTS

Capability for Return to Prime Recovery Networks

Under the three constraints considered in figure 2, the prime recovery sites are always located in the American quadrant of the Northern Hemisphere. The results shown in figure 2 demonstrate that location of the recovery network by the three constraints considered here does not result in a reduction of recall capabilities of the several classes of spacecraft by more than 2 per day except for vehicles with a lateral-range capability of 1500 and 2000 nautical miles in a 30° orbit and vehicles with a lateral-range capability of 500 nautical miles in a 75° orbit. Figure 2 also shows that three prime sites are seldom required to achieve a maximum capability for return to the recovery networks considered. The addition of a single emergency recovery site is shown to be extremely effective as a means of increasing vehicle recall capability, regardless of orbit inclination.

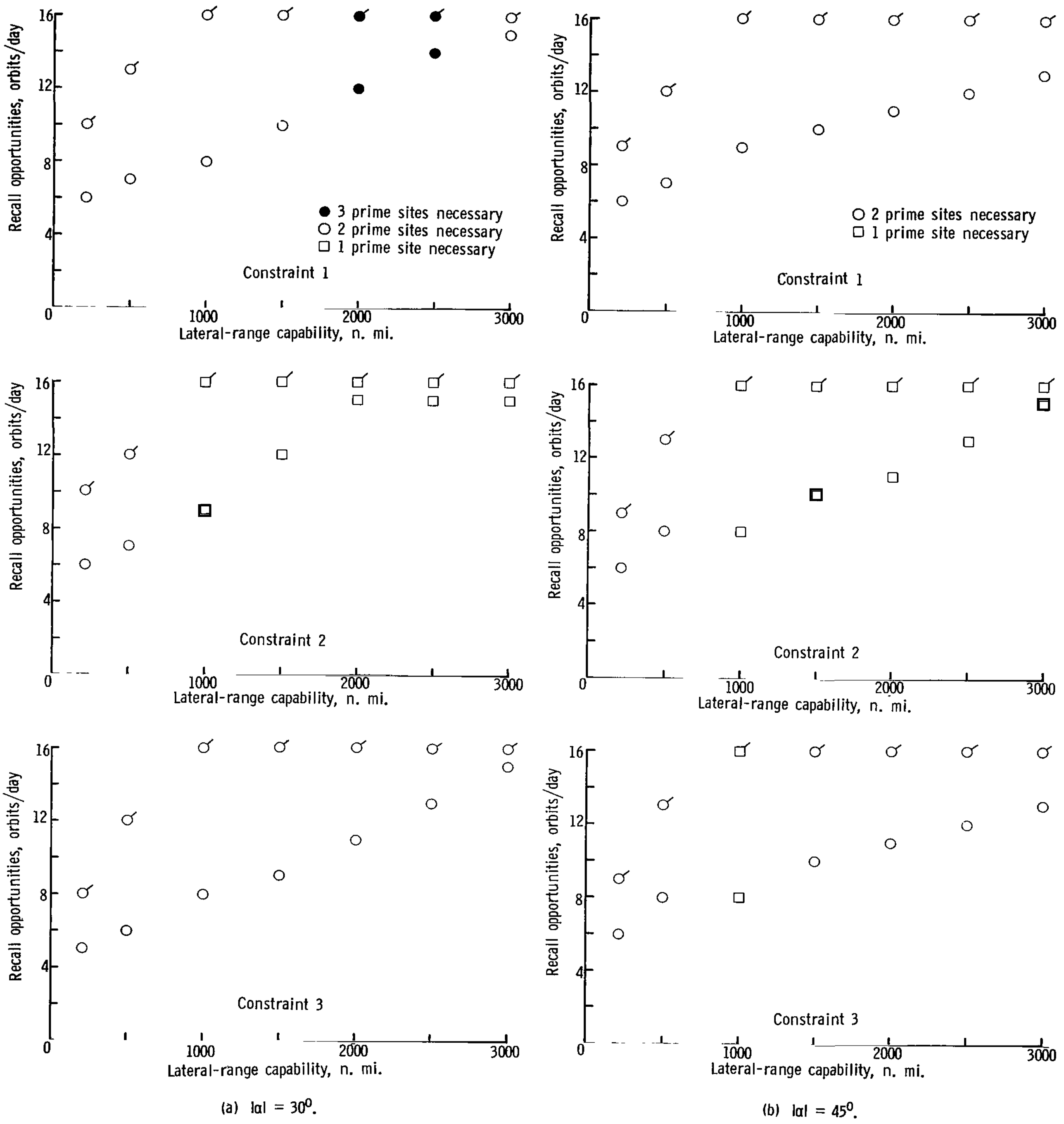
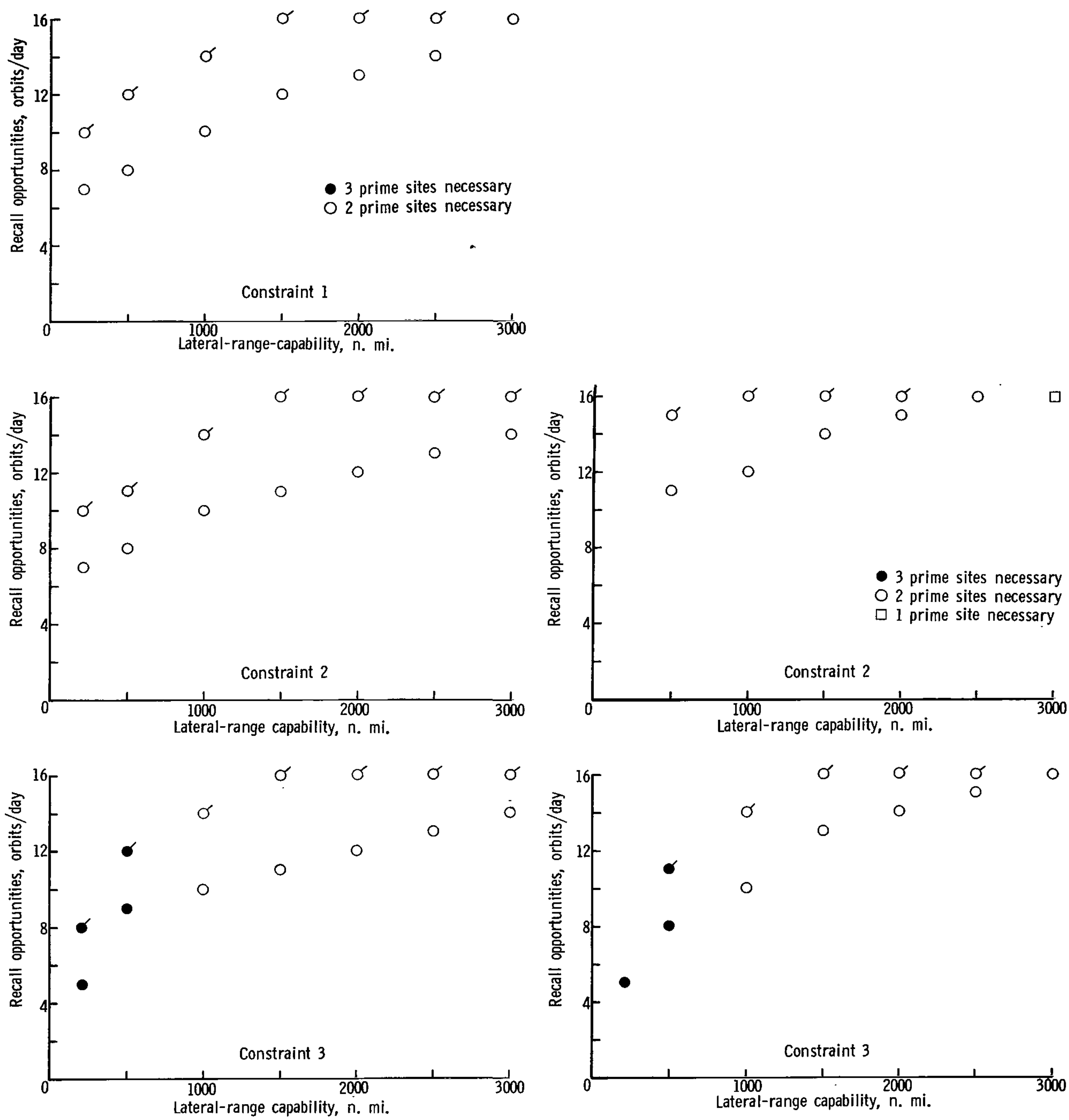


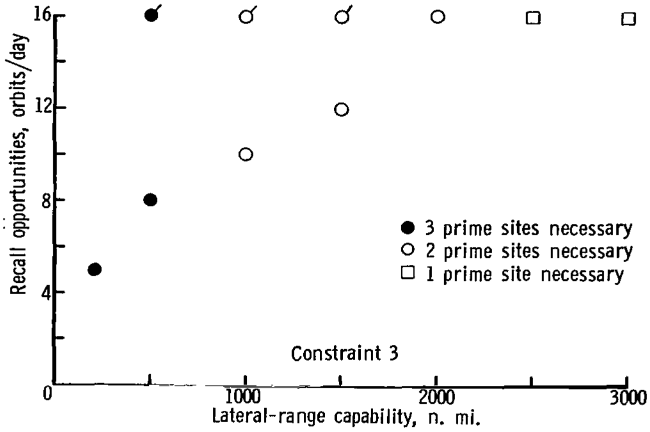
Figure 2.- Recall capability for various orbit inclinations. Constraints: 1- Prime sites located by λ' capability of semiballistic vehicle; 2-Prime sites located by each λ' capability considered; 3- Prime sites located at optimum U.S. location for λ capability considered. Flagged symbols indicate that emergency site is included.



(c) |α| = 60°.

(d) |α| = 75°.

Figure 2.- Continued.



(e) $|\alpha| = 90^{\circ}$. (Polar orbit.)

Figure 2.- Concluded.

Consideration of the results of figure 2 and table I clearly indicates that the needs of future manned entry spacecraft in terms of lateral-range capability shall depend almost entirely upon the constraints imposed upon the mission which the spacecraft is designed to complete. To illustrate, consider the recovery sites to be located at the best United States location for the various lateral ranges and orbit inclinations shown (constraint 3, fig. 2). If an entry vehicle which obtains all its lateral range through aerodynamic maneuvering is considered, the following results are obtained:

(1) If a capability of return during 5 of the 16 orbits per day to the prime recovery network is satisfactory, the semiballistic spacecraft ($\lambda' = 210$ nautical miles, $L/D = 0.5$) would be sufficient for the mission.

(2) If the vehicle is required to be able to reach the prime recovery network at least 75 percent of the time (12 orbits), then lateral-range capabilities of 1500 to 2500 nautical miles ($L/D \approx 1.6$ to 2.2, see fig. 1), depending on orbit inclination, will be necessary.

(3) If a capability of quick return to the prime recovery network is required, a lateral-range capability in the neighborhood of 3000 nautical miles ($L/D \approx 2.4$) would be required.

Next, consider the addition of one optimally located emergency recovery site to the prime recovery network dictated by constraint 3. Table I indicates that, for orbital inclinations of 30° to 60°, the emergency site is generally located either in India or central Europe. For an orbit inclined 75°, the emergency site is located either in Sweden or Norway, except for the semiballistic vehicle for which no acceptable optimum site exists. For a 90° orbit inclination, the emergency site is located in Greenland; again, no acceptable optimum site exists for the semiballistic vehicle. As shown in figure 2, addition of an emergency site greatly increases the recall capability of a vehicle with the following results:

(1) A vehicle with a lateral-range capability of 500 nautical miles ($L/D \approx 0.8$) would be capable of return to the recovery network during a minimum of 11 orbits per day (as compared with a minimum of 6 orbits per day without an emergency site) for an orbit with

an inclination in the range of 30° to 90°. (Note that the location of sites may be required to change with changing orbit inclination or lateral-range capability.)

(2) A vehicle with a lateral-range capability of about 1000 to 1500 nautical miles (L/D ≈ 1.25 to 1.6) would be capable of return to the recovery network during any orbit.

Minimum Number of Recovery Sites

As stated previously, the needs of future entry vehicles in terms of lateral-range requirements will depend strongly upon mission constraints. In the selection of the minimum number of recovery sites shown in figure 3, a rigid constraint of return capability at least once per orbit has been imposed. Because of the stringency of this constraint, the number of sites required to provide a prime network, a prime plus weather-alternate network, and a prime plus daylight-alternate network for return once per orbit could be considered as a maximum. It should be emphasized, however, that missions could be conceived which would require an increased number of sites. Alternatively, many missions exist which require less stringent restrictions and hence fewer sites than those obtained here.

The results of figure 3 may be viewed from two points. First, if a given vehicle is to be utilized for a given mission, this figure indicates a maximum number of sites that should be required, and the corresponding table (table III) gives a possible location of sites. Note that the recovery networks represented by the symbols in figure 3 are tabulated in table III with the nominal prime site within each prime recovery network indicated by an asterisk. Second, if it is desired to keep the number of sites necessary to

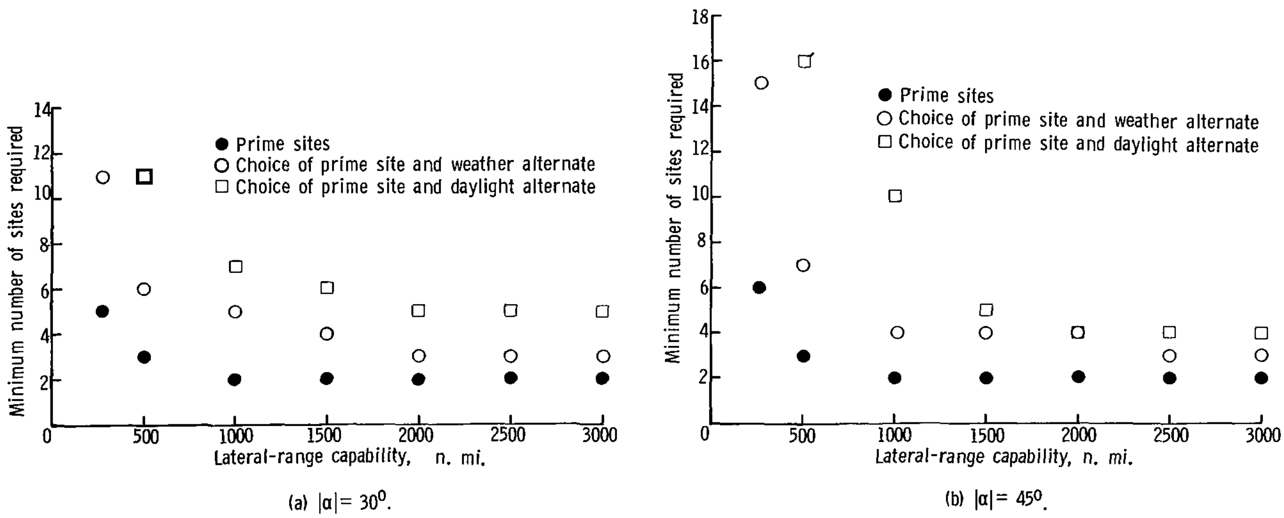
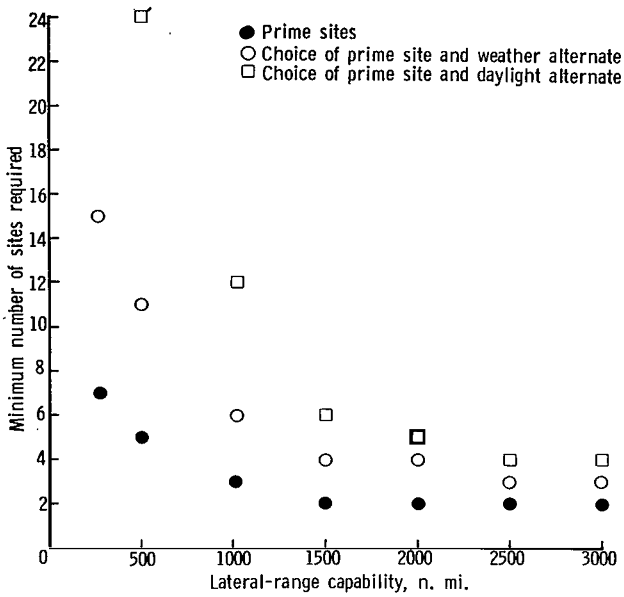
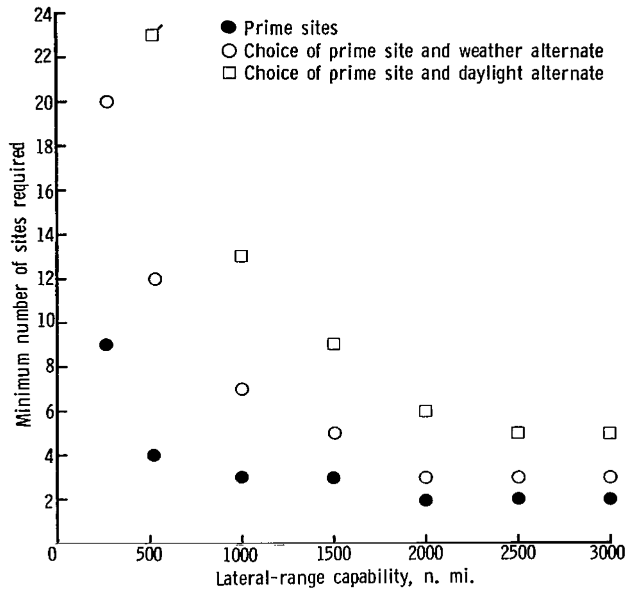


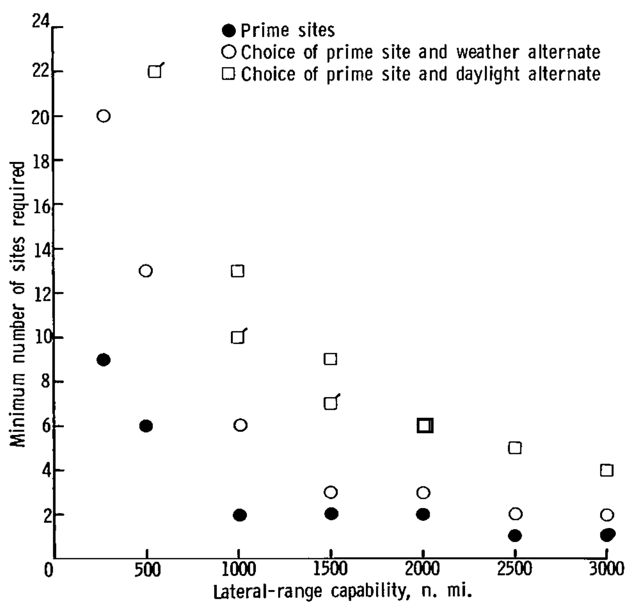
Figure 3.- Minimum number of sites required for quick return from orbits inclined from 30° to 90°. Flagged symbols indicate that network contains unprepared site or sites.



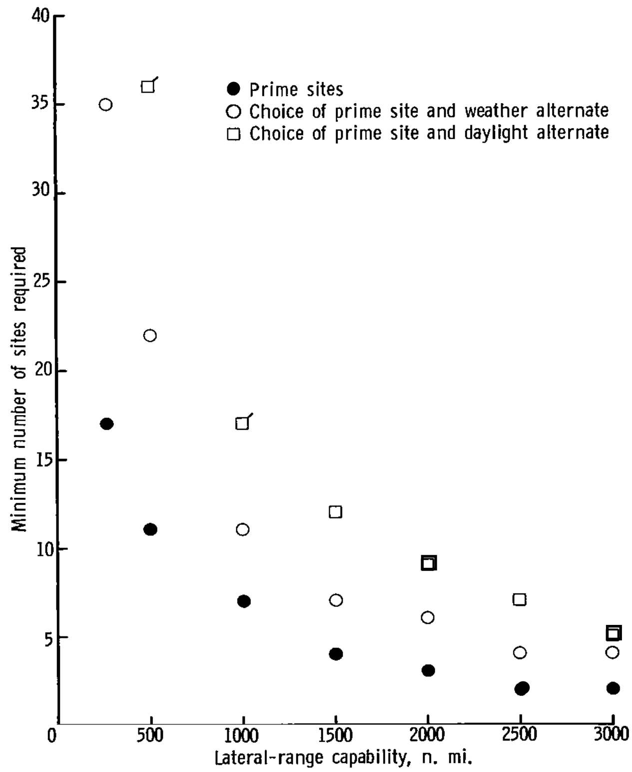
(c) $|\alpha| = 60^0$.



(d) $|\alpha| = 75^0$.



(e) $|\alpha| = 90^0$.



(f) $30^0 \leq |\alpha| \leq 90^0$.

Figure 3.- Concluded.

support a given mission as low as possible, this figure can indicate a goal toward which future vehicle technology can be directed.

From the first point of view, the results are self-explanatory and need not be discussed in detail. An example of this type of application can be obtained by application of the results to the lifting-body vehicle ($L/D = 1.25$, $\lambda' \approx 1000$ nautical miles). For this class of vehicle, the following table describes the variation of the number of sites required with orbit inclination (from table III):

$\|\alpha\|$, deg	Minimum number of sites required for provision of –		
	Prime network	Prime plus weather	Prime plus daylight
30	2	5	7
45	2	4	10
60	3	6	12
75	3	7	13
90	2	6	13
30 to 90	7	11	17

It was pointed out in Part I of this report (ref. 1) that the command pilot of a spacecraft is more interested in the time intervals between return opportunities than in the orbit during which the opportunity occurs. To illustrate how this time interval varies, figure 4 shows the variation of Δt_r with time for the return of a lifting-body class of vehicle to a prime recovery network. It can be easily seen from figure 4 that the time intervals are reasonably constant (with a value slightly higher than the orbital period of the spacecraft) except at the points of change from one prime site to another. Even at these points, the time interval between return opportunities has a maximum value of somewhat less than 2 hours.

From the second viewpoint, that of defining the vehicle capabilities which are necessary to minimize the number of required recovery sites for return once per orbit, the following results are obtained:

(1) Considering the number of sites necessary to provide a prime recovery network for return from some orbit with an inclination of 30° to 90° (see figs. 3(a) to 3(e)), little advantage is gained in increasing lateral-range capability above 1000 nautical miles (for purely aerodynamic maneuvering, the lifting-body class of vehicles).

(2) In order to provide a weather alternate to the prime site for each orbit, a lateral-range capability of 2000 nautical miles (an L/D of 1.8 class of vehicle) would be desirable.

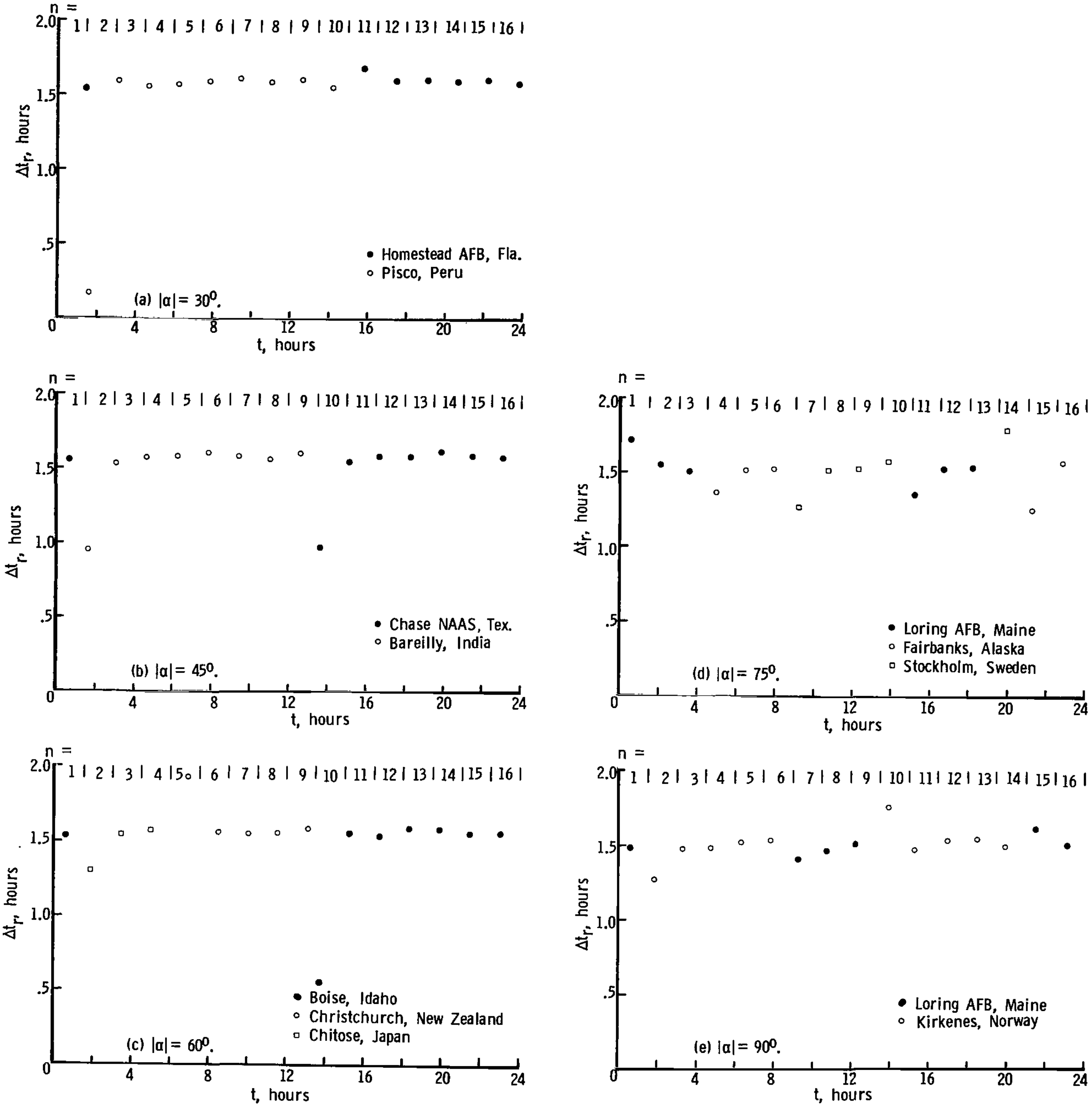


Figure 4.- Time intervals between return opportunities of lifting-body class of vehicle. $L/D \approx 1.25$; $\lambda = 1000$ n. mi.

(3) In order to provide a daylight (and hence weather) alternate to the prime site for each orbit, a lateral-range capability of 2000 to 3000 nautical miles (L/D of 1.8 to 2.4) would be desirable.

(4) If classes of vehicles in the range of $0.5 < L/D < 0.8$ are to be utilized, land recovery of once per orbit will require relatively large numbers of recovery sites. For example, an L/D of 0.8 ($\lambda' = 500$ n. mi.) class of vehicle would require from 11 to 24 recovery sites to provide capability of return to either a prime or a daylight-alternate site once per orbit.

(5) Development of a vehicle which can undertake any mission with an orbit inclination in the range of $30^\circ \leqq |\alpha| \leqq 90^\circ$ (see fig. 3(f)) will require a lateral-range capability of 2500 to 3000 nautical miles (L/D of 2.2 to 2.4) to minimize the required number of recovery sites. A vehicle with a lateral-range capability of 500 nautical miles ($L/D = 0.8$) would require 36 sites for the provision of a prime plus daylight-alternate recovery network, whereas a vehicle with a lateral-range capability of 270 nautical miles ($L/D = 0.6$) would require 35 sites for the provision of a prime plus weather-alternate recovery network.

Examples of Selection Constraints on Number of Required Sites

Figure 3(d) shows that a vehicle with a lateral-range capability of 2500 nautical miles returning from an orbit inclined 75° would require two recovery sites for the prime network, three for the prime plus weather-alternate network, and five for the prime plus daylight-alternate network. These sites (from table III(d)) are:

Prime – Loring AFB, Maine; and Fairbanks International Airport, Alaska

Weather – Stockholm, Sweden

Daylight – Perth, Australia; JBM Gertzog, Republic of South Africa; and Luanda, Angola

An alternate selection of sites would be:

Prime – Whidbey Island NAS, Washington; and Christchurch, New Zealand

Weather – Chitose, Japan

Daylight – Istres, France; and Arivonimamo, Malagasy Republic

Thus, the required number of sites for the provision of a prime plus daylight-alternate recovery network could be reduced by one. The former network was selected, however, because of the emphasis placed on the location of prime sites. That is, in the former network both prime sites are located within the United States, whereas in the later network only one is so located.

Similarly, figure 3(d) shows that a vehicle with a lateral-range capability of 3000 nautical miles returning from an orbit inclined 75° would require two prime recovery sites, three prime plus weather-alternate recovery sites, and five prime plus daylight-alternate recovery sites. From table III(d), these sites are:

Prime – Loring AFB, Maine; and Juneau, Alaska

Weather – Hickam AFB, Hawaii

Daylight – Perth, Australia; Arivonimamo, Malagasy Republic; and JBM Gertzog, Republic of South Africa

An alternate selection of sites would be:

Prime – Whidbey Island NAS, Washington; and Christchurch, New Zealand

Weather – Chitose, Japan

Daylight – Istres, France; and Arivonimamo, Malagasy Republic

and thus the required number of sites for the provision of a prime plus daylight-alternate recovery network would be reduced by one. In this case, for the former network, both prime sites and the weather alternate are located within the United States, whereas for the latter network, only one prime site is within the United States.

Considering a vehicle with a lateral-range capability of 2500 nautical miles for return from any orbit inclination in the range of 30° to 90°, the selected sites are (from table III(f)):

Prime – Whidbey Island NAS, Washington; and Merzifon, Turkey

Daylight – Hickam AFB, Hawaii; Kimpo Airfield, South Korea; Papeete, Tahiti; JBM Gertzog, Republic of South Africa; and Tandil, Argentina

for a prime plus daylight-alternate recovery network of seven sites. An alternate approach would have been to increase the number of prime sites which would then reduce the total number of sites for the prime plus daylight-alternate recovery network to six sites. This alternate recovery network would be:

Prime – Whidbey Island NAS, Washington; Christchurch, New Zealand; and Kimpo Airfield, South Korea

Daylight – Tandil, Argentina; Istres, France; and Arivonimamo, Malagasy Republic

This reduction in the number of sites required is a result of the availability of near-optimum daylight alternates for the prime sites of the latter network. However, the former network was selected because of the reduced number of prime sites required.

Two final examples illustrate how the number of recovery sites necessary to provide daylight alternates to the prime site for each orbit may be reduced by the use of unlisted sites. From figure 3(e), it can be seen that exclusive use of listed sites requires a total of 13 recovery sites in the provision of the prime plus daylight-alternate network for a vehicle possessing a lateral-range capability of 1000 nautical miles. The use of one unlisted site, the Kerguelen Islands, in combination with Grand Forks International Airport, North Dakota, would make sites at Whidbey Island NAS, Washington; Chimbote, Peru; Keeling Island; Arivonimamo, Malagasy Republic; and Waru, Indonesia unnecessary. Thus, the total number of sites would be reduced to 10. Similarly, for a vehicle with a 1500-nautical-mile lateral-range capability, the Kerguelen Islands in combination with Grand Forks, North Dakota may be used to replace Homestead AFB, Florida; Whidbey Island NAS, Washington; Keeling Island; and Arivonimamo, Malagasy Republic. Thus, the number of sites required to provide a prime plus daylight-alternate recovery network would be reduced from nine to seven.

IMPLICATIONS OF RESULTS TO NEEDS OF FUTURE ENTRY VEHICLES

The future development of vehicles with an increased L/D capability, in terms of lateral-range considerations, may possibly be justified by the increased crew safety, mission versatility, and probability of success. Crew safety may be dependent upon the capability to reach an acceptable recovery location as soon as possible after the decision to return to earth. It has been demonstrated that vehicles in the semiballistic class will require either relatively long wait times in orbit or a relatively large number of foreign recovery sites. If neither of these arrangements is satisfactory, then return through the much-tested technique of water recovery must always be accepted as a possibility for emergency recovery. The development of a lifting-body class of vehicle ($\lambda' = 1000$ n. mi., $L/D \approx 1.25$) would create a high degree of probability of return to a recovery network with the prime sites located in the United States and one foreign emergency site for a given orbit inclination. Mission versatility would be enhanced since this class of vehicle would be capable of return once per orbit from all orbit inclinations in the range of 30° to 90° to a seven-site recovery network consisting of three United States sites (two continental and one Hawaiian), a Canadian site, a New Zealand site, an Argentine site, and a site in Turkey. This versatility can be very important since such a vehicle would be capable of performing missions involving rather large orbital-plane changes without altering its capability of return to a prepared recovery network.

Another factor which must be considered is the size and extent of the ground-based recovery operation system which must be provided and its location. For this consideration, vehicles possessing L/D capabilities of approximately 2 ($\lambda' \geqq 2000$ n. mi.) would be desirable to minimize the required number of recovery sites and yet provide the maximum crew safety factor through the availability of a weather- or daylight- (and hence weather) alternate recovery site for the prime site during each orbit. This vehicle would be capable of return once per orbit from all orbits in the range of 30° to 90° to a three-prime-site network (Whidbey Island NAS, Washington; Christchurch, New Zealand; and Kimpo Airfield, South Korea). A weather-alternate capability is available to the vehicle with three additional sites (Hickam AFB, Hawaii; Keflavík, Iceland; and Merzifon, Turkey). A daylight-landing capability would require five sites in addition to the three prime sites (Istres, France; Hickam AFB, Hawaii; Tandil, Argentina; JBM Gertzog, Republic of South Africa; and Arivonimamo, Malagasy Republic).

As would be expected, the restrictions on the locations of the necessary recovery sites decrease significantly with increasing L/D (or lateral range) capability.

Finally, in the appendix, it is shown that, for quick-return restrictions, the development of a spacecraft which has vertical-landing capability will not cause large reductions in lateral-range requirements by considering large recovery areas such as the continental United States as compared with the careful selection of point recovery sites. However, it must be pointed out that the vertical-landing capability may reduce chances of mission failure in the landing phase. For example, an error in touchdown point of many miles will not necessarily prevent safe landing of a spacecraft with a vertical-landing capability.

CONCLUSIONS

The problem of return from a circular orbit with an altitude of 150 nautical miles to land-based recovery sites has been analyzed in detail and conclusions have been drawn for each of the following considerations:

1. The consideration of the capability of various classes of spacecraft for recall to multiple-site recovery networks located in the American quadrant of the Northern Hemisphere has led to the following conclusions:

(a) The sites may generally be further restricted to lie within the continental United States without reducing the recall capability of the various classes of spacecraft by more than two opportunities per day.

(b) A vehicle with a lateral-range capability of 500 nautical miles (lift-drag ratio of ≈ 0.8) would be capable of returning to the prime continental recovery sites during at least 6 of the 16 orbits daily, regardless of orbit inclination. The addition of an emergency site increases the number of recall opportunities to at least 11 of the 16 orbits daily.

(c) A capability of return once per orbit to a continental United States recovery network will require a lateral-range capability of approximately 3000 nautical miles (lift-drag ratio of 2.4).

(d) The addition of one optimally located emergency site to the prime network will make possible a return capability of once per orbit by vehicles possessing a lateral-range capability of 1000 to 1500 nautical miles (lift-drag ratios of about 1.25 to 1.6).

2. The consideration of the minimum number of recovery sites necessary to support return to earth once per orbit and of the definition of the vehicle capabilities necessary to reach these minimum-site recovery networks has led to the following conclusions:

(a) Vehicles of the semiballistic class will require either relatively long wait times in orbit after the decision to return or large numbers of foreign sites within the recovery network. If neither of these arrangements is satisfactory, emergency water landing must be permitted.

(b) Increases in lateral-range capability for the attainment of a network with a minimum number of recovery sites offers only small reductions beyond the vehicle requirements obtained for the following constraints and return from a given orbit inclination in the range of 30° to 90°:

(i) Lateral-range capability of 1000 nautical miles (lift-drag ratio of 1.25) for provision of prime recovery network

(ii) Lateral-range capability of 2000 nautical miles (lift-drag ratio of 1.8) for provision of prime plus weather-alternate recovery network

(iii) Lateral-range capability of 2500 to 3000 nautical miles (lift-drag ratio of $\approx$2.2 to 2.4) for the provision of prime plus daylight (and hence weather) alternate network

(c) Minimum numbers of sites can be obtained for return to a single recovery network from all orbit inclinations in the range of 30° to 90° with lateral-range capabilities of 2500 to 3000 nautical miles (lift-drag ratio of 2.2 to 2.4).

3. The consideration of the return of spacecraft with vertical-landing capability to large recovery areas once per orbit has led to the following conclusion:

(a) Large recovery areas will not cause significant reductions in lateral-range requirements as compared with the requirements resulting from the careful selection of a small number of point recovery sites.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., December 7, 1966,
789-30-01-02-23.

APPENDIX

RETURN TO LARGE RECOVERY AREAS

By Paul F. Holloway, E. Brian Pritchard,
and Helen S. Creekmore

Vehicles which possess a vertical-landing capability may not require prepared recovery sites for emergency return to earth since a semihard landing, even in remote areas, would be acceptable under emergency conditions. It is the purpose of this appendix to consider the return of such vertical-landing vehicles to large land recovery areas. The maximum vehicle lateral-range requirements will be defined for return from orbit inclinations of 30° to 90°. These lateral-range requirements represent the distance between the closest point of a given land area (or combination of areas) and the orbital plane (as was done in ref. 2). This distance, which varies as a function of time (earth rotation), is the maximum daily requirement necessary to insure return during any orbit to some point within the recovery area.

The recovery areas considered are as follows:

(1) Continental United States
$25^{\circ} \leqq \lambda \leqq 49^{\circ}$; $79^{\circ} \leqq \theta \leqq 120^{\circ}$

(2) Hawaii
$\lambda = 19.5^{\circ}$; $\theta = 155.5^{\circ}$

(3) Alaska
$60^{\circ} \leqq \lambda \leqq 70^{\circ}$; $141^{\circ} \leqq \theta \leqq 160^{\circ}$

(4) Canada
$49^{\circ} \leqq \lambda \leqq 60^{\circ}$; $60^{\circ} \leqq \theta \leqq 130^{\circ}$

(5) Australia
$-35^{\circ} \leqq \lambda \leqq -15^{\circ}$; $-150^{\circ} \leqq \theta \leqq -120^{\circ}$

(6) Argentina
$-45^{\circ} \leqq \lambda \leqq -25^{\circ}$; $65^{\circ} \leqq \theta \leqq 70^{\circ}$

(7) Brazil
$-30^{\circ} \leqq \lambda \leqq 0^{\circ}$; $50^{\circ} \leqq \theta \leqq 55^{\circ}$

From figure A1(a), it can be seen that return to some point within the bounds of the continental United States at any time will require large lateral-range capabilities of 2300 to 4200 nautical miles, depending on the orbit inclination. However, the addition of Hawaii and Alaska as acceptable recovery areas will reduce this range requirement to

1100 to 3100 nautical miles. In figure A1(b), the reductions possible by adding recovery areas in either Argentina, Australia, Brazil, or Canada to that in the continental United States are illustrated. It can be seen that the addition of a South American recovery area is generally more effective in reducing lateral-range requirements than the addition of either Canada or Australia.

The return requirements to reach the combination of all the recovery areas considered are shown in figure A1(c). Large reductions in lateral-range requirements are apparent when return to some point within either of the recovery areas is permissible. A semiballistic type of vehicle (λ' = 210 n. mi., L/D = 0.5) would be capable of quick return from any orbit in the range of 30° to 50°. The lifting body class of vehicle (λ' = 1000 n. mi., L/D = 1.25) would be capable of quick return from any orbit in the range of 30° to 62° and 84° to 90°.

An important factor in the consideration of the range requirements of figure A1 is the amount of time daily that the spacecraft is capable of return to each recovery area. This return parameter is shown in figure A2 in the form of a bar graph for each orbit inclination considered and for the lateral range required to obtain quick-return capability. With the return-time parameter presented in this form, the minimum number of recovery areas considered necessary to provide quick-return capability may be determined as follows:

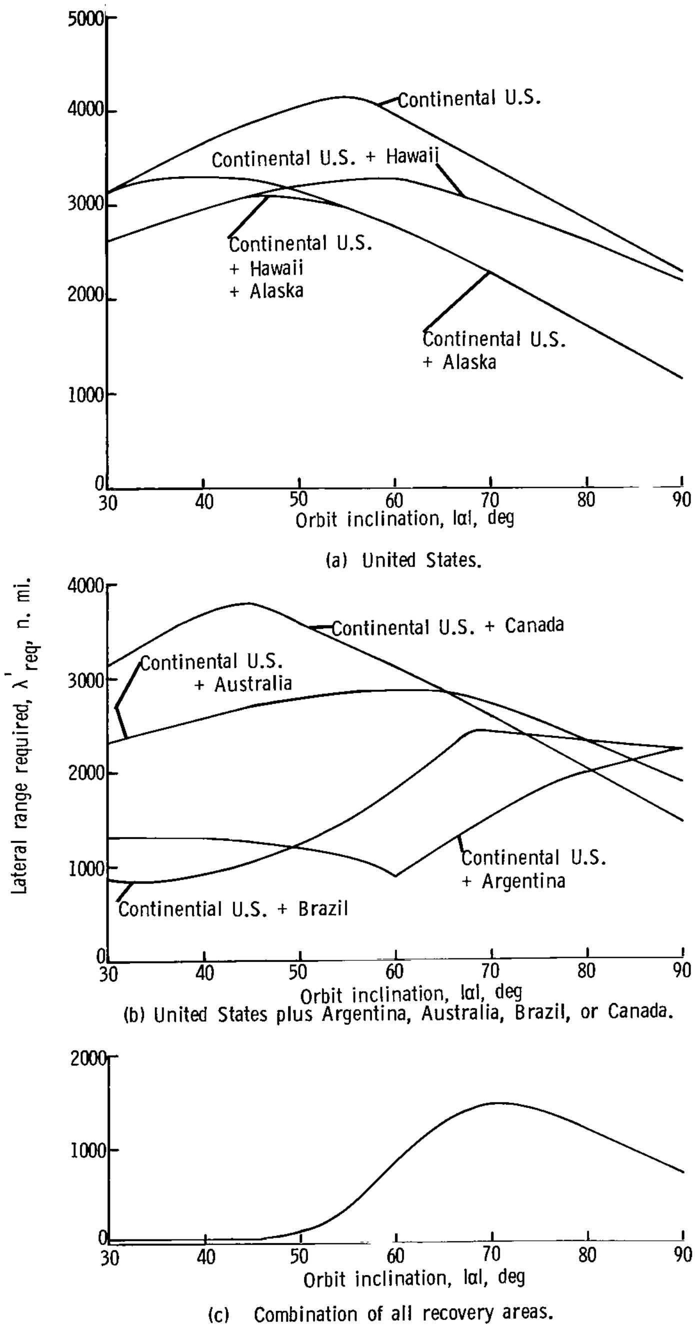


Figure A1.- Lateral range required for quick return to large recovery areas.

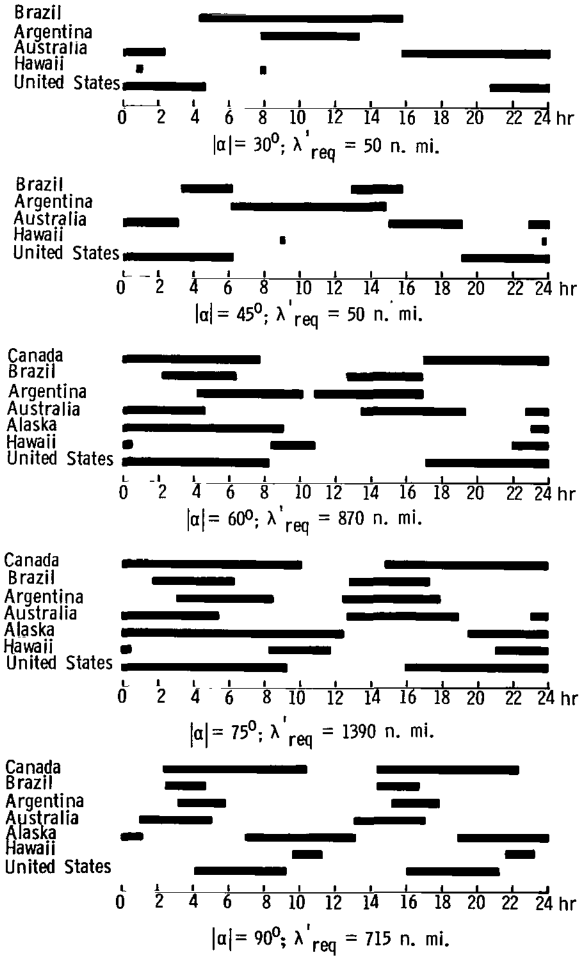


Figure A2.- Time of daily opportunities for return to each recovery area for vehicles possessing minimum lateral-range capability necessary for quick return from different orbit inclinations.

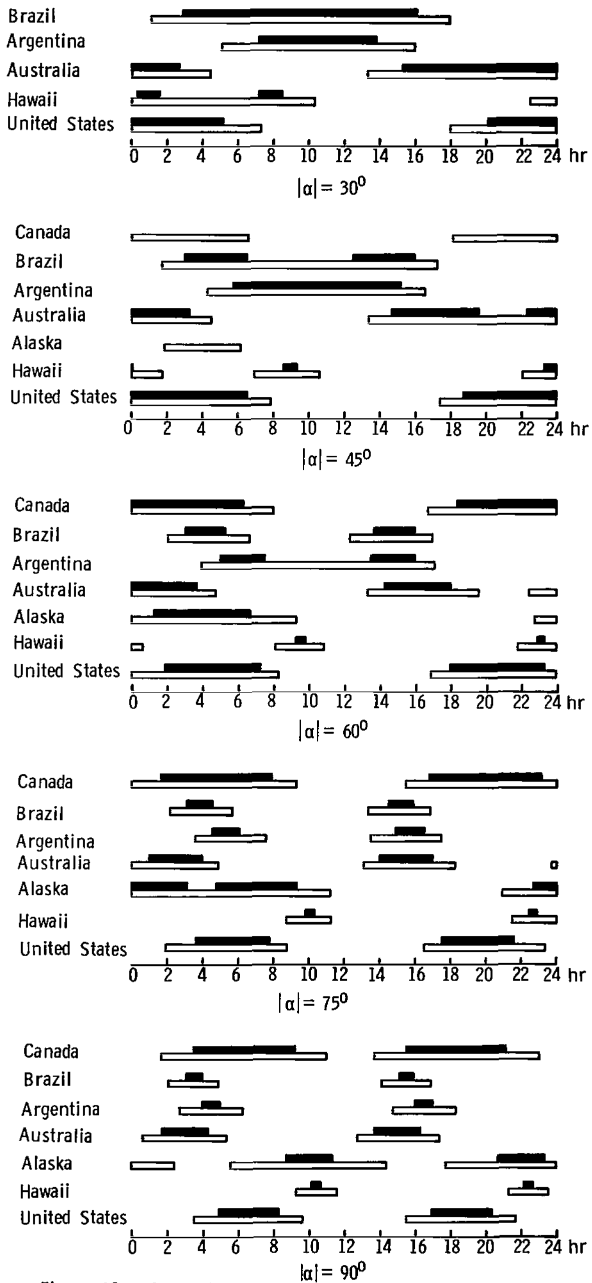


Figure A3.- Comparison of return opportunities for semi-ballistic vehicle (λ' = 210 n. mi.; solid bars) and lifting-body vehicle (λ' = 1000 n. mi.; open bars).

$|\alpha| = 30^{\circ}$; $\lambda'_{req} = 50$ n. mi.; United States, Brazil, and Australia

$|\alpha| = 45^{\circ}$; $\lambda'_{req} = 50$ n. mi.; United States, Argentina, and Australia

$|\alpha| = 60^{\circ}$; $\lambda'_{req} = 870$ n. mi.; United States, Hawaii, and Argentina

$|\alpha| = 75^{\circ}$; $\lambda'_{req} = 1390$ n. mi.; United States, Alaska, and Argentina

$|\alpha| = 90^{\circ}$; $\lambda'_{req} = 715$ n. mi.; United States, Alaska, and Australia

Bar graphs such as those in figure A2 can also be helpful in demonstrating the advantages of increasing lateral-range capability. This type of comparison is presented in figure A3 for the semiballistic class of vehicle ($\lambda' = 210$ n. mi.) and the lifting-body class of vehicle ($\lambda' = 1000$ n. mi.). From figure A3 it can be seen that if the lateral-range capability is increased from 210 to 1000 nautical miles, there are substantial increases in the time during which the spacecraft can return to a given recovery area.

In general, the number of recovery areas required for quick return are also decreased. An exception, however, is the 30° orbit inclination where both classes of vehicles require a minimum of two recovery areas to achieve a quick-return capability.

A vertical-landing capability coupled with large land recovery areas may be desirable for return from some missions, particularly if stringent emergency constraints are imposed. The use of large land recovery areas does not, however, afford large reductions in the lateral-range requirements as compared with those determined for careful selection of point recovery sites.

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TABLE I.- CAPABILITY FOR RECALL TO PRIME RECOVERY NETWORKS

[Asterisk denotes nominal prime site; P, prime; and E, emergency]

(a) $|\alpha| = 30^{\circ}$

λ', n. mi.	Site	λ, deg	θ, deg	Type of site	Runway prepared	Orbit, n															
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Constraint 1																					
210	Baja California, Mexico	26.5	112.0	P	No	X													X	X	X
	*Palm Beach International Airport, Florida	26.7	80.1	P	Yes												X	X	X	X	
	Baghdogra, India	26.7	-88.3	E	Yes					X	X	X	X								
500	Baja California, Mexico	26.5	112.0	P	No	X												X	X	X	X
	*Palm Beach International Airport, Florida	26.7	80.1	P	Yes											X	X	X	X	X	
	Kalai Kundah, India	22.3	-87.2	E	Yes			X	X	X	X	X	X								
1000	Baja California, Mexico	26.5	112.0	P	No	X										X	X	X	X	X	X
	*Palm Beach International Airport, Florida	26.7	80.1	P	Yes										X	X	X	X	X	X	
	Madras, India	13.0	-80.2	E	Yes	X	X	X	X	X	X	X	X	X							
1500	Baja California, Mexico	26.5	112.0	P	No	X								X	X	X	X	X	X	X	X
	*Palm Beach International Airport, Florida	26.7	80.1	P	Yes								X	X	X	X	X	X	X	X	
	Madras, India	13.0	-80.2	E	Yes	X	X	X	X	X	X	X	X	X						X	
2000	Baja California, Mexico	26.5	112.0	P	No	X							X	X	X	X	X	X	X	X	X
	Cameron County Airport, Texas	26.2	97.4	P	Yes						X		X	X	X	X	X	X	X	X	X
	*Palm Beach International Airport, Florida	26.7	80.1	P	Yes							X	X	X	X	X	X	X	X	X	
	Madras, India	13.0	-80.2	E	Yes	X	X	X	X	X	X	X	X	X				X	X		X
2500	Baja California, Mexico	26.5	112.0	P	No	X					X		X	X	X	X	X	X	X	X	X
	Cameron County Airport, Texas	26.2	97.4	P	Yes					X		X	X	X	X	X	X	X	X	X	X
	*Palm Beach International Airport, Florida	26.7	80.1	P	Yes				X		X	X	X	X	X	X	X	X	X	X	
	Madras, India	13.0	-80.2	E	Yes	X	X	X	X	X	X	X	X	X				X		X	X
3000	Baja California, Mexico	26.5	112.0	P	No	X			X	X		X	X	X	X	X	X	X	X	X	X
	*Palm Beach International Airport, Florida	26.7	80.1	P	Yes			X		X	X	X	X	X	X	X	X	X	X	X	
	Madras, India	13.0	-80.2	E	Yes	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X

TABLE I.- CAPABILITY FOR RECALL TO PRIME RECOVERY NETWORKS – Continued

(a) $|\alpha| = 30^{\circ}$ – Concluded

λ', n. mi.	Site	λ, deg	θ, deg	Type of site	Runway prepared	Orbit, n															
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Constraint 2																				
210	Baja California, Mexico	26.5	112.0	P	No	X													X	X	X
	*Palm Beach International Airport, Florida	26.7	80.1	P	Yes												X	X	X	X	
	Baghdogra, India	26.7	-88.3	E	Yes					X	X	X	X								
500	*Key West NAS, Florida	24.6	81.7	P	Yes	X											X	X	X	X	X
	Kalai Kundah, India	22.3	-87.2	E	Yes					X	X	X	X	X							
1000	*La Aurora Airport, Guatemala	14.6	90.5	P	Yes	X								X	X	X	X	X	X	X	X
	Madras, India	13.0	-80.2	E	Yes		X	X	X	X	X	X	X	X							
1500	*Palanquero Municipal Airport, Colombia	5.5	74.7	P	Yes	X				X	X		X	X	X	X	X	X	X	X	X
	Madras, India	13.0	-80.2	E	Yes	X	X	X	X	X	X	X	X	X						X	
2000	*El Rosal Airport, Ecuador	0.8	77.7	P	Yes	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
	Madras, India	13.0	-80.2	E	Yes			X	X		X	X	X	X	X	X	X	X	X		
2500	*El Rosal Airport, Ecuador	0.8	77.7	P	Yes	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
	Madras, India	13.0	-80.2	E	Yes		X	X	X		X	X	X	X	X	X	X	X	X	X	X
3000	*El Rosal Airport, Ecuador	0.8	77.7	P	Yes	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
	Madras, India	13.0	-80.2	E	Yes	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
	Constraint 3																				
210	*Cameron County Airport, Texas	26.2	97.4	P	Yes	X													X	X	X
	Palm Beach International Airport, Florida	26.7	80.1	P	Yes													X	X	X	X
	Baghdogra, India	26.7	-88.3	E	Yes						X	X	X								
500	*Cameron County Airport, Texas	26.2	97.4	P	Yes	X												X	X	X	X
	Key West NAS, Florida	24.6	81.7	P	Yes												X	X	X	X	X
	Kalai Kundah, India	22.3	-87.2	E	Yes				X	X	X	X	X	X							
1000	*Cameron County Airport, Texas	26.2	97.4	P	Yes	X										X	X	X	X	X	X
	Key West NAS, Florida	24.6	81.7	P	Yes										X	X	X	X	X	X	X
	Madras, India	13.0	-80.2	E	Yes		X	X	X	X	X	X	X	X	X						
1500	*Cameron County Airport, Texas	26.2	97.4	P	Yes	X								X	X	X	X	X	X	X	X
	Madras, India	13.0	-80.2	E	Yes	X	X	X	X	X	X	X	X	X	X						
2000	*Cameron County Airport, Texas	26.2	97.4	P	Yes	X							X	X	X	X	X	X	X	X	X
	Key West NAS, Florida	24.6	81.7	P	Yes						X		X	X	X	X	X	X	X	X	X
	Madras, India	13.0	-80.2	E	Yes	X	X	X	X	X	X	X	X	X	X				X	X	
2500	*Cameron County Airport, Texas	26.2	97.4	P	Yes	X					X		X	X	X	X	X	X	X	X	X
	Key West NAS, Florida	24.6	81.7	P	Yes					X		X	X	X	X	X	X	X	X	X	X
	Madras, India	13.0	-80.2	E	Yes	X	X	X	X	X	X	X	X	X	X		X	X	X		X
3000	*Cameron County Airport, Texas	26.2	97.4	P	Yes	X			X	X		X	X	X	X	X	X	X	X	X	X
	Key West NAS, Florida	24.6	81.7	P	Yes			X	X		X	X	X	X	X	X	X	X	X	X	X
	Madras, India	13.0	-80.2	E	Yes	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X

TABLE I.- CAPABILITY FOR RECALL TO PRIME RECOVERY NETWORKS – Continued

(b) $|\alpha| = 45^{\circ}$

λ', n. mi.	Site	λ, deg	θ, deg	Type of site	Runway prepared	Orbit, n															
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
					Constraint 1																
210	*Kingsley Airport, Oregon	42.2	121.7	P	Yes	X													X	X	X
	Otis AFB, Mass.	41.7	70.5	P	Yes												X	X	X		
	Chitose, Japan	42.8	-141.7	E	Yes			X	X	X											
500	*Kingsley Airport, Oregon	42.2	121.7	P	Yes	X												X	X	X	X
	Otis AFB, Mass.	41.7	70.5	P	Yes											X	X	X	X		
	Tandil, Argentina	-37.3	59.2	E	Yes	X	X	X	X	X	X										
1000	*Kingsley Airport, Oregon	42.2	121.7	P	Yes	X											X	X	X	X	X
	Otis AFB, Mass.	41.7	70.5	P	Yes									X	X	X	X	X	X		
	Bareilly, India	28.4	-79.5	E	Yes		X	X	X	X	X	X	X								
1500	*Kingsley Airport, Oregon	42.2	121.7	P	Yes	X									X	X	X	X	X	X	X
	Otis AFB, Mass.	41.7	70.5	P	Yes								X	X	X	X	X	X	X		
	Kalai Kundah, India	22.3	-87.2	E	Yes	X	X	X	X	X	X	X	X								X
2000	*Kingsley Airport, Oregon	42.2	121.7	P	Yes	X								X	X	X	X	X	X	X	X
	Otis AFB, Mass.	41.7	70.5	P	Yes							X	X	X	X	X	X	X	X		
	Kalai Kundah, India	22.3	-87.2	E	Yes	X	X	X	X	X	X	X	X							X	X
2500	*Kingsley Airport, Oregon	42.2	121.7	P	Yes	X							X	X	X	X	X	X	X	X	X
	Otis AFB, Mass.	41.7	70.5	P	Yes						X	X	X	X	X	X	X	X	X		
	Kalai Kundah, India	22.3	-87.2	E	Yes	X	X	X	X	X	X	X	X					X		X	X
3000	*Kingsley Airport, Oregon	42.2	121.7	P	Yes	X						X	X	X	X	X	X	X	X	X	X
	Otis AFB, Mass.	41.7	70.5	P	Yes					X	X	X	X	X	X	X	X	X	X		
	Kalai Kundah, India	22.3	-87.2	E	Yes	X	X	X	X	X	X	X	X					X		X	X

TABLE I.- CAPABILITY FOR RECALL TO PRIME RECOVERY NETWORKS – Continued

(b) $|\alpha| = 45^{\circ}$ – Concluded

λ', n. mi.	Site	λ, deg	θ, deg	Type of site	Runway prepared	Orbit, n															
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Constraint 2																				
210	*Kingsley Airport, Oregon	42.2	121.7	P	Yes	X													X	X	X
	Otis AFB, Mass.	41.7	70.5	P	Yes												X	X	X		
	Chitose, Japan	42.8	-141.7	E	Yes			X	X	X											
500	*Fresno Air Terminal, Calif.	36.8	119.7	P	Yes	X											X	X	X	X	X
	Oceana NAS, Virginia	36.8	76.0	P	Yes										X	X	X	X	X	X	
	Incirlik, Turkey	37.0	-35.4	E	Yes					X	X	X	X	X	X						
1000	*Chase NAAS, Texas	28.4	97.7	P	Yes	X									X	X	X	X	X	X	X
	Bareilly, India	28.4	-79.5	E	Yes		X	X	X	X	X	X	X	X							
1500	*Central Airport, Mexico	19.4	99.1	P	Yes	X							X	X	X	X	X	X	X	X	X
	Kalai Kundah, India	22.3	-87.2	E	Yes	X	X	X	X	X	X	X	X								
2000	*Princess Beatrix Airport, Aruba	12.5	70.0	P	Yes	X							X	X	X	X	X	X	X	X	X
	Kalai Kundah, India	22.3	-87.2	E	Yes	X	X	X	X	X	X	X	X	X							X
2500	*El Dorado International Airport, Colombia	4.7	74.2	P	Yes	X			X	X		X	X	X	X	X	X	X	X	X	X
	Kalai Kundah, India	22.3	-87.2	E	Yes	X	X	X	X	X	X	X	X							X	X
3000	*El Rosal Airport, Ecuador	0.8	77.7	P	Yes	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
	Kalai Kundah, India	22.3	-87.2	E	Yes		X	X		X	X	X	X	X	X	X	X	X	X		
	Constraint 3																				
210	*Kingsley Airport, Oregon	42.2	121.7	P	Yes	X													X	X	X
	Otis AFB, Mass.	41.7	70.5	P	Yes												X	X	X		
	Chitose, Japan	42.8	-141.7	E	Yes			X	X	X											
500	*Fresno Air Terminal, Calif.	36.8	119.7	P	Yes	X											X	X	X	X	X
	Oceana NAS, Virginia	36.8	76.0	P	Yes										X	X	X	X	X	X	
	Incirlik, Turkey	37.0	-35.4	E	Yes					X	X	X	X	X	X						
1000	*Chase NAAS, Texas	28.4	97.7	P	Yes	X									X	X	X	X	X	X	X
	Bareilly, India	28.4	-79.5	E	Yes		X	X	X	X	X	X	X	X							
1500	*Key West NAS, Florida	24.6	81.7	P	Yes	X								X	X	X	X	X	X	X	X
	Brown Field Municipal Airport, Calif.	32.6	117.0	P	Yes	X	X									X	X	X	X	X	X
	Kalai Kundah, India	22.3	-87.2	E	Yes	X	X	X	X	X	X	X	X	X							
2000	*Key West NAS, Florida	24.6	81.7	P	Yes	X							X	X	X	X	X	X	X	X	X
	Brown Field Municipal Airport, Calif.	32.6	117.0	P	Yes	X	X								X	X	X	X	X	X	X
	Kalai Kundah, India	22.3	-87.2	E	Yes	X	X	X	X	X	X	X	X	X							X
2500	*Key West NAS, Florida	24.6	81.7	P	Yes	X						X	X	X	X	X	X	X	X	X	X
	Brown Field Municipal Airport, Calif.	32.6	117.0	P	Yes	X	X							X	X	X	X	X	X	X	X
	Kalai Kundah, India	22.3	-87.2	E	Yes	X	X	X	X	X	X	X	X	X					X		X
3000	*Key West NAS, Florida	24.6	81.7	P	Yes	X				X		X	X	X	X	X	X	X	X	X	X
	Brown Field Municipal Airport, Calif.	32.6	117.0	P	Yes	X	X						X	X	X	X	X	X	X	X	X
	Kalai Kundah, India	22.3	-87.2	E	Yes	X	X	X	X	X	X	X	X	X				X		X	X

TABLE I.- CAPABILITY FOR RECALL TO PRIME RECOVERY NETWORKS – Continued

(c) $|\alpha| = 60^{\circ}$

λ', n. mi.	Site	λ, deg	θ, deg	Type of site	Runway prepared	Orbit, n															
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Constraint 1																					
210	*Juneau, Alaska	58.4	134.6	P	Yes	X													X	X	X
	Newfoundland, Canada	56.5	62.0	P	No											X	X	X	X		
	Tirstrup, Denmark	56.3	-10.6	E	Yes								X	X	X						
500	*Juneau, Alaska	58.4	134.6	P	Yes	X												X	X	X	X
	Newfoundland, Canada	56.5	62.0	P	No										X	X	X	X			
	Laarbruck, Germany	51.6	-6.2	E	Yes						X	X	X	X	X	X					
1000	*Juneau, Alaska	58.4	134.6	P	Yes	X										X	X	X	X	X	X
	Newfoundland, Canada	56.5	62.0	P	No								X	X	X	X	X	X			
	Ancona, Italy	43.6	-13.4	E	Yes				X	X	X	X	X	X	X						
1500	*Juneau, Alaska	58.4	134.6	P	Yes	X									X	X	X	X	X	X	X
	Newfoundland, Canada	56.5	62.0	P	No						X	X	X	X	X	X	X	X			
	Tehrān-Mehrābād, Iran	35.7	-51.3	E	Yes	X	X	X	X	X	X	X	X	X							
2000	*Juneau, Alaska	58.4	134.6	P	Yes	X							X	X	X	X	X	X	X	X	X
	Newfoundland, Canada	56.5	62.0	P	No					X	X	X	X	X	X	X	X	X			
	Fukche, India	32.9	-79.2	E	Yes	X	X	X	X	X	X	X								X	X
2500	*Juneau, Alaska	58.4	134.6	P	Yes	X						X	X	X	X	X	X	X	X	X	X
	Newfoundland, Canada	56.5	62.0	P	No				X	X	X	X	X	X	X	X	X	X			
	Fukche, India	32.9	-79.2	E	Yes	X	X	X	X	X	X	X						X	X	X	X
3000	*Juneau, Alaska	58.4	134.6	P	Yes	X				X	X	X	X	X	X	X	X	X	X	X	X
	Newfoundland, Canada	56.5	62.0	P	No		X	X	X	X	X	X	X	X	X	X	X	X			

TABLE I.- CAPABILITY FOR RECALL TO PRIME RECOVERY NETWORKS – Continued

(c) $|\alpha| = 60^{\circ}$ – Concluded

λ', n. mi.	Site	λ, deg	θ, deg	Type of site	Runway prepared	Orbit, n 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Constraint 2																				
210	*Juneau, Alaska	58.4	134.6	P	Yes	X													X	X	X
	Newfoundland, Canada	56.5	62.0	P	No											X	X	X	X		
	Tirstrup, Denmark	56.3	-10.6	E	Yes								X	X	X						
500	*Edmonton International Airport, Alberta	53.3	113.6	P	Yes	X											X	X	X	X	X
	Goose Bay, Newfoundland, Canada	53.3	60.4	P	Yes										X	X	X	X	X		
	Laarbruck, Germany	51.6	-6.2	E	Yes							X	X	X	X	X					
1000	*Boise, Idaho	43.6	116.2	P	Yes	X									X	X	X	X	X	X	X
	Brunswick NAS, Maine	43.9	69.9	P	Yes								X	X	X	X	X	X	X		
	Ancona, Italy	43.6	-13.4	E	Yes				X	X	X	X	X	X	X	X					
1500	*Edwards AFB, Calif.	34.9	117.9	P	Yes	X								X	X	X	X	X	X	X	X
	Seymour Johnson AFB, N.C.	35.3	78.0	P	Yes							X	X	X	X	X	X	X	X	X	
	Tehrān-Mehrābād, Iran	35.7	-51.3	E	Yes	X	X	X	X	X	X	X	X	X							
2000	*Brown Field Municipal Airport, Calif.	32.6	117.0	P	Yes	X							X	X	X	X	X	X	X	X	X
	Cecil Field NAS, Florida	30.2	81.9	P	Yes						X	X	X	X	X	X	X	X	X	X	
	Fukche, India	32.9	-79.2	E	Yes	X	X	X	X	X	X	X	X							X	X
2500	*Brown Field Municipal Airport, Calif.	32.6	117.0	P	Yes	X						X	X	X	X	X	X	X	X	X	X
	Cecil Field NAS, Florida	30.2	81.9	P	Yes					X	X	X	X	X	X	X	X	X	X	X	
	Fukche, India	32.9	-79.2	E	Yes	X	X	X	X	X	X	X	X						X	X	X
3000	*Brown Field Municipal Airport, Calif.	32.6	117.0	P	Yes	X					X	X	X	X	X	X	X	X	X	X	X
	Cecil Field NAS, Florida	30.2	81.9	P	Yes				X	X	X	X	X	X	X	X	X	X	X	X	
	Fukche, India	32.9	-79.2	E	Yes	X	X	X	X	X	X	X	X					X	X	X	X
	Constraint 3																				
210	*Whidbey Island NAS, Washington	48.4	122.7	P	Yes	X												X			
	Grand Forks International Airport, N.D.	48.0	97.4	P	Yes												X				X
	Loring AFB, Maine	47.0	67.9	P	Yes															X	
	Tirstrup, Denmark	56.3	-10.6	E	Yes								X	X	X						
500	*Whidbey Island NAS, Washington	48.4	122.7	P	Yes	X											X	X			X
	Grand Forks International Airport, N.D.	48.0	97.4	P	Yes											X				X	
	Loring AFB, Maine	47.0	67.9	P	Yes									X	X			X	X		
	Laarbruck, Germany	51.6	-6.2	E	Yes						X	X	X	X	X	X					
1000	*Boise, Idaho	43.6	116.2	P	Yes	X									X	X	X	X	X	X	X
	Brunswick NAS, Maine	43.9	69.9	P	Yes								X	X	X	X	X	X	X		
	Ancona, Italy	43.6	-13.4	E	Yes				X	X	X	X	X	X	X	X					
1500	*Edwards AFB, Calif.	34.9	117.9	P	Yes	X								X	X	X	X	X	X	X	X
	Seymour Johnson AFB, N.C.	35.3	78.0	P	Yes							X	X	X	X	X	X	X	X	X	
	Tehrān-Mehrābād, Iran	35.7	-51.3	E	Yes	X	X	X	X	X	X	X	X	X							
2000	*Brown Field Municipal Airport, Calif.	32.6	117.0	P	Yes	X							X	X	X	X	X	X	X	X	X
	Cecil Field NAS, Florida	30.2	81.9	P	Yes						X	X	X	X	X	X	X	X	X	X	
	Fukche, India	32.9	-79.2	E	Yes	X	X	X	X	X	X	X	X							X	X
2500	*Brown Field Municipal Airport, Calif.	32.6	117.0	P	Yes	X						X	X	X	X	X	X	X	X	X	X
	Cecil Field NAS, Florida	30.2	81.9	P	Yes					X	X	X	X	X	X	X	X	X	X	X	
	Fukche, India	32.9	-79.2	E	Yes	X	X	X	X	X	X	X	X						X	X	X
3000	*Brown Field Municipal Airport, Calif.	32.6	117.0	P	Yes	X					X	X	X	X	X	X	X	X	X	X	X
	Cecil Field NAS, Florida	30.2	81.9	P	Yes				X	X	X	X	X	X	X	X	X	X	X	X	
	Fukche, India	32.9	-79.2	E	Yes	X	X	X	X	X	X	X	X					X	X	X	X

TABLE I.- CAPABILITY FOR RECALL TO PRIME RECOVERY NETWORKS – Continued

(d) $|\alpha| = 75^{\circ}$

λ', n. mi.	Site	λ, deg	θ, deg	Type of site	Runway prepared	Orbit, n: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Constraint 2																				
210	None available																				
500	*Selawik, Alaska	66.7	160.0	P	No	X										X	X	X	X	X	X
	Repulse Bay, NWT, Canada	66.7	86.0	P	No							X	X	X	X	X	X	X			
	Bodø, Norway	67.3	-14.4	E	Yes			X	X	X	X	X	X	X							
1000	*Juneau, Alaska	58.4	134.6	P	Yes	X								X	X	X	X	X	X	X	X
	Hebron, Newfoundland, Canada	57.5	63.0	P	No						X	X	X	X	X	X	X	X			
	Nyköping, Sweden	58.8	-16.5	E	Yes		X	X	X	X	X	X	X	X	X						
1500	*Juneau, Alaska	58.4	134.6	P	Yes	X							X	X	X	X	X	X	X	X	X
	Hebron, Newfoundland, Canada	57.5	63.0	P	No				X	X	X	X	X	X	X	X	X	X			
	Nyköping, Sweden	58.8	-16.5	E	Yes	X	X	X	X	X	X	X	X	X	X						
2000	*Juneau, Alaska	58.4	134.6	P	Yes	X					X	X	X	X	X	X	X	X	X	X	X
	Hebron, Newfoundland, Canada	57.5	63.0	P	No			X	X	X	X	X	X	X	X	X	X	X			
	Nyköping, Sweden	58.8	-16.5	E	Yes	X	X	X	X	X	X	X	X	X	X					X	X
2500	*Juneau, Alaska	58.4	134.6	P	Yes	X			X	X	X	X	X	X	X	X	X	X	X	X	X
	Hebron, Newfoundland, Canada	57.5	63.0	P	No	X	X	X	X	X	X	X	X	X	X	X	X	X			
3000	*Juneau, Alaska	58.4	134.6	P	Yes	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Constraint 3																				
210	*Whidbey Island NAS, Washington	48.4	122.7	P	Yes	X										X					
	Grand Forks International Airport, N.D.	48.0	97.4	P	Yes										X						X
	Loring AFB, Maine	47.0	67.9	P	Yes															X	
500	*Whidbey Island NAS, Washington	48.4	122.7	P	Yes	X	X									X	X				
	Grand Forks International Airport, N.D.	48.0	97.4	P	Yes	X									X						X
	Loring AFB, Maine	47.0	67.9	P	Yes									X						X	
	Bodø, Norway	67.3	-14.4	E	Yes						X	X	X	X	X	X					
1000	*Whidbey Island NAS, Washington	48.4	122.7	P	Yes	X								X	X	X				X	X
	Loring AFB, Maine	47.0	67.9	P	Yes							X	X					X	X		
	Nyköping, Sweden	58.8	-16.5	E	Yes			X	X	X	X	X	X	X	X						
1500	*Whidbey Island NAS, Washington	48.4	122.7	P	Yes	X							X	X	X	X		X	X	X	X
	Loring AFB, Maine	47.0	67.9	P	Yes					X	X	X	X			X	X	X	X		
	Nyköping, Sweden	58.8	-16.5	E	Yes	X	X	X	X	X	X	X	X	X	X						
2000	*Whidbey Island NAS, Washington	48.4	122.7	P	Yes	X						X	X	X	X	X	X	X	X	X	X
	Loring AFB, Maine	47.0	67.9	P	Yes				X	X	X	X	X	X	X	X	X	X	X		
	Nyköping, Sweden	58.8	-16.5	E	Yes	X	X	X	X	X	X	X	X	X	X	X					X
2500	*Whidbey Island NAS, Washington	48.4	122.7	P	Yes	X				X	X	X	X	X	X	X	X	X	X	X	X
	Loring AFB, Maine	47.0	67.9	P	Yes			X	X	X	X	X	X	X	X	X	X	X	X		
	Nyköping, Sweden	58.8	-16.5	E	Yes	X	X	X	X	X	X	X	X	X	X	X				X	X
3000	*Whidbey Island NAS, Washington	48.4	122.7	P	Yes	X			X	X	X	X	X	X	X	X	X	X	X	X	X
	Loring AFB, Maine	47.0	67.9	P	Yes		X	X	X	X	X	X	X	X	X	X	X	X	X		

TABLE I.- CAPABILITY FOR RECALL TO PRIME RECOVERY NETWORKS – Concluded

(e) $|\alpha| = 90^{o}$

λ', n. mi.	Site	λ, deg	θ, deg	Type of site	Runway prepared	Orbit, n 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Constraint 3																				
210	*Whidbey Island NAS, Washington	48.4	122.7	P	Yes	X								X							
	Grand Forks International Airport, N.D.	48.0	97.4	P	Yes								X								X
	Loring AFB, Maine	47.0	67.9	P	Yes							X									
500	*Whidbey Island NAS, Washington	48.4	122.7	P	Yes	X								X							X
	Grand Forks International Airport, N.D.	48.0	97.4	P	Yes							X	X							X	
	Loring AFB, Maine	47.0	67.9	P	Yes						X								X		
	Nord, Greenland	81.7	17.9	E	Yes	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1000	*Whidbey Island NAS, Washington	48.4	122.7	P	Yes	X						X	X	X						X	X
	Loring AFB, Maine	47.0	67.9	P	Yes					X	X							X	X		
	Thule Air Base, Greenland	76.5	68.8	E	Yes	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1500	*Whidbey Island NAS, Washington	48.4	122.7	P	Yes	X					X	X	X	X					X	X	X
	Loring AFB, Maine	47.0	67.9	P	Yes				X	X	X						X	X	X		
	Fairbanks International Airport, Alaska	64.8	147.9	E	Yes	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2000	*Whidbey Island NAS, Washington	48.4	122.7	P	Yes	X				X	X	X	X	X			X	X	X	X	X
	Loring AFB, Maine	47.0	67.9	P	Yes		X	X	X	X	X				X	X	X	X	X		
2500	*Whidbey Island NAS, Washington	48.4	122.7	P	Yes	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3000	*Whidbey Island NAS, Washington	48.4	122.7	P	Yes	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

TABLE II.- ACCEPTABLE RECOVERY SITES

American group

Latitude*	Longitude*	Site
76 32 N	68 45 W	Thule Air Base, Greenland
67 01 N	50 41 W	Søndre Strømfjord, Greenland
64 49 N	147 52 W	Fairbanks International Airport, Alaska
63 45 N	68 34 W	Frobisher Bay, N.W.T., Canada
58 45 N	94 04 W	Churchill, Manitoba, Canada
58 21 N	134 34 W	Juneau, Alaska
53 19 N	113 35 W	Edmonton International Airport, Alberta
53 19 N	60 25 W	Goose Bay, Newfoundland, Canada
48 57 N	54 34 W	Gander International Airport, Newfoundland, Canada
48 21 N	122 40 W	Whidbey Island NAS, Washington
47 58 N	97 24 W	Grand Forks International Airport, N.D.
47 38 N	117 32 W	Spokane International Airport, Washington
46 57 N	67 53 W	Loring AFB, Maine
43 54 N	69 56 W	Brunswick NAS, Maine
43 34 N	116 13 W	Boise, Idaho
42 22 N	71 00 W	Logan International Airport, Mass.
42 10 N	121 44 W	Kingsley Airport, Oregon
41 39 N	70 31 W	Otis AFB, Massachusetts
40 47 N	111 58 W	Salt Lake City Municipal Airport, Utah
37 25 N	122 03 W	Moffett Field NAS, Calif.
37 05 N	76 22 W	Langley AFB, Virginia
36 50 N	76 02 W	Oceana NAS, Virginia
36 46 N	119 43 W	Fresno Air Terminal, Calif.
35 20 N	77 58 W	Seymour Johnson AFB, North Carolina
34 54 N	117 52 W	Edwards AFB, California
32 34 N	116 59 W	Brown Field Municipal Airport, Calif.
30 13 N	81 53 W	Cecil Field NAS, Florida
29 50 N	90 01 W	New Orleans International Airport, La.
28 22 N	97 40 W	Chase NAAS, Texas
26 41 N	80 06 W	Palm Beach International Airport, Florida
26 10 N	97 21 W	Cameron County Airport, Texas
25 29 N	80 23 W	Homestead AFB, Florida
24 34 N	81 41 W	Key West NAS, Florida
19 26 N	99 05 W	Central Airport, Mexico
14 35 N	90 32 W	La Aurora Airport, Guatemala
13 04 N	59 29 W	Sewell Airport, Barbados
12 30 N	70 01 W	Princess Beatrix Airport, Aruba
10 54 N	74 47 W	Soledad County Airport, Colombia
5 29 N	74 39 W	Palanquero Municipal Airport, Colombia
4 42 N	74 09 W	El Dorado International Airport, Colombia
0 49 N	77 41 W	El Rosal Airport, Ecuador
9 09 S	78 33 W	Chimbote, Peru
12 01 S	77 08 W	Lima International Airport, Peru
14 45 S	76 14 W	Pisco, Peru
15 51 S	47 56 W	Brazilia, Brazil
17 33 S	149 36 W	Papeete International Airport, Tahiti, Society Islands
22 29 S	68 55 W	Calama, Chile
22 49 S	43 14 W	Galẽao International Airport, Brazil
24 23 S	65 05 W	El Cadill Airport, Argentina
27 21 S	55 53 W	Posadas, Argentina
31 19 S	64 12 W	Cordoba, Argentina
35 50 S	68 47 W	Mendoza, Argentina
37 14 S	59 14 W	Tandil, Argentina

*Values are in degrees and minutes.

TABLE II.- ACCEPTABLE RECOVERY SITES – Continued

Afro-Eurasian group

Latitude*	Longitude*	Site
81 43 N	17 57 W	Nord, Greenland
69 45 N	30 02 E	Kirkenes, Norway
67 16 N	14 22 E	Bodø, Norway
63 59 N	22 36 W	Keflavík, Iceland
59 39 N	17 55 E	Stockholm, Sweden
58 47 N	16 30 E	Nyköping, Sweden
56 18 N	10 37 E	Tirstrup, Denmark
51 36 N	6 08 E	Laarbruck, Germany
51 28 N	1 27 W	London, United Kingdom
43 37 N	13 22 E	Ancona, Italy
43 32 N	4 56 E	Istres, France
40 56 N	8 38 W	Ovar, Portugal
40 50 N	35 32 E	Merzifon, Turkey
39 57 N	41 10 E	Erzurum, Turkey
37 54 N	40 15 E	Diyarbakir, Turkey
37 54 N	23 44 E	Athens, Greece
37 10 N	5 36 W	Morón, Spain
37 00 N	35 26 E	Incirlik, Turkey
36 58 N	25 10 W	Vila do Porto, Azores
35 41 N	51 19 E	Tehrān-Mehrābād, Iran
32 55 N	79 10 E	Fukche, India
28 25 N	79 27 E	Bareilly, India
28 22 N	36 38 E	Tabūk, Saudi Arabia
27 57 N	15 23 W	Las Palmas, Canary Islands
26 41 N	0 17 E	Reggan, Algeria
26 41 N	88 19 E	Baghdogra, India
26 16 N	50 10 E	Dhahran, Saudia Arabia
25 36 N	84 53 E	Bihta, India
22 33 N	14 19 W	Auserd, Spanish Sahara
22 20 N	87 13 E	Kalai Kundah, India
21 29 N	40 33 E	At Tāif, Saudia Arabia
13 00 N	80 11 E	Madras, India
12 08 N	15 02 E	Fort Lamy, Chad
8 56 N	40 05 E	Auasc New, Ethiopia
0 41 S	73 09 E	Gan Island, Maldive Islands
8 51 S	13 14 E	Luanda, Angola
19 02 S	47 10 E	Arivonimamo, Malagasy Republic
23 51 S	29 27 E	Pietersburg, Republic of South Africa
26 08 S	28 15 E	Jan Smuts Airport, Republic of South Africa
29 06 S	26 18 E	JBM Gertzog, Republic of South Africa

*Values are in degrees and minutes.

TABLE II.- ACCEPTABLE RECOVERY SITES – Concluded

Australian-Asian group

Latitude*	Longitude*	Site
53 22 N	167 54 W	Cape, Aleutian Islands, Alaska
52 43 N	174 05 E	Shema Aerodrome, Aleutian Islands, Alaska
42 48 N	141 40 E	Chitose, Japan
38 24 N	141 13 E	Camp Matsushima, Japan
37 33 N	126 48 E	Kimpo Airfield, South Korea
27 48 N	95 07 E	Chabua, India
26 21 N	127 47 E	Kadena Airfield, Okinawa
25 21 N	97 18 E	Namponmad, Burma
24 47 N	141 19 E	Iwo Jima Air Base, Iwo Jima, Volcano Islands
21 20 N	157 55 W	Hickam AFB, Hawaii
19 17 N	166 38 E	Wake Airport, Wake Islands
14 31 N	121 01 E	Manila International Airport, Philippines
13 42 N	100 35 E	Klongtoi, Thailand
13 35 N	144 55 E	Anderson AFB, Guam
7 23 N	112 47 E	Waru, Indonesia
2 03 N	128 19 E	Pitu, Indonesia
12 11 S	96 50 E	Keeling Island
14 05 S	126 23 E	Truscott, Australia
14 20 S	170 43 W	Tafuna Airport, Pago Pago, American Samoa
17 45 S	177 27 E	Nandi International Airport, Fiji Islands
23 48 S	133 53 E	Alice Springs, Australia
27 39 S	152 43 E	Amberly, Australia
31 39 S	116 00 E	Perth, Australia
32 48 S	151 51 E	Willeamtowne, Australia
38 02 S	144 29 E	Avalon Beach, Australia
43 29 S	172 32 E	Christchurch, New Zealand

*Values are in degrees and minutes.

TABLE III.- MINIMUM-SITE RECOVERY NETWORKS

[Asterisk denotes nominal prime site, † denotes unprepared site]

(a) $|\alpha| = 30^{o}$

λ', n. mi.	Type of site	Location
270	Prime	*Homestead AFB, Florida
		Amberly, Australia
		Kadena Airfield, Okinawa
		Jan Smuts Airport, Republic of South Africa
		Dhahran, Saudi Arabia
	Weather alternate	Alice Springs, Australia
		El Cadill Airport, Argentina
		Galẽao International Airport, Brazil
		Soledad County Airport, Columbia
		Bihta, India
		Reggan, Algeria
500	Prime	*Homestead AFB, Florida
		Galẽao International Airport, Brazil
		At Tāif, Saudi Arabia
	Weather alternate	Hickam AFB, Hawaii
		Alice Springs, Australia
		Kalai Kundah, India
	Daylight alternate	Hickam AFB, Hawaii
		Perth, Australia
		Amberly, Australia
		Iwo Jima Air Base, Iwo Jima, Volcano Islands
		Calama, Chile
		Pietersburg, Republic of South Africa
		Auserd, Spanish Sahara
		Nandi International Airport, Fiji Islands
1000	Prime	*Homestead AFB, Florida
		Pisco, Peru
	Weather alternate	Hickam AFB, Hawaii
		Truscott, Australia
		Madras, India
	Daylight alternate	Perth, Australia
		Sewell Airport, Barbados
		Keeling Island
		Klongtoi, Thailand
		Auserd, Spanish Sahara
1500	Prime	*Homestead, AFB, Florida
		Chimbote, Peru
	Weather alternate	Auasc New, Ethiopia
		Keeling Island
	Daylight alternate	Iwo Jima Air Base, Iwo Jima, Volcano Islands
		Sewell Airport, Barbados
		Keeling Island
		Pitu, Indonesia
2000	Prime	*Homestead AFB, Florida
2500		Gan Island, Maldive Islands
3000	Weather alternate	Chimbote, Peru
	Daylight alternate	El Rosal Airport, Ecuador
		Kalai Kundah, India
		Pitu, Indonesia

TABLE III.- MINIMUM-SITE RECOVERY NETWORKS – Continued

(b) $|\alpha| = 45^{\circ}$

λ', n. mi.	Type of site	Location
270	Prime	*Kingsley Airport, Oregon
↓	↓	Logan International Airport, Mass.
↓	↓	Christchurch, New Zealand
↓	↓	Tandil, Argentina
↓	↓	Chitose, Japan
↓	↓	Merzifon, Turkey
↓	Weather alternate	Langley AFB, Virginia
↓	↓	Papeete International Airport, Tahiti, Society Islands
↓	↓	Anderson AFB, Guam
↓	↓	Iwo Jima Air Base, Iwo Jima, Volcano Islands
↓	↓	Kadena Airfield, Okinawa
↓	↓	Willeamtowne, Australia
↓	↓	Ovar, Portugal
↓	↓	Mendoza, Argentina
↓	↓	Fukche, India
500	Prime	*Moffett Field NAS, California
↓	↓	Morón, Spain
↓	↓	Tandil, Argentina
↓	Weather alternate	Langley AFB, Virginia
↓	↓	Iwo Jima Air Base, Iwo Jima, Volcano Islands
↓	↓	Incirlik, Turkey
↓	↓	Kimpo Airfield, South Korea
↓	Daylight alternate	Tafuna Airport, Pago Pago, American Samoa
↓	↓	Avalon Beach, Australia
↓	↓	Perth, Australia
↓	↓	Christchurch, New Zealand
↓	↓	Iwo Jima Air Base, Iwo Jima, Volcano Islands
↓	↓	Calama, Chile
↓	↓	Galẽao International Airport, Brazil
↓	↓	Incirlik, Turkey
↓	↓	†Capetown, Republic of South Africa
↓	↓	JBM Gertzog, Republic of South Africa
↓	↓	Kimpo Airfield, South Korea
↓	↓	Fort Lamy, Chad
↓	↓	Vila do Porto, Azores
1020	Prime	*Chase NAAS, Texas
↓	↓	Bareilly, India
↓	Weather alternate	Tabūk, Saudi Arabia
↓	↓	JBM Gertzog, Republic of South Africa
↓	Daylight alternate	Hickam AFB, Hawaii
↓	↓	Christchurch, New Zealand

TABLE III.- MINIMUM-SITE RECOVERY NETWORKS – Continued

(b) $|\alpha| = 45^{\circ}$ – Concluded

λ', n. mi.	Type of site	Location
1020	Daylight alternate	Perth, Australia
↓	↓	Las Palmas, Canary Islands
		Anderson AFB, Guam
		Cordoba, Argentina
		JBM Gertzog, Republic of South Africa
		Camp Matsushima, Japan
1500	Prime	*Key West NAS, Florida
↓	↓	Calama, Chile
	Weather alternate	Hickam AFB, Hawaii
	↓	At Tāif, Saudi Arabia
	Daylight alternate	Perth, Australia
	↓	Namponmad, Burma
		Manila International Airport, Philippines
2000	Prime	*Homestead AFB, Florida
↓	↓	Anderson AFB, Guam
	Weather alternate	Fort Lamy, Chad
	↓	Papeete International Airport, Tahiti, Society Islands
	Daylight alternate	Perth, Australia
	↓	Brazilia, Brazil
2500	Prime	*Homestead AFB, Florida
3000	↓	Anderson AFB, Guam
↓	Weather alternate	Fort Lamy, Chad
	Daylight alternate	Perth, Australia
	↓	Brazilia, Brazil

TABLE III.- MINIMUM-SITE RECOVERY NETWORKS – Continued

(c) $|\alpha| = 60^{\circ}$

λ', n. mi.	Type of site	Location
270	Prime	*Homestead AFB, Florida
		Cape, Aleutian Islands, Alaska
		Papeete International Airport, Tahiti, Society Islands
		Tafuna Airport, Pago Pago, American Samoa
		Churchill, Manitoba, Canada
		Stockholm, Sweden
		Tandil, Argentina
	Weather alternate	Cameron County Airport, Texas
		Las Palmas, Canary Islands
		Alice Springs, Australia
		Iwo Jima Air Base, Iwo Jima, Volcano Islands
		Merzifon, Turkey
		Fukche, India
		Chabua, India
		Auasc New, Ethiopia
500	Prime	*Spokane International Airport, Washington
		Shema Aerodrome, Aleutian Islands, Alaska
		Goose Bay, Newfoundland, Canada
		Stockholm, Sweden
		Diyarbakir, Turkey
	Weather alternate	Juneau, Alaska
		Papeete International Airport, Tahiti, Society Islands
		Tafuna Airport, Pago Pago, American Samoa
		Churchill, Manitoba, Canada
		Christchurch, New Zealand
		Fukche, India
	Daylight alternate	Hickam AFB, Hawaii
		Papeete International Airport, Tahiti, Society Islands
		Tafuna Airport, Pago Pago, American Samoa
		Iwo Jima Air Base, Iwo Jima, Volcano Islands
		Perth, Australia
		Willeamtowne, Australia
		Christchurch, New Zealand
		La Aurora Airport, Guatemala
		Galẽao International Airport, Brazil
		Mendoza, Argentina
		Tandil, Argentina
		Kimpo Airfield, South Korea
		Madras, India
		Istres, France
		JBM Gertzog, Republic of South Africa

TABLE III.- MINIMUM-SITE RECOVERY NETWORKS – Continued

(c) $|\alpha| = 60^{\circ}$ – Concluded

λ', n. mi.	Type of site	Location
500	Daylight alternate	Luanda, Angola
		Auserd, Spanish Sahara
		Namponmad, Burma
		†Easter Island (Chile)
1020	Prime	*Boise, Idaho
		Christchurch, New Zealand
		Chitose, Japan
	Weather alternate	Loring AFB, Maine
		Hickam AFB, Hawaii
		Ancona, Italy
	Daylight alternate	Hickam AFB, Hawaii
		Iwo Jima Air Base, Iwo Jima, Volcano Islands
		Vila do Porto, Azores
		Avalon Beach, Australia
		Galẽao International Airport, Brazil
		Istres, France
		Arivonimamo, Malagasy Republic
		JBM Gertzog, Republic of South Africa
		Luanda, Angola
1500	Prime	*Langley AFB, Virginia
		Kimpo Airfield, South Korea
	Weather alternate	Edwards AFB, California
		Tehrān-Mehrābād, Iran
	Daylight alternate	Vila do Porto, Azores
		Perth, Australia
		Avalon Beach, Austrailia
		Tandil, Argentina
2000	Prime	*Langley AFB, Virginia
		Tandil, Argentina
	Weather alternate	Edwards AFB, California
		Chabua, India
	Daylight alternate	Kimpo Airfield, South Korea
		Avalon Beach, Australia
		Vila do Porto, Azores
2500	Prime	*Edwards AFB, California
3000		Christchurch, New Zealand
	Weather alternate	Kadena Airfield, Okinawa
	Daylight alternate	Istres, France
		Arivonimamo, Malagasy Republic

TABLE III.- MINIMUM-SITE RECOVERY NETWORKS – Continued

(d) $|\alpha| = 75^{\circ}$

λ', n. mi.	Type of site	Location
270	Prime	Whidbey Island NAS, Washington
		Loring AFB, Maine
		*Homestead AFB, Florida
		Fairbanks International Airport, Alaska
		Cape, Aleutian Islands, Alaska
		Shema Aerodrome, Aleutian Islands, Alaska
		Gander International Airport, Newfoundland, Canada
		Keflavík, Iceland
		Kirkenes, Norway
	Weather alternate	Hickam AFB, Hawaii
		Iwo Jima Air Base, Iwo Jima, Volcano Islands
		Wake Airport, Wake Islands
		Churchill, Manitoba, Canada
		Willeamtowne, Australia
		Stockholm, Sweden
		Manila International Airport, Philippines
		Merzifon, Turkey
		Dhahran, Saudi Arabia
		Fukche, India
		Namponmad, Burma
525	Prime	Loring AFB, Maine
		*Fairbanks International Airport, Alaska
		Shema Aerodrome, Aleutian Islands, Alaska
		Bodø, Norway
	Weather alternate	Edwards AFB, California
		Hickam AFB, Hawaii
		Frobisher Bay, N.W.T., Canada
		Christchurch, New Zealand
		Perth, Australia
		Mendoza, Argentina
		Kirkenes, Norway
		JBM Gertzog, Republic of South Africa
	Daylight alternate	Edwards AFB, California
		Cameron County Airport, Texas
		Vila do Porto, Azores
		Papeete International Airport, Tahiti, Society Islands
		Tafuna Airport, Pago Pago, American Samoa
		Willeamtowne, Australia
		Perth, Australia
		Avalon Beach, Australia
		Christchurch, New Zealand
		Keeling Island
		Lima International Airport, Peru
		Istres, France

TABLE III.- MINIMUM-SITE RECOVERY NETWORKS – Continued

(d) $|\alpha| = 75^{\circ}$ – Continued

λ', n. mi.	Type of site	Location
525	Daylight alternate	Merzifon, Turkey
		Athens, Greece
		JBM Gertzog, Republic of South Africa
		Auserd, Spanish Sahara
		Arivonimamo, Malagasy Republic
		Klongtoi, Thailand
		†Kerguelen Island
1000	Prime	*Loring AFB, Maine
		Fairbanks International Airport, Alaska
		Stockholm, Sweden
	Weather alternate	Edwards AFB, California
		Hickam AFB, Hawaii
		Shema Aerodrome, Aleutian Islands, Alaska
		Willeamtowne, Australia
	Daylight alternate	Whidbey Island NAS, Washington
		Vila do Porto, Azores
		Papeete International Airport, Tahiti, Society Islands
		Perth, Australia
		Avalon Beach, Australia
		Christchurch, New Zealand
		Keeling Island
		Istres, France
		JBM Gertzog, Republic of South Africa
		Arivonimamo, Malagasy Republic
1500	Prime	Loring AFB, Maine
		*Whidbey Island NAS, Washington
		Christchurch, New Zealand
	Weather alternate	Shema Aerodrome, Aleutian Islands, Alaska
		Stockholm, Sweden
	Daylight alternate	Hickam AFB, Hawaii
		Perth, Australia
		Keeling Island
		Istres, France
		Arivonimamo, Malagasy Republic
		JBM Gertzog, Republic of South Africa

TABLE III.- MINIMUM-SITE RECOVERY NETWORKS – Continued

(d) $|\alpha| = 75^{\circ}$ – Concluded

λ', n. mi.	Type of site	Location
2000	Prime	*Spokane International Airport, Washington
		Christchurch, New Zealand
	Weather alternate	Chitose, Japan
	Daylight alternate	Loring AFB, Maine
		Perth, Australia
		Istres, France
		Arivonimamo, Malagasy Republic
2500	Prime	*Loring AFB, Maine
		Fairbanks International Airport, Alaska
	Weather alternate	Stockholm, Sweden
	Daylight alternate	Perth, Australia
		JBM Gertzog, Republic of South Africa
		Luanda, Angola
3000	Prime	*Loring AFB, Maine
		Juneau, Alaska
	Weather alternate	Hickam AFB, Hawaii
	Daylight alternate	Perth, Australia
		Arivonimamo, Malagasy Republic
		JBM Gertzog, Republic of South Africa

TABLE III.- MINIMUM-SITE RECOVERY NETWORKS – Continued

(e) $|\alpha| = 90^{o}$

λ', n. mi.	Type of site	Location
270	Prime	*Whidbey Island NAS, Washington
		Cameron County Airport, Texas
		Fairbanks International Airport, Alaska
		Salt Lake City Municipal Airport, Utah
		Cape, Aleutian Islands, Alaska
		Goose Bay, Newfoundland, Canada
		Keflavík, Iceland
		Chitose, Japan
		Namponmad, Burma
	Weather alternate	Homestead AFB, Florida
		New Orleans International Airport, La.
		Churchill, Manitoba, Canada
		Alice Springs, Australia
		Mendoza, Argentina
		Galẽao International Airport, Brazil
		Kirkenes, Norway
		Istres, France
		Fukche, India
		Tehrān-Mehrābād, Iran
		Auserd, Spanish Sahara
500	Prime	*Whidbey Island NAS, Washington
		Fairbanks International Airport, Alaska
		Shema Aerodrome, Aleutian Islands, Alaska
		Churchill, Manitoba, Canada
		Keflavík, Iceland
		Søndre Strømfjord, Greenland
	Weather alternate	Cameron County Airport, Texas
		Perth, Australia
		Willeamtowne, Australia
		Christchurch, New Zealand
		Kirkenes, Norway
		Kimpo Airfield, South Korea
		Fukche, India
550	Daylight alternate	Homestead AFB, Florida
		Loring AFB, Maine
		Hickam AFB, Hawaii
		Perth, Australia
		Willeamtowne, Australia
		Christchurch, New Zealand
		Keeling Island
		Galẽao International Airport, Brazil
		Tandil, Argentina
		Kimpo Airfield, South Korea
		Chitose, Japan
		Istres, France
		Luanda, Angola
		JBM Gertzog, Republic of South Africa
		Avironimamo, Malagasy Republic
		†Kerguelen Island

TABLE III.- MINIMUM-SITE RECOVERY NETWORKS – Continued

(e) $|\alpha| = 90^{\circ}$ – Concluded

λ', n. mi.	Type of site	Location
1000	Prime	*Loring AFB, Maine
↓	↓	Kirkenes, Norway
	Weather alternate	Cameron County Airport, Texas
	↓	Fairbanks International Airport, Alaska
		Perth, Australia
		Willeamtowne, Australia
	Daylight alternate	Whidbey Island NAS, Washington
	↓	Pateete International Airport, Tahiti, Society Islands
		Perth, Australia
		Willeamtowne, Australia
		Christchurch, New Zealand
		Istres, France
		Keeling Island
		Chimbote, Peru
		Waru, Indonesia
		Auserd, Spanish Sahara
		Arivonimamo, Malagasy Republic
1500	Prime	*Loring AFB, Maine
↓	↓	Fairbanks International Airport, Alaska
	Weather alternate	Kirkenes, Norway
	Daylight alternate	Homestead AFB, Florida
	↓	Whidbey Island NAS, Washington
		Perth, Australia
		Christchurch, New Zealand
		Keeling Island
		Istres, France
		Arivonimamo, Malagasy Republic
2000	Prime	*Loring AFB, Maine
↓	↓	Juneau, Alaska
	Weather alternate	Keflavík, Iceland
	Daylight alternate	Tandil, Argentina
	↓	Kimpo Airfield, South Korea
		JBM Gertzog, Republic of South Africa
		Arivonimamo, Malagasy Republic
2500	Prime	*Whidbey Island NAS, Washington
↓	Weather alternate	Goose Bay, Newfoundland, Canada
	Daylight alternate	Christchurch, New Zealand
	↓	Istres, France
		Arivonimamo, Malagasy Republic
3000	Prime	*Loring AFB, Maine
↓	Weather alternate	Christchurch, New Zealand
	Daylight alternate	Christchurch, New Zealand
	↓	Istres, France

TABLE III.- MINIMUM-SITE RECOVERY NETWORKS – Continued

(f) $|\alpha| = 30^\circ$ to 90°

λ', n. mi.	Type of site	Location
270	Prime	*Homestead AFB, Florida
		Whidbey Island NAS, Washington
		Loring AFB, Maine
		Cape, Aleutian Islands, Alaska
		Churchill, Manitoba, Canada
		Alice Springs, Australia
		Christchurch, New Zealand
		Iwo Jima Air Base, Iwo Jima, Volcano Islands
		Chitose, Japan
		Stockholm, Sweden
		Keflavík, Iceland
		Mendoza, Argentina
		Fukche, India
		Dhahran, Saudi Arabia
		JBM Gertzog, Republic of South Africa
		Merzifon, Turkey
		Namponmad, Burma
	Weather alternate	Cameron County Airport, Texas
		Langley AFB, Virginia
		New Orleans International Airport, Louisiana
		Salt Lake City Municipal Airport, Utah
		Fairbanks International Airport, Alaska
		Shema Aerodrome, Aleutian Islands, Alaska
		Hickam AFB, Hawaii
		Anderson AFB, Guam
		Wake Airport, Wake Islands
		Papeete International Airport, Tahiti, Society Islands
		Gander International Airport, Newfoundland, Canada
		Manila International Airport, Philippines
		Posados, Argentina
		Kirkenes, Norway
		Tehrān-Mehrābād, Iran
		Reggan, Algeria
		Auserd, Spanish Sahara
		Arivonimamo, Malagasy Republic
500	Prime	Whidbey Island NAS, Washington
		*Cameron County Airport, Texas
		Hickam AFB, Hawaii
		Shema Aerodrome, Aleutian Islands, Alaska
		Goose Bay, Newfoundland, Canada
		Willeamtowne, Australia
		Tandil, Argentina
		Kirkenes, Norway
		Fukche, India
		At Tāif, Saudi Arabia
		Merzifon, Turkey

TABLE III.- MINIMUM-SITE RECOVERY NETWORKS – Continued

(f) $|\alpha| = 30^{\circ}$ to 90° – Continued

λ', n. mi.	Type of site	Location
500	Weather alternate	Homestead AFB, Florida
		Loring AFB, Maine
		Fairbanks International Airport, Alaska
		Anderson AFB, Guam
		Perth, Australia
		Christchurch, New Zealand
		Churchill, Manitoba, Canada
		Galẽao International Airport, Brazil
		London, England
		Papeete International Airport, Tahiti, Society Islands
		Kimpo Airfield, South Korea
	Daylight alternate	Homestead AFB, Florida
		Fairbanks International Airport, Alaska
		Papeete International Airport, Tahiti, Society Islands
		Iwo Jima Air Base, Iwo Jima, Volcano Islands
		Nandi International Airport, Fiji Islands
		Keeling Island
		Tafuna Airport, Pago Pago, American Samoa
		Alice Springs, Australia
		Perth, Australia
		Christchurch, New Zealand
		Kimpo Airfield, South Korea
		Chabua, India
		Mendoza, Argentina
		La Aurora Airport, Guatemala
		Galẽao International Airport, Brazil
		Istres, France
		Vila do Porto, Azores
		Athens, Greece
		Arivonimamo, Malagasy Republic
		JBM Gertzog, Republic of South Africa
		Auserd, Spanish Sahara
		†Columbo, Ceylon
		Luanda, Angola
		†Easter Island (Chile)
		†Kerguelen Island
1000	Prime	Whidbey Island NAS, Washington
		*Homestead AFB, Florida
		Hickam AFB, Hawaii
		Gander International Airport, Newfoundland, Canada
		Christchurch, New Zealand
		Tandil, Argentina
		Merzifon, Turkey
	Weather alternate	London, England
		Perth, Australia
		Willeamtowne, Australia
		Fukche, India
	Daylight alternate	Papeete International Airport, Tahiti, Society Islands
		Perth, Australia
		Avalon Beach, Australia
		Kimpo Airfield, South Korea
		Istres, France

TABLE III.- MINIMUM-SITE RECOVERY NETWORKS – Concluded

(f) $|\alpha| = 30^\circ$ to 90° – Concluded

λ', n. mi.	Type of site	Location
1000	Daylight alternate	JBM Gertzog, Republic of South Africa
↓	↓	Keeling Island
		Fukche, India
		Arivonimamo, Malagasy Republic
		†Easter Island (Chile)
1500	Prime	*Whidbey Island NAS, Washington
↓	↓	Christchurch, New Zealand
		Keflavík, Iceland
		Tandil, Argentina
	Weather alternate	Perth, Australia
	↓	Hickam AFB, Hawaii
		Erzurum, Turkey
	Daylight alternate	Homestead AFB, Florida
	↓	Hickam AFB, Hawaii
		Willeamtowne, Australia
		Kimpo Airfield, South Korea
		Istres, France
		Keeling Island
		JBM Gertzog, Republic of South Africa
		Arivonimamo, Malagasy Republic
2000	Prime	*Whidbey Island NAS, Washington
↓	↓	Christchurch, New Zealand
		Kimpo Airfield, South Korea
	Weather alternate	Hickam AFB, Hawaii
	↓	Keflavík, Iceland
		Merzifon, Turkey
	Daylight alternate	Istres, France
	↓	Hickam AFB, Hawaii
		Tandil, Argentina
		JBM Gertzog, Republic of South Africa
		Arivonimamo, Malagasy Republic
2500	Prime	*Whidbey Island NAS, Washington
↓	↓	Merzifon, Turkey
	Weather alternate	Perth, Australia
	↓	Chitose, Japan
	Daylight alternate	Hickam AFB, Hawaii
	↓	Papeete International Airport, Tahiti, Society Islands
		Tandil, Argentina
		Kimpo Airfield, South Korea
		JBM Gertzog, Republic of South Africa
3000	Prime	*Whidbey Island NAS, Washington
↓	↓	Christchurch, New Zealand
	Weather alternate	Hickam AFB, Hawaii
	↓	Perth, Australia
	Daylight alternate	Istres, France
	↓	Tandil, Argentina
		Kimpo Airfield, South Korea

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