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PRODUCTION VERIFICATION FLIGHT TEST PROGRAM FOR FLIGHT CONTROL SYSTEM, TARGET DRONE, USAF TYPE A/A37G-8

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TECHNICAL REPORT ASD-TR-73-19

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FOREWORD

This report was prepared by the Flight Control Division (ASD/ENFC), Directorate of Airframe Engineering, Deputy for Engineering, Aeronautical Systems Division, at Wright-Patterson AFB, Ohio. It describes tests conducted on the A/A37G-8 AFCS per contract No. F33657-71-C-0353 at Holloman AFB, New Mexico. The tests were carried out by the 6585th Test Group, Target Drone Division, HAFB and were supervised by the equipment contractor, Lear Siegler Inc/Astronics Division (LSI) at Santa Monica, California. The flight test work carried out on this contract was performed between September 1971 and May 1972. The manuscript was released by the authors in May 1973 for publication as a technical report.

The authors wish to express appreciation to Miss Fonda Lilly for her patience in preparing this report for publication.

This technical report has been reviewed and is approved.

ARTHUR L. MARTINSON
Chief, Flight Control Division
Directorate of Airframe Engineering

ABSTRACT

This report presents the description and results of the Production Verification Flight Test Program for the A/A37G-8 Automatic Flight Control System (AFCS) for the USAF and USN BQM-34A Target Drone. Identified as the "Versatile Automatic Flight Control System - VAFCS" by its manufacturer, Lear Siegler Incorporated/Astronics Division, Santa Monica, California, the A/A37G-8 AFCS was first procured as production hardware under USAF contract F33657-71-C-0353. This production verification flight test was performed at Holloman AFB to insure that the system performance realized with the prototype hardware was valid for the production hardware. During September 1971 through May 1972, the AFCS was flown in BQM-34A Target Drones as a Class II modification over all ranges of altitude, airspeed and basic maneuverability which can be achieved by the BQM-34A. In addition, the Increased Maneuverability Kit (IMK) mode was flown. Based on the testing performed and the minor modifications made necessary by these tests, the A/A37G-8 AFCS was shown to be capable of performing the flight control function in an acceptable manner and should prove to be satisfactory GFAE flight control system for the BQM-34A Target Drone.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS AND GRAPHS

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

Symbols

β	Sideslip Angle
C_{l_β}	Rolling moment coefficient with variation in side-slip angle or "effective dihedral derivative"
δ_a	Aileron deflection
δ_e	Elevator deflection
g	Acceleration level (1g = 32.2 ft/sec^2)
ϕ	Roll Angle
θ	Pitch angle
K	Thousand

Abbreviations

AFB	Air Force Base
AFCS	Automatic Flight Control System
AGE	Aeronautical Ground Equipment
AIM	Advanced Increased Maneuverability
ASD	Aeronautical Systems Division
BAO	Bank Angle Override
FCB	Flight Control Box
FCS	Flight Control System
GFAE	Government Furnished Aeronautical Equipment
G-8	A/A37G-8 AFCS
HAFB	Holloman Air Force Base
IAS	Indicated Airspeed
IMK	Increased Manueverability Kit or Mode
ITCS	Integrated Target Command System

KIAS	Indicated Airspeed, in Knots
LSI	Lear Siegler Incorporated
Lt	Left turn
LOC	Loss of Carrier
MSL	Altitude above Mean Sea Level
RAD	Required Action Document
R&D	Research and Development
RALACS	Radar Altimeter Low Altitude Control System
RPM	Revolutions Per Minute
Rt	Right turn
S&L	Straight and Level
TMCB	Telemetry Calibration Box
TMCS	Telemetry Signal Conditioner and Calibration System
TMCU	Telemetry Signal Conditioner Unit
T.O.	Technical Order
TRA	Teledyne Ryan Aeronautical Inc.
UMR	Unsatisfactory Material Report
USAF	United States Air Force
VAFCS	Versatile Automatic Flight Control System (LSI designation for A/A37G-8 AFCS)
VCO	Voltage Controlled Oscillator
VSTT	Variable Speed Training Target

SECTION I

INTRODUCTION

The A/A37G-8 Automatic Flight Control System (AFCS) is a state-of-the-art (1968) subsystem used to control and stabilize the BQM-34A target drone. As such, it is a successor to the A/A37G-3 series AFCS used in earlier BQM-34A drones.

When Teledyne Ryan Aeronautical (TRA) first developed the KDA and Q-2A target drones for the Navy and Air Force, TRA developed its own autopilot. When the XQ-2C was developed in the late 1950's, TRA wrote a flight control specification which was subcontracted on a competitive basis. Lear Siegler Inc/Astronautics Division (LSI) won the contract and proceeded to develop and manufacture the A/A37G-3() AFCS for TRA. When the XQ-2C became the Q-2C in early 1960, the LSI FCS became the Flight Control System, Target Aircraft, Type A/A37G-3. With the addition of the ground launch capability to the Q-2C, the FCS was redesignated as the A/A37G-3A. Addition of product improvements for tie-in to the Ryan Increased Maneuverability Kit (IMK) and Radar Altimeter Low Altitude Control System (RALACS) made the AFCS the A/A37G-3B in 1966. In the interim, the drone designation changed from Q-2C to BQM-34A and the A/A37G-3 AFCS became a GFAE item procured directly from LSI by ASD for the Army, Navy, and USAF.

From the time the BQM-34A became operational in the early 1960's until late 1967, the maneuverability requirements of the drone continued to increase. Furthermore, the nominal gross weight of the BQM-34A continued to increase as additional scoring and augmentation systems were placed on-board. Finally, the cost of the A/A37G-3 AFCS grew from a unit cost of less than $10,000 in the early 1960's as GFAE to over $20,000 in 1969 when IMK, RALACS, etc., were bought from TRA along with the A/A37G-3B from LSI. Consequently, LSI was informally asked in 1967 to look into the possibilities of developing a new AFCS which would use state-of-the-art electronics, incorporate IMK and RALACS plus space for future modes, show significant cost, weight and volume savings and yield greater reliability and reduced maintenance.

In early 1968, LSI submitted their study. Based on their findings, an RAD was prepared and the three services provided $20,000 each for a research and development contract. LSI's proposal showed that a new system could be developed with the above goals in mind. Cost, weight and volume savings were given as 30% each. Utilizing state-of-the-art electronics, LSI proposed a "Versatile Drone Autopilot" which could be used in the subsonic BQM-34A, the Army's MQM-34D (Army version of BQM-34A), the supersonic BQM-34E/F, the Navy's QT-33 and the future Variable Speed Training Target (VSTT).

Contract F33657-69-C-1073 was let in April 1969 for the LSI R&D effort; the Air Force was designated as the tri-service procuring agency. Under -1073 LSI began prototype flight testing of the new autopilot at Holloman AFB in July 1970. Six flights were made through October 1970. The test program was reported in LSI Report ADR-750, 22 Oct 70, and indicated that the new system was sufficiently developed to grant a production go-ahead for 298 systems under an FY71 contract. In early 1971, prototype flight testing of advanced modes for g-controlled turns, low altitude control, etc. began, also funded under -1073. The Advanced Modes Flight Test Program is not to be confused with this Production Verification Flight Test Program. Contract F33657-71-C-0353 was let in January 1971 for production hardware. Part of the effort to be accomplished under this contract was a Production Verification Flight Test Program run by the Government (6585th/TD and ASD/RWDE). Basic goals of the program were to be accomplished in two phases. Phase I covered the ground maintenance and checkout capabilities. Phase II called for six successful flights on two A/A37G-8 AFCS installed in two BQM-34A drones as a Class II modification. The six flights were to prove whether or not the AFCS met LSI Specification CP 10650.

It should be noted that when a production A/A37G-8 AFCS is used in a BQM-34A, a Telemetry Signal Conditioner Unit (TMCU) is required for compatibility between the G-8 FCB and the telemetry transmitter. The TMCU is also procured from LSI on a one-for-one basis with each AFCS and was used in this flight test program. However, during this testing the performance of the TMCU was not evaluated per se and is mentioned only on occasions in passing in this report.

The Production Verification Flight Test Program was conducted in accordance with the Flight Test Plan prepared jointly by 6585th/TD and ASD/RWDE. The results of Phase I were summarized by the 6585th/TD and are presented in Section III. The objective of the proposed six flight program required 13 flights for accomplishment of all goals of Phase II. Flight testing began on 29 September 1971 and continued through 11 May 1972.

In the following sections the system is described, the Phase I results are given and all of the aspects of the Phase II testing are discussed. Finally, the test program results are presented in terms of overall observations, detailed conclusions and program recommendations. A copy of the Flight Test Plan is included as an appendix.

SECTION II

SYSTEM DESCRIPTION

The Lear Siegler Inc A/A37G-8 Automatic Flight Control System consists of five basic Line Replaceable Units: one Flight Control Box, one Flight Control Box Rack, one Elevator Servo Actuator, one Aileron Servo Actuator and one Normal Accelerometer Assembly. An Adaptive Cable Assembly Kit containing four harnesses and a shorting plug is also required to install the A/A37G-8 AFCS in any BQM-34A which will accept the older A/A37G-3B AFCS.

Because of electrical interface differences between the A/A37G-8 AFCS telemetry output and the BQM-34A Telemetry Set, a Telemetry Signal Conditioner and Calibration System (TMCS) was developed by LSI to work with the A/A37G-8 AFCS. The TMCS consists of one Telmetry Calibration Box (TMCB) and three adaptive cables.

The following is a description of the operation of the A/A37G-8 AFCS and TMCS quoted from LSI Specification CP 10650 for these equipments. (For VAFCS read A/A37G-8 AFCS):

> "The VAFCS shall be capable of controlling and stabilizing the BQM-34A Drone about the pitch and roll axes throughout the guaranteed speed, altitude and maneuvering envelopes and within the defined limitations of gross weight, center of gravity, aerodynamic configuration and engine power as defined by detail specification for the BQM-34A Drone (12459-100E and SD2018-1-6 with the exception of paragraph 3.15.16).
>
> The VAFCS shall include both basic and increased maneuvering modes and provisions for advanced modes. These modes provide the normal maneuvering capability required for general target use. The advanced modes will be designed to meet specific operational requirements.
>
> The VAFCS basic autopilot modes for the BQM-34A shall have the same capabilities as the system presently being used in the vehicle, including the existing type of increased maneuvering (bank angles up to 75.5°). The basic system shall employ roll and pitch attitude references as inner loops for the command modes, which are initiated from a controller station and transmitted to the drone."

For the TMCS:

> "The Telemetry Signal Conditioner and Calibration System performs the following:
>
> (a) Conditioning flight control box and aircraft

system signals for telemetry.

(b) Provides "in the air" telemetry calibration data.

(c) Provides "on the ground" accelerometer test capability.

(d) Provides indication of inverter failure."

SECTION III

SUMMARY OF PHASE I - (Prepared by 6585th Test Gp/TD)

1. Introduction

The A/A37G-8 AFCS and TMCS were installed in two standard BQM-34A Target Drones at Holloman AFB, New Mexico, for the purpose of checking AFCS and TMCS installation instructions; verification of appropriate adaptive cable harness sizing; evaluation of checkout procedures and test panel capabilities; and verification of accuracy and completeness of maintenance and checkout instructions.

The Phase I Test Plan was accomplished by personnel of the 6585th Test Group at Holloman AFB, New Mexico, with the assistance of Lear Siegler Inc., the manufacturer of the A/A37G-8 AFCS and the TMCS.

2. Objectives

The following objectives were met:

a. Verification of accuracy and completeness of maintenance and checkout instructions. Each manual was reviewed by page and all errors or omissions were recorded.

b. Evaluation of ease of installation of the A/A37G-8 AFCS and the TMCS.

c. All cables were checked for accuracy in wiring and adaptability to the drone system.

d. Interchangeability of the A/A37G-8 AFCS and the A/A37G-3B AFCS was evaluated.

e. All AGE used for AFCS checkout was evaluated for proper operation.

f. The A/A37G-8 AFCS was checked out according to manuals and all errors or malfunctions noted or corrected.

g. The TMCS was checked out according to calibration procedures in manuals and accuracy verified with measurements of actual positions, angles and/or simulated airspeeds and altitudes of the A/A37G-8 AFCS.

h. Lost Carrier relay function and accelerometer function was verified.

3. Results

The checkout procedures for the A/A37G-8 AFCS were written by Lear Siegler Inc. and amended as needed during the checkout phase. The time for the checkout on the partial panel was found to be the same for both the A/A37G-8 AFCS and the A/A37G-3B AFCS. However, the bench checkout procedures for the A/A37G-8 took twice as long (3 hours) as compared to the bench checkout procedures for the A/A37G-3B (1.5 hours).

The installation of equipment bag ground studs could not be accomplished in accordance with Lear Siegler Inc. instructions. The instructions call for the mounting of four ground studs on the overhead angle bracket. It was found that much more work was involved in the mounting of the ground studs than is outlined by Lear Siegler Inc. Therefore, the ground wires were clamped together and grounded to the distribution box mounting stud.

It was also found that several cable numbers, as given in the Lear Siegler Inc. instructions, were incorrect and should be corrected as shown below:

Lear Siegler Inc. INSTRUCTION NO.	CABLE NO. GIVEN AS	CABLE NO. SHOULD BE
3.7.13	124E869-1	124E364-5
3.8.6	124E870-1	124E656-9
3.8.7	124E886-1	124E690-1

The Checkout of the TMCS unit was accomplished in the presence of a Lear Siegler Inc. Technical Representative who verified that the unit was operating properly. This procedure was used because of the unavailability of both the technical data and the operational data on the TMCS unit. No problems on the installation of the TMCS unit were encountered in the drone.

4. Recommendations

Referring to the problem of the installation of the equipment bay ground studs, it is suggested that the ground wires be lengthened and a ground stud be installed on the longeron about four inches aft of the bulkhead fuselage station 112, instead of the overhead angle bracket as suggested by Lear Siegler Inc.

It was also suggested that the cable between P201A (connected to the flight control box rack) and J201A (connected to another cable, P/N 124E869) be lengthened about six inches in order to allow for an easier installation of this cable.

The final recommendation is made with reference to the A/A37G-8 FCB. The adjustment screws for the A/A37G-8 FCB were found to be concealed behind one of the side panels of the unit. This made it necessary to remove this panel before any adjustments could be made.

It is suggested that access ports be drilled in the side panel opposite the adjustment screws. The would eliminate the removal of the panel for the purpose of making adjustments to the FCB. (The adjustment screws for the A/A37G-3B AFCS are accessible through access ports in the front panel.)

SECTION IV

PHASE II FLIGHT TEST OBJECTIVES

The objective of these flight tests was to evaluate the performance of the A/A37G-8 AFCS by comparing BQM-34A Target Drone performance with the A/A37G-8 installed and operating against the Lear Siegler Inc., "Contract End Item Detail Specification Performance/Design and Qualification Requirements Versatile Automatic Flight Control System and Telemetry Signal Conditioner and Calibration System for BQM-34A Drone", Specification CP 10650. The above mentioned specification describes performance requirements for automatic control of the BQM-34A Target Drone about its roll and pitch axes, controlling and maintaining altitude, scheduling airspeed during climb, dive and glide modes, programing bank angles as functions of altitude and providing an airspeed climb feature during initiation of the recovery phase at altitudes below 15,000 feet.

Table IV.1 summarizes the flight performance parameters and characteristics which the Specification CP 10650 specifically designates and describes and which can be evaluated during flight tests.

The "Production Verification Flight Test Plan" used for Phase II flights is attached hereto as Appendix A.

Flight Parameter or Characteristic	CP10650 Figure No.	CP10650 Paragraph No.
Mechanization		
Wings level within ±2.0° roll		3.1.1.1.1
Control Modes		3.1.1.1.2
Airspeed Climb Schedule	Fig. 3.3	3.1.1.1.2.A
Airspeed Dive Schedule	Fig. 3.4	3.1.1.1.2.A
Bank Schedule: Normal	Fig. 3.5	3.1.1.1.2.D
BAO		3.1.1.1.2.D
IMK		3.1.1.1.2.D
Performance		
Pitch Axis		3.1.1.1.3
Pitch oscillation less than 2° peak-to-peak or		3.1.1.1.3.A
10°/sec peak-to-peak pitch rate in 12 cps and		3.1.1.1.3.A
10% overshoot		3.1.1.1.3.A
Altitude hold in S&L		3.1.1.1.3.B
Normal turns ±100' to 15K feet, ±100' press-alt above		3.1.1.1.3.B
IMK turns ±400' to 15K feet, ±400' press-alt above		3.1.1.1.3.B
Longitudinal Mode Damping 30% peak-to-peak/cycle		3.1.1.1.3.C
Airspeed Control Mode Steady-State Accuracy ±3 kts		3.1.1.1.3.E
Maximum pitch rate 40°/sec		3.1.1.1.3.D
Normal Acceleration 4g's maximum normal, 6g's maximum IMK & AIM		3.1.1.1.3.F
Elevator Time Constant less than one second		3.1.1.1.3.G
Roll Axis		3.1.1.1.4
Roll oscillations amplitude less than 2° peak-to-peak, steady-state		3.1.1.1.4.A
Steady-state roll rate osc. less than 10°/sec		3.1.1.1.4.A
Damping within 2° peak-to-peak in 8 cycles		3.1.1.1.4.B
Overshoot less than 5° or 10% (lower)		3.1.1.1.4.B
Aileron Time Constant less than 0.7 sec		3.1.1.1.4.C
Maximum roll rate 100°/sec		3.1.1.1.4.E

Specification CP10650 Performance Parameters & Characteristics

Table IV.I

SECTION V

PHASE II FLIGHT TEST PARAMETERS

All of the test parameters measured during these test flights were those which were transmitted over the telemetry system. For Flights No. 1 through No. 3 the telemetry system made possible the recording of the following:

a. Altitude (Ft-MSL)

b. Airspeed (KIAS)

c. Engine Speed (RPM)

d. Fuel Flow Rate (lb/min)

e. Pitch Attitude (degrees)

f. Roll Attitude (degrees)

g. Elevator Position (degrees)

h. Aileron Position (degrees)

i. Derived Roll Rate (degrees/sec)

j. Derived Pitch Rate (degrees/sec)

For subsequent flights the roll rate and pitch rate information was eliminated and normal acceleration and altitude error were added. The roll and pitch rates are relatively easy to determine from the slope of the roll attitude and pitch attitude time histories respectively. Normal acceleration is an essential measurement to determine loading and drone performances in high bank angle turns. Altitude error is necessary to check accurately the altitude hold functions. In Flights No. 10 through No. 13 altitude information was not telemetered due to a need to transmit the sideslip angle (β). The drones used in these flights were instrumented to measure this parameter; there were not enough telemetry channels available to transmit both sideslip and altitude information.

From the received telemetry, the specified parameters and characteristics given in Table IV.1 were evaluated except for elevator and aileron servo actuator time constants and steady-state accuracy of the airspeed control mode. The actuator time constants were checked on the ground before the test flights of these drones and were found to be well within the specification limits (See Table VII.3). The specified ±3 knots steady-state accuracy of the airspeed control mode given in section 3.1.1.1.3.D of CP 10650 was found to be impossible to evaluate.

The airspeed control was compared to requirements of Figures 3.3 and 3.4 of CP10650 in climbs and dives. Telemetry data is not transmitted while the AFCS is in the Glide mode, thus exact evaluations of airspeed control in the Glide mode are not possible. Glide performance can be given here only as reported by observers. Climb, dive, and bank angle responses as functions of altitude were checked on all flights except flights No. 10 through No. 13 because altitude information was not transmitted during these flights.

SECTION VI

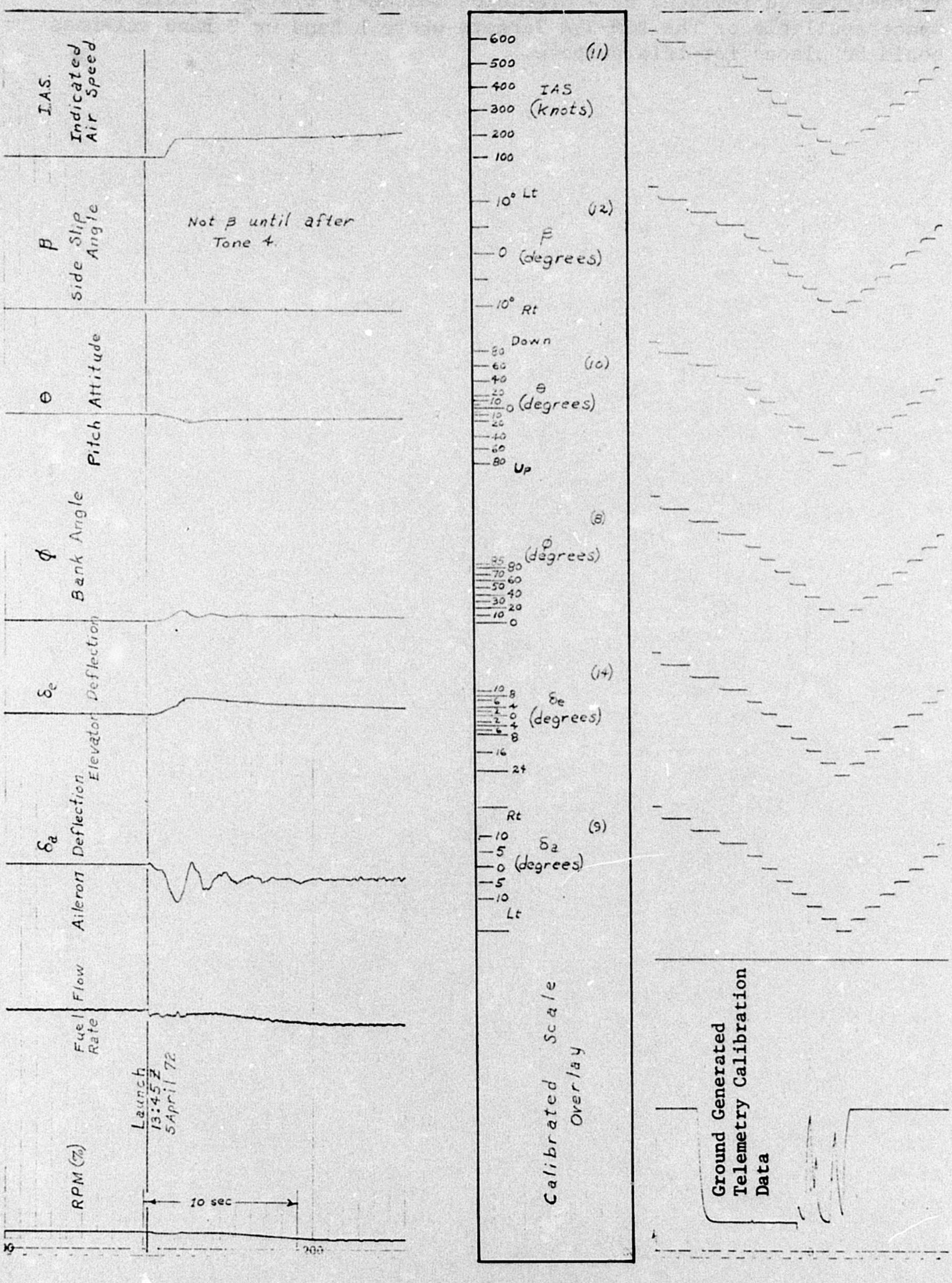
TELEMETRY READOUT DISCUSSION

Problems with telemetry readout are discussed here. (See Figure VI.1.) The presentation of telemetry data was on CEC Data Graph recording paper with traces made on the Sandborn Model 7700 Recorder or a Techni-rite Electronics Model TR-668 Recorder. Each channel was presented on a four centimeter wide graphic display with eight channels displayed on a sheet. It was necessary to make a calibrated scale overlay by hand from telemetry calibration information so that the recordings (strip charts) could be read. These overlays were only as accurate as the care of the individual who makes them would allow. Unfortunately, the calibration is different for each test flight and new overlays had to be made after each flight in order to be able to read the telemetry data. A means to remedy this situation is not in process; however, a solution was not available for these test flights.

Another problem within the telemetry system was the voltage controlled oscillators (VCOs) in the TM-431A Telemetry Transmitter. Adjustments of these VCOs were not possible at the launch sites because the required AGE was not available. There was a severe frequency drift problem of center frequency in some of the VCOs used. The problem was probably temperature drift. The transmitting package heats up to higher temperatures when in a drone than when on the test bench. Available temperature information from sensors which were located very close to the transmitter during some different test flights indicates that the temperature does not exceed VCO specification levels; however, the experience of the 6585th Test Group/TD has been that high frequency VCOs drift excessively. At the launch site, as the target is prepared for launch, errors in telemetry indications determined by comparing sensor conditions, i.e., control surface positions and gyro atitudes, with telemetry output indications. HAFB standard operating procedure is to abort target missions if the aileron and elevator channels have indicated position errors exceeding five degrees. Errors in other channels require command decision as to target launch. Many missions have been aborted because of telemetry errors. After launch, it is practically impossible to estimate VCO drift unless the TMCS in-flight calibration provisions are used. In-flight calibration was not used during this test program as it should have been.

In general, the telemetry tolerances in other areas are minimal. Resolution on strip charts is within one percent. Recorder amplifiers are specified to have a maximum possible error of ±2 percent. The specified most probable error of these amplifiers is ±1 percent and lineraity is with 0.5 percent. Sensor errors are minimized by using actual sensor signals for telemetry calibration.

It is recommended for future test flights, if precision engineering measurements are required, to determine out-of specification conditions of parameters, that in-flight calibration be commanded before each important maneuver. It is also recommended that the TM-431 Telemetry Transmitter be replaced by a precision telemetry system. There is space available on the BQM-34A Targets where L Band or S Band antennas could be placed for this purpose.



Typical Telemetry Recordings

Figure VI.1

SECTION VII

INDIVIDUAL SUMMARIES OF PHASE II FLIGHTS

For the purpose of this test program, thirteen production verification test flights were attempted using three different BQM-34A Target Drones. Two production model A/A37G-8 AFCS packages were installed in these drones for these tests; one A/A37G-8 was used in two different drones. Eleven of these attempts resulted in successful launches and flights, which accomplished at least part of each of the mission objectives. All of the launches were made from the mobile launcher at LC-251.

Each flight summary given in this section is subdivided into mission profiles, special observations, and mission anomalies, except where launches were unsuccessful. Mission profiles roughly described the maneuvers carried out, flight durations, etc. Nearly all of the special observations came from analysis of transmitted telemetry data. The mission anomalies describe unexpected events, out-of-specification conditions, and brief resolutions of problems encountered.

Shown in Table VII.1 is a summary of the important launch and release mode data. Assigned production flight test numbers are listed along with drone serial numbers, drone gross weight, center of gravity location, maximum pitch attitude attained, maximum roll attitude, steady-state pitch attitude, and an evaluation of the launch. This information is documented for future reference and is not discussed further herein.

Shown in Table VII.2 is a summary of the important mission flight data. This table includes test plan numbers, number of level turns completed, automatic roll trim required for straight and level flight and flight durations. It should be noted here that both BAO and IMK turns cannot be done during the same mission. The AFCS has to be set up prior to a flight for the type of turns which will be commanded.

Shown in Table VII.3 are the time constants of the aileron and elevator servo actuators for each of the three target drones. These time constants were found to be well within the requirements of sections 3.1.1.1.3G and 3.1.1.1.4C of Specification CP 10650.

Shown in Figure VII.1 through Figure VII.11 are flight bank angles and airspeed responses at various altitudes for those flights where this information is available. Also shown in these figures are the schedules and tolerances given in Figures 3.3, 3.4 and 3.5 of Specification CP 10650. These responses could not be graphed for Flights No. 10 through 13 because altitude data was not transmitted during these flights.

Prod. Flt. No.	Target Drone SN	Gross Weight (Lbs.)	C.G. (F.S.) (In.)	C.G. (W.L.) (In.)	Maximum Pitch Attitude (degrees)	Maximum Roll Attitude (degrees)	Steady-State Pitch Attitude (degrees)	Steady-State Roll Attitude (degrees)	Evaluation
1	68-10372	2311	87.99	21.62	58 N. Up	90 Rt Dn	----	----	Launch not successful
2	68-8386	2300	88.08	21.74	35	7	15 N. Up	5 Rt. Dn	Excessive Pitch, Launch successful
3	68-10372	2284	87.09	21.74	22	12	15	10	Good Launch
4	68-8386	2656	87.40	21.65	22	10	15	7	Good Launch
5	68-10372	2290	87.18	21.73	35	20	15	10	Excessive Pitch & Roll, Launch Successful
6	68-8386	[illegible]	[illegible]	[illegible]	25	13	14	4	Good Launch
7	68-8386	2330	87.42	[illegible]	27	18	15	[illegible]	Excessive Roll, Launch Successful
8	68-10372	2279	[illegible]	[illegible]	[illegible]	16	15	10	Good Launch
9	68-8346	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15	9	Good Launch
10	68-8346	2299	[illegible]	[illegible]	[illegible]	[illegible]	13	5	Very good launch, New Tech Order Procedure
11	68-834[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	----	----	Launch not successful
12	68-834[illegible]	[illegible]	[illegible]	[illegible].96	[illegible]	[illegible]	[illegible]	3	Good Launch
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	Excessive Pitch, Launch Successful

[illegible] Data

Table VII.1

Prod. Flt. No.	Test Plan No.	No. Level Turns Completed Rt	Lt	No. Climbing & Diving Turns Completed Rt	Lt	No. BAO Turns Completed Rt	Lt	No. IMK Turns Completed Rt	Lt	Roll Trim Required (degrees)	Flight Duration (min.)	Comments
1	1	---	---	----	----	----	----	----	----	-----	16 (sec)	Elevator Servo Problem
2	4	7	10	9	14	3	3	0	0	3	48.5	OK lt rudder trim, 3 sec
3	1	5	9	14	27	1	4	0	0	6	39.4	10K ft climb during 1 BAO turn
4	4	4	9	5	20	0	2	0	0	4	30.5	38K ft lost during 1 BAO turn
5	2	2	4	0	0	0	0	2	2	2	14.0	Engine Flameout
6	5	16	9	4	6	0	0	4	6	3	34.5	Altitude losses during IMK turns
7	6	3	1	1	3	0	0	0	1	5	8.3	Out of control during IMK turn
8	3	5	4	1	4	0	0	10	5	5	31.8	Trim Adjustments made to hold Alt during IMK
9	Baseline	9	9	0	3	0	0	0	0	2	37.0	No IMK or BAO turns
10	β-Vane Test	13	15	1	1	0	0	0	2	2	35.0	One IMK Turn Bank Angle Abort
11	IMK, β, Hi θ	---	---	----	----	----	----	----	----	-----	8 (sec)	Error in Bottle Alignment
12	IMK, β,	5	7	1	0	0	0	3	6	2.5	31.0	IMK turns not completed
13	IMK, β,	7	3	0	2	0	0	3	3	4	33.3	Two Altitudes No major problems

Mission Flight Data

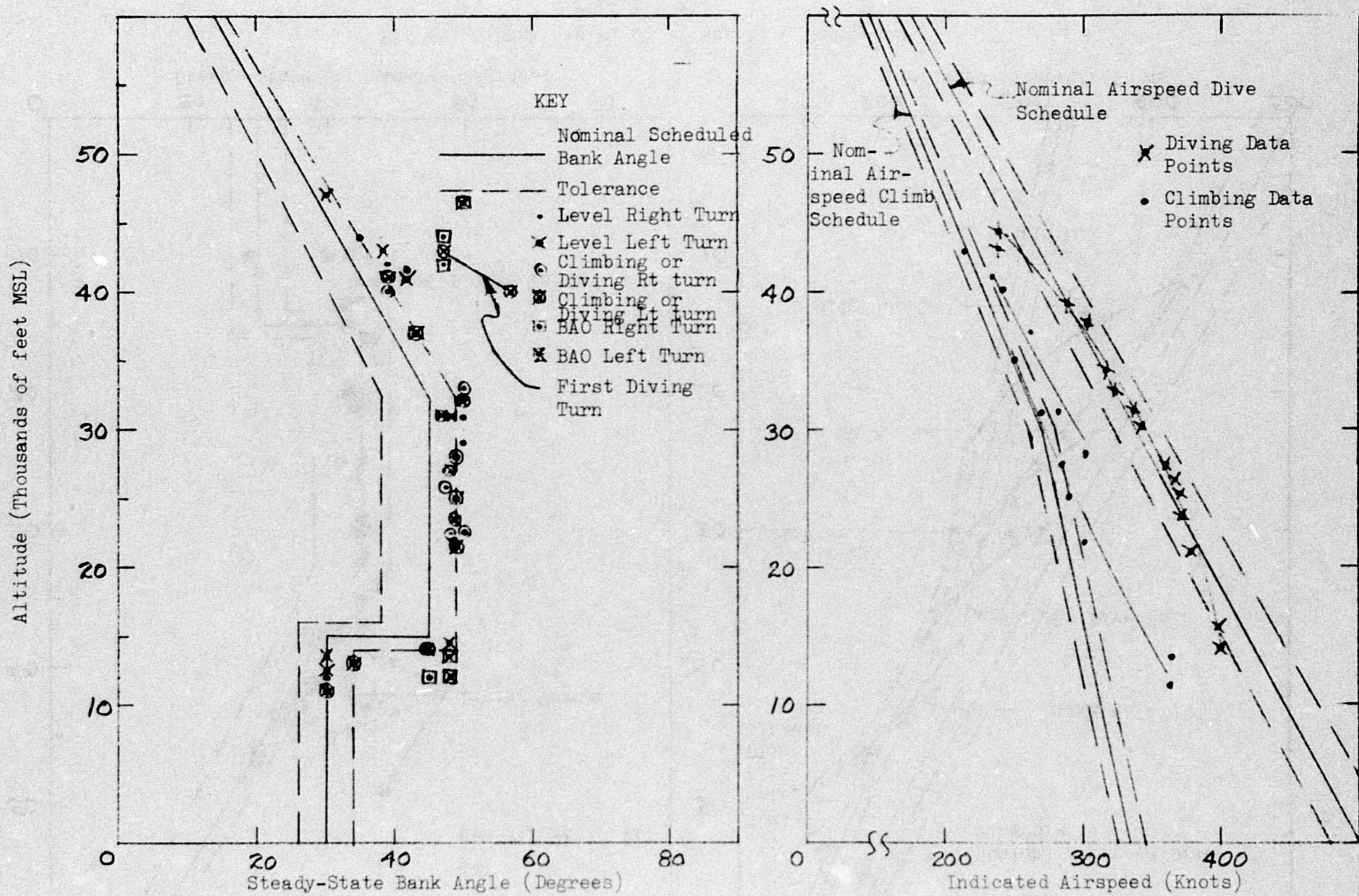
Table VII.2

Target Drone SN	Aileron Servo Actuator 68% Rise Time (sec)	Aileron Servo Actuator 68% Fall Time (sec)	Aileron Servo Actuator Linear Intersection Rise Time (sec)	Aileron Servo Actuator Linear Intersection Fall time (sec)	Elevator Servo Actuator 68% Rise time (sec)	Elevator Servo Actuator 68% Fall time (sec)	Elevator Servo Actuator Linear Instersection Rise time (sec)	Elevator Servo Actuator Linear Instersection Fall time (sec)
68-8386	.23	.21	.27	.26	.50	.46	.69	.65
68-10372	.25	.23	.29	.28	.37	.36	.63	.60
68-8346	←---	------	------	Not	Accomplished	------	------	---→
VAFCS Specification CP10650	Less than 0.7	←---	NA	---→	Less than 1.0	←---	NA	---→
Aileron Actuator Acceptance Specification CA 428890-02	←---	NA ---→	Less than .52	Less than .52	←---	------	NA	---→
Elevator Actuator Acceptance Specification CA42895-02	←---	NA	------	------	------	---→	Less than 1.1	Less than 1.1

Servo Actuator Response Time Constants

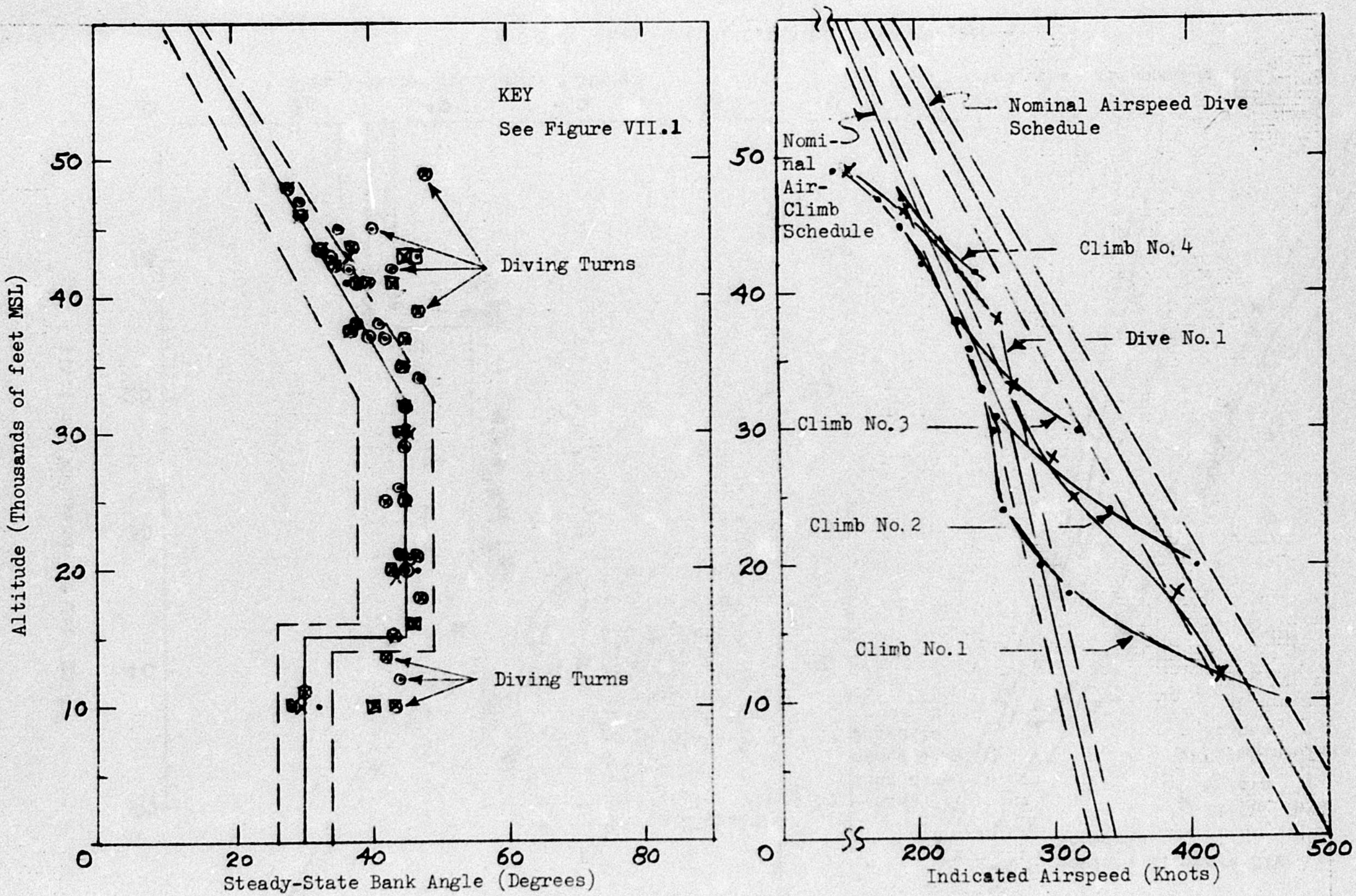
for Step Input

Table VII.3



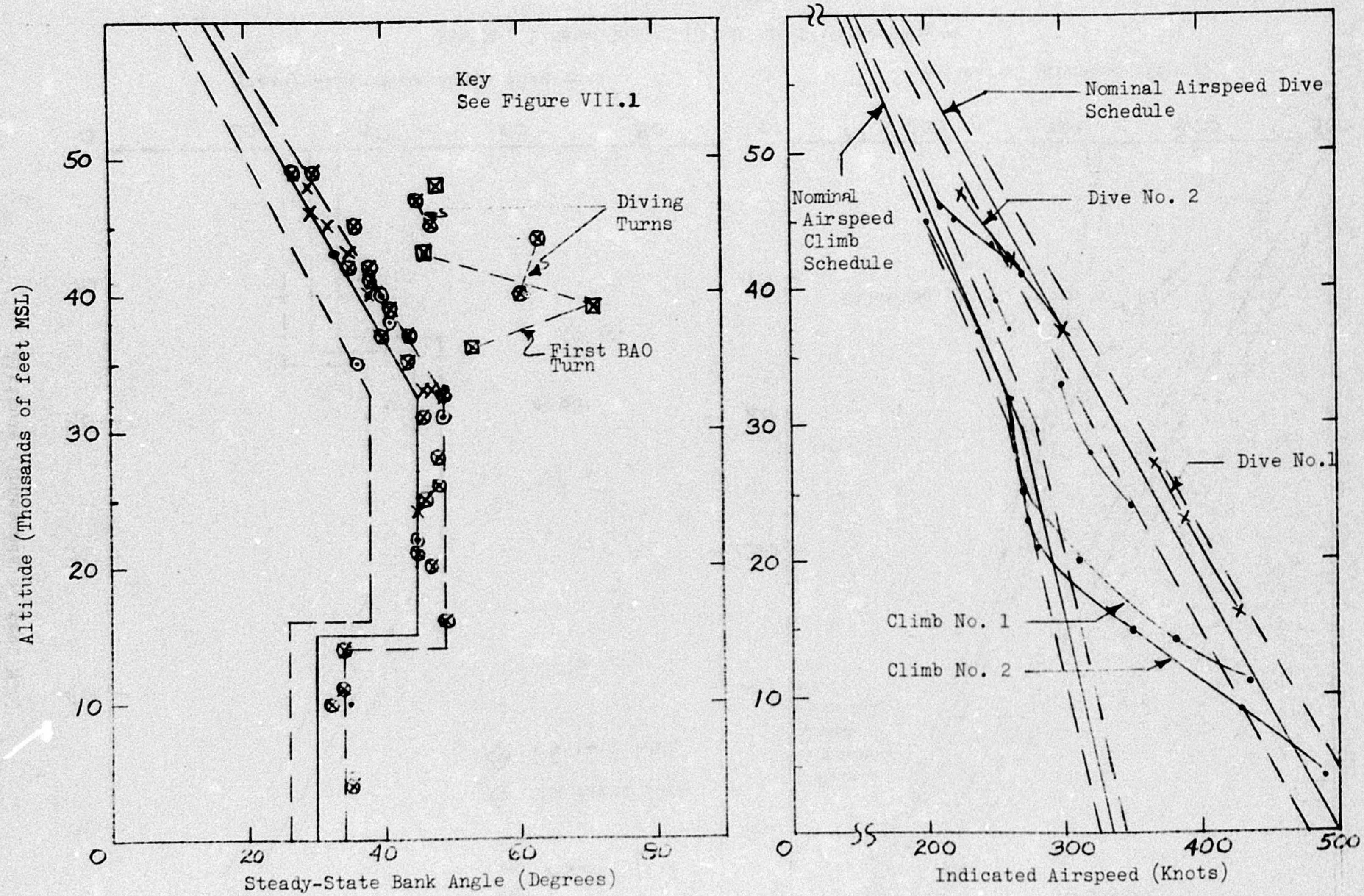
Flt No. 2 Bank Angle, Climb and Dive Responses

Figure VII.1



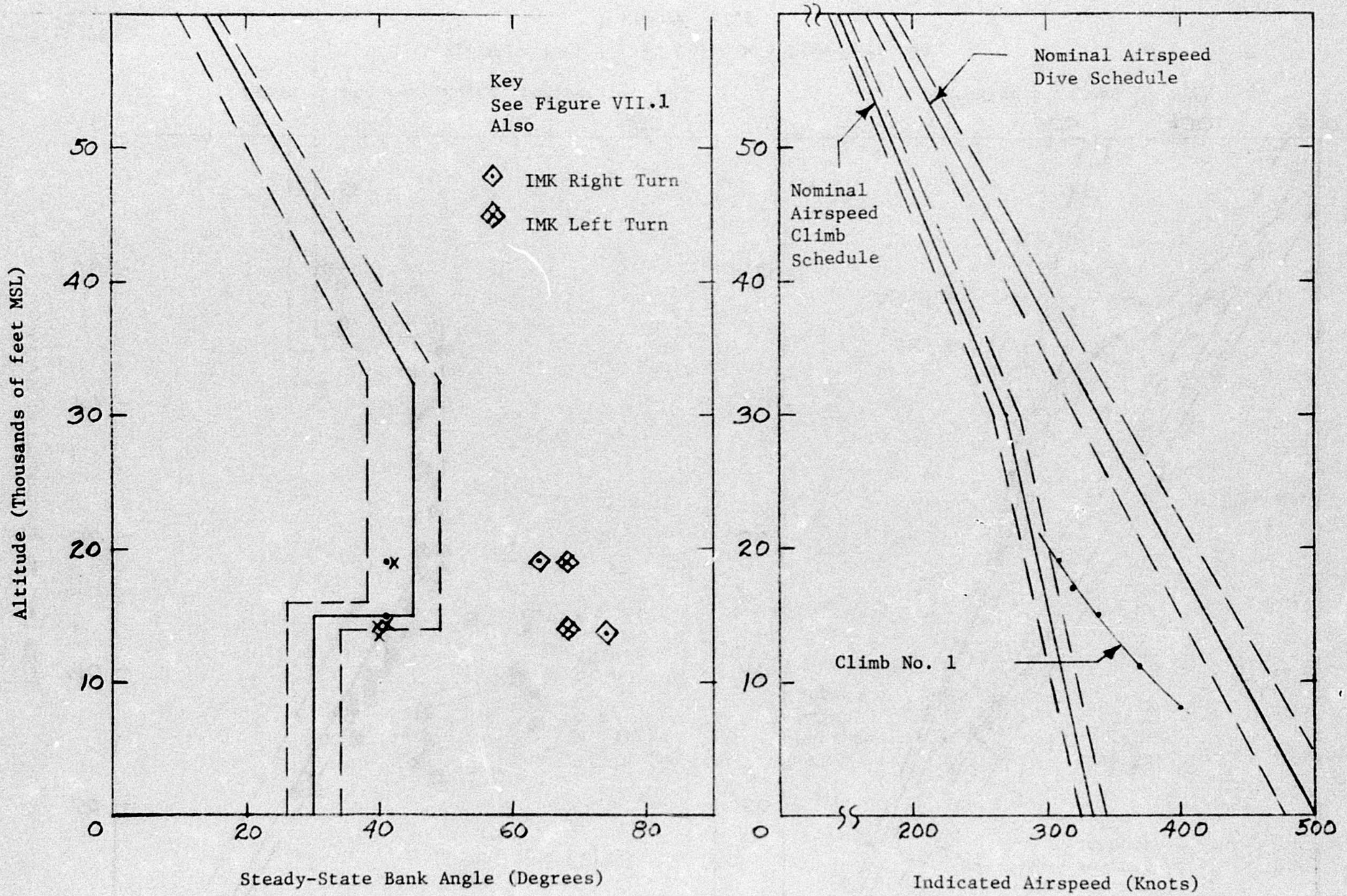
Flt No. 3 Bank Angle, Climb and Dive Responses

Figure VII.2



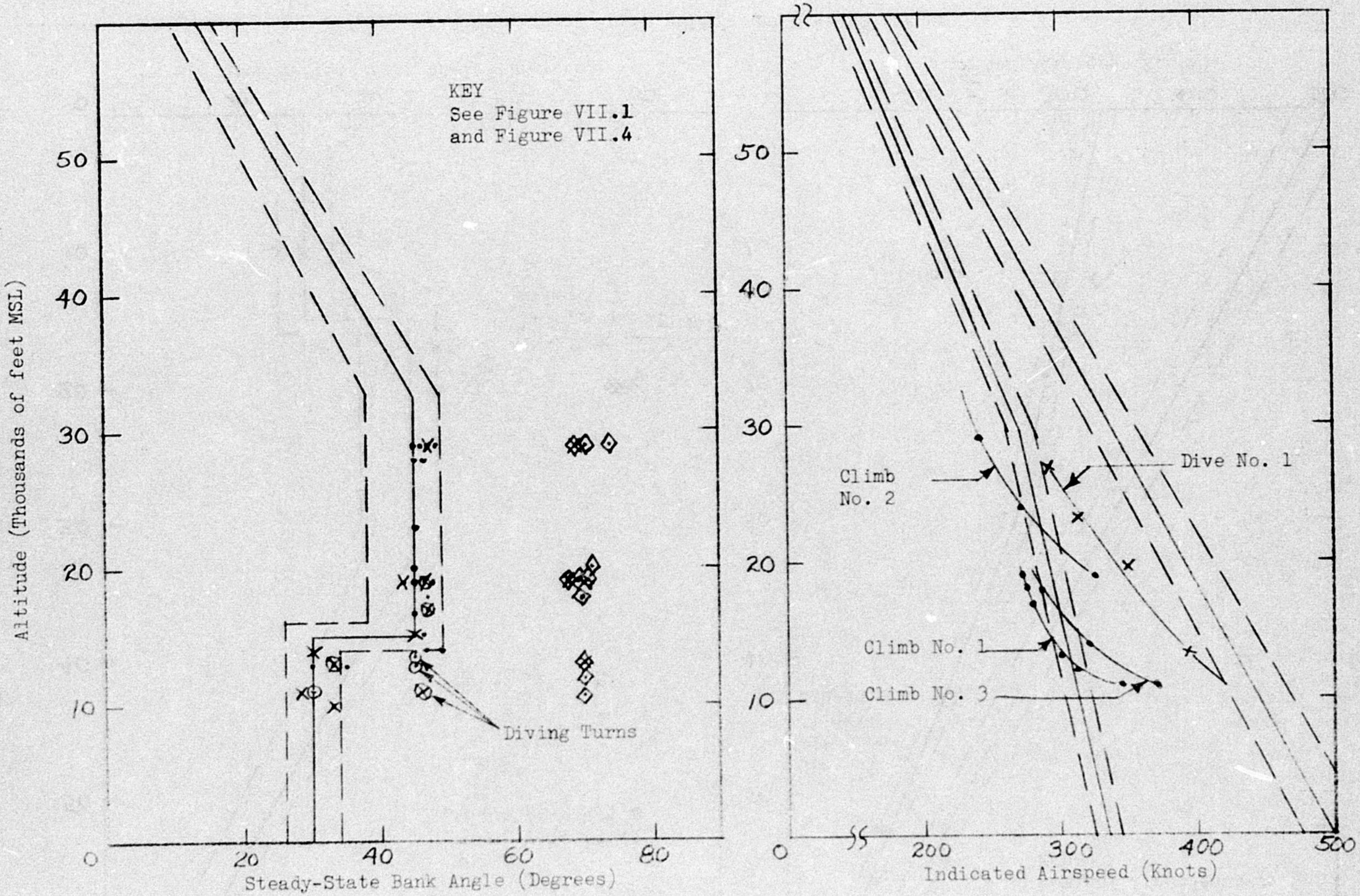
Flt No. 4 Bank Angle, Climb and Dive Response

Figure VII.3



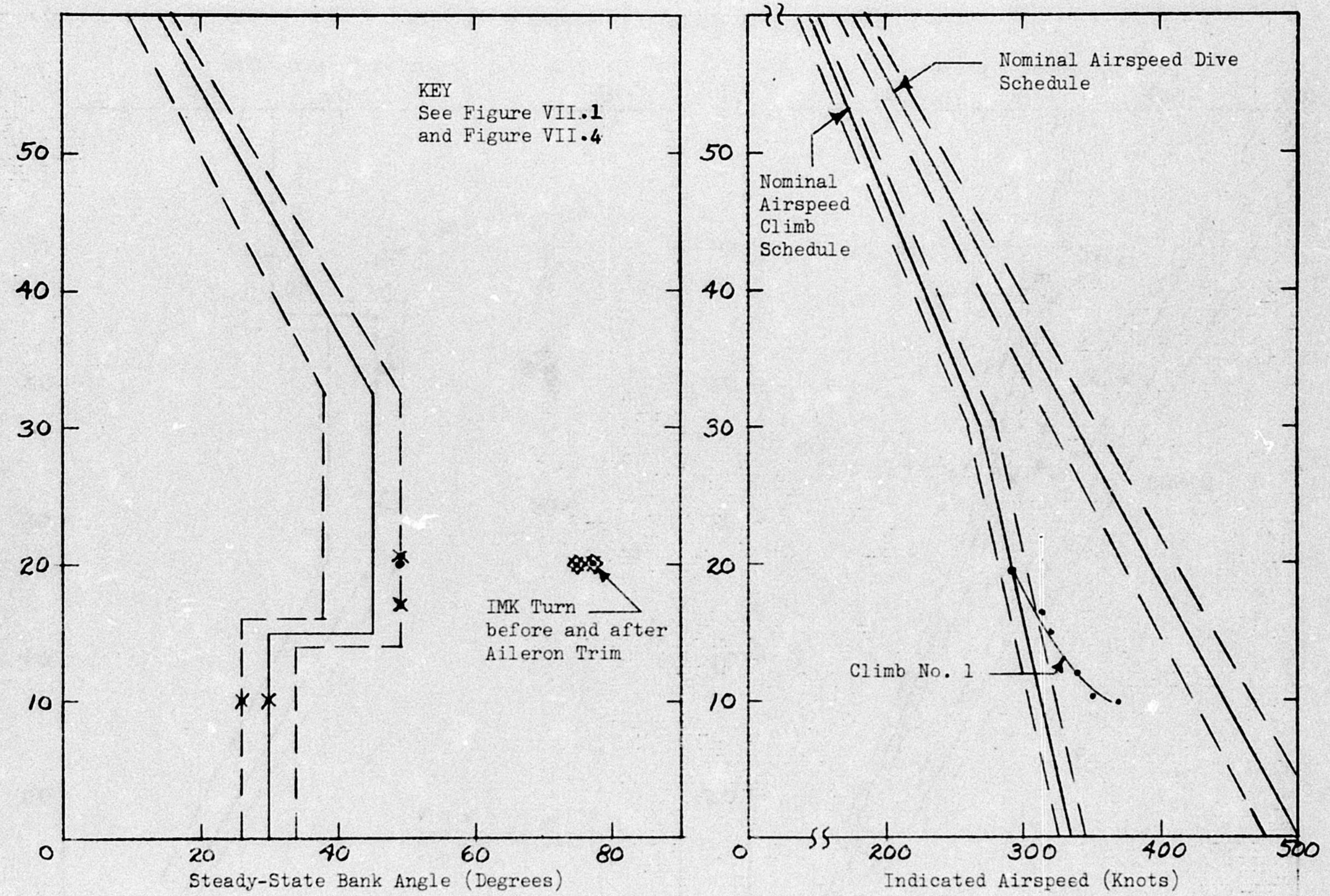
Flt No. 5 Bank Angle, Climb and Dive Responses

Figure VII.4



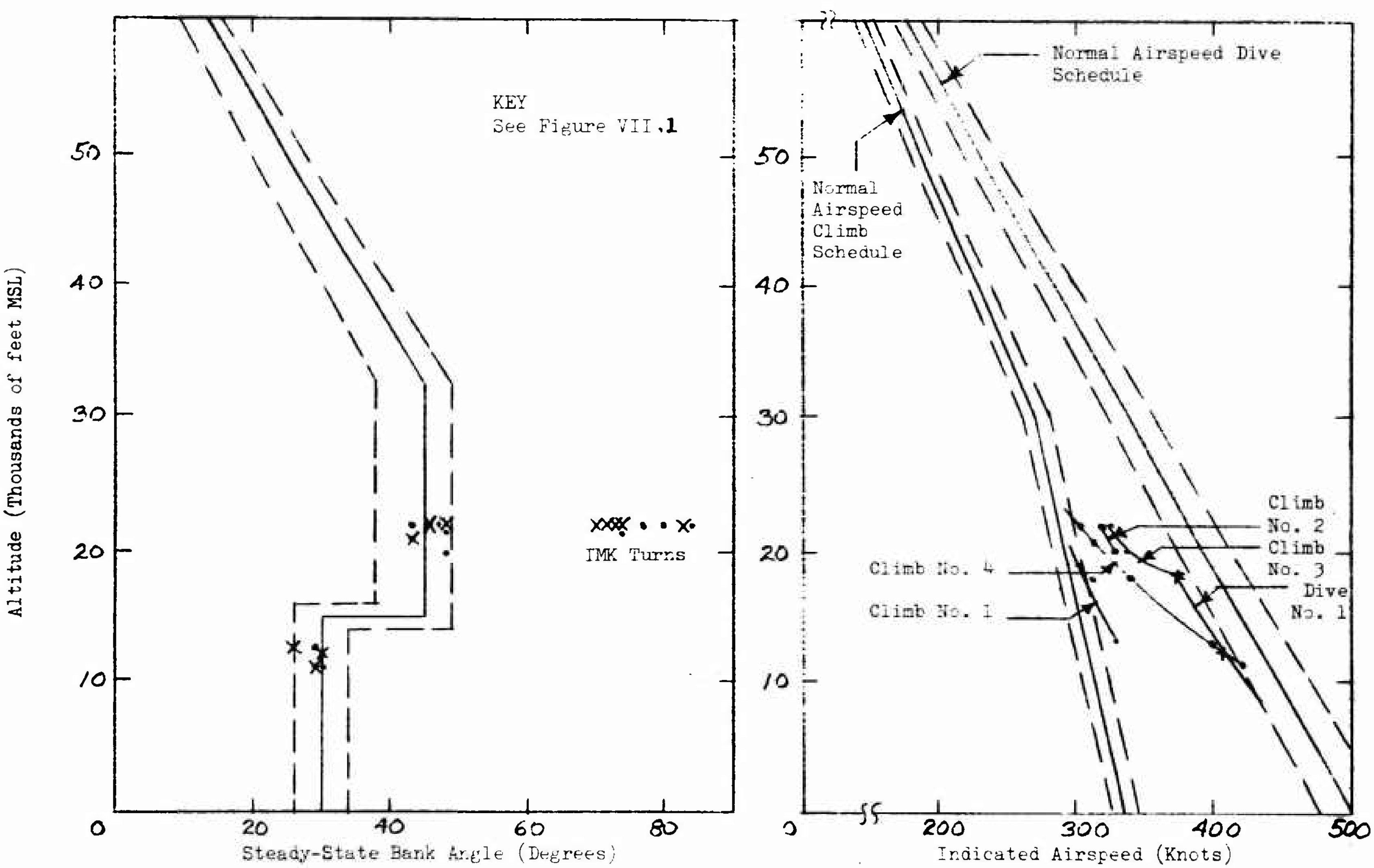
Flt. No. 6 Bank Angle, Climb and Dive Responses

Figure VII.5



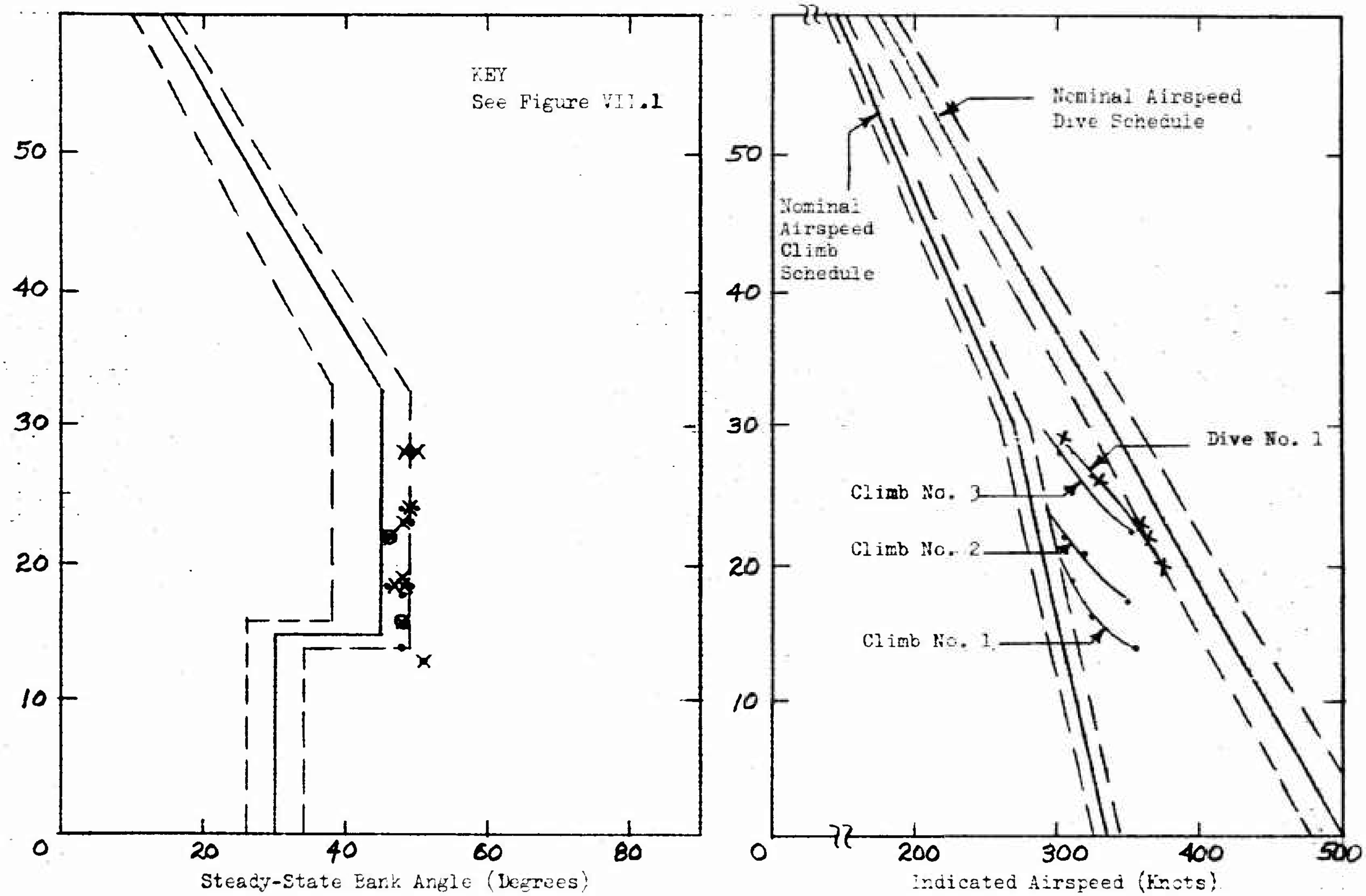
Flt No. 7 Bank Angle, Climb and Dive Responses

Figure VII.6



Flt No. 8 Bank Angle, Climb and Dive Responses

Figure VII.7



Flt No. 9 Bank Angle, Climb and Dive Responses

Figure VII.8

Production Verification Flight Test No. 1

This first flight of the production AFCS was to have been carried out on 29 September 1971 according to Plan No. 1 on target drone SN 68-10372. Launch time was 0910 hours MST, but the launch was not successful. Launch during boost was normal, but after bottle separation the drone started to pitch up and roll to the right. A maximum pitch attitude of 58 degrees was reached and 90 degrees of roll when the drone stalled. Fuel dump lockout and emergency chute were commanded after 16 seconds of flight and the drone was successfully recovered with minimal damage. Post-flight inspection revealed a loose screw had been lodged in the elevator servo motor armature which either jammed or shorted causing a high current drain thus burning in half a jumper wire and disabling the servo.

The servo was UMR'd and returned to LSI for repair. All servos delivered to date were re-cycled through LSI for inspection. This is considered an isolated quality assurance problem; however, to facilitate future inspections, these screw heads are being doped after installation

Production Verification Flight Test No. 2

A. Mission Profile

This flight of 8 October 1971 was carried out according to Plan No. 4 on drone SN 68-8386. This was the first production verification test flight of the Lear Siegler AFCS in this target drone. Launch time was 1002 hours MST and the launch was successful. The flight duration was 46.5 minutes to engine flame out and 90 percent of the mission objectives were accomplished. A summary of the flight profile actually carried out follows:

1. Launched and climbed to 43K feet MSL, checked climbing turns every 10K feet while in climb.

2. Leveled at 43K feet MSL, adjusted fuel flow rate for 200 KIAS, then dived to 14K feet MSL. Diving turns were checked during descent.

3. Leveled at 15K feet MSL, checked level turns and checked BAO turns.

4. Climbed to 22K feet MSL, leveled off, checked level turns and checked BAO turns.

5. Climbed to 30K feet MSL, leveled off, checked level turns and checked BAO turns.

6. Climbed to 40K feet MSL, leveled off, checked level turns and checked BAO turns.

7. Climbed to 48K feet MSL, leveled off, checked level turns and checked BAO turns.

8. Engine flame out occurred at 42K feet MSL while in a right turn.

9. Glide mode continued for 2.25 minutes until recovery commanded at 32K feet MSL.

B. Special Observations

The test plan was followed closely during this mission. Operation in the Glide Mode was satisfactory. The following observations are made from recorded telemetry data.

1. Loss of Carrier (LOC) telemetry returns occurred quite frequently during this mission. There were 13 LOC sequences during the mission with the longest LOC period being 1.4 seconds.

2. The maximum pitch attitude at launch was excessive, over 35 degrees.

3. AFCS performance was monitored up to an altitude of 48K feet MSL during this mission.

4. In Airspeed modes the AFCS caused the drone to approach the climb or dive schedules in a satisfactory manner.

5. Normal turn performance followed the bank angle schedule satisfactorily.

6. In the altitude hold mode, normal turns resulted in no noticeable altitude changes; however, exact altitude deviations were not determined because altitude error data was not transmitted.

7. Excessive pitch oscillations occurred during turns at altitudes above 30K feet MSL. The pitch oscillations coupled into the roll axis.

8. The loss of altitude during some BAO turns was greater than expected. Some turns resulted in losses in excess of 3000 feet.

9. BAO and diving turns resulted in steady state bank angles often not within the specified command angle of 45 degrees +2-5, expecially at high altitudes.

10. No normal acceleration data was transmitted.

11. While in level flight at an altitude of 13K feet MSL, the drone required 2.4 seconds to reach a steady-state bank angle after a left turn was commanded and a right turn required 2.2 seconds.

12. While in level flight at an altitude of 44K feet MSL, the drone required 2.6 seconds to reach a steady-state bank angle after a left turn was commanded and a right turn required 2.3 seconds.

13. The automatic roll trim feature resulted in a three degree steady-state aileron deflection during straight and level flight to maintain wings level within two degrees. This was with the aid of some left rudder trim.

C. Missions Anomalies

1. Normal turns commanded from straight and level resulted in pitch oscillations at altitudes above 30K feet MSL. These oscillations ceased whenever Straight and Level or BAO were commanded. The pitch oscillations coupled the roll axis but roll oscillations tended to damp out in a satisfactory manner. Subsequent to this flight it was decided that a pitch rate gain change was necessary, and this change was made. A filter was also added to filter altitude error.

2. Excessive altitude losses occurred during some of the BAO turns; sometimes losses were in excess of 3000 feet. BAO turns disengage the altitude hold loop and general slight altitude losses occur.

Specifications on the maximum allowable altitude deviation during BAO turns are not given in the specification CP 10650.

3. BAO turns have target steady-state bank angles in excess of the specified command maximum of 47 degrees. Bank angles for diving turns are not specified but are supposed to comply with BAO schedules. The specification should be clarified in this area. Subsequent test flights should reveal whether the changes made at the conclusion of this flight, affect BAO and Diving Turn bank angles.

Production Verification Flight Test No. 3

A. Mission Profile

This flight of 24 November 1971 was to have been carried out according to Plan No. 1 on drone SN 68-10372. It was the first flight of this drone after repair of the elevator servo actuator which had presented problems during Flight No. 1. It was also the first flight of the AFCS since incorporation of higher pitch rate gain and a filter on altitude error. Launch time was 0815 hours MST and the launch was successful. The flight duration was 40 minutes and 95 percent of the mission objectives were accomplished. A summary of the flight profile actually carried out follows:

1. Launched and climbed to 10K feet MSL in launch mode, leveled off and checked normal turns.

2. Climbed to 48 K feet MSL doing climbing turns ever 10K feet.

3. Dived to 10K feet MSL doing diving turns every 10K feet.

4. Leveled off at 10K feet MSL and checked BAO turns.

5. Climbed to 48K feet MSL, leveled off every 10K feet and checked level turns during climb.

6. Leveled off at 48K feet MSL and checked BAO turns.

7. Range Control ordered recovery which was successfully initiated.

8. The recovery sequence was initiated at 40K feet MSL.

B. Special Observations

The test plan was followed closely during this mission, except the flight was not continued to BINGO fuel as range time was limited. The following observations are made from recorded telemetry data:

1. There were 11 LOC sequences during the mission with the longest LOC period being 1.0 seconds.

2. AFCS performance was monitored up to an altitude of 48K feet MSL during this mission.

3. Airspeed modes caused the drone to approach the climb or dive schedules as expected; however, the performance tended to remain on the low side of these schedules. During short changes (10K feet), AFCS performance was very good.

4. Normal turn performance followed the bank angle schedule satisfactorily.

5. In the altitude hold mode, normal turns resulted in no noticeable altitude changes; however, exact altitude deviations were not determined because altitude error data was not transmitted.

6. One left BAO turn at 10K feet MSL resulted in a 10K feet climb. The drone banked to 41° during this maneuver. The shallow bank angle may have been the cause of the climb.

7. High altitude BAO turns showed altitude losses of 4200 fpm maximum.

8. BAO turns complied with the specification bank angle requirements and diving turns complied with BAO requirements.

9. The automatic roll trim feature resulted in a six degree steady-state aileron deflection during straight and level flight to maintain wings level within two degrees. This was with the aid of some rudder trim.

10. Left normal turns were generally two or three degrees shallower than right turns.

11. While in level flight at an altitude of 10K feet MSL, the drone required 2.6 seconds to reach a steady-state bank angle after a left turn was commanded and a right turn required 2.3 seconds. Bank angles were symmetric in each direction for these turns.

12. While in level flight at an altitude of 44K feet MSL, the drone required 3.4 seconds to reach a steady-state bank angle after a left turn was commanded and a right turn required 3.2 seconds.

13. The pitch oscillations encountered during the previous flight were alleviated by the pitch rate gain change and added filter.

C. Mission Anomalies

The climb encountered when a left BAO turn was commanded at 10K feet MSL was unexpected. BAO turns disengage the altitude hold loop and generally slight altitude losses occur. The altitude deviation during BAO turns is not specified in the AFCS specification. The bank angle was shallow (41 degrees) during this turn, the IAS was very high (in excess of 435Kts) and the turn was held for over 90 seconds. These conditions apparently caused the large altitude gain.

Production Verification Flight Test No. 4

A. Mission Profile

This flight of 2 December 1971 was to have been carried out according to Plan No. 4 on drone SN 68-8386. A loss of 38K feet of altitude was encountered after a BAO command was transmitted. This event necessitated deviating from the test plan and some of the planned maneuvers were not carried out. Launch time was 1036 hours MST and the launch was successful. The flight duration was 30 minutes and about half of the mission objectives were accomplished. A summary of the flight profile actually carried out follows:

1. Launched and climbed to 10K feet MSL, leveled off and checked level turns.

2. Climbed to 45K feet MSL with several climbing turns in each direction during climb.

3. At an altitude of 43K feet MSL the vehicle went into an uncontrolled dive. The BAO mode had been engaged during a left turn when this occurred. Control was not regained for some 97 seconds when a straight and level command was accepted and the drone leveled at a minimum altitude of 4200 feet MSL.

4. At minimum altitude the maximum IAS encountered was 520Kts. Another climb was initiated.

5. During a second climb to 50K feet MSL the drone was leveled every 10K feet and level turns were checked.

6. At 50K feet MSL a left BAO turn was initiated and successfully performed.

7. Level turns were checked at 48K feet MSL.

8. A dive was initiated and diving turns checked.

9. Recovery was at 25K feet MSL.

B. Special Observations

The mission deviated from the test plan after about 15 minutes of flight due to unexpected events. The following observations are made from recorded telemetry data:

1. There were no LOC sequences indicated during this mission.

2. AFCS performance was monitored up to an altitude of 50K feet MSL during this mission.

3. In airspeed modes the AFCS caused the drone to approach climb and dive schedules satisfactorily.

4. Normal turn performance followed the bank angle schedule satisfactorily.

5. In the altitude hold mode, normal turns resulted in altitude changes within the specified ±100 feet.

6. Altitude error was telemetered during this flight providing a more precise measurement of altitude changes during altitude hold modes. There was a steady-state altitude error of approximately 200 feet.

7. An uncontrolled dive resulted when BAO was commanded during a left turn at 43K feet MSL. During the dive the elevator position appears to have been limited at approximately ten degrees up. The up elevator position was ineffective in terminating the dive. Pitch commands did not effect the elevator or dive rate for abut 90 seconds. The bank angle initially reached after the BAO command was correct, about 46 degrees; however, during the dive the bank angle increased to 67 degrees when the BAO function was terminated. After the Release BAO command the bank angle reduced to about 55 degrees. The bank angle continued to be larger than commanded with a result that aileron trim shift to the right took place to 20 degrees right aileron up. After about 39 seconds, S&L was commanded which did level the wings, but did not terminate the dive. When a minimum altitude of 4200 feet MSL was reached, a climb command was accepted, the elevator moved, and a controlled climb was started.

8. A second BAO turn commanded near the end of the missions was successful; however, this turn was not held as long as the first.

9. One diving turn and on BAO turn had bank angles exceeding the specified 47 degrees.

10. The automatic roll trim feature resulted in a four-degree steady-state aileron deflection during straight and level flight to maintain wings level within two degrees. This was with the aid of full rudder trim.

11. Left and right turns appeared to have symmetrical bank angles.

12. While in a climb at an altitude of 10K feet MSL, the drone required 2.4 seconds to reach a steady-state bank angle after either a left or right turn was commanded.

13. While in level flight at an altitude of 40K feet MSL, the drone required 2.6 seconds to reach a steady-state bank angle after either a left or right turn was commanded.

14. When crossing the 15K feet altitude during a climbing turn there was a change in roll from 34 degrees to 49 degrees. This shows that the bank altitude schedule programmed into the AFCS was

functioning properly.

15. At 17:56:08Z a climb was commanded and 16 seconds later a left turn which did not latch. Some 34 seconds after the climb command a left turn was commanded which did latch, with no straight and level command given in the interval. None of these abort parameters appear to be at levels which would cause an abort to straight and level, but the drone appeared to be in a straight and level mode.

16. The normal acceleration data transmitted correlates with bank angle data.

17. The maximum normal acceleration encountered during this mission occurred at the time of pullout of the first dive and was 3g's.

C. Mission Anomalies

1. At 17:56:08Z while in a climb mode the AFCS shifted to a straight and level mode without such a command having been transmitted or conditions for an abort being present. The reason for this change of mode is unknown. The AFCS did not accept spurious commands or change modes without commands at any other time during these test flights. The command may have been transmitted for too short a time interval to register on the strip chart recording.

2. The reason for the loss of control and altitude which occurred when BAO was commanded at 43K feet MSL has partially been determined.

The loss of aileron control was probably the result of a reduction in the effective dihedral derivative, C_{l_β}, due to a compressibility phenomenon which occurs near 0.9 Mach number on the BQM-34A Target. The compressibility phenomenon explains the failure of the ailerons to return the target to the correct bank angle after Release BAO was commanded. The initial loss of altitude increased the target speed to a critical level and the high Mach number continued until lower altitudes brought about increased drag and increased speed of sound. At the lower Mach number the ailerons were again effective.

The initial loss of altitude appears to have been caused by an unexplained AFCS limit in the elevator channel. The target was losing altitude in the level left turn commanded before the BAO function. After the BAO command the elevator held at approximately ten degrees up. The elevator position remained constant even after an S&L command was received by the FCS. The dive was not terminated until the FCS began moving the elevator properly. LSI has considered the elevator position limit to be a torque limit; however, neither calculated hinge moments or measurements taken on BQM-34A Targets in another test program have confirmed the torque limit theory.

3. A very steep diving turn occurred on the next to last turn carried out during the mission. It resulted in an aileron trim shift the same as the earlier BAO turn but control was not lost. Right turn aileron held to 10 degrees did not prevent the target drone from

banking to 63 degrees left wing down. It should be noted here that diving turns are contolled in the same manner as BAO turns. This turn was commanded at an altitude of 44K feet MSL. The altitude lost during the turn conformed to the dive schedule. Pitch attitude was 7 degrees nose down. The aileron trim shift and steep bank angle may have been the result of the same phenomenon discussed in paragraph 2 above as the Mach number during this maneuver was approximately 0.92.

Production Verification Flight Test No. 5

A. Mission Profile

This flight of 13 December 1971 was to have been carried out according to Plan No. 2 on drone SN 68-10372. After 13.7 minutes of flight during this mission, engine flameout occurred. The engine shutdown was not caused by the AFCS. Only half of the planned maneuvers were carried out due to the short flight time. Launch time was 0801 hours MST. A summary of the flight profile actually carried out follows:

1. Launched and climbed to 15K feet MSL, leveled off and checked level turns.

2. Thrust was set to give an IAS of approximately 330kts and level turns were checked.

3. The IMK mode was armed and a right turn to 180 degrees heading change was carried out.

4. An IMK left turn to 180 degrees was carried out.

5. Climbed to 20K feet MSL, leveled off, adjusted thrust for 340kts IAS and checked level turns.

6. Checked an IMK left turn to 180 degrees.

7. Checked an IMK right turn to 180 degrees.

8. Increase Thrust command was transmitted and engine stopped.

9. Automatic recovery sequence was successfully initiated.

B. Special Observations

The test plan was followed closely on this mission until the engine flameout occurred. Engine dissassembly at the conclusion of this flight revealed that the forward main bearing of the engine had failed. The following observations are made from recorded telemetry data:

1. There were 4 LOC sequences during this mission with the longest LOC period being 1.2 seconds.

2. AFCS performance was monitored up to an altitude of 20K feet MSL during this mission.

3. Launch was abnormal with a maximum pitch attitude of 35 degrees and maximum roll attitude of 20 degrees right wing down.

4. The AFCS caused the drone to approach the climb schedule in a satisfactory manner when in the climb mode.

5. Turn performance followed the bank angle schedule satisfactorily.

6. IMK turns stabilized at bank angles very close to the programmed 70.5 degrees.

7. In the altitude hold mode one altitude deviation exceeded the specified ±100 feet. Turns were satisfactory.

8. The first IMK turn caused an altitude loss in excess of 800 feet. All other IMK turns were within the specified ±400 feet.

9. Two IMK turns were successfully completed at each of two altitudes, 15K feet MSL and 20K feet MSL.

10. The automatic roll trim feature required only two degrees of steady-state aileron deflection to maintain wings level within two degrees. This was with the aid of full rudder trim.

11. The normal acceleration channel recordings were noisy; however, acceleration levels did not correlate with bank angle measurements and the IMK turns appeared to be within 0.5g's of the anticipated 3g's programmed.

12. The dive mode was never engaged during this mission.

13. In level flight at an altitude of 20K feet MSL, the drone required 3.0 seconds to reach a steady-state bank angle after a left turn was commanded and a right turn required 2.8 seconds. These turns tended to be symmetric in bank angle.

14. Fuel flow rates were not constant during the flight. On occasions there were sudden increases in fuel flow and corresponding RPM fluctuations.

C. Mission Anomalies

1. Engine flameout occurred after 13.7 minutes of flight time due to failure of this forward main bearings of the engine. Cause of the bearing failure has not been determined.

2. The altitude loss during the first IMK turns occurred under conditions of reduced throttle (IAS was set for 330kts). The drone recovered the altitude loss after completion of the turn with no problems and no negative g's.

3. Launch was abnormal with a maximum of 35 degrees of pitch attitude after bottle separation (T + 2.1 sec). At T +26 sec, the airspeed increased substantially and the normal release mode pitch altitude was obtained. Action was taken to update launch procedures during the

period when these tests were being conducted.

4. Fuel flow was abnormal. At the time of engine failure the RPM started to decrease and a step increase in fuel flow occurred, then the engine seized. The raw fuel being poured into the burner caused a back pressure which blew smoke out the inlet (reverse flow) and gave the characteristics of a compressor stall.

5. The altitude deviation mentioned in Straight and Level occurred at the conclusion of an IMK turn after Straight and Level was commanded. The altitude error in the system at this time exceeded 100 feet, thus an altitude deviation in excess of 100 feet was unavoidable. The altitude error was dissipated satisfactorily.

Production Verification Flight Test No. 6

A. Mission Profile

This flight of 16 December 1971 was carried out according to Plan No. 5 on drone SN 68-8386. Launch time was 0752 hours MST and the launch was successful. The flight duration was 34.5 minutes to BINGO fuel and 80 percent of the mission objectives were accomplished. A summary of the flight profile actually carried out follows:

1. Launch and climbed to 14K feet MSL, leveled off and checked level turns.

2. Carried out right and left IMK turns (approximately 180-degree heading change).

3. Climbed to 20K feet MSL, leveled off and again carried out 180-degree right and left IMK turns.

4. Climbed to 30K feet MSL, leveled off and again carried out 180-degree right and left IMK turns.

5. Dived to 10K feet MSL and carried out diving turns during descent.

6. Climbed to 20K feet MSL, leveled off and carried out normal and IMK turns.

7. Recovery after BINGO fuel was at 20K feet MSL.

B. Special Observations

The test plan was followed closely during this mission. The following observations are made from recorded telemetry data:

1. ere were no LOC periods indicated during this mission.

2. AFCS performance was monitored up to an altitude of 30K feet MSL during the mission.

3. Climb and dive schedules were approached satisfactorily during these maneuvers.

4. Turn performance followed the bank angle schedule satisfactorily.

5. The altitude hold function was unable to hold altitude within ±100 feet during some maneuvers.

6. Altitude losses during IMK turns often exceeded 1000 feet.

7. Longitudinal and pitch oscillation often occurred at the conclusion of IMK turns, but these damped out satisfactorily.

8. Normal acceleration data correlates with bank angle data. Two normal right turns; however, registered 2g acceleration levels.

9. Normal acceleration levels during IMK turns were generally within the expected proximity of 3g's (IMK bank angle set for 70.5 degrees); however, g levels up to 4.2g's were encountered.

10. In level flight at an altitude of 20K feet MSL the drone required 3.0 seconds to reach a steady-state bank angle after a left or a right turn was commanded. These turns were symmetric in bank angle.

11. In level flight at an altitude of 30K feet MSL the drone required 3.2 seconds to reach a steady-state bank angle after a left or a right turn was commanded. These turns were symmetric in bank angle.

12. The automatic roll trim feature resulted in three degrees of steady-state left aileron up to maintain wings level within two degrees. This was with the aid of half rudder trim.

C. Mission Anomalies

1. Altitude losses were excessive during IMK turns, many times in excess of 1000 feet. These losses were greater for right turns than for left turns. However, IMK turn normal acceleration levels and bank angles were reasonable. LSI maintains that the eccentric IMK turn altitude performance of this target is due to target asymmetrics which they refer to as "bent bird characteristics". The altitude hold performance during these IMK turns was not considered satisfactory; however, the drone was felt to be at fault rather than the AFCS.

2. A two cycle per second oscillation in the pitch axis occurred several times when rolling out of IMK turns. These oscillations. damped out satisfactorily. It has been found that this condition can be alleviated by holding S&L commands for more than five seconds.

3. Straight-and-Level altitude hold capability was generally good. The deviations that exceeded ±100 feet occurred when S&L was commanded to conclude IMK turns and altitude error already exceeded 100 feet, or when thrust was changed while in the altitude hold mode.

Production Verification Flight Test No. 7

A. Mission Profile

This flight of 6 January 1972 was to have been carried out according to Plan No. 3 on drone SN 68-8386. Launch time was 0751 hours MST and the launch was successful. After about seven minutes of flight time a left IMK turn was commanded which resulted in the drone going out of control to such an extent that the recovery command was intiated. Only 15 percent of the planned objectives were accomplished due to the short flight time. A summary of the flight profile actually carried out follows:

1. Launched and climbed to 20K feet MSL, leveled off and checked level turns.

2. Adjusted fuel flow rate for an IAS of about 350kts and carried out level turns.

3. A left IMK turn was commanded and 150 degrees of a planned 180-degree heading change were completed.

4. Drone went out of oontrol so the recovery sequence was initiated. Recovery was successful

B. Special Observations

The test plan was followed until the drone went out of control during this mission. The following observations are made from recorded telemetry data:

1. There were no LOC periods indicated during the mission.

2. AFCS performance was monitored up to an altitude of 20K feet MSL during this mission.

3. In the climb mode the drone approached the climb schedule very satisfactorily.

4. Normal turn performance followed the bank angle schedule satisfactorily.

5. In the altitude hold mode, pitch oscillations occurred while in a right turn. These damped out poorly.

6. The only IMK turn commanded started satisfactorily with a steady-state bank angle of about 74 degrees. A roll trim command was transmitted and the bank angle increased to 76 degrees. Three seconds after the bank angle was established the target drone began to roll out of the turn without having been commanded or without having reached an abort level. The drone rolled back to wings level and pitched nose

straight up. It fell over on its back and completed two 360-degree rolls. Recovery was initiated.

7. The automatic roll trim feature required five degrees of aileron deflection to maintain wings level within two degrees. This was with the aid of some rudder trim.

8. In level flight at an altitude of 20K feet MSL, the drone required 3.0 seconds to reach a steady-state bank angle after a left turn was commanded and a right turn required 3.4 seconds. These turns were symmetric in bank angle.

9. The Dive mode was not engaged during this mission.

10. Normal acceleration levels generally correlate with bank angle measurements; however, the normal acceleration level during the IMK turn was considerably less than the expected 4g's (measured about 2.5g's).

11. Pitch oscillations exceeding specification limits occurred until the drone began to go out of control during the right level turn some six minutes after launch.

C. Mission Anomalies

1. Pitch oscillations occurring six minutes after launch appear to have been induced by turbulence. They damped out poorly.

2. The drone went out of control before the first IMK turn was completed. The AFCS had been present for 4.0g IMK turns (75.5 degrees). It is suspected that the drone had some discrepancy within it, rather than the AFCS because discrepancies have occurred during every flight of drone SN 68-8386. At the recommendation of 6585th/TD, the drone was taken out of use for this test program. Drone SN 68-8346 was substituted for 68-8386.

Production Verification Flight Test No. 8

A. Mission Profile

This flight of 12 January 1972 was carried out according to Plan No. 3 on drone SN 68-10372. Launch time was 0745 hours MST and the launch was successful. The flight duration was 31.8 minutes to BINGO fuel and recovery. Ninety percent of the mission objectives were accomplished. A summary of the mission profile actually carried out follows:

1. Launched and climbed to 20K feet MSL, rudder trim adjusted and checked climbing turns.

2. Leveled at 20K feet MSL, checked level turns, then continued climb to 22K feet MSL.

3. Leveled off at 22K feet MSL, adjusted fuel flow rate for an IAS of approximately 350kts and checked level turns.

4. Engaged the IMK mode and carried out a 180-degree left turn using IMK aileron trim to hold normal acceleration at 4g's.

5. Engaged the IMK mode and carried out a 180-degree right turn using IMK aileron trim to hold normal acceleration at 4g's.

6. Adjusted fuel flow rate for an IAS of approximately 350kts, carried out level turn and one additional IMK turn.

7. Reduced fuel flow rate to 330kts IAS, carried out one IMK turn, then commanded Straight and Level and SMOKE.

8. Carried out level turns at 22K feet MSL, and commanded SMOKE.

9. Reduced IAS to 310kts and dived to 12K feet MSL following dive airspeed schedule, reached a 400kts IAS at 12K feet MSL.

10. Carried out level turns and IMK turns, used IMK aileron trim to adjust normal acceleration to 4g's.

11. Climbed to 22K feet MSL, adjusted fuel flow rate for an IAS of 380kts, carried out level turns and IMK turns using IMK aileron trim.

12. Successfully commanded recovery sequence at BINGO fuel.

B. Special Observations

The test plan was followed very closely during this mission. The following observations are made from recorded telemetry data:

1. There were no LOC periods indicated during this mission.

2. AFCS performance was monitored up to an altitude of 22K feet MSL.

3. In airspeed modes the AFCS caused the drone to approach climb and dive schedule satisfactorily. These maneuvers were not held sufficiently long for the drone to reach the schedules.

4. Turn performance followed the bank angle schedule satisfactorily.

5. In the altitude hold mode, level turns resulted in altitude changes within the specified ±100 feet.

6. IMK turns (set for 75.5 degrees bank angle or 4g's in a coordinated turn) resulted in excessive altitude deviations sometimes in excess of 1000 feet.

7. Normal acceleration levels during IMK turns were not constant and deviated considerably from 4'gs. Some IMK turn maneuvers resulted in normal acceleration levels exceeding 6g's. Right turns generally resulted in greater normal acceleration levels than left turns.

8. It is very difficult to set IMK aileron trim and rudder trim so that both altitude hold and bank angle requirements can be met by the AFCS.

9. Left IMK turns required additional left IMK aileron trim to maintain normal accleration at 4g's and right IMK turns required left IMK aileron trim as normal acceleration levels exceed 4g's.

10. Considerable altitude deviations are encountered when Straight and Level is commanded to conclude IMK turns.

11. In level flight at an altitude of 22K feet MLS, the drone required 3.0 seconds to reach a steady-state bank angle after a left turns was commanded and a right turn required 2.8 seconds.

12. In level flight at an altitude of 12K feet MSL, the drone required 2.4 seconds to reach a steady-state bank angle after either a left or a right turn was commanded.

13. At 15:14Z longitudinal oscillations were encountered during a right IMK turn which damped satisfactorily.

14. Acceleration data correlates closely with bank angle data for normal turns.

15. A Straight and Level command removes IMK aileron trim so that when IMK turns are commanded, IMK aileron trim must be readjusted to give normal acceleration levels during the next IMK turn.

16. The automatic roll trim feature required five degrees of aileron deflection to maintain wings level within two degrees. This was with the aid of some rudder trim.

C. Mission Anomalies

1. Considerable altitude deviations were encountered during IMK turns sometimes in excess of 1000 feet. During one IMK turn 2800 feet were lost. It is practically impossible to adjust IMK aileron trim and rudder trim so that both altitude deviations are within specification limits and normal acceleration levels are at the levels expected for coordinated turns. Generally, if altitude deviations are to be held within specification limits, normal acceleration levels have to be allowed to deviate considerably.

2. Altitude deviations experienced when Straight and Level is commanded to conclude IMK turns are expected when altitude error exceeds 100 feet at the time S&L is commanded.

3. Longitudinal oscillations which occurred at 14:14Z while in a right IMK turn may have been the result of turbulence or changes in IMK trim which were commanded at the time of these oscillations. Damping was satisfactory and this was not an out-of-specification condition.

Production Verification Flight Test No. 9

A. Mission Profile

This flight of 24 January was carried out according to a special Baseline Test Plan on drone SN 68-8346. The AFCS package used is the one that had previously been installed and flown in drone SN 68-8386. It was installed in this target drone to determine whether basic drone problems or flight control problems were the cause of the poor flight characteristics encountered in the previous flights of drone SN 68-8386. Launch time was 0800 hours MST and the launch was successful. The flight duration was 36.9 minutes and ninety percent of the mission objectives were accomplished. BAO and IMK turns were not attempted as these were not part of the test plan for this flight. They are tested for this drone in subsequent flights. A summary of the mission profile actually carried out follows:

1. Launched and climbed to 14K feet MSL and leveled off.

2. Adjusted the fuel flow rate for an IAS of 350kts and checked level turns and one figure 8 pattern.

3. Climbed to 20K feet MSL, again checked level turns, and flew one more figure 8 pattern.

4. Climbed to 30K feet MSL, leveled off, and flew a figure 8 pattern.

5. Dived to 20K feet MSL, leveled off, and adjusted fuel flow rate for an IAS of 350kts.

6. Successfully initiated recovery sequence.

B. Special Observations

The flight test plan was followed closely during this mission. The following observations are made from recorded telemetry data:

1. There were two LOC sequences during the mission with the longest LOC period being 0.1 seconds.

2. AFCS performance was monitored up to an altitude of 30K feet MSL.

3. This flight proved to be satisfactory using the AFCS package previously used in drone SN 68-8386. Nearly all parameters were within specification limits.

4. In airspeed modes the AFCS caused the drone to approach climb and dive schedules in a satisfactory manner.

5. Turn performance followed the bank angle schedule closely except all turns were approximately four degrees steeper than normally expected. (Within specification limits.)

6. The altitude hold function allowed the drone altitude to vary by $\pm$170 feet at one time during the mission. Generally altitude deviations were within specified limits.

7. In level flight at an altitude of 20K feet MSL, the drone required 2.8 seconds to reach a steady-state bank angle after a left turn was commanded; a right turn required 3.1 seconds.

8. In level flight at an altitude of 30K feet MSL, the drone required 2.9 seconds to reach a steady-state bank angle after a left turn was commanded; a right turn required 3.4 seconds.

9. There were evidences of dutch roll after about 14 minutes of flight time. These low frequency oscillations did not exceed the specification limits of 2 degrees peak to peak.

10. Normal acceleration data correlates well with bank angle data.

11. The automatic roll trim feature required two degrees of aileron deflection to maintain wings level within two degrees. This was with the aid of six degrees of left rudder trim.

C. Mission Anomalies

1. Altitude deviations slightly in excess of specification limits were encountered. The larger altitude deviations occurred when changes in the throttle settings were made.

2. The dutch roll phenomenon detected was within specification limits.

Production Verification Flight Test No. 10

A. Mission Profile

This flight of 5 April 1972 was to have been carried out according to a special beta vane baseline test plan on drone SN 63-8346. A beta vane had been installed to enable making measurements of the sideslip angle, β. Launch time was 0645 hours MST and the launch was successful. The flight duration was 35 minutes to recovery and 65 percent of the mission objectives were accomplished. A summary of the mission profile actually carried out follows:

1. Launched and climbed to 20K feet MSL with one climbing turn carried out during the climb.

2. Leveled at 20K feet MSL, adjusted fuel flow rate for an IAS of 370 knots, rudder trim was zeroed, and left and right normal turns were completed while measuring β .

3. Adjusted rudder trim for zero β in Straight and Level flight, and completed a right and left turn while measuring β .

4. Adjusted fuel flow rate for an IAS of 410 knots, returned rudder trim to zero, carried out right and left normal turns, and measured β .

5. Adjusted rudder trim for zero β in Straight and Level flight, and carried out left and right normal turns while measuring β .

6. Climbed to 25K feet MSL.

7. Leveled at 25K feet MSL, adjusted fuel flow rate for an IAS of 330 kts, zeroed rudder trim and measured β .

8. Completed right and left normal turns and measured β.

9. Adjusted rudder trim for zero β in Straight and Level flight and carried out left and right normal turns while measuring β .

10. Adjusted fuel flow rate for an IAS of 275kts, zeroed rudder trim and measured β .

11. Carried out right and left normal turns whiles measuring β.

12. Adjusted rudder trim for zero β in Straight and Level flight and carried out left and right normal turns while measuring β .

13. Twice engaged the IMK mode while in left turns.

14. Recovery was initiated at 25K feet MSL

B. Special Observations

The test plan was followed to obtain sideslip angle measurements at two altitudes; however, two other planned altitudes were not flown. IMK turns checked near the end of the mission were done in addition to the original test plan. The launch and climb-out during this mission were exceptionally good. RATO bottle alignment was accomplished using a new Technical Order procedure. The following observations are made from recorded telemetry data:

1. There were eight LOC sequences during this mission with the longest lasting 1.5 seconds.

2. AFCS performance was monitored up to an altitude of 25K feet MSL during this mission.

3. Level turns generally resulted in altitude changes within the specified ±100 feet; however, there were some level turns that resulted in altitude deviations greater than this amount.

4. IMK turns were successful; however, they were very steep and bank angle increased until Straight and Level was commanded. Altitude decreased during both of these turns, but remained within specifications limits. The first IMK turn was maintained for about 8 seconds and the second about 4 seconds.

5. At 20K feet MSL in level flight the drone required 3.3 seconds to reach a steady-state bank angle after a left turn was commanded and 3.4 seconds after a right turn was commanded.

6. At 25K feet MSL in level flight the drone required 3.4 seconds to reach a steady-state bank angle after a left turn was commanded and 3.6 seconds to reach a steady-state bank angle after a right turn was commanded.

7. In Straight and Level flight, the automatic roll trim feature required from 5 degrees of left aileron to 2 degrees of right aileron deflection to maintain wings level within two degrees, dependent on the position of the rudder trim.

8, The normal acceleration data correlates closely with bank angle data.

9. Sideslip angle, β , data taken is summarized in Table VII.4.

C. Mission Anomalies

1. Altitude deviations encountered while in the altitude hold mode were not a severe problem. The AFCS tended to maintain a steady-state positive altitude error at full throttle and a steady-state negative altitude error at the reduced throttle setting used. Changes in throttle setting cause altitude deviations that were satisfactorily damped.

Beta Measurements

Altitude	Rudder Trim	Conditions	Mach .8 (β)	Mach .9 (β)
20K ft MSL	Zero degrees	S&L	2.6°R	2.9°R
		Lt	2.5°R	2.2°R
		Rt	2.2°R	2.3°R
	6 degrees Left	S&L	0°	
		Lt	0°	
		Rt	0.4°L	
	Full Left	S&L		0°
		Lt		0.6°R
		Rt		0.6°R
25K ft MSL	Zero degrees	S&L	2.5°R	2.5°R
		Lt	2.2°R	2.8°R
		Rt	2.0°R	2.5°R
	6 degrees Left	S&L	0°	
		Lt	0°	
		Rt	0°	
	Full Left	S&L		0°
		Lt		0.7°R
		Rt		0.5°L

Beta Measurements Flt No. 10

Table VII.4

Production Verification Flight Test No. 11

This flight of 17 April 1971 was to have been carried out according to a special test plan which included IMK turns and high pitch attitudes during turns on drone SN 68-8346. Launch time was 0716 hours MST and the launch was not successful. At RATO bottle separation the pitch attitude was 48 degrees and IAS dropped from 170 knots to 147 knots. Recovery was commanded and the drone was successfully recovered. The flight duration was approximately eight seconds. The throttle had been retarded in an effort to reduce pitch three seconds after launch.

The cause of the high pitch attitude was improper bottle alignment due to an error made by someone in computing the waterline. Had the waterline been correctly determined, the bottle alignment would have been set at an angle to cause a flatter launch.

Production Verification Flight Test No. 12

A. Mission Profile

This flight of 24 April 1972 was to have been carried out on target drone SN 68-8346 according to a special test plan which included beta measurements during IMK turns. A restriction was established for this mission which required that the normal acceleration level of 4.0 ± 0.5g's be reached within four seconds after an IMK turn was commanded or the IMK turn be aborted. This restriction resulted in the aborting of all IMK turns initiated during this mission. Launch time was 1150 hours MST and the launch was successful. The flight duration was 31 minutes to recovery command. Thirty percent of the mission objectives were accomplished. A summary of the mission profile actually carried out follows:

1. Launched and climbed to 20K feet MSL.

2. Leveled off at 20K feet MSL, adjusted fuel flow rate for an IAS of 360 knots, and measured β.

3. Trimmed rudder to give zero β and flew one figure 8 pattern using normal bank angles.

4. Adjusted fuel flow for 100 percent rpm and started a left IMK turn which was aborted after 5 seconds due to excessive bank angle.

5. Fuel flow rate was reduced to an IAS of 340 knots and increased just prior to entering a left IMK turn.

6. The left IMK turn was aborted by a Straight and Level command because the normal acceleration did not reach 4 ± 0.5g's within four seconds.

7. Level left and right normal turns were carried out and fuel flow rate was reduced to an IAS of 340 knots.

8. Fuel flow rate was again increased and two right IMK turns were started. Both were aborted by Straight and Level commands as the normal acceleration did not reach the expected level.

9. Fuel flow rate was reduced to an IAS of 370 knots and a level right turn carried out.

10. Fuel flow rate was increased and two different left IMK turns were started. Both were aborted by Straight and Level commands.

11. One level left turn was carried out.

12. Fuel flow rate was increased and left and right IMK turns started. Both were ground aborted.

13. The fuel flow rate was reduced, three level left turns were carried out.

14. Recovery was successfully initiated at an altitude of approximately 16K feet MSL.

B. Special Observations

The test plan was followed closely during this mission except IMK turns were not held for 90-degree heading changes as planned. The maximum altitude attained during this mission according to the test plan was 20K feet MSL. The following observations are made from recorded telemetry data:

1. There was a total of 6 LOC sequences during this mission with the longest LOC period lasting 1.2 seconds.

2. Roll oscillations occurred during the launch phase.

3. Level turns generally resulted in altitude changes within the specified ±100 feet; however, two turns resulted in deviations sometimes exceeding this amount.

4. In Straight and Level flight, altitude deviations sometimes exceeded ±100 feet.

5. IMK turns resulted in altitude deviations within the specified ±400; however, no IMK turns were held for more than 7 seconds and the first IMK turn commanded resulted in a bank angle abort.

6. Left IMK turns were generally about 6 degrees steeper than right IMK turns.

7. At 20K feet MSL in level flight the drone required 3.0 seconds to reach a steady-state bank angle after a left turn was commanded and 2.6 seconds after a right turn was commanded.

8. In Straight and Level flight, the automatic roll trim feature required 2.5 degrees of left aileron to maintain wings level within two degrees.

9. The normal acceleration data correlates closely with bank angle data, except steep bank angle turns resulted in smaller normal acceleration levels than expected.

10. Adjustment of rudder trim, to an out of trim condition, resulted in dutch roll oscillations which damped satisfactorily.

11. β measurements made during IMK turns were of very little significance because these turns were not held long enough.

C. Mission Anomalies

1. The first IMK turn attempted resulted in a bank angle abort. This is not an out-of-specification condition, but is not expected or desirable. The steep turn response for left turns was probably the cause of this abort.

2. All but one of the IMK turns attempted were aborted because of the artificial restrictions placed on the mission. The specifications of attaining normal acceleration levels within four seconds is applicable only to AIM turns. In IMK turns the AFCS does not directly control normal acceleration and so it is not a valid parameter for evaluation. In IMK turns the acceleration builds up slowly and is not necessarily symmetrical for left and right turns. It was decided that a better requirement would be that IMK turns reach the preset bank angle ±5 degrees within 5 seconds.

3. Altitude deviations in altitude hold modes were not excessive. The maximum deviation was about 440 feet, and this occurred when S&L was commanded for less than 3 seconds to change from the IMK mode when an altitude error of 300 feet was present in the system.

4. The dutch roll phenomenon encountered in the out of trim condition and during launch is not an out of specification condition. The roll oscillations damped out within the required 8 cycles. LSI thought that the drone was out of rig and requested that the next test flight be in a different drone. This request was complied with.

Production Verification Flight Test No. 13

A. Mission Profile

This flight of 11 May 1972 was carried out according to Plan No. 6 on drone SN 68-10372. Launch time was 0700 hours MST and the launch was successful. The flight duration was 33.3 minutes to BINGO fuel and recovery command. A summary of the flight profile actually carried out follows:

1. Launched and climbed to 20K feet MSL, checked climbing turns during this climb.

2. Leveled at 20K feet MSL, adjusted fuel flow rate for an IAS of 350 knots, adjusted rudder trim for zero β, and checked level turns.

3. Armed IMK mode, adjusted fuel flow for 100 percent power, and carried out two IMK turns, one in each direction to heading changes of 180 degrees. (IMK mode preset for 75.5 degree bank angles during turns).

4. Dived to 10K feet MSL, stabilized fuel flow rate for 420 knots IAS, and checked level turns.

5. Carried out IMK turns to 180 degree heading changes in each direction.

6. Climbed to 14K feet MSL, leveled off, adjusted fuel flow for and IAS of 400 knots, and checked level turns.

7. Carried out IMK turns to 180 degree heading changes in each direction.

8. Adjusted fuel flow rate for 360 knots IAS and proceeded to recovery area.

9. Recovery was successfully initiated from 15K feet MSL.

B. Special Observations

The flight test plan was followed closely during this mission. The maximum altitude attained during the flight according to the test plan was 20K feet MSL. The following observations are made from recorded telemetry data:

1. There were some 14 LOC periods indicated by telemetry returns. The maximum LOC period was 1.5 seconds.

2. The launch was abnormal. The maximum pitch attitude was 36 degrees nose up. The maximum roll attitude was 21 degrees right wing down.

3. Level turns generally resulted in altitude changes within the specified ±100 feet; however, one turn resulted in a total altitude deviation of 330 feet.

4. In Straight and Level flight, altitude deviations sometimes exceeded ±100 feet.

5. Six IMK turns were successfully carried out.

6. IMK turns resulted in altitude deviations within the specified ±400 feet.

7. Two IMK turns resulted in normal acceleration levels of 6.5g's.

8. At 20K feet MSL the drone required 2.6 seconds to reach a steady-state bank angle after a left turn was commanded and 3.4 seconds after a right turn was commanded.

9. At 10K feet MSL the drone required 2.5 seconds to reach a steady-state bank angle after a left turn was commanded and 2.6 seconds after a right turn was commanded.

10. Normal acceleration data correlates with bank angle data, except very steep left and right turns do not cause symmetrical load factors.

11. Right IMK turns averaged about six degrees steeper than left IMK turns.

12. The automatic roll trim feature required four degrees of aileron deflection to maintain wings level within two degrees. This was with the aid of six degrees of left rudder trim.

13. Sideslip angle, data taken during IMK turns is summarized in Table VII.5.

14. Straight and Level commands were held for more than five seconds when commanded to change pitch modes.

15. Dutch roll oscillations were evidenced at times during Straight and Level flight that were satisfactorily damped.

C. Mission Anomalies

1. The high pitch attitude during launch was probably caused by the RATO bottle not generating enough thrust. Subsequent to this flight, the RATO bottle batch was UMR'd. The problem was not caused by the AFCS as the elevator moved to the electrical limit 1.1 seconds after launch in an attempt to force the nose of the target down.

2. The altitude deviations in the altitude hold mode are not excessive. Holding S&L commands when changing pitch modes did not

always prevent altitude deviation exceeding specification limits. Thrust changes sometimes caused altitude deviations in excess of specification limits.

3. Altitude deviations in Straight and Level modes occurring at the conclusion of IMK turns are to be expected bacause large altitude errors are present in the system at this time.

4. The high load factors encountered during IMK turns can be limited by IMK aileron trim. As they occurred, however, load factors exceeding 6g's are an out-of-specification condition.

5. The dutch roll oscillations encountered were not an out-of-specification conditions. These roll oscillations damped within the required 8 cycles.

Direction	Start/End Altitude	Duration	Bank Angle	Normal Acceleration Load Factor	Steady-State Sideslip Angle β
	(K feet MSL)	(Sec)	(Degrees)	(G's)	(Degrees)
L	19.0/19.0	42	71.5	3.5	0.50 L
R	19.0/18.5	11	78.0	4.0	0.50 L
R	10.5/11.0	11	75	6.5	0.25 L
L	10.5/11.0	56	71.0	3.3	0.50 R
R	15.0/14.5	11	75	6.5	0.25 L
L	15.0/15.2	53	70	3.25	0.50 R

Beta Measurements Flt No. 13

Table VII.5

Section VIII, Summary of Phase II

In the evaluation of the A/A37G-8 AFCS, there were two main areas of concern. The first was the encounter of apparently out-of-specification conditions and the second was the encounter of anomalies not covered by the specification. Recommended specification changes are discussed in Section X.

1. Out-of-Specification Conditions

A summary of out-of-specification conditions observed during Phase II testing is shown in Table V111.1. These are discussed in the following paragraphs.

a. BAO Roll Angles Not Per Schedule

Test Flight No. 2, 3 and 4 included BAO turns. Some BAO turns were successfully carried out in each of these flights. Test Flight No. 2 had steady-state bank angles up to 50° during BAO turns (maximum specified command angle is 45°). The first diving turn of Flt No. 2 reached a bank angle of 57 degrees. It is not clearly specified in CP 10650 that diving turns should comply with the BAO turn schedule; therefore, this is not an out-of-specification condition. Test Flight No. 3 successfully carried out BAO turns with bank angle performance according to the schedule. Test Flight No. 4 had one diving turn with a very large bank angle and one BAO turn which caused the vehicle to go out of control. It was concluded at the termination of this flight to restrict BAO turns to altitudes below 35K feet MSL. The problem was associated with target drone SN 68-8386. The restriction is probably unnecessary in targets which do not exhibit high bank angle turn asymmetries.

b. Pitch Oscillations, Amplitude, and Rate

Two Test Flights No. 2 and No. 7 had problems with pitch oscillations. A fix was incorporated in the FCB after the No. 2 flight which included a change in the pitch rate gain and a filter to filter altitude error. These changes effectively eliminated the problem encountered during Test Flight No. 2. The pitch oscillations which occurred during Test Flight No. 7 were different. They may have been caused by turbulence or may have been a problem inherent in Drone SN 68-8386. Turbulence was reported during this flight. Pitch oscillations were not encountered, after the fix mentioned above was incorporated in any flight except No. 7. The problem during this flight was considered to be an isolated incident no repeatable.

c. Altitude Hold In Level Flight

The holding of the S&L command for five seconds when changing pitch modes also tends to reduce altitude deviations. The

CP 10650 Requirements	Para No.	Flight Number 2	3	4	5	6	7	8	9	10	12	13
Wings Level within two degrees of roll	3.1.1.1.1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Airspeed Climb per schedule	3.1.1.1.2A	✓	✓	✓	✓	✓	✓	✓	✓			
Airspeed Dive per schedule	3.1.1.1.2A	✓	✓	✓	✓	✓	✓	✓	✓			
Normal Bank per schedule	3.1.1.1.2D	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
BAO roll angles per schedule	3.1.1.1.2D	X	✓	X								
Pitch Oscillations Amplitude less than 2° peak-to-peak or	3.1.1.1.3A	X	✓	✓	✓	✓	X	✓	✓	✓	✓	✓
Rate less than 10°/sec peak-to-peak in 12 cycles	3.1.1.1.3A	X	✓	✓	✓	✓	X	✓	✓	✓	✓	✓
Pitch response overshoot less than 10%	3.1.1.1.3A	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Altitude Hold S&L ±100 ft	3.1.1.1.3B	✓	✓	✓	X	X	✓	X	X	X	X	X
Altitude Hold Normal Turns ±100 ft	3.1.1.1.3B	✓	✓	✓	✓	X	✓	✓	✓	✓	X	X
Altitude Hold IMK Turns ±400 ft	3.1.1.1.3B				X	X	X	X		✓	✓	✓
Longitudinal Mode Damping 30% peak-to-peak per cycle	3.1.1.1.3C	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Maximum pitch rate 40° sec	3.1.1.1.3D	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Normal Acceleration 4g's max norm, 6g's max IMK	3.1.1.1.3			✓	✓	✓	✓	✓	✓	✓	✓	X
Roll Oscillations steady-state less than 2° peak-to-peak	3.1.1.1.4A	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Roll rate oscillations steady-state less than 10°/sec peak-to-peak	4.1.1.1.4A	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Roll disturbance oscillations damped to within 2° peak-to-peak after 8 cycles	3.1.1.1.4B	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Roll response overshoot less than 10% or 5° (lower)	3.1.1.1.4B	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Maximum Roll rate 100°/sec	3.1.1.1.4E	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Summary of Phase II Test Observations

Table VIII.1

KEY

✓ - OK
X - Not Acceptable
Blank - Information Not Available

requirement to hold altitude in this mode within ±100 feet is a very tight requirement. This cannot always be met except on a steady-state basis with the present AFCS. There were significant altitude deviations when S&L was commanded at the conclusion of IMK turns. If the system has an error of 400 feet at the conclusion if an IMK turn and S&L is commanded, it cannot be expected to maintain altitude within ±100 feet until the 400-foot error has been dissipated. Throttle changes sometimes also resulted in altitude deviations if excess of ±100 feet. This situation should be clarified in CP 10650.

d. Altitude Hold During IMK Turns

The requirement to hold altitude within ±400 feet during IMK turns is also a very tight requirement. It appears that it can be done by adjusting aileron trim during IMK turns; however, the trim is not an automatic function and this procedure places quite a burden on the operator. The AFCS does not have normal acceleration feedback in an IMK mode so accelerations cannot be expected to be held constant. The IMK mode only approximates high G turns. If a target does not exhibit severe asymmetric characteristics in high bank angle turns, the normal acceleration levels, bank angles and altitude hold will be near desired values. It should be noted that normal acceleration can be maintained at a constant level in the AIM modes which is presently under development.

e. Roll Oscillations, Amplitude, Rate and Damping

Roll oscillations were a problem during Test Flight No. 2. The problem was an oscillation which coupled from the pitch axis to the roll axis. This problem was eliminated by the fix mentioned in paragraph b. of this section.

2. Anomalies Not Covered By The Specification

Unexpected events of concern which occurred during this flight test program, but which were not out-of-specification conditions are discussed here.

a. Altitude Deviations During BAO Turns

The excessive altitude deviations encountered during BAO turns while this test program was being conducted all occurred in target drone SN 68-8386. It is believed that the problem is peculiar to this drone or is related to the drone high bank angle turn asymmetry problem. The altitude hold control loop is open during BAO turns; however, the up elevator commanded is that normally required to hold altitude and should not result in excessive altitude deviations. Further study of BQM-34A high bank angle turn asymmetries is now under consideration.

b. IMK Roll Angles Reaching Abort Levels

The steady state bank angle of IMK turns has no specified tolerance in CP 10650. The nominal value is adjustable. During Flight No. 12 an IMK turn resulted in a bank angle abort after the first IMK turn was commanded. The probable cause of this abort is the target asymmetric behavior in high bank angle turns. Left IMK turns were all steep during this mission. The steep bank angles could probably be prevented by commanding IMK Aileron trim before the IMK turn is commanded; however, such a procedure puts an extra burden on the operator and should not be necessary. The IMK aileron trim function should, however, be explained better in CP 10650.

c. Dutch Roll Oscillations

Dutch roll oscillations were experienced to some extent in Flights Nos. 2, 9, 12, and 13. Some modifications were made after Flight No. 2 which helped. The dutch roll ocillations occurring in the latter flights were not out-of-specification conditions and do not appear to be a significant problem.

d. Inability Of The A/A37G-8 To Control Target SN 68-8386

The reasons for excessive altitude losses during IMK turns and the out-of-control condition encountered while flight testing Target SN 68-8386 have not been satisfactorily determined. It has been found that asymmetric high bank angle turn characteristics of the BQM-34A are a problem on targets other than 8386. A separate program to investigate this problem has been initiated. If changes are needed in the AFCS, they will be instituted when the AIM mode modifications are contracted.

Section IX CONCLUSIONS

The A/A37G-8 AFCS can control the BQM-34A Target Drone in a satisfactory manner. It can perform functionally equal to the A/A37G-3B AFCS including the IMK modification and at less cost, weight, and volume. Certain minor modifications to the specification CP 10650 are necessary to clarify its requirements, and certain of the present requirements were not met during all of these test flights. Generally, out-of-specification conditions encountered did not represent unacceptable operation, but rather situations not taken into account when the specification was written. The changes needed in the specification for these reasons are described in the next section on Recommendations.

These conclusions are based on the completion of successful AFCS test flights using two different target drones during this test program. Additional studies and testing are expected to be carried out to determine the cause, or methods to control the high bank angle asymmetric characteristics exhibited by some of the BQM-34A Target Drones.

Section X RECOMMENDATIONS

The recommendations of this report belong in four categories as follows:

a. Recommendations for future test programs of this type.

b. Recommended changes to Specification CP 10650.

c. Recommended procedures for BQM-34A use.

d. Phase I Recommendations.

1. Recommendations for Future Test Programs

Measurements taken for the purpose of comparing AFCS performance with specification requirements should not be compromised by the telemetry system transmitting these measurements. Also, the method used to record these measurements should be convenient for evaluation. The manual process used in evaluating the measurements recorded during these test flights was very time consuming. For future programs of this type, precision telemetry transmitters should be used. The data should be recorded on magnetic tapes in a manner that would enable computer evaluations of measured parameters. As a minimum, the telemetry calibration should be standardized so that a precision calibrated scale could be used to check measurements if manual reading of this data is necessary. The Integrated Target Control System (ITCS), now in the design phase or the VEGA system proposed by Vega Precision Laboratories Inc., should provide precise digital telemetry channels for test programs in 1974. In the meantime, precision FM/FM telemetry transmitters can be used in place of the TM-431A now installed on the BQM-34A whenever precise engineering data is needed.

2. Recommended Changes to the Specification CP 10650

Revisions recommended to Specification CP 10650 are given here with section numbers.

"3.1.1.1.2 D. If the bank override mode is selected, the command is 45° + 2 - 5° regardless of altitude."

This section should explain that Diving Turns follow the BAO schedule. The A/A37G-8 AFCS does not place the BQM-34A at the bank angle commanded within the above tolerance limits under all conditions. A paragraph in the Performance section should specify AFCS performance for BAO turns. The time to reach steady-state BAO roll angles should be given.

"3.1.1.1.2 D. A ground adjustable bank angle command with a maximum of 75.5° is used in the increased maneuvering mode, with an abort level of 80.5°."

The bank angle abort level is adjustable. No tolerance is given for IMK turn bank angles. A time to reach steady-state IMK bank angles should be given in the Performance Section. Section 3.1.1.1.2 D should also describe the IMK aileron trim function.

"3.1.1.1.3 B. The pressure altitude will be maintained within ±400 feet for the increased maneuverability mode and ±100 feet during normal modes up to an altitude of 15,000 feet and the pressure equivalent of ±400 feet for the increaded maneuverability mode and ±100 feet during normal modes from 15,000 to 60,000 feet altitude."

The term "pressure equivalent" should be clearly explained. The requirement given should be a steady-state requirement. The requirement as stated cannot be met under conditions of some pitch mode changes and throttle changes. Time limits should be given for dissipating altitude error when changing from the IMK mode to S&L, and for dissipating altitude errors caused by throttle changes.

"3.1.1.1.3 D. The steady-state accuracy of the airspeed mode will be ±3 knots of commanded airspeed."

As stated, this section does not specify the transient requirements for achieving the steady-state condition. The addition of transient requirements to this section should cover time to achieve the steady-state conditions or the maximum altitude change permitted in capturing the schedule. This addition to this section would provide a definitively stated performance requirement; as stated now, there is no requirement to reach the steady-state condition.

3. Recommended Procedures for BQM-34A Use

The following procedures are recommended when using the BQM-34A Target Drone with the A/A37G-8 AFCS to prevent some of the difficulties encountered during these flights.

a. Command Straight and Level for at least five seconds to terminate climbs, dives or IMK turns.

b. If a target does not perform BAO or IMK turns properly at low altitudes, do not command BAO, IMK or diving turns at altitudes above 35K feet MSL.

c. If a dive is started and the drone fails to respond to further command, do not command turns until the drone responds to pitch commands or recovery is initiated.

d. Do not command IMK or BAO or AIM turns if the drone requires more than eight degrees of aileron trim to fly Straight and Level (single aileron).

e. Do not change rudder trim during turns.

f. Use IMK aileron trim to reduce bank angle if the drone starts to lose altitude during a level IMK turn.

4. Phase I Recommendations (Summary of 6585th Test GP/TD Recommendations)

It is recommended that the cable P/N 124E869 be lengthened by six inches and that the ground wires be lengthened which are supplied with A/A37G-8 AFCS installation kits. See Section III for details.

The A/A37G-8 should have access ports drilled in the side panel opposite the adjustment screws so that these adjustments will be accessible after installation.

PRODUCTION VAFCS AND TMCS FLIGHT TEST PLAN

VERSATILE AUTOMATIC FLIGHT CONTROL SYSTEM (VAFCS)
AND TELEMETRY SIGNAL CONDITIONER AND CALIBRATION SYSTEM
(TMCS) FOR BQM-34A TARGET DRONE

CONTRACT F33657-71-C-1107

1 AUGUST 1971

1.0 INTRODUCTION

This flight test program is to verify the system capabilities of two VAFCS and two TMCS as delineated in Lear Siegler Inc., Astronics Division Specification CP10650, dated 28 April 1971.

The VAFCS and TMCS are to be installed in two standard BQM-34A target drones at Holloman AFB, New Mexico for the purpose of checking VAFCS and TMCS installation; instructions; verification of appropriate adaptive cable harness sizing; evaluation checkout procedures and test panel capabilities; and verification of accuracy and completeness of maintenance and checkout instructions. Upon completion of these preflight tests, the two drones will be scheduled for three flights each in order to verify achievement of the performance parameters given in Specification CP10650. These flights will include operation of the release mode, climbing and diving on the airspeed schedules, right and left normal, IMK and bank angle override turns, straight and level mode entry response, altitude hold capabilities, and aileron trim performance.

This flight test plan identifies the objectives to be accomplished on each flight, the personnel and organizational support required, and the documentation to be performed.

2.0 FLIGHT TEST PROGRAM

The Production Flight Testing of the VAFCS and TMCS will be conducted in two phases. Phase I will cover the ground maintenance and checkout capabilities; Phase II will cover the six flights to prove that the VAFCS and TMCS meet Specification CP10650.

This test program will be accomplished by personnel of the 6585 Test Group at Holloman AFB, New Mexico. Lear Siegler Inc., manufacturers of the VAFCS and the TMCS, will assist 6585 Test Group as necessary.

3.0 PHASE I TEST PLAN

The following objectives will be met:

a. Verification of accuracy and completeness of maintenance and checkout instructions. Each manual will be reviewed by page and all errors or omissions will be recorded.*

b. Evaluation of ease of VAFCS and TMCS installation.

c. All cables will be checked for accuracy in wiring and adaptability to the drone system.

*Initial installation and checkout and flight testing will be done with preliminary technical orders.

d. All AGE provided for VAFCS checkout will be evaluated for proper operation.

e. The VAFCS will be checked out according to manuals and all errors or malfunctions noted for correction.

f. The TMCS will be checked out according to calibration procedures in manuals and accuracy verified with measurement of actual positions, angles and/or simulated airspeeds and altitudes of the VAFCS.

g. Lost Carrier Relay function, Inverter failure function, and Accelerometer function, will be verified.

All information gathered in Phase I testing will be gathered by AFSWC, 6585 Test Group, Target Drone Division (TD) for ASD (RWD).

The following equipment will be needed for Phase I testing:

a. VAFCS and TMCS equipment

b. Associated AGE

c. Technical Manuals

d. Other equipment as prescribed in the Technical Manuals

4.0 PHASE II FLIGHT PLAN

Table one will be utilized to accomplish the Phase II goals of this flight test program. The initial flight on each TMCS and VAFCS will cover basic system performance. Flight profiles to accomplish the flight-by-flight objectives of Table one will be standardized in accordance with paragraph 4.1.

4.1 BQM-34A Normal Modes:

NOTE: Unless otherwise specified, the drone configuration will be clean.

4.1.1 Climb - Dive Modes:

The climb mode will be engaged after launch when 350 KIAS is reached and the airspeed and altitude recorded. Climb to 50,000 feet (MSL). Engage left and right turns briefly at 10KMSL, 20KMSL, 40KMSL, and 50KMSL while in the climb mode.

The dive mode will be engaged at approximately 50,000 feet (MSL) with an airspeed of approximately 200 knots. Airspeed and altitudes should be recorded. Dive to 10KMSL. Engage left and right turns briefly at 40KMSL, 30KMSL, 20KMSL, and 10KMSL while in the dive mode.

The climb mode will again be engaged at 10KMSL at 375 knots or greater airspeed. Readings will be repeated as before. The dive command will be repeated at approximately 50,000 MSL, but with an airspeed greater than 250 knots, if possible (100% PRM). If the drone reaches an altitude at which it will not dive - decrease throttle to reduce airspeed until the dive resumes.

4.1.2 Glide Mode:

The drone will be positioned at 40KMSL to 50KMSL altitude at the end of a mission. When glide mode is engaged (fuel out) drone will be given left and right turns to verify proper operation of the roll axis. Radar data will be used to give indicated airspeed of the drone in the glide mode.

4.1.3 Altitude Hold Mode

Turns left and right will be commanded at 10KMSL, 20KMSL, 30KMSL, 40KMSL, and 50KMSL; Bank Angle Override will be commanded with left and right turns at 10KMSL and 50KMSL. The altitude and altitude error signals will be recorded.

4.1.4 Launch:

All test drones will be ground launched. As a minimum, airspeed, altitude, roll, pitch, roll rate, and pitch rate will be monitored during the launch mode.

4.1.5 Recovery:

At least two recoveries will be low altitude (below 12KMSL) at an airspeed of 350 knots indicated airspeed. At least two recoveries will be at 20KMSL or higher. Visual documentation of at least one low altitude recovery and one high altitude recovery is desired.

4.1.6 The IMK Mode:

Left and right turns at 10K, 15K, and 20K at load settings of 3.0G's and 4.0G's will be executed. Acceleration, airspeed, altitude, and bank angle will be recorded. Aileron trim will be used to verify its operation. Bank angle abort schedule and airspeed abort schedule will be verified.

4.2 Telemetry Requirements:

The following functions should be recorded on telemetry by WSMR. Digital reduction of some data will be required of WSMR. A maximum of 10 channels are available. The least important data will not be obtained. The decision will be made on a flight-by-flight basis.

a. Airspeed

b. Altitude

c. RPM

d. Fuel Flow

e. Roll

f. Pitch

g. Derived Roll Rate

h. Derived Pitch Rate

i. Aileron Position

j. Elevator Position

k. Acceleration

l. Altitude Error

m. Altitude Rate

n. Tone Monitor

4.3 Radar Requirements:

Two FPS-16 radars supplied by WSMR will be used to track the BQM-34A target drone. During recovery and glide modes, the radar data will be used to verify production VAFCS specification requirements.

5.0 SUPPORT REQUIREMENTS

WSMR will provide radar, telemetry record, plotting boards, command control, communication lines, and any other support normally required of WSMR for a BQM-34A launch.

6585 Test Group (Target Drone Division (TD) will provide project management, launch and maintenance facilities for BQM-34A and VAFCS, all launch crew personnel, and the remote control operator. Also, TD will provide a project officer who will supervise testing, and gather data, write Quick Look Reports, Phase I and the Final Test Reports, and coordination with WSMR concerning support requirements.

ASD will provide funding for these tests, engineering assistance and contract management.

Lear Siegler will provide technical assistance during these tests.

6.0 <u>DATA REQUIREMENTS</u> (Target Drone Requirements)

a. Prior to each mission, a detailed flight plan will be prepared for and followed by the drone controller.

b. After each flight, a Quick Look Report of the mission describing the maneuvers accomplished, will be submitted to ASD.

c. Phase I and Phase II test reports will be submitted to ASD including telemetry and radar data on each mission.

d. Digital processing of telemetry and radar data will be accomplished by WSMR and submitted to ASD if required.

VERSATILE AUTOPILOT FLIGHT CONTROL SYSTEM-PRODUCTION MODE FLIGHT TEST OBJECTIVE

Flight Number	1	2	3	4	5	6	
Telemetry Eval	X	X	X	X	X	X	
50,000 ft	X			X			
40,000 ft	X			X			
30,000 ft	X	X		X	X		
20,000 ft	X	X	X	X	X	X	
15,000 ft	X	X	X	X	X	X	
10,000 ft	X	X	X	X	X	X	
Climbs	X	X	X	X	X	X	
Dives	X	X	X	X	X	X	
Climb Scheduled	X	X	X	X	X	X	
Dive Scheduled	X	X	X	X	X	X	
Altitude Hold	X	X	X	X	X	X	
Glide	X			X			Radar Digital Data Needed
IMK		X	X		X	X	
3 G		X			X		
4 G			X			X	
Airspeed Abort		X	X		X	X	
Bank Angle Abort		X	X		X	X	
Altitude Hold		X	X		X	X	
Bank Angle Override	X						
Aileron Trim		X	X		X	X	
Autopilot #1	X	X	X				
Autopilot #2				X	X	X	
TLM Conditioning	X	X	X	X	X	X	
Inflight TLM Cal	X	X	X	X	X	X	
Automatic roll trim	X	X	X	X	X	X	
Low Altitude Recovery		X			X		Radar Digital Data Needed
High Altitude Recovery	X		X	X		X	
Roll & Pitch Axes Damping	X	X	X	X	X	X	

Table A-1

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13. ABSTRACT

This report presents the description and results of the Production Verification Flight Test Program for the A/A37G-8 Automatic Flight Control System (AFCS) for the USAF and USN BQM-34A Target Drone. Identified as the "Versatile Automatic Flight Control System - VAFCS" by its manufacturer, Lear Siegler Incorporated/ Astronics Division, Santa Monica, California, the A/A37G-8 AFCS was first procured as production hardware under USAF contract F33657-71-C-0353. This production verification flight test was performed at Holloman AFB to insure that the system performance realized with the prototype hardware was valid for the production hardware. During September 1971 through May 1972, the AFCS was flown in BQM-34A Target Drones as a Class II modification over all ranges of altitude, airspeed, and basic maneuverability which can be achieved by the BQM-34A. In addition, the Increased Maneuverability Kit (IMK) mode was flown. Based on the testing performed and the minor modifications made necessary by these tests, the A/A37G-8 AFCS was shown to be capable of performing the flight control function in an acceptable manner and should prove to be a satisfactory GFAE flight control system for the BQM-34A Target Drone.

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