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A FEASIBILITY STUDY FOR SCOUT POLAR LAUNCHES FROM NASA WALLOPS FLIGHT CENTER

T. R. Myler

Prepared by
LTV AEROSPACE CORPORATION
Dallas, Texas 75222
for Langley Research Center

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16. Abstract

This report describes a Feasiblity Study for launching the Scout vehicle into a polar orbit from Wallops Flight Center. The impact of these proposed flights on vehicle hardware and range safety are defined. The launch and flight modes are described.

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A FEASIBILITY STUDY FOR SCOUT POLAR LAUNCHES FROM NASA WALLOPS FLIGHT CENTER

By T. R. Myler
LTV Aerospace Corporation

SUMMARY

A feasibility study was performed which evaluates using the Scout vehicle to achieve polar orbit when launched from NASA Wallops Flight Center. The mode of flight necessary to achieve polar orbit is defined, in addition to the evaluation of vehicle payload weight capabilities, range safety constraints and vehicle hardware changes.

Scout F–1 can achieve a 1111 km (600 n.mi.) circular polar orbit with a payload weight of 72.1 kg (159 lb) without critical impact on range safety constraints or vehicle hardware. This capability is 12.7 kg (28 lb) in excess of the desired weight of 59.4 kg (131 lb), which is a typical payload weight for a Navy mission when launched from Vandenberg Air Force Base (VAFB), California. The polar orbit obtained by launching from NASA Wallops is achieved with a trajectory which places first stage impact off the coast of North Carolina, second stage impact north of the Bahama Islands and third stage impact off the west coast of South America.

Minimum motor improvements to Scout F–1 were identified which will provide a 555 km (300 n.mi.) circular polar orbit with a 141.5 kg (312 lb) payload weight, which is the current capability of Scout F–1 when launched from VAFB. The improved Scout configuration is F–1 with the addition of four Black Brant II strap-on motors, cross-linked-double-base (XLDB) propellant in the third stage and hydroxyl-terminated-polybutadiene (HTPB) propellant in the fourth stage. Elliptical polar orbit performance is presented for both Scout F–1 and the improved configuration.

Based on this analysis, it is concluded that launching Scout into polar orbit from NASA Wallops Flight Center is feasible.

1.0 INTRODUCTION

The feasibility of the Scout launch vehicle to achieve polar orbit (90 deg. inclination) when launched from NASA Wallops Flight Center has been considered in past years. This report describes a study which investigated launching Scout into polar orbit from NASA Wallops and the impact of such flights on vehicle hardware and range safety criteria. The scope of this effort is a technical evaluation of achieving polar orbit from NASA Wallops with the Scout launch vehicle. No hardware was designed.

Of primary interest in this study was the ability of Scout F–1 to perform the Navy mission, which is typically a 1074 x 1148 km (580 x 620 n.mi.) polar orbit with a 59.4 kg (131 lb) payload weight. The importance of this mission is due to the number of past Scout launches for the Navy mission.

2.0 DISCUSSION

This study was divided into two phases. Phase I primarily consisted of determining the payload weight capability of Scout F–1 for a 1111 km (600 n. mi.) circular polar orbit, *based on pre-defined flight guidelines. This orbit was selected due to the similarity to the Navy* mission. The ability of Scout F–1 to achieve this orbit with the desired weight of 59.4 kg (131 lbs) was the main criteria considered before proceeding into Phase II. At the completion of Phase I, a presentation was made at the Scout Project Office, Langley Research Center. Phase II go-ahead was given because the desired payload of 59.4 kg was obtained with Scout F–1. Phase II primarily consisted of defining a Scout configuration which achieves a 555 km (300 n.mi.) circular polar orbit from Wallops with a 141.5 kg (312 lb) payload weight, which is the current capability of the Scout F–1 when launched south from Vandenberg AFB.

2.1 Vehicle Configuration

The Scout configuration used in Phase I was an F–1 configuration with a 42 inch diameter, -45 inch nose-station heatshield. The F–1 consists of the Algol IIIA, Castor IIA, Antares IIB and Altair IIIA motors. Nominal performance characteristics of these motors are shown in Tables 1 through 4.

Nominal vehicle weights are shown in Table 5. The fourth stage burnout weight used is 39.70 kg (87.52 lb) which includes the T/M module but does not include payload, payload separation system or payload separation ignition system.

2.2 Study Guidelines

Guidelines for this study were;

A. Basic configuration shall be Scout F–1 with 42 inch heatshield and launch site shall be the NASA Wallops Island, Virginia, facility.

B. The impact area of each stage shall not contact or contain any land mass.

C. The impact area of each stage shall have a six-sigma dispersion area as indicated by the following guidelines with the exception of South America as noted below. The first stage dispersion area shall be a 12 x 6 nautical mile ellipse. The second stage dispersion area shall be 48 x 20 nautical mile ellipse. The third stage dispersion area shall be a 152 x 66 nautical mile ellipse. The South American impact area shall be a three-sigma dispersion area at least one hundred nautical miles from any land mass.

D. The third stage may be allowed to impact in either the Atlantic or Pacific Oceans.

E. The overflight of land masses will be permitted.

F. The overflight of cities having populations greater than one million shall be avoided, if possible, but the flight profile should not be eliminated from consideration for that reason alone.

G. The launch azimuth shall have only those constraints necessary to effect the six-sigma dispersion area and impact area requirements stated under "Study Guidelines B and C".

H. Present vehicle constraints are to be used as a basic guideline, with the exception of launch azimuth stated under "Study Guideline G".

I. Present vehicle basic constraints may be relaxed if this procedure becomes necessary in order to satisfy other requirements stated under "Study Guidelines," i.e., dogleg maneuver in one or more stages.

J. The fourth-stage inert weight of 87.52 pounds shall include the burned-out weight of Altair IIIA, and the upper-D and fourth stage modular telemetry system. The total weight in orbit and payload weight shall be presented.

K. The ability of the Scout F–1 configuration to perform the present Navy mission (maximum altitude orbit with maximum probability of the eccentricity lying between 0.003 and 0.01) will be the main criteria which shall be used to proceed to Phase II of this study. With Scout A–1 this mission criteria results in an orbit of about 580 x 620 nautical miles with a 131-pound payload.

L. Alternate vehicle configuration: In the event that Scout F–1 cannot achieve the Navy mission as described in "Guideline K", an alternate configuration requiring the minimum amount of change may be selected from the following list:

1. Algol IIIA, Castor IIA, Antares IIB with XLDB, Altair IIIA.
2. Algol IIIA, Castor IIA, Antares IIB with XLDB, Altair IIIA with HTPB.
3. Algol IIIA with (4) strap on motors, Castor IIA, Antares IIB with XLDB, Altair IIIA with HTPB.
4. Algol IIIA, Castor IIA with XLDB, Antares IIB with XLDB, Altair IIIA with HTPB.

2.3 Phase I Analysis

Using the guidelines in paragraph 2.2, two trajectories were developed which produce a 1111 km (600 n. mi.) circular polar orbit. One trajectory has third stage impact in the Atlantic Ocean and the other has third stage impact in the Pacific Ocean. These two trajectories are described in the following paragraphs.

2.3.1 Atlantic Ocean impact trajectory. – With third stage impact in the Atlantic Ocean, maximum payload weight is obtainable by launching along the most southerly azimuth which has third stage impact just off the coast of South America. This launch azimuth was determined to be 123 deg., which provides acceptable stage impact locations; however, without an orbit plane change, the inclination would be about 51 deg. To achieve a polar orbit while maintaining third stage impact location, the velocity vector azimuth (velocity direction from North) is turned southward after the third stage is burned out. This is accomplished by yaw-torquing (changing direction of the thrust axis) the fourth stage to the right, in order to add velocity in the westward direction. For the 123 deg. launch azimuth, a yaw angle of 86 deg. is required to achieve polar orbit. Due to this extremely large yaw angle and the resulting velocity losses, a payload weight of 11.8 kg (26 lb) results. Boost groundtrack and instantaneous impact point (IIP) trace for the above trajectory are shown in Figure 1. The IIP trace is a locus of vehicle vacuum impact locations in the event of premature motor termination.

Due to the minimal payload weight of 11.8 kg, this mode of flight is impractical with Scout F–1.

2.3.2 Pacific Ocean impact trajectory. –

2.3.2.1 1111 km circular orbit: In developing a trajectory with third stage impact in the Pacific Ocean, two of the guidelines in paragraph 2.2 are of primary concern. These are (1) the impact area of each stage shall not contact or contain any land mass and (2) the overflight of land masses will be permitted. A due South launch is desirable for optimum performance but land impact would occur. To avoid land impact with the spent first and second stage, the most southerly launch azimuth allowable is 170 deg. A somewhat greater launch azimuth would place first stage impact in North Carolina and second stage impact in the Bahama Islands. Thus, a launch azimuth of 170 deg. was selected.

To achieve Scout third stage impact in the Pacific Ocean, the vehicle must be yaw-torqued to the right prior to third stage burnout. Yaw-torquing can be accomplished during second stage coast when the vehicle is experiencing very low dynamic pressure. Therefore, a yaw maneuver was used during second stage coast with a yaw rate of 10 deg/sec. The coast time was lengthened by the required time for the yaw maneuver. The yaw angle required is that which results in the third stage impact dispersion area being 185.2 km (100 n.mi.) off the West coast of South America.

Having achieved acceptable stage impact locations by launching at a 170 deg. launch azimuth and yaw-torquing the vehicle to the right prior to third stage ignition, the vehicle must then be yaw-torqued to the left prior to fourth stage ignition in order to achieve polar orbit. The boost groundtrack and IIP using this mode of flight for a 1111 km circular orbit is shown in Figure 2. As shown, the 1111 km trajectory IIP crosses the Bahama Islands, Cuba, the tip of Jamaica and Panama. The elapsed time during IIP crossing Cuba and Panama is 1.2 sec and 0.5 sec, respectively. The elapsed time crossing the Bahama Islands and Jamaica was not defined, but is estimated to be significantly less than 0.5 second.

Stage impact locations, but not IIP, were calculated with atmospheric effects included. However, the difference in impact location due to atmospheric effects cannot be seen on the scale used in Figure 2. Nominal stage impact locations and dispersion areas are shown in Figure 2 for stages two and three and Figure 3 for stage one. Dispersion areas shown are the size specified in paragraph 2.2.

2.3.2.2 Circular orbit performance: The mode of flight described in paragraph 2.3.2.1 was used to calculate circular orbit performance. The trajectories obtained differ significantly in third stage impact location but not in first or second stage impact location. Stage impact locations for the various circular orbit altitudes are shown in Figures 4 and 5. First and second stage impact locations for each circular orbit altitude are acceptable, i.e., they do not contact or contain any land masses. However, the low altitude orbits (222 to 407 km) do result in third stage impact inside the range safety boundaries about Panama as defined under the guidelines of this study. An acceptable impact location is achieved by a higher orbit altitude trajectory and an early fourth stage ignition.

To achieve altitudes between 222 and 407 km, the lower three stages are flown on the same trajectory as the 407 km altitude orbit trajectory, which provides third stage impact location on the southern limit about Central America (shown in Figure 2). Then by igniting the fourth stage early in time, a lower circular orbit altitude is obtained.

2.3.2.3 Internal hardware evaluation: The flight profile described in paragraph 2.3.2.1 was developed to achieve polar orbits when launching Scout from NASA Wallops. This profile, which requires two non-consecutive yaw rate steps, cannot be achieved by the current guidance system.

Therefore, an evaluation was made of vehicle wiring changes required to accomplish the two non-consecutive yaw rate steps.

The flight profile requires a pitch-yaw program sequence as follows: pitch down – yaw right – pitch down – yaw left. The evaluation shows that no internal wiring changes are required to the programmer, intervalometer or inertial reference package. Vehicle Upper D section interface wiring between these three units, however, will require modification. The required interface wiring is shown schematically in Figure 6. Wiring for Scout F–1, S–193 and subsequent vehicles, was used as the baseline configuration. Channel assignments for those intervalometer changes associated with pitch/yaw program are made. Channels associated with ignition and staging sequencing are not reassigned. Similarly, no rewiring associated with these channels and circuits is required.

The addition of each yaw rate step replaces a pitch rate step. The current limit of rate steps is ten, so since two yaw rate steps are needed and the tenth rate step must be zero, seven unique non-zero pitch rate steps are available. The acceptability of seven pitch steps for all orbit missions was considered. It was determined that seven pitch steps are sufficient when using the current Scout F–1 vehicle.

2.4 Phase I Results

Paragraph 2.3.2 describes a mode of flight by which the Scout can achieve a polar orbit, based on the guidelines specified for this analysis, when launching from NASA Wallops. The pecularities of this mode of flight are a launch azimuth of 170 deg., yaw-torque to the right just prior to stage three ignition and yaw-torque to the left prior to stage four ignition. The payload weight capability using this mode of flight is 72.1 kg (159 lb) into a 1111 km (600 n.mi.) circular polar orbit with the Scout F–1 configuration. This weight is 12.7 kg (28 lb) in excess of the desired weight, specified in the guidelines of paragraph 2.2, for the Navy mission. Circular orbit performance capability is shown in Figure 7. For comparison, performance is shown when launching south from Vandenberg AFB. The required yaw-torque angles are shown in Figure 8 for each circular altitude orbit.

The above described trajectory with third stage impact in the Pacific Ocean violates three current Scout constraints. First, a launch azimuth of 170 deg. is used. The current limit is 129 deg., but this exists due to third stage impact constraint of the typical Scout trajectory (no third stage yaw maneuver). Secondly, the third stage is yaw-torqued. A third stage yaw rate step is an allowable event but currently pitch program steps are not allowed after yaw program steps. Therefore, third stage maneuvers cannot currently be used due to the necessity of pitch program steps during third stage coast to orient the fourth stage. Thus, the necessary sequence of pitch and yaw programs is pitch-yaw-pitch-yaw. Thirdly, the IIP crosses land. Allowing the IIP to cross land is a constraint violation which requires approval by Wallops Flight Center Range Safety. However, approval has been granted in the past for specific Scout launches when required.

One of the guidelines in paragraph 2.2 specifies that overflight of cities with a population of one million or greater should be avoided. The IIP of the Pacific Ocean impact trajectory does not cross cities of this size. Figure 9 shows the location and population of major cities in the vicinity of the IIP. As shown, the IIP crosses very near Santiago de Cuba, Kingston, Jamaica and Panama City. The most populated of these three cities is Panama City at 0.42 million.

2.5 Phase II Analysis

The initial Phase II task was to optimize the time to initiate the first yaw maneuver of the flight profile developed in Phase I, paragraph 2.3.2, in order to obtain maximum payload weight capability. The outcome of this optimization dictates the optimum yaw maneuver time for use in developing the Phase II performance.

Using the flight profile with the optimum yaw maneuver time, a Scout configuration was defined which can achieve a 555 km (300 n. mi.) circular polar orbit with a payload weight capability of 141.5 kg (312 lb). This payload weight is the current capability of Scout F–1 when launched south from Vandenberg AFB. Phase I results show a payload weight capability of 103.9 kg (229 lbs) in a 555 km (300 n. mi.) circular polar orbit with Scout F–1, therefore, an increase of 37.6 kg (83 lb) above the Scout F–1 capability is needed.

Additionally, elliptical polar orbit performance data was calculated for both Scout F–1 and the improved Scout configuration.

2.5.1 Optimization of time of first yaw maneuver. – The polar orbit trajectory with third stage impact in the Pacific Ocean, which was developed in Phase I and discussed in paragraph 2.3.2, utilizes a yaw maneuver just prior to third stage ignition. This second stage coast yaw maneuver was selected over the alternatives of first stage coast or second stage boost yaw maneuvers since it was expected that fewer violations of Scout constraints would occur. This supposition is verified by the optimization procedure which follows.

2.5.1.1 First stage coast yaw maneuver: Yaw torquing during first stage coast is unacceptable due to the extremely large product of dynamic pressure and angle-of-sideslip at second stage ignition. Typically, this product could be 800 deg-psf with the first stage coast yaw maneuver. The current maximum allowable value at second stage ignition is estimated to be 100 deg-psf for adequate second stage control.

2.5.1.2 Second stage boost yaw maneuver: Evaluation of a second stage boost yaw maneuver is made by developing a polar orbit trajectory similarly to the Phase I trajectory. As in Phase I, the guidelines in paragraph 2.2 are applicable. The development of this trajectory is discussed below.

To maintain an acceptable first stage impact location, the 170 deg. launch azimuth was used. During second stage boost, a yaw maneuver was used to place second stage impact just off the east coast of Florida. A second yaw maneuver was used during second stage coast which places third stage impact location just off the west coast of South America. Prior to stage four ignition, a third yaw maneuver was performed to provide the desired polar orbit. Additionally, a steeper trajectory is necessary to provide second stage impact north of the Bahama Islands. The steeper trajectory necessitates use of the third stage to decrease the fourth stage ignition altitude by maintaining a pitch down attitude during third stage boost. The fourth stage could be ignited early rather than use the third stage pitch down attitude but this would result in less performance. The IIP of the above defined trajectory is shown in Figure 10. For comparison, the Phase I flight profile IIP is also shown.

The second stage boost yaw maneuver provides a gain in payload weight capability by turning the velocity vector when it is low in magnitude. This increase in capability is approximately 10 to 15 kg in payload weight. However, this gain is offset by the loss in capability due to the pitch down attitude, during third stage boost, required for acceptable stage impact and orbit altitude. The net result is a loss of 2.7 kg (6 lbs) payload weight capability when the second stage boost yaw maneuver is used, in comparison to the Phase I flight profile. In addition to the payload weight loss, seven current Scout constraints are violated, including the three identified in Phase I. The remaining four constraint violations are (1) simultaneous pitch and yaw rate steps, (2) product of dynamic pressure and angle-of-sideslip exceeds estimated limit of 100 deg-psf during stage two boost, (3) required sequence of torquing rate steps is pitch down, pitch down and yaw right, yaw left, pitch down, yaw right or left and (4) number of available pitch rate steps is six, two less than needed.

Since the mode-of-flight discussed in Phase I produces more payload weight capability than the trajectory which utilizes a second stage boost yaw maneuver, the Phase II analysis proceeded with the third stage yaw maneuver mode-of-flight, as developed in Phase I.

2.5.2 Improved scout configuration. – Minimum motor improvements to the Scout F-1 were made to achieve a 555 km (300 n. mi.) circular polar orbit with a 141.5 kg (312 lb) payload weight capability, using the Phase I mode-of-flight described in paragraph 2.3.2. Acceptable motor improvements for consideration in this analysis are listed in the guidelines of paragraph 2.2. This analysis shows that the minimum motor improvements to achieve the 141.5 kg payload weight are (1) the addition of four Black Brant II (Bristol 15KS25000) motors as Algol IIIA strap-ons, (2) the incorporation of cross-linked-double-base (XLDB) propellant in the Antares IIB third stage motor and (3) the incorporation of hydroxyl-terminated-polybutadiene (HTPB) propellant in the Altair IIIA fourth stage motor. Both of these propellants provide an increase in specific impulse and propellant density.

Characteristics of the Black Brant II motor are shown in Table 6. This information is from an unpublished document from the motor manufacturer. Definition of the Antares IIB motor with XLDB, as shown in Table 7, was obtained using the thrust trace of the standard Antares IIB, Table 3, with motor characteristics for the XLDB propellant. Similarly, the definition of the Altair IIIA motor with HTPB, as shown in Table 8, was obtained using the thrust trace of the standard Altair IIIA, Table 4, with motor characteristics for the HTPB propellant. A vehicle weight summary is shown in Table 9. Zero lift drag coefficient of Scout, with and without strap-on motors, is shown in Figure 11.

Using the above defined Scout configuration, orbit inclinations other than 90 deg. were obtained for the 555 km (300 n. mi.) circular orbit. The resulting payload weight capability is shown in Figure 12. For each inclination, the optimum payload weight is shown which is achievable within the guidelines of this study. Orbit inclinations greater than 90 deg. are achieved by yaw-torquing the fourth stage less than for the 90 deg. case, resulting in a gain in performance. The required yaw torque angle is less because, in this case, the inclination angle at fourth stage ignition is initially greater than 90 deg. Third stage impact location requires this initial fourth stage heading. This is illustrated in Figure 2.

Orbit inclinations less than 90 deg. are achieved by yaw-torquing the fourth stage more than for the 90 deg. case, resulting in a loss in performance. For all inclinations greater than 77 deg., second and third stage impact locations are as shown in Figure 5 for the 555 km (300 n. mi.) circular orbit, i.e. the Pacific Ocean impact trajectory.

For inclinations less than 77 deg., maximum payload weight is attained by using the Atlantic Ocean impact trajectory as described in paragraph 2.3.1. The Atlantic Ocean impact trajectory yields greater payload weight capability in this circumstance than the Pacific Ocean impact trajectory because smaller fourth stage yaw-torque angles are required.

2.5.3 Elliptical polar orbit performance. – Elliptical polar orbit performance capability was calculated for both Scout F-1 and the improved Scout configuration defined in paragraph 2.5.2. The mode of flight used is that defined in paragraph 2.3.2, which places stage three impact in the Pacific Ocean. Apogee altitude is presented as a function of perigee altitude and payload weight for Scout F-1 and the improved Scout configuration in Figures 13 and 14, respectively.

For Scout F-1, the payload weight capability at perigee altitudes of 200 km and 400 km is very nearly the same. This is because of the third stage impact constraint in the vicinity of Central America, as discussed in paragraph 2.3.2.2.

In Figure 14, the unusual shape of the circular orbit performance curve is a result of the second stage impact location constraint. A 170 deg. launch azimuth was used for orbit altitudes below 555 km (300 n. mi.). For higher orbit altitudes, the second stage impact location will contain the Bahama Islands if the 170 deg. launch azimuth is used. Therefore, the launch azimuth is decreased to 164 deg. for 676 km (365 n. mi.) altitude orbits and above.

2.5.4 Stage impact dispersion areas. – One purpose of this study was to evaluate first, second and third stage impact dispersion areas when yaw maneuvers are used. Fourth stage yaw maneuvers do not affect lower stage impact dispersion areas. Therefore, since past Scout flights have had only fourth stage yaw maneuvers and not second or third stage yaw maneuvers, impact dispersion areas cannot be evaluated for trajectories using lower stage yaw maneuvers, based on flight experience results.

2.6 Phase II Results

The Scout configuration which can achieve a 141.5 kg (312 lb) payload weight in a 555 km (300 n. mi.) circular polar orbit is the Algol IIIA with 4 Black Brant II strap-ons/Castor IIA/Antares IIB with XLDB/Altair IIIA with HTPB and a 42-inch diameter, –45 inch nose station heatshield. The mode-of-flight used is the same as discussed in paragraph 2.3.2 for the Scout F-1. Thus, the polar orbit trajectories have third stage impact in the Pacific Ocean. Other orbit inclinations were obtained using this mode-of-flight; however, for inclinations less than 77 deg., the Atlantic Ocean impact trajectory discussed in paragraph 2.3.1 is used since it results in the highest payload weight.

Elliptical polar orbit performance for both Scout F-1 and the improved configuration were calculated and are presented in Figures 13 and 14.

3.0 CONCLUSIONS

Trajectories were developed which achieve polar orbit for launches from NASA Wallops Flight Center, using the Scout F-1 and an improved Scout F-1 configuration. The analysis included (1) the calculation of vehicle payload weight capabilities, (2) the identification of violations to NASA Wallops Flight Center range safety constraints and (3) the identification of required changes in vehicle hardware.

Scout F-1 achieves an 1111 km (600 n. mi.) circular polar orbit with greater capability than the design criteria. The flight profile used to achieve this orbit has been preliminarily approved by NASA Wallops range safety and the necessary vehicle re-wiring for this flight profile was identified and can be made in a reasonable time. Based on the above considerations, it is concluded that Scout polar launches from NASA Wallops are feasible.

TABLE 1. – ROCKET ENGINE DATA – ALOGL IIIA

Cons weight = 28181.13 lb
Prop weight = 27963.13 lb
Total weight = 31271.95 lb

Time (sec)	Jet vane drag (lbf)	Vacuum thrust (lbf)	Consumed weight remaining (lb)
0.00	0.00	0.00	28181.13
0.30	1559.22	149924.95	28094.00
1.00	1332.03	128080.06	27717.01
1.50	1287.59	123806.26	27473.10
2.50	1250.33	120223.96	27000.39
4.99	1155.63	111118.26	25880.10
5.99	1125.50	108221.26	25455.24
7.49	1097.72	105549.76	24834.15
9.98	1079.31	103780.26	23820.47
12.47	1078.72	103723.06	22815.58
14.96	1087.62	104578.76	21806.90
21.95	1010.39	97152.57	19071.62
24.94	1009.37	97054.37	17943.04
29.93	1046.77	100650.77	16028.19
34.92	1092.27	105025.66	14036.21
39.91	1138.56	109476.86	11958.80
54.87	1282.05	123274.26	5196.08
56.27	1293.87	124410.56	4524.43
57.37	1238.99	119133.76	4005.45
59.86	1044.60	100442.37	2942.21
62.36	814.17	78285.77	2076.71
64.85	603.93	58070.28	1416.35
67.35	440.48	42353.99	930.05
69.84	312.64	30061.79	579.43
72.34	213.64	20542.19	334.33
74.82	130.27	12525.70	174.16
77.32	78.16	7515.40	77.14
80.81	31.26	3006.20	5.80
81.82	0.00	0.00	0.00

Total impulse	Impulse jet vane	Specific impulse	Exit area
7257830.4 lbf-sec	75481.4 lbf-sec	259.550 sec	5.670 ft^2

TABLE 2. – ROCKET ENGINE DATA – CASTOR IIA

Cons weight = 8269.92 lb
Prop weight = 8214.72 lb
Total weight = 9760.59 lb

Time (sec)	Vacuum thrust (lbf)	Consumed weight remaining (lb)
0.00	0.00	8269.92
0.09	15409.67	8266.23
0.14	41606.11	8260.45
0.43	40578.81	8213.93
0.96	41606.11	8129.51
3.85	46742.60	7646.71
6.75	51879.29	7120.40
9.64	57015.77	6545.28
12.54	61638.66	5922.37
15.43	65747.95	5258.24
18.33	69343.45	4558.49
20.26	71141.34	4075.08
22.19	72425.24	3583.00
24.12	73195.84	3086.13
25.57	73452.64	2711.40
27.01	73195.84	2341.96
28.95	71911.84	1843.79
30.87	70370.74	1361.19
31.46	69600.25	1219.38
31.84	69343.45	1125.17
34.54	69857.05	466.84
35.31	68573.05	279.92
35.69	66261.55	188.42
35.90	63693.16	142.22
36.47	30819.33	48.60
36.81	10273.08	24.55
37.63	2054.60	5.78
38.11	1027.40	2.89
39.36	0.00	0.00

Total inpulse	Specific impulse	Exit area
2308254.2 lbf-sec	280.99 sec	7.950 ft^2

TABLE 3. – ROCKET ENGINE DATA – ANTARES IIB

Cons weight = 2575.07 lb
Prop weight = 2558.87 lb
Total weight = 2789.54 lb

Time (sec)	Vacuum thrust (lbf)	Consumed weight remaining (lb)
0.00	0.00	2575.07
0.17	27839.83	2566.70
0.41	27526.62	2543.37
0.44	27519.62	2540.88
1.37	29567.55	2447.47
1.63	29930.86	2420.15
2.00	29566.55	2380.88
2.30	29584.56	2349.68
4.00	30391.27	2170.14
6.35	31413.38	1914.44
7.50	31746.59	1786.54
9.00	31721.59	1618.85
11.50	30978.88	1342.91
14.00	29527.55	1076.54
16.00	28042.03	873.78
17.00	27450.52	776.07
18.00	27169.22	679.88
20.00	26443.61	491.17
22.00	25262.39	309.04
23.50	23961.17	179.05
24.25	22938.15	117.13
24.75	21791.04	77.75
25.00	21035.32	58.82
25.21	20257.61	43.57
25.40	19544.90	30.31
25.56	17792.27	19.74
26.01	3233.15	3.09
26.21	662.61	1.69
26.35	330.31	1.49
28.90	0.00	0.00

Total impulse	Specific impulse	Exit area
731222.7 lbf-sec	285.760 sec	4.350 ft^2

TABLE 4. – ROCKET ENGINE DATA – ALTAIR IIIA

Cons weight = 604.33 lb
Prop weight = 601.23 lb
Total weight = 662.41 lb

Time (sec)	Vacuum thrust (lb_f)	Consumed weight remaining (lb)
0.00	0.00	604.33
0.15	1318.43	603.45
0.30	3798.30	601.46
0.40	4193.87	599.98
0.70	4113.07	595.46
2.30	5381.91	568.03
4.00	6421.80	532.72
4.31	6484.64	526.00
4.78	6255.48	515.54
5.31	6240.62	504.15
8.51	6601.07	432.77
10.10	6722.52	395.81
11.70	6805.63	357.80
12.71	6814.77	333.79
14.11	6783.35	300.33
15.31	6716.50	271.84
16.71	6580.79	239.13
18.11	6350.94	207.36
20.51	5816.24	155.16
23.21	5037.63	104.71
26.80	4771.33	42.45
28.20	4517.28	19.68
28.61	4113.17	13.57
29.11	3127.99	7.41
29.81	1142.17	2.61
30.10	772.59	1.81
30.90	278.44	0.61
31.40	113.42	0.34
33.30	0.00	0.00

Total impulse	Specific impulse	Exit area
172222.3 lb_f-sec	286.450 sec	1.500 ft^2

TABLE 5. – VEHICLE WEIGHT SUMMARY SCOUT F–1

	Pounds
Payload	0.00
Stage 4 inert	87.52
Stage 4 burnout	87.52
Altair IIIA consumed	604.33
Stage 4 ignition	691.85
Stage 3 inert	769.56
Stage 3 burnout	1461.41
Antares IIB consumed*	2579.37
Stage 3 ignition	4040.78
42/–45 inch heatshield	349.58
Stage 2 inert	2073.96
Stage 2 burnout	6464.32
Castor IIA consumed**	8307.42
Stage 2 ignition	14771.74
Stage 1 inert	4275.12
Stage 1 burnout	19046.86
Algol IIIA consumed	28181.13
Stage 1 ignition	47227.99

*Includes 4.3 lbs H_2O_2
**Includes 37.5 lbs H_2O_2

TABLE 6.– ROCKET ENGINE DATA – BLACK BRANT II

(One 15KS25000 motor)

Cons weight = 1782.1 lb
Prop weight = 1760.0 lb
Total weight = 2212.3 lb

Time (sec)	Vacuum thrust (lb_f)	Consumed weight remaining (lb)
0.00	0	1782.1
0.10	25876	1776.8
0.25	30602	1758.8
0.50	29506	1725.8
1.00	28450	1663.8
2.00	28315	1541.8
3.00	28374	1419.8
4.00	27906	1298.8
6.00	27667	1060.8
8.00	27200	824.8
10.00	26578	593.8
12.00	25760	368.8
14.00	21430	165.8
15.00	14261	88.8
16.00	8768	39.8
17.00	4652	10.8
17.50	3220	2.8
17.85	0	0.0

Total impulse	Specific impulse	Exit area
414,700 lb-sec	235.625 sec	0.9735 ft^2

TABLE 7. – ROCKET ENGINE DATA – ANTARES IIB WITH XLDB

Cons weight = 2783.20 lb
Prop weight = 2767.00 lb
Total weight = 3002.00 lb

Time (sec)	Vacuum thrust (lb_f)	Total impulse (lb-sec)	Consumed weight remaining (lb)
0.000	0.00	0.0	2783.20
0.195	27152.40	2643.4	2774.15
0.470	26846.93	10065.1	2748.94
0.504	26840.11	10987.4	2746.25
1.569	28837.47	40640.4	2645.29
1.867	29191.80	49280.6	2615.76
2.291	28836.49	61576.1	2573.31
2.634	28854.05	71487.3	2539.59
4.581	29640.84	128434.4	2345.54
7.273	30637.72	209555.7	2069.17
8.590	30962.70	250123.9	1930.94
10.308	30938.32	303297.1	1749.69
13.171	30213.94	390847.2	1451.45
16.035	28798.46	475333.7	1163.55
18.325	27349.62	539642.3	944.40
19.471	26772.71	570636.5	838.80
20.616	26498.35	601143.2	734.83
22.907	25790.66	661031.9	530.87
25.197	24638.61	718790.5	334.02
26.915	23369.52	760029.7	193.52
27.774	22371.76	779675.6	126.60
28.347	21252.97	792166.9	84.03
28.633	20515.92	798146.9	63.57
28.874	19757.41	802990.2	47.09
29.092	19062.30	807214.0	32.76
29.275	17352.95	810550.7	21.34
29.790	3153.32	815835.1	3.34
30.019	646.25	816270.3	1.83
30.180	322.15	816348.0	1.61
33.100	0.00	816818.4	0.00

Total impulse	Specific impulse	Exit area
816818.4 lb-sec	295.200 sec	4.350 ft^2

TABLE 8. – ROCKET ENGINE DATA – ALTAIR IIIA WITH HTPB

Cons weight = 634.10 lb
Prop weight = 631.00 lb
Total weight = 696.00 lb

Time (sec)	Vacuum thrust (lb_f)	Total impulse (lb-sec)	Consumed weight remaining (lb)
0.000	0.00	0.0	634.10
0.143	1482.79	106.2	633.18
0.286	4271.83	518.4	631.09
0.382	4716.72	947.5	629.54
0.668	4625.84	2285.8	624.80
2.196	6052.87	10444.1	596.01
3.820	7222.40	21219.9	558.96
4.116	7293.07	23368.4	551.91
4.565	7035.34	26584.0	540.94
5.071	7018.64	30140.5	528.98
8.127	7424.02	52208.1	454.09
9.645	7560.62	63584.4	415.31
11.173	7654.09	75208.0	375.42
12.138	7664.36	82595.4	350.23
13.475	7629.03	92818.7	315.12
14.621	7553.84	101518.1	285.23
15.957	7401.22	111515.2	250.91
17.294	7142.70	121237.5	217.58
19.586	6541.34	136918.8	162.80
22.165	5665.66	152656.1	109.87
25.593	5366.17	171566.4	44.54
26.930	5080.45	178549.7	20.65
27.322	4625.96	180449.9	14.23
27.799	3517.95	182394.2	7.77
28.467	1284.56	183999.4	2.74
28.744	868.91	184297.6	1.90
29.508	313.15	184749.1	.64
29.986	127.56	184854.3	.36
31.800	0.00	184970.1	0.00

Total impulse	Specific impulse	Exit area
184970.1 lb-sec	293.138 sec	1.500 ft^2

TABLE 9. – VEHICLE WEIGHT SUMMARY – IMPROVED SCOUT CONFIGURATION

	Pounds
Payload	0.00
Stage 4 inert	91.34
Stage 4 burnout	91.34
Altair IIIA consumed (HTPB propellant)	634.10
Stage 4 ignition	725.44
Stage 3 inert	778.19
Stage 3 burnout	1503.63
Antares IIB consumed* (XLDB propellant)	2787.50
Stage 3 ignition	4286.83
42/–45 inch heatshield	349.58
Stage 2 inert	2111.46
Stage 2 burnout	6747.87
Castor IIA consumed**	8307.42
Stage 2 ignition	15017.79
Stage 1 inert	4325.12
Stage 1 burnout	19342.91
Algol IIIA consumed (remaining)	20676.00
Stage 1 burn continued	40018.91
Strap-on inert	1770.80
Strap-on burnout	41789.71
Black Brant II consumed	7128.40
Algol IIIA consumed (partial)	7505.13
Stage 1 and strap-on ignition	56423.24

*Including 4.3 lb H_2O_2
**Including 37.5 lb H_2O_2

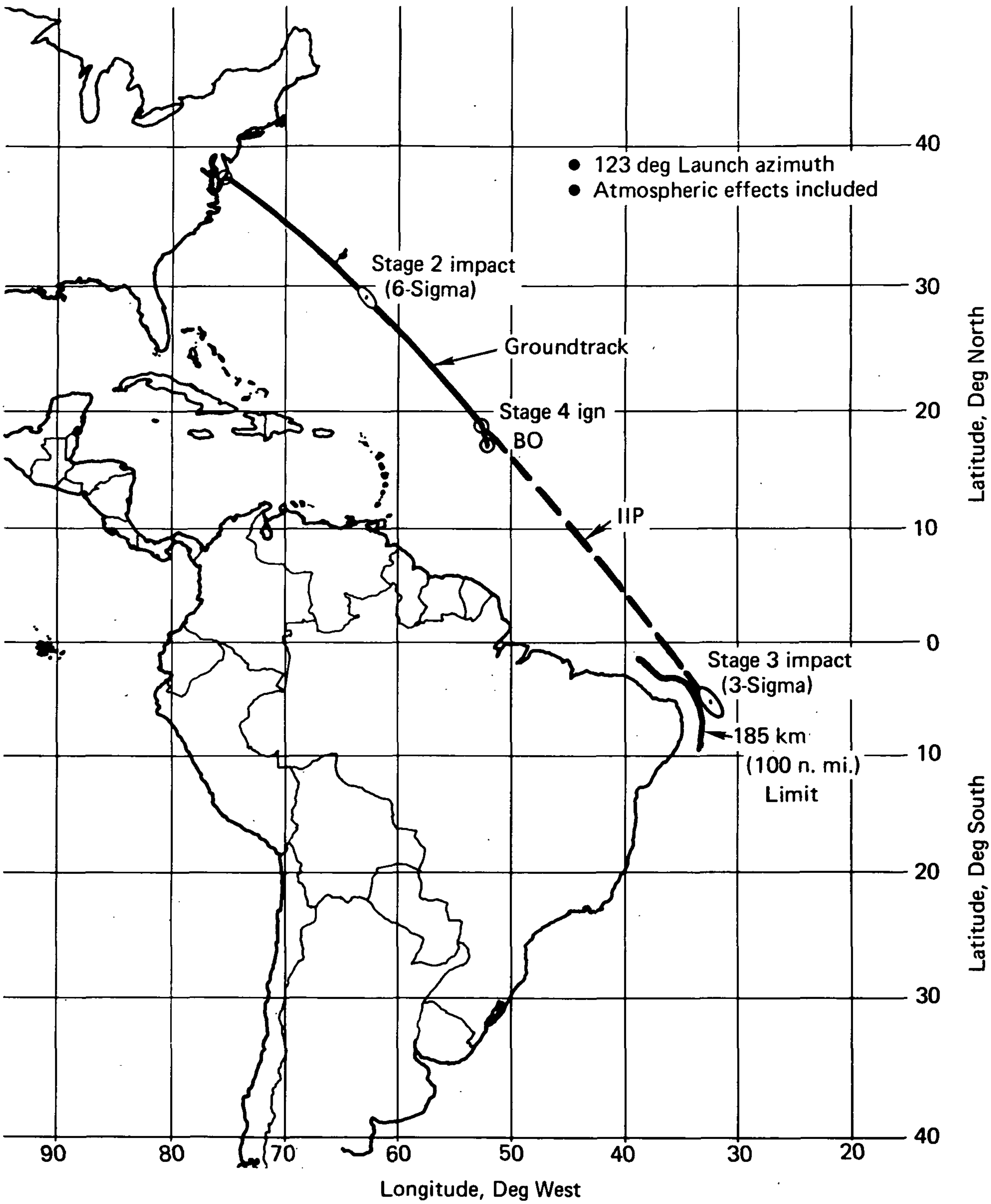


FIGURE 1. – ATLANTIC OCEAN IMPACT TRAJECTORY GROUNDTRACK AND IIP – 1111 KM CIRCULAR ORBIT

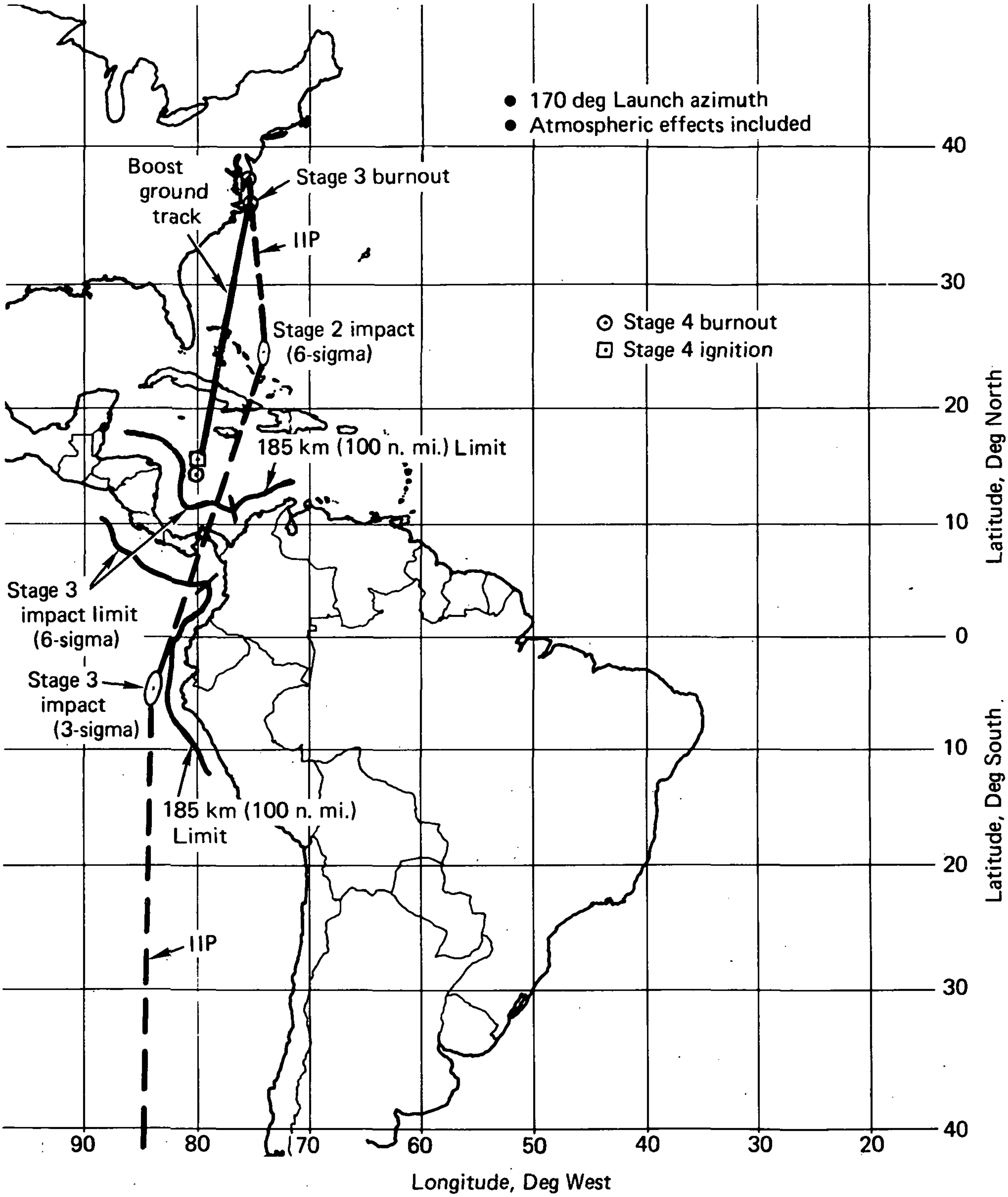


FIGURE 2. – PACIFIC OCEAN IMPACT TRAJECTORY GROUNDTRACK AND IIP – 1111 KM CIRCULAR ORBIT

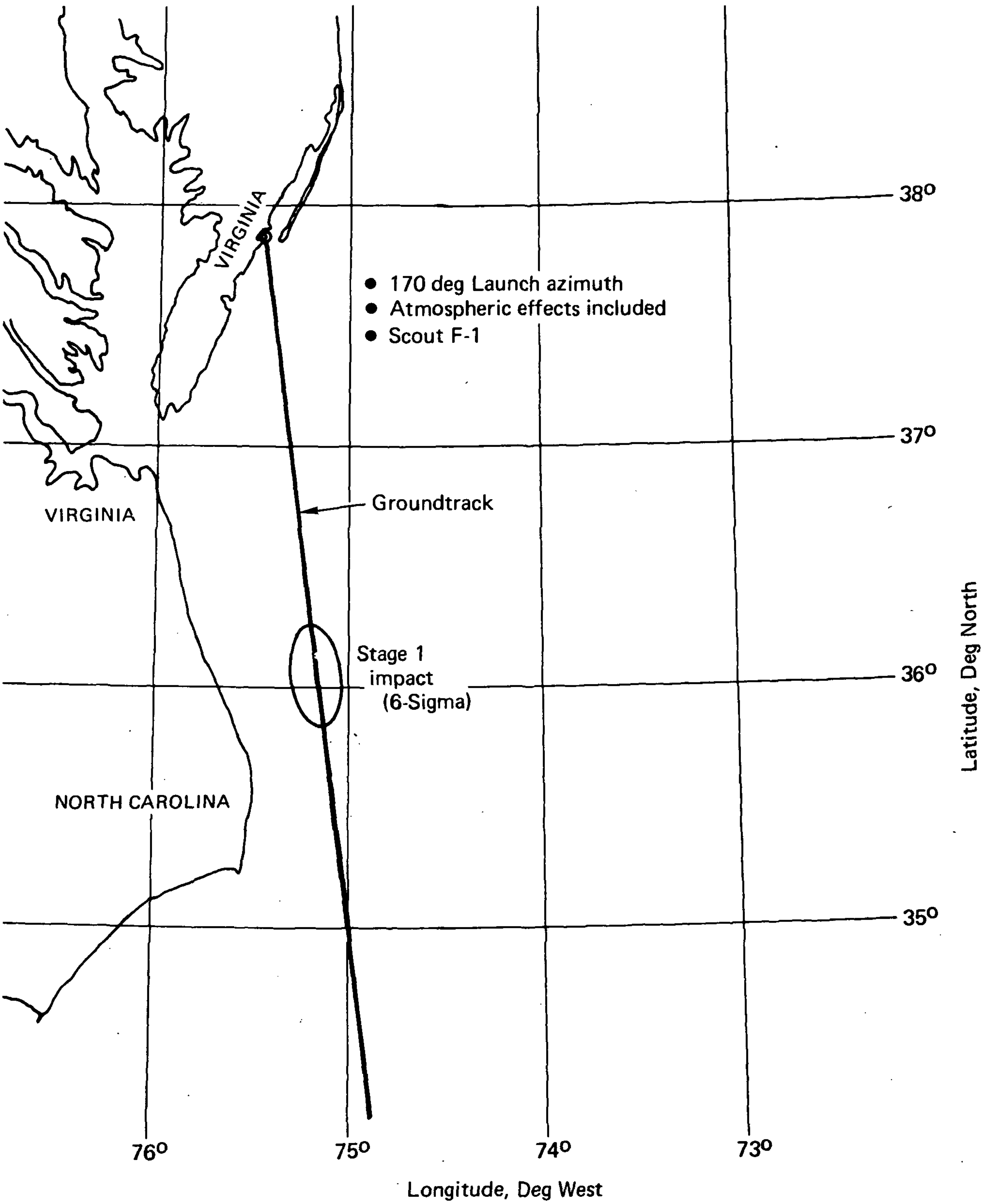


FIGURE 3. – FIRST STAGE IMPACT AREA AND GROUNDTRACK – 1111 KM CIRCULAR ORBIT

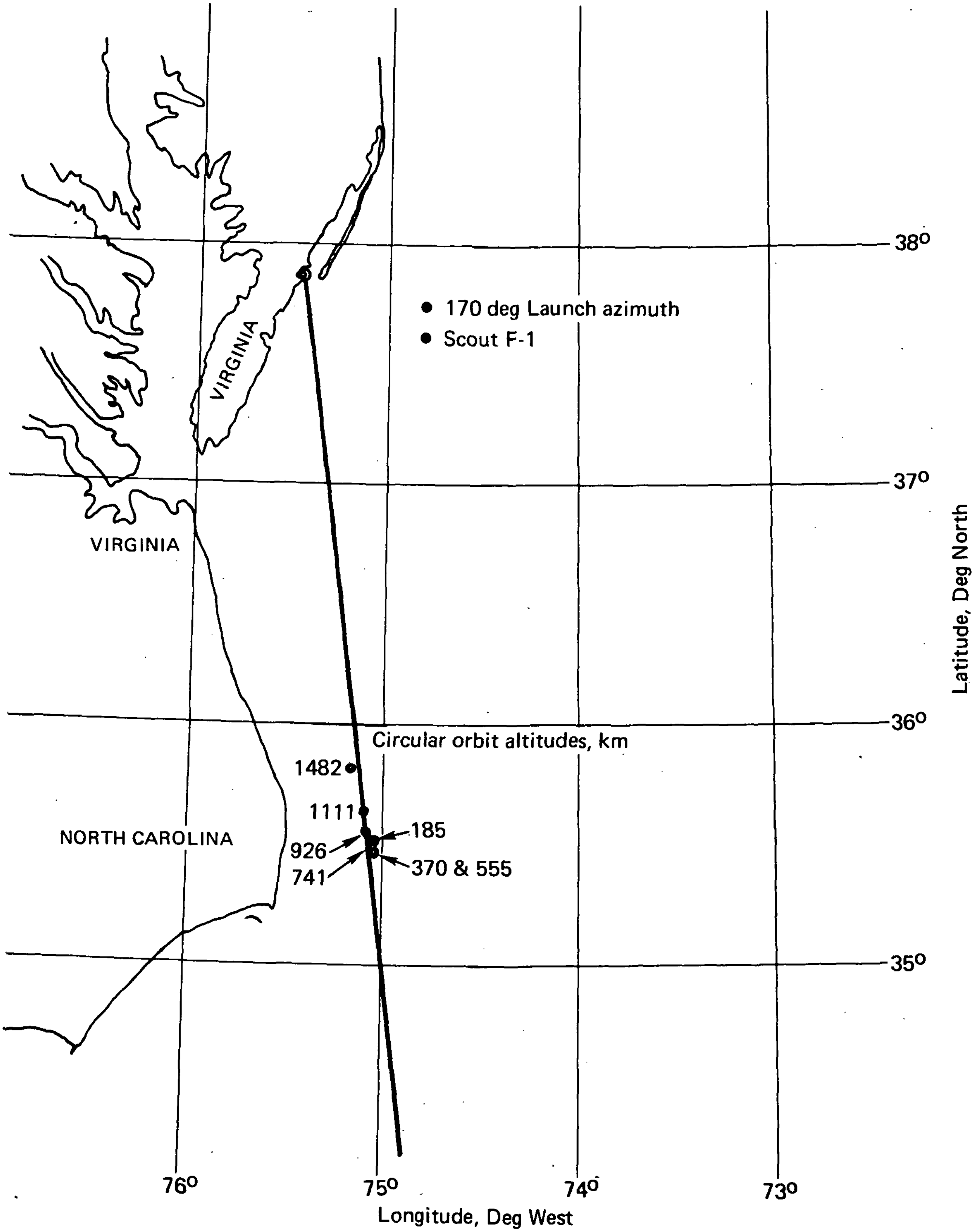


FIGURE 4. – FIRST STAGE VACUUM IMPACT LOCATION

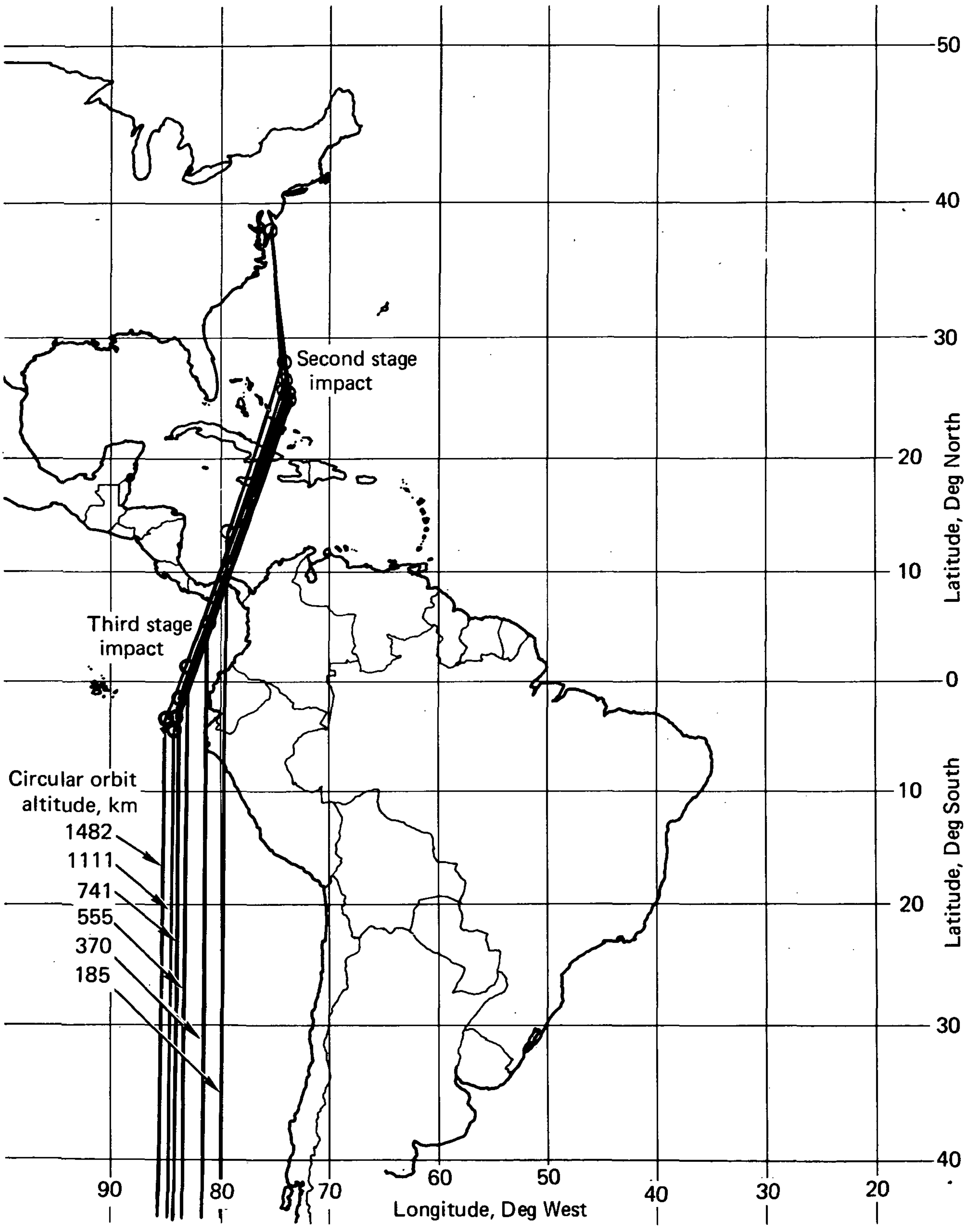


FIGURE 5. – STAGE IMPACT LOCATIONS AND IIP FOR VARIOUS CIRCULAR ORBITS

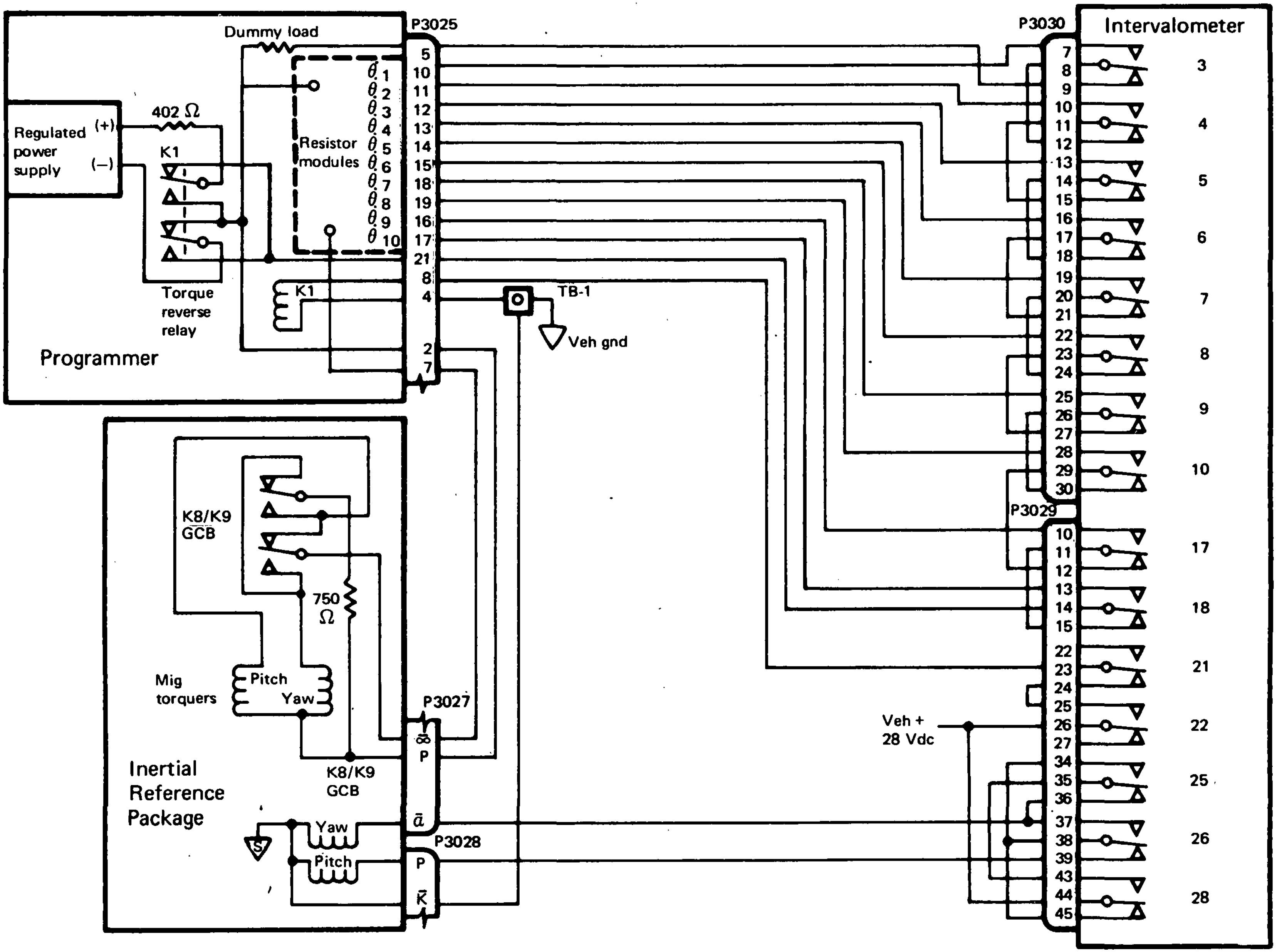


FIGURE 6. – VEHICLE WIRING FOR TWO NON-CONSECUTIVE YAW RATE STEPS

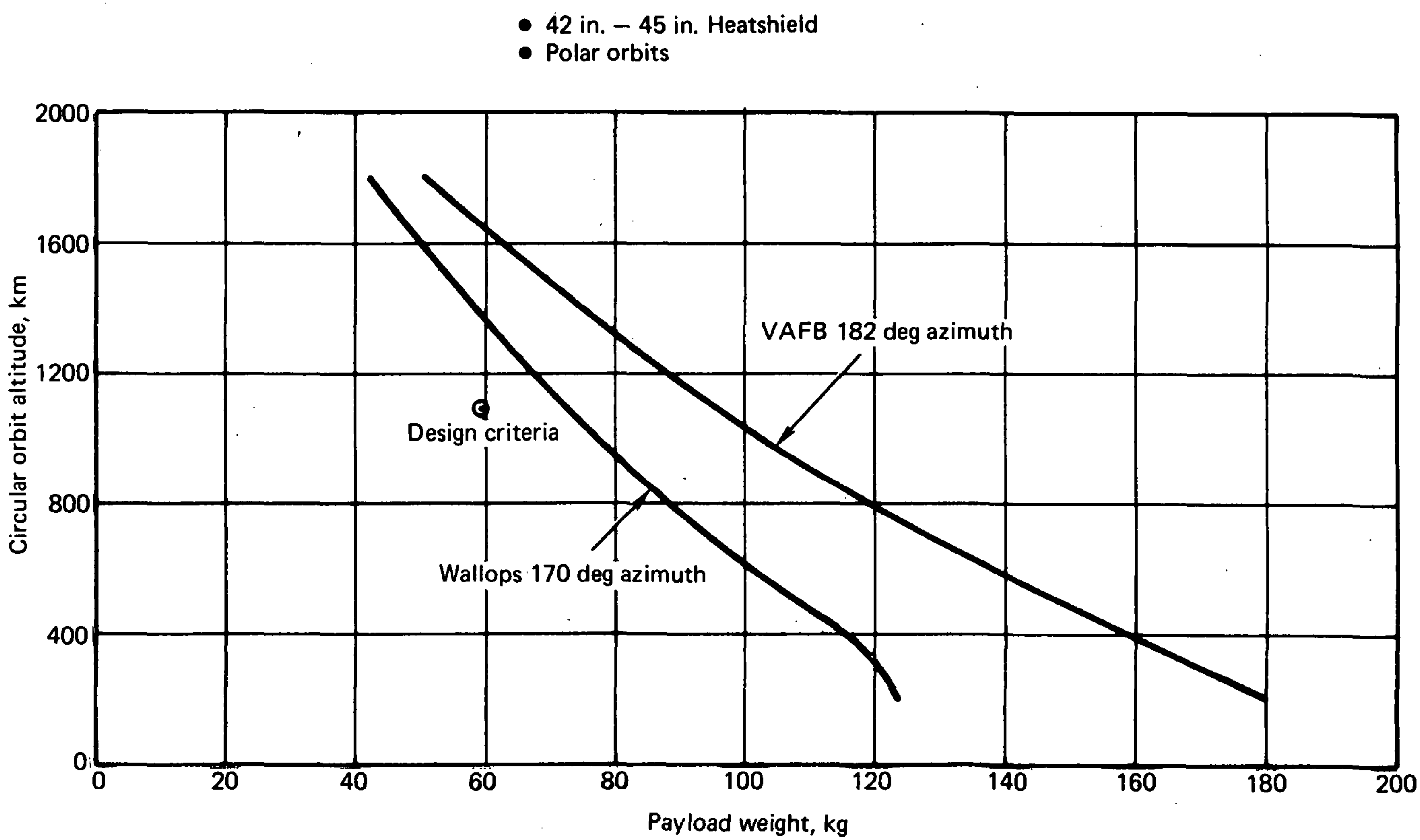


FIGURE 7. – CIRCULAR ORBIT PERFORMANCE CAPABILITY SCOUT F-1

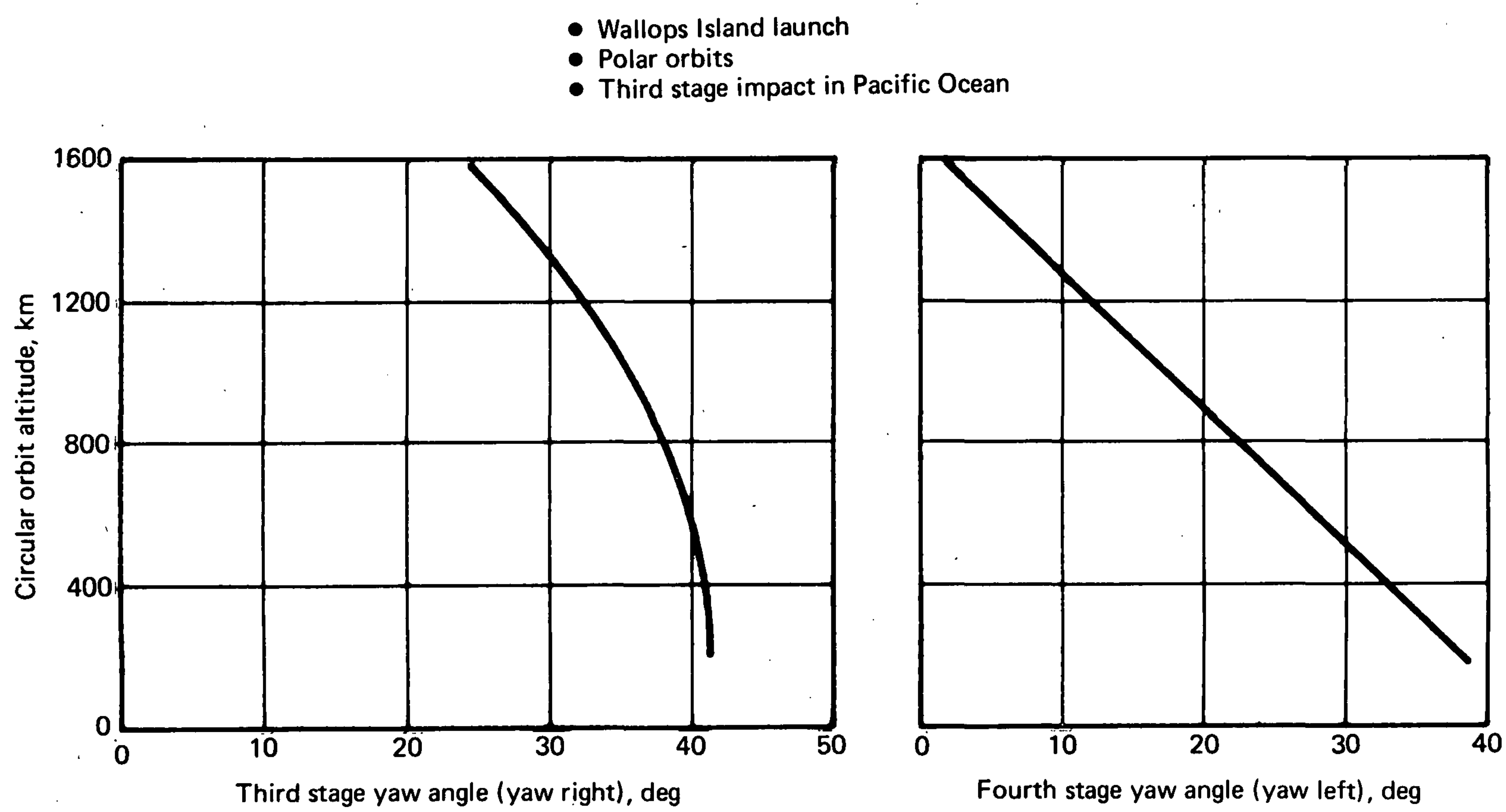
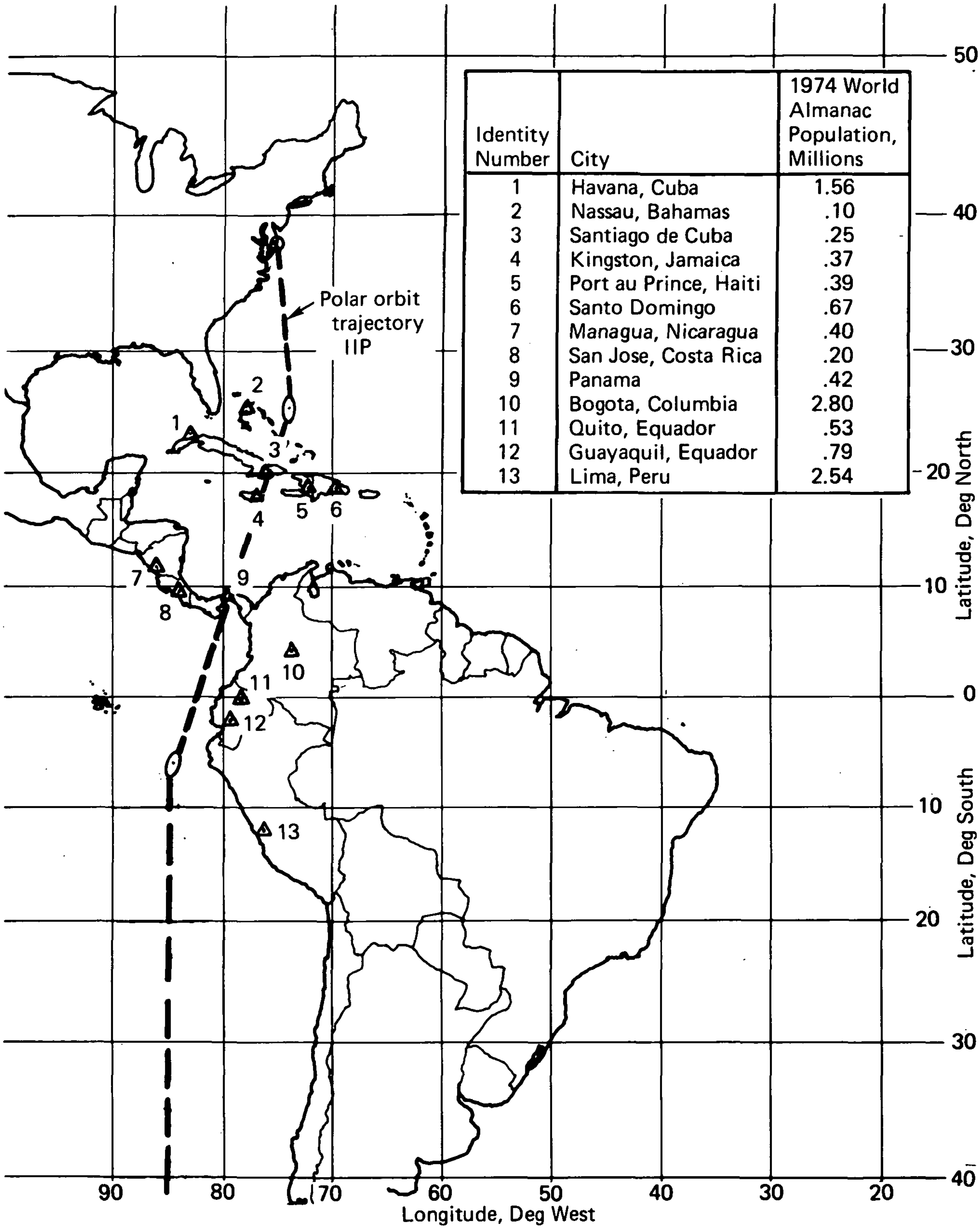


**FIGURE 8. – YAW MANEUVER ANGLES
SCOUT F-1**



Identity Number	City	1974 World Almanac Population, Millions
1	Havana, Cuba	1.56
2	Nassau, Bahamas	.10
3	Santiago de Cuba	.25
4	Kingston, Jamaica	.37
5	Port au Prince, Haiti	.39
6	Santo Domingo	.67
7	Managua, Nicaragua	.40
8	San Jose, Costa Rica	.20
9	Panama	.42
10	Bogota, Columbia	2.80
11	Quito, Equador	.53
12	Guayaquil, Equador	.79
13	Lima, Peru	2.54

FIGURE 9. – LARGE CITY POPULATION IN THE VICINITY OF CENTRAL AMERICA

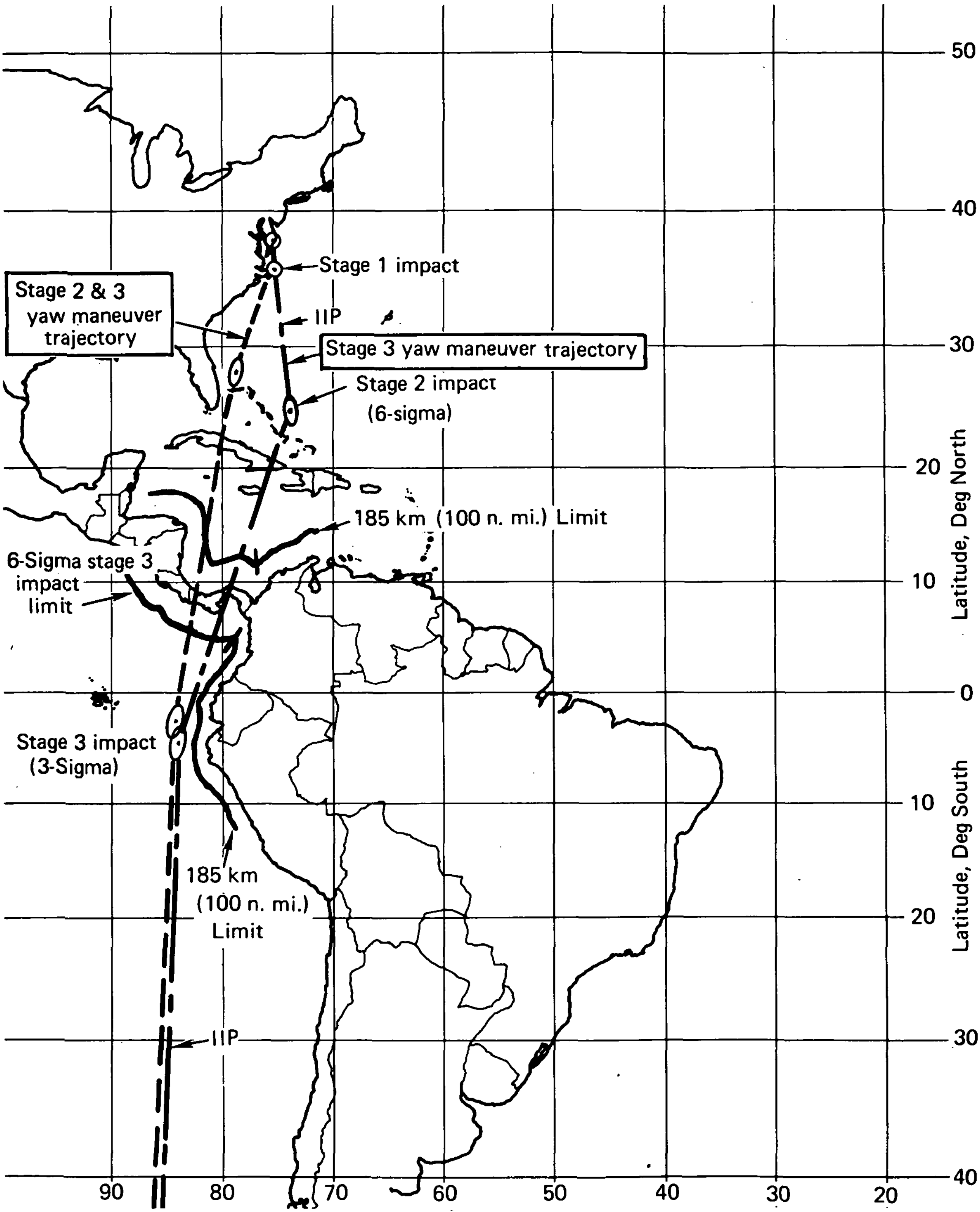


FIGURE 10. – COMPARISON OF POLAR ORBIT TRAJECTORY IIP

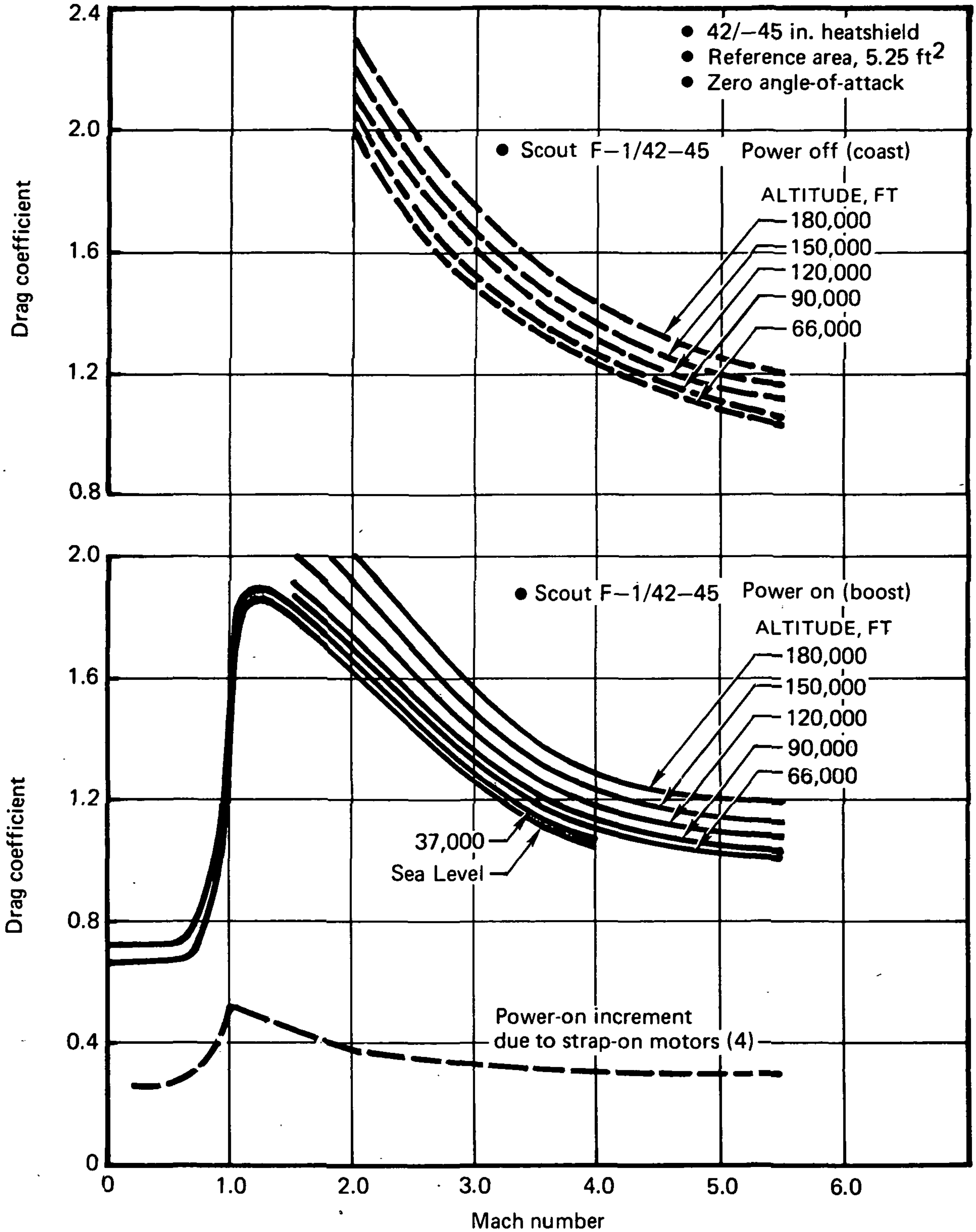


FIGURE 11. – DRAG COEFFICIENT SCOUT F–1

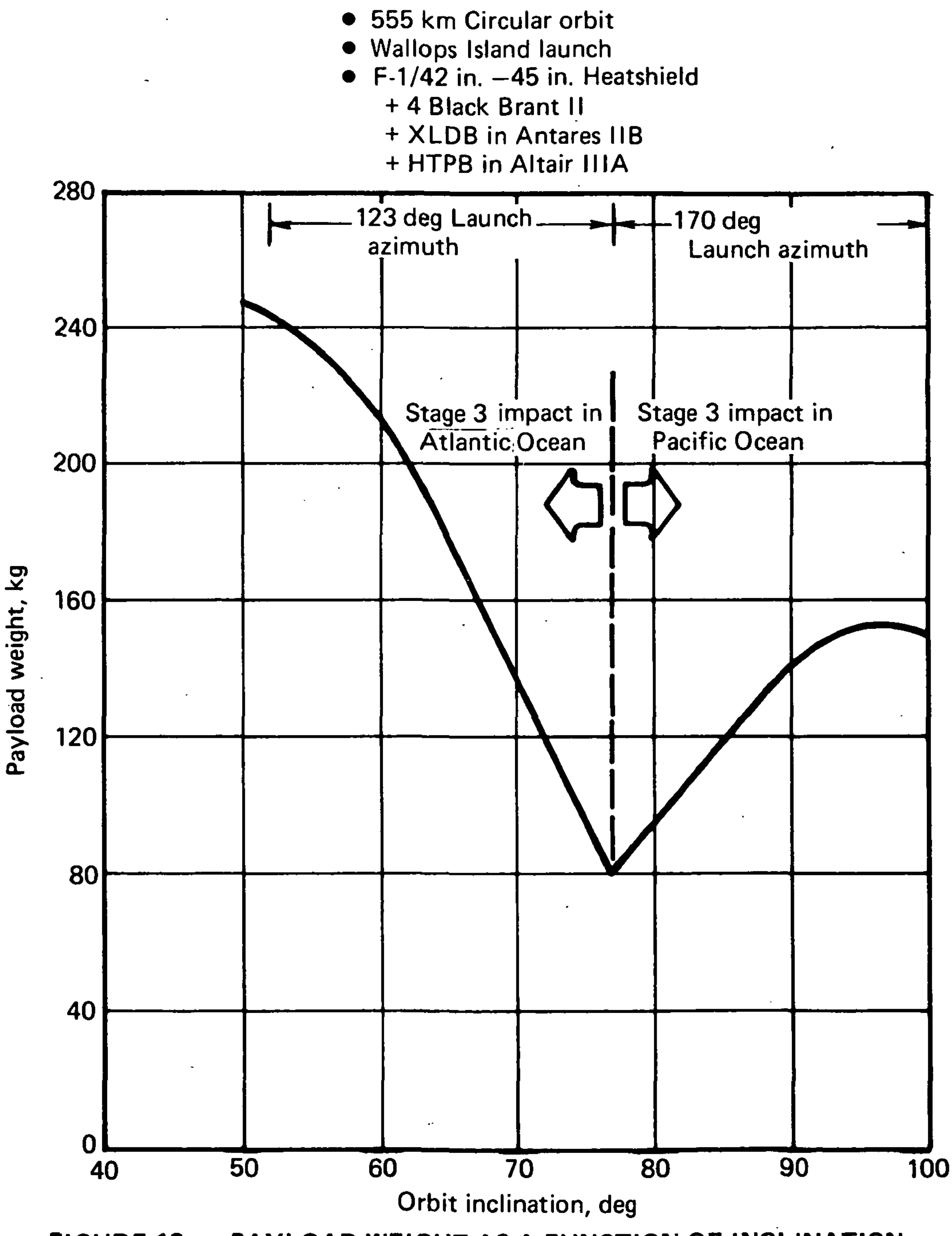


FIGURE 12. – PAYLOAD WEIGHT AS A FUNCTION OF INCLINATION IMPROVED SCOUT CONFIGURATION

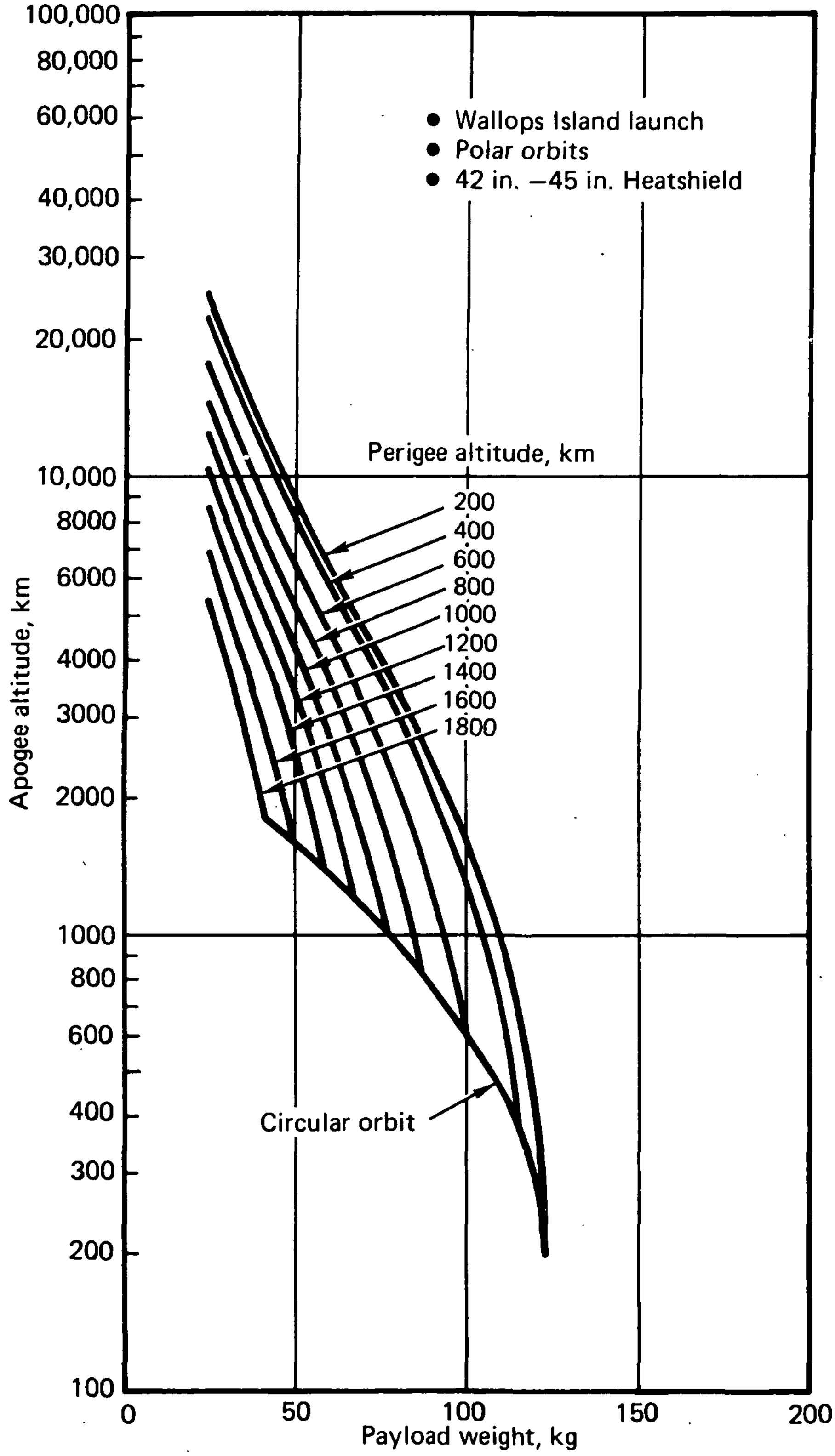


FIGURE 13. – GENERAL ELLIPTICAL ORBIT PERFORMANCE SCOUT F-1

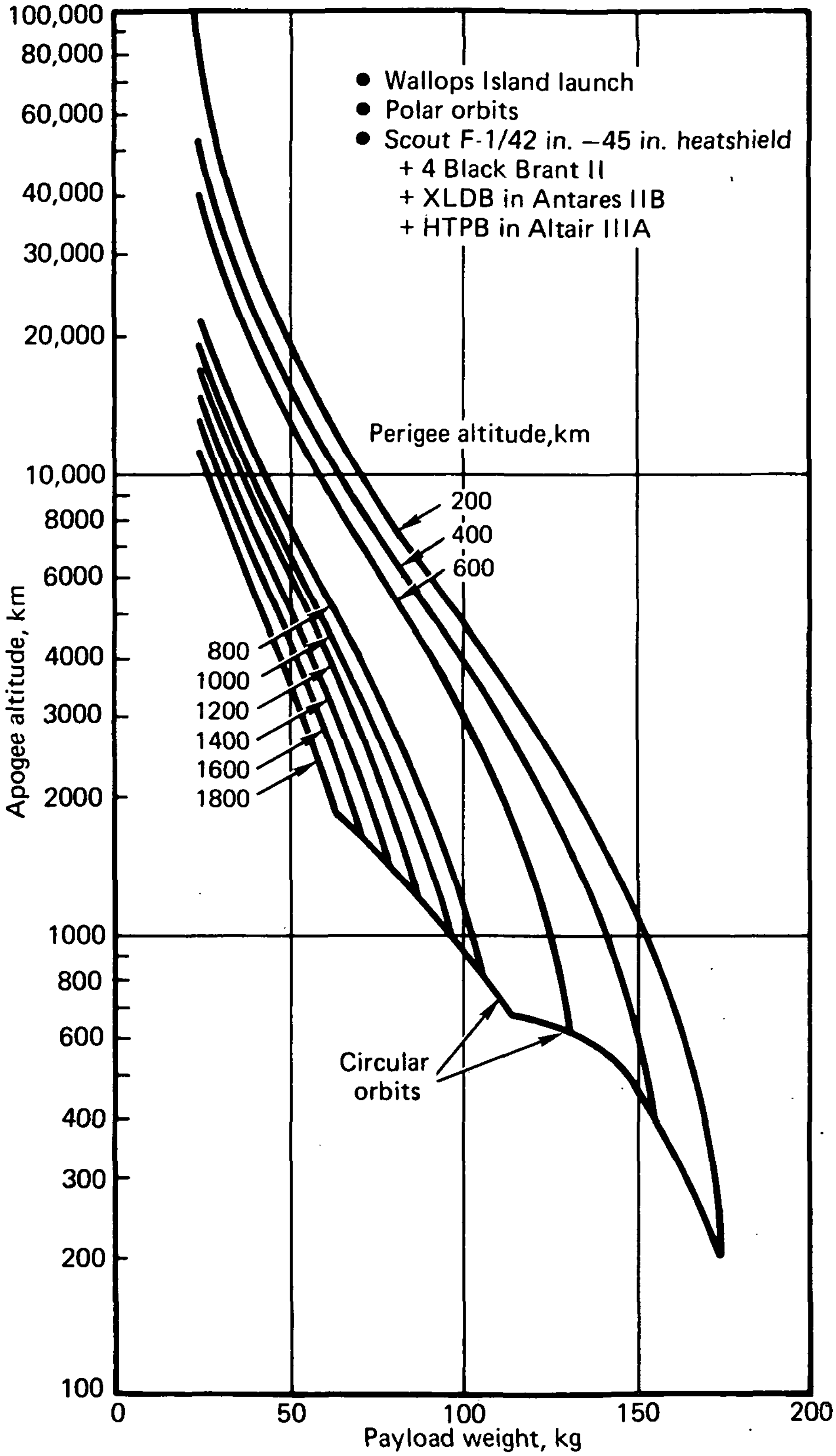


FIGURE 14. – GENERAL ELLIPTICAL ORBIT PERFORMANCE IMPROVED SCOUT CONFIGURATION

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—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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