CR 54633

[redacted]

N66-22931
(ACCESSION NUMBER)

27
(PAGES)

CR-54633
(NASA CR OR TMX OR AD NUMBER)

(THRU)

1
(CODE)

30
(CATEGORY)

FACILITY FORM 602

[redacted]

GENERAL DYNAMICS

Convair Division

GPO PRICE $ ____

CFSTI PRICE(S) $ ____

Hard copy (HC) 2.00

Microfiche (MF) .50

ff 653 July 65

[redacted]

A2136-1 (REV. 5-65)

[redacted]

A PRELIMINARY ANALYSIS OF DIRECT-ASCENT LAUNCH WINDOW EXTENSION USING A DOGLEG MANEUVER

28 May 1965

GD|C-BTD65-095

Contract NAS3-3232

Prepared by G. Griffith

Checked by J. J. Andrews

Approved by H. B. Anthony
Research Group Engineer

Approved by R. S. Wentink
Assistant Chief Engineer
Centaur Design Analysis

GENERAL DYNAMICS | CONVAIR

[redacted]

FOREWORD

This report presents data showing the effect of executing a dogleg maneuver on the Surveyor direct-ascent launch window lengths and the instantaneous impact point earth traces. The intent of this study is to establish the potential gain in launch window obtainable by using this maneuver.

SUMMARY

N66-22931

This study shows that from the performance standpoint it is possible to significantly increase the Surveyor direct-ascent launch window time by executing a dogleg maneuver at BECO after the 114-degree launch azimuth limit has been reached. The precise increase in launch window time is principally a function of payload weight and lunar declination at impact. Data is included (Figure 1) which shows that for a 2186-pound payload, launch windows can be extended by 11.8, 16.0, and 25.5 minutes for lunar declinations of -24.5, -22.1, and -18.6 degrees, respectively. However, the dogleg maneuver can cause the instantaneous impact point trace to cross downrange land areas and may require the validation of guidance equation constants to ensure that the desired lunar impact conditions are maintained. Additional investigation is required to determine the effect of this maneuver on guidance internal scaling.

Author

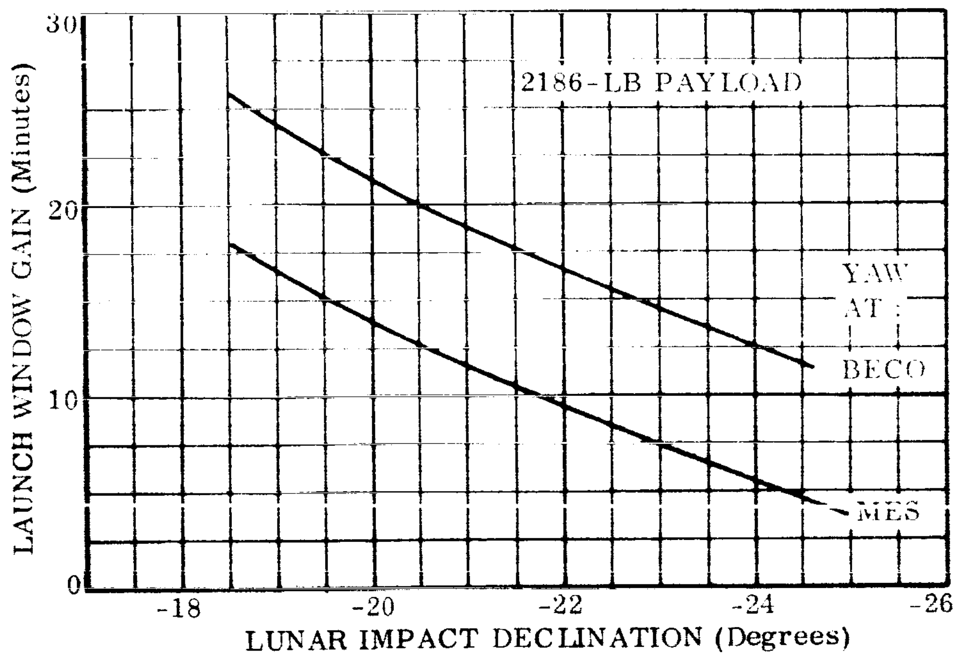


Figure 1. Launch Window Time Increase Due to Dogleg Maneuver

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF SYMBOLS

BECO	Atlas booster engine cutoff
FPR	Propellant flight performance reserve
MES	Centaur main engine start
Σ_L	Launch azimuth (east of north)

SECTION 1

INTRODUCTION

Operational, direct-ascent, Atlas/Centaur/Surveyor vehicles have launch windows that are defined by launch azimuth limits and payload weight. It is typical for a launch window to be constrained at the start by the payload weight requirement and at the end by the maximum launch azimuth limit (currently 114 degrees). If the launch azimuth is extended beyond 114 degrees, range safety could be violated by the normal jettisoning of hardware prior to Centaur ignition.

The purpose of this study is to investigate the practicability of using the excess performance capability available at the 114-degree launch azimuth limit to perform a downrange dogleg maneuver (which avoids the range safety problem associated with normal jettisoning at higher launch azimuths) in order to extend the launch window. The effect of the dogleg maneuver on the launch window, instantaneous impact point, and lunar impact conditions are considered.

SECTION 2

DISCUSSION

The AC-7 vehicle described in Reference 1 was selected for the basis of this study. The AC-7 vehicle will launch a 2186-pound spacecraft, targeted to impact the moon as shown in Table 1. These three days were selected for this study because the range of lunar declination is typical of direct-ascent launch opportunities.

Table 1. Targeted Impact Conditions

LAUNCH DATE	IMPACT DECLINATION	LUNAR IMPACT LATITUDE (deg)	LUNAR IMPACT LONGITUDE (deg)	LUNAR IMPACT VELOCITY* (m/s)
10/1/65	-24.5°	-1.20	350.08	2682
10/2/65	-22.1°	+1.03	346.92	2682
10/3/65	-18.6°	-3.75	337.25	2682

* unbraked speed

The launch window for each day is defined by the 2186-pound payload weight and the acceptable launch azimuth range, which extends from 90 degrees to 114 degrees. This study utilized the precision trajectory program (Reference 2) to simulate targeted trajectories for the above launch dates.

Three closed-loop guidance modes were considered. Initially, the launch azimuth was extended past the current 114-degree limit. Next, the maximum launch azimuth was held constant at 114 degrees and a dogleg maneuver was executed at booster engine cutoff. Finally, the maximum launch azimuth was held constant at 114 degrees and yaw steering was locked out until Centaur main engine start (dogleg at MES).

SECTION 3

RESULTS

3.1 PERFORMANCE. The performance aspects of this study are illustrated in Figures 2, 3, and 4 which present payload capability as a function of launch time for the three lunar impact declinations. Time is normalized to the opening of the window. Each window is currently closed by the 114-degree launch azimuth restriction with excess performance capability. These data are extended by either maintaining the launch azimuth constant at 114 degrees and closing the guidance loop at either BECO or MES (shown as a dashed line), or by increasing the maximum launch azimuth. The resulting window extensions, given in Table 2, are illustrated in Figure 1.

Table 2. Launch Windows

LAUNCH DATE	MAXIMUM WINDOW (MINUTES)			
	REFERENCE	EXTENDED AZIMUTH LIMITS	GUIDANCE LOOP CLOSED AT	
			MES	BECO
10/1/65	68.2	85.8	72.6	80.0
10/2/65	41.7	73.3	50.7	57.7
10/3/65	4.0	58.2	21.5	29.5

It is evident from Table 2 that the yaw maneuver is most effective where it is needed most; i.e., at the end of the launch period.

There are three other aspects of this problem to be considered. They include:

a. Effect on range safety.

b. Effect on lunar impact conditions.

c. Effect on guidance internal scaling.

The first and second items will be discussed next. The third item is beyond the scope of this preliminary study.

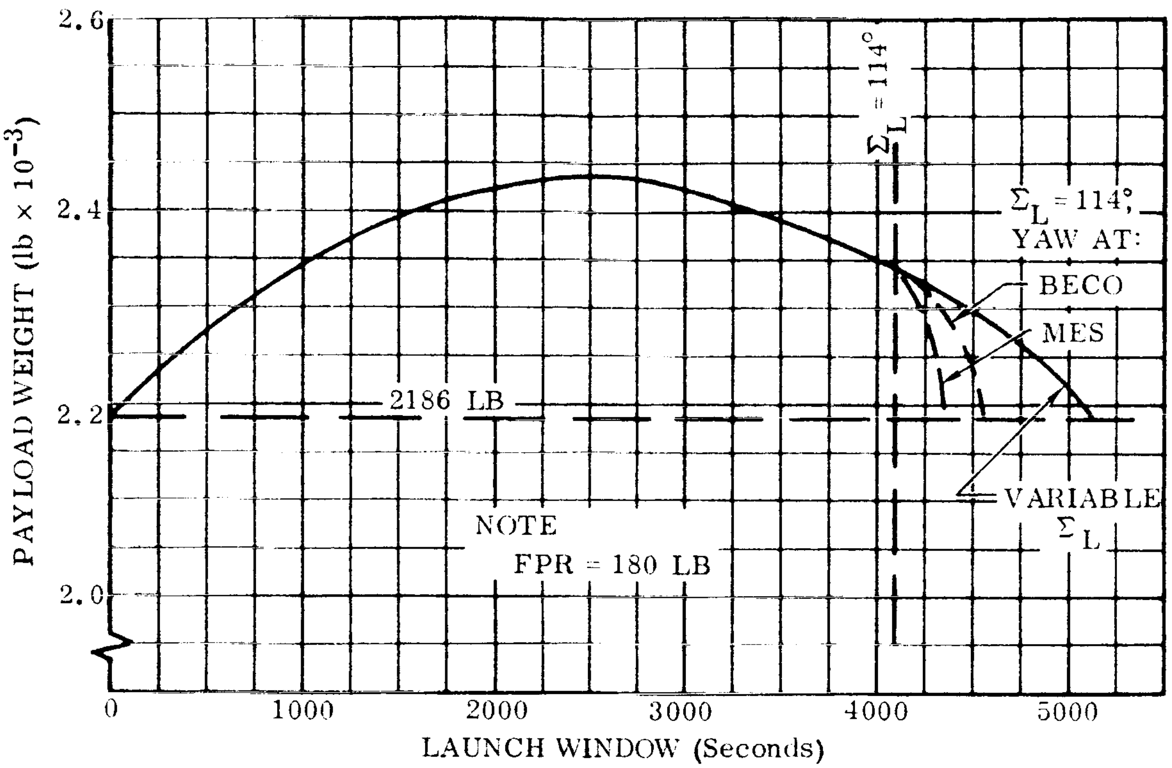


Figure 2. Launch Window for 1 October 1965
(Impact Declination = - 24.5°)

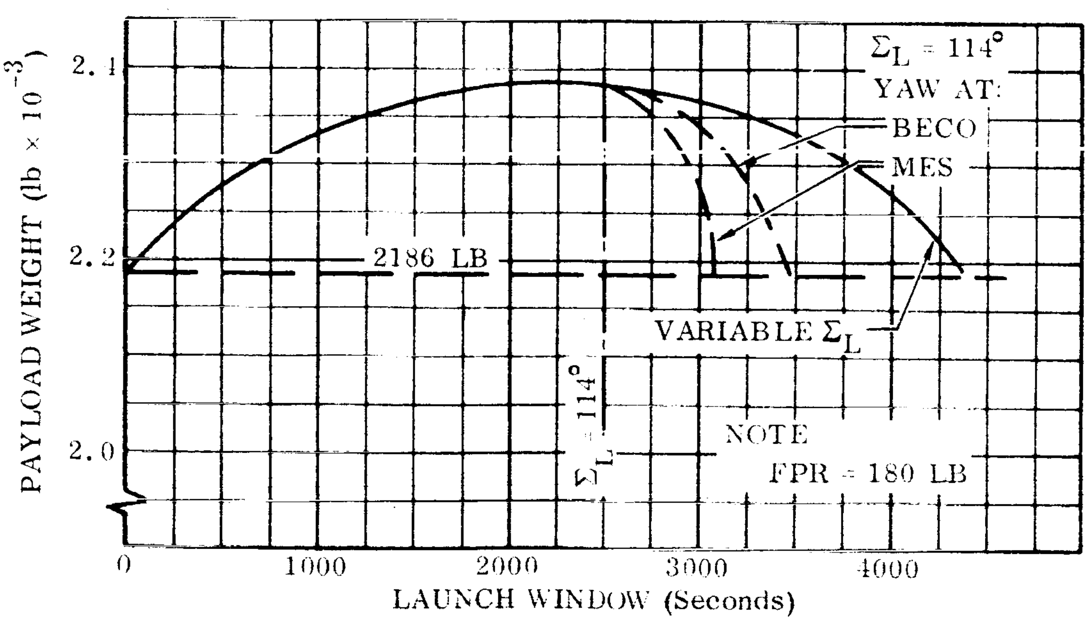


Figure 3. Launch Window for 2 October 1965
(Impact Declination = - 22.1°)

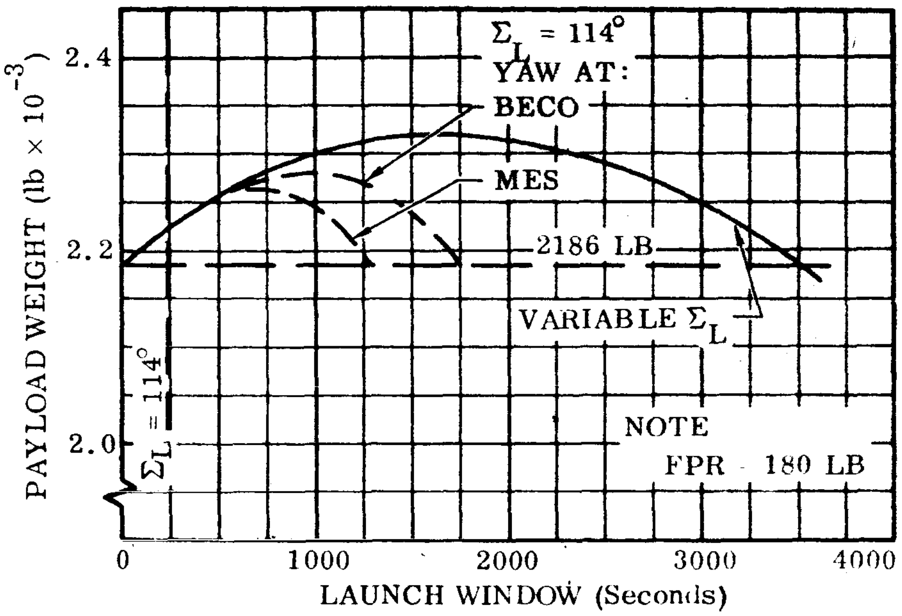
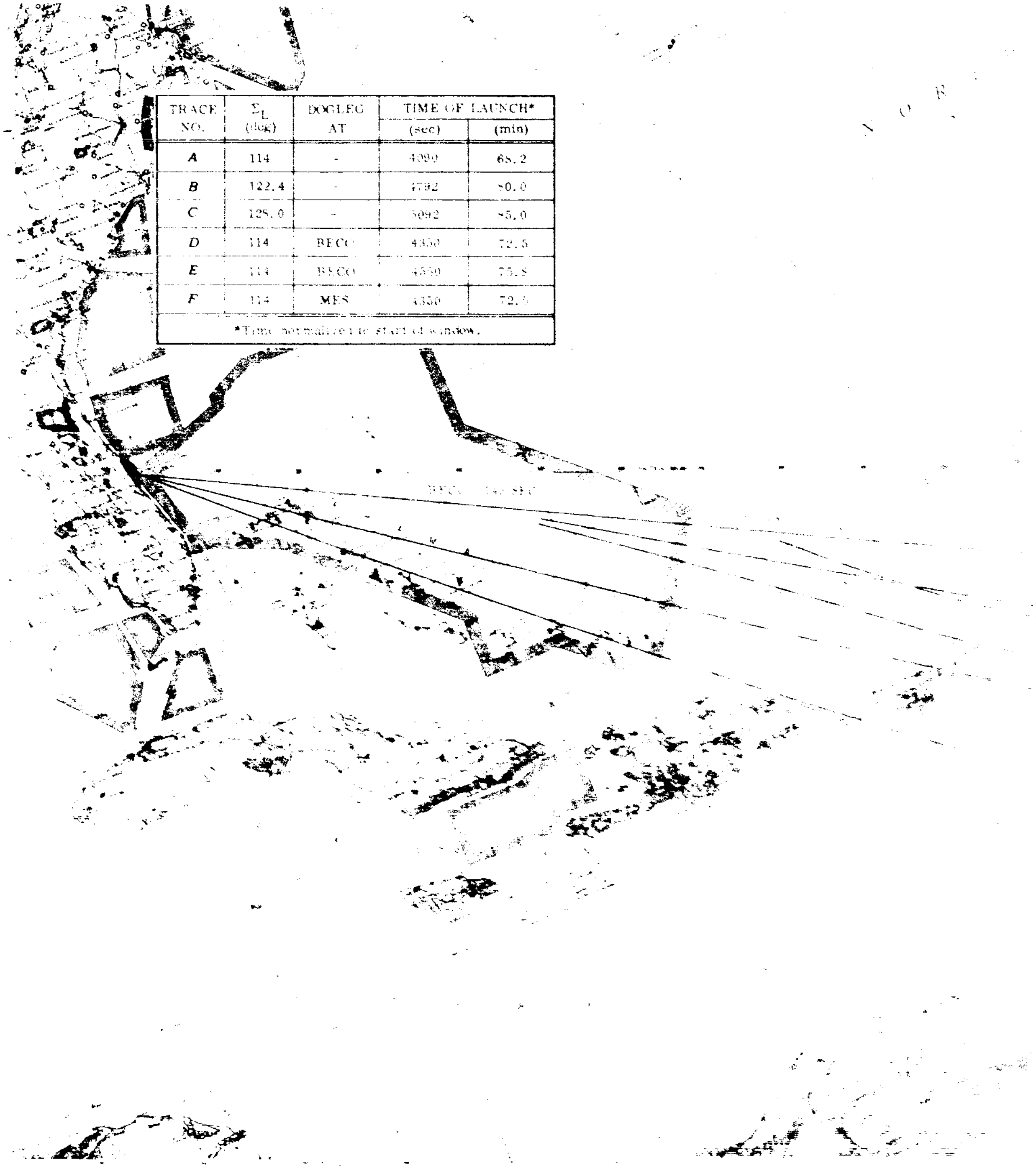


Figure 4. Launch Window for 3 October 1965
(Impact Declination = - 18.6°)

3.2 RANGE SAFETY. Figures 5, 6, and 7 present traces of the instantaneous impact points for trajectories that extend the launch window beyond the nominal 114-degree launch azimuth limit. The most northerly trace on each figure corresponds to the nominal 114-degree launch azimuth trajectory. Flight time increments which are noted on this trace are characteristic of all trajectories. These data show that there is a possibility of impacting in the area of the Bahama Islands or Puerto Rico when the launch azimuth is increased appreciably beyond 114 degrees. Even more significant is the fact that normal jettisoning of the booster, insulation panels, and nose fairing will occur over the Bahama Islands. This is not the case when the window is extended by executing a dogleg maneuver at either BECO or MES. However, any extensive increase in launch window can result in the impact trace crossing the larger islands of the Lesser Antilles, and portions of South America. Still, the 3 October window can be significantly increased with very little intrusion of the trace on land areas.

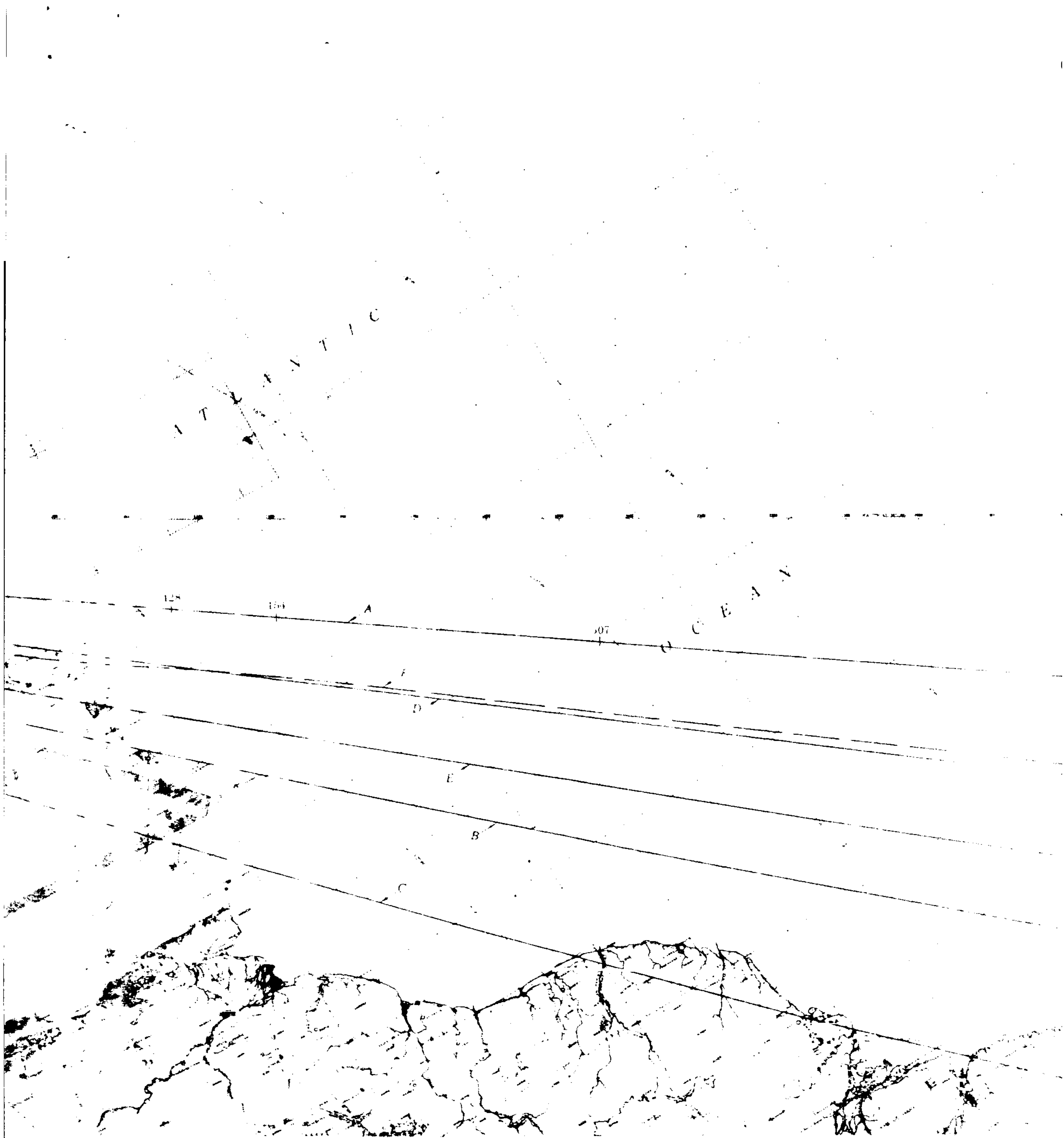
The South American overflights may not be critical from the range safety viewpoint due to short impact dwell time and sparse population. Additional investigation of the South American overflight, with emphasis on the kill probability aspect of range safety, is warranted.



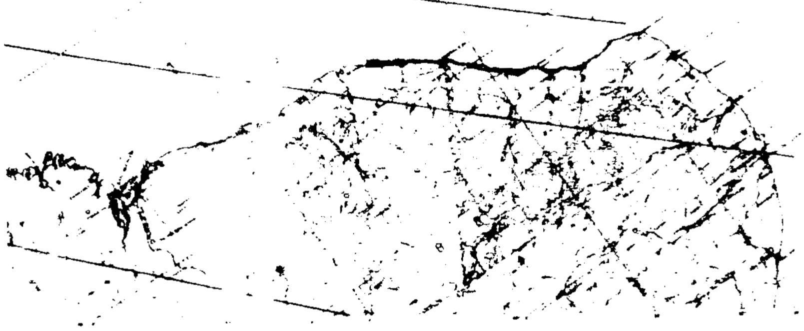
TRACE NO.	Σ_L (deg)	DOGLEG AT	TIME OF LAUNCH* (sec)	(min)
A	114	-	4090	68.2
B	122.4	-	4792	80.0
C	125.0	-	5092	85.0
D	114	BECO	4350	72.5
E	114	BECO	4550	75.8
F	114	MES	4350	72.5

*Time normalized to start of window.

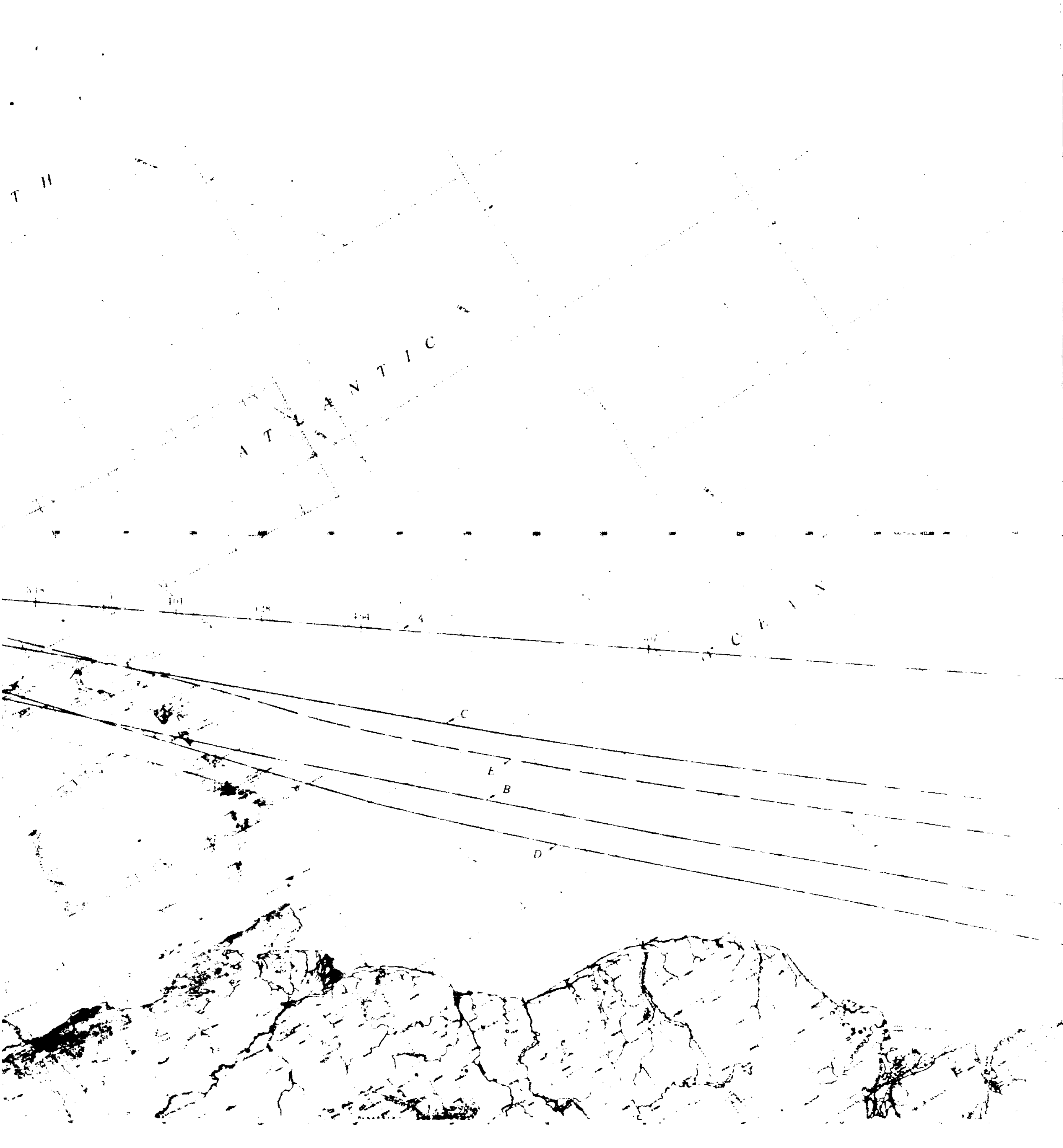
Figure 5. Instantaneous Impact Point Trace for 1 October 1965 Launch



2




BECO



2

TRACE	Σ_L (deg)	DOGLEG AT	TIME OF LAUNCH*	
			(sec)	(min)
A	114	-	2500	41.7
B	122.4	-	3460	57.7
C	114	BECO	3000	50.9
D	114	BECO	3400	56.7
E	114	MES	3000	50.0

*Time normalized to start of window.

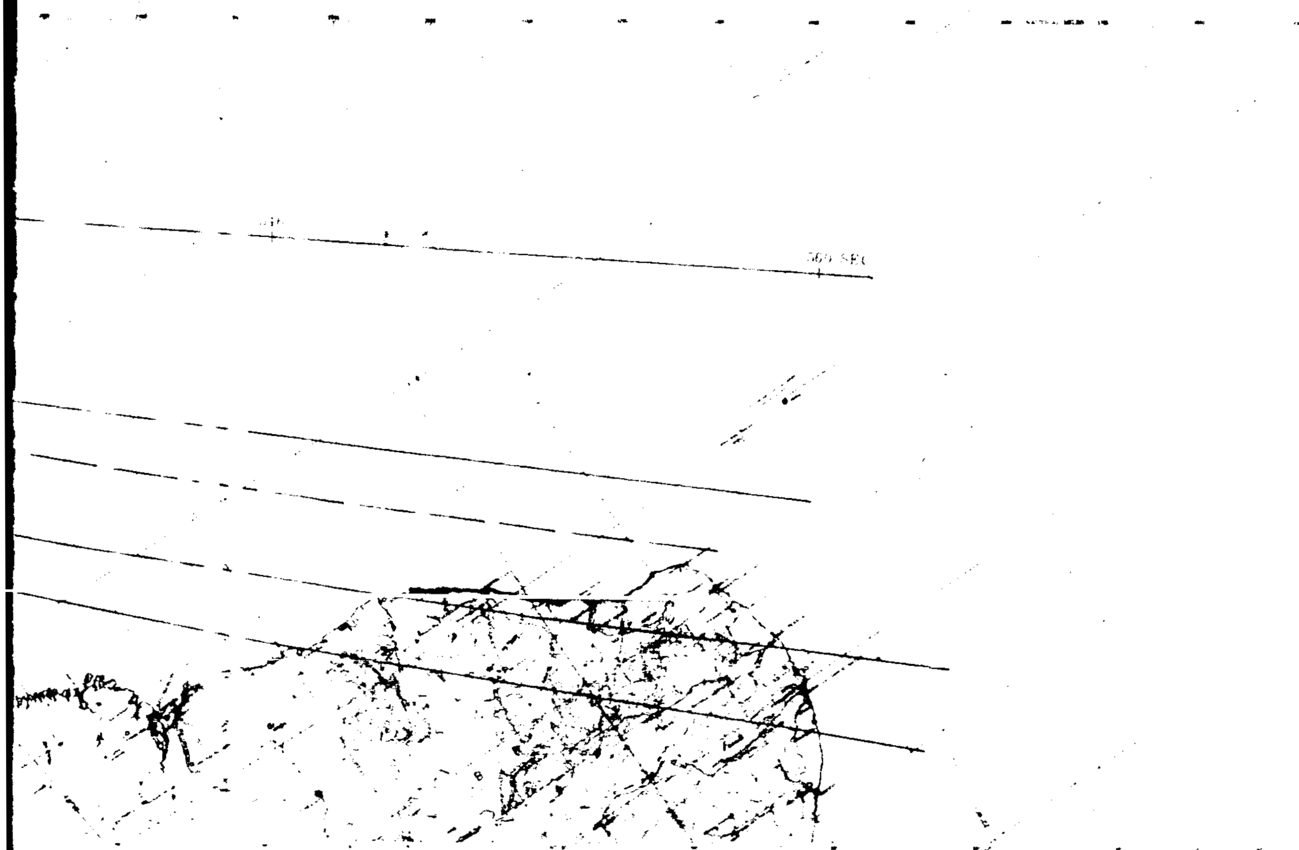
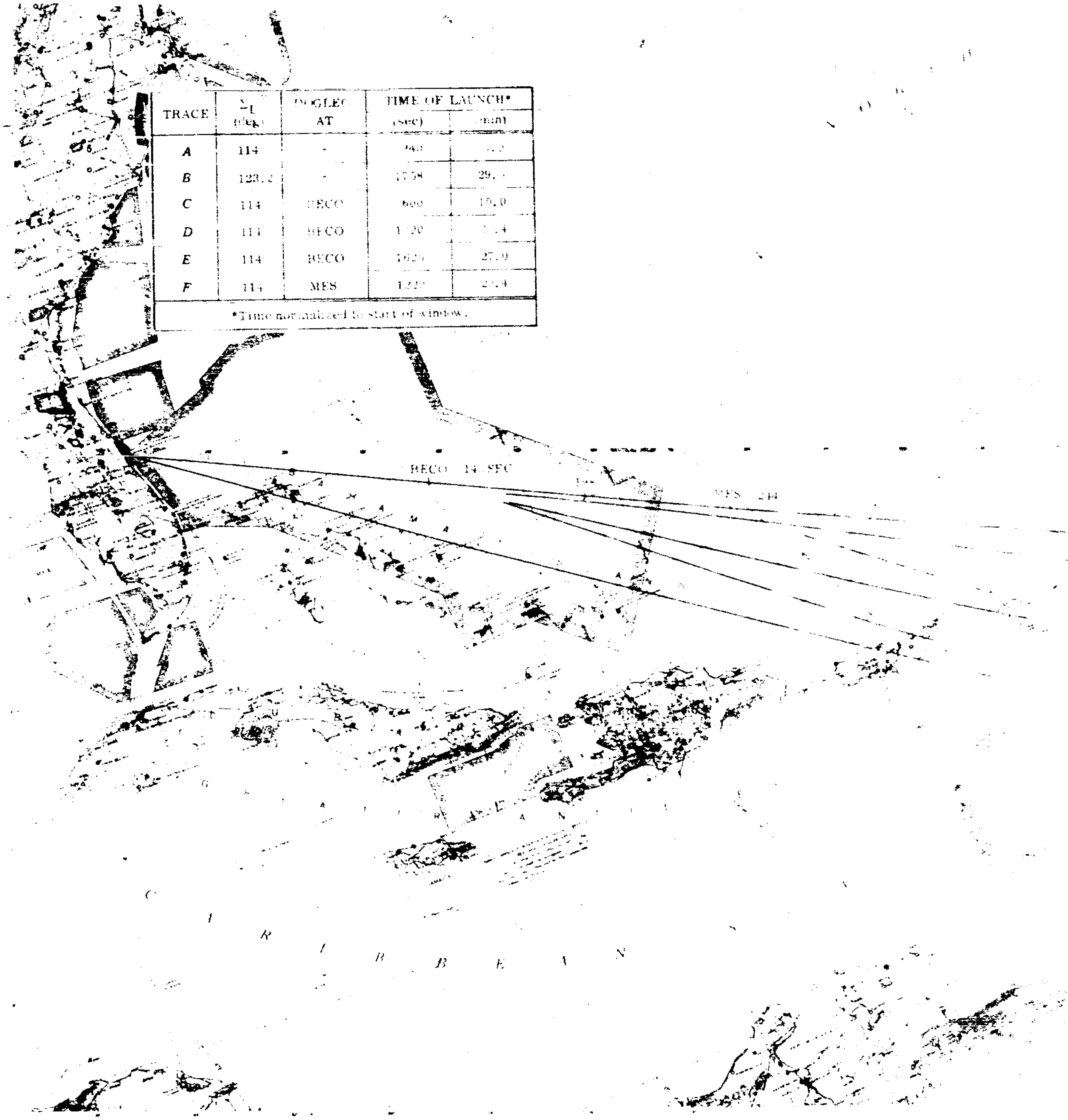


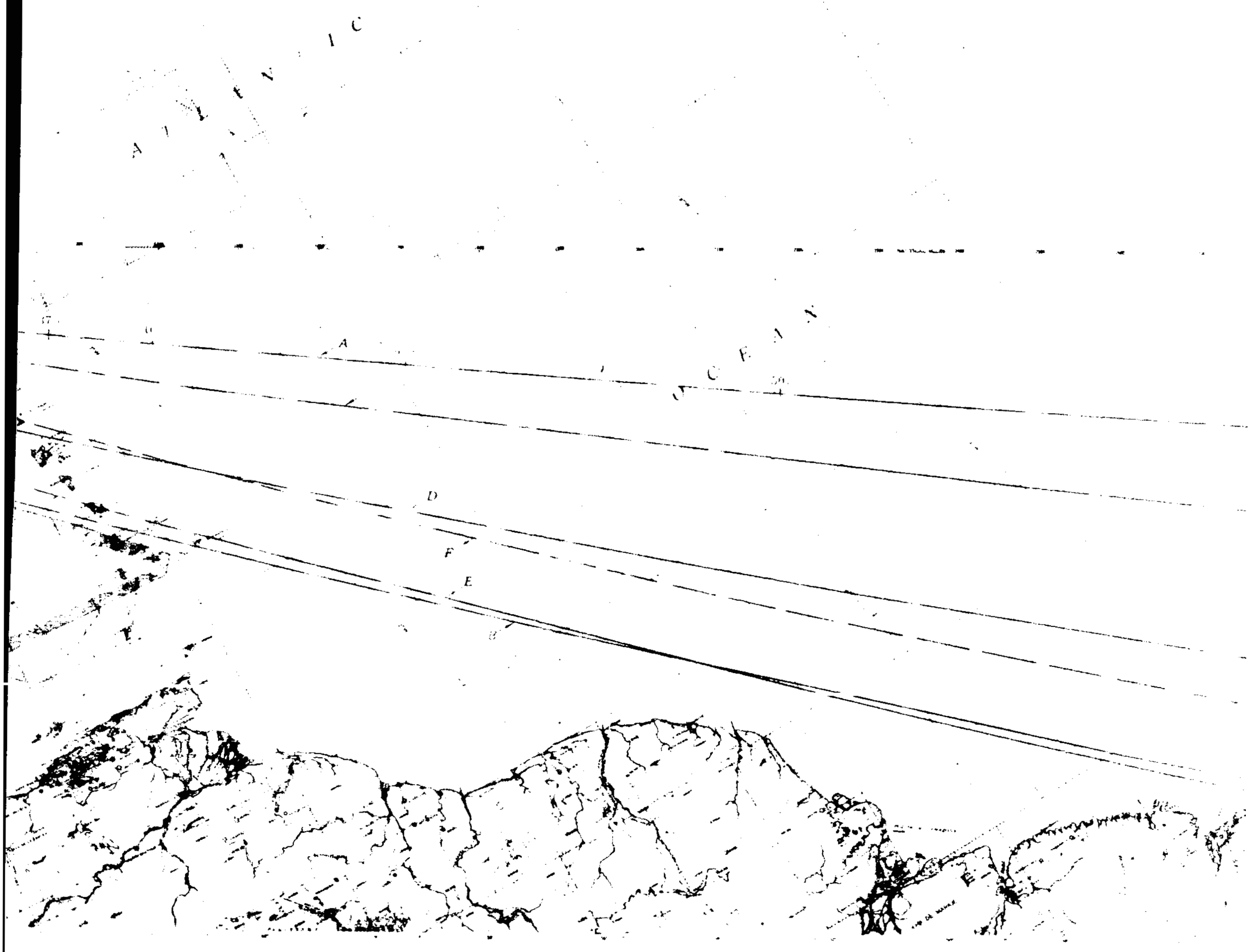
Figure 6. Instantaneous Impact Point Trace for 2 October 1965 Launch



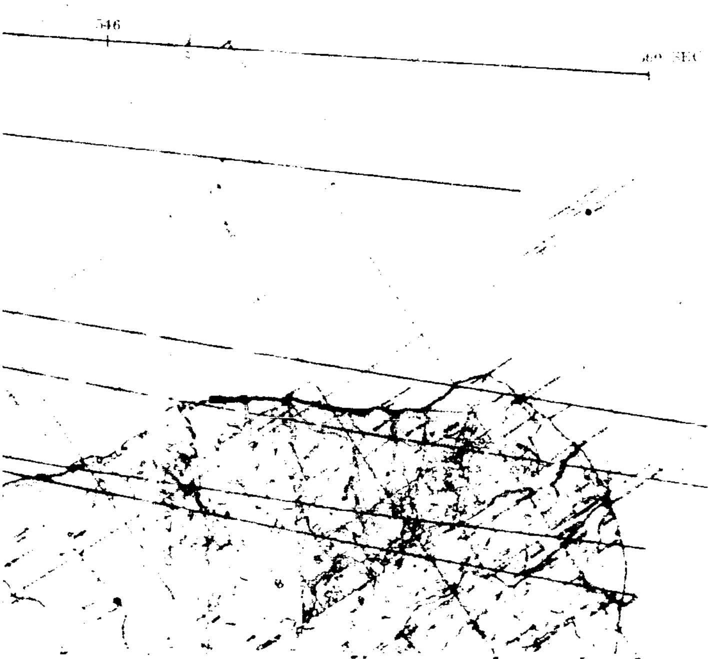
TRACE	Σ_I (deg)	DOGLEG AT	TIME OF LAUNCH* (sec)	(min)
A	114	-	[illegible]	[illegible]
B	123.2	-	1758	[illegible]
C	114	RECO	[illegible]	10.0
D	114	BECO	[illegible]	[illegible]
E	114	BECO	[illegible]	27.9
F	114	MES	[illegible]	[illegible]

*Time normalized to start of window.

Figure 7. Instantaneous Impact Point Trace for 3 October 1965 Launch



2



3

3.3 LUNAR IMPACT CONDITIONS. Nominal lunar impact conditions were presented previously (Table 1). Table 3 presents the maximum dispersion from the nominal values caused by extending the launch window (dogleg at BECO) to the limit of the performance capability using current guidance constants. This table shows that it may be necessary to recalculate the closed-loop guidance equation constants in order to adequately cover the extended launch window times and maintain acceptable dispersion limits.

Table 3. Maximum Impact Dispersion for Dogleg at BECO

LAUNCH DATE	LUNAR IMPACT DISPERSION		
	LATITUDE (deg)	LONGITUDE (deg)	VELOCITY* (m/s)
10/1/65	1	2	1
10/2/65	2	2	2
10/3/65	2	4	2

* unbraked speed

SECTION 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS. From this analysis, the following is concluded.

a. The dogleg maneuver is an effective method of increasing the launch window time at both ends of a direct-ascent launch period.

b. Initiating the dogleg maneuver at BECO provides the best compromise between performance and range safety considerations.

4.2 RECOMMENDATIONS. As a result of this preliminary effort, it is recommended that studies be initiated to answer the following questions.

a. Are the current guidance equations valid for the extended launch windows?

b. Are range safety procedures violated by the proposed dogleg flights?

c. What are the impact and kill probabilities associated with these flights?

SECTION 5

REFERENCES

1. Centaur Monthly Configuration, Performance, and Weight Status Report (C). GDC63-0495-23, 21 April 1965.

2. Swanson, D. C., and Hoeft, R. F., Centaur Precision Targeting Program, GDA63-1356, 31 December 1963.

GENERAL DYNAMICS

Convair Division