FOREWORD

This report was prepared for the United States Air Force by the Cornell Aeronautical Laboratory, Inc., Buffalo, New York in partial fulfillment of Contract AF33(657)-7442; Exhibit B-1, Item XI.

The program was performed by the Flight Research Department of Cornell Aeronautical Laboratory, Inc. under the sponsorship of the AF Flight Dynamics Laboratory, Research and Technology Division, United States Air Force, Wright-Patterson Air Force Base, Ohio as Task 821905 of Project 8219. Mr. Richard Wilson was project officer for the Flight Dynamics Laboratory.

This report is also being published as Cornell Aeronautical Laboratory Report No. TB-1630-F-3.

The work reported in this document is the result of the efforts of a group of individuals with special skills. The evaluation pilot was Mr. R. Harper, the safety pilot and test conductor was Mr. N. Infanti, and the person responsible for the modifications, calibration and operation of the variable stability and variable drag systems was Mr. R. Huber.

ABSTRACT

The T-33 variable stability and variable drag airplane was used in a flight program to evaluate various longitudinal short period characteristics at each of four drag configurations for the landing approach task. Pilot rating and comment data were collected and used to determine short period requirements for the landing approach task.

The importance of the slope of the thrust required vs. velocity curve is discussed and related to pilot comments and control difficulties.

The longitudinal control gain selected by the pilot was a function of short period frequency and damping ratio. Curves relating control authority and short period frequency and damping ratio are derived from these data.

The power spectral density of the pilot's elevator stick motion was found to be significantly affected by short period dynamics and atmospheric turbulence.

This technical documentary report has been reviewed and is approved.

C. R. Bryan

for W. A. SLOAN, Jr.
Colonel, USAF
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SYMBOLS AND DEFINITIONS

The basic symbols used in this report are defined below. In a few cases symbols are used which relate only to the immediate text in which they appear, these are defined when they are introduced.

Dimensional Units

Distance	-	feet
Time	-	seconds
Angle	-	radians (unless otherwise stated)
Force	-	pounds
Moment	-	foot-pounds
Mass	-	slugs

Aerodynamic Notation

a_z	component of acceleration of airplane cg along Z stability axis
b	wing span
c	wing chord
z_i	thrust line offset, positive when cg above thrust line
C_ℓ	rolling moment coefficient, $L/q_0 Sb$
C_m	pitching moment coefficient, $M/q_0 Sc$
C_n	yawing moment coefficient, $N/q_0 Sb$
C_D	drag coefficient, $D/q_0 S$
C_L	lift coefficient, $L/q_0 S$
C_Y	side force coefficient, $Y/q_0 S$
C_T	thrust coefficient, $T/q_0 S$
D	drag, force in plane of symmetry and parallel to component of relative wind in plane of symmetry, positive aft
F_{ES}	elevator stick force
F_{AS}	aileron stick force
g	acceleration of gravity (i.e., 32.2 ft/sec^2)

Aerodynamic Notation (continued)

h	altitude
I_{xx}, I_{YY} I_{zz}, I_{xz}	airplane moments of inertia about body axes
L	lift, force in plane of symmetry and normal to component of relative wind in the plane of symmetry, positive up
L	rolling moment about X body axis, right wing down
M	pitching moment about Y body axis, positive nose up
N	yawing moment about Z body axis, positive nose right
m	mass
n_z	normal accelerometer reading in g units, positive in pullup
p, q, r	angular velocities about X, Y, Z body axes, respectively
T	thrust force along X body axis
q_0	dynamic pressure, $\frac{1}{2}\rho U^2$
S	wing area
u, v, w	incremental velocity along the X, Y, Z reference axes respectively
U	airspeed
W	weight
X_S	aerodynamic force along X stability axis, positive forward
Y_S	aerodynamic force along Y stability axis, positive to right
Z_S	aerodynamic force along Z stability axis, positive down
α	angle of attack
α_V	angle of attack measured by vane
β	angle of sideslip
γ	flight path angle, positive up
γ_{DES}	desired flight path, defined by landing aid
ξ	angle between X axis and thrust line

Aerodynamic Notation (continued)

δ_a	aileron angle, positive right aileron down
δ_{AS}	aileron stick deflection, positive right
δ_e	elevator angle, positive trailing edge down
δ_{ES}	elevator stick deflection, positive back
δ_r	rudder angle, positive trailing edge left
δ_{RP}	rudder pedal deflection, positive right pedal forward
δ_p	drag petal deflection, $\frac{1}{2}$ included angle
Θ	attitude angle, angle between X body axis and the horizontal plane
ρ	air density
ϕ	bank angle, angle between Y body axis and a horizontal line in the Y-Z plane
ψ	heading angle, angle between reference azimuth (North) and the projection of the X body axis in the horizontal plane

The following stability derivative notation is used:

$$C_{D_\alpha} = \frac{\partial C_D}{\partial \alpha} \qquad C_{m_q} = \frac{2U}{c}\frac{\partial C_m}{\partial q} \qquad C_{m_u} = \frac{U}{2}\frac{\partial C_m}{\partial u}$$

$$C_{L_\alpha} = \frac{\partial C_L}{\partial \alpha} \qquad C_{m_\alpha} = \frac{\partial C_m}{\partial \alpha} \qquad C_{m_{\delta_e}} = \frac{\partial C_m}{\partial \delta_e}$$

$$C_{L_{\delta_e}} = \frac{\partial C_L}{\partial \delta_e} \qquad C_{m_{\dot\alpha}} = \frac{2U}{c}\frac{\partial C_m}{\partial \dot\alpha} \qquad C_{T_u} = \frac{U}{2}\frac{\partial C_T}{\partial u}$$

$$C_{L_u} = \frac{U}{2}\frac{\partial C_L}{\partial u} \qquad C_{D_u} = \frac{U}{2}\frac{\partial C_D}{\partial u}$$

The following dimensional stability derivative notation is used:

$$M_q = \frac{q_0 S c}{I_{YY}} \frac{c}{2U} C_{m_q}$$

$$M_\alpha = \frac{q_0 S c}{I_{YY}} C_{m_\alpha}$$

$$M_{\dot\alpha} = \frac{q_0 S c}{I_{YY}} \frac{c}{2U} C_{m_{\dot\alpha}}$$

$$M_u = \frac{\rho S U c}{I_{YY}} (C_{m_u} + C_m)$$

$$M_\delta = \frac{\rho S U^2 c}{2 I_{YY}} C_{m_{\delta_e}}$$

$$T_u = \frac{\rho S U}{m} (C_{T_u} + C_T)$$

$$X_u = \frac{-\rho S U}{m} (C_{D_u} + C_D)$$

$$X_w = \frac{\rho S U}{2m} (C_L - C_{D_\alpha})$$

$$Z_u = -\frac{\rho S U}{m} (C_L + C_{L_u})$$

$$Z_w = -\frac{\rho S U}{2m} (C_{L_\alpha} + C_D)$$

$$Z_\delta = -\frac{\rho S U^2}{2m} C_{L_{\delta_e}}$$

Transfer Function Notation

f	frequency, cycles/second
f_n	undamped natural frequency, cycles/second
K	gain factor
N	transfer function numerator
s	Laplace operator
T	time constant
ζ	damping ratio
τ	time constant
λ	real root
ω	frequency, radians/second
ω_n	undamped natural frequency, radians/second
ω''_p	closed-loop phugoid frequency, θ controlled by δ_e, h by throttle
$G(j\omega)$	transfer function of filter
$\Phi(f)$	power spectral density
$R(\tau)$	autocorrelation function

Subscripts

SP	short period
P	phugoid
θ_1, θ_2	identifies factors of numerator of θ/δ_e transfer function
T	throttle, as in throttle deflection δ_T, also as in factor of numerator of h/δ_T transfer function $1/T_{h_T}$
h_1, h_2, h_3	identifies factors of numerator of h/δ_e transfer function $\frac{1}{T_{h_1}}, \frac{1}{T_{h_2}}, \frac{1}{T_{h_3}}$

Axes

The following axes are right-hand orthogonal sets with origin at the center of gravity.

X	in the plane of symmetry, directed toward the nose and along the projection of the wind vector in that plane
Y	normal to the plane of symmetry, directed along the right wing
Z	in the plane of symmetry, directed "down"

These axes are fixed in the airplane.

General

a_n	coefficient of polynomial
$E\{\ \}$	expected value or statistical average
$P.R.$	pilot rating
$\ln$	natural logarithm

SECTION 1

INTRODUCTION

1.1 BACKGROUND

Reduction of approach and touchdown speeds and improvement of aircraft handling qualities during the power approach and landing maneuver promise attractive gains in the form of lower accident rates, reduced aircraft structural loads, shorter runways, and reduced strength and capacity requirements for aircraft carrier decks and arresting gear equipment.

Because the gains are so attractive, considerable research effort has been directed at: defining and investigating the many factors which enter into a pilot's selection of minimum approach speeds, the development of methods or criteria for calculating or predicting the minimum approach speed, and the development of ways to reduce approach speeds.

The factors considered by pilots in selecting minimum approach speeds are discussed in References 1 through 7. In Reference 7, the reasons for limiting approach speeds are divided into three main categories, each of which is based on a number of different factors as follows:

I. Speed and Altitude Control

Included in this category are:

a. Lift characteristics
b. Drag characteristics
c. Thrust level and thrust response

II. Stability and Control Characteristics

Included in this category are:

a. Static and dynamic stability - both longitudinal and lateral-directional
b. Pitch control authority
c. Trim change characteristics - flaps and gear extension and thrust changes
d. Lateral control effectiveness

III. Physical and Sensory Limitations

Included in this category are:

a. Visibility limitations
b. Buffet characteristics
c. Ground clearance angle

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The following items should perhaps be added to category III:

d. Aircraft structural characteristics
e. Turbulence and weather conditions
f. Pilot preference and capabilities

References 4 through 8 and 10 through 13 deal with the development of analysis and calculation methods for predicting minimum approach speeds of aircraft for which the approach speed is limited by the reasons listed in category I above. Tests of the validity of the calculation methods and criteria developed in these studies are to some extent frustrated by the lack of accurate aerodynamic and physical data for specific configurations and complicated by the diverse preferences and capabilities of different pilots. The latter factor often results in the selection of different minimum approach speeds for a single configuration (see, for example, Reference 4). Statistical data on approach speeds for several airplane types have been collected during fleet operations by the Navy and are reported in References 14 through 17. These data best define mean operational approach speeds, however, rather than the minimum approach speed that the prediction methods are designed to calculate.

Significant reductions in approach speeds have been obtained through boundary-layer control and automatic throttle control. References 18 through 27 describe several of these projects.

In the flight tests of References 1 through 4 a number of pilots flew a variety of airplanes and/or configurations in the landing approach maneuver at successively lower speeds. They then commented on the factors which limited the minimum comfortable approach speed that they were willing to accept. Although this technique was successful in bringing to light the many factors that influence the pilot's choice of approach speed, it had a disadvantage in that often more than one factor would become unsatisfactory as the approach speed was reduced. Thus it was often difficult to determine the relative importance of these factors in limiting the approach speed. For example, Reference 1 lists seven items which influenced the pilot's choice of minimum approach speed for the F9F-7 airplane.

1.2 PURPOSE

The T-33 variable stability, variable control and variable drag airplane is uniquely suited for research on many of the factors listed above under categories I and II. Although the lift and thrust characteristics of the T-33 are not variable, the drag characteristics and the stability and control characteristics about all three axes are variable. Thus, this airplane can be used to determine the effect of each of the latter factors on the landing approach task.

In the investigation described in this report, the T-33 airplane was used to study the effect of short period dynamics and drag characteristics on longitudinal handling qualities for the landing approach task. Future landing approach programs are planned in which the effects of drag modulation with elevator control, pitching moment with throttle control, and lateral-directional stability and control characteristics will be investigated.

1.3 APPROACH

In the program conducted, given drag and longitudinal short period configurations were established through the T-33 variable drag and variable stability systems. The piloting task was to fly a constant speed approach which consisted of a straight-in IFR portion followed by transition to a visual glide path defined by an arrangement of lights. This approach was terminated by a waveoff and followed by a visual circuit of the field and a second visual approach on the glide path with the same configuration.

The pilot then commented on the control difficulties that he had experienced, answered a list of specific questions (designed to determine how he uses the information and controls available to him), and finally assigned a pilot rating to the configuration.

1.4 ARRANGEMENT OF REPORT

In Section 2 of the report, the experimental procedure is described. In this section, the equipment used to perform the experiment is described, the evaluation task is defined, and the selection of configurations to be evaluated is discussed.

In Section 3 of the report, the results of the experiment are discussed in detail. These results consist of pilot rating and comment data, optimum longitudinal gains selected by the pilot and typical time histories of visual approaches.

Section 4 lists the major conclusions drawn from the results of the experiment.

SECTION 2

EXPERIMENTAL PROCEDURE

2.1 VARIABLE STABILITY AND VARIABLE DRAG EQUIPMENT

2.1.1 General Description

The design and installation of the variable stability and control system in the T-33 airplane are described in Reference 31. The design, installation and calibration of the variable drag system are described in Reference 32. The photographs of Figure 1 illustrate the T-33 airplane with variable drag petals on the tip tanks.

Briefly, the airplane has been equipped with electro-hydraulic servos to position the elevator, rudder, aileron and drag surfaces in response to combinations of pilot commands and airplane response parameters. Airplane angle of attack, angle of sideslip, angular rates, linear and angular accelerations, dynamic pressure and random noise generator are available as inputs to the servos. In addition, the front cockpit controls have been mechanically disconnected from the airplane control surfaces and connected instead to hydraulic feel servos. In this manner, the control system characteristics and the airplane characteristics can be varied independently.

The T-33 variable stability, control and drag airplane is described and illustrated in a 25-minute movie listed as Reference 33.

2.1.2 Control System Characteristics

For the landing approach flight program, the control surface servos were commanded by signals proportional to control stick and rudder pedal position. The aileron and rudder control gains and feel characteristics were maintained constant throughout the program at values initially selected by the pilot as being satisfactory. The elevator stick force per unit deflection was also maintained constant throughout the program; however, the gain between the control stick and the elevator was selected by the evaluation pilot for each configuration at the beginning of each evaluation. This technique was used because it seemed more logical to assume the spring rate known and fixed, and to let the pilot select the control gain.

The feel system static stiffness or spring rate and the longitudinal control gains used in the program are listed in Table 1.

The response of the elevator feel servo to a step input is shown in Figure 2. An equivalent first order system would have a time constant of 0.33 sec.

Figure 1 T-33 Variable Stability and Control Airplane with Variable Drag Tip Tanks Installed

TABLE I
IDENTIFICATION OF CONFIGURATIONS TESTED

DRAG CONFIGURATION KEY:	TURBULENCE KEY:
FS - FRONT SIDE	S - SMOOTH
BG - BOTTOM GEAR	L - LIGHT
BF - BOTTOM FLAPS	M - MODERATE
BS - BACK SIDE	H - HEAVY

DRAG CONFIG.	FLIGHT NO.	PILOT RATING	ω_{sp}	ζ_{sp}	F_{ES}/δ_{ES}	α/δ_{ES}	$-\frac{1}{T_{h_1}}$	TURB.	DATE 1963	SCALED TIME HISTORIES
BG	337-1	7	.83	.67	8.20	4.40	.00079	L	7-18	✓
BG	-2	4	2.00	.50	8.14	3.50	.0057	L	7-18	
FS	338-1	4½	1.30	1.00	8.18	3.15	-.012	M	7-18	
FS	-2	2	2.19	.46	8.02	2.93	-.012	M	7-18	
BS	339-1	6	2.05	.33	8.23	2.61	.012	S-L	7-19	
BG	-2	3	1.91	.31	8.28	2.55	.0053	S-L	7-19	
BG	340-1	3	1.98	.28	8.13	2.28	.0021	S	7-22	
BG	-2	4	.95	1.25	8.10	9.55 PUSH 5.75 PULL	.0024	S	7-22	
BG	341-1	5½	2.30	.20	8.28	1.72	.0028	L-M	7-22	✓
BG	-2	9½	4.06	.14	8.35	1.32	.0012	L-M	7-22	
BG	342-1	2	2.60	.33	8.23	2.04	.0022	S	7-23	
BG	-2	3½	1.63	.45	8.19	2.49	.0023	S	7-23	
BG	343-1	3½	1.30	1.08	8.35	3.13	.0038	L	7-23	
BG	-2	5½	.90	.95	8.26	3.77	.0025	L-M	7-23	
BG	344-1	2	2.45	.52	7.93	1.96	.0022	S	7-24	✓
BG	-2	5	1.10	.46	7.48	3.26	.0022	S	7-24	✓
BG	345-1	8	$\lambda_1 \doteq -1.6$	$\lambda \doteq +.20$	8.61	6.90	.0034	S-L	7-24	✓
BG	-2	4½	1.69	.26	8.12	2.17	.0022	S-L	7-24	
BG	346-1	4	.95	.75	8.42	5.84	.0028	S	7-25	
BG	-2	2½	2.35	.78	8.05	3.14	.0022	S	7-25	
BG	347-1	6½	.96	.47	8.56	4.48	.0022	L	7-25	
BG	-2	3½	1.40	.80	8.26	4.27	.0022	L	7-25	
BS	348-1	4	2.49	.30	7.95	1.85	.016	S	7-26	
BS	-2	6	1.70	.70	8.02	4.00	.020	S	7-26	
BS	349-1	7	1.27	.25	7.67	3.76	.016	M	7-30	
BS	-2	5	2.57	.69	7.97	2.92	.020	M	7-30	
FS	350-1	3	2.43	.27	8.07	1.88	-.012	L	7-30	
FS	-2	4½	1.75	.23	7.62	2.60	-.0076	L	7-30	
BG	351-1	8	1.15	.20	8.09	2.84	.0018	M	7-31	
BG	-2	3½	1.89	.69	8.11	3.78	.0052	M	7-31	
FS	352-1	4	1.13	.38	7.83	3.97	-.012	M	8-1	✓
FS	-2	3	1.78	.60	7.79	3.98	-.0047	M	8-1	
BS	353-1	7	.95	.58	7.81	5.37	.018	S	8-2	
FS	354-1	2	2.75	.76	7.97	2.07	-.013	M	8-2	✓
BG	355	2½	2.13	.34	8.14	2.03	.0057	S	8-20	
BS	356	4½	2.07	.37	8.07	2.26	.020	S	8-21	
BG	357-1	3½	2.01	.46	8.26	3.00	.0054	L	8-21	
BF	-2	4	1.94	.42	8.05	2.72	.0029	L	8-21	
BS	358-1	4½	2.37	.45	8.28	2.67	.018	S	8-22	
BF	-2	3½	2.27	.31	7.95	1.56	.0056	S-L	8-22	
BF	359-1	5	1.51	.65	8.12	3.09	.0035	L-M	8-22	
BF	-2	5½	1.82	.28	8.54	1.95	.0057	L-M	8-22	
BS	360-1	8	1.47	.28	7.74	3.88	.017	L-M	8-23	
BF	-2	5	2.68	.34	7.79	1.83	.0055	L-M	8-23	

TABLE I (cont.)

DRAG CONFIG.	FLIGHT NO.	PILOT RATING	ω_{sp}	ζ_{sp}	F_{ES}/δ_{ES}	α/δ_{ES}	$-\frac{1}{T_{h_1}}$	TURB.	DATE 1963	SCALED TIME HISTORIES
BS	361-1	6	1.05	.75	7.83	2.88	.017	S-L	9-9	
BF	-2	5	1.33	.61	7.78	2.97	---	S-L	9-9	
BF	362-1	4½	1.41	.56	7.53	3.56	.0037	S-L	9-9	
BG	-2	3½	1.20	.54	8.21	3.78	.0085	S-L	9-9	
BS	363-1	4	1.86	.44	8.40	3.36	.018	M	9-10	
BS	-2	5	2.58	.43	8.47	1.57	.022	M	9-10	
BF	364-1	3½	2.55	.40	8.45	1.54	.0034	S-L	9-10	
BF	-2	5	1.23	.42	8.96	4.28	.0054	L-M	9-10	
BS	365-1	3	1.57	.35	8.59	3.12	.018	S	9-11	
BS	-2	7	.9~1.05	.3~.4	7.90	2.86	.022	S	9-11	
BF	366-1	4	2.69	.29	8.33	1.43	.0037	M	9-11	
BF	-2	7½	1.0	.4~.5	8.05	3.55	.0056	M	9-11	
FS	367-1	3½	≐ 1.6	.3~.4	NO RECORD		---	L	9-11	
FS	-2	2½	≐ 2.8	≐ .4				L	9-11	
BS	368-1	4½	1.52	.41	8.30	2.78	.018	M	9-13	
BS	-2	5	1.65	.34	7.95	2.20	.022	H	9-13	
	369				CALIBRATION				10-14	
FS	370-1	2½	2.13	.55	8.32	2.19	-.013	S-L	10-14	
FS	-2	7	1.22	.89	8.11	4.11	-.0046	L	10-14	
BF	371-1	6	1.77	.36	8.05	3.12	.0035	L	10-15	
BF	-2	4	1.92	.61	8.19	1.86	.0054	L-M	10-15	
BS	372-1	4½	1.69	.68	8.42	4.03	.019	S	10-16	
BS	-2	6½	1.70	.41	7.73	2.07	.023	S	10-16	
BF	373-1	5	1.42	1.13	8.36	5.85	.0035	S	10-16	
BF	-2	2½	2.76	.57	8.07	1.72	.0059	L	10-16	✓
BS	374-1	4	2.83	.45	8.18	1.46	.019	S	10-16	✓
BS	-2	4½	2.58	.30	8.19	1.47	.026	S	10-16	
BS	375-1	5½	1.51	.45	8.48	3.24	.021	L-M	10-17	
BS	-2	4½	1.88	.68	8.06	2.54	.023	L	10-17	
BS	376-1	8	2.20	.16	8.05	1.62	.020	S	10-18	✓
BS	-2	6	1.03	.90	8.30	2.82	.024	S	10-18	
BG	377-1	3	1.87	.39	8.44	2.17	.0018	L-M	10-18	
BG	-2	5½	1.56	.36	8.39	2.64	.0046	M	10-18	
BF	378-1	4½	1.58	.29	8.26	2.89	.0034	L-M	10-21	
BF	-2	3½	2.37	.58	8.17	1.89	.0056	M	10-21	
BS	379-1	6½	1.51	.35	8.43	3.14	.020	S	10-22	
BS	-2	4	2.02	.48	8.15	2.21	.024	S	10-22	
BF	380-1	6	2.51	.21	8.30	1.61	.0033	L	10-22	✓
BF	-2	7	1.10	.28	7.84	3.16	.0060	L-M	10-22	✓
FS	381-1	3½	1.30	.45	8.42	3.67	-.012	M	10-22	
BG	-2	6½	1.46	.30	8.16	3.32	.0049	M	10-22	
BS	382-1	8	1.14	.52	8.42	5.16	.021	L-M	10-23	✓
BS	-2	5½	1.57	.84	8.23	3.33	.023	M	10-23	
BS	383-1	7	2.77	.19	8.20	1.37	.020	H	10-23	
FS	-2	5	1.36	.75	8.33	3.89	-.016	M	10-23	

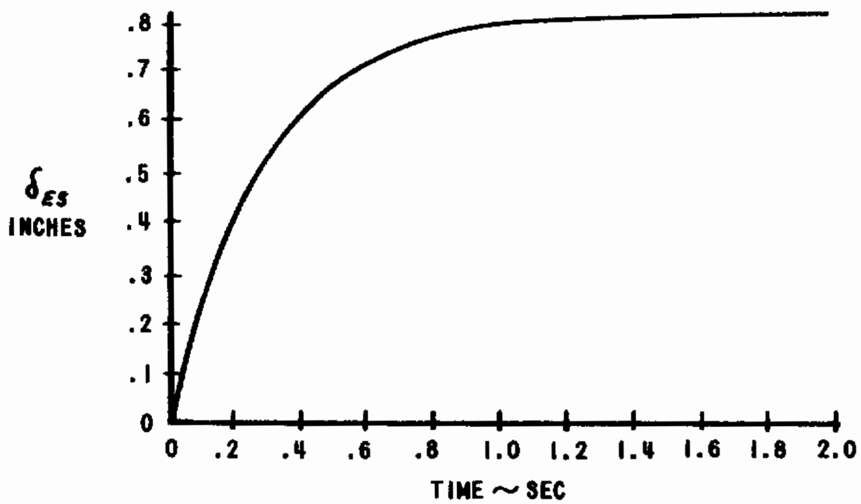

Figure 2 Response of Elevator Feel Servo to Step Command

2.1.3 Lateral-Directional Dynamics

The primary purpose of the flight program was to study longitudinal handling qualities in the landing approach task; therefore it was considered desirable to have sufficiently good lateral-directional handling qualities so as not to cause compression of the rating scale. It was also desirable to use a minimum number of lateral-directional feedback signals so as to simplify flight operations.

With the exception of the low Dutch roll damping ratio, the evaluation pilot considered the normal* T-33 lateral-directional dynamics to be adequate for the landing approach task. Attempts were made to augment the Dutch roll damping ratio through $\dot{\beta}$ feedback, but this soon proved impractical because of the rudder servo response to high-frequency components of atmospheric turbulence. Previous programs with the T-33 had been conducted at altitude in smooth air conditions where it was feasible to use $\dot{\beta}$ to control the Dutch roll damping ratio without special filtering to remove the higher frequency components of the turbulence. In the landing approach flight program, however, considerable time was to be spent at altitudes below 3000 ft and turbulence was nearly always present to some degree.

In order to avoid the turbulence problem in the lateral-directional case, it was decided to augment the Dutch roll damping ratio through yaw rate feedback. This, however, introduces another problem. Since the airplane was not equipped with a yaw rate washout circuit, it became necessary for the pilot to hold rudder in steady turns. Although the evaluation pilot did not consider this to be a desirable situation, he did not consider it to be sufficiently objectionable to demand that a wash-out circuit be installed. Thus, the compromise solution was to increase the damping ratio of the Dutch roll mode through yaw rate feedback and for the pilot to accept the rudder coordination required for steady turns. This solution was acceptable because the landing approach evaluation task did not place very stringent requirements on turning flight.

2.1.4 Longitudinal Dynamics

The longitudinal short period dynamics of the T-33 were varied through the use of feedback signals proportional to angle of attack, rate of change of angle of attack and pitch rate.

The angle-of-attack vane used on the T-33 has a natural frequency of approximately 25 cps and a low damping ratio. The α and $\dot{\alpha}$ signals derived from this vane were originally used as inputs to the elevator servo without filtering. In smooth air this system was quite satisfactory; however, in turbulent air the elevator servo exhibited high-frequency motions of large amplitude. These servo motions were seldom noticeable to the evaluation

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unaugmented but flown through CAL power control system pilot and were not of concern as an influence on the evaluations. They were, however, evident to the safety pilot and appeared on the oscillograph records. As the landing approach program progressed, concern developed over the possible accumulation of fatigue damage to the elevator control system. This situation was essentially rectified by the installation of a notched low-pass filter in the angle-of-attack channel. The frequency response characteristics of this filter are plotted in Figure 3.

2.1.5 Drag Characteristics

The drag characteristics of the T-33 variable drag airplane were varied through the airplane configuration (i.e., landing gear up or down, flaps up or down), the nominal position of the drag petals, and the gain between the petals and the angle-of-attack vane. The maximum engine thrust and the thrust response to throttle, however, imposed restraints on the nominal or trimmed drag levels that could be used. For example, at 160 kt with the gear extended and the drag petals open approximately 60 degrees, it required 100% rpm to fly level, leaving no excess thrust for maneuvering.** Conversely, with the gear and flaps retracted and a low drag petal deflection, the drag was low enough that power settings below 60% rpm were required during descents on the glide slope at 160 kt. The engine response to increased throttle from this rpm was extremely slow (approximately 8 seconds to reach 100%) and the pilots considered it unsafe to make low approaches and to take wave-off's with such slow engine response characteristics.

Thus the nominal drag configuration was bounded by engine characteristics. For the landing approach flight tests, the following nominal configurations were used:

Configuration	Landing Gear	Wing Flaps	Dive Brakes	Nominal Drag Petal Deflection Function of Wt.	δ_P/α_V
A	Down	Up	Closed	25° - 30°	Low-Med.-Hi
B	Up	24°	Closed	25° - 30°	Med.

The method used to calculate drag polars for each configuration evaluated and the selection of drag configurations to be evaluated are discussed in detail in Sections 2.3 and 2.4. The drag variation with angle of attack about the nominal or trimmed value was controlled through the

* Since the front stick does not move in response to stability augmentation inputs, the high-frequency elevator motions are evident to the evaluation pilot only through structural vibrations.

**With the gear and flaps down, speed brakes open and drag petals full open, an L/D of 2.3 can be produced at 160 knots.

δ_P/α_V servo gain. Since δ_P/α_V gains as high as 7.5 were used in the flight program, the response of the drag petal servos to turbulence was of concern. This system originally had a low-pass filter installed; however, significant reduction in the response to turbulence was achieved by modifying the filter to include a notch at 8 cps. The modified filter was identical to the one installed in the elevator channel - Figure 3.

The drag petals on the tip tanks are positioned by servos mounted in each tank. To guard against a malfunction in one or both of these servos, which might result in large yawing moments, the system is equipped with monitoring circuits. These circuits monitor petal rates and differential petal deflection. If either of these signals exceed preset limits, the hydraulic system is dumped and the petals blow closed. Attempts to operate the variable drag system in turbulent air with high δ_P/α_V gains often resulted in the petal rate limit dumping the system, thus interrupting the evaluation. Such interruptions were avoided as much as possible by scheduling flights early in the day before turbulence developed and by scheduling configurations which required high servo gains to take advantage of smooth air conditions. The interruptions could also have been avoided by increasing the petal rate limit since the choice of a particular limit was somewhat arbitrary. This was not done, however, since the scheduling limitation was not severe.

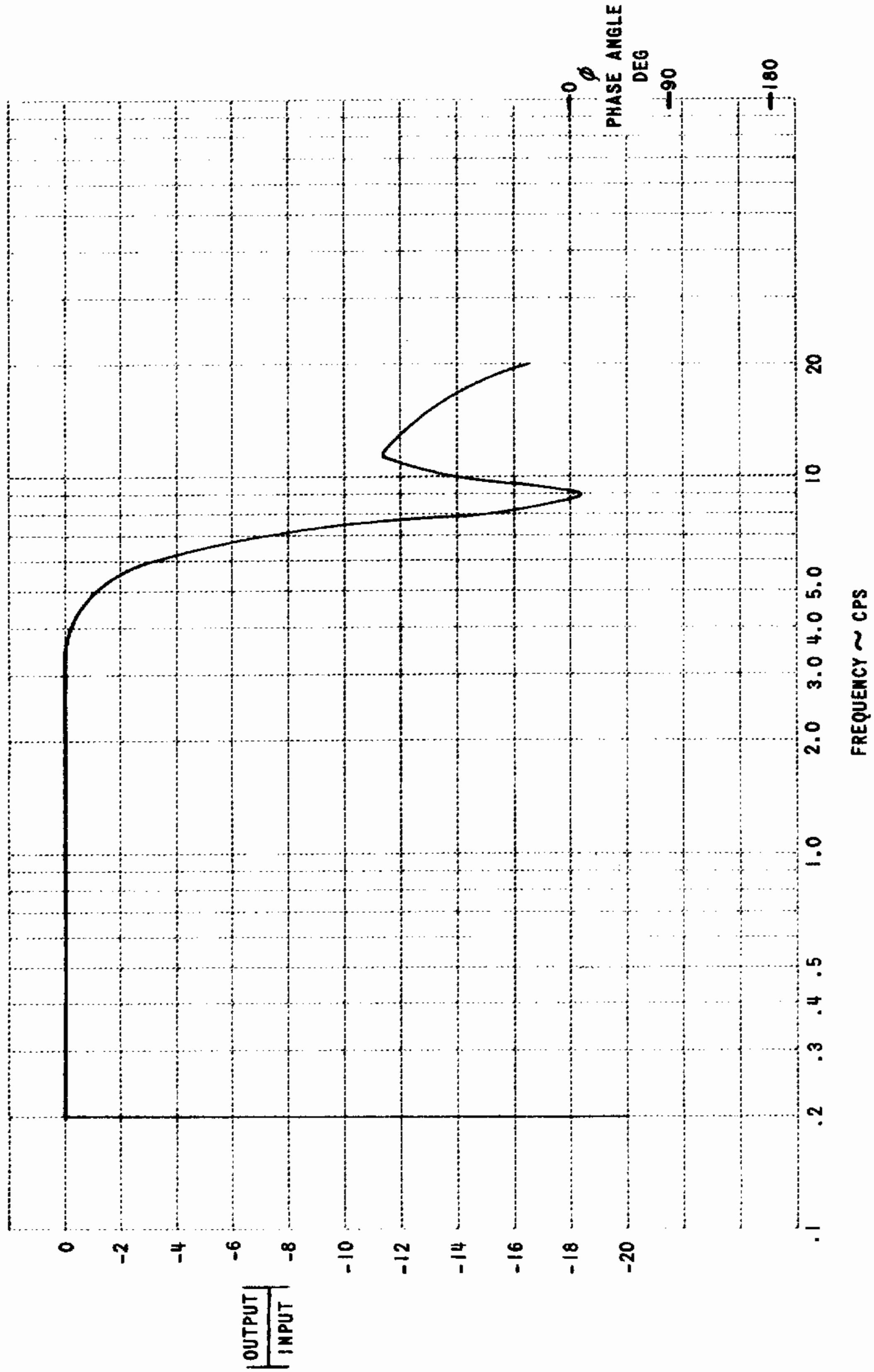

Figure 3 Frequency Response of the Notched Low-Pass Filter Installed in the Angle of Attack Channel

2.2 EVALUATION TASK

2.2.1 Flight Path

The flight path used for the evaluation task is sketched in Figure 4. The straight-in instrument approach started twelve miles out at 5000 ft above ground level. Track over the ground was maintained by reference to the radio magnetic indicator. The initial rate of descent was approximately 2300 ft/min. This rate of descent was held down to 1600 ft altitude at which point it was decreased to 700 ft/min. This rate was held down to 600 ft altitude. Arrival at 600 ft altitude occurred prior to reaching the outer marker (4.2 miles). The 600 ft altitude was maintained until 2 miles from the end of the runway. When the safety pilot called the 2-mile point, the evaluation pilot raised the instrument hood (masked helmet visor), and the final approach to the runway was made with visual reference. Visual glide slope information was obtained from a light glide-path indicating system. This equipment is illustrated in Figure 5. At approximately 25 to 100 ft, wave-off was initiated at the pilot's discretion.

A left, closed-traffic turn to down wind was followed by a second visual approach and wave-off. After wave-off, a climbing turn to the right completed the landing approach maneuver. The pilot climbed back to 5000 ft altitude and recorded his comments and ratings. He also performed level turns at this time when sufficient fuel was available. Generally two configurations were evaluated on each flight.

2.2.2 Glide Slope Equipment

The glide slope indicating system was developed by the Navy for Marine use at advanced airfields. The approach angle is obtained by placing a single light bar (source light) behind and between a pair of light bars (datum lights) adjusted vertically to present the desired approach angle. To maintain the proper glide path, the pilot lines up the source light bar with the datum light bars in a single horizontal line and keeps them lined up. If he is low, the source light bar appears below the datum bars. If he is high, the source bar appears above the datum bars (see Figure 5). The system does not provide lateral guidance.

The gain of this system (i.e. the magnitude of the vertical displacement between light bars for a given altitude error) is proportional to the horizontal separation between the source lights and the datum lights and inversely proportional to the distance from the airplane to the source light. The system was designed for 50 ft horizontal separation between source and datum lights. This separation, however, results in a very low gain. For the landing approach program the light system was modified by extending the supports of the datum lights and moving the source light back to 135 ft. These modifications resulted in a gain approaching that of the Navy Mirror System which has a source to datum distance of 150 ft. The glide path angle was 3.6°. The glide slope thus defined intersected the runway approximately 1100 ft from the threshold.

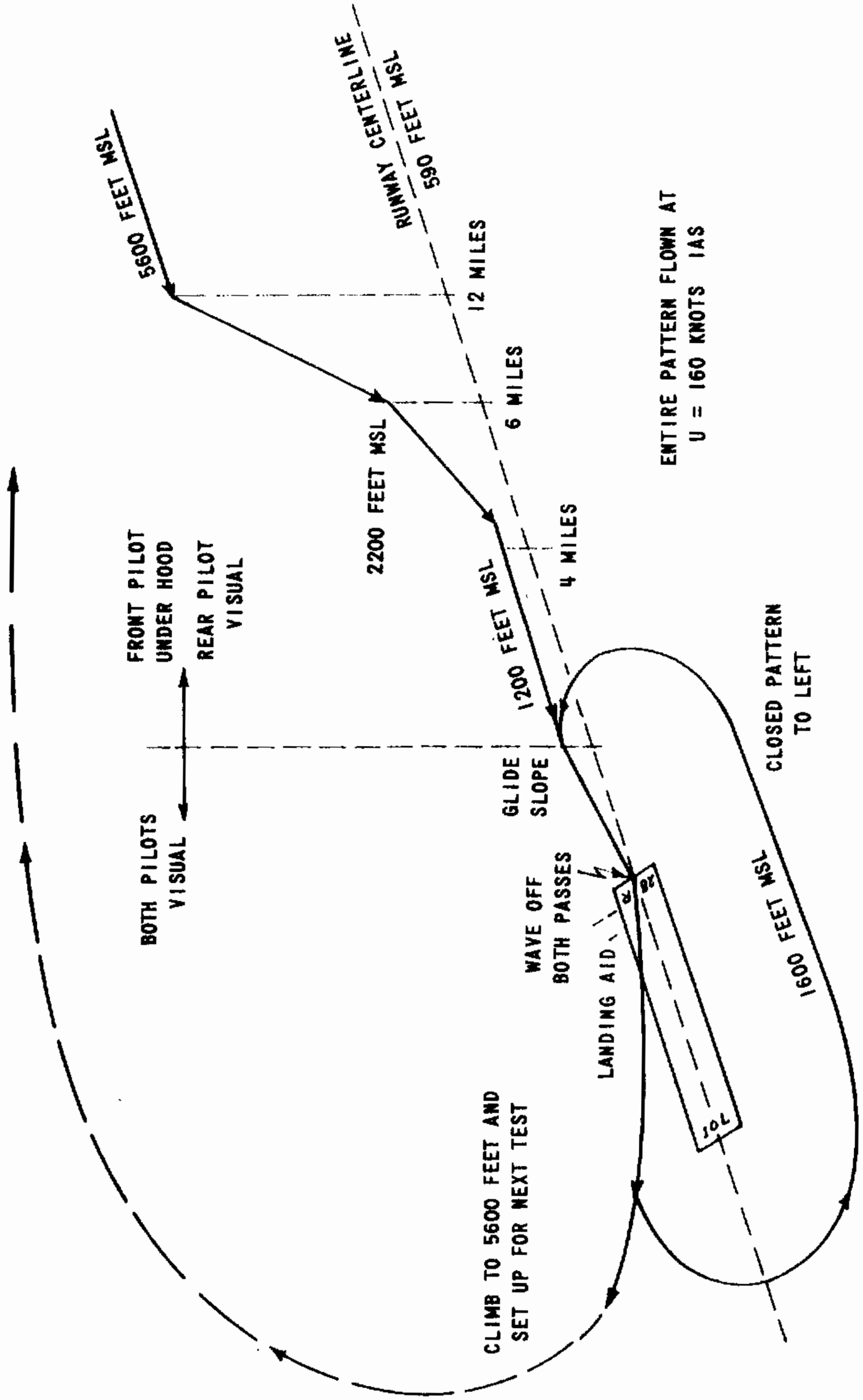

Figure 4 Landing Approach Evaluation Flight Control Task

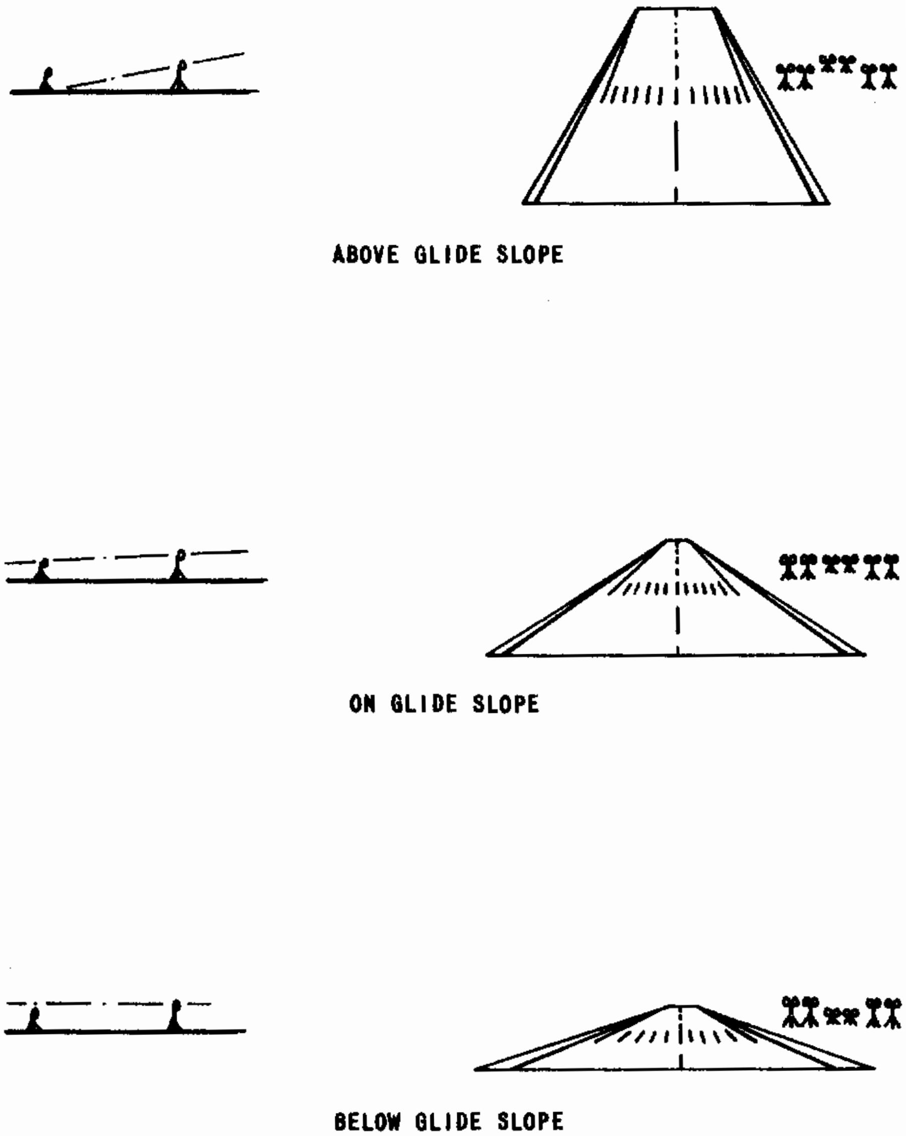

Figure 5   Glide Path Presentation

2.2.3 Flight Instruments

The front-cockpit instrument panel arrangement is diagrammed in Figure 6. Grouped on the left side of the panel are altimeter, rate of climb, normal acceleration, airspeed and angle of attack. A Lear remote attitude indicator (Model 4005) displayed pitch and roll atttitude, sideslip angle, yaw rate and side acceleration. The ADF, engine rpm, and tail pipe temperature are grouped on the right side of the panel. The scale on the angle-of-attack indicator was quite compressed, so this instrument was of limited utility. The engine tachometer was moved at the pilot's request after flight 355.

2.2.4 Pilot Comment List and Rating Scale

When the pilot had completed the approach maneuver he wire-recorded his observations and described the control difficulties he had experienced. In each case he answered the questions on the following check list.

1. Is the airplane difficult to trim?
2. Is the elevator control gain satisfactory?
3. Is attitude control satisfactory?
4. Is maintaining altitude a problem?
   a. straight and level
   b. turns
5. Can you establish a specific rate of descent?
6. Is maintaining airspeed a problem?
7. What instruments are you using most?
8. Is a special control technique required?
9. Are throttle adjustments necessary?

   Are they used to control:

   Attitude? Rate of climb? Other?
   Altitude? Airspeed?
10. Is elevator used to control:

    Attitude? Rate of climb? Other?
    Altitude? Airspeed? Normal Acceleration?
11. Could you make an instrument landing approach with this configuration at this speed?
12. What happens when you transition to visual flight? How do you fly the visual approach, particularly regarding glide slope control? Are you checking airspeed and/or angle of attack on final? If so, when do you quit?
13. Comment on wave-off.
14. Comment on the visual circling approach.

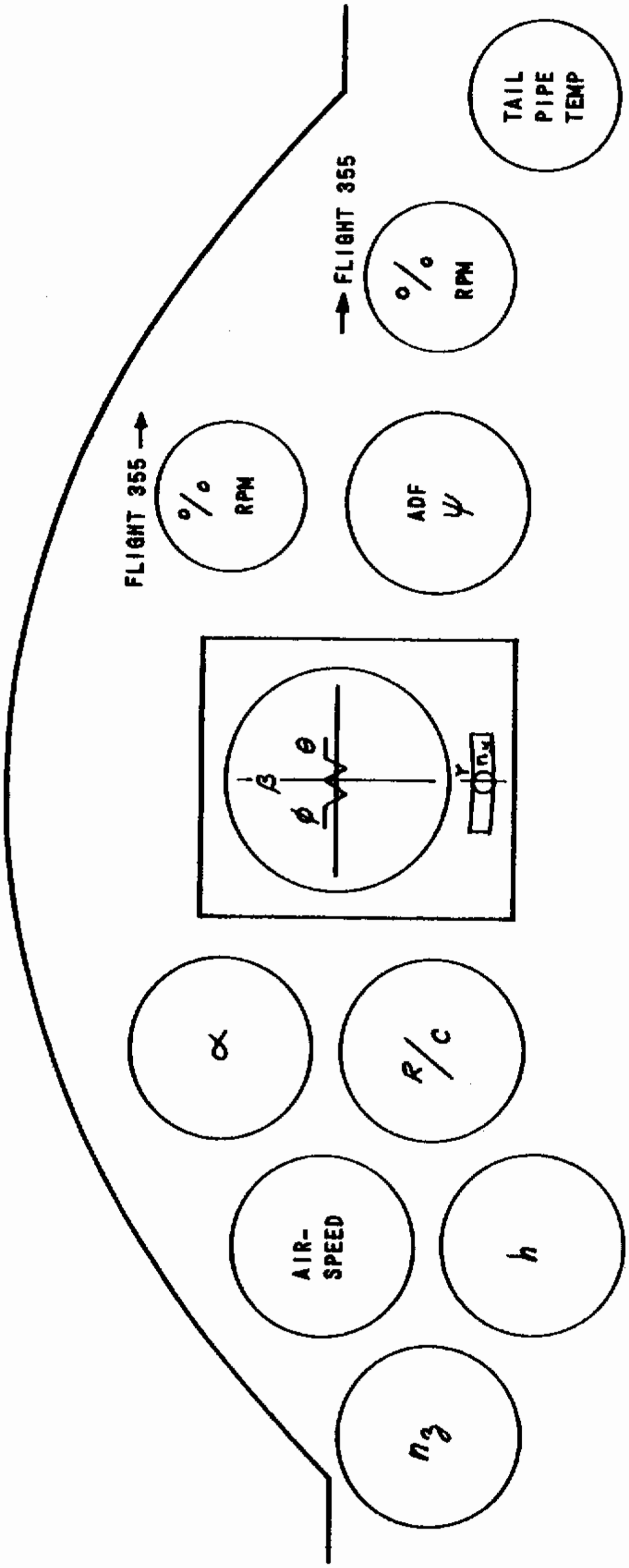

Figure 6 T-33 Panel Arrangement

The following rating scale was used to rate the suitability of each configuration for the landing approach task:

Category	Adjective	Number
Acceptable and Satisfactory	Excellent	1
	Good	2
	Fair	3
Acceptable but Unsatisfactory	Fair	4
	Poor	5
	Bad	6
Unacceptable	Bad	7
	Very bad	8
	Dangerous	9
Unflyable		10

2.3 CALCULATION OF DRAG CURVES

The procedure used to compute the lift-drag relation for the configurations evaluated is described in the following paragraphs.

The T-33 airplane was not equipped with instrumentation to measure engine thrust, so the lift-drag relation could not be measured directly. The technique used was to assume that the data published by Lockheed Aircraft Corporation (Figure 11 of Reference 34) for the clean airplane plus tip tanks was applicable, and to modify these data by adding increments based on flight test measurements. Flight-measured drag coefficient data for the landing gear, wing flaps and drag petals are given in Reference 32.

From the flight data of Reference 32 it was determined that the drag increment of 24° wing flap was equivalent to the landing gear drag at 160 kt. A base curve of C_D vs. C_L was constructed for the airplane plus gear or 24° flap by adding $\Delta C_D = .027$ to the Lockheed data of Reference 34. Drag coefficient increments due to the drag petals were computed by the technique illustrated in the nomograph of Figure 7. These increments were added to the base curve to give the net C_D vs. C_L curve for a particular configuration. The various curves in the nomograph were obtained from flight measurements as follows. The α_V vs. C_L curves were obtained from level-flight trim data (α_V was the measured position of the angle-of-attack vane relative to the fuselage reference and C_L was calculated from the weight, dynamic pressure and wing area). Straight lines were fitted to these data by the least-squares technique. The δ_P vs. α_V curves were obtained from oscillograph records of δ_P and α_V responses to elevator step inputs of various amplitudes. The slope and position of a given curve in this set are determined by the combination of δ_P/α_V gain and δ_P trim control settings. The ΔC_D vs. δ_P curve was obtained from flight calibrations described in Reference 32. The drag coefficient increments thus calculated are added to the base C_D vs. C_L curve to give the net C_D vs. C_L curve.

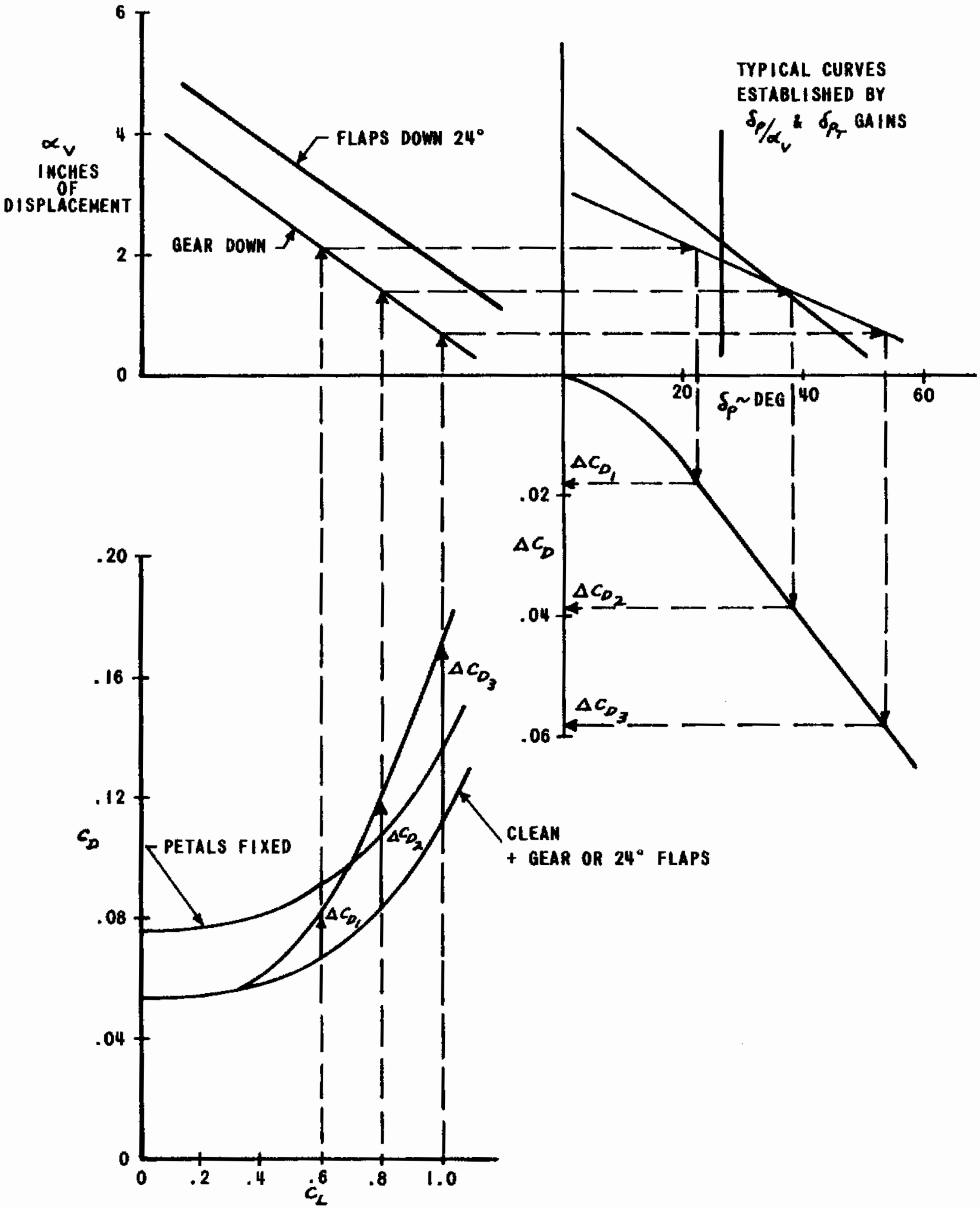

Figure 7 Example of Calculation of C_D vs. C_L Curve

2.4 SELECTION OF CONFIGURATIONS TO BE EVALUATED

2.4.1 Short Period Dynamics

The purpose of investigating short period dynamics was to define minimum satisfactory and minimum acceptable dynamics for the landing approach task. Previous longitudinal short period studies were directed either at tasks other than landing approach (References 28 and 30) or were directed at defining minimum flyable short period dynamics for the landing approach task (Reference 29).

The short period configurations evaluated were in the low-frequency region, $\omega_{n_{sp}} < 3.0$ rad/sec, with damping $2\zeta_{sp}\omega_{sp} < 4$ 1/sec. To investigate the interactions, short period configurations in this region were evaluated for four drag configurations.

2.4.2 Drag Configurations

All evaluations were flown at 160 kt IAS; however, the drag-velocity curve was shaped such that this speed was above, approximately equal to, or below the speed for minimum drag. The shape of the drag-speed curve was varied through the petal trim and δ_p/α_V gain controls as outlined in paragraph 2.3.

The following expression for the slope of the drag vs. velocity curve is developed in Reference 12 for trimmed, level flight:

$$\frac{dD}{du} = \rho S U \left[C_D + C_{D_u} - \frac{C_{D_\alpha}}{C_{L_\alpha}} \left(C_L + C_{L_u} \right) \right] \tag{1}$$

For $C_{D_u} = C_{L_u} = 0$, substituting $\frac{C_{D_\alpha}}{C_{L_\alpha}} = \frac{\partial C_D}{\partial C_L}$ and factoring out C_L yields

$$\frac{dD}{du} \doteq \rho S U C_L \left[\frac{C_D}{C_L} - \frac{\partial C_D}{\partial C_L} \right] \tag{2}$$

Nominal values of $\frac{dD}{du} = +5$, 0 and -10 $\frac{\text{lb}}{\text{ft/sec}}$ were selected as the drag configurations to be evaluated.

The choice of these values of $\frac{dD}{du}$ was influenced by engine thrust limits and thrust response time characteristics, together with the limits on δ_p/α_V gain.

Since the weight and therefore the trim angle of attack of the T-33 varied as fuel was consumed, this factor had to be considered in calculating variable drag system gains. The fuel capacity of the T-33 with the modified tip tanks is 700 gallons, of which approximately 500 gallons were available for evaluation maneuvers. During the evaluation portion of a flight the gross weight ranged from 15,100 lb to 11,850 lb. For planning purposes, this weight range was divided into three equal increments and the mid-points of these three increments (W = 14,620, 13,500 and 12,360 lb) were used in the calculations to determine variable drag system gain settings. During a flight, the safety pilot used the gain settings which corresponded to the weight increment existing during the evaluation period.

By using the curve for C_L vs. α_V for landing gear down and by assuming δ_P vs. α_V curves of various slopes and positions, families of C_D vs. C_L curves were computed and plotted. The slopes of these curves were then measured at the trim C_L values corresponding to the reference weights. For each reference weight, combinations of C_L, C_D and $\frac{\partial C_D}{\partial C_L}$ were determined such that equation 2 was satisfied for dD/du = 5, 0 and -10. The particular δ_P vs. α_V curves required were thus determined and could be related to the variable drag system petal trim and δ_P/α_V gain settings. The above described calculations are not illustrated; instead, the "after the fact" calculations made to identify the specific configurations evaluated will be illustrated in Section 3.

In Reference 11 a closed-loop analysis is made of an airplane (represented by phugoid equations of motion) controlled by a simple gain autopilot which actuates the throttle proportional to altitude errors and the elevator proportional to pitch attitude errors. From this study, a parameter is derived which describes the condition for which an increase in autopilot attitude gain will result in a decrease in closed-loop system bandwidth. Setting this "reversal parameter" $\frac{\partial(\omega_p'')^2}{\partial K_\theta}$ equal to zero is proposed in Reference 11 as a criterion for calculating expected minimum approach speeds for piloted approaches made with the Navy mirror landing aid.

For zero thrust inclination, the "reversal parameter" calculates the minimum drag speed; however, for thrust inclinations above the flight path, a speed lower than the minimum drag speed is calculated.

The inclination of the thrust line of the T-33 can be decreased by extending the wing flaps. Thus the fourth drag configuration selected for study consisted of landing gear up, wing flaps extended 24°, and the variable drag system adjusted such that dD/du = 0. The thrust inclination relative to the flight path was approximately 2.9° less for this configuration than for the corresponding landing-gear-down case.

The hypothesis was that the dD/du = 0 landing-gear-down configurations would be rated more satisfactory than the flap-down configurations because of the higher thrust inclination.

SECTION 3

RESULTS OF THE EXPERIMENT

3.1 IDENTIFICATION OF CONFIGURATIONS EVALUATED

At the beginning of each evaluation, oscillograph records were taken to permit identification of the short period dynamics and drag characteristics. These records were taken at 160 kt indicated airspeed at 5500 ft pressure altitude and consisted of a level flight trim portion followed by a series of elevator stick force doublets and stick position steps.

The trim records were used to define the C_L vs. α_V curves used in the calculation of the drag curves. Considerable scatter occurred in these data because of the varying levels of turbulence that existed from one record to another and also because on many of the flights very poor visibility conditions existed. Straight lines were fitted to these data by the least-squares technique to get the two curves in Figure 7 (one for the landing gear down and one for the flaps extended 24°).

The free responses to elevator stick force doublets were analyzed by the transient peak or time ratio methods of Reference 35. The resulting frequency and damping ratio measurements represent the best second-order fit to the angle-of-attack response. The doublet input has most of its energy at high frequency and so can be used to excite the short period mode while causing a minimum of disturbance to the phugoid mode. The frequency and damping ratio measurements thus obtained are plotted in Figure 8 for each of the four nominal drag configurations.

The responses to elevator stick position step inputs were used to measure the ratios F_{ES}/δ_{ES} and α/δ_{ES} , and to define the δ_P vs α_V curve for each configuration. With the δ_P vs. α_V curve defined, the C_D vs. C_L curve could be calculated by the method of Figure 7. The values of C_L , C_D and $\frac{\partial C_D}{\partial C_L}$ to be associated with each configuration were determined from the C_D vs. C_L curve by using the average weight which existed during each evaluation. During the time from the start of the descent at 5000 ft to the second wave-off, an average of 440 lb of fuel was consumed. Thus the average weight used to represent each configuration has a tolerance of approximately ± 220 lb or ± 1.5% to ± 1.9% of the gross weight.

A total of 88 configurations was evaluated, of which 13 were on the front side of the drag-velocity curve, 27 were near the minimum drag point with landing gear down, 19 were near the minimum drag point with flaps down, and 29 were on the back side of the drag-velocity curve.

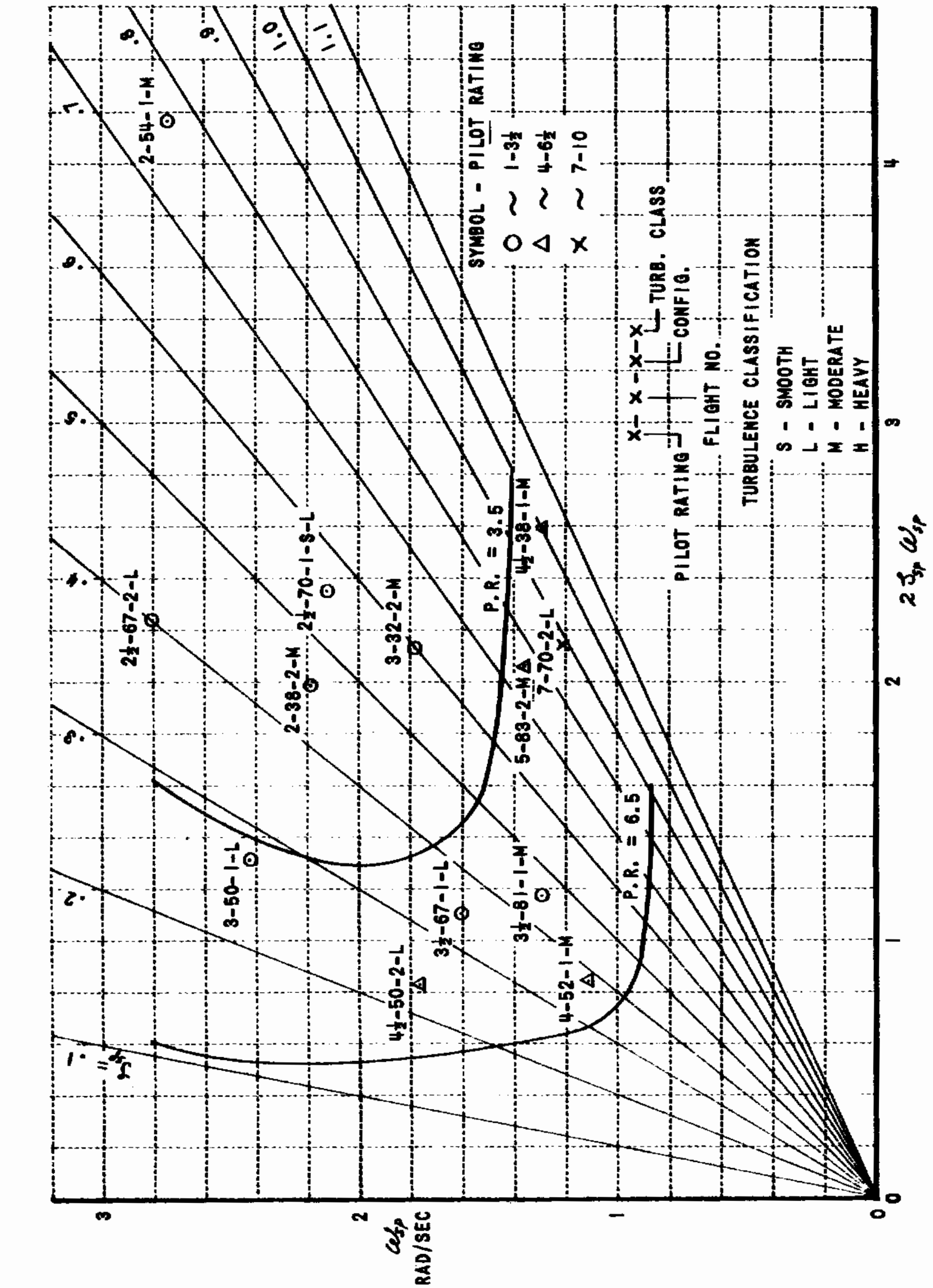

Figure 8a Pilot Rating Data as a Function of Short Period Dynamics and Drag Characteristics - Front Side, Landing Gear Down

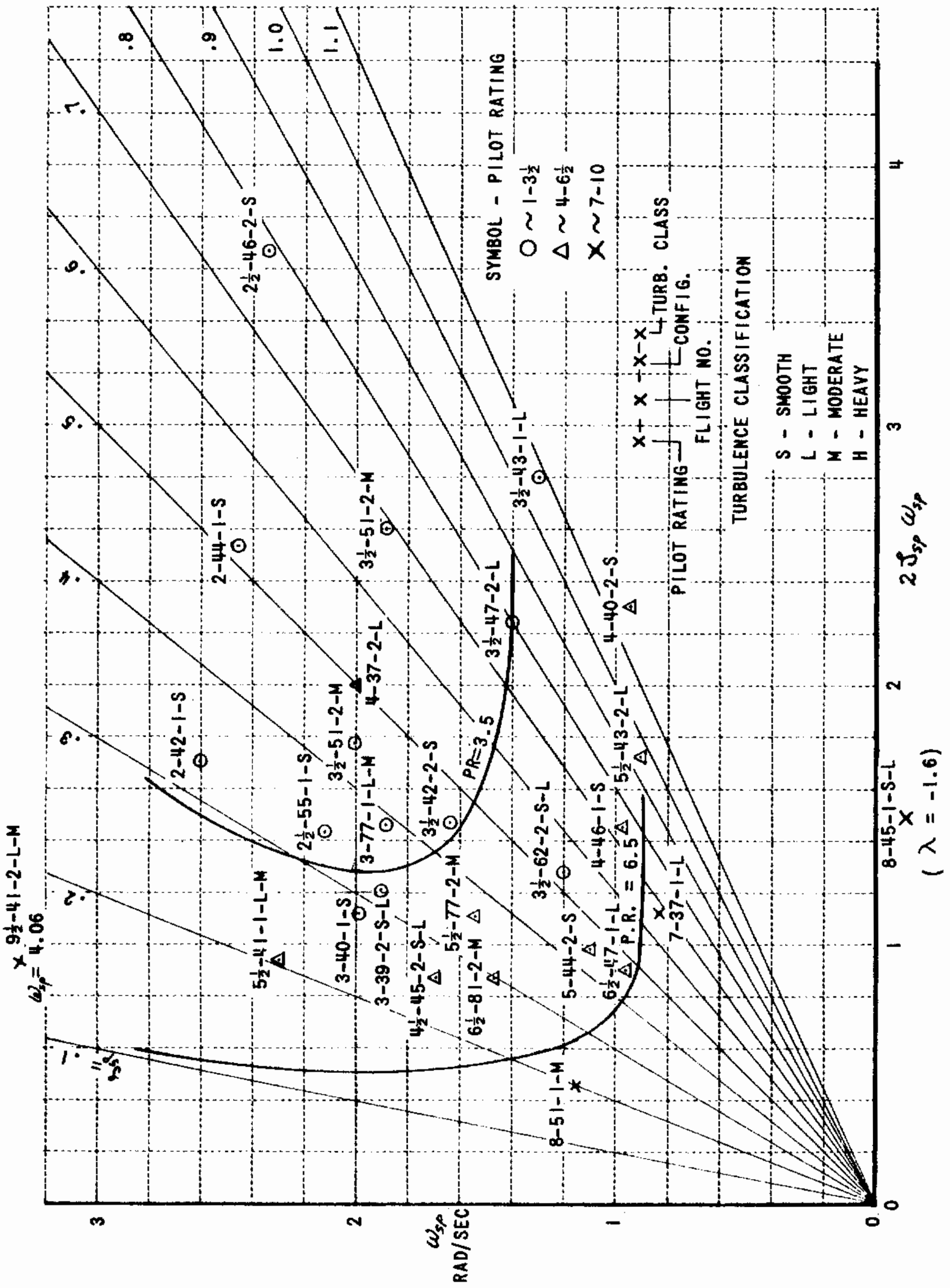

Figure 8b Pilot Rating Data as a Function of Short Period Dynamics and Drag Characteristics - Bottom, Landing Gear Down

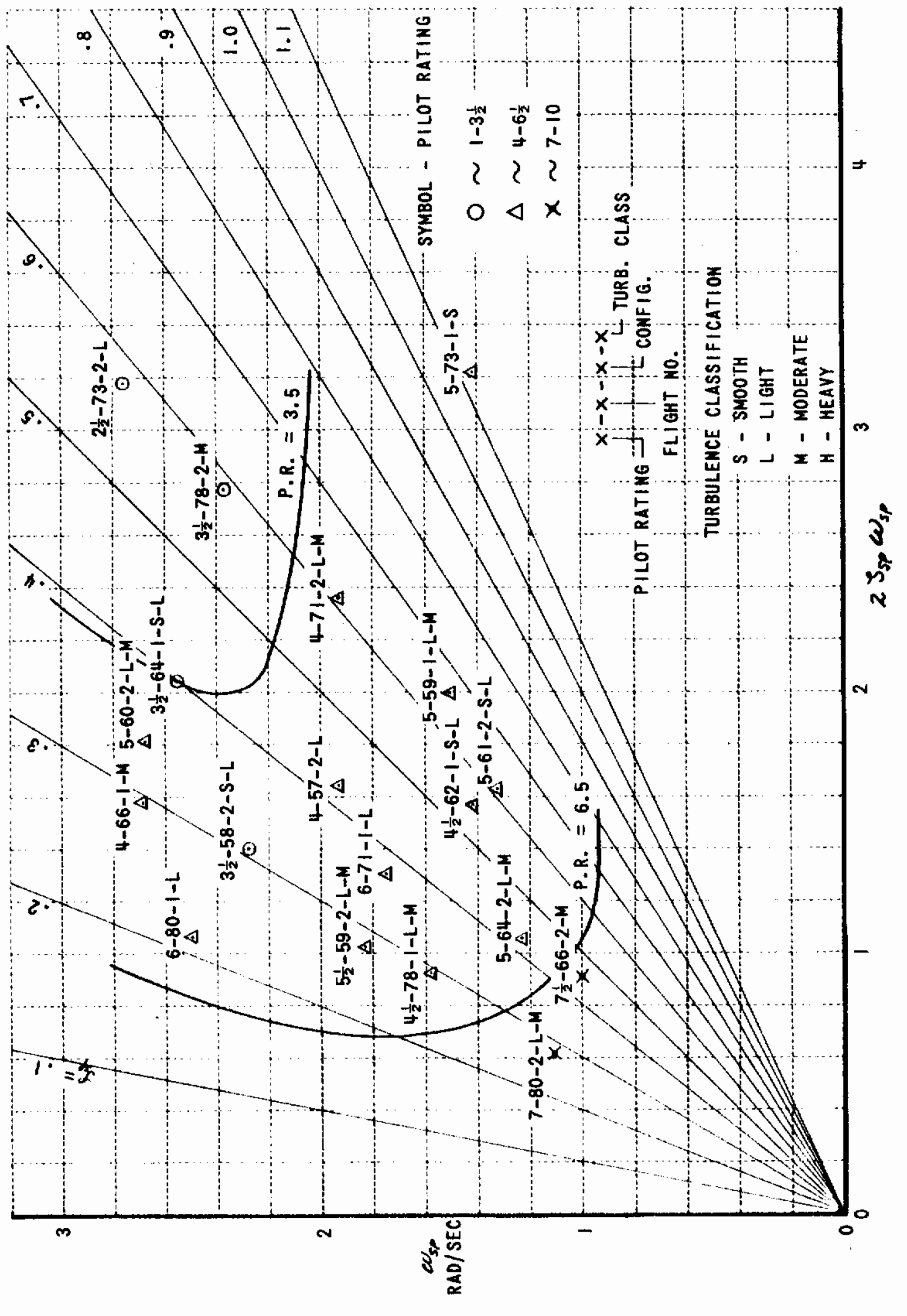

Figure 8c Pilot Rating Data as a Function of Short Period Dynamics and Drag Characteristics - Bottom, Flaps at 24°

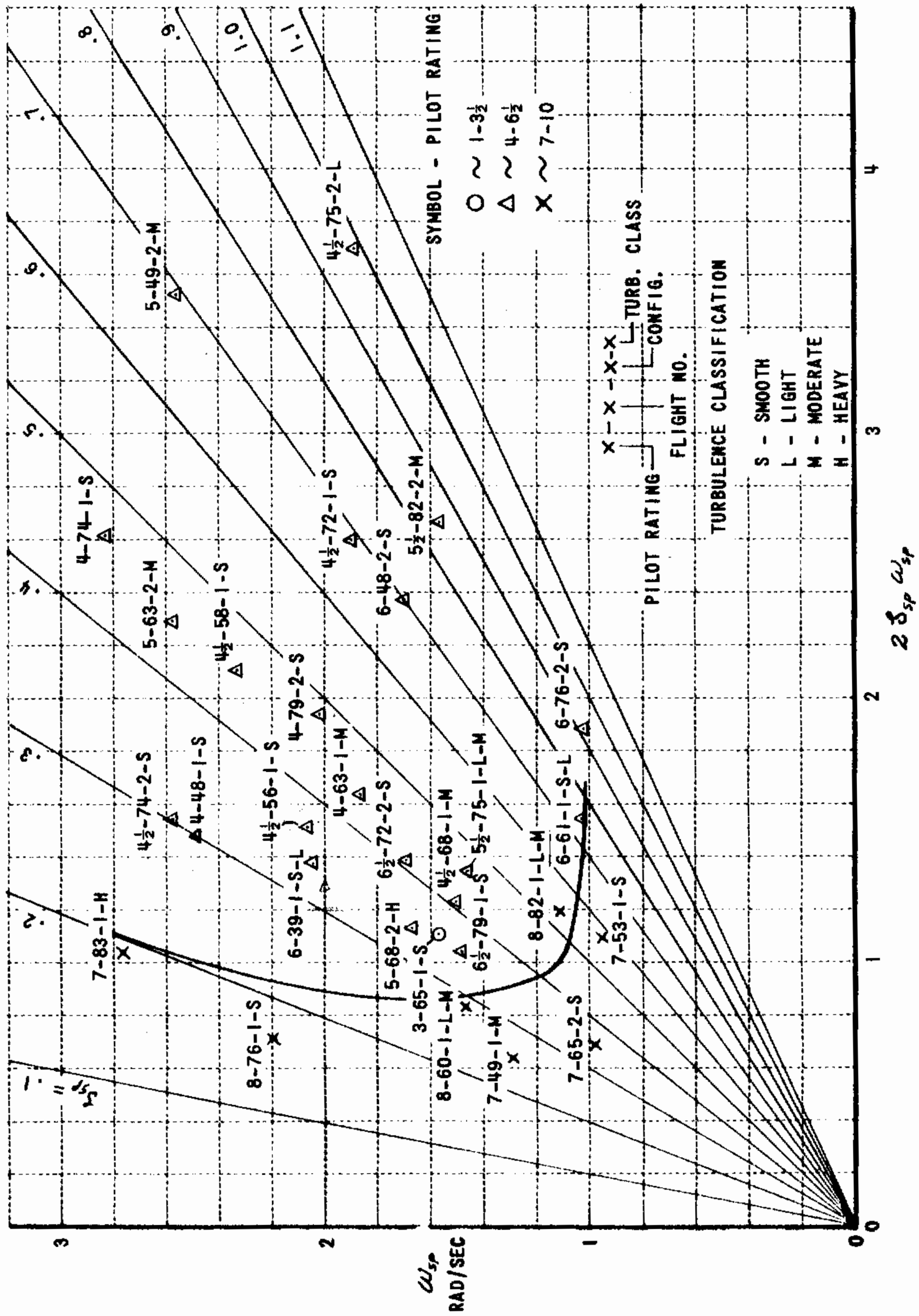

Figure 8d Pilot Rating Data as a Function of Short Period Dynamics and Drag Characteristics - Back Side, Landing Gear Down

Since for planning purposes the fuel load was divided into three ranges and variable drag gains were computed for each of these, at least three C_D vs. C_L plots are required for each nominal drag case. Because of various difficulties in establishing the proper combination of δ_p trim and δ_p/α_v gain settings, more than three C_D vs. C_L curves had to be computed for the front side and the back side nominal drag cases.

In References 5, 6, 9, 11, 12 and 13 the stability or behavior of airspeed, when the pilot is using the elevator to control attitude and altitude, is analyzed and related to airplane aerodynamic and thrust characteristics. It is shown that the behavior of airspeed, when elevator is used to control attitude and altitude, is characterized by a first-order root which is stable for trim speeds higher than minimum drag and unstable for trim speeds below minimum drag. Further, it is shown that as the pilot increases the elevator gain for altitude errors, this root approaches a limiting value (assuming linearized small perturbation equations) which is determined by the value of the low-frequency factor of the altitude to elevator transfer function numerator.

Consider the following longitudinal equations of motion developed in Reference 36, page II-33. The equations are written in matrix notation and simplified by assuming $Z_{\dot{w}} = X_q = X_{\dot{w}} = Z_q = \sin\gamma_0 = 0$ and $\cos\gamma_0 = 1$. The additional equation $sh(s) = U\theta(s) - w(s)$ is derived from $\dot{h} = U\sin\gamma$ by assuming $\sin\gamma = \gamma$ and $\gamma = \theta - \alpha$ where $\alpha = w/U$.

$$\begin{bmatrix} s-(x_u + T_u\cos\xi) & -X_w & g & 0 \\ -(Z_u - T_u\sin\xi) & s - Z_w & -Us & 0 \\ -\left(M_u + \frac{z_i m}{I_y}T_u\right) & -(M_{\dot{w}}s + M_w) & (s^2 - M_q s) & 0 \\ 0 & 1 & -U & s \end{bmatrix} \begin{bmatrix} u(s) \\ w(s) \\ \theta(s) \\ h(s) \end{bmatrix} = \begin{bmatrix} X_{\delta_e} \\ Z_{\delta_e} \\ M_{\delta_e} \\ 0 \end{bmatrix} \delta_e(s) \tag{3}$$

The altitude to elevator $h(s)/\delta_e(s)$ transfer function numerator can be derived by substituting the column of control derivatives for the column of altitude coefficients on the left-hand side of equations 3. The result is of the form:

$$\frac{h(s)}{\delta_e(s)} = \frac{AS^3 + BS^2 + CS + D}{S\Delta} \tag{4}$$

where Δ is the characteristic determinant of the first three equations and factors into the airplane phugoid and short period roots. The coefficients of the numerator cubic are expressed in terms of stability derivatives by equations 5.

$$A = -Z_{\delta_e}$$

$$B = -(Z_u - T_u \sin\xi)X_{\delta_e} + (M_q + UM_{\dot{w}} + X_u + T_u\cos\xi)Z_{\delta_e}$$

$$C = (Z_u - T_u\sin\xi)(M_q + UM_{\dot{w}})X_{\delta_e} - \left[(X_u + T_u\cos\xi)(M_q + UM_{\dot{w}}) - UM_w\right]Z_{\delta_e} - \underline{UZ_w M_{\delta_e}}$$

$$\begin{aligned} D = & -\left[UZ_w\left(M_u + \frac{z_i m}{I_{YY}}T_u\right) - (Z_u - T_u\sin\xi)UM_w\right]X_{\delta_e} \\ & + \left[\left(M_u + \frac{z_i m}{I_{YY}}T_u\right)(UX_w - g) - UM_w(X_u + T_u\cos\xi)\right]Z_{\delta_e} \\ & + \left[\underline{UZ_w}(\underline{X_u} + T_u\cos\xi) - (\underline{Z_u} - T_u\sin\xi)\underline{(UX_w - g)}\right]\underline{M_{\delta_e}} \end{aligned} \tag{5}$$

For aft tailed vehicles, this numerator cubic factors into a small real root $1/T_{h_1}$ which may be in either the right- or left-half plane and two higher frequency real roots $1/T_{h_2}$ and $1/T_{h_3}$ which are nearly equally spaced about the origin. Assuming this root distribution, $1/T_{h_1}$ can be well approximated by the ratio of the last two coefficients of the cubic

$$\frac{1}{T_{h_1}} \doteq \frac{D}{C} \tag{6}$$

In the following paragraphs this expression for $1/T_{h_1}$ will be simplified to illustrate its relation to basic lift-drag characteristics and the trimmed thrust required vs. velocity curve. First it is assumed that the contribution of the X_{δ_e} and Z_{δ_e} terms in C and D are negligible relative to the M_{δ_e} terms, this is equivalent to assuming a long effective tail length and may not be justified for delta wing configurations. Next it is assumed that $|X_u| \gg |T_u|\cos\xi$ and $|Z_u| \gg |T_u \sin\xi|$. This is a valid assumption for turbojet aircraft but may not be justified for propeller driven aircraft. Under these assumptions Equation 6 reduces to the underlined terms of equations 5 and $1/T_{h_1}$ is approximated by

$$\frac{1}{T_{h_1}} \doteq -X_u + \frac{Z_u}{Z_w}\left(X_w - \frac{g}{U}\right) \tag{7}$$

Substituting definitions for the stability derivatives

$$\frac{1}{T_{h_1}} \doteq \frac{\rho S U}{m}\left(C_D + C_{D_u}\right) + \frac{-\frac{\rho S U}{m}\left(C_L + C_{L_u}\right)}{-\frac{\rho S U}{2m}\left(C_{L_\alpha} + C_D\right)} \left[\frac{\rho S U}{2m}\left(C_L - C_{D_\alpha}\right) - \frac{g}{U}\right] \tag{8}$$

Assuming $C_{D_u} = C_{L_u} = 0$ and simplifying,

$$\frac{1}{T_{h_1}} \doteq \frac{2g}{U} \frac{\frac{1}{2}\rho S U^2}{W} \left[C_D + \frac{C_L}{C_{L_\alpha} + C_D} \left(C_L - C_{D_\alpha} - \frac{W}{\frac{1}{2}\rho S U^2}\right)\right] \tag{9}$$

For level trim flight,

$$D = T \cos \xi \tag{10}$$

$$W = L + T \sin \xi \tag{11}$$

Solve equation 10 for T , substitute in equation 11 and nondimensionalize:

$$W = L + D \tan \xi \tag{12}$$

$$W = \frac{\rho S U^2}{2}\left(C_L + C_D \tan \xi\right) \tag{13}$$

$$\frac{W}{\frac{1}{2}\rho S U^2} = C_L + C_D \tan \xi \tag{14}$$

If equation 14 is substituted into equation 9 and C_L is factored out the result is

$$\frac{1}{T_{h_1}} \doteq \frac{2g}{U} \frac{C_L}{C_L + C_D \tan \xi} \left[\frac{C_D}{C_L} - \frac{C_{D_\alpha} + C_D \tan \xi}{C_{L_\alpha} + C_D}\right] \tag{15}$$

This expression can be further simplified if the thrust line inclination relative to the reference stability axis is small such that $C_D \tan \xi$ is negligible relative to C_{D_α} and also if $C_D \ll C_{L_\alpha}$

$$\frac{1}{T_{h_1}} \doteq \frac{2g}{U} \frac{C_L}{C_L + C_D \tan \xi} \left[\frac{C_D}{C_L} - \frac{C_{D_\alpha}}{C_{L_\alpha}} \right] \tag{16}$$

Substituting $\frac{C_{D_\alpha}}{C_{L_\alpha}} = \frac{\partial C_D}{\partial C_L}$ as before yields an approximate expression for $1/T_{h_1}$ which involves only basic lift-drag data:

$$\frac{1}{T_{h_1}} \doteq \frac{2g}{U} \frac{C_L}{C_L + C_D \tan \xi} \left[\frac{C_D}{C_L} - \frac{\partial C_D}{\partial C_L} \right] \tag{17}$$

Comparing equations 2 and 17 and using equation 14 it is seen that

$$\frac{1}{T_{h_1}} \doteq \frac{1}{m} \frac{dD}{dU} \tag{18}$$

Thus, under certain circumstances, the low-frequency factor of the h/δ_e transfer function numerator is equal to the slope of the trim drag vs. velocity curve divided by the mass of the airplane.

While this approximation is adequate for the present purpose, a more rigorous derivation gives

$$\frac{1}{T_{h_1}} \doteq -\frac{1}{m} \frac{dX}{du} \tag{18a}$$

where $X = T \cos \xi - D$ and the derivative is taken about a trimmed operating point in level flight. The necessary assumptions are then only that equations 3 hold and that the X_{δ_e} and Z_{δ_e} terms in $N_{h\delta_e}$ have negligible effect on $1/T_{h_1}$. The further assumptions required for equation 18 are that:

$$\frac{\partial T}{\partial u} \cos \xi \ll \frac{dD}{du}$$

and

$$C_D \tan \xi \ll C_{D_\alpha} .$$

Equation 17 was used to calculate values of $1/T_{h_1}$ for each configuration evaluated in the flight program. These values of $1/T_{h_1}$ are tabulated in Table 1 and are located on the real axis of the s -plane in Figure 9. This figure illustrates the variability of the configurations in each nominal drag case.

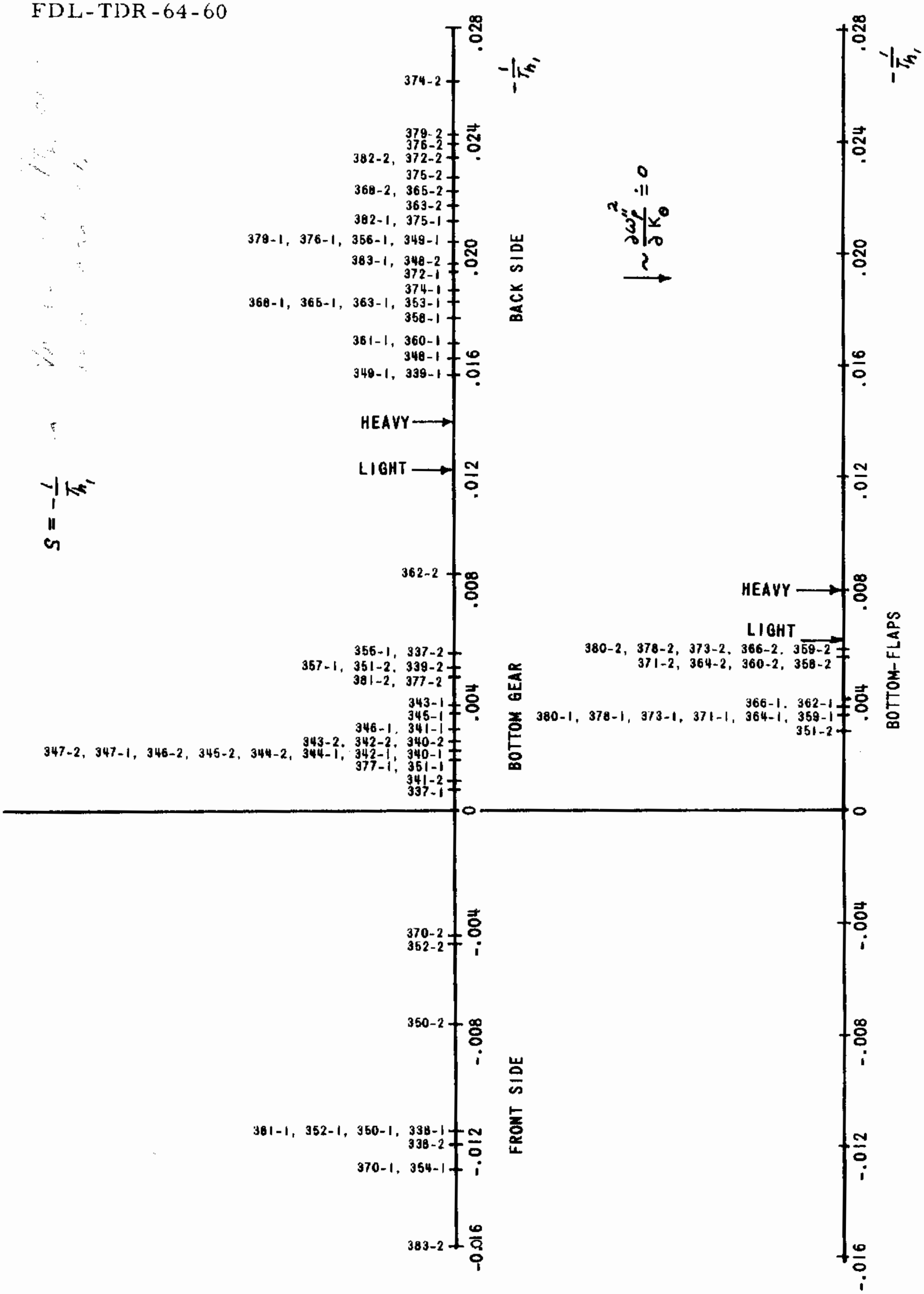

Figure 9 Values of $-\frac{1}{T_{h_1}}$ Corresponding to the Four Nominal Drag Cases

The "reversal parameter" developed in References 11 and 12 is defined as follows for the case where the thrust line passes through the center of gravity

$$\frac{\partial(\omega_p'')^2_{\zeta_p''=0}}{\partial K_\theta} = \frac{\frac{1}{T_{\theta_1}T_{\theta_2}}\left(\frac{1}{T_{h_T}} - 2\zeta_p\omega_p\right) + \omega_p^2\left(\frac{1}{T_{\theta_1}} + \frac{1}{T_{\theta_2}} - \frac{1}{T_{h_T}}\right)}{\left[T_{h_T} \quad (1+K_\theta)\frac{1}{T_{h_T}} - 2\zeta_p\omega_p - K_\theta\left(\frac{1}{T_{\theta_1}} + \frac{1}{T_{\theta_2}}\right)\right]^2} \tag{19}$$

The minimum approach speed is estimated as the speed which causes the numerator of this partial derivative to be zero. This is the speed at which the closed-loop system bandwidth stops increasing with increased attitude loop gain. For higher speeds, increasing the "autopilot" attitude-loop gain results in increased closed-loop phugoid frequency at zero damping ratio. While for lower speeds, increasing the attitude-loop gain results in decreased closed-loop phugoid frequency.

Calculation of the parameter as expressed above requires the assumption of a value of K_θ , the attitude-loop gain. However, the critical value of the reversal parameter is zero and occurs when the numerator is equal to zero. Therefore, considering only the numerator,

$$\frac{1}{T_{\theta_1}T_{\theta_2}}\left(\frac{1}{T_{h_T}} - 2\zeta_p\omega_p\right) + \omega_p^2\left(\frac{1}{T_{\theta_1}} + \frac{1}{T_{\theta_2}} - \frac{1}{T_{h_T}}\right) = 0 \tag{20}$$

Rearrange terms and divide through by $\frac{1}{T_{h_T}}$,

$$\left[\frac{1}{T_{\theta_1}}\frac{1}{T_{\theta_2}} - \omega_p^2\right] + \frac{-\frac{2\zeta_p\omega_p}{T_{\theta_1}T_{\theta_2}} + \omega_p^2\left[\frac{1}{T_{\theta_1}} + \frac{1}{T_{\theta_2}}\right]}{\frac{1}{T_{h_T}}} = 0 \tag{21}$$

Consider the first term of this expression. If X_{δ_e} , Z_{δ_e} , and T_u can be neglected, then from equation 3 it can be derived:

$$\frac{1}{T_{\theta_1}}\frac{1}{T_{\theta_2}} \doteq Z_w X_u - X_w Z_u \tag{22}$$

If $M_u = 0$ and $UM_w \gg Z_w M_q$, then

$$\omega_p^2 \doteq -\frac{g}{U} Z_u \tag{23}$$

Then

$$\left[\frac{1}{T_{\theta_1} T_{\theta_2}} - \omega_p^2\right] \doteq -Z_w\left[-X_u + \frac{Z_u}{Z_w}\left(X_w - \frac{g}{U}\right)\right] \tag{24}$$

Comparing equation 24 and equation 7 it is seen that

$$\left[\frac{1}{T_{\theta_1} T_{\theta_2}} - \omega_p^2\right] \doteq -Z_w \frac{1}{T_{h_1}} \tag{25}$$

Substituting equation 25 in equation 21 and dividing by $-Z_w$

$$\frac{1}{T_{h_1}} + \frac{\dfrac{2\zeta_p\omega_p}{T_{\theta_1} T_{\theta_2}} - \omega_p^2\left[\dfrac{1}{T_{\theta_1}} + \dfrac{1}{T_{\theta_2}}\right]}{Z_w \dfrac{1}{T_{h_T}}} = 0 \tag{26}$$

The following approximation for $1/T_{h_T}$ is given in Reference 11,

$$\frac{1}{T_{h_T}} = -\frac{Z_u}{\xi} \tag{27}$$

Since $1/T_{h_T}$ is inversely proportional to the thrust line inclination, $1/T_{h_T}$ approaches infinity as the thrust inclination approaches zero. In this case the "reversal parameter" equals zero when $1/T_{h_1} = 0$. For positive thrust inclinations the "reversal parameter" equals zero for a negative value of $1/T_{h_1}$. Using Equations 22 and 23 plus the following additional approximations from Reference 11,

$$2\zeta_p\omega_p \doteq -X_u \tag{28}$$

$$\frac{1}{T_{\theta_1}} + \frac{1}{T_{\theta_2}} \doteq -Z_w - X_u \tag{29}$$

and subsituting into equation 26

$$\frac{1}{T_{h_1}} + \frac{-X_u\left(Z_w X_u - X_w Z_u\right) - \left(-\frac{g}{U} Z_u\right)\left(-Z_w - X_u\right)}{Z_w\left(-\frac{Z_u}{\xi}\right)} = 0 \tag{30}$$

Rearranging terms,

$$\frac{1}{T_{h_1}} + \left[\frac{X_u^2}{Z_u} - \frac{X_u X_w}{Z_w} + \frac{g}{U}\frac{X_u}{Z_w} + \frac{g}{U} \right] \xi = 0 \tag{31}$$

This expression can be approximated quite well by

$$\frac{1}{T_{h_1}} + \frac{g}{U}\xi \doteq 0 \tag{32}$$

Thus the value of $1/T_{h_1}$ which makes the "reversal parameter" of Reference 11 approximately equal to zero (for the case where the thrust line passes through the center of gravity but is inclined relative to the X stability axis or the trim flight path) is;

$$\frac{1}{T_{h_1}} \doteq -\frac{g}{U}\xi . \tag{33}$$

The value of $1/T_{h_1}$ for which equation 33 is satisfied depends directly on the thrust line incidence. In the case of the T-33, therefore, it depends on the gross weight and the landing gear and flap configuration. In general, two configurations were evaluated on each flight: one at high fuel-remaining and one at low fuel-remaining. The average weight at which the first configurations in each flight were evaluated was 14,200 lb and the average weight at which the second configurations were evaluated was 12,350 lb. These weights correspond to $\xi \doteq 6.70°$ and $5.86°$ respectively for the landing-gear down case and $\xi \doteq 3.79°$ and $2.89°$ for the gear up, flaps extended 24° case.

The average values of $1/T_{h_1}$ for which $\dfrac{\partial(\omega_p'')^2_{\zeta_p=0}}{\partial K_\theta} \doteq 0$ were then:

Airplane Configuration	Heavy	Light
Landing Gear Down	$\frac{1}{T_{h_1}}$ = -.0139 1/sec	-.0122
Flaps Extended 24°	-.0079	-.0060

These values of $1/T_{h_1}$ are located in Figure 9. This figure indicates that for the back side drag configurations, 160 kt was below the minimum approach speed calculated by the reversal parameter of Reference 11.

No measurements were made of the airplane phugoid dynamics. However, for configurations with significant short period frequency, the phugoid roots are estimated as $\omega_p \doteq .17$ rad/sec, $\zeta_p \doteq .1$. Small variations of the phugoid damping ratio occurred as a result of the small variations in X_u (-.033 to -.038) that were experienced. For configurations with low short period frequency, the phugoid roots probably were of lower frequency than ω_p = .17 rad/sec but the damping ratio was probably equal to or greater than $\zeta_p \doteq .1$. See Reference 45 for a discussion of the effect of C_{m_α} on the locus of short period and phugoid roots.

3.2 DISCUSSION OF RESULTS

3.2.1 Pilot Rating Data

The pilot rating assigned each configuration was based on the amount of effort the pilot was required to put forth relative to the precision of flight path control that he achieved. He evaluated the effort, skill, concentration, and the practicability of any special control techniques required to accomplish the task, as well as his performance in actually accomplishing it. His rating also reflects whether or not a configuration possessed any characteristic which he considered potentially dangerous.

The pilot rating data plotted in Figure 8 clearly indicate the importance to the pilot of short period dynamics and drag characteristics for the landing approach task. The pilot ratings of the various configurations tested ranged from 2 (Acceptable, Satisfactory, Good) to 9.5 (Unacceptable, Dangerous). The gradients of pilot rating with the parameters varied in the test program are also evident from Figure 8.

The most severe rating degradation occurred when either the short period damping ratio or natural frequency were decreased. The pilot ratings were generally unsatisfactory when the damping ratio was less than 0.3 and became unacceptable when the damping ratio was further decreased. Similarly, the ratings are generally unsatisfactory for short period frequencies lower than $\omega_{sp} \doteq 2$ rad/sec and become unacceptable for frequencies lower than $\omega_{sp} \doteq 1$ rad/sec. The degradation in pilot rating from $\omega_{sp} \doteq 2$ rad/sec to $\omega_{sp} \doteq 1$ rad/sec appears to be gradual.

As was expected, the pilot ratings became generally less satisfactory when the drag configurations were changed from the front to the back of the drag-velocity curve. Only one of the 29 back side drag configurations evaluated was rated satisfactory. This evaluation was conducted under ideal weather circumstances and the rating was not repeated when similar configurations were evaluated under less ideal conditions.

The major objections to each of the above-mentioned factors which caused degradation in the pilot rating are as follows:

Low damping ratio - Airplane bobbles in response to both control inputs and turbulence. Pilot must smooth inputs and provide damping to eliminate oscillations resulting from external disturbances.

Low frequency - Airplane does not maintain angle of attack or attitude by itself, the pilot must constantly provide stabilization and must overdrive the airplane to obtain satisfactory attitude response.

Back side drag configuration - Control of airspeed and altitude requires constant attention and considerable coordination of elevator and throttle manipulations.

These objections are all directed at the degree of attention, coordination and compensation demanded of the pilot in accomplishing the task. Further discussion of the pilot comments is contained in Section 3.2.3.

Because pilot rating is a function of short period frequency and damping ratio, comparisons between different drag cases must be made at the same short period frequency and damping ratio. Direct comparison of pilot ratings for the different drag cases is not possible because exactly the same short period configurations were not tested for each drag case. This was due in part to the fact that the drag petals influenced the short period dynamics and this influence depended on the δ_p/α_v gain. Therefore, an extensive calibration program would have been required to permit exact duplication of specific short period configurations at each drag case. Thus, to make comparisons between drag cases, it is necessary to interpolate or fair the rating data. This was done initially by eye and it was concluded that the pilot ratings for the front-side drag case and the ratings for the bottom with gear down drag case could be treated as a single population. The ratings for the bottom with flaps down drag case and the back-side drag case were considered to be sufficiently different to be treated separately. These three populations were then fitted with third degree surfaces by the least-squares technique:

$$E\{\text{PILOT RATING}\} = a_0 + a_1\omega_{sp} + a_2\omega_{sp}^2 + a_3\zeta_{sp} + a_4\zeta_{sp}^2 + a_5\zeta_{sp}^3 + a_6\zeta_{sp}\omega_{sp} + a_7\omega_{sp}^2\zeta_{sp} + a_8\omega_{sp}\zeta_{sp}^2 \quad (34)$$

No particular significance should be attached to the form of this equation; a third degree surface was used only because it was considered to be the least complicated mathematical form that would provide a reasonable fit to the data. The resulting equations were solved for 0.2 increments of ω_{sp} from $\omega_{sp} = 1.0$ rad/sec to ω_{sp} 2.8 rad/sec and for increments of ζ_{sp} from $\zeta_{sp} = 0.1$ to $\zeta_{sp} = 1.0$. From these solutions the pilot rating boundaries of 3.5 (boundary between satisfactory and unsatisfactory) and 6.5 (boundary between acceptable and unacceptable were determined and are plotted on the pilot rating listings of Figure 8. These boundaries are considered to be reasonable fairings of of the available data. The unacceptable boundary (pilot rating of 6.5) is similar for all drag cases, except that it moves to higher frequency and damping ratio when the drag characteristics become more troublesome. The acceptable but unsatisfactory boundary (pilot rating of 3.5) for the bottom gear down data encompasses the largest satisfactory area. When additional objectional factors are introduced, as in the bottom with flaps down drag case, the short period frequency and damping ratio values required by the pilot are higher. Finally, when the drag characteristics are such that control of airspeed becomes a significant factor, as in the back-side drag case, this factor alone will prevent the pilot from rating the configuration satisfactory regardless of short period dynamics.

Calculated pilot ratings are plotted in Figure 10 as a function of short period damping ratio for $\omega_{sp} = 1.0$, 1.6, 2.2, and 2.8 rad/sec. These curves illustrate the severe degradation in pilot rating that results when the damping ratio is less than $\zeta_{sp} = .4$. These curves also indicate that on the average the back-side drag case was rated one to two rating units less satisfactory than

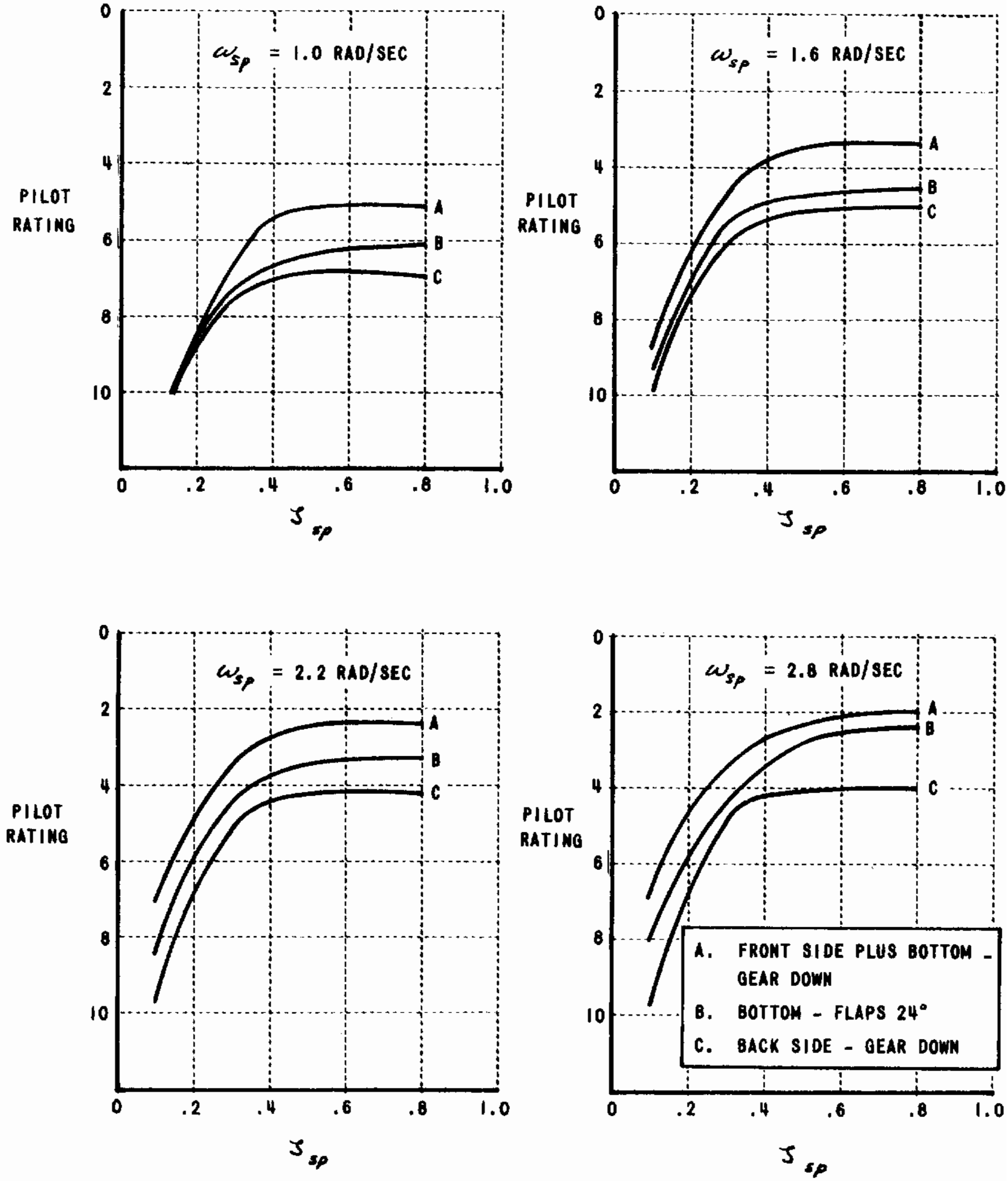

Figure 10 Calculated Pilot Ratings

the front side plus bottom drag cases (all with gear down). The mean pilot ratings for the bottom drag case with flaps down are intermediate to the ratings for the back side and bottom drag cases with gear down. The flap-down ratings tend to be closer to the back side ratings when the short period dynamics are poor and closer to the bottom with gear down ratings when the short period dynamics are good.

Comparison of pilot ratings for the various drag cases would seem to support the theory of Reference 11; i.e., that the inclination of the thrust line influences closed-loop phugoid frequency and therefore the pilot rating. Examination of the pilot comment data, however, does not reveal any comments that could be construed as decreased phugoid bandwidth with increased attitude-loop gain. The pilot's comments are in fact just the opposite. When on the glide slope with the landing gear down, the apparent touchdown point on the runway was close to the nose of the airplane in the pilot's field of view. He therefore had a good pitch attitude reference. However, when the flaps were deflected 24°, the zero lift angle of attack was reduced approximately 2.9° so that the touch-down point moved up to the center of the windshield, with the result that the pilot had a less sensitive indication of pitch attitude. Because of this, the pilot had less perception of attitude errors and thus was not as precise in maintaining the pitch attitude he desired. As a result he experienced what he described as a galloping oscillation about the glide slope. He was able to eliminate this tendency by making use of bug spots on the windshield for attitude reference (spots that happened to be near the touch-down point in his field of view). By using these spots he could detect small deviations in pitch attitude, and by closing a tight attitude loop with elevator he was able to eliminate the galloping tendency and improve the quality of the approach. That is, tightening the pilot's attitude loop improved his performance on the glide slope and did not cause any vaguely defined performance reversal.

The lack of a good attitude reference was most noticeable for short period configurations with low frequency and/or damping ratio, i.e., whenever the pilot was required to provide attitude stabilization. When the short period was stiff and well damped, the pilot commented that the lack of a precise attitude reference was less important because the airplane was stable in angle of attack and tended to maintain its own pitch attitude. That this is true is graphically illustrated by the time histories of the landing approaches (see Section 3.2.4).

In comparing pilot ratings for the flaps-down drag case with those for the gear-down drag cases, it should be remembered that the values of $1/T_{h_1}$ have been calculated by adding drag increments due to petals to the common C_D vs. C_L curve used to represent the airplane with either flaps down or gear down. If this curve is in error for either case, then the comparison of pilot ratings for flaps down with pilot ratings for gear down on the basis of calculated $1/T_{h_1}$ is not valid; however, comparisons between gear-down cases should be valid.

Ground simulator studies of the carrier landing approach task are reported in References 7 and 12. In the tests reported in Reference 7, the thrust inclination relative to the flight path was varied from 14° to 24° with no effect on the minimum approach speed selected by the pilots. In the tests reported in Reference 12, the thrust inclination was varied from 0° to 19.75°. The results for this part of the simulation experiment as presented in Figure 7 and Table 5 of Reference 12 exhibit considerable scatter with no clearly significant effect of thrust inclination established. Thus the experimental evidence indicates that thrust inclination has only a minor effect on pilot choice of minimum approach speed and on pilot rating of longitudinal handling qualities in the landing approach.

Of the parameters varied in the simulation experiments reported in Reference 7, the ones that caused the largest change in the approach speed selected by the pilots were: static margin or short period dynamics in combination with longitudinal control effectiveness, the shape of the drag-velocity curve, thrust lag time constants larger than .8 sec, and large thrust offset above the center of gravity.

In the simulation experiment reported in Reference 12, the parameters that caused the largest change in pilot rating were X_w, X_{δ_e} and thrust offset above the center of gravity. As indicated in equation 6, X_w and X_{δ_e} both effect the value of $1/T_{h_1}$.

References 38, 39 and 13 report and discuss a simulator experiment and supporting analytical study directed at longitudinal handling qualities of large transport airplanes for ILS and simulated visual landing approach tasks. The results of these experiments and studies indicate that short period dynamics, longitudinal control gain, and speed-thrust stability are of primary importance to the landing approach task, particularly for the ILS portion.

References 6 and 40 describe the results of a flight test program conducted to investigate the influence of speed stability on the landing approach. The tests were conducted using a small delta-wing jet (Avro 707A) equipped with an autothrottle which varied thrust with airspeed and/or angle of attack. Thus, speed stability could be varied through augmentation of the stability derivatives T_u and/or X_w. The effect on $1/T_{h_1}$ can be determined from equation 6. The airplane was also equipped with an auxiliary throttle which commanded engine operation through an adjustable time lag. The evaluation task consisted of a visual approach with errors from the glide path transmitted to the pilot by radio from a ground observer who was tracking the airplane with a theodolite. Some further flights were made using precision approach radar control, although the pilot was apparently not hooded for these tests. The results of this program indicate a direct correlation of pilot rating with increasing levels of speed instability. The degradation of pilot rating with speed instability was markedly accentuated when a lag was introduced between the auxiliary throttle and the engine. The levels of speed instability quoted in Reference 40 are extreme ($1/\tau = .35$ 1/sec) by comparison to the maximum value quoted in the simulator tests of Reference 12 ($1/T_{h_1} = .10$) or to the maximum tested in the T-33 flight program ($1/T_{h_1} = .025$). The ability of the pilots to cope with instabilities of this magnitude is surprising; caution is

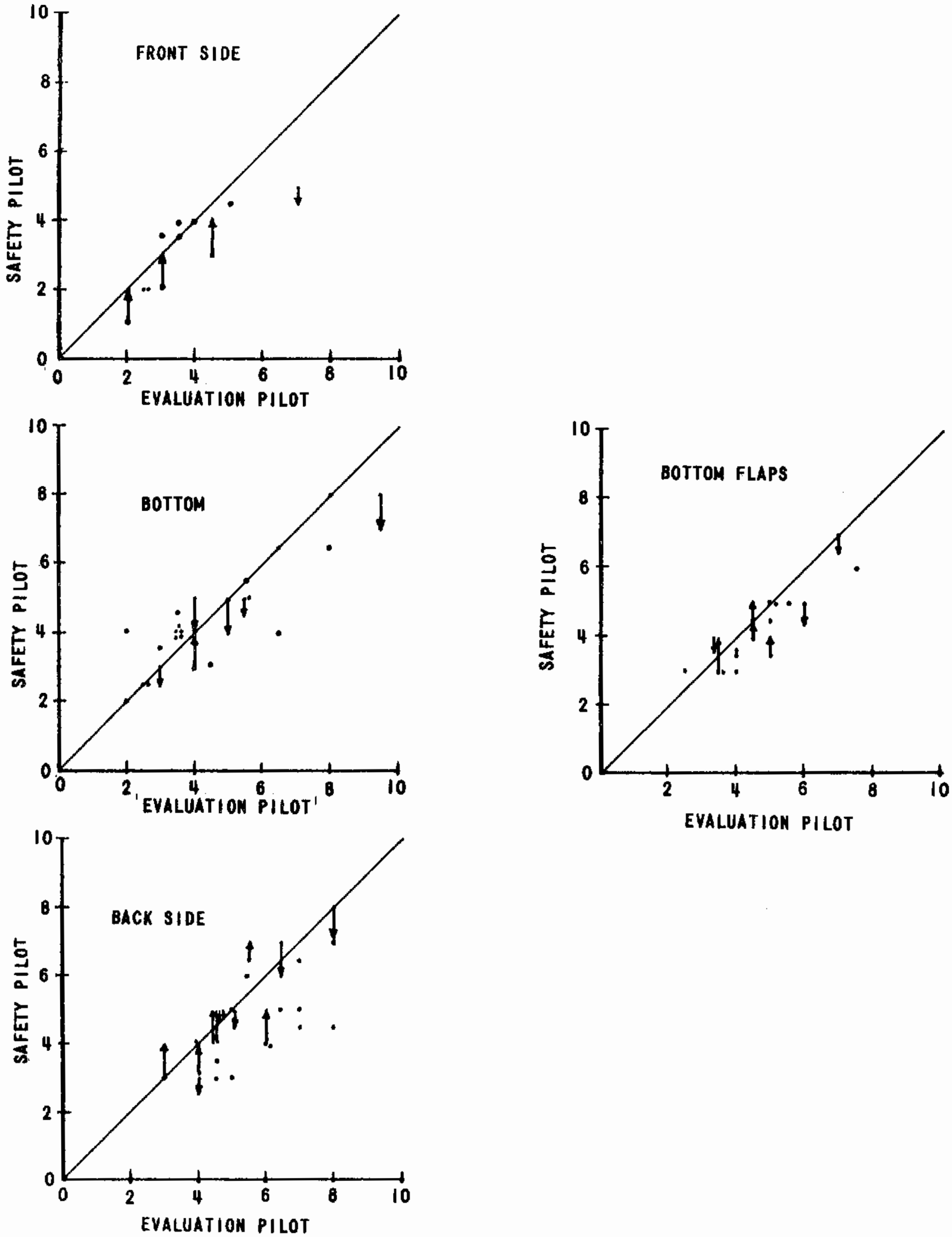

Figure 11 Comparison of Safety Pilot's Ratings with Evaluation Pilot's Ratings

advisable in applying these results. The pilots in these tests could see the main throttle level moving (under the action of the servo) and could hear the change in engine noise. These cues were in advance of, and drew attention to, large airspeed changes; thus the pilots had considerable information not normally available.

During flight operations with the T-33 variable stability airplane the safety pilot serves as observer and test conductor. In the landing approach flight program he could observe both the performance of the evaluation pilot and the circumstances under which each approach was made. He was, then, in a good position to judge or rate each configuration based primarily on the performance attained by the evaluation pilot. At the completion of each evaluation, the safety pilot noted his prediction of the rating the evaluation pilot would render. These ratings have been plotted against the evaluation pilot's ratings in Figure 11. Often the safety pilot would give the range he expected the evaluation pilot's rating to be in (the range quoted is indicated by an arrow with the head indicating the most probable rating).

The correlation of the safety pilot's ratings with those of the evaluation pilot was in general fairly good. It should be observed that when there was disagreement in the ratings the safety pilot's rating was usually more satisfactory than the evaluation pilot's rating. This result demonstrated a situation often observed in handling qualities investigations: the evaluation pilot's ratings tend to deteriorate before his performance of the task becomes affected. This reflects the fact that, although the pilot may be capable of the effort, skill, and attention required to make performance acceptable, he may consider the situation undesirable and/or potentially dangerous. He will indicate this by his rating and comments. This phenomenon was observed and commented on by each of the experimenters in References 7, 12, 38 and 40. In all of these simulation experiments, attempts were made to measure performance of the evaluation task. In each case, however, the results indicated that the pilot's skill was effective in obscuring the effects of poor handling qualities on task performance. As indicated in Reference 6, a successful measure will probably require measurement of both the physical and mental effort that the pilot is required to use in accomplishing the evaluation task, together with the actual task performance.

3.2.2 Longitudinal Control Gain Selected by Pilot

As was stated in Section 2.1.2, the evaluation pilot was required to select a stick-to-elevator gear ratio prior to evaluating each configuration. This procedure was used primarily because the experimenter did not feel that there was a valid criterion for establishing the longitudinal control gain a priori. The investigations of Reference 37 indicated that for $n_z/\alpha < 10\,g/rad$ and a given short period configuration, the pilots tended to choose the gear ratio such that the steady state α/δ_{ES} gain was constant; however, these results also indicated that the preferred value of α/δ_{ES} was a function of short period frequency and damping ratio. In the landing approach program, therefore, the pilot was asked to select the longitudinal gain that he considered satisfactory prior to each evaluation and then to comment on this selection after the evaluation was completed.

Values of α/δ_{ES} were measured from the elevator step records* taken for each configuration. These values are tabulated in Table 1 and in Figure 12 on a grid of short period frequency and damping ratio. These data indicate a trend from small mean values at high frequency and low damping ratio to large mean values at low frequency and high damping ratio. The variability of the gain values about the mean is due in part to the fact that the pilot did not spend a large amount of time in optimizing his choice. His main purpose was to select a gain value that would not cause undue bias in the evaluation and rating of the short period and drag configurations.

The gain data for all configurations evaluated are contained in Figure 12. A second degree surface was fitted to these data by the least-squares technique. Again, the second degree surface was used because it seemed to be the least complicated expression that would provide a reasonable fit to the data. The equation obtained for the expected value of α/δ_{ES} (which has the units degrees per inch) was

$$E\left\{\frac{\alpha}{\delta_{ES}}\right\} = 5.48 - 2.54\,\omega_{sp} + .671\,\zeta_{sp} + .296\,\omega_{sp}^2 + .736\,\zeta_{sp}^2 + .0894\,\zeta_{sp}\omega_{sp}. \tag{35}$$

Sections through this surface at constant ω_{sp} are plotted in Figure 13 for ω_{sp} = 1.0, 1.8 and 2.8 rad/sec. The circled data points in Figure 13 are the pilot-selected values of α/δ_{ES} lying within a band of ± .2 rad/sec about ω_{sp} = 1.0, 1.8 and 2.8 rad/sec respectively. This plot illustrates the form of the variation of α/δ_{ES} with short period frequency and damping ratio and also illustrates the scatter of the data about the least-square estimate of the mean value of α/δ_{ES} . Examination of the pilot comment data for individual points tends to increase confidence in the least-square estimate, i.e., points below the least-square curves are in general accompanied by the comment that the gain selected was a little low and conversely, points above the least-square curves are generally accompanied by the comment that the gain selected was a little sensitive.

The gain selected by the pilot was usually based on a compromise between the low-frequency gain (steady forces in maneuvers such as pullups and turns) and the gain at higher frequencies (the transient forces in tracking maneuvers and the ability to command rapid attitude changes).

For low frequency ($\omega_{sp} \doteq 1.0$ rad/sec) the pilot commented that the airplane was slow and sluggish and that he must overdrive it to obtain satisfactory pitch response. He tended to select a high control gain for this purpose. However, this resulted in light steady forces and he lost feel for angle of attack in turns. Further it became difficult to judge the input required to command a response after overdriving it to get it started, and a small out-of-trim condition could exist without the pilot feeling the steady force.

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*α/δ_{ES} is taken to be the steady-state response in the short-period mode.

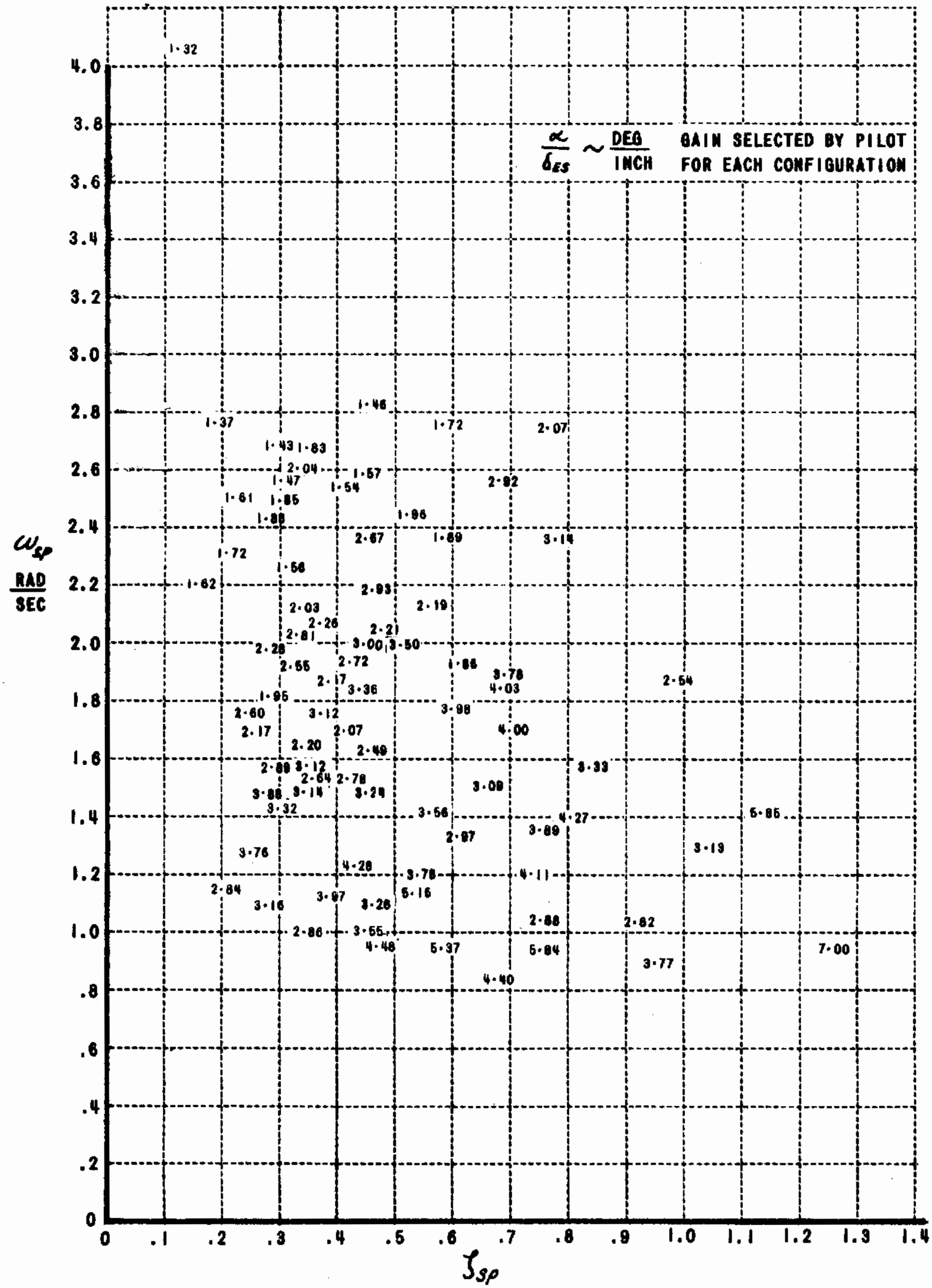

Figure 12 Longitudinal Control Gain Selected by Pilot for the Landing Approach Task

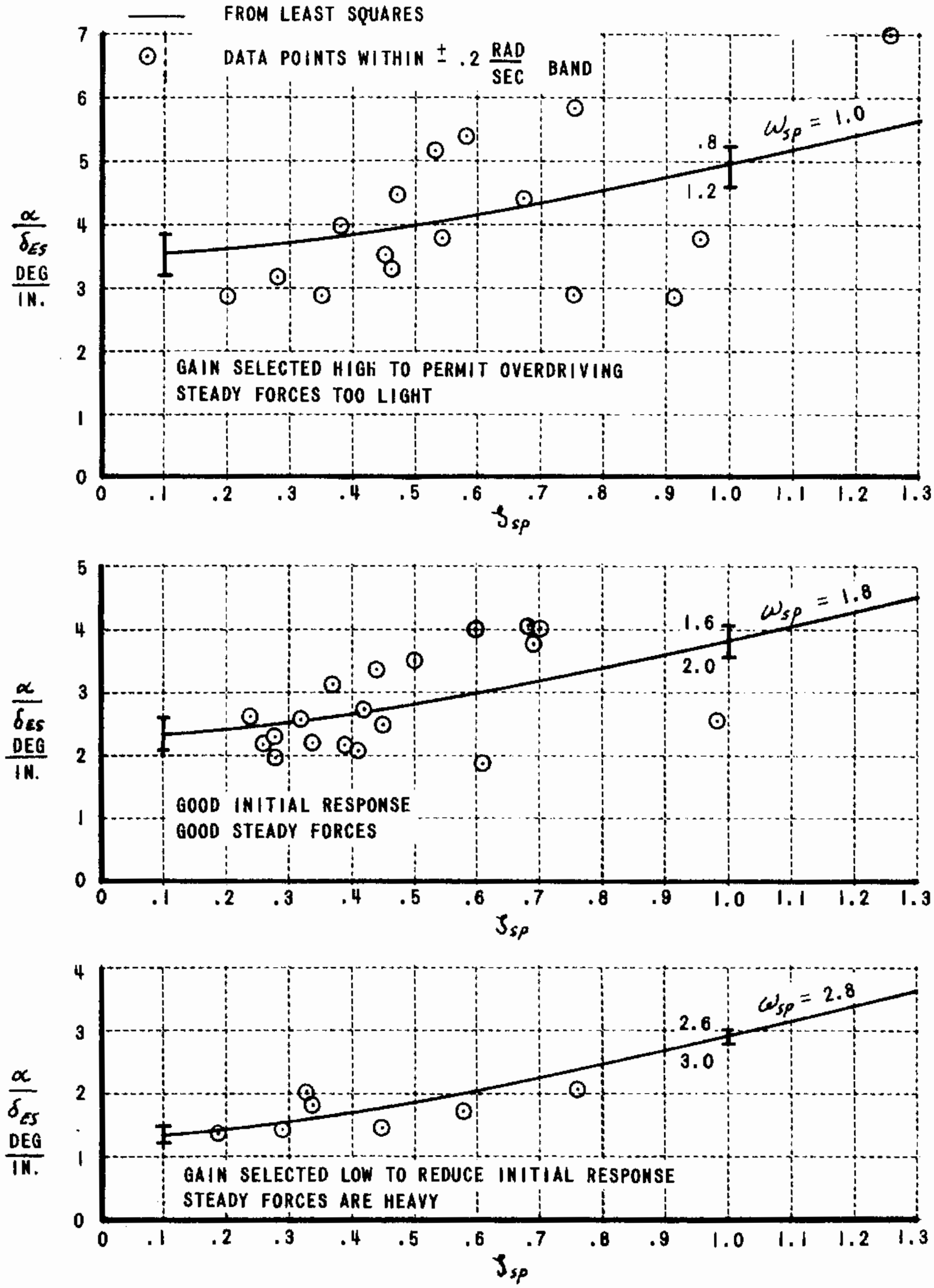

Figure 13 Cross Sections through the $\frac{\alpha}{\delta_{ES}}$ Data at Constant Frequency

For short period frequencies higher than $\omega_{sp} \doteq 2.8$ rad/sec, the pilot commented that the initial pitch response was fast and abrupt for high gain, so he tended to choose a low control gain to reduce this tendency. However, in this case the steady forces in turns became heavy.

At intermediate short period frequencies, $\omega_{sp} \doteq 1.8$ rad/sec, the pilot was able to select gains which gave good initial pitch response and good steady forces without undue compromise of either.

Thus, the longitudinal control gain selected by the pilot was usually a compromise between his desire for comfortable and adequate steady forces in turns and his requirement that he be able to make rapid and precise pitch attitude changes. Pilot comments, and also Bode plots of the pitch attitude and angle-of-attack transfer functions for elevator stick inputs, indicate that the compromise is usually made in favor of the requirement for rapid pitch response.

A quantity of interest to the airplane and control system designer is the initial pitching acceleration that should be commanded by an input to the elevator stick. Mathematically this quantity may be defined as follows:

$$M_{\delta_{ES}} \equiv \frac{1}{I_y} \frac{\partial M}{\partial \delta_{ES}} \tag{36}$$

This can be rewritten as follows

$$M_{\delta_{ES}} = M_{\delta_e} \frac{\delta_e}{\delta_{ES}} \tag{37}$$

From Reference 37, for constant speed and long-tail-length airplanes, equation 37 is approximately equal to

$$M_{\delta_{ES}} \doteq \omega_{sp}^2 \frac{\alpha}{\delta_{ES}} \tag{38}$$

Values of this control derivative have been calculated using the $E\left\{\alpha/\delta_{ES}\right\}$ equation obtained from the least-squares fit of the pilot-selected α/δ_{ES} gain data. The $M_{\delta_{ES}}$ values calculated are plotted in Figure 14 as a function of short period natural frequency with short period damping ratio as a parameter. Data obtained in the ground simulator studies of Reference 44 and the control gain selected by the pilot for the first configuration of Flight 345 indicate that for short period frequencies below ω_{sp} 1 rad/sec and for statically unstable airplanes, a constant value of $M_{\delta_{ES}} \doteq .061 \left(\frac{\text{rad/sec}^2}{\text{in.}}\right)$ should be used.

The curves of Figure 14 are based on data obtained using a stick length of 20 inches and a spring rate $F_{ES}/\delta_{ES} = 8.2$ lb/in. These curves should be of value in establishing longitudinal control authority for low speed flight conditions for airplanes with center control sticks and similar spring rates.

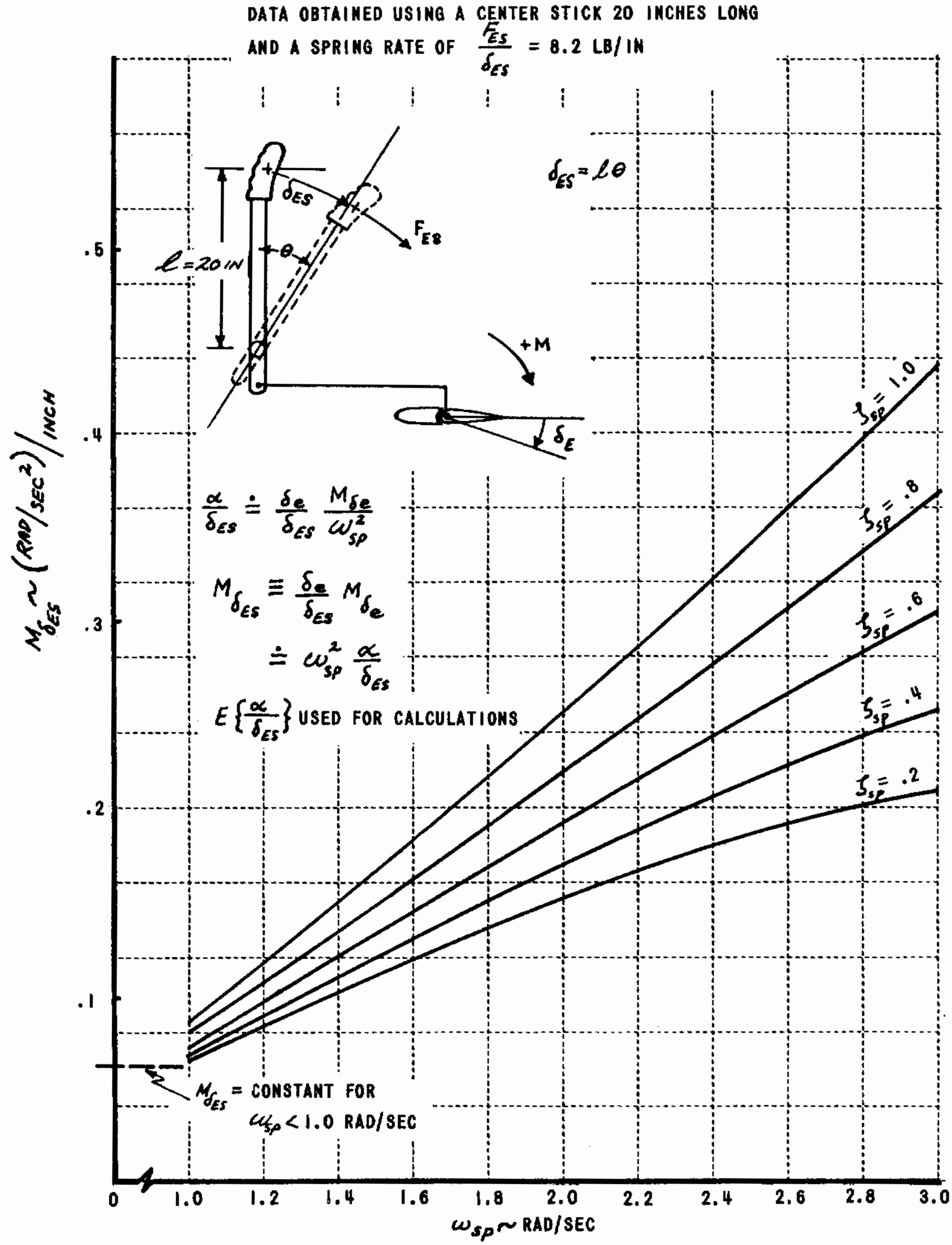

Figure 14 Longitudinal Control Authority Selected by Pilot for Landing Approach Task

3.2.3 Pilot Comment Data

As was indicated in Sections 1.2 and 2.2.4, when the pilot had completed each evaluation he wire-recorded his observations, described the control difficulties he had experienced, and answered the specific questions listed in Section 2.2.4. These questions were designed to determine how the pilot used the information and controls available to him in accomplishing the assigned task. The comment data generated were valuable in understanding the reasons for the pilot ratings and for identifying the airplane characteristics most significant to handling qualities.

Study of these comment data has given sufficient insight into the piloting task to permit diagramming in some detail his function as an information collector, data processor, decision maker, and control actuator.

The block diagram of Figure 15 is based on the pilot's answers to the questions listed in Section 2.2.4 together with his general comments and his description of specific landing approaches. This diagram attempts to account for all of the information sources and cues available to the pilot. To what extent he uses each cue or information item in a given case will depend on the task requirements, the display characteristics and the characteristics of the control system, engine and airframe. It is evident that in all cases the pilot closes an attitude stabilization inner loop in which he acts as a servomechanism element, probably much in the way he has been described in analytical studies such as Reference 11. This loop is dominated by the control system characteristics, the open-loop airplane short period dynamics and the sensory input of pitch attitude. The signals flowing in this control loop are of relatively high frequency content (see Section 3.2.4); thus frequent sampling of attitude information is required and elevator control actuation is nearly continuous. The amount of concentration, compensation and control actuation required of the pilot in closing this stabilization loop has a dominant effect on the pilot's rating of longitudinal handling qualities.

The attitude command to the stabilization inner loop is the output of what has been termed the pilot's elevator logic block. This block has as inputs the task definition and requirements, flight path information, attitude information and an awareness of motion cues, elevator stick force and motion, and the output of the pilot's throttle logic block.

The pilot's throttle logic block has as inputs the task requirements and also precognitive or learned maneuvers, flight path information, engine rpm, throttle position, elevator stick force and the output of the elevator logic block. Precognitive or learned maneuvers include transition from level flight to the glide slope and throttle coordination with increased angle of attack during turns.

It should be noted that the pilot will make control inputs as a function of angle of attack even if he is not provided with a display instrument. Although this may be done in part as a precognitive or learned response, the angle-of-

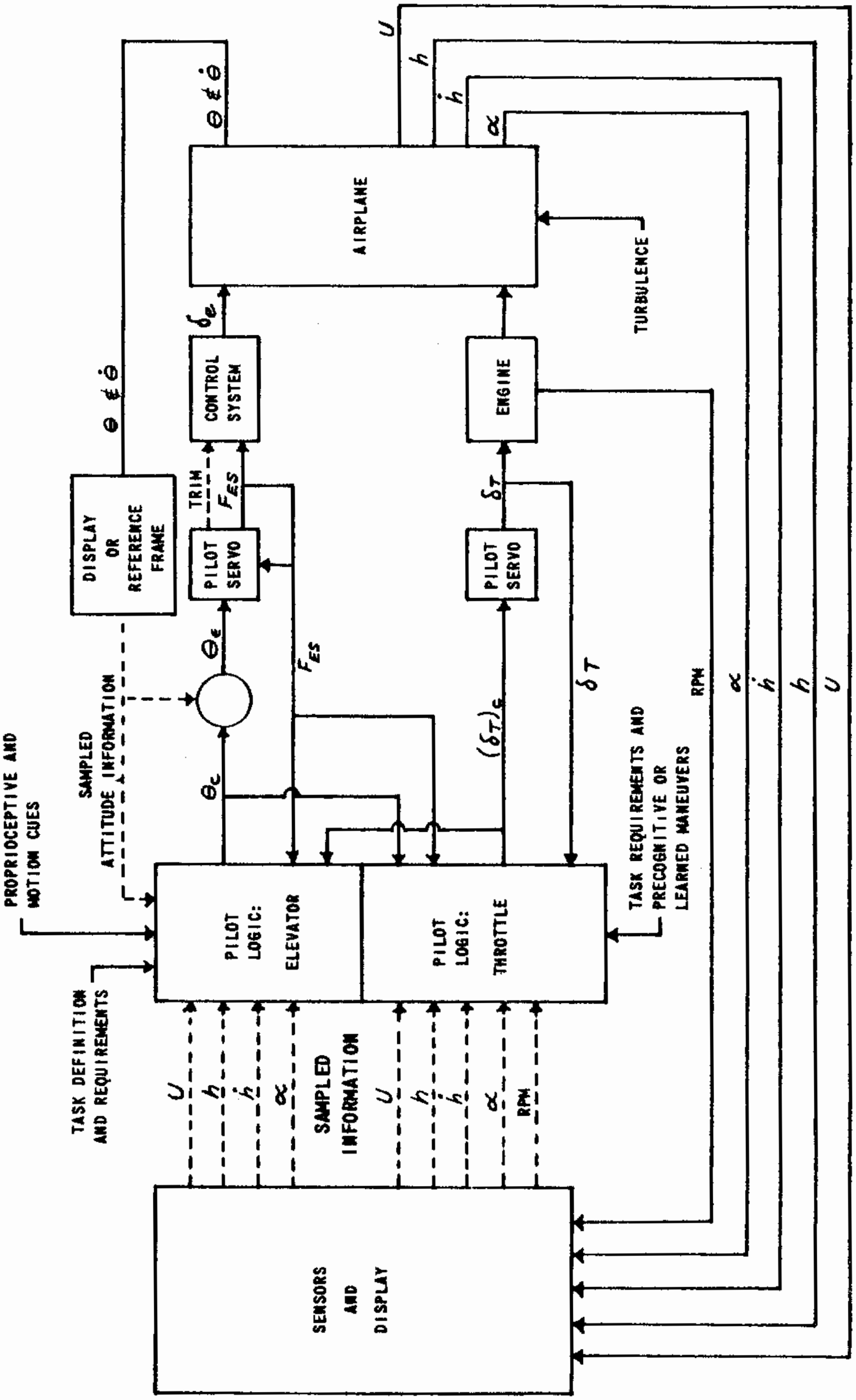

Figure 15 Longitudinal Control Model for Landing Approach

attack changes required in maneuvers can also be sensed through the steady stick forces, provided the airplane was trimmed and has sufficient short period stiffness.

Elevator stick feel is, in general, an important input to the pilot since it can be interpreted as a measure of angle of attack, normal acceleration, pitch rate and/or airspeed error, depending on the flight situation and the control action being attempted by the pilot.

Since the information sampled and the action taken by the pilot is dependent on the task and the particular situation, these functions of the pilot have been represented by logic blocks in the model of Figure 15. The control actions taken by the pilot to correct various combinations of speed and altitude errors during the mirror portion of the landing approach are described in Figure 16. From these descriptions, it is seen that the throttle and pitch attitude are used in combination to control the flight path and velocity of the airplane. The pitch attitude commands are of course accomplished through the elevator as indicated in the model of Figure 15.

Thus, the representation of the pilot as a simple gain autopilot (that actuates the throttle proportional to altitude errors and the elevator proportional to attitude errors) that was studied in References 11 and 12 has not been verified by these flight tests. The simulation studies of Reference 7 and the flight tests of Reference 40 report similar conclusions, i.e., that the pilot uses elevator and throttle in combination to control the speed and altitude of the airplane during the landing approach.

The pilot's answers to the questions in the comment check list have been condensed and are contained in the appendix. The answers to the questions have been grouped according to drag case and then further separated into four groups as follows:

A. $\omega_{sp} > 1.6$ rad/sec, $\zeta_{sp} > 0.4$

B. $\omega_{sp} < 1.6$ rad/sec, $\zeta_{sp} > 0.4$

C. $\omega_{sp} > 1.6$ rad/sec, $\zeta_{sp} < 0.4$

D. $\omega_{sp} < 1.6$ rad/sec, $\zeta_{sp} < 0.4$

Thus the effects of short period dynamics on longitudinal handling qualities can be determined by comparing the pilot's answers to the questions for groups A, B, C and D. The effects of drag characteristics can be determined by comparing the answers to the questions in a given short period group for each of the four drag cases.

In addition to pilot answers to the specific questions, the appendix also includes a summary of the major problems that the pilot encountered with each configuration, together with general comments concerning control techniques.

ALTITUDE, h / AIRSPEED, U	HIGH	ON	LOW
FAST	1. THROTTLE BACK 2a. REDUCE θ 3a. RESUME θ WHEN γ OK 4a. RESUME T WHEN U OK 1. THROTTLE BACK 2b. HOLD θ UNTIL U OK 3b. REDUCE θ HOLDING U CONSTANT. 4b. RESUME T AND θ WHEN U OK.	1. THROTTLE BACK 2. GRADUALLY INCREASE θ (AND α) AS U DECREASES TO STAY ON γ_{DES}. 3. RESUME T WHEN U OK	1. INCREASE θ, CREATING REDUCTION IN U AND CORRECTION IN LOW γ_{DES}. 2a. IF U OK BEFORE γ_{DES}, ADD T, CONTROL θ TO HOLD U, UNTIL γ_{DES} OK. 2b. IF γ OK BEFORE U, REDUCE T, CONTROL θ TO MAINTAIN γ_{DES} UNTIL U OK. 3. THEN RE-ESTABLISH θ AND T TO MAINTAIN γ_{DES} AND U.
ON	1. REDUCE T, REDUCE θ TO MAINTAIN CONSTANT U 2. RESUME T AND θ WHEN γ_{DES} OK	SMILE	1. INCREASE T, INCREASE θ TO MAINTAIN CONSTANT U. 2. RESUME T AND θ WHEN γ_{DES} OK.
SLOW	1. REDUCE θ (ADD T ONLY IF REQUIRED) 2. RESUME θ AND T WHEN γ_{DES} OK 3a. IF U OK BEFORE γ, REDUCE T, CONTROL θ TO HOLD U UNTIL γ_{DES} OK. RESUME T AND θ. 3b. IF γ OK BEFORE U, ADD T, CONTROL θ TO MAINTAIN γ_{DES} UNTIL U OK, THEN RESUME T AND θ.	1. INCREASE T, REDUCE θ (AND α) GRADUALLY TO MAINTAIN γ_{DES} UNTIL U OK 2. THEN RESUME T AND θ	1. LARGE INCREASE IN T. 2. HOLD θ (OR EVEN REDUCE α IF NECESSARY) UNTIL U OK, THEN INCREASE TO MAINTAIN U CONSTANT. 3. WHEN γ_{DES} OK, RESUME θ AND T.

Figure 16 Control Action Taken by Pilot to Correct Airspeed and Altitude-Errors during "Mirror" Portion of the Approach

3.2.4 Approach Time Histories

Oscillograph records were taken of the visual portion of the first landing approach made with each configuration evaluated. The records were approximately one minute long and included a short portion of level flight after the pilot had gone to visual reference, followed by the pushover and power reduction, tracking on the glide slope, and the wave-off. The early portions of these records usually included lateral maneuvers to correct for runway line-up errors and crosswinds. The oscillograph paper speed was such that these records were approximately 10 feet in length; thus it was awkward to study or manipulate these data without some compression in size. It was impractical to scale and replot each of the available records, so a selection was made which was intended to illustrate the effects of short period natural frequency, damping ratio and drag variation. The configurations selected are listed in Table 1. For each of these records the traces listed below were read every 0.20 seconds, scaled, and replotted in Figure 17. The data were punched on IBM cards for processing on a digital computer. The traces read were:

1. Elevator stick deflection
2. Angle of attack
3. Pitch attitude (pitch rate for the flaps-down case because the pitch attitude trace was off scale)
4. Bank angle
5. Aileron stick deflection
6. Rudder pedal deflection
7. Altitude
8. Incremental dynamic pressure which was converted to changes in airspeed from U = 160 kt IAS
9. Engine rotational speed in % rpm

The following observations are made from these time histories:

1. Good short period dynamics (2-54-1, 2-44-1, $2\frac{1}{2}$-73-2, 4-74-1):

   The maneuvers are more distinct, i.e., there is a definite pushover (except for the back side configuration 4-74-1), the tracking corrections on the glide slope are small, and the wave-off is definite. These task-required maneuvers become less distinct when the short period frequency and/or damping ratio become too low.

   The stick displacement is correlated with angle of attack in these maneuvers. Thus, the pilot can use the stick-force feel as an indication of angle of attack. This is a definite advantage in establishing pitch attitude after transition to the glide slope; also, the change in stick force with trim angle of attack is an indication of airspeed errors on the glide slope. For low short period frequency configurations, the control action associated with these maneuvers is hardly distinguishable from the control motions required for attitude stabilization.

2. Low damping ratio ($5\frac{1}{2}$-41-1, 6-80-1, 8-76-1):

   When there is some turbulence present there is considerable elevator control activity, at frequencies of the order of the airplane short period and higher, which is presumably associated with the attitude stabilization task.

3. Short period frequency near ω_{sp} = 1.1 rad/sec (4-52-1, 5-44-2, 7-80-2, 8-82-1):

   The elevator stick, angle of attack and pitch attitude exhibit large amplitude, low frequency oscillations.

4. Very low short period frequency or stiffness (7-37-1, 8-45-1):

   The elevator stick, angle of attack, and pitch attitude traces exhibit large amplitude, low frequency variations; but in addition the elevator stick trace has considerable high-frequency content that is similar to the control motions associated with configurations with low damping ratio except the high frequency component is not as continuous or periodic in character.

5. The power adjustments tend to be discrete, with the time between changes ranging from about 2 seconds to 18 seconds. The acceleration time of the engine is indicated by the response at wave-off.

6. The high-frequency content of the incremental dynamic pressure trace tends to correlate with the safety pilot's estimate of the turbulence level.

7. Rudder pedal input to coordinate turns is noticeable.

8. With the exception of the statically unstable configuration (8-45-1), the airspeed was maintained within ±4 knots of 160 kt IAS.

9. Time on the glide slope was approximately 36 seconds.

10. The altitude errors from the commanded glide slope cannot be determined, because only the pressure altitude as a function of time is known. No information was recorded which could be used to relate this information to the glide path established by the optical system.

11. Some of the records tend to exhibit a low-frequency oscillation in airspeed which might be interpreted as indicating the closed-loop phugoid mode of motion. Even with a recorded time history, however, it would be difficult to estimate a representative period for the suggested oscillation. Thus, it is difficult to see how the pilot could be expected to sense variations in this period as a function of his attitude loop gain, as is suggested in References 11 and 12 in justification of the reversal parameter $\frac{\partial (\omega_p'')^2}{\partial K_\theta}\zeta_p = 0$

The mathematical techniques of References 42 and 43 have been applied to the recorded time histories to obtain power spectral density and cross spectral density plots of several of the variables. One of the most interesting is the power spectral density, $\Phi_{\delta_{ES}}$, of elevator stick motion δ_{ES} . In Reference 42 it is shown that the mean square of a variable is related to the autocorrelation function and the spectral density by

$$\overline{\delta_{ES}^2} = R(0) = \int_{-\infty}^{\infty} \Phi_{\delta_{ES}}(f)\, df \tag{39}$$

It is often convenient to have frequency expressed on a log scale. The following operation can be used to weight the power spectra so that they can be plotted versus frequency on a log scale while keeping the area under the curve equal to the mean square.

$$\overline{\delta_{ES}^2} = \int_{-\infty}^{\infty} f\, \Phi_{\delta_{ES}} \frac{df}{f} \tag{40}$$

Note that

$$d(\ln f) = \frac{df}{f} \tag{41}$$

$$\overline{\delta_{ES}^2} = \int_{-\infty}^{\infty} f\, \Phi_{\delta_{ES}}\, d(\ln f) \tag{42}$$

Thus by plotting $f\Phi_{\delta_{ES}}$ vs f , with f measured on a log scale, the resulting curve indicates the distribution of elevator stick motion with frequency and the area under the curve between two values of (f) is equal to the mean square stick motion in that frequency band. Note that the steady state or zero frequency value of δ_{ES} is eliminated from the plot.

Consider first the five short period configurations for the bottom gear down drag case, configurations 2-44-1, $5\frac{1}{2}$-41-1, 5-44-2, 7-37-1 and $8\frac{1}{2}$-45-1 which are plotted in Figure 18. Configuration 2-44-1 had a good

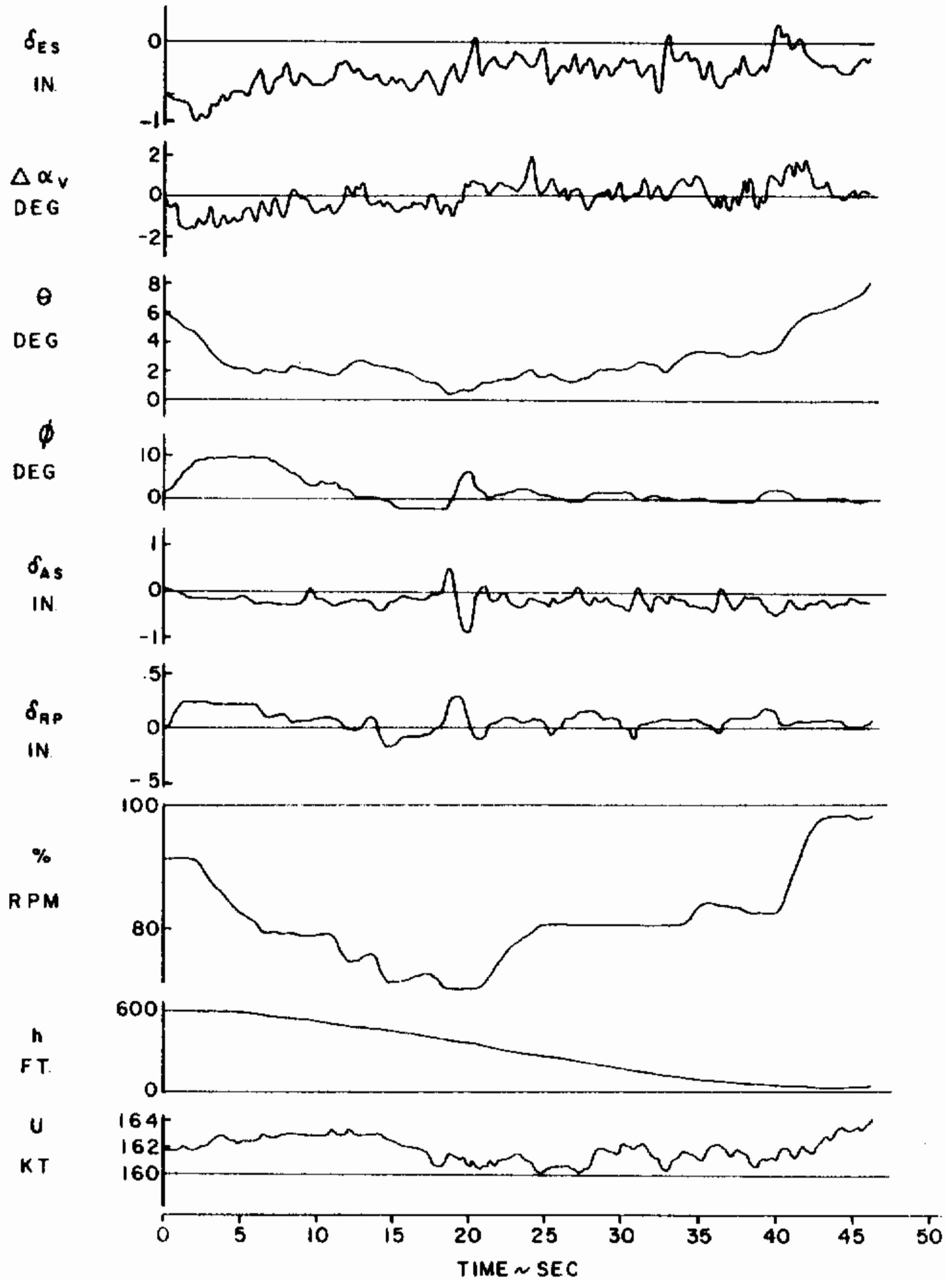

Figure 17 Time Histories of Landing Approaches

a. Configuration 2-54-1 Front Side, ω_{sp} = 2.75 Rad/Sec, ζ_{sp} = .76

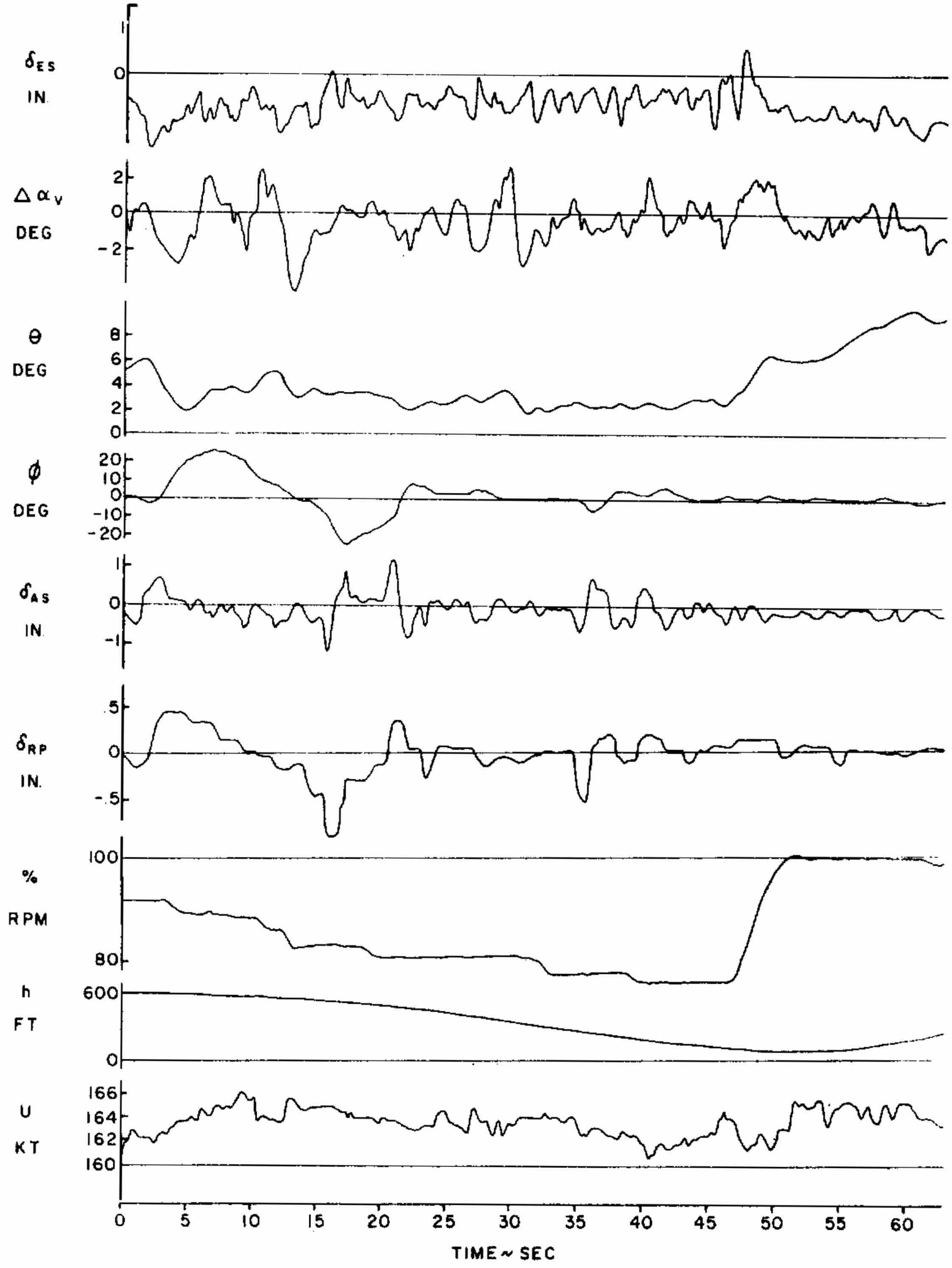

Figure 17 Time Histories of Landing Approaches

b. Configuration 4-52-1 Front Side, ω_{sp} = 1.13 Rad/Sec, ζ_{sp} = .38

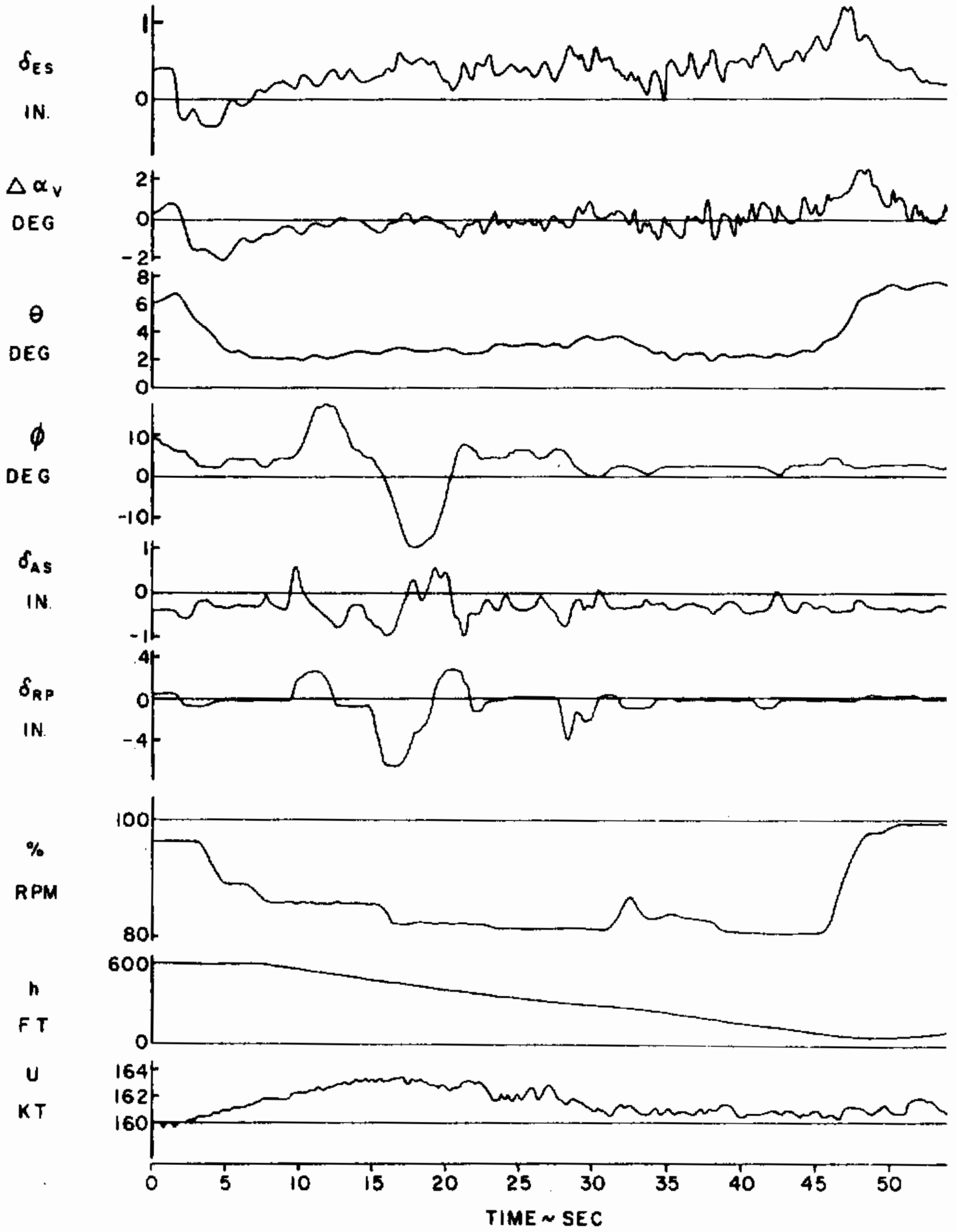

Figure 17 Time Histories of Landing Approaches

c. Configuration 2-44-1 Bottom Gear, ω_{sp} = 2.45 Rad/Sec, ζ_{sp} = .52

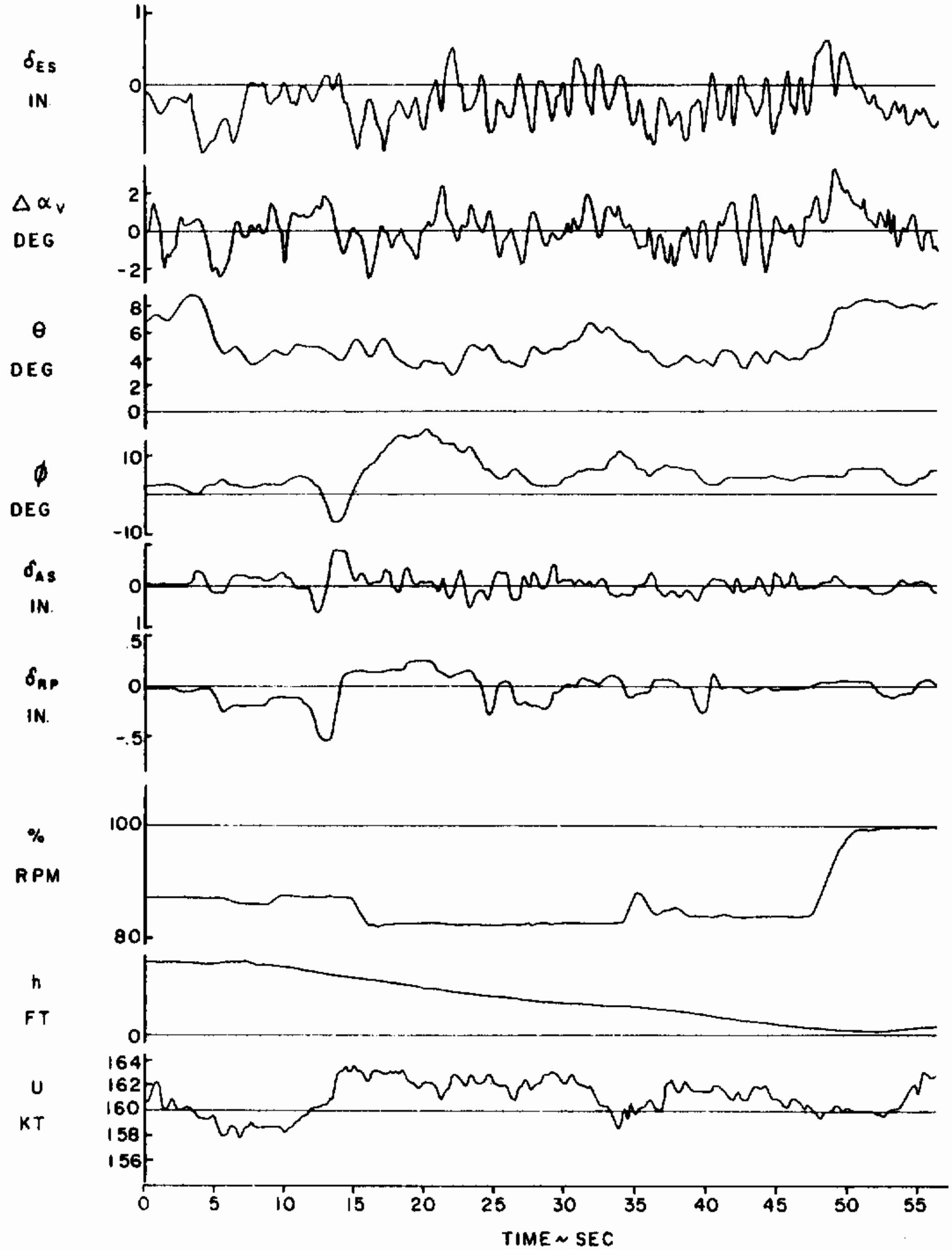

Figure 17 Time Histories of Landing Approaches

d. Configuration 5½-41-1 Bottom Gear, ω_{sp} = 2.30 Rad/Sec, ζ_{sp} = .20

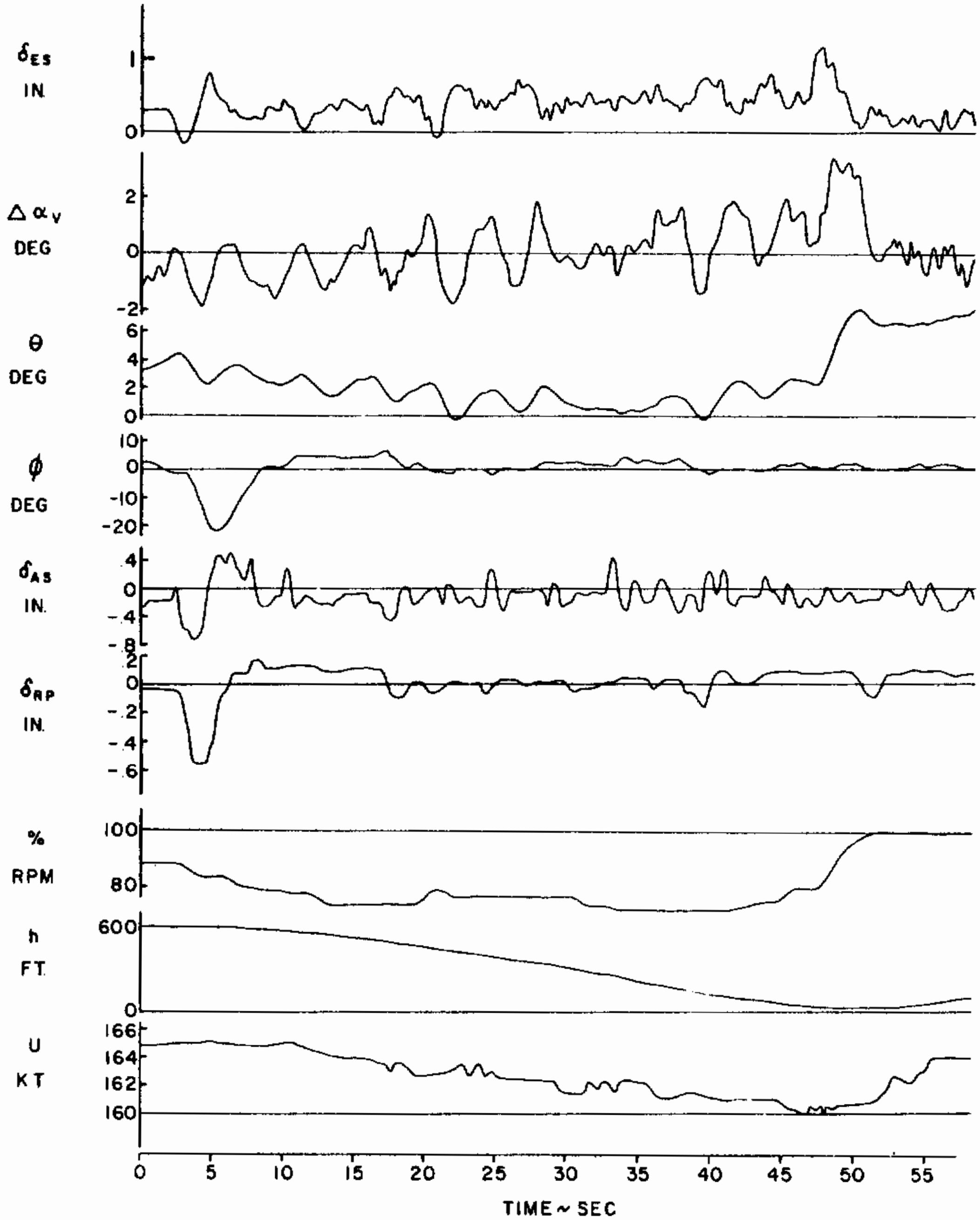

Figure 17 Time Histories of Landing Approaches

e. Configuration 5-44-2 Bottom Gear, ω_{sp} = 1.10 Rad/Sec, ζ_{sp} = .46

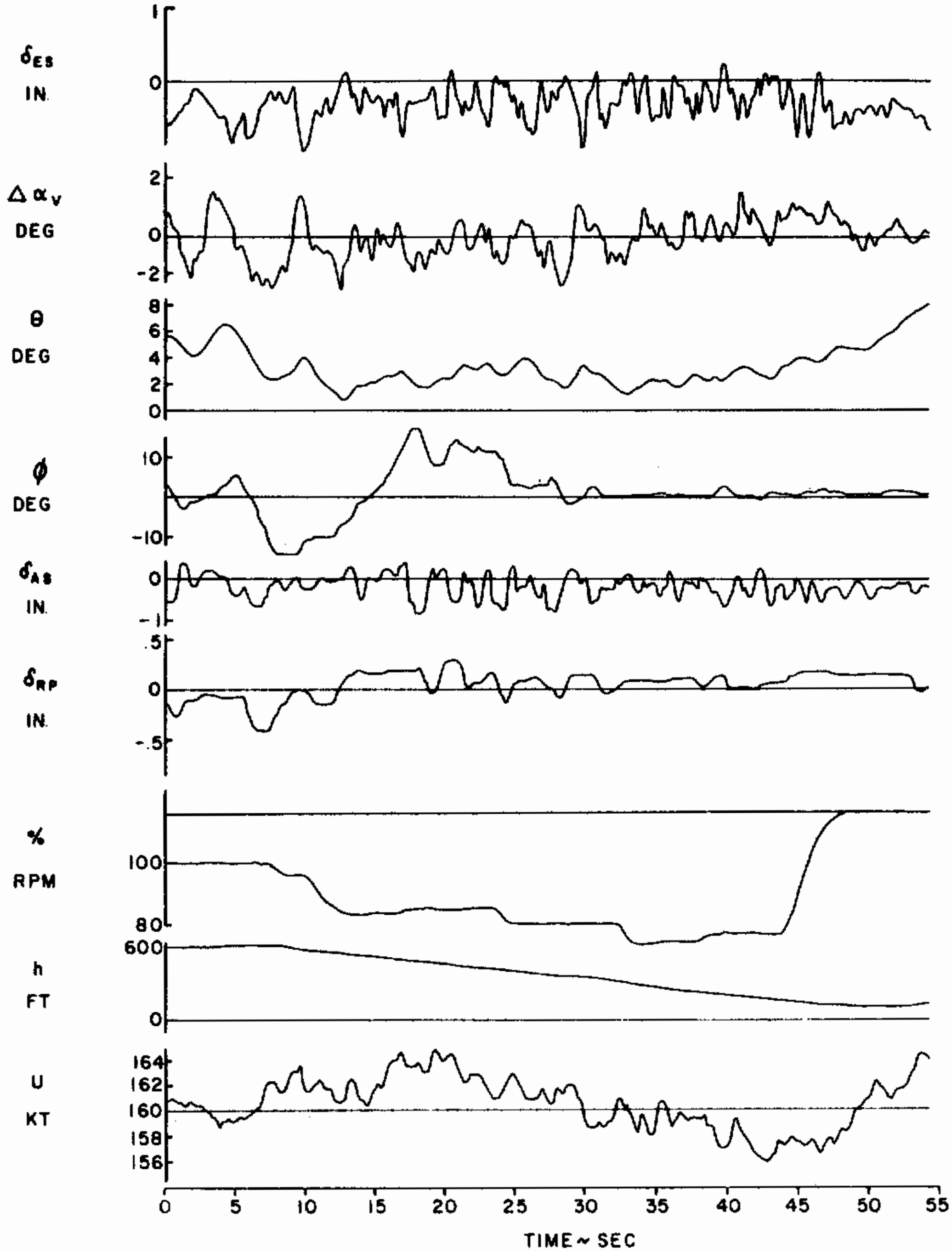

Figure 17 Time Histories of Landing Approaches

f. Configuration 7-37-1 Bottom Gear, ω_{sp} = .84 Rad/Sec, ζ_{sp} = .67

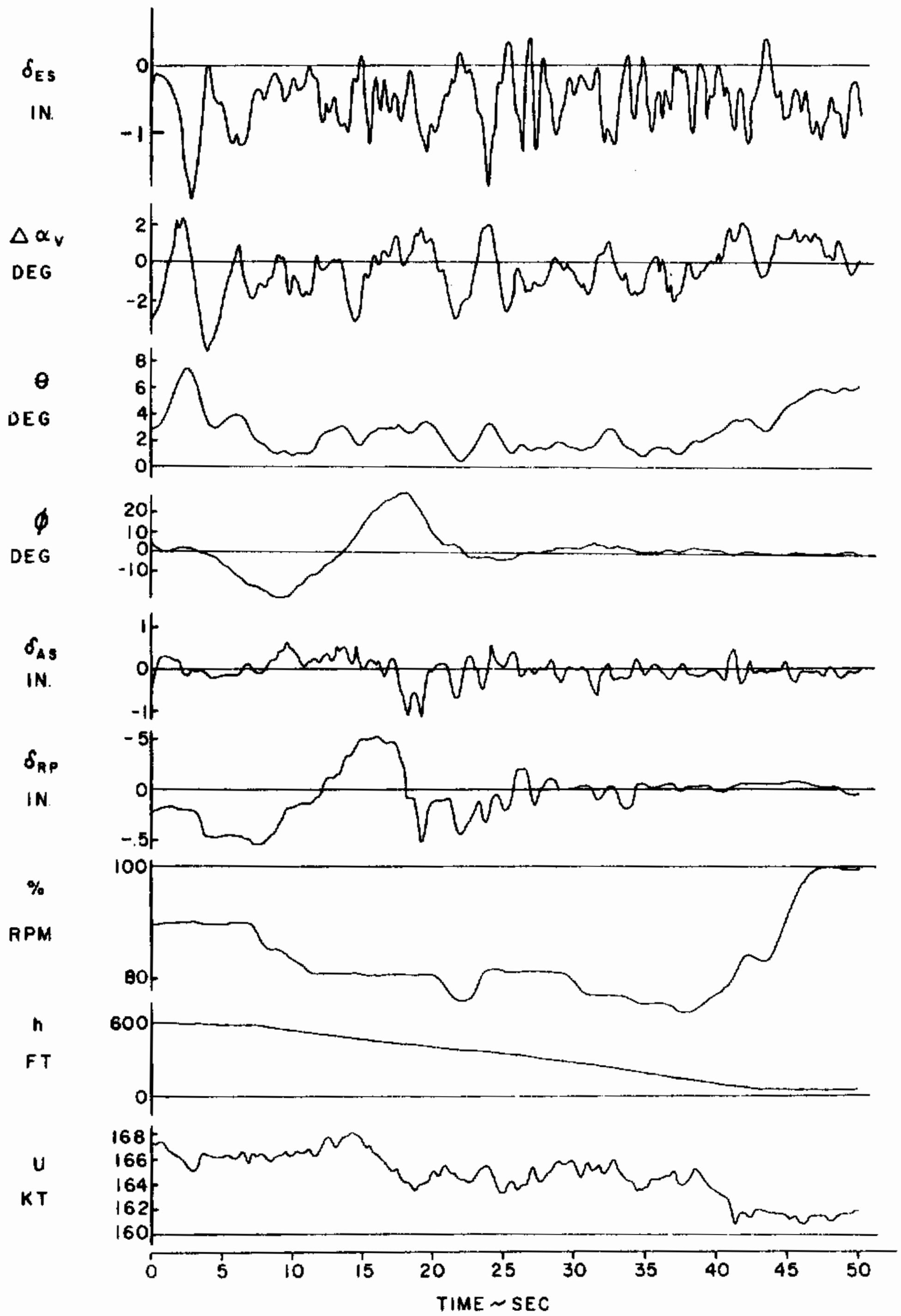

Figure 17 Time Histories of Landing Approaches

g. Configuration 8-45-1 Bottom Gear, $\lambda_1 = -1.6 \frac{1}{sec}$ $\lambda_2 = .2 \frac{1}{sec}$

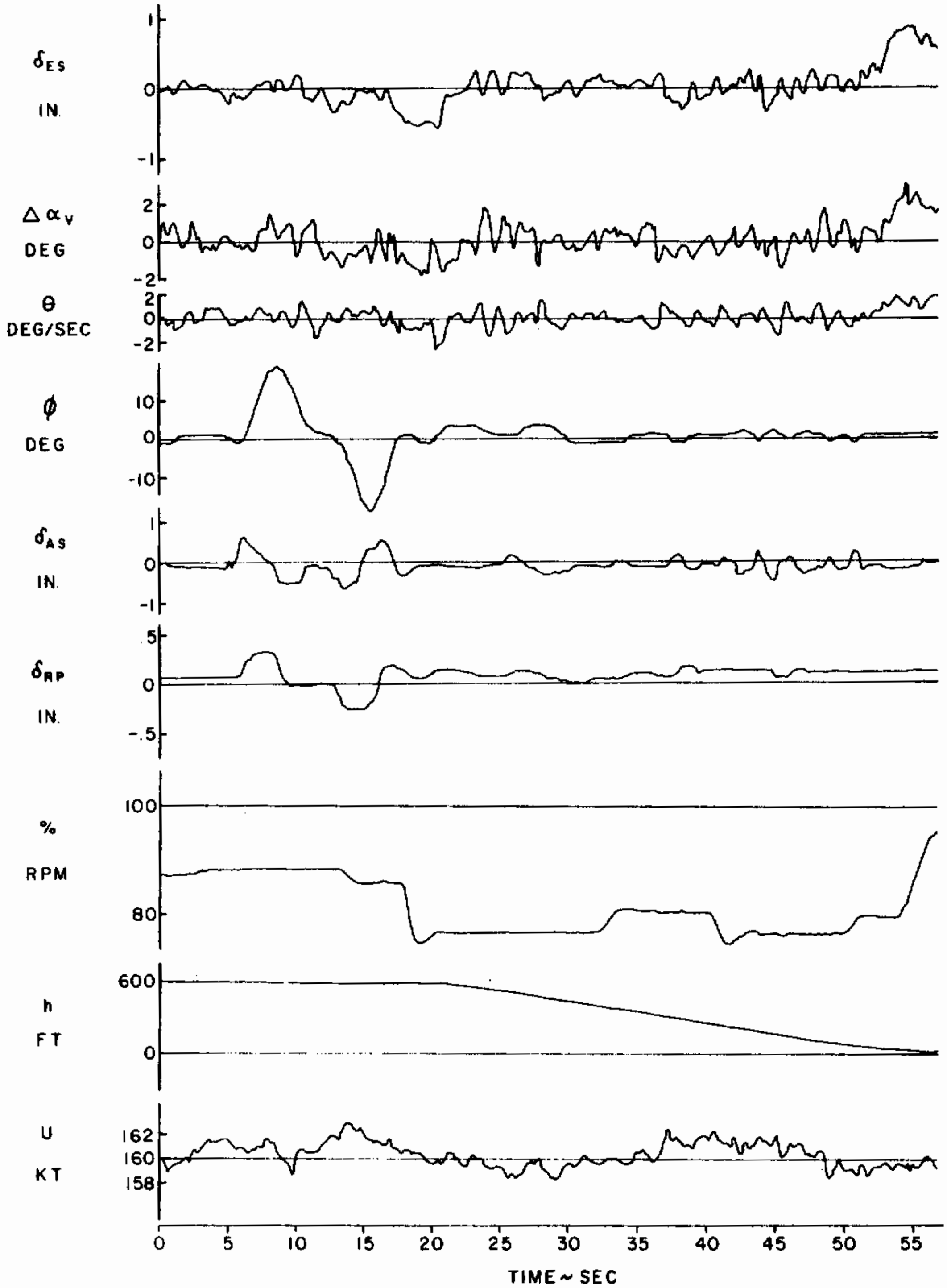

Figure 17 Time Histories of Landing Approaches

h. Configuration 2½-73-2 Bottom Flaps, ω_{sp} = 2.76 Rad/Sec, ζ_{sp} = .58

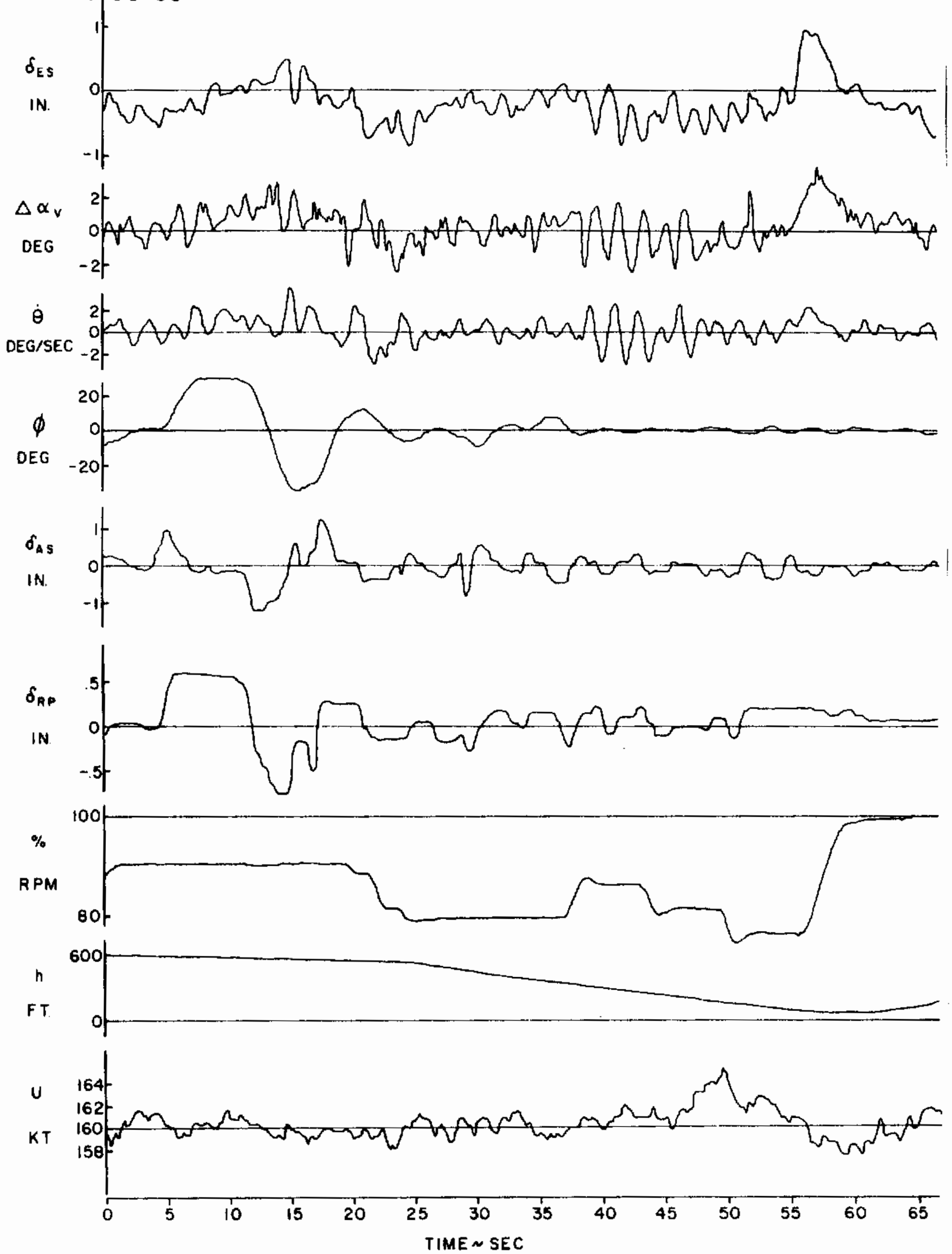

Figure 17 Time Histories of Landing Approaches

i. Configuration 6-80-1 Bottom Flaps, ω_{sp} = 2.51 Rad/Sec, ζ_{sp} = .22

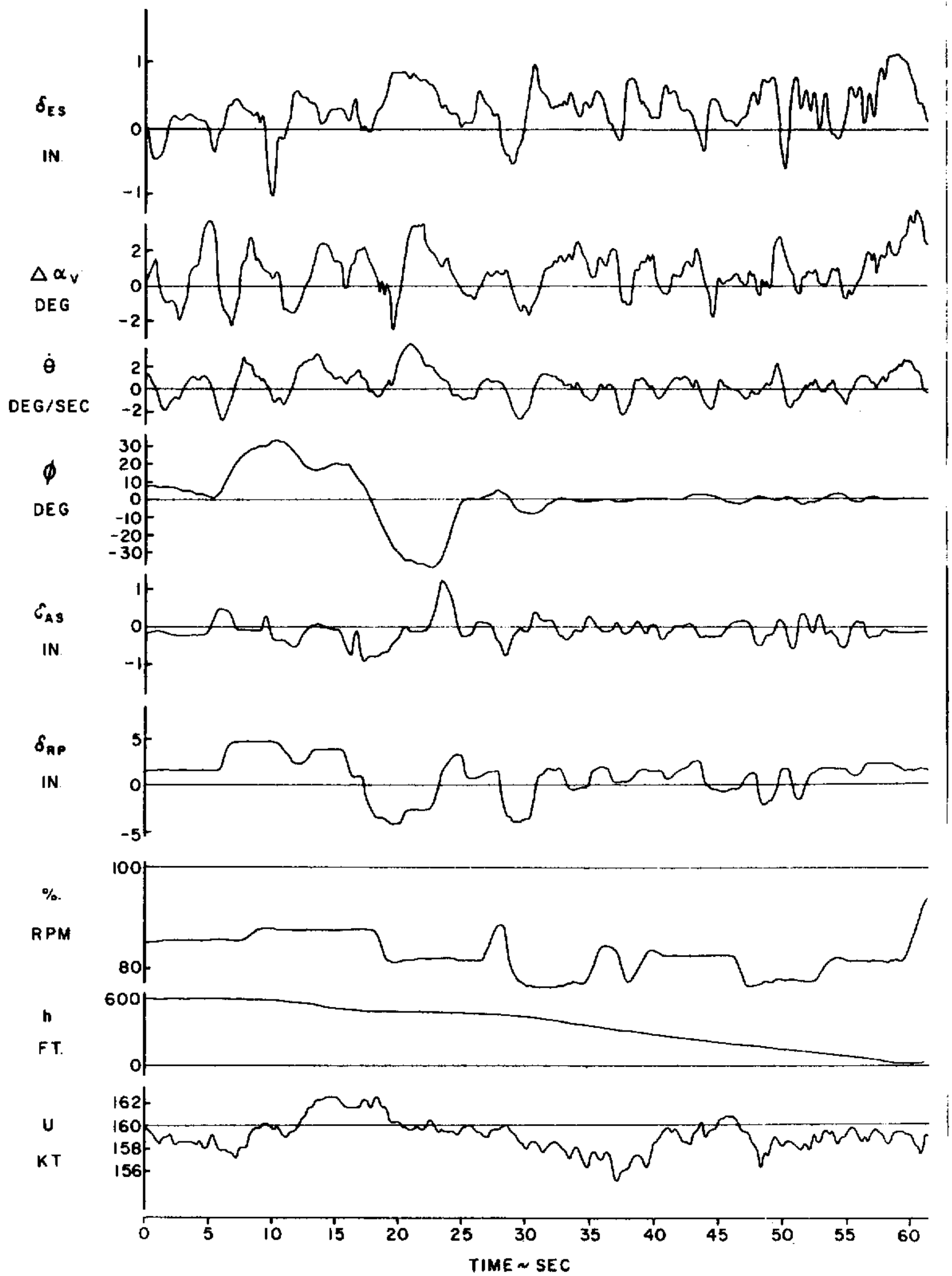

Figure 17 Time Histories of Landing Approaches

j. Configuration 7-80-2 Bottom Flaps, ω_{sp} = 1.10 Rad/Sec, ζ_{sp} = .28

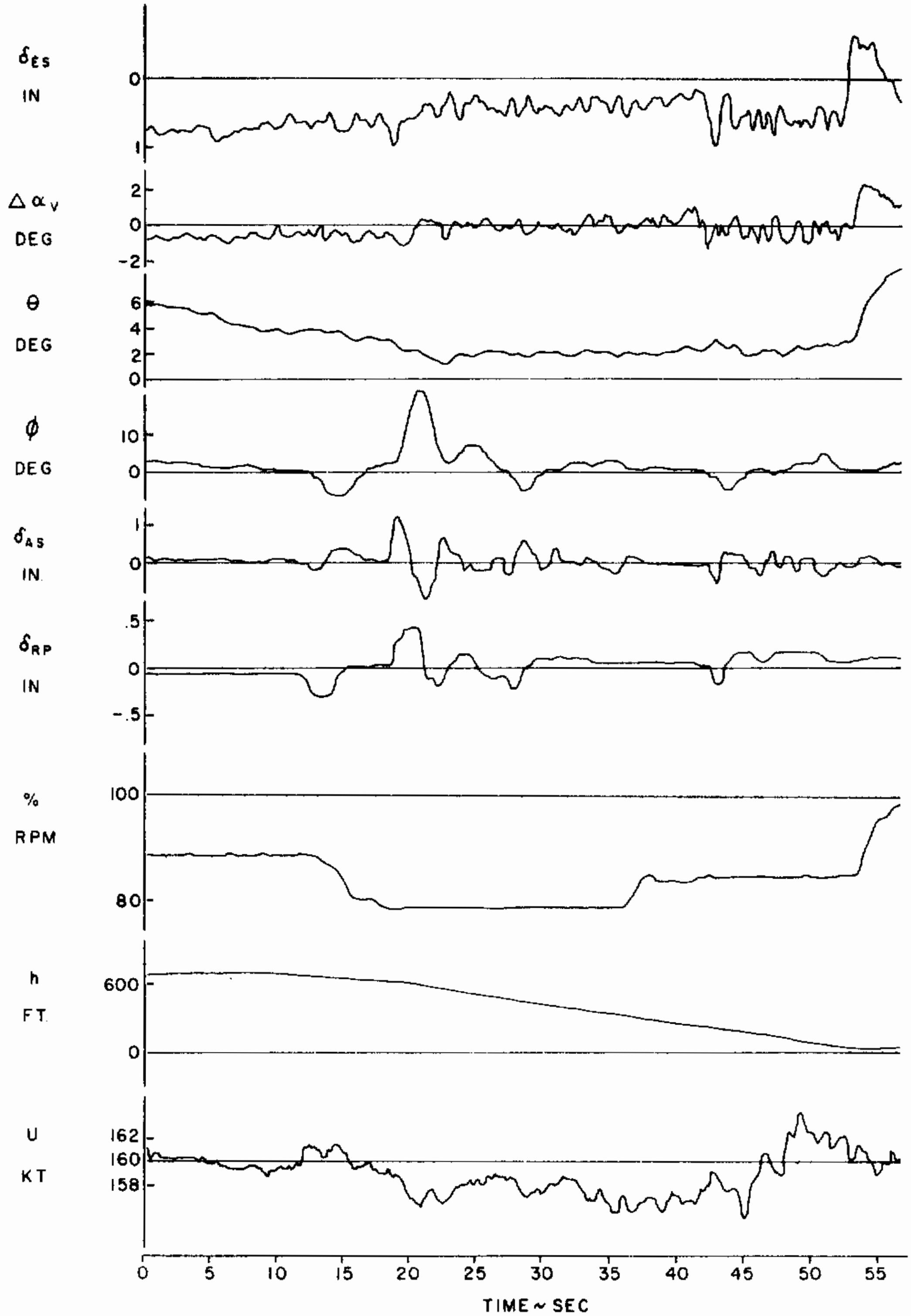

Figure 17 Time Histories of Landing Approaches

k. Configuration 4-74-1 Back Side, ω_{sp} = 2.83 Rad/Sec, ζ_{sp} = .45

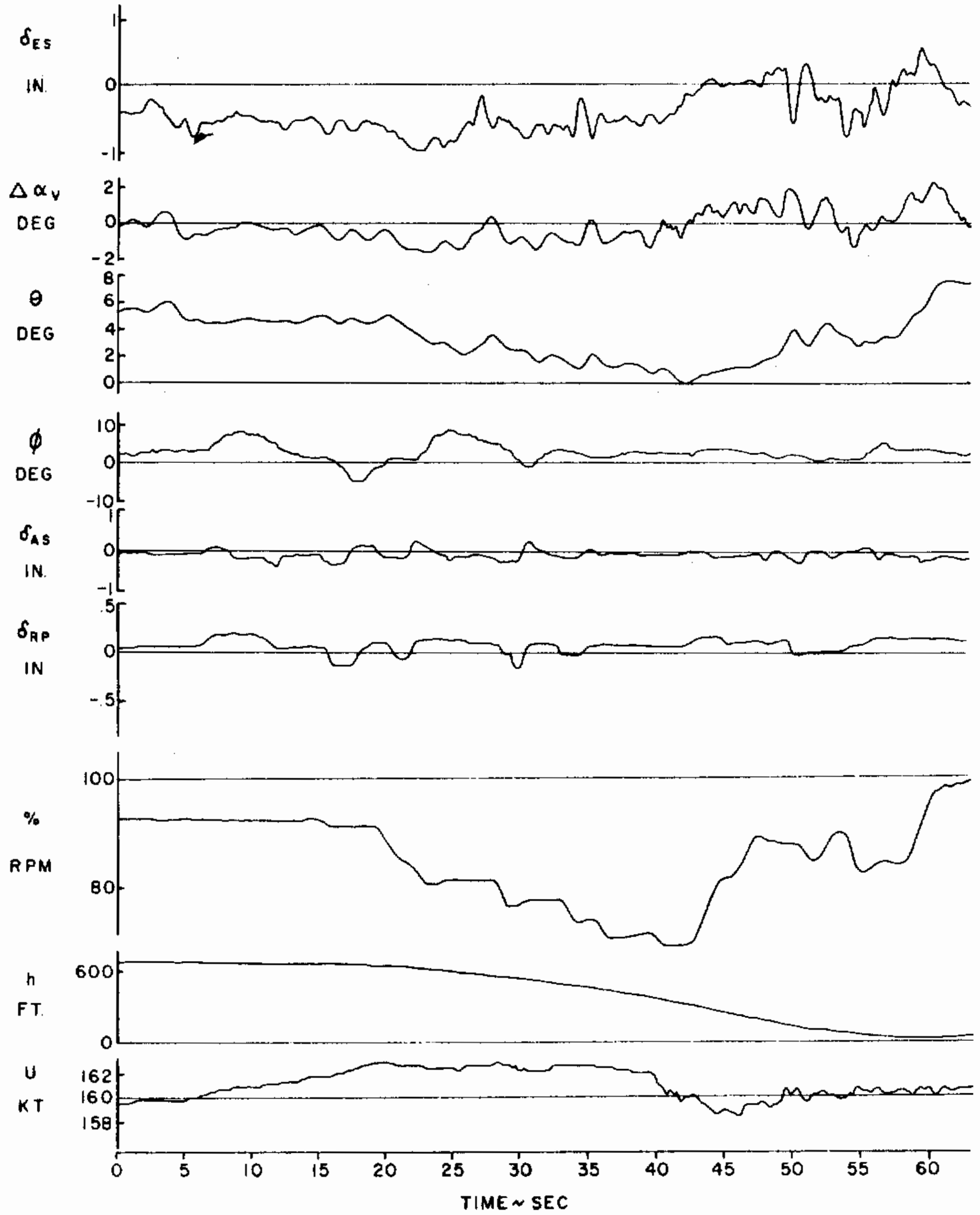

Figure 17 Time Histories of Landing Approaches

1. Configuration 8-76-1 Back Side, ω_{sp} = 2.20 Rad/Sec, ζ_{sp} = .16

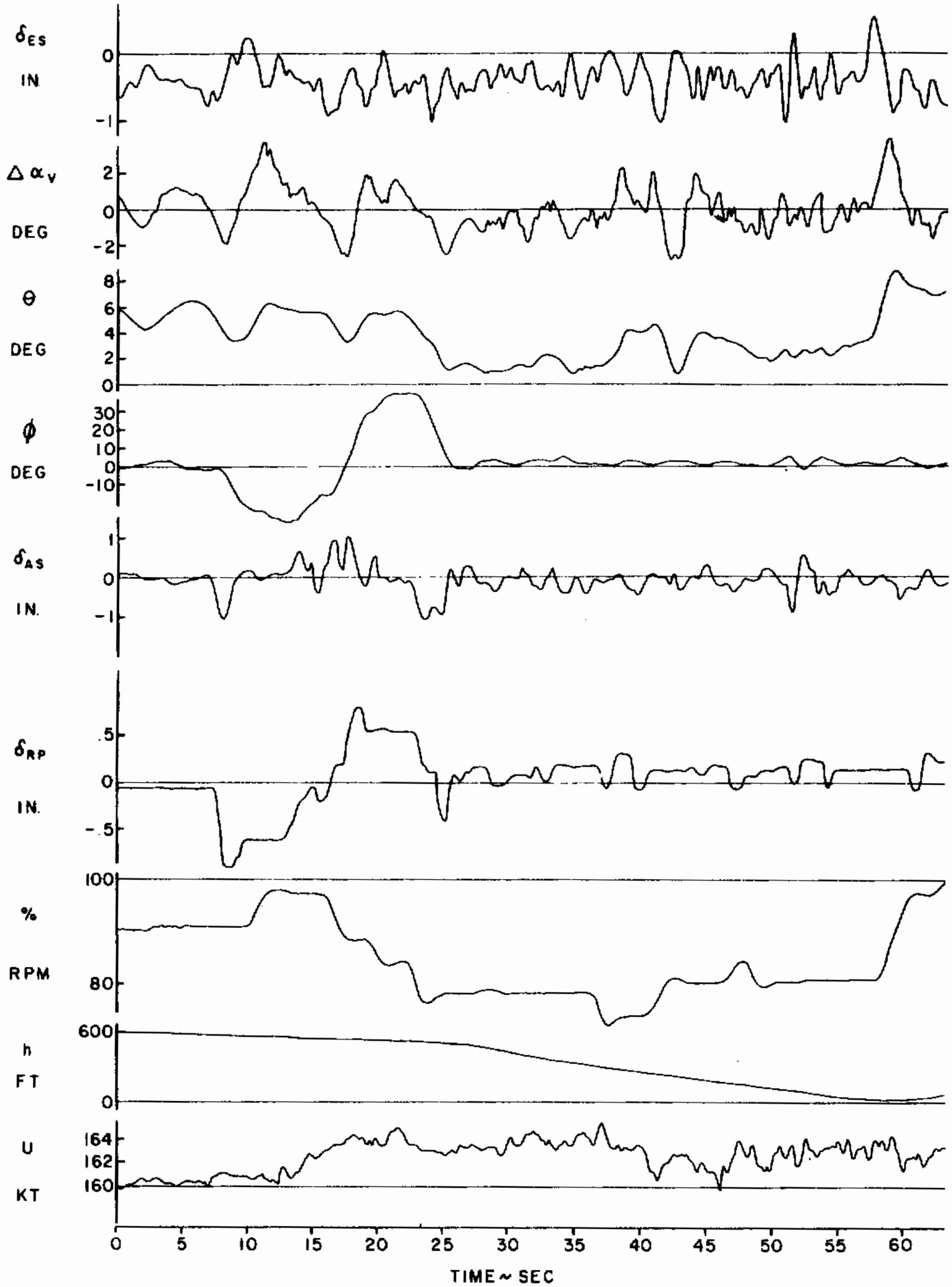

Figure 17 Time Histories of Landing Approaches

m. Configuration 8-82-1 Back Side, ω_{sp} = 1.14 Rad/Sec, ζ_{sp} = .53

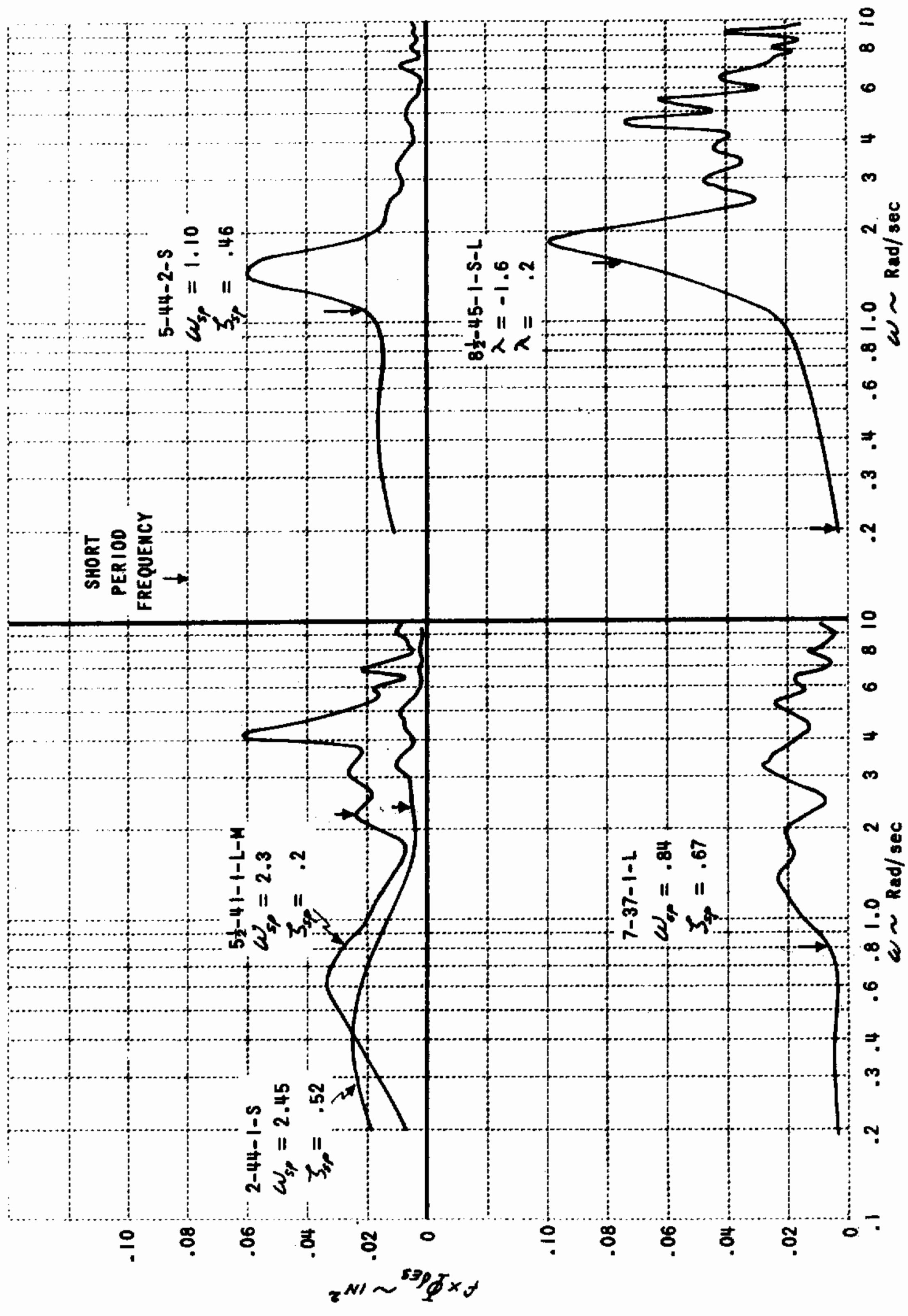

Figure 18 Power Spectra of Elevator Stick Motion - Bottom-Gear Drag Configurations

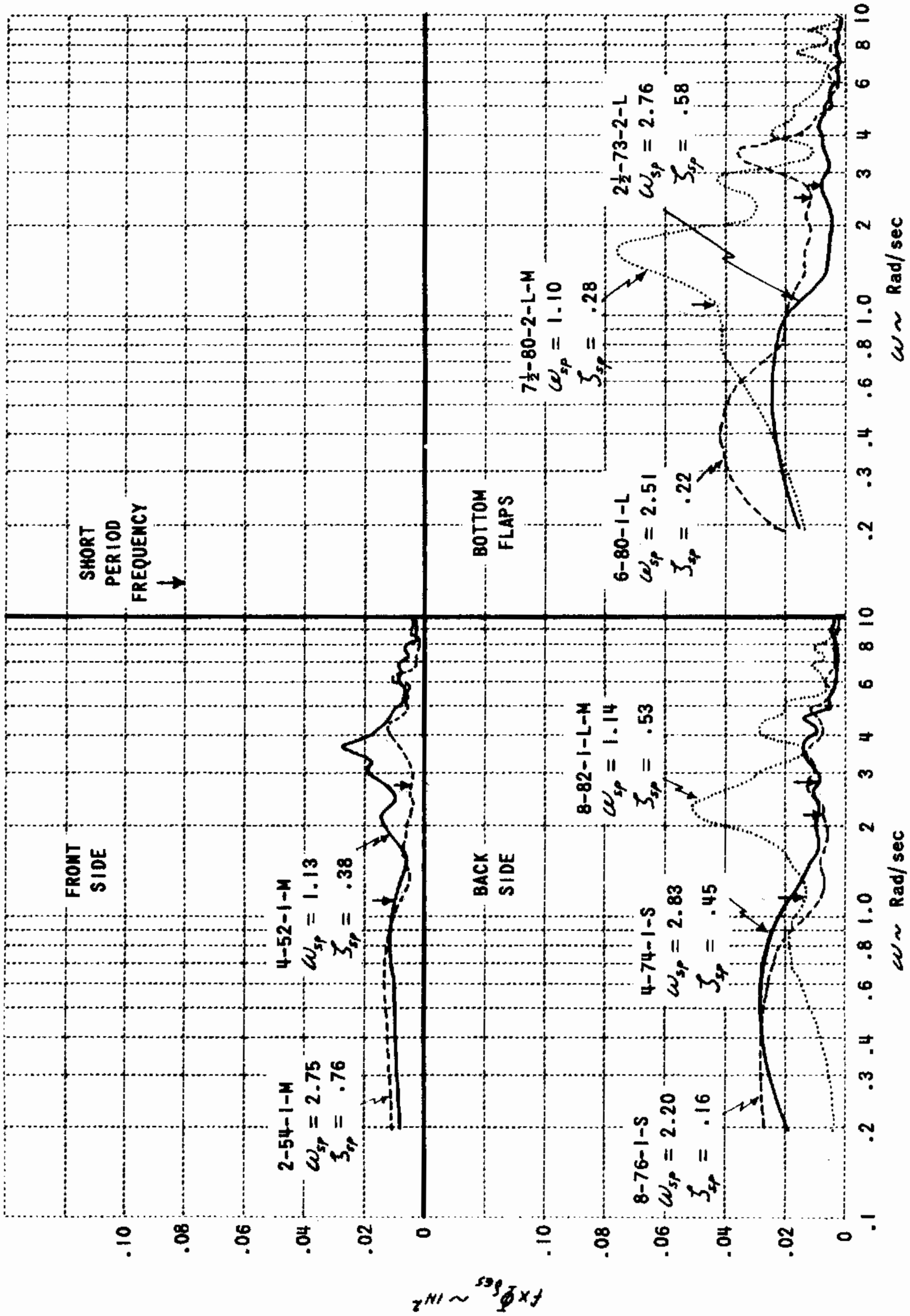

Figure 19 Power Spectra of Elevator Stick Motion - Front-Side, Bottom-Flaps and Back Side Drag Configurations

short period frequency, ω_{sp} = 2.45 rad/sec, good short period damping ratio, ζ_{sp} = .52, and the approach was made in smooth air. The power spectral density of elevator stick motion has large amplitude at low frequency (presumably due to the maneuvers associated with the pushover, pullup and flight path adjustments) and two small peaks at higher frequency (presumably due to control inputs for attitude stabilization).

Consider next configuration $5\frac{1}{2}$-41-1 which had a similar short period frequency ω_{sp} = 2.30 rad/sec, but a low damping ratio, ζ_{sp} = .2, and light to moderate turbulence. The low-frequency stick motion is similar to that in configuration 2-44-1; however, the high-frequency control motion required to stabilize the oscillatory pitch response to turbulence is greatly increased.

Consider next configuration 5-44-2 which had an objectionably low short period frequency, ω_{sp} = 1.10 rad/sec, a damping ratio of ζ_{sp} = .46, and smooth air. The pilot commented that he must overdrive this configuration with the elevator to get it started and then back off to hold the pitch response that he wants. The power spectral density of elevator stick motions for this configuration is distinctly different from those for either 2-44-1 or $5\frac{1}{2}$-41-1. The amplitude at frequencies lower than ω_{sp} = 1 rad/sec is reduced and a very large peak has appeared at ω_{sp} = 1.5 rad/sec. This frequency is above the open-loop airplane short period frequency and is presumably associated with the pilot's efforts to overdrive the pitch response. There is relatively little amplitude at frequencies above ω_{sp} = 3 rad/sec, possibly because the air was smooth.

Consider next configuration 7-37-1, which had a very low short period frequency, ω_{sp} = .84 rad/sec, a good damping ratio, ζ_{sp} = .67, and light turbulence. The pilot complains of inadequate pitch response, he must overdrive this configuration in pitch to obtain satisfactory response. He also says it does not have good stick force feel in steady state maneuvers and requires constant closed-loop attention. These comments are reflected in the power spectral density of the elevator control inputs. At low frequency the control inputs are of small amplitude, which indicates the low stick motion required for low frequency or steady state maneuvers. At higher frequency, however, the control motions are of larger amplitude and cover a broad spectrum of frequencies. This is evident from the time histories also by the high-frequency nonsinusoidal control motions. These control motions are associated with the pilot's efforts to speed up the pitch response of the airplane by overdriving it with the elevator; they are also associated with his efforts to stabilize the airplane in the presence of turbulence.

Consider next configuration $8\frac{1}{2}$-45-1, which was slightly unstable (λ_1 = -1.6, λ_2 = +.2) and was evaluated in light turbulence. The power spectral ensity of elevator stick motion for this configuration is similar in profile to that of configuration 7-37-1, except the amplitudes are considerably magnified. The pilot comments for configuration $8\frac{1}{2}$-45-1 are also similar to those for configuration 7-37-1, except the complaints are considerably magnified.

It is evident from the power spectral density plots of Figure 18 that the elevator stick control motions used by the pilot to accomplish the landing approach task are strongly affected by the open-loop airplane short period dynamics and the level of turbulence in which the approach is made.

The elevator stick power spectral density plots for the other three drag cases are contained in Figure 19. These plots have characteristics similar to those of Figure 18. That is; when the short period frequency and damping ratio are in the desirable area the control motions at frequencies above ω = 1 rad/sec are a minimum. When the damping ratio is decreased below $\zeta_{sp} \doteq .4$ or the short period frequency is decreased below $\omega_{sp} \doteq 1.6$ rad/sec, the elevator stick control motions at frequencies above ω = 1 rad/sec become large in amplitude. The one exception to this is configuration 8-76-1 of Figure 19. This configuration had a damping ratio of $\zeta_{sp} = .16$ but the control motions are very small for $\omega >$ 1 rad/sec. This approach was made in very smooth air, so there were no external disturbances to excite the pitch oscillation. The pilot commented that he purposely smoothed his control inputs to avoid exciting the short period oscillation.

The time history and the detail pilot comments for the first approach of configuration 8-76-1 indicate that the pilot rating of 8 was based to a large extent on the poor performance that was achieved on the glide slope.

Quoting from the pilot comments and referring to the time history of Figure 171:

"I was high and fast [possibly because he was slow in pushing the nose down, t = 20-26 sec, because of the low short period damping ratio] and had to make an awful large correction in power to start it down. When I did, I couldn't stop it. I had a very difficult time stopping the rate of sink [At t = 43 sec the slope of the altitude trace is steep and airspeed is decreasing rapidly. The control action initiated at this point was to add power and gradually increase pitch attitude as required to hold airspeed constant]. I went quite low and would have had to wave off. So, correcting a high and fast is a difficult thing and you end up, as I have been afraid I would do all along, taking too much power off and then you pick up a rate of sink that you are unaware of and you sink too fast and you can't stop it."

Reference 41 lists the above described chain of events as one of the two most common accidents in Navy carrier landing operations.

3.2.5 Turbulence Effects

The most obvious effect of turbulence on the landing approach is to make the task more difficult in the sense that unwanted forces and moments are introduced which disturb the flight path and tend to add "noise" to the pilot's information sources.

The manner in which the airplane responds to turbulence is strongly influenced by the short period dynamics. If the short period frequency is high and the damping ratio is high, the airplane will pitch into vertical gusts with little overshoot or residual oscillation, but with high initial angular acceleration. With a low damping ratio, however, the airplane will have continuous pitch disturbances which will require considerable stabilization effort from the pilot. The pilot rating of moderate to low damping ratio ($\xi < .4$) configurations may be considerably influenced by the degree of turbulence. For example, the rating difference between configurations 2-42-1 (which was evaluated in smooth air) and 5-60-2 (which was evaluated in light to moderate turbulence) is thought to be an example of this effect.

When the short period frequency is low, the airplane is slow to pitch into vertical gusts and may be heaved off the glide slope. When this happens the pilot must use larger elevator inputs in an attempt to get the pitch response necessary to keep the airplane on the glide slope. On several flights for which the short period frequency was low (8-45-1, 7-65-2, 7-70-2, 7-80-2, and 5-83-2) the pilot commented that the approach was going well until a gust caused the airplane to heave off the glide slope and that he did not have enough pitch response to correct the heave rapidly and would not have completed the approach successfully. This was especially true of configuration 8-45-1 which had essentially zero static stability.

In Reference 37 it was demonstrated that high short period natural frequency and damping ratio are desirable to minimize the normal acceleration response to turbulence and thus increase pilot comfort. In the landing approach, however, the normal acceleration response is not severe enough to cause discomfort. The primary effects of turbulence in the landing approach are the flight path deviations induced when the short period frequency is low, the increased work required for attitude stabilization when the short period damping ratio is low, and the initial pitch acceleration which results from sharp gusts when the short period frequency is high.

SECTION 4

CONCLUSIONS

4.1 The airplane short period dynamics and longitudinal control gain are of major importance to longitudinal handling qualities in the landing approach task.

a. When the damping ratio is decreased below $\zeta_{sp} \doteq .4$ the airplane will bobble in response to both control inputs and turbulence. The pilot must smooth his control inputs and provide damping to eliminate oscillations resulting from external disturbances.

b. When the short-period frequency is less than $\omega_{sp} \doteq 1.6$ rad/sec the airplane does not readily maintain angle of attack or attitude by itself; the pilot must constantly provide stabilization and moreover he must overdrive the airplane to obtain satisfactory attitude response.

c. The optimum longitudinal control gain is a function of the short period frequency and damping ratio. For short period frequencies, either higher or lower than $\omega_{sp} \doteq 1.8$ rad/sec, the optimum control gain is a compromise between the pilot's desire for comfortable and adequate steady forces in turns and his requirement that he be able to make rapid and precise pitch attitude changes.

d. Too high a control gain can cause closed-loop stability problems or pilot-induced oscillations, while too low a control gain results in excessive control motion and the feeling that the control authority is inadequate and/or the airplane response is sluggish.

e. The power spectral density of elevator stick motion is a function of short period dynamics and turbulence intensity. When the short period frequency and damping ratio are in the desirable area, the control motions at frequencies above $\omega \doteq 1$ rad/sec are a minimum. When the damping ratio is decreased below $\zeta_{sp} \doteq .4$ or the short period frequency is decreased below $\omega \doteq 1.6$ rad/sec, the elevator stick control motions at frequencies above $\omega \doteq 1$ rad/sec become large in amplitude. These control motions are associated with the pilot's efforts to stabilize the airplane in the presence of turbulence and his efforts to speed up the pitch response of the airplane by overdriving it with the elevator.

4.2 Control of airspeed and flight path angle becomes progressively more difficult as approaches are made at increasing negative slope of the trimmed thrust-speed curve; or more exactly, as the value of $s = -1/T_{h_1}$, moves farther into the right-half plane.

a. Control of airspeed and altitude on the glide slope is achieved through coordinated use of pitch attitude and engine thrust.

b. Short period dynamic characteristics which reduce the precision of pitch attitude control will consequently degrade the precision of flight path and velocity control.

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APPENDIX

SUMMARY OF PILOT COMMENTS

The pilot comments summarized in this Appendix are arranged according to the four drag cases. These are listed below in tabular form.

Each drag case is also separated into four short-period groups as follows:

A	$\omega_n > 1.6$ rad/sec	$\zeta > .4$
B	$\omega_n < 1.6$ rad/sec	$\zeta > .4$
C	$\omega_n > 1.6$ rad/sec	$\zeta < .4$
D	$\omega_n < 1.6$ rad/sec	$\zeta < .4$

DRAG CASE: FRONT SIDE

Major Problem

A.

Rating	Flt.	Conf.	Problem	Pilot Comments
2	54	1		Little bit of trouble with airspeed; good attitude control.
$2\frac{1}{2}$	67	2	No major problem	Drag characteristics o.k.; good attitude characteristics except it's slightly responsive to turbulence; slightly responsive in rough air; good airspeed control; pilot would like a little more pitch damping.
$2\frac{1}{2}$	70	1	Sluggish short period	Slow short period; good positive short period but on the slow side; not a very high drag rise with angle of attack; airspeed wasn't unstable.
2	38	2	No major problem	Much confidence in airspeed, good positive control, good banking characteristics, however, wouldn't call it an optimum aircraft.
3	52	2	Airspeed in rough air	Excellent pitch control; when attitude was disturbed by a gust, got large changes in airspeed; good and comfortable maneuvering ability.

B.

Rating	Flt.	Conf.	Problem	Pilot Comments
$4\frac{1}{2}$	38	1	Attitude Control	Didn't feel it had good positive control.
5	83	2	Attitude response and airspeed	Didn't have enough stiffness in pitch. Did not have good positive control. Low drag rise with angle of attack. Airspeed seemed disassociated from what I was doing with airplane. Did not have good control of either flight path or airspeed. Airplane "heaves" in turbulence and poor attitude control makes corrections difficult. Large throttle variations to try to correct airspeed. Airspeed did not get away like it tends to in high drag configuration but could not keep it constant.
$3\frac{1}{2}$	81	1	Slow and lacks positive control in pitch	Low drag rise with angle of attack; attitude control was slow and sluggish but marginally satisfactory; have to overdrive it.

DRAG CASE: FRONT SIDE

Major Problem

B. (Cont.)

Rating	Flt.	Conf.	Problem	Pilot Comments
7	70	2	Airspeed control, attitude control	Difficult to determine what is causing airspeed problems (poor short period, drag rise); poor short period characteristics; well damped, stable, very, very slow, can't fly precisely; overdrive configuration (pilot not in good mood either).
C.				
3	50	1	Airspeed had a tendency to get fast	Airspeed control good; attitude control was good, but had a slight bobbling tendency; good drag characteristics.
$3\frac{1}{2}$	67	1	Light short period damping; airspeed control	Low drag rise with angle of attack; airspeed tends to drift; turbulence tended to disturb aircraft; attitude control was on the borderline between satisfactory and unsatisfactory.
$4\frac{1}{2}$	50	2	Short period characteristics	Attitude control was less stiff on this one; good drag characteristics; long response time; short period not fast enough.
D.				
4	52	1	Airspeed control	Pitch characteristics were sluggish; airspeed tended to get high.

DRAG CASE: FRONT SIDE

General Comments on Control Technique

A.

Rating	Flt.	Conf.	Pilot Comments
2	54	1	Glide slope - On the glide slope to control attitude and through attitude airspeed and I suppose altitude a little. The throttle adjustments were for altitude on the glide slope and they worked real good. This was a configuration that I could use the throttle to control the altitude real well and I didn't seem to have to consciously think of changing pitch attitude. Changing attitude was not very effective in changing airspeed.
$2\frac{1}{2}$	67	2	Glide slope - I found that as long as I happened to hit it pretty close with fixed throttle and maintain my attitude to keep me on the glide slope. If I had small attitude error that looked like it was producing a deviation from the glide slope. I'd just correct the attitude because airspeed was on. If I actually departed from the glide slope far enough to visually see a high or low, then I'd make a throttle correction, assuming airspeed was on. So elevator is used to control attitude tightly to keep me on the glide slope and throttle is used to compensate for any altitude errors on the glide slope.
$2\frac{1}{2}$	70	1	Mostly a one control airplane. Did not have to close too tight a throttle loop. Used small amount of throttle for angle of attack changes. Corrected altitude errors on glide slope with throttle very well. Did not get any airspeed errors on glide slope. Elevator used to control attitude and secondarily altitude and airspeed.
2	38	2	Visual approach - I controlled altitude with throttle, of course, if I was high I took off throttle and if I was low I added throttle. But I also correspondingly adjusted pitch attitude. I controlled airspeed with pitch attitude. I also controlled airspeed with throttle. I couldn't help but do that. If I was low on airspeed and on glide slope, the only way to get the airspeed back is to add throttle. I did cross check the airspeed and in the manner I have all the way up to $\frac{1}{2}$ mile. From then on I was on the mirror. When I'm on the mirror after I've quit watching airspeed, I control glide slope with a combination of throttle and pitch attitude, I think. But I sure don't hold constant attitude and just add or take off power. I'm most certain I don't do that.

DRAG CASE: FRONT SIDE

General Comments on Control Technique

A. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
3	52	2	Throttle Control on Glide Slope - I'm not sure whether it's altitude or rate of descent, but when I have an altitude error, I change rate of descent with the throttle. (I think this is what I do.)
			Glide Slope - I flew the visual approach using throttle due to altitude errors and elevator for attitude and and secondarily throttle and attitude for airspeed.
			First one I had a feeling airspeed was fairly well under control and I had a feeling that I could listen to the power and set the throttle right, fly attitude and not need to know airspeed.
			For high drag configuration, I can pull the nose up, if the airspeed is high, and boy it really bleeds. With this one, I pull the nose up and the speed comes back only slowly. It's like the airspeed is controlled through a weak spring.

B.

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	38	1	This is a moderately poor configuration in pitch, but its airspeed keeping qualities seem to be fair; by that I mean that most of my airspeed troubles seem from two sources: 1) My attitude gets away from what I want it to be, and 2) I'm used to high drag rise configuration and I tend to use throttle too much.
			Must use real tight attitude control. If you loosen up or look away, then the attitude will change, the airspeed will change, and consequently there will be altitude change, but primary effect is airspeed change.
			Throttle - On the visual glide slope throttle inputs are used to control altitude and pitch attitude is used to control airspeed (unless the airspeed errors are large and then throttle is used for airspeed).
5	83	2	Airspeed seems to be "connected" to pilot's commands by a "loose spring."
			Airplane heaves in turbulence and you don't have enough attitude control to correct the heave rapidly.
			Glide Slope - You end up with wild throttle variations in order to try to get the airspeed to do what you want it to do and in the course of doing this I couldn't help but get off the flight path. I made four approaches and none of them could I call a good pass. I certainly couldn't use throttle with altitude errors and elevator with attitude errors in the conventional sense because the major thing I was correcting was airspeed errors (turbulent air, poor visibility).

DRAG CASE: FRONT SIDE

General Comments on Control Technique

B. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
5	83	2(Cont.)	When I make changes in airspeed attitude or power setting or angle of attack, the airspeed change is very slow to take place.
$3\frac{1}{2}$	81	1	Glide Slope - When I took off the power, I definitely had to nose the airplane over with the elevator. It was fairly easy to find the right attitude to stay on the glide slope because the nose was very much in view near the touchdown point, a little below it, and so I could easily hold the altitude where I thought it was correct and observe what happened to the airspeed and flight path and make attitude changes if there were errors.
7	70	2	First Approach - I waited until I got an on-course and I started down by reducing the throttle and nosing over to what seemed to be the right attitude. I made a couple of corrections and the airspeed got a little high, but basically it wasn't too horrible until I got down to the last quarter mile and all of a sudden I started to heave off the glide slope. I don't know whether it was a windshear or what, but I pushed and not much happened and then I just rose off the glide slope and I'd have never made that approach.
			Attitude control was unacceptable. Now whether the attitude control is unacceptable by itself, I couldn't tell you. I can't separate the problems I had with airspeed as to whether they were due to attitude control difficulties or due to the trimming characteristics.
			Trouble maintaining pitch attitude and airspeed. When scan pattern left the pitch attitude for even a few seconds, it seemed to drift off from what I was trying to hold and the airspeed would drift off.

C.

Rating	Flt.	Conf.	Pilot Comments
3	50	1	Throttle and Elevator - Throttle adjustments for rate of climb and for altitude on glide slope. Elevator for attitude. If the airspeed got off and the flight path was on, then the throttle was used to adjust airspeed. Not much throttle required in turns.
			Elevator controls attitude and through attitude airspeed and then secondarily altitude on the glide slope.
$3\frac{1}{2}$	67	1	Turns - Can use pretty steep banked turns and require only a small amount of throttle. Also you don't have to coordinate very precisely, the airspeed will only change slowly.

DRAG CASE: FRONT SIDE

General Comments on Control Technique

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	50	2	Glide Slope - Elevator is used to control attitude and through attitude, airspeed and then altitude on the glide slope. I tried to look at the mirror and to control attitude looking at the glide slope, and use the throttle for altitude, but I found that I had to look back in the cockpit and I found airspeed errors existed , so I would have to make throttle and attitude adjustments accordingly.
D.			
4	52	1	Turns - Very little throttle required in turns.
			Glide Slope - Throttle is used to control altitude and it seemed to work fairly well but quite a lag and I had a tendency to overcompensate. Throttle is also an important control for airspeed on this configuration.

DRAG CASE: FRONT SIDE

Question No. 1 Is the Airplane Difficult to Trim?

A.

Rating	Flt.	Conf.	Pilot Comments
2	54	1	Little bit, but basically quite good.
$2\frac{1}{2}$	67	2	Very easy.
$2\frac{1}{2}$	70	1	No. Fairly easy.
2	38	2	No. Easy.
3	52	2	No. Easy.

B.

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	38	1	Yes. Principally because attitude is not as easily kept with this configuration -- long response time in the short period.
5	83	2	No. Not in smooth air.
$3\frac{1}{2}$	81	1	No. Might be little easier if it were stiffer in pitch.
7	70	2	Yes. Because of long response time of short period.

C.

Rating	Flt.	Conf.	Pilot Comments
3	50	1	No. Easy
$3\frac{1}{2}$	67	1	No. Fairly easy, reasonable pitch stiffness.
4	50	2	No.

D.

Rating	Flt.	Conf.	Pilot Comments
4	52	1	Just a little bit because of long response time.

DRAG CASE: FRONT SIDE

Question No. 2 Is the Elevator Control Gain Satisfactory?

Rating	Flt.	Conf.	Pilot Comments
A.			
2	54	1	Yes. Good choice.
2½	67	2	Yes, steady forces are little heavy and transient response is little sensitive, so it's a good compromise.
2½	70	1	Yes, but I've picked pretty heavy forces.
2	38	2	Yes.
3	52	2	Yes.
B.			
4½	38	1	Yes, but pilot should have used BF = 57.
5	83	2	Yes.
3½	81	1	Yes. Have to overdrive it, so picked high value.
7	70	2	Yes. Maybe would like little more sensitive.
C.			
3	50	1	Yes.
3½	67	1	Yes, I compromised toward a low value to keep initial transient response from appearing too responsive, steady forces are then little heavy.
4½	50	2	Yes -- good compromise.
D.			
4	52	1	Yes.

DRAG CASE: FRONT SIDE

Question No. 3 Is Attitude Control Satisfactory?

Rating	Flt.	Conf.	Pilot Comments
A.			
2	54	1	Yes -- quite good.
2½	67	2	Yes. However pitch rate during transient is little more than I anticipate.
2½	70	1	Yes, little slow.
2	38	2	Good.
3	52	2	Yes -- very good.
B.			
4½	38	1	No -- slow response time.
5	83	2	Too sluggish; quite marginal close to ground.
3½	81	1	Marginally, so should be stiffer.
7	70	2	No. Unacceptable, too slow.
C.			
3	50	1	Yes, but only marginally so (tendency to bobble).
3½	67	1	Borderline -- damping little low.
4½	50	2	No -- unsatisfactory because of long response time. Had to overdrive the airplane.
D.			
4	52	1	Not quite as good as pilot would like it.

DRAG CASE: FRONT SIDE

Question No. 4 Is Maintaining Altitude a Problem?
(a) Straight & Level
(b) Turns

A.

Rating	Flt.	Conf.	Pilot Comments	
2	54	1	a) No	b) No
$2\frac{1}{2}$	67	2	No	No. Can make corrections with precision.
$2\frac{1}{2}$	70	1	No	No. Forces little heavy in turns.
2	38	2	No, Ok.	Ok.
3	52	2	Very good.	b) Very good.
B.				
$4\frac{1}{2}$	38	1	a) No	b) No, however attitude problem does affect airspeed which affects altitude.
5	83	2	a) and	b) Little bit because attitude control is not positive.
$3\frac{1}{2}$	81	1	a) Easy	
7	70	2	a) Yes	b) Yes. Probably due to poor attitude response.
C.				
3	50	1	a) No -- altitude control is good.	b) No -- altitude control is good.
$3\frac{1}{2}$	67	1	a) No	b) No
$4\frac{1}{2}$	50	2	a) Satisfactory	b) Can only guess it would be satisfactory.
D.				
4	52	1	a) Ok	b) Ok

DRAG CASE: FRONT SIDE

Question No. 5 Can You Establish a Specific Rate of Descent?

Rating	Flt.	Conf.	Pilot Comments
A.			
2	54	1	Yes. Airspeed had a tendency to get away.
$2\frac{1}{2}$	67	2	Yes. Turbulence caused some troubles.
$2\frac{1}{2}$	70	1	Ok.
2	38	2	Yes. Even with it being turbulent.
3	52	2	Yes. Went well.
B.			
$4\frac{1}{2}$	38	1	Yes, but R/S is adversely influenced by the attitude control.
5	83	2	Wasn't comfortable. Didn't have good positive control of attitude and airspeed.
$3\frac{1}{2}$	81	1	Yes, as long as maintain attitude stabilized.
7	70	2	Difficult to maintain because of poor attitude control.
C.			
3	50	1	Yes.
$3\frac{1}{2}$	67	1	Yes.
$4\frac{1}{2}$	50	2	Went fairly well -- it was only limited by attitude control problem (turbulence).
D.			
4	52	1	Yes -- smooth air; yes, rough air (with tight attitude control).

DRAG CASE: FRONT SIDE

Question No. 6 Is Maintaining Airspeed a Problem?

Rating	Flt.	Conf.	Pilot Comments
A.			
2	54	1	A little bit of one.
2½	67	2	No, required some attention probably because of attitude changes.
2½	70	1	No, it's not glued but corrections required are small.
2	38	2	No -- had much confidence even when 3 kt. low.
3	52	2	Sometimes, but something could always be done about it
B.			
4½	38	1	Yes, due to poor attitude control.
5	83	2	Yes. Seems to be connected to pilot's control efforts by a "loose spring."
3½	81	1	No. Turbulence and attitude errors caused some trouble.
7	70	2	Yes, on the visual approach.
C.			
3	50	1	Little bit -- this aircraft would probably have a tendency to be fast on approaches.
3½	67	1	No, but it does require attention because it tends to drift off.
4½	50	2	Only a small problem because of the lack of precise attitude control.
D.			
4	52	1	Tended to get high on instrument approach and mirror approach.

DRAG CASE: FRONT SIDE

Question No. 7 What Instruments Are You Using Most?

A.

Rating	Flt.	Conf.	Pilot Comments
2	54	1	1st, Attitude and Airspeed; 2nd, R/C, Altitude, Heading, RPM
$2\frac{1}{2}$	67	2	Attitude - Airspeed, R/C, Altitude, RPM
$2\frac{1}{2}$	70	1	Attitude - Airspeed, R/C, Altitude, RPM
2	38	2	Attitude, Airspeed. 2nd, R/C, Altitude, Heading & throttle, occasionally α
3	52	2	1st, attitude & airspeed; 2nd, R/C, altimeter, heading throttle or RPM.

B.

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	38	1	1st, attitude & airspeed, 2nd, R/C, altimeter, heading, power.
5	83	2	Attitude - Airspeed, Altitude, R/C, heading, RPM
$3\frac{1}{2}$	81	1	Attitude - Airspeed, Altitude, R/C, heading, RPM
7	70	2	Attitude - Strong check with airspeed to find effect of attitude errors, R/C, Altitude, heading, RPM

C.

Rating	Flt.	Conf.	Pilot Comments
3	50	1	1st attitude - airspeed, 2nd R/C, Altitude, heading, and RPM.
$3\frac{1}{2}$	67	1	Attitude - airspeed; R/C, Altitude, heading, RPM
$4\frac{1}{2}$	50	2	Attitude and cross-checking with airspeed, R/C, Altitude, heading, RPM

D.

Rating	Flt.	Conf.	Pilot Comments
4	52	1	1st Attitude, airspeed, 2nd, R/C, Altimeter, heading, throttle

DRAG CASE: FRONT SIDE

Question No. 7 Is a Special Control Technique Required?

Rating	Flt.	Conf.	Pilot Comments
A.			
2	54	1	None
2½	67	2	None, except some tendency to smooth inputs.
2½	70	1	None. One-control type airplane.
2	38	2	None -- good solid-feeling airplane.
3	52	2	None
B.			
4½	38	1	Goes well if you add power in turns and take it off when you come out.
5	83	2	Must overdrive in pitch. Use throttle to get airspeed.
3½	81	1	Overdrive with elevator, coordinate throttle with $\Delta\alpha$
7	70	2	Overdrive with elevator.
C.			
3	50	1	None -- except couldn't add throttle on the turns.
3½	67	1	Try not to excite short period.
4½	50	2	Yes, had to overdrive the airplane in pitch in order to get the responses moving and then back off on the controls to provide that which was necessary to maintain the steady-state response.
D.			
4	52	1	Overdrive the configuration a little bit.

DRAG CASE: FRONT SIDE

Question No. 9 Are Throttle Adjustments Necessary?
Are They Used to Control: Attitude? R/C? Other?
Altitude? Airspeed?

A.

Rating	Flt.	Conf.	Pilot Comments
2	54	1	R/C, a little for airspeed control and a little for α changes.
$2\frac{1}{2}$	67	2	Small adjustments for $\Delta\alpha$. To control R/C; altitude on glide slope; airspeed errors.
$2\frac{1}{2}$	70	1	Small amount for $\Delta\alpha$. Altitude errors on glide slope. Airspeed errors.
2	38	2	Yes. Adjustments required for α changes. Control R/C, altitude on visual approach, and airspeed.
3	52	2	Yes -- 1st R/C, 2nd α, airspeed error, altitude on glide slope.

B.

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	38	1	Yes -- control level turns airspeed and visual glide slope altitude.
5	83	2	R/C, Altitude errors on glide slope and then airspeed. Airspeed is biggest item.
$3\frac{1}{2}$	81	1	Small amount with $\Delta\alpha$. R/C, altitude and airspeed errors on glide slope.
7	70	2	Small, intermediate amount with $\Delta\alpha$. R/C, altitude errors and airspeed errors.

C.

Rating	Flt.	Conf.	Pilot Comments
3	50	1	Yes -- R/C and altitude on glide slope -- used to adjust airspeed. (Note: didn't have to adjust throttle with α changes).
$3\frac{1}{2}$	67	1	Small adjustments necessary with $\Delta\alpha$, but they don't have to be coordinated very precisely. Airspeed changes slowly. R/C primarily and any significant airspeed errors. Altitude errors on glide slope.
$4\frac{1}{2}$	50	2	1st R/C and, a little bit of compensation for changes, and control altitude on glide slope, correct for airspeed errors.

D.

Rating	Flt.	Conf.	Pilot Comments
4	52	1	Yes -- for airspeed errors and setting up R/S and controlled altitude on glide slope.

DRAG CASE: FRONT SIDE

Question No. 10 Is Elevator Used to Control:
Attitude? R/C? Other?
Altitude? Airspeed? n_z?

A.

Rating	Flt.	Conf.	Pilot Comments
2	54	1	Attitude; 2nd, airspeed, altitude on glide slope a little bit.
$2\frac{1}{2}$	67	2	Attitude -- Attitude commands to correct altitude and airspeed changes.
$2\frac{1}{2}$	70	1	Attitude -- altitude and airspeed.
2	38	2	Yes -- controls pitch angle and airspeed.
3	52	2	Yes -- attitude and airspeed; 2nd, altitude.

B.

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	38	1	Yes -- airspeed, altitude.
5	83	2	Attitude -- attitude to make altitude and airspeed corrections.
$3\frac{1}{2}$	81	1	Attitude -- Attitude in conjunction with altitude and airspeed errors.
7	70	2	Attitude -- altitude and airspeed with throttle.

C.

Rating	Flt.	Conf.	Pilot Comments
3	50	1	Yes -- attitude and airspeed thru attitude-altitude on glide slope.
$3\frac{1}{2}$	67	1	Attitude -- attitude used to correct altitude and air-speed.
$4\frac{1}{2}$	50	2	Yes -- attitude and airspeed thru attitude-altitude on glide slope.

D.

Rating	Flt.	Conf.	Pilot Comments
4	52	1	Yes -- attitude and airspeed; 2nd, altitude on glide slope.

DRAG CASE: FRONT SIDE

Question No. 11 Could You Make an Instrument Landing Approach with this Configuration at this Speed?

Rating	Flt.	Conf.	Pilot Comments
A.			
2	54	1	Yes -- a real good one.
$2\frac{1}{2}$	67	2	Definitely.
$2\frac{1}{2}$	70	1	Definitely.
2	38	2	Yes.
3	52	2	Yes -- tended to get fast.
B.			
$4\frac{1}{2}$	38	1	Yes.
5	83	2	Yes.
$3\frac{1}{2}$	81	1	Definitely.
7	70	2	Under good conditions and good proficiency. Can't trim up and expect attitude to stay constant while you attend to other tasks. Airspeed difficulties.
C.			
3	50	1	Yes -- most certainly.
$3\frac{1}{2}$	67	1	Definitely in smooth air -- Reservations if rough weather.
$4\frac{1}{2}$	50	2	Yes -- may be a problem in turbulence where the attitude would be disturbed.
D.			
4	52	1	Yes -- however there's a tendency to get fast.

DRAG CASE: FRONT SIDE

Question No. 12 What Happens When you Transition to Visual Flight? How Do You Fly the Visual Approach, Particularly Regarding Glide Slope Control? Are You Checking Airspeed and/or α on Final? If so, When Do You Quit?

Rating	Flt.	Conf.	Pilot Comments
A.			
2	54	1	Transition (off a little, but was able to get on and stay well).
$2\frac{1}{2}$	67	2	Had to make azimuth correction. Transitioned immediately. Got low once added power -- small corrections.
$2\frac{1}{2}$	70	1	Good visibility, very comfortable.
3	52	2	Transition (busy getting lined up), visual (flew it using throttle for altitude errors and elevator for attitude ; 2nd, throttle in attitude to control airspeed). Airspeed -- $\frac{1}{2}$ mile.
B.			
$4\frac{1}{2}$	38	1	Way off after transition to right. Same as before airspeed -- $\frac{1}{2}$ mile.
5	83	2	Made four approaches and did not feel I had good positive control on any of them. Heaved off glide slope. Then difficult to make correction because of attitude characteristics.
$3\frac{1}{2}$	81	1	Poor visibility -- airport turned on strobe lights. Went well. 2nd, went well also. Checked airspeed all the way.
7	70	2	ADF not working well. 1st approach -- got high $\frac{1}{4}$ mile out, tried to push over but continued to get high (wind shear?) Would have missed approach. 2nd, not very good performance even though he worked hard. Checked airspeed as often as he had time for it.
C.			
3	50	1	Transition (comfortable and in control--no problems). No problems making corrections on glide slope. Checked airspeed all the way down.
$3\frac{1}{2}$	67	1	Went pretty well, turbulence tended to upset attitude. Didn't seem to have positive control of airspeed. Not serious objection, however.
$4\frac{1}{2}$	50	2	Transition (was fairly comfortable); visual (had to take off quite a bit more throttle than most configurations); airspeed to $\frac{1}{2}$ mile or less.
D.			
4	52	1	Transition (trouble getting established--was high and fast). Airspeed -- $\frac{1}{4}$ mile.

DRAG CASE: FRONT SIDE

Question No. 13 Comment on the Wave-Off

A.

Rating	Flt.	Conf.	Pilot Comments
2	54	1	Everything was good -- good positive control, climb-out was good.
$2\frac{1}{2}$	67	2	O.K.
$2\frac{1}{2}$	70	1	O.K.
2	38	2	Went well.
3	52	2	Comfortable -- felt good positive control.
B.			
$4\frac{1}{2}$	38	1	Tend to be a little fast.
5	83	2	O.K.
$3\frac{1}{2}$	81	1	O.K.
7	70	2	O.K. Attitude response sluggish.
C.			
3	50	1	Went comfortably (more so than most). Seemed like had excess thrust.
$3\frac{1}{2}$	67	1	Comfortable, no problem. Might over rotate.
$4\frac{1}{2}$	50	2	Was comfortable, had a surplus of power; good steep wave-off.
D.			
4	52	1	Was comfortable, but pitch characteristics made pilot work a little bit on attitude to compensate for the trim changes.

DRAG CASE: FRONT SIDE

Question No. 14 Comment on the Visual Circling Approach.

Rating	Flt.	Conf.	Pilot Comments
A.			
2	54	1	Comfortable -- no high R/S.
$2\frac{1}{2}$	67	2	Good.
$2\frac{1}{2}$	70	1	Good. Very little power manipulation.
2	38	2	Good.
3	52	2	Good and comfortable; some work on airspeed.
B.			
$4\frac{1}{2}$	38	1	Went fairly well.
5	83	2	Little difficult because of lack of horizon and poor pitch control.
$3\frac{1}{2}$	81	1	Good.
7	70	2	Couldn't get stabilized on altitude and airspeed.
C.			
3	50	1	Got on glide slope all right, my course corrections and the glide slope stayed on fairly well.
$3\frac{1}{2}$	67	1	Good. Could pull .3g in turns and hold airspeed with minimum throttle coordination.
$4\frac{1}{2}$	50	2	Comfortable -- no trouble controlling it.
D.			
4	52	1	No large R/S while turning base.

DRAG CASE: BOTTOM - GEAR

Major Problem

A.

Rating	Flt.	Conf.	Problem	Pilot Comments
$2\frac{1}{2}$	46	2		Noticeable drag with angle of attack; attitude control good; airspeed no problem.
2	44	1		No problem. Things went well.
$3\frac{1}{2}$	51	2	Airspeed (a little bit)	Good attitude control; had slight trouble with drag characteristics. (Marginal).
$3\frac{1}{2}$	57	1	Airspeed (a little bit)	Quite controllable; well damped; easily flown; high drag rise with angle of attack helped keep airspeed; good attitude control.
4	37	2	Airspeed control	May have been a little airspeed instability.
$3\frac{1}{2}$	42	2	Sluggishness	More sluggish than 1st configuration, but it's adequate; substantial pitch rate overshoot; overdrove configuration.

B.

Rating	Flt.	Conf.	Problem	Pilot Comments
$3\frac{1}{2}$	47	2		Had troubles, but they weren't repeatable. If these unknown problems were more serious, pilot would object to configuration. (unsatisfactory)
$3\frac{1}{2}$	43	1	Sluggish	Sluggish in pitch; no pitch rate overshoot; had to watch airspeed a lot; had to use a large amount of throttle.
$3\frac{1}{2}$	62	2	Airspeed	Attitude control was either on the borderline or a little unsatisfactory; a little airspeed trouble due to a turbulence and lack of precise attitude control.
4	40	2		Down-graded because of lack of stiffness in pitch rate.
4	46	1	Sluggish attitude control	Pitch response is initially too slow.
5	44	2	Attitude control	Sluggish in pitch, had to overdrive.
$5\frac{1}{2}$	43	2	Attitude control slow responding	Couldn't fly precisely; trouble trimming on glide path; poor attitude control; had to overdrive.
$6\frac{1}{2}$	47	1	Attitude control; maintaining altitude	Had airspeed difficulties due principally to poor attitude control and possibly some drag.

DRAG CASE: BOTTOM - GEAR

Major Problem

B. (Cont.)

Rating	Flt.	Conf.	Problem	Pilot Comments
7	37	1	Attitude stiffness	Didn't have enough pitch stiffness.
8	45	1	Attitude control	Attitude control was unacceptable; airspeed was poor due to poor attitude control.
C.				
2	42	1		Good positive attitude and airspeed control; slight looseness in pitch (little pitch rate overshoot).
$2\frac{1}{2}$	55	1	Airspeed (a little bit tended to get fast)	Good long. characteristics; little loose in airspeed; slight overshoot in pitch; fairly large trim changes with different power settings.
3	77	1	Airspeed	Good attitude control; fairly large drag rise with angle of attack, pitch characteristics are a little slow and lightly damped; airspeed was stable and errors were slow; overdrive configuration a little.
3	39	2		Attitude control is objectionable, but not unsatisfactory.
3	40	1	Attitude overshoot	Everything was fairly good except for pitch rate overshoot.
$5\frac{1}{2}$	41	1	Attitude control slight galloping	Aircraft tended to bobble; ζ_{sp} too low.
$4\frac{1}{2}$	45	2	Attitude control	Attitude control was acceptable but not satisfactory, had to overdrive a little bit. Airspeed was good.
$9\frac{1}{2}$	41	2	Attitude control airspeed	Had pitch oscillations; couldn't maintain airspeed; sensitive to turbulence.
D.				
$5\frac{1}{2}$	77	2	Attitude trim; attitude control; airspeed (fast & slow) Drag due to angle of attack	Slow and sluggish in pitch and lightly damped; attitude stability was too small; airspeed was a problem due to attitude control and drag charcteristics; have to overdrive configuration.

DRAG CASE: BOTTOM - GEAR

Major Problem

D. (Cont.)

Rating	Flt.	Conf.	Problem	Pilot Comments
$6\frac{1}{2}$	81	2	Attitude control	Attitude characteristics of aircraft were slow, sluggish, and lightly damped; had to overdrive configuration; noticeable drag rise with angle of attack, but it was manageable; lacked feeling of good positive control; attitude control was marginally acceptable; airspeed was somewhat a problem due to attitude control.
8	51	1	Attitude control drag rise with angle of attack airspeed	Poor pitch stiffness; airspeed problems due to high drag rise with angle of attack; have to overdrive configuration.

DRAG CASE: BOTTOM - GEAR

General Comments on Control Technique

A.

Rating	Flt.	Conf.	Pilot Comments
$2\frac{1}{2}$	46	2	No specific comment.
2	44	1	No specific comment.
$3\frac{1}{2}$	51	2	No specific comment.
$3\frac{1}{2}$	57	1	Hazy -- had trouble seeing and interpreting the lights. We were fairly close in when we got the mirror indication. When I first saw the lights I couldn't tell whether we were high-low or anything. My only indication that I'm on glide slope is when the amber lights disappear behind the green ones. That always looks a little high to me. This is a little steeper than normal type of approach and by the time I get that "on-course" indication and make a throttle and flight path change, I'm getting a little high and then I have a tendency to stay high. I've already told you the loops that I close on the glide slope, attitude with elevator and altitude with the throttle and then secondarily alter my attitude or elevator commands with changes of throttle, and then also you use throttle to control airspeed. So I check airspeed probably to the 1/2 1/4 mile point.
4	37	2	No specific comments.
$3\frac{1}{2}$	42	2	No specific comments.

B.

Rating	Flt.	Conf.	Pilot Comments
$3\frac{1}{2}$	47	2	Comments on Second Approach -- Didn't go well at all, would have waved-off a carrier. I think it was because I waited until I got a solid "on" indication and consequently by the time I got that indication and allowed for any errors -- then the errors would all be on the high side, and then by the time I take off the power and push the nose over to get down on the glide slope, I apparently was getting a definite high and so I would take off a lot of power, and if I didn't take off as much as I should, the airspeed would get high while I was trying to keep the high glide slope indication from going higher. So I had this high and fast and I just didn't seem to be able to do anything about it.
$3\frac{1}{2}$	43	1	No specific comments.

DRAG CASE: BOTTOM - GEAR

General Comments on Control Technique

B. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
$3\frac{1}{2}$	62	2	Seemed to be able to handle corrections on glide slope fairly well. If I was going a little slow, I could add power and climb right back up and the response time to altitude errors seemed reasonable and fairly quick. In other words, if I felt I was a little low, I felt I could squirt a little throttle (and I actually did this) and get back up, back it off again and continue on down. I didn't have to consciously think about attitude control -- it seemed to be that my nose was more up in the picture and I had a strong sensory input of attitude anyway. I don't necessarily think my attitude control was any better on this one but I think it a little more natural.
			How do I fly it? I flew it in the conventional sense -- if I was high or low on the glide slope, I'd make a throttle correction and secondarily an attitude correction to keep the airspeed constant. If I was low or high on airspeed, I'd make a throttle correction and a corresponding attitude correction, depending on my flight path with respect to the glide slope. I was checking airspeed but didn't feel that it had to be a tight loop.
4	40	2	Throttle Adjustment - Adjustments are necessary to compensate for additional drag in level turns, to control rate of climb when you're IFR, also to pick up or change airspeed if you're off the desired glide path. When you are on the VFR portion, the throttle adjustments are used to control altitude above and below the glide slope, and if you are off airspeed you also use the throttle adjustments to control airspeed.
			Elevator to Control - Elevator is used to control attitude and attitude is used to control the airspeed primarily, but, altitude also on the visual portions of the glide slope. In other words, if I'm high, I'll decrease my pitch attitude and take off throttle.
4	46	1	No specific comments.
5	44	2	Throttle Control - On the glide slope, throttle is used to control altitude errors. It was also used to correct airspeed errors if I was on the glide slope. That did happen to me a couple of times, it got fast and it looked like I had an "on" indication until the airspeed got right, then put the power back on. It seemed to work O.K.

DRAG CASE: BOTTOM - GEAR

General Comments on Control Technique

B. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
5	44	2(Cont.)	Elevator Control - Elevator is used to control attitude, and through attitude, then airspeed, and altitude on glide slope you have to use the elevator to control altitude on the glide slope; because if you pull power off, the airspeed just bleeds, and then you start to sink, but while that's going on, you're still sitting up there kind of high, and then you end up sinking at low speed and this is kind of a miserable situation to be in. So, you've got to push the nose over when you take power off.
$5\frac{1}{2}$	43	2	Throttle Adjustment - One time I was low, and on airspeed for a change, I added power, it came right up and I got an on-course indication and I took the power off, or took the power back to what would seem about right for my rate of descent. It seemed to work well.
$6\frac{1}{2}$	47	1	No specific comment.
7	37	1	No specific comment.
8	45	1	LOUSY - Don't give anybody an airplane like this to fly an instrument approach or a mirror approach. If you have an emergency or something, yes, you can fly it and get it down VFR, and I expect you can land it all right, but gracious goodness, I worked on that one and I was panting by the time we did two approaches. I was all over the cockpit in trying to control pitch. Gusts would come along and they weren't severe at all, and pitch the airplane up and it would hang up there, it wouldn't come back down, I'd have to push hard, nothing would happen for a little bit and then the nose would really start going down, and I'd have to yank to stop it. It's not a good configuration at all. It seemed my troubles were attitude, not drag, but attitude meant I had all sorts of problems with airspeed, I don't think I was even on airspeed.
			Gear Ratio - Turned down BF until the initial response was so slow I didn't want it any slower and that's what I used, BF = 55. I don't know what I've got here, but it's not very good.

DRAG CASE: BOTTOM - GEAR

General Comments on Control Technique

B. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
8	45	1 (Cont.)	Taking record of level turn - I'm moving the stick double amplitude about three inches and I bet Nello can hardly detect a change in airplane response. You do have a little bit of force to hold it a steady turn and that's kind of why I picked this gear ratio but I think I've got the initial response pretty sluggish. I might have picked something a little lighter but then when I was lighter I did too much overdriving. So I don't know ----- I'll use BF = 55.
			Comments on Question 2 - Was Elevator Gain Satisfactory?
			No, it was not. I did not have enough control of the initial response and I had too much control of the final response. I know it was a fault of the dynamics but I'm still saying it. You can't select a good gear ratio, but I think a lighter one than I selected would have been better, especially in the turbulence. I wouldn't have had to use such large control inputs.

C.

Rating	Flt.	Conf.	Pilot Comments
2	42	1	No specific comment.
$2\frac{1}{2}$	55	1	Transition and On Glide Slope - I was almost on glide slope so I reduced power, and of course didn't know exactly how much to reduce it, and started down the glide slope and then some seconds later realized I was slightly low as I got closer in, so I decided to -- climb up a little bit, I added power and climbed up -- got an on-course indication. But by the time I could take the power off and change the pitch attitude, I was high, and there I stayed the rest of the way down the glide slope. I had to make a sizable power reduction and I'm sure I have a definite tendency to minimize the power reductions and hence I had a tendency to stay high. The reason I minimize the power reductions is because of the acceleration characteristics of the engine. I don't think the airspeed got high. If I had pushed back down on the glide slope, for the power corrections I made, I would have definitely been fast, but instead I stayed high but on airspeed.

DRAG CASE: BOTTOM - GEAR

General Comments on Control Technique

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
3	77	1	No specific comment.
3	39	2	On the glide slope, elevator is definitely used to control attitude. If I'm high and take off power and ease the nose over, so you can say altitude feeds both the throttle and elevator. It doesn't actually feed the elevator directly; I think it feeds the pitch attitude command just like airspeed acts as pitch attitude command. Transition to Visual - Picked up glide slope as soon as I went visual approximately 2 miles. Got a pretty much on-course indication, or a slight low, so I just delay a little and then start taking off power, that's the first thing I do, and then ease the nose down to where it looks about right--pitch attitude and cross check the airspeed to make sure I have about the right attitude. Then on in; if I'm low in airspeed, I add power and ease the nose down just a little bit, if I can, i.e., if I'm not low in altitude. So I'm definitely checking airspeed in to about $\frac{1}{2}$ - $\frac{1}{4}$ mile.
3	40	1	No specific comment.
$5\frac{1}{2}$	41	1	No specific comment.
$4\frac{1}{2}$	45	2	I flew the mirror approach in the manner I've been flying them, with throttle controlling altitude errors (if the airspeed was correct) and elevator controlling attitude errors always, but being influenced by altitude and airspeed errors. Of course, the throttle control is influenced by whether or not my airspeed is correct.
$9\frac{1}{2}$	41	2	No specific comment.

D.

Rating	Flt.	Conf.	Pilot Comments
$6\frac{1}{2}$	81	2	It kept having a tendency to go low - Couple of times I started to go low and I had to ease the nose up and add a little power, but generally I didn't have to add much power because the airspeed was so high. So, apparently I was just dropping the nose but in the course of adding a little power, I guess I got just a little fast and I started to take off a little power and about that time I transferred my entire attention to the mirror ($\approx \frac{1}{2}$ mile) and didn't look at airspeed again until wave-off at which time it was about 5 kt slow.

DRAG CASE: BOTTOM - GEAR

General Comments on Control Technique

D. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
$6\frac{1}{2}$	81	2(Cont.)	So, I would have made the approach but didn't have as good airspeed control as I thought I might have. If you ask why I didn't look at airspeed any more -- it's because I had been dropping my nose apparently and going below the glide slope and so I was trying to fly the glide very tightly and in so doing, apparently I didn't have enough throttle on and the airspeed got low.
$5\frac{1}{2}$	77	2	No specific comment.
8	51	1	No specific comment.

DRAG CASE: BOTTOM - GEAR

Question No. 1 Is the Airplane Difficult to Trim?

A.

Rating	Flt.	Conf.	Pilot Comments
2½	46	2	No (noticeable drag with angle of attack).
2	44	1	No, easy.
3½	51	2	No.
3½	57	1	No, quite easy.
4	37	2	No, it's easy.
3½	42	2	No.

B.

Rating	Flt.	Conf.	Pilot Comments
3½	47	2	It was satisfactory, but not the easiest.
3½	43	1	No.
3½	62	2	Trimmed up moderately well.
4	40	2	No.
4	46	1	Some difficulty -- not much pitch stiffness.
5	44	2	Not an easy aircraft to trim.
5½	43	2	Not in level flight. Had difficulty during approach.
6½	47	1	Fairly difficult.
7	37	1	Yes, because of the lack of pitch stiffness.
8	45	1	Yes, unstable.

C.

Rating	Flt.	Conf.	Pilot Comments
2	42	1	No, good positive airspeed stability.
2½	55	1	No, quite easy.
3	77	1	No.
3	39	2	No.
5½	41	1	Yes, Due to a combination of pitch and drag characteristics.
4½	45	2	No.
9½	41	2	Relatively easy.
3	40	1	No, easy.

D.

Rating	Flt.	Conf.	Pilot Comments
5½	77	2	Yes, attitude trim was a problem.
6½	81	2	Not very good but there was no horizon -- poor visibility, had to trim on instruments.
8	51	1	Yes, very little pitch stiffness and it's very susceptible to turbulence.

DRAG CASE: BOTTOM - GEAR

Question No. 2 Is the Elevator Control Gain Satisfactory?

A.

Rating	Flt.	Conf.	Pilot Comments
2½	46	2	Yes.
2	44	1	Yes, 62
3½	51	2	Yes, a good value.
3½	57	1	Yes, good choice.
4	37	2	Yes, BF = 65.
3½	42	2	Yes, a compromise between sluggish initial response and light steady state forces.

B.

Rating	Flt.	Conf.	Pilot Comments
3½	47	2	Yes, worked out well.
3½	43	1	Yes, a good compromise.
3½	62	2	Yes, BF = 60 because of a fair amount of pitch rate overshoot and the response was on sluggish side.
4	40	2	"I'm not sure what I see . . ."
4	46	1	Yes, but the results obtained are not? ?
5	44	2	It's a good compromise.
5½	43	2	Yes, it was a compromise.
6½	47	1	It's a satisfactory compromise, but it's not good -- Don't have enough initial response control.
7	37	1	On sensitive side (BF = 57) -- compromise because at a lower setting the stick motion to maneuver was large and response of sluggish stick bothered pilot.
8	45	1	No. Didn't have enough control of the initial response and too much control of the final response. (Probably could've selected a slightly better gear ratio.)

C.

Rating	Flt.	Conf.	Pilot Comments
2	42	1	Yes, chose value to put initial response at an acceptable level (a little pitch rate overshoot).
2½	55	1	Yes (little on the sensitive side).
3	77	1	Yes, good choice.
3	39	2	Yes.
3	40	1	Yes, BF = 65.

DRAG CASE: BOTTOM - GEAR

Question No. 2 Is the Elevator Control Gain Satisfactory? (Cont.)

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
$5\frac{1}{2}$	41	1	Yes, It was a compromise between initial response and heavy steady forces.
$4\frac{1}{2}$	45	2	Good compromise.
$9\frac{1}{2}$	41	2	Yes, it was a compromise between an abrupt and too fast initial response and high steady state forces.
D.			
$5\frac{1}{2}$	77	2	Yes.
$6\frac{1}{2}$	81	2	Yes. Sluggish in pitch and lightly damped: Thus wanted high gear ratio because of sluggish response but wanted lower gear ratio because of low damping. A low gear ratio causes me to run out of control when overdriving configuration, so I picked a high value to avoid this. However, I tended to PI0 in turbulence. Over-all, glad I made the compromise the way I did.
8	51	1	No, should've been around 60 instead of 55. Had to work hard because of turbulence.

DRAG CASE: BOTTOM - GEAR

Question No. 3 Is Attitude Control Satisfactory?

A.

Rating	Flt.	Conf.	Pilot Comments
$2\frac{1}{2}$	46	2	Yes.
2	44	1	Yes.
$3\frac{1}{2}$	51	2	Yes, quite good.
$3\frac{1}{2}$	57	1	Yes, very very good.
4	37	2	Excellent.
$3\frac{1}{2}$	42	2	Yes, only fair because pitch rate overshoot.

B.

Rating	Flt.	Conf.	Pilot Comments
$3\frac{1}{2}$	47	2	Fair (rating of 3 for attitude control) -- satisfactory but on slow side.
$3\frac{1}{2}$	43	1	Marginally satisfactory -- could be better on approach.
$3\frac{1}{2}$	62	2	It's on the borderline between satisfactory and unsatisfactory.
4	40	2	No or just probably fair due to long response time in the short period.
4	46	1	Yes, but has tendency to sluggishness on the initial response or relatively long time delay in getting what is wanted.
4	44	2	Slow and sluggish initially -- have to overdrive to get started and then back off on input.
$5\frac{1}{2}$	43	2	No, couldn't keep attitude right.
$6\frac{1}{2}$	47	1	No, it's unacceptable --It's sluggish in pitch feels like it wants to dig in. Takes 4-5 seconds to do anything with it.
7	37	1	No. Not enough pitch stiffness. When closed-loop on attitude it was o.k., but if you look away, the pitch rate would not necessarily be zero when you look back.
8	45	1	Unacceptable -- really had to fly a tight closed loop and work hard. I was panting after two approaches. I was all over the cockpit trying to control attitude. Gusts would come along and pitch it up and it would just hang there. I'd have to push hard -- nothing would happen for a little bit and then the nose would really start going down and I'd have to yank to stop it. Had lousy attitude control and this caused problems with airspeed.

DRAG CASE: BOTTOM - GEAR

Question No. 3 Is Attitude Control Satisfactory? (Cont.)

C.

Rating	Flt.	Conf.	Pilot Comments
2	42	1	Yes, just a slight looseness in pitch (pitch rate overshoot).
$2\frac{1}{2}$	55	1	Yes (little tendency to overshoot).
3	77	1	Yes, rate it about fair ($3 - 2\frac{1}{2}$)
3	39	2	Yes, but only fair.
3	40	1	Fair -- the only objectionable thing is a pitch-rate overshoot.
$5\frac{1}{2}$	41	1	No, bobble tendency in pitch, low short period damping.
$4\frac{1}{2}$	45	2	No, it was acceptable, but not satisfactory.
$9\frac{1}{2}$	41	2	No, unacceptable. Responsiveness to turbulence is tremendous. Turbulence acts as an exciter for pitch oscillation and gave me quite a bit of difficulty.

D.

Rating	Flt.	Conf.	Pilot Comments
$5\frac{1}{2}$	77	2	No, too slow and sluggish, very little stability.
$6\frac{1}{2}$	81	2	No. Absolutely not. Attitude control is nearly unacceptable. Might over rotate on flare. Slow, sluggish and light damping.
8	51	1	It's unacceptable.

DRAG CASE: BOTTOM - GEAR

Question No. 4 Is Maintaining Altitude a Problem?
a) Straight and Level
b) Turns

A.

Rating	Flt.	Conf.	Pilot Comments	
2½	46	2	a) No. -	b) No. (could hold altitude precisely)
2	44	1	a) O.K.	b) O.K.
3½	51	2	a) No.	b) May have some.
3½	57	1	a) No.	b) Not too much.
4	37	2		b) Yes, trouble in turns -- drag rises required a substantial throttle input for compensation.
3½	42	2	a) Not much.	b) No, it's good.

B.

Rating	Flt.	Conf.	Pilot Comments	
3½	47	2	a) Just a little trouble.	b) Can't answer.
3½	43	1	a) No problem.	b) Had to add throttle, but airspeed seemed stable.
3½	62	2	a) No.	b) Minor problem probably due to lack of real positive attitude control.
4	40	2	a) No.	b) Not as good as above.
4	46	1	a) O.K.	b) O.K. (not particularly difficult)
5	44	2	a) Yes, even more trouble than in turns.	b) Yes,
5½	43	2	a) Tended to get high.	b) Had to add a lot of power.
6½	47	1	a) Yes.	
7	37	1	a) Had difficulty because of lack of attitude stiffness.	
8	45	1	a) Yes	b) Yes, but better than straight and level.

C.

Rating	Flt.	Conf.	Pilot Comments	
2	42	1	a) No.	b) No, it's good.
2½	55	1	a) No.	b) No.

DRAG CASE: BOTTOM - GEAR

Question No. 4 Is Maintaining Altitude a Problem? (Cont.)
a) Straight and Level
b) Turns

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments	
3	77	1	a) No.	b) No. (As long as you applied a throttle closure).
3	39	2	a) No.	b) A little bit of trouble.
3	40	1	a) No.	b) O.K.
$5\frac{1}{2}$	41	1	a) O.K.	b) Slight problem.
$4\frac{1}{2}$	45	2	a) No.	b) No.
$9\frac{1}{2}$	41	2	a) Somewhat a problem but not critical.	

D.

Rating	Flt.	Conf.	Pilot Comments	
$5\frac{1}{2}$	77	2	a) Little, due to trim difficulties.	b) Yes, because it was difficult to hold attitude.
$6\frac{1}{2}$	81	2	a) Not serious problem.	b) Not serious problem. Did not go real well -- mostly because of poor attitude control had to fly attitude tightly to do good job.
8	51	1	a) Yes, due to attitude problems during any disturbance.	b) Yes, due to attitude problems and drag increases with increased angles of attack.

DRAG CASE: BOTTOM - GEAR

Question No. 5 Can Your Establish a Specific Rate of Descent?

A.

Rating	Flt.	Conf.	Pilot Comments
$2\frac{1}{2}$	46	2	Yes, throttle controlled R/S.
2	44	1	Yes.
$3\frac{1}{2}$	51	2	Yes, but not as well as pilot would like.
$3\frac{1}{2}$	57	1	Yes, went fairly well.
4	37	2	Yes, fairly well.
$3\frac{1}{2}$	42	2	Yes, pilot comments "when you have a stiff configuration, moderately high frequency stiff short period, the pilot has confidence that things will be where you left them when you get back to them in your scan pattern". This configuration is on the fringes of this desirable region.

B.

Rating	Flt.	Conf.	Pilot Comments
$3\frac{1}{2}$	47	2	Yes, but would tend to lose a little airspeed, then on glide slope he would get a little fast, possibly because he was high.
$3\frac{1}{2}$	43	1	Fairly well.
$3\frac{1}{2}$	62	2	Yes.
4	40	2	Yes, fairly well.
4	46	1	Yes, fairly well.
5	44	2	Seemed to go fair.
$5\frac{1}{2}$	43	2	Not well, couldn't keep airspeed and attitude coordinated too well together.
$6\frac{1}{2}$	47	1	No - yes, initially, but couldn't hold it.
7	37	1	Yes, as long as pilot had good tight attitude control.
8	45	1	No, because pilot couldn't hold attitude and couldn't get trimmed (power effects on trim were substantial).

C.

Rating	Flt.	Conf.	Pilot Comments
2	42	1	Yes.
$2\frac{1}{2}$	55	1	Yes, (but didn't like the low power setting that it required).
3	77	1	It was all right.
3	39	2	Yes.
3	40	1	Yes, pretty well.
$5\frac{1}{2}$	41	1	Had little difficulty because of trouble holding attitude and airspeed bothered pilot.

DRAG CASE: BOTTOM - GEAR

Question No. 5 Can You Establish a Specific Rate of Descent? (Cont.)

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	45	2	Yes.
$9\frac{1}{2}$	41	2	R/C was a problem because of high response to gusts which created an attitude problem.

D.

Rating	Flt.	Conf.	Pilot Comments
$5\frac{1}{2}$	77	2	Yes, but higher turbulence may cause a problem.
$6\frac{1}{2}$	81	2	Only if I provide continuous attitude stabilization.
8	51	1	Very hard to do.

DRAG CASE: BOTTOM - GEAR

Question No. 6 Is Maintaining Airspeed a Problem?

A.

Rating	Flt.	Conf.	Pilot Comments
$2\frac{1}{2}$	46	2	No, but had to be a little careful.
2	44	1	No, however, not a real stiff phugoid.
$3\frac{1}{2}$	51	2	A little bit whenever a new flight conditions is established.
$3\frac{1}{2}$	57	1	Yes, a little bit, but within pilot capability.
4	37	2	Yes, especially in turns -- pilot thinks there is a degree of airspeed instability.
$3\frac{1}{2}$	42	2	No, had a little bit of a problem due to slight attitude problem.

B.

Rating	Flt.	Conf.	Pilot Comments
$3\frac{1}{2}$	47	2	It's the beginnings of a problem and that's what makes this configuration a borderline case ($3\frac{1}{2}$).
$3\frac{1}{2}$	43	1	Pilot had to spend a lot of time on airspeed.
$3\frac{1}{2}$	62	2	No, but the not quite precise attitude control and the turbulence did cause a little difficulty.
4	40	2	No.
4	46	1	Went fairly well (in rough air, it may be a problem).
5	44	2	No.
$5\frac{1}{2}$	43	2	Yes, because attitude was a problem -- airspeed was stable.
$6\frac{1}{2}$	47	1	Yes, definitely -- principally due to poor attitude control and may have been influenced by drag equation.
7	37	1	Yes, because of problem with attitude control.
8	45	1	Yes, all the way, except when flying tight closed loop in attitude.

C.

Rating	Flt.	Conf.	Pilot Comments
2	42	1	No.
$2\frac{1}{2}$	55	1	Just a little bit (tendency to get fast).
3	77	1	You have to monitor airspeed error and make a throttle closure with α
3	39	2	No (not quite as good as Flt. 338, rating 2).
3	40	1	No.
$5\frac{1}{2}$	41	1	Yes, in approach due to attitude and drag characteristics.

DRAG CASE: BOTTOM - GEAR

Question No. 6 Is Maintaining Airspeed a Problem? (Cont.)

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
4½	45	2	No.
9½	41	2	Yes.
D.			
5½	77	2	Yes, probably equally due to the attitude control difficulties as to the drag characteristics.
6½	81	2	Yes.
8	51	1	Quite difficult.

DRAG CASE: BOTTOM - GEAR

Question No. 7 What Instruments are You Using Most?

A.

Rating	Flt.	Conf.	Pilot Comments
$2\frac{1}{2}$	46	2	Altitude, airspeed, throttle.
2	44	1	1st, attitude, airspeed, 2nd, heading, R/C, altitude, and RPM.
$3\frac{1}{2}$	51	2	Attitude, airspeed, R/C, altitude, heading, throttle (use them all this time; didn't concentrate on any one).
$3\frac{1}{2}$	57	1	Attitude and airspeed, 2nd, R/C, altitude, heading, throttle.
4	37	2	Pitch attitude primarily, cross checked with airspeed and R/C, altimeter, heading and power -- don't particularly use α .
$3\frac{1}{2}$	42	2	1st attitude, airspeed, 2nd heading, R/C, altitude, power.

B.

Rating	Flt.	Conf.	Pilot Comments
$3\frac{1}{2}$	47	2	1st, attitude, airspeed (cross checking); 2nd R/C, altitude, heading, RPM.
$3\frac{1}{2}$	43	1	1st, attitude and airspeed; 2nd heading, R/C, power.
$3\frac{1}{2}$	62	2	Question not answered.
4	40	2	1st attitude, airspeed, 2nd R/C, altimeter, heading, power.
4	46	1	Attitude, airspeed, R/C, altitude, heading, throttle, RPM.
5	44	2	1st attitude, airspeed, 2nd R/C, altimeter, heading, throttle, RPM.
$5\frac{1}{2}$	43	2	1st attitude, airspeed, 2nd heading, altimeter, R/C, throttle.
$6\frac{1}{2}$	47	1	Primarily attitude and airspeed -- R/C, altitude, heading and RPM.
7	37	1	Attitude indicator primarily cross checked closely with airspeed.
8	45	1	

C.

Rating	Flt.	Conf.	Pilot Comments
2	42	1	Attitude, airspeed, R/C, altimeter, heading (had lots of time for studying heading).
$2\frac{1}{2}$	55	1	Attitude, airspeed, R/C, altitude, RPM,heading.

DRAG CASE: BOTTOM - GEAR

Question No. 7 What Instruments are You Using Most? (Cont.)

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
3	77	1	1st, attitude and airspeed, 2nd R/C,altimeter, heading, RPM.
3	39	2	Attitude (most), airspeed, R/C, altimeter, airspeed, heading power.
3	40	1	Attitude, airspeed, R/C, altimeter, heading.
5½	41	1	1st, attitude, airspeed, 2nd R/C, altimeter.
4½	45	2	Attitude, airspeed, R/C, altitude, heading, RPM.
9½	41	2	1st, attitude, airspeed, 2nd, heading, R/C, altimeter, throttle.

D.

Rating	Flt.	Conf.	Pilot Comments
5½	77	2	1st, attitude and airspeed, 2nd, altimeter, R/C, heading, RPM.
6½	81	2	Attitude and airspeed --altimeter, rate of climb, heading, power.
8	51	1	Attitude, airspeed, 2nd altimeter, heading, RPM.

DRAG CASE: BOTTOM - GEAR

Question No. 8 Is a Special Control Technique Required?

A.

Rating	Flt.	Conf.	Pilot Comments
2½	46	2	None.
2	44	1	None.
3½	51	2	None -- except have to make good throttle closure (whenever you change angle of attack).
3½	57	1	None -- except for throttle closure.
4	37	2	None.
3½	42	2	Slightly overdrives configuration.

B.

Rating	Flt.	Conf.	Pilot Comments
3½	47	2	No.
3½	43	1	Slightly overdrives configuration
3½	62	2	No.
4	40	2	Yes, tend to overdrive the aircraft in pitch to get the response you want going, and then back off to leave in the amount of control which will maintain the response.
4	46	1	--
5	44	2	Yes, but it's easy -- you overdrive the configuration initially to get it going, and back off to maintain the steady response.
5½	43	2	Yes, overdrives configuration.
6½	47	1	Throttle adjustments control R/C, airspeed and altitude.
7	37	1	Tight attitude control.
8	45	1	--

C.

Rating	Flt.	Conf.	Pilot Comments
2	42	1	No.
2½	55	1	None.
3	77	1	Throttle with angle of attack and additional throttle for airspeed error; 2nd, overdrive configuration.
3	39	2	None.
3	40	1	None.
5½	41	1	Yes - ? ?

DRAG CASE: BOTTOM - GEAR

Question No. 8 Is a Special Control Technique Required? (Cont.)

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	45	2	Overdrive it initially.
$9\frac{1}{2}$	41	2	Yes, had to continuously control two closed-loop (attitude and airspeed). Throttle controlled airspeed -- elevator controlled attitude. Controllable with only a minimum of cockpit duties.

D.

Rating	Flt.	Conf.	Pilot Comments
$5\frac{1}{2}$	77	2	Had to overdrive configuration; throttle with α .
$6\frac{1}{2}$	81	2	Pilot must overdrive and damp to get desired pitch response. Must use throttle with α and U errors.
8	51	1	Yes, got to overdrive it in pitch to get any response.

DRAG CASE: BOTTOM - GEAR

Question No. 9 Are Throttle Adjustments Necessary?
Are They Used to Control: Attitude? R/C? Other?
Altitude? Airspeed?

A.

Rating	Flt.	Conf.	Pilot Comments
$2\frac{1}{2}$	46	2	Yes -- R/C
2	44	1	Yes -- 1st R/C -- 2nd airspeed and altitude on the glide slope.
$3\frac{1}{2}$	51	2	Yes -- R/C, α , 2nd airspeed errors and altitude on glide slope.
$3\frac{1}{2}$	57	1	R/C, altitude on glide slope, airspeed errors, α changes.
4	37	2	Yes -- Control R/C, altitude, airspeed
$3\frac{1}{2}$	42	2	Yes -- for compensating increases in α and for controlling R/C. 2nd airspeed and altitude.

B.

Rating	Flt.	Conf.	Pilot Comments
$3\frac{1}{2}$	47	2	Yes -- R/C and airspeed errors and altitude on glide slope.
$3\frac{1}{2}$	43	1	Yes -- R/C, airspeed and attitude on the glide slope.
$3\frac{1}{2}$	62	2	Yes -- control R/C, α 2nd airspeed errors.
4	40	2	Yes -- compensate for drag in level turn, for R/C in IFR, for ΔU if you are off glide slope.
4	46	1	Yes -- R/C control and occasionally for airspeed control.
5	44	2	Yes -- for controlling altitude errors on glide slope.
$5\frac{1}{2}$	43	2	Yes -- throttle a lot for airspeed and R/C.
$6\frac{1}{2}$	47	1	Yes -- altitude on glide slope 1st and 2nd airspeed.
7	37	1	Yes -- control altitude error on flight path (on visual flight path -- used to control R/C IFR).
8	45	1	Yes -- R/C and airspeed and altitude on glide slope.

C.

Rating	Flt.	Conf.	Pilot Comments
2	42	1	Yes -- instruments - R/C - visual - altitude - airspeed.
$2\frac{1}{2}$	55	1	Control R/C, altitude on glide slope, compensate for airspeed errors when other factors (like flight path) are okay.
3	77	1	Yes -- R/C, $\Delta\alpha$, altitude error, airspeed error.

DRAG CASE: BOTTOM - GEAR

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
3	39	2	Not much on R/C, airspeed, altitude, glide slope.
3	40	1	Yes -- in level turns for airspeed -- in IFR for R/S -- in visual part of glide slope for altitude.
5½	41	1	Yes -- control airspeed, R/C, altitude.
9½	41	2	Yes -- airspeed.

D.

Rating	Flt.	Conf.	Pilot Comments
5½	77	2	Yes -- R/C, $\Delta\alpha$, airspeed error, altitude errors on glide slope.
6½	81	2	Yes -- R/C, $\Delta\alpha$, altitude errors on glide slope, also airspeed errors.
8	51	1	R/C, airspeed errors, altitude on glide slope and angle of attack changes.

DRAG CASE: BOTTOM - GEAR

Question No. 10 Is Elevator Used to Control: Attitude? R/C? Other? Altitude? Airspeed? n_z?

A.

Rating	Flt.	Conf.	Pilot Comments
$2\frac{1}{2}$	46	2	Yes -- attitude and thru attitude, airspeed and altitude.
2	44	1	Controls attitude and thru attitude, airspeed and second, altitude on glide slope.
$3\frac{1}{2}$	51	2	Yes -- attitude and through attitude airspeed, and altitude on the glide slope.
$3\frac{1}{2}$	57	1	Attitude, airspeed, altitude on glide slope.
4	37	2	Yes -- attitude, airspeed and some R/C.
$3\frac{1}{2}$	42	2	Yes -- 1st controls attitude, 2nd airspeed and altitude.

B.

Rating	Flt.	Conf.	Pilot Comments
$3\frac{1}{2}$	47	2	Primarily attitude and thru attitude airspeed; secondary, altitude on glide slope.
$3\frac{1}{2}$	43	1	Yes -- pitch angle then airspeed and altitude on glide slope.
$3\frac{1}{2}$	62	2	1st attitude, 2nd altitude, airspeed.
4	40	2	Yes -- control attitude, which controlled airspeed and altitude a little.
4	46	1	Yes -- attitude and thru attitude, airspeed and altitude.
5	44	2	Yes -- controls attitude and thru attitude, airspeed and altitude on glide slope.
$5\frac{1}{2}$	43	2	Yes -- secondarily, airspeed and altitude.
$6\frac{1}{2}$	47	1	Yes -- attitude and thru attitude; R/C and airspeed. Altitude on glide slope.
7	37	1	Elevator was used to control attitude and attitude controlled airspeed.
8	45	1	Yes -- attitude, altitude, airspeed (had to work hard for it to control anything.)

DRAG CASE: BOTTOM - GEAR

C.

Rating	Flt.	Conf.	Pilot Comments
2	42	1	Yes -- attitude which controlled airspeed and a little altitude.
2½	55	1	1st attitude, 2nd airspeed.
3	77	1	1st attitude, 2nd altitude, airspeed.
3	39	2	Yes -- controlled attitude.
3	40	1	Yes -- control attitude, which controlled airspeed amd a;totide a little.
5½	41	1	Yes -- attitude, which corrects airspeed and altitude.
9½	41	2	Yes -- attitude which was a real problem on this lightly damped configuration.

D.

Rating	Flt.	Conf.	Pilot Comments
5½	77	2	1st attitude, 2nd altitude errors, airspeed errors.
6½	81	2	1st attitude, 2nd to change nominal attitude when throttle changes are made to change altitude or airspeed.
8	51	1	Yes -- attitude and airspeed thru attitude (have to be very tight -- inadequate response to control the attitude properly).

DRAG CASE: BOTTOM - GEAR

Question No. 11 Could You Make an Instrument Landing Approach with this Configuration at this Speed?

A.

Rating	Flt.	Conf.	Pilot Comments
2½	46	2	Most certainly can.
2	44	1	Yes.
3½	51	2	Yes -- even under turbulence.
3½	57	1	Yes -- under all conditions (weather, etc.)
4	37	2	Yes, but you have to be careful with airspeed. Good attitude control makes up for some deficiencies in airspeed control.
3½	42	2	Yes, definitely.

B.

Rating	Flt.	Conf.	Pilot Comments
3½	47	2	Yes, better than visual.
3½	43	1	Sure could.
3½	62	2	Yes.
4	40	2	Yes -- definitely.
4	46	1	Yes.
5	44	2	Yes -- not much of a problem.
5½	43	2	Yes -- might have some trouble where handling characteristics are significant.
6½	47	1	Yes, but marginally.
7	37	1	Yes, but pilot didn't like it -- a dangerous aircraft for instrument aircraft.
8	45	1	Yes -- but would have serious difficulty.

C.

Rating	Flt.	Conf.	Pilot Comments
2	42	1	Yes -- definitely.
2½	55	1	Good -- comfortable configuration for that.
3	77	1	Yes.
3	39	2	Yes -- definitely.
3	40	1	Yes.
5½	41	1	Yes -- but pilot doesn't like it in gusty air.
4½	45	2	Certainly could.
9½	41	2	Yes, in more severe turbulence, no.

DRAG CASE: BOTTOM - GEAR

D.

Rating	Flt.	Conf.	Pilot Comments
$5\frac{1}{2}$	77	2	Yes, acceptable, but most unsatisfactory -- requires a lot of pilot closed-loop control.
$6\frac{1}{2}$	81	2	Yes, in smooth air. In turbulence, would not want to. It bucked and pitched in turbulence. Performance depends on pilot closing attitude loop to stabilize it. If he doesn't, it goes to pot in a hurry.
8	51	1	Under good conditions, yes; under marginal conditions (turbulence, cockpit troubles, etc.), no.

DRAG CASE: BOTTOM - GEAR

Question No. 12 What Happens When You Transition to Visual Flight? How Do You Fly the Visual Approach, Particularly Regarding Glide Slope Control? Are You Checking Airspeed and/or α on Final? If So, When Do You Quit?

A.

Rating	Flt.	Conf.	Pilot Comments
$2\frac{1}{2}$	46	2	Transition was comfortable. Checked airspeed -- quit same as usual.
2	44	1	Pretty much on; glide slope went well; airspeed stayed on well.
$3\frac{1}{2}$	51	2	
$3\frac{1}{2}$	57	1	Transition (had trouble seeing because of haze), visual (close attitude with elevator loop and altitude with throttle loop) airspeed to $\frac{1}{2}$ to $\frac{1}{4}$ mile.
4	37	2	Didn't notice anything. Used attitude control to compensate any airspeed difficulties. Controlled altitude with throttle checked airspeed on final. Quit at $\frac{1}{2}$ mile out.
$3\frac{1}{2}$	42	2	Had to make course correction. Used throttle on glide slope. Airspeed - $\frac{1}{2}$ mile.

B.

Rating	Flt.	Conf.	Pilot Comments
$3\frac{1}{2}$	47	2	Difficult because he was high and fast. Conventional--throttle controlling altitude and 2nd airspeed; the elevator controlling attitude and through attitude command for altitude and/or airspeed errors. Airspeed to $\frac{1}{2}$ mile or less.
$3\frac{1}{2}$	43	1	On transition -- had to positively push the aircraft over. On glide slope used throttle corrections (little more than other configurations) airspeed a lot -- $\frac{1}{2}$ mile.
$3\frac{1}{2}$	62	2	Transition -- had to make course corrections and on glide slope had to make drift correction because of cross wind; on visual approach made throttle and attitude corrections to keep airspeed constant. Checked airspeed.
4	40	2	Slightly off. Flew it same as above. Airspeed $\frac{1}{2}$ mile.
4	46	1	Transition was routine. Airspeed -- $\frac{1}{2}$ mile or less.
5	44	2	On fairly well; glide slope -- elevator used to control attitude which then controlled altitude and airspeed. $\frac{1}{2}$ mile.

DRAG CASE: BOTTOM - GEAR

B. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
$5\frac{1}{2}$	43	2	Transition -- had to make corrections; didn't seem to have ability to keep aircraft on glide slope.
$6\frac{1}{2}$	47	1	
7	37	1	Because of attitude problems, slow response of inputs for correcting flight. Check airspeed on final. Quit $\frac{1}{2}$ mile out.
8	45	1	Airplane pitched up on transition when pilot let go of stick to lift visor. On approach, used throttle and elevator in trying to stay on glide slope.
C.			
2	42	1	Had to make course correction and start on glide slope airspeed -- $\frac{1}{2}$ mile.
$2\frac{1}{2}$	55	1	Transition (corrections went well), visual (corrections went well, except when high and fast). Airspeed and α - $\frac{1}{2}$ to $\frac{1}{4}$ mile.
3	77	1	Transition -- took off too much power on 1st one; airspeed.
3	39	2	Fairly well on track. Pitch to about right attitude. Cross check airspeed, control airspeed with power. Airspeed quit about $\frac{1}{2}$ mile out.
3	40	1	Lined up all right. Used throttle on altitude, elevator pitch attitude for airspeed and a little attitude to compensate for the altitude changes caused by throttle changes. Airspeed. $\frac{1}{2}$ mile.
$5\frac{1}{2}$	41	1	Standard transition. Flew visual approach standard way. Pitch attitude, cross checking airspeed, making throttle adjustments to correct airspeed. For low airspeed corrections, used both throttle and pitch attitude.
$4\frac{1}{2}$	45	2	Lined up well. Flew approach with throttle controlling altitude errors if airspeed was correct and elevator controlling the attitude always, but being influenced by the correctness of altitude and airspeed.
$9\frac{1}{4}$	41	2	System disengaged during transition. Closing both attitude and airspeed loops.

DRAG CASE: BOTTOM - GEAR

D.

Rating	Flt.	Conf.	Pilot Comments
$5\frac{1}{2}$	77	2	Transition went well; visual -- good tight attitude control, however, airspeed would get fast or slow; airspeed all the way in ($\approx \frac{1}{4}$ mile).
$6\frac{1}{2}$	81	2	(Not many specific comments). Had to really pump stick and work hard to control attitude. Having the nose in the field of view was helpful in maintaining attitude. Second Approach: Checking airspeed and making throttle corrections down to $\frac{1}{2}$ mile. Concentrated entirely on glide slope with elevator and airspeed was 5 kt low at wave-off.
8	51	1	Transition (just tried to fly the thing and keep altitude somewhere near right); visual (varied altitude with throttle and kept cross-checking airspeed). Airspeed all the way down.

DRAG CASE: BOTTOM - GEAR

Question No. 13 Comment on Wave-Off.

A.

Rating	Flt.	Conf.	Pilot Comments
$2\frac{1}{2}$	46	2	Airspeed control is good -- indication was drag rise from angle of attack was substantial.
2	44	1	Seemed to be good.
$3\frac{1}{2}$	51	2	Good configuration -- could handle the trim changes with power quite well.
$3\frac{1}{2}$	57	1	Was comfortable -- airspeed got a little high.
4	37	2	Much better than above -- had more thrust available good attitude control. Good short-period characteristics.
$3\frac{1}{2}$	42	2	Went well -- no problems except U was off a little due to attitude.

B.

Rating	Flt.	Conf.	Pilot Comments
$3\frac{1}{2}$	47	2	No problems -- good control.
$3\frac{1}{2}$	43	1	O. K.
$3\frac{1}{2}$	62	2	Went well.
4	40	2	Good -- attitude control was sufficient.
4	46	1	Airspeed control was fair.
5	44	2	Didn't have a very precise control of pitch attitude.
$5\frac{1}{2}$	43	2	Tended to lose airspeed.
$6\frac{1}{2}$	47	1	Not able to make valid comment.
7	37	1	O. K. -- airspeed control wasn't too good because of attitude problems.
8	45	1	Couldn't control airspeed well on climb-out because couldn't control attitude well.

C.

Rating	Flt.	Conf.	Pilot Comments
2	42	1	Smooth with some bobble which made pilot wonder -- What would happen if there were gusts?
$2\frac{1}{2}$	55	1	Satisfactory with a little tendency to get fast.
3	77	1	O. K. except when he turned on base, developed a high R/S.
3	39	2	Good -- seem to have reasonable control.

DRAG CASE: BOTTOM - GEAR

Question No. 13 Comment on Wave-Off (Cont.)

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
3	40	1	Fine --R/C was low because of high drag.
$5\frac{1}{2}$	41	1	Went all right -- no excessive power though.
$4\frac{1}{2}$	45	2	Seemed O. K. except aircraft not quite in phase with pilot inputs (Galloped a couple of times).
$9\frac{1}{2}$	41	2	O. K. -- oscillated a bit.

D.

Rating	Flt.	Conf.	Pilot Comments
$5\frac{1}{2}$	77	2	It's fairly comfortable, but had to manhandle it. (It had a slow, sluggish response).
$6\frac{1}{2}$	81	2	All right.
8	51	1	Control was O. K., but not precise -- difficult to compensate for trim changes with power.

DRAG CASE: BOTTOM - GEAR

Question No. 14 Comment on the Visual Circling Approach.

A.

Rating	Flt.	Conf.	Pilot Comments
$2\frac{1}{2}$	46	2	Had tendency to set up substantial R/S.
2	44	1	Seemed good.
$3\frac{1}{2}$	51	2	High R/S turning base, some difficulty on glide slope.
$3\frac{1}{2}$	57	1	Comfortable except high R/S turning base.
4	37	2	Went well as long as pilot cross checked with airspeed.
$3\frac{1}{2}$	42	2	No problem -- pick up a R/S, but had plenty of compensating power.

B.

Rating	Flt.	Conf.	Pilot Comments
$3\frac{1}{2}$	47	2	Went fairly well. It stayed on pretty much, but pilot had to work at it.
$3\frac{1}{2}$	43	1	Had pretty good R/S, so didn't pull throttle off when pilot turned base, and that worked fine.
$3\frac{1}{2}$	62	2	Normal except didn't have a big sink rate because of the cross wind.
4	40	2	Fairly comfortable.
4	46	1	Didn't pick up excessive R/S. Turning base was fairly comfortable (rpm = 85 - 86%). Turbulence might have been a problem.
5	44	2	Able to take off power down to about 85% and didn't develop the large sink rate in the initial turn on the base that have been experienced on some.
$5\frac{1}{2}$	43	2	Different -- had to re-engage on the downwind.
$6\frac{1}{2}$	47	1	Fairly comfortable.
7	37	1	Went fairly well.
8	45	1	Had airspeed troubles because of attitude control problems.

C.

Rating	Flt.	Conf.	Pilot Comments
2	42	1	Was comfortable.
$2\frac{1}{2}$	55	1	
3	77	1	
3	39	2	Good -- seem to have reasonable control.
3	40	1	Fair.

DRAG CASE: BOTTOM - GEAR

Question No. 14 Comment on the Visual Circling Approach (Cont.)

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
$5\frac{1}{2}$	41	1	Moderately comfortable.
$4\frac{1}{2}$	45	2	When pilot turned base and took off power, didn't get high R/S like some configurations.
$9\frac{1}{2}$	41	2	Not too bad.

D.

Rating	Flt.	Conf.	Pilot Comments
$5\frac{1}{2}$	77	2	It was normal.
$6\frac{1}{2}$	81	2	Attitude tended to wander and airspeed got off. Moderate sink rate in turns but controllable with throttle.
8	51	1	Downwind -- had airspeed and altitude troubles -- had to add power due to high R/S.

DRAG CASE: BOTTOM - FLAPS

MAJOR PROBLEM

A.

Rating	Flt.	Conf.	Problem	Pilot Comments
$2\frac{1}{2}$	73	2		Very good configuration; slight objections-- 1) initial response was abrupt, 2) attitude response on sensitive side; quite good on mirror approaches; had an acceptable drag rise with angle of attack; good attitude control; good airspeed control.
$3\frac{1}{2}$	78	2	Airspeed altitude	Good pitch characteristics; objectionable drag characteristics; good attitude control; the combination of maintaining airspeed and altitude was main problem.
$3\frac{1}{2}$	64	1	Low pitch damping	Stable airspeed, noticeable drag rise with angle of attack; a little too light on pitch damping; had tail wind.
4	71	2	Lacked good precise control to be satisfactory	Pitch characteristics were only fair; Drag rise with angle of attack; airspeed was stable; during approach, the system went off; attitude control was a little on the slow side.
4	57	2	Adjusting to configuration	Attitude control was satisfactory; when visual, tended to be nose high and then airspeed got low; some trouble was due to learning to fly this type of configuration; lack of positive flight pattern control. System disengaged.

B.

Rating	Flt.	Conf.	Problem	Pilot Comments
5	73	1	Short period response airspeed	Drag rise with angle of attack produces some airspeed problems; slow, sluggish short period response; attitude control fair; airspeed is the principle problem of configuration; have to overdrive response; got slow when distracted by traffic. Caused rating $4\frac{1}{2}$ -- 5.
5	59	1	Attitude control airspeed	Not much pitch stiffness, creates control difficulties and reduces preciseness of control; airspeed problems probably caused by lack of precise attitude control and drag rises with angle of attack.

DRAG CASE: BOTTOM - FLAPS

MAJOR PROBLEM

B. (Cont.)

Rating	Flt.	Conf.	Problem	Pilot Comments
$4\frac{1}{2}$	62	1	Pitch response slightly slow oscillation on glide slope.	Must use tight attitude stabilization. (High sink rate in turns due to high drag rise with angle of attack).
5	61	2	Pitch little slow Airspeed	Did not make approaches.
5	64	2	Poor pitch characteristics (attitude control)	Response to control inputs was sluggish; low stiffness, low damping, couldn't overdrive the response enough; can't fly precisely -- lacked the feeling of good positive control; attitude control is unsatisfactory.
$7\frac{1}{2}$	66	2	Pitch characteristics: High drag rise with angle of attack; trim; altitude; airspeed.	Stiffness and pitch response way too low; no precise control, especially in final stages of approach where you need it most; attitude control is unsatisfactory and at times unacceptable; both attitude and drag characteristics cause altitude problems and airspeed problems.

C.

Rating	Flt.	Conf.	Problem	Pilot Comments
5	60	2	Airspeed a little bit in turbulence; attitude control	Oscillatory response to turbulence; airspeed trouble in rough air; good airspeed control; need more pitch damping; good positive angle of attack stiffness.
4	66	1	Bobbling	Bobbling tendency in turbulence; good stiffness but too lightly damped.
$3\frac{1}{2}$	58	2	Low pitch damping	A little looseness in pitch; a fair drag rise with angle of attack; attitude control was marginally O.K The light pitch damping may cause trouble in turbulence.
6	80	1	Pitch damping; poor visibility. Attitude gyro may not be working right.	Lightly damped--loose in pitch; attitude reference wasn't good; attitude control was unsatisfactory (poor); turbulence made rate of sink uncomfortable; needed tight attitude control; didn't feel he had real good airspeed control.

DRAG CASE: BOTTOM - FLAPS

MAJOR PROBLEM

C. (Cont.)

Rating	Flt.	Conf.	Problem	Pilot Comments
6	71	1	Drag characteristics; airspeed	Good attitude control; had trouble establishing a specific rate of sink; airspeed and drag sensitive to angle of attack changes; unstable airspeed.
5½	59	2	Airspeed. Attitude control	Lightly damped -- loose in pitch; responsive to turbulence, airspeed wasn't too much of a problem with high drag rise with angle of attack; airspeed tended to get both fast and slow.

D.

Rating	Flt.	Conf.	Problem	Pilot Comments
4½	78	1	Short period characteristics; attitude control	Configuration feels loose in pitch; drag characteristics not objectionable; airspeed requires good throttle with angle of attack; have to overdrive configuration and add damping.
7	80	2	Attitude response maintaining altitude; attitude control; specific rate of sink	Poor attitude characteristics; trouble staying on glide slope in turbulence; damping is too low and long response time; not a good aircraft for carrier landings; difficult to trim; had to overdrive configuration; attitude control marginally acceptable; need tight attitude control to maintain altitude and rate of sink; attitude control causes some airspeed problems.

DRAG CASE: BOTTOM - FLAPS

General Comments on Control Technique

A.

Rating	Flt.	Conf.	Pilot Comments
$2\frac{1}{2}$	73	2	Quite good on the glide slope. It seemed to seek its own airspeed. I didn't have to worry much about airspeed. Did three mirror approaches. I might comment that the mirror approaches were quite good, in spite of the nose-down attitude and I found that with this nose-down attitude, I have more of a tendency to watch the touch-down point and look for relative motion of it. Also watching the mirror. If the airspeed was off a little bit, you had good cues of it and the airplane tended to nose down if it was slow and nose up if it was fast. On the glide slope about all I had to do was adjust the throttle, if I had altitude errors; otherwise I just drove the thing down and held my attitude. Had some disturbances but, even so, it wasn't too difficult.
$3\frac{1}{2}$	78	2	On the second approach, I pulled off the throttle and was able to change the flight path to downward quite rapidly. It didn't heave like the previous one. I took off a little more power than on the first one and held the airspeed well. I didn't have to fly it tight in attitude with this one. It just wanted to; all I had to do was set the power about right and control the attitude, but it kind of maintained its own attitude. The angle of attack is stable and all I had to do was control the trim attitude. I didn't feel the lack of good pitch attitude references like I did the first configuration.
$3\frac{1}{2}$	64	1	Nose Attitude - I know that I've had trouble with the nose-down attitude on other configurations in staying on the glide slope and controlling my attitude, but I didn't take any particular pains to track attitude right tightly or anything and I got no bug spots on the windshield. Yet with the nose-down attitude, I was able to do all right.
4	71	2	With the nose-down attitude, I don't have a strong attitude sense in the approach, I found a spot on the the windshield that was somewhat helpful, but it wasn't really visible enough to be a great deal of help. I could use a stronger sense of my attitude with this configuration. Whenever you make a throttle change, the elevator is used to make a corresponding attitude change.

DRAG CASE: BOTTOM - FLAPS

General Comments on Control Technique (Cont.)

A. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
4	57	2	Elevator Control - Used elevator to control attitude and the attitude commands airspeed and altitude on the glide slope. In other words, when I make a throttle change to correct for altitude error; say high, then I have to nose down in order to keep on airspeed. This is what I tended not to do with this configuration. I tended to keep the attitude because of a reluctance to push the nose any further down than it already was, especially with the landing gear up; and consequently the airspeed would bleed off.

B.

Rating	Flt.	Conf.	Pilot Comments
5	73	1	No specific comment.
5	59	1	On Glide Slope - When you pull the throttle off, you really have to push the nose down to go back on. The airplane doesn't have much of a tendency to change attitude when there are airspeed changes. It doesn't nose down when you pull the power off, it just hangs there and the airspeed bleeds, you really have to push the nose over.
			I used the throttle to control altitude and attitude to control airspeed but there was a lot of cross talk between the two.
$4\frac{1}{2}$	62	1	On Glide Slope - I seemed to have a long period oscillation on the glide slope. I was oscillating between a slight low and an on-course long period, had two cycles from about $1\frac{1}{2}$ miles out. The first approach was kind of galloping one and I didn't seem to be able to make a correction and get it steadied down.
			The second approach though I carefully set up 80% rpm which is about right for this fuel remaining and decided I would try to stay out of this galloping oscillation by a tight attitude stabilization. I used bug spots on the windshield and tried to keep my attitude deviations very small and I made that approach with essentially constant throttle and bleeding just a slight amount of airspeed. Got down to about 157 kt in the front (162 kt nominal), but I didn't seem to be picking up any excessive sink rate. However, I did wave off a bit sooner.

DRAG CASE: BOTTOM - FLAPS

General Comments on Control Technique (Cont.)

B. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	62	1	I'm sure from flying the approach with this configuration that I'm influenced by my attitude display or reference. On the glide slope, the absence of the nose near the aim point of the glide path is a detriment with this configuration. When I forced myself to use spots on the windshield, I did better; with more tight attitude stabilization I got away from that galloping type oscillation.
5	61	2	No specific comments.
5	64	2	Flying level and intersect glide slope:

1. Pull back power to estimate of what is required on glide slope.
2. Nose over to attitude, to estimate of right attitude.
3. Then monitor glide slope and airspeed and attitude to see how good estimates were.
   a. Airspeed low - Add throttle, then as airspeed starts to come back, you ease nose over.
   b. If high in altitude but on airspeed - Take off some power and nose down to keep airspeed constant until you're near glide slope. Then bring nose up and add power which you estimate will keep you on glide slope.
   c. Low and slow - Add throttle to try to get airspeed back, try to get altitude back if this is consistent with keeping airspeed coming back.
   d. High and slow - Nose over and depending on drag characteristics maybe add power. It depends on how large the errors are also. On some configurations, if you nose over and adjust angle of attack you effectively accelerate so rapidly that you can just nose over, but for most of the time you'd add power. Low airspeed is a worrisome area.

DRAG CASE: BOTTOM - FLAPS

General Comments on Control Technique (Cont.)

B. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
$7\frac{1}{2}$	66	2	Something that has become clear to me today in flying two configurations with inadequate pitch response. That is, where it really gets you into trouble is down close in. You need a pretty precise control of the flight path and, therefore, of the attitude. Close in the mirror gain goes up and becomes more precise indication of errors. To do good approaches you have to have precise control in the final stages so that any tendency to depart from the flight path can be corrected quickly because the time available to correct is becoming progressively smaller. With this one, you can struggle down with it until you get close in and then it gets away. You tend to overcontrol when you use throttle to control airspeed errors, but you have to. At least on the glide slope, that is true. In other words, I was on glide slope and I was low on airspeed and so I had to add throttle and I tended to get fast.
5	60	2	No specific comments.
4	66	1	On Glide Slope - I was quite comfortable. I was able to make corrections and the airspeed would tend to go off, but I sensed when the airspeed would tend to go off, I would get a stick force feel. In other words, the airplane had enough angle of attack stability that if I got off airspeed, I had cues of this and the airplane would tend to nose down, let's say, so I'd note that I had to add a little power to accommodate the sink rate that I was going to pick up.
$3\frac{1}{2}$	58	2	Nose Attitude - I might comment here, that one thing that perhaps influences me is that, with this large nose-down attitude, I have a little less perception of pitch attitude during this nose down descent portion (descending and turning on visual go-around). In other words, I'm banked up, my nose is pointed down and I don't have a good pitch attitude reference. I think with a more nose-up pitch attitude, the nose is up nearer the horizon when the flight path is the same; hence, you end up with a little better perception of (more sensitive perception) what the attitude of the airplane is ----- I've heard this comment before from other pilots, and I've felt this myself. The airplanes that have real excellent visibility out the nose leave something to be desired in the way of pitch attitude reference.

DRAG CASE: BOTTOM - FLAPS

General Comments on Control Technique (Cont.)

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
$3\frac{1}{2}$	58	2 (Cont.)	I think it was Tymczyczm of the FAA said on the 707's they painted some cross hairs on the windshield, just to give him an attitude reference. I think a little bit of this is bothering me here with this configuration and that is why I keep going off the glide slope.
			On Glide Slope - During the descent I got off high, I pushed the nose over and got back on the glide slope. In fact, I was perhaps oscillating a little bit about the glide slope at constant throttle and I was controlling altitude a little bit with elevator. This was fairly high frequency and would not have been satisfactory for large errors probably. One of the reasons I kept going off was that I wasn't in good trim. Also, I think I have less perception of my pitch attitude when the nose is down.
6	80	1	Trouble on Glide Slope - My lack of good attitude reference bothered me.
			Definitely have to keep after the attitude when making throttle corrections.
6	71	1	On the second approach I made an intentional high and found it very difficult to correct, but I got back down on the glide slope by pulling off lots of throttle, but once I got down, I couldn't get the throttle back on at the right amount to keep the airplane on the glide slope.
$5\frac{1}{2}$	59	2	No specific comment.

D.

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	78	1	I object to the lack of a strong attitude sense, i.e., something to line up with the touchdown point. I had to constantly search for attitude cues.
			Did not have adequate sense of speed change in my force feel.
7	80	2	No specific comment.

DRAG CASE: BOTTOM - FLAPS

Question No. 1 Is the Airplane Difficult to Trim?

A.

Rating	Flt.	Conf.	Pilot Comments
2½	73	2	No. Easy.
3½	78	2	No. Easy.
3½	64	1	Little loose, damping low.
4	71	2	Slightly difficult -- takes time.
4	57	2	Slightly difficult.

B.

Rating	Flt.	Conf.	Pilot Comments
5	73	1	Satisfactory but not good.
5	59	1	Yes -- a little bit -- doesn't have a lot of pitch stiffness and response time to the short period is moderately long.
4½	62	1	Only slightly.
5	61	2	Somewhat difficult.
5	64	2	A little objectionable due to slow short period.
7½	66	2	Yes, quite difficult due to low pitch stiffness.

C.

Rating	Flt.	Conf.	Pilot Comments
5	60	2	Yes, a little bit -- the response time in airspeed to a given trim angle is fairly long.
4	66	1	No. Easy.
3½	58	2	No -- not the easiest, but not difficult either.
6	80	1	No. Pretty easy.
6	71	1	Slightly difficult, short period little slow.
5½	59	2	No, but lack of horizon forced pilot to trim up using instruments which made it more difficult.

D.

Rating	Flt.	Conf.	Pilot Comments
4½	78	1	No. Had to wait for short-period transient.
7	80	2	Yes, because of slow, low-damped short period.

DRAG CASE: BOTTOM - FLAPS

Question No. 2 Is the Elevator Control Gain Satisfactory?

Rating	Flt.	Conf.	Pilot Comments
A.			
$2\frac{1}{2}$	73	2	Little heavy in turns, compromise to prevent initial response from being too abrupt.
$3\frac{1}{2}$	78	2	Good compromise, steady forces little heavy to avoid abruptness in initial pitch response.
$3\frac{1}{2}$	64	1	Selected such that have fairly heavy forces, but prevents initial response from being over-sensitive apparently due to light damping.
4	71	2	Yes, picked little heavy.
4	57	2	Yes.
B.			
5	73	1	Compromise O.K. BF=55 -- initial response too slow. BF=58 -- compromise.
5	59	1	Yes -- chose a little on the heavy side.
$4\frac{1}{2}$	62	1	Yes -- can sense stick motion before airplane response.
5	61	2	Difficult to select. BF = 60 -- too sensitive in level B = 55 -- too sluggish, particularly in turns. Choose B = 58 -- may be little heavy.
5	64	2	Airplane sluggish in pitch so picked high gain to permit overdriving. This is limited by light steady forces. Also, for high gain it tended to respond too fast once it got going.
$7\frac{1}{2}$	66	2	Compromise pilot selected high gain to permit overdriving pitch. Tend to PIO. Makes trimming difficult also.
C.			
5	60	2	Yes -- right maneuvering forces, but a little sensitive about trim.
4	66	1	Good compromise. BF = 60 initial response good but steady forces too high. BF = 65 steady forces good but transient response too high. BF = 62 compromise.
$3\frac{1}{2}$	58	2	Yes -- but a little on the heavy side.
6	80	1	Yes.
6	71	1	Yes. Satisfactory compromise. Picked so steady forces are little heavy because with higher BF the transient response too fast becomes loose in pitch.
$5\frac{1}{2}$	59	2	Yes -- good compromise and didn't run out of trim.

DRAG CASE: BOTTOM - FLAPS

Question No. 2 Is the Elevator Control Gain Satisfactory? (Cont.)

D.

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	78	1	Compromise. If initial response was O.K.; the steady forces are too high. If steady forces O.K., then initial response too loose.
7	80	2	Only looked at one value and it seemed satisfactory. However, I did not have ability to correct for disturbances on glide slope. Not sure whether higher gain would have helped. Have to overdrive configuration and don't seem to have control power to do it.

DRAG CASE: BOTTOM - FLAPS

Question No. 3 Is Attitude Control Satisfactory?

Rating	Flt.	Conf.	Pilot Comments
A.			
2½	73	2	Yes, definitely. However, pullups nose tends to stop and then move on.
3½	78	2	Yes.
4	71	2	Yes, although maybe little slow.
4	57	2	Yes.
B.			
5	73	1	Fair, slow and sluggish.
5	59	1	No -- pilot objected to it (not good enough); it's slow and creates control difficulties and reduces the preciseness of control.
4½	62	1	Slightly unsatisfactory, i.e., slow.
5	61	2	Little difficulty.
5	64	2	Unsatisfactory, too slow.
7½	66	2	No. Too slow. Unacceptable in final part of approach.
C.			
5	60	2	No -- should have more pitch damping -- not too bad in smooth air, but it bucked in turbulence.
4	66	1	No, damping too low; stiffness good.
3½	58	2	Yes, but only marginally so.
6	80	1	No, loose in pitch due to low damping ratio.
5½	59	2	No -- it's objectionable enough to complain about. Damping should be better.
D.			
4½	78	1	No. Stiffness too low and damping too low. Inadequate speed sense in stick force.
7	80	2	No, loose in pitch due to low damping ratio.

DRAG CASE: BOTTOM - FLAPS

Question No. 4 Is Maintaining Altitude a Problem?
a) Straight and Level
b) Turns

A.

Rating	Flt.	Conf.	Pilot Comments	
$2\frac{1}{2}$	73	2	a) Slightly.	b) No.
$3\frac{1}{2}$	78	2	a) Yes.	b) Yes. Not too clear in objections.
$3\frac{1}{2}$	64	1	a) No.	b) No.
4	71	2	a) & b) Didn't do very much on this task. But got the impression it was little imprecise.	
4	57	2	a) No.	b) No (incomplete evaluation)

B.

Rating	Flt.	Conf.	Pilot Comments	
5	73	1	a) and b) No.	
5	59	1	a) No.	b) No.
$4\frac{1}{2}$	62	1	a) No.	b) Yes. Do better with tight attitude control.
5	61	2	a) Yes	b) Yes
5	64	2	a) Responds to low frequency turbulence, i.e., heaves.	b) Must control attitude carefully to maintain attitude.
$7\frac{1}{2}$	66	2	a) Yes.	b) Yes. Poor attitude control coupled with need tocoordinate throttle with angle of attack.

C.

Rating	Flt.	Conf.	Pilot Comments	
5	60	2	a) A little bit due to large response time in airspeed.	b) Not the greatest, but the altitude gains or losses were not large.
4	66	1	a) No.	b) No, provided throttle coordinate with angle of attack.
$3\frac{1}{2}$	58	2	a) No -- airspeed bleed slightly	b) A little -- had to add power as a function of angle of attack.
6	80	1	a) Some problem but may have been due to attitude.	b) Quite good.
6	71	1	a) No.	b) No must coordinate power.
$5\frac{1}{2}$	59	2	a) Not much.	b) Not much.

DRAG CASE: BOTTOM - FLAPS

Question No. 4 Is Maintaining Altitude a Problem? (Cont.)

D.

Rating	Flt.	Conf.	Pilot Comments	
$4\frac{1}{2}$	78	1	a) Not too difficult.	b) Had to fly attitude tightly to do a good job.
7	80	2	a) Yes, must use tight attitude control and this is somewhat difficult due to lack of attitude reference.	b) Yes, same reasons as (a).

DRAG CASE: BOTTOM - FLAPS

Question No. 5 Can You Establish a Specific Rate of Descent?

A.

Rating	Flt.	Conf.	Pilot Comments
2½	73	2	Yes.
3½	78	2	Fairly good. Airplane responded to turbulence, which caused some objection.
3½	64	1	Required some attention but O. K.
4	71	2	Not very well.
4	57	2	Yes -- but incomplete evaluation.

B.

Rating	Flt.	Conf.	Pilot Comments
5	73	1	Apparently yes.
5	59	1	Yes -- except turbulence attitude which disturbed airspeed.
4½	62	1	Difficult to establish.
5	61	2	Didn't do.
5	64	2	Somewhat difficult due to poor attitude control.
7½	66	2	Not very well. Must use tight attitude control.

C.

Rating	Flt.	Conf.	Pilot Comments
5	60	2	Yes.
4	66	1	Quite well.
3½	58	2	Yes -- except turbulence upset trim.
6	80	1	No, have turbulence and low damping make holding attitude difficult.
6	71	1	Not very well.
5½	59	2	Yes -- airspeed tends to get off.

D.

Rating	Flt.	Conf.	Pilot Comments
4½	78	1	Didn't get good look. Saw no real objections.
7	80	2	No, difficult. Had to use tight attitude control. If scan pattern is interrupted, it was very difficult.

DRAG CASE: BOTTOM - FLAPS

Question No. 6 Is Maintaining Airspeed a Problem?

A.

Rating	Flt.	Conf.	Pilot Comments
$2\frac{1}{2}$	73	2	No. Quite good.
$3\frac{1}{2}$	78	2	Principal problem. Maintaining altitude and airspeed together.
$3\frac{1}{2}$	64	1	Yes, must coordinate throttle in turns.
4	71	2	Some difficulty on mirror.
4	57	2	Little bit, but may be due to pilot (new type of configuration).

B.

Rating	Flt.	Conf.	Pilot Comments
5	73	1	Yes. Although changes fairly slowly.
5	59	1	Yes -- both fast and slow.
$4\frac{1}{2}$	62	1	Yes -- airspeed response connected by loose spring to airplane.
5	61	2	Yes, particularly in turns.
5	64	2	Not serious, problem was presumably due to low pitch stiffness.
$7\frac{1}{2}$	66	2	Yes, due as much to attitude control as to drag.

C.

Rating	Flt.	Conf.	Pilot Comments
5	60	2	Yes -- especially in turbulence.
4	66	1	Did not comment specifically.
$3\frac{1}{2}$	58	2	No particular problems, however, airspeed-wise it's not the best configuration either.
6	80	1	Yes, didn't have good control unless I was tight on the instruments.
6	71	1	Yes, have to add throttle with angle of attack.
$5\frac{1}{2}$	59	2	Yes, due to drag characteristics and the lack of precise attitude control.

D.

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	78	1	Requires throttle coordination with angle of attack. Also, same throttle setting applies for 160 and 168 knots.
7	80	2	Yes. Poor attitude control and turbulence contributes.

DRAG CASE: BOTTOM - FLAPS

Question No. 7 What Instruments are You Using Most?

A.

Rating	Flt.	Conf.	Pilot Comments
$2\frac{1}{2}$	73	2	Attitude, (airspeed, altitude, rate of climb, heading, RPM) second.
$3\frac{1}{2}$	78	2	Attitude and airspeed, altitude, rate of climb.
$3\frac{1}{2}$	64	1	Attitude -- airspeed, altitude, rate of climb, and RPM, heading.
4	71	2	Attitude and strong cross check with airspeed, rate of climb, altitude, heading and RPM when throttle is changed. Nose down attitude -- does not have any good reference to use to control pitch attitude.
4	57	2	Attitude, airspeed, 2nd throttle, rate of climb, altimeter, heading.

B.

Rating	Flt.	Conf.	Pilot Comments
5	73	1	Attitude and airspeed, altitude, rate of climb, heading and RPM.
5	59	1	1st, attitude, 2nd airspeed, rate of climb, altimeter, heading, angle of attack, throttle.
$4\frac{1}{2}$	62	1	Attitude -- airspeed, rate of climb, altitude, RPM, heading.
5	61	2	Evaluation not completed.
5	64	2	Attitude 1st, airspeed, rate of climb, altitude, RPM, Note that power is adjusted by feel for throttle position and not by looking at and reading % RPM every time.
$7\frac{1}{2}$	66	2	Attitude -- airspeed, altitude, rate of climb, heading, RPM. Check RPM when throttle is changed.

C.

Rating	Flt.	Conf.	Pilot Comments
5	60	2	1st attitude and airspeed, 2nd rate of climb, altimeter, heading, throttle, RPM.
4	66	1	Attitude -- airspeed, rate of climb, altitude, RPM,heading.
$3\frac{1}{2}$	58	2	1st attitude, airspeed, 2nd rate of climb, altitude, throttle, heading.
6	80	1	Attitude and cross check airspeed; altitude, rate of climb, heading, RPM.
6	71	1	Attitude and airspeed, rate of climb, altitude, heading PRM when changing power.
$5\frac{1}{2}$	59	2	1st attitude, airspeed, 2nd, rate of climb, altimeter, heading, angle of attack, throttle.

DRAG CASE: BOTTOM - FLAPS

Question No. 7 What Instruments are You Using Most? (Cont.)

D.

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	78	1	Attitude and airspeed, altitude, heading, rate of climb, and RPM.
7	80	2	Attitude! Airspeed, altitude, rate of climb, heading, RPM when throttle is changed.

DRAG CASE: BOTTOM - FLAPS

Question No. 8 Is a Special Control Technique Required?

A.

Rating	Flt.	Conf.	Pilot Comments
$2\frac{1}{2}$	73	2	No, only to add little throttle with angle of attack.
$3\frac{1}{2}$	78	2	Yes, throttle with angle of attack and airspeed errors.
$3\frac{1}{2}$	64	1	Tight attitude control.
4	71	2	Only throttle with angle of attack.
4	57	2	None.
B.			
5	73	1	Yes, must overdrive and coordinate throttle with angle of attack.
5	59	1	None, except maybe a slight overdriving of the configuration.
$4\frac{1}{2}$	62	1	Tight attitude stability.
5	61	2	Evaluation not completed.
5	64	2	Overdrive with elevator to get desired pitch response.
$7\frac{1}{2}$	66	2	Yes overdrive it, or lead it.
C.			
5	60	2	None, except close throttle with angle of attack more than normally.
4	66	1	No special except smooth elevator inputs.
$3\frac{1}{2}$	58	2	Throttle closure with angle of attack and with airspeed errors.
6	80	1	Must use tight attitude control. Also, throttle with α.
6	71	1	Yes, throttle proportional to airspeed. Lots of it.
$5\frac{1}{2}$	59	2	None, except throttle closure with angle of attack and airspeed.
D.			
$4\frac{1}{2}$	78	1	Yes, must stiffen and damp short period. Coordinate throttle.
7	80	2	Overdrive it in pitch, throttle with angle of attack.

DRAG CASE: BOTTOM - FLAPS

Question No. 9 Are Throttle Adjustments Necessary?
Are They Used to Control: Attitude? RC? Other?
Altitude? Airspeed

A.

Rating	Flt.	Conf.	Pilot Comments
$2\frac{1}{2}$	73	2	Coordinate with angle of attack, adjust for rate of climb, altitude on glide slope, and airspeed when in error.
$3\frac{1}{2}$	78	2	Coordinate with angle of attack, adjust rate of climb, altitude on glide slope, airspeed errors.
$3\frac{1}{2}$	64	1	Coordinate with angle of attack, adjust for rate of climb, airspeed, altitude errors on glide slope.
4	71	2	Coordinate with angle of attack, adjust for airspeed, altitude errors on glide slope.
4	57	2	Rate of climb, altitude on glide slope, airspeed errors.

B.

Rating	Flt.	Conf.	Pilot Comments
5	73	1	Coordinate with angle of attack, adjust for rate of climb, attitude and heading on the glide slope.
5	59	1	Rate of climb, angle of attack changes, airspeed errors, altitude on glide slope.
$4\frac{1}{2}$	62	1	Coordinate with angle of attack; corrections for angle of attack, rate of climb, altitude on glide slope.
5	61	2	Evaluation not completed.
5	64	2	Coordinate with angle of attack, adjust for rate of climb, airspeed, altitude errors on glide slope.
$7\frac{1}{2}$	66	2	Coordinate with angle of attack, adjust for rate of climb, airspeed, altitude on the glide slope. Tend to overcontrol when use throttle for airspeed.

C.

Rating	Flt.	Conf.	Pilot Comments
5	60	2	Yes -- rate of climb, airspeed errors, angle of attack changes.
4	66	1	Coordinate with angle of attack, adjust for rate of climb, airspeed, altitude on the glide slope.
$3\frac{1}{2}$	58	2	Rate of climb, angle of attack, airspeed errors, altitude on glide slope.
6	80	1	Some coordination with angle of attack, adjust for rate of climb, altitude on glide slope and for airspeed errors.
6	71	1	Coordinate with angle of attack, adjust for airspeed, altitude errors on glide slope.
$5\frac{1}{2}$	59	2	Rate of climb, angle of attack, airspeed errors, altitude on glide slope.

DRAG CASE: BOTTOM - FLAPS

Question No. 9 Are Throttle Adjustments Necessary? (Cont.)

D.

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	78	1	Coordinate with angle of attack, adjust rate of climb, altitude on glide slope, airspeed errors.
7	80	2	Coordinate with angle of attack, adjust for rate of climb, altitude on the glide slope, and airspeed errors.

DRAG CASE: BOTTOM - FLAPS

Question No. 10 Is Elevator Used to Control Attitude? R/C? Other? Altitude? Airspeed? n_z?

A.

Rating	Flt.	Conf.	Pilot Comments
$2\frac{1}{2}$	73	2	Attitude -- altitude and airspeed through attitude. Airplane had good cues of airspeed errors through stick.
$3\frac{1}{2}$	78	2	Attitude -- altitude and airspeed through attitude.
$3\frac{1}{2}$	64	1	Attitude 1st, airspeed and altitude on glide slope.
4	71	2	Attitude -- coordinate attitude with throttle changes.
4	57	2	Attitude, airspeed, altitude.

B.

Rating	Flt.	Conf.	Pilot Comments
5	73	1	Attitude -- altitude and airspeed through attitude.
5	59	1	Attitude, airspeed, altitude on glide slope.
$4\frac{1}{2}$	62	1	Attitude primary, airspeed second, altitude errors on glide slope.
5	61	2	Not completed.
5	64	2	Attitude -- use attitude to change airspeed and altitude.
$7\frac{1}{2}$	66	2	Attitude controls airspeed and altitude errors.

C.

Rating	Flt.	Conf.	Pilot Comments
5	60	2	1st attitude, 2nd, airspeed, altitude on glide slope.
4	66	1	Attitude -- attitude commands are airspeed and altitude errors on the glide slope.
$3\frac{1}{2}$	58	2	Attitude, airspeed, altitude on glide slope.
6	80	1	Attitude -- altitude and airspeed through attitude; have to keep after attitude.
$5\frac{1}{2}$	59	2	Attitude, airspeed, altitude on glide slope.

D.

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	78	1	Attitude -- have to push nose around.
7	80	2	Attitude -- altitude and airspeed through attitude.

DRAG CASE: BOTTOM - FLAPS

Question No. 11 Could You Make an Instrument Landing Approach with this Configuration at This Speed?

A.

Rating	Flt.	Conf.	Pilot Comments
$2\frac{1}{2}$	73	2	Definitely.
$3\frac{1}{2}$	78	2	Definitely, principal problem would be maintaining altitude and airspeed.
4	71	2	Definitely -- but could be more satisfactory.
4	57	2	Yes, under all conditions (reasonable).
B.			
5	73	1	Yes, but could be better.
5	59	1	Yes, a safe one and acceptable, but an unsatisfactory one.
$4\frac{1}{2}$	62	1	Definitely.
5	61	2	Not completed.
5	64	2	Yes.
$7\frac{1}{2}$	66	2	Under reasonable circumstances. But there is no margin for unusual circumstances.
C.			
5	60	2	Yes.
4	66	1	Definitely -- but throttle coordination would be troublesome in bad weather, etc.
$3\frac{1}{2}$	58	2	Yes -- but turbulence might cause some trouble.
6	80	1	Yes -- but I wouldn't like it.
6	71	1	Yes -- but not comfortable. Control of altitude and airspeed close to ground is not as good as pilot would like.
D.			
$4\frac{1}{2}$	78	1	Yes.
7	80	2	Probably but you would be praying.

DRAG CASE: BOTTOM - FLAPS

Question No. 12 What Happens When You Transition to Visual Flight? How Do You Fly the Visual Approach, Particularly Regarding Glide Slope Control? Are You Checking Airspeed and/or Angle of Attack on Final? If So, When Do You Quit?

A.

Rating	Flt.	Conf.	Pilot Comments
2½	73	2	Quite good, used throttle for altitude errors on the glide slope.
3½	78	2	Quite good -- if power was set right it was easy to make approaches. Had good pitch characteristics.
3½	64	1	Went well, was not troubled by nose-down attitude as much as on other flap configuration. Airspeed not much of a problem either.
4	71	2	Fairly well -- airspeed required attention. Checked airspeed to ¼ mile, did not check angle of attack.
4	57	2	Transition (this is where problems began -- not familiar with this type of configuration, visual airspeed tended to bleed) airspeed - ¼ mile.

B.

Rating	Flt.	Conf.	Pilot Comments
5	73	1	Poor visibility, very smooth air, had to use tight attitude control on glide slope. Didn't seem to have enough control over attitude with elevator.
5	59	1	On glide slope (throttle to control altitude and attitude.
4½	62	1	First approach had low frequency oscillation on glide slope. Second approach used tight attitude control (used bug spots on window) and essentially fixed throttle. Airspeed bleeds a little.
5	61	2	Not completed.
5	64	2	Moderately well.
7½	66	2	Could transition O.K., but at 1-2 miles things would start to happen due mainly to poor attitude control. Also turbulence heaves airplane off glide slope.

C.

Rating	Flt.	Conf.	Pilot Comments
5	60	2	Transition (went fairly well), visual (had some airspeed troubles -- then system disengaged). Airspeed ¼ mile.
4	66	1	Quite comfortable. It had stick force feel to indicate airspeed errors.

DRAG CASE: BOTTOM - FLAPS

Question No. 12 What Happens When You Transition to Visual Flight, etc.? (Cont.)

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
$3\frac{1}{2}$	58	2	Visual (flew glide slope controlling altitude errors with throttle and attitude with elevator).
6	80	1	Never felt good with this one, watched airspeed all way down. Didn't perform very well with it.
6	71	1	Transition went well but control of altitude and air-speed on the glide slope was problem. Correcting a high was particularly troublesome.
$5\frac{1}{2}$	59	2	Transition (had trouble interpreting the glide slope--unsatisfactory; 2nd one was good), visual (high and fast; 2nd one right on airspeed and glide slope all the way, but had to fly tight loop).

D.

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	78	1	Adequate but airplane was big and unresponsive. Had tail wind. Had to look for attitude cues.
7	80	2	If gust hits airplane it heaves off glide slope and the pilot must use elevator to correct but the short period response is very low. Also pilot is reluctant to jam stick forward to correct heave because if he overdoes it, he may not be able to recover.

DRAG CASE: BOTTOM - FLAPS

Question No. 13 Comment on the Wave-Off

A.

Rating	Flt.	Conf.	Pilot Comments
$2\frac{1}{2}$	73	2	Good.
$3\frac{1}{2}$	78	2	Very comfortable.
$3\frac{1}{2}$	64	1	O.K. Got little slow on one.
4	71	2	Comfortable.
4	57	2	Went reasonably well.

B.

Rating	Flt.	Conf.	Pilot Comments
5	73	1	O.K.
5	59	1	O.K. -- had a little airspeed control difficulty.
$4\frac{1}{2}$	62	1	Went well first time, took little sooner on second.
5	61	2	Not done
5	64	2	O.K.
$7\frac{1}{2}$	66	2	O.K. -- not much excess thrust.

C.

Rating	Flt.	Conf.	Pilot Comments
5	60	2	(Didn't see much of it -- disengaged on wave-off)
4	66	1	Comfortable--tended to lose little airspeed.
$3\frac{1}{2}$	58	2	Airspeed stayed under control.
6	80	1	No problem.
6	71	1	No comment.
$5\frac{1}{2}$	59	2	O.K. -- except got a little fast and used a lot of throttle, so there may have been R/S problems.

D.

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	78	1	O.K.
7	80	2	No comment.

DRAG CASE: BOTTOM - FLAPS

Question No. 14 Comment on the Visual Circling Approach.

Rating	Flt.	Conf.	Pilot Comments
A.			
$2\frac{1}{2}$	73	2	O. K. Steady forces in turns slightly heavy.
$3\frac{1}{2}$	78	2	O. K. -- but had difficulty finding throttle and attitude for level flight.
$3\frac{1}{2}$	64	1	Moderately comfortable; have to close throttle loop.
4	71	2	Some difficulty getting the right power setting.
4	57	2	Much better than first one.
B.			
5	73	1	O. K. Some complaint about attitude control.
5	59	1	Used a lot of throttle and R/S = 0.
$4\frac{1}{2}$	62	1	O. K. Could make fairly steep turn.
5	61	2	Not done.
5	64	2	O. K.
$7\frac{1}{2}$	66	2	Fair.
C.			
5	60	2	Had a R/S (should've brought power up to 89-90% instead of 88% -- slow airspeed response time).
4	66	1	Have to use throttle.
$3\frac{1}{2}$	58	2	Used throttle to control R/S and airspeed, but felt like a good positive control.
6	80	1	Wasn't comfortable. High sink rate on down-wind turn.
6	71	1	High sink rate on down-wind turn. Tended to get slow in climb.
$5\frac{1}{2}$	59	2	Went well.
D.			
$4\frac{1}{2}$	78	1	O. K. but poor attitude control made difficult.
7	80	2	Airplane doesn't take care of itself enough.

DRAG CASE: BACK SIDE

Major Problem

A.

Rating	Flt.	Conf.	Problem	Pilot Comments
5	49	2	Airspeed	Attitude control was good; airspeed very sensitive to angle of attack. System dumped several times.
4	74	1	Airspeed; drag rise with angle of attack	Very high drag rise with angle of attack. A little too much short period stiffness. Needs a little bit more damping; run out of power at high bank angles; rate of sink good. Rate of change in airspeed was slow, it could be handled.
$4\frac{1}{2}$	72	1	Airspeed; flight path	Configuration - good in pitch, poor in airspeed, poor drag-wise; drag causes airspeed troubles and flight path angle troubles; good attitude control.
$4\frac{1}{2}$	75	2	Drag characteristics; airspeed	Stiffer short period and better damped than 75-1; good; attitude control was satisfactory but little sluggish; couldn't control airspeed while trying to maintain a fixed flight path; objectionable drag characteristics.
$4\frac{1}{2}$	58	1	High drag rise with angle of attack. Airspeed	Satisfactory pitch control; a lot of power is required when drag increases with angle of attack, but it's manageable.
4	79	2	Airspeed control; altitude control.	Attitude characteristics are satisfactory (could have a little more damping); drag characteristics are bothersome; airspeed mode had light damping - get on high side or low side; maintaining altitude in turns was a problem due to airspeed errors and not attitude control.
6	48	2	Drag characteristics; attitude control	Attitude control should be better, sluggish; unsatisfactory; large drag increases with angle of attack.
4	63	1	(no record)	
$6\frac{1}{2}$	72	2	Learning to fly this low power required configuration; airspeed maintaining altitude.	Fairly large drag rise with angle of attack, but lower than normal power required; good attitude control.

DRAG CASE: BACK SIDE

Major Problem

B.

Rating	Flt.	Conf.	Problem	Pilot Comments
$4\frac{1}{2}$	68	1	Airspeed	Attitude control was on the borderline between satisfactory and unsatisfactory; airspeed always kept changing; tendency to overdrive configuration.
$5\frac{1}{2}$	75	1	Drag characteristics; attitude control	Short period was too slow and lightly damped; attitude control wasn't satisfactory; had to overdrive configuration a lot of throttle for angle of attack and airspeed errors; pitch not responsive to turbulence.
$5\frac{1}{2}$	82	2	Airspeed on mirror. Throttle coordination with maneuvers	Quite good pitch characteristics, little slow and sluggish. Miserable drag characteristics (airplane seems less stiff for pullup than it is for pushover. Gives impression of digging in). Can lose airspeed very fast if throttle is not coordinated with maneuvers. On mirror angle of attack high and fast, is very difficult to correct.
6	76	2	Attitude control; Maintaining altitude; airspeed drag characteristics	Short period is well damped but sluggish; attitude control is unsatisfactory but acceptable; maintaining altitude was a problem due to a combination of the drag characteristics and slow short period; throttle adjustments for angle of attack, airspeed, altitude, rate of climb; overdrove configuration.
6	61	1	Pitch characteristics; airspeed; high drag rise with angle of attack.	Aircraft too sluggish to fly precisely; high drag rise with angle of attack; airspeed slightly unstable.
8	82	1	Everything. Attitude, angle of attack, altitude, airspeed	(Airplane is nonlinear in response to elevator). Pretty terrible configuration. Can't fly level, hold airspeed, or rate of climb. Takes so much closed-loop control to "stagger" this around the altitude and airspeed you want that you can't do anything else.
7	53	1	Airspeed	Unstable in airspeed - high and low. So-so pitch characteristics.

DRAG CASE: BACK SIDE

Major Problem

C.

Rating	Flt.	Conf.	Problem	Pilot Comments
5	63	2	Attitude control air-speed; response to turbulence	Attitude control was slightly unsatisfactory; airspeed tended to get too fast, this is partly due to over estimating the drag rise due to angle of attack (add too much power).
$4\frac{1}{2}$	74	2	Loose in pitch; Drag rise; air-speed	Too loose in pitch and may become a problem in turbulence--tendency to bobble; because of drag characteristics, a lot of throttle corrections were required for angle of attack changes; attitude was a little unsatisfactory; airspeed is a problem, but it could be handled.
4	48	1	Large drag rise with angle of attack; couldn't maintain airspeed well.	Good pitch control with slight tendency to bobble; large drag rise with angle of attack; difficult to maintain altitude; airspeed was a problem (airspeed watching configuration - pilot objected to it). (If it weren't for airspeed problems it would be $2\frac{1}{2}$).
$4\frac{1}{2}$	56	1	Airspeed drag rise with angle of attack.	Satisfactory pitch control; a lot of power is required when drag increases with angle of attack, but it's manageable.
6	39	1	Airspeed changes; Large drag rise with angle of attack.	Good attitude control, airspeed control is difficult.
5	68	2	Airspeed	Again, attitude control was on the borderline between satisfactory and unsatisfactory; airspeed always kept changing; tendency to overdrive configuration.
3	65	1	High drag rise with angle of attack; air-speed.	Good attitude control; had to use a lot of throttle for the drag rise; airspeed was a problem due to high drag rise, and this required a tight throttle closure with airspeed. Smooth air.

DRAG CASE: BACK SIDE

Major Problem

C. (Cont.)

Rating	Flt.	Conf.	Problem	Pilot Comments
7	83	1	Pitch oscillation in turbulent air.	Partial evaluation - system dumped repeatedly. Turbulent air at low altitude. Pretty high drag rise with angle of attack. Pretty good in smooth air but in rough air got nose oscillation which would cause control difficulties.
8	76	1	Attitude control; short period; drag with angle of attack; airspeed.	Lousy short period characteristics. Short period easily excited in oscillatory fashion; extremely high drag rise with angle of attack; attitude control marginal between acceptable and unacceptable; control of airspeed was almost impossible on glide slope; have to try not to excite short period.
D.				
$6\frac{1}{2}$	79	1	Drag characteristics; airspeed.	Full throttle for much over 30°, attitude control around a 4; Difficult to maintain specific rate of sink; airspeed mode seemed unstable, it tended to get quite slow and quite fast; overdrive.
8	60	1	Extremely high drag rise with angle of attack airspeed.	Light damping; slow sluggish short period response; airspeed seems unstable; turbulence easily disturbed aircraft and caused oscillations; airspeed requires large throttle corrections.
7	49	1	High drag rise with angle of attack. Attitude control; airspeed.	Exceedingly high drag rise with angle of attack; short period mode was oscillatory and of long period (created a very loose feeling); either fast or slow on airspeed.
7	65	2	Glide slope; attitude control airspeed; high drag rise with angle of attack.	Can't make flight path corrections quickly to get back on glide slope; attitude control is unsatisfactory; airspeed is an extreme problem (cause for aircraft being unacceptable), the airspeed trouble is caused either by high drag rise with angle of attack of it's unstable. Air pretty smooth.

DRAG CASE: BACK SIDE

General Comments on Control Technique

A.

Rating	Flt.	Conf.	Pilot Comments
5	49	2	Level Turn - Attitude control was quite good and I could hold the attitude right on, then I had time to look away and check airspeed. If the airspeed wasn't quite right on, then changing nose position was far more effective because the power setting was about right for trim. So, as airspeed started to bleed then the angle of attack was too high and the nose was a little too high. I found that the most effective way to control airspeed was by varying the bank angle and thus changing the angle of attack.
			Airspeed - Major Problem. It sneaks away. As long as you're tight on attitude and keep the attitude right for the power setting then the airspeed is all right, but if you look away and you don't tightly monitor your attitude or don't correlate your attitude with your throttle setting and angle of attack, boy, it bleeds in a hurry.
			Throttle and Elevator - Throttle is used to control rate of climb and airspeed and really as a function of angle of attack. It's a big input to get lead on the airspeed bleed. If you don't put in throttle proportional to angle of attack your airspeed will start to bleed and then you got real problems trying to get it back. Pilot has very little tolerance for error. He's in trouble if he does something wrong or even if he skips doing something right.
4	74	1	Rate of change of airspeed is pretty slow so you can handle it. You do it by using a lot of throttle when you make an angle of attack change. You have to monitor airspeed to see if you did it right. (Smooth Air).
$4\frac{1}{2}$	72	1	Use strong throttle closure with angle of attack and airspeed.
$4\frac{1}{2}$	75	2	Glide Slope - Got high and fast and had to take power off so I was down to 76% and still boiling along fast and high. Don't like to take off any more throttle than that because I'm afraid and can't get it back on.
			Airspeed - Any time I was controlling airspeed with attitude it looked like airspeed control was good. Whenever I was trying to maintain a fixed flight path and control airspeed it wasn't so good.

DRAG CASE: BACK SIDE

General Comments on Control Technique

A. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	58	1	Turns - If I rolled into a turn, I had to add power and increase the angle of attack. In other words, bring the indicated nose above the horizon and the airspeed response was fairly rapid if I didn't have enough power on, the airspeed restoring rate to trim was very, very slow and all the time these airspeed errors existed the angle of attack had to be altered correspondingly to keep the flight path level.
4	79	2	Glide Slope - Started fast - U = 170 kt - and then came back on the power in an attempt to re-establish my speed and then I came back further than I had on the first configuration and so I had some learning benefit. Came back quite far and had good attitude control and just held that attitude, increasing the nose slightly with the angle of attack, to maintain myself on the glide slope, and in just a few seconds I was back to 162. I added power and stayed right on the glide slope. (Perfectly smooth air).
			Elevator Control - Elevator primarily to control attitude, however, in controlling attitude the commands to that attitude loop are a whole lot of different things depending on the situation. If I'm correcting an airspeed error on the glide slope, the commanded attitude is changed to account for the angle of attack increase as the airspeed decreases. So you have altitude and airspeed inputs to the attitude command system.
6	48	2	Maintaining Airspeed - It certainly was a problem. It is of same order as the first one except I introduce additional airspeed problems because of imprecise attitude control.
			High and Fast is Difficult - If I was above the glide slope and a little fast, I just couldn't pull enough throttle off and I even tried to increase the angle of attack with the elevator to give it some drag to slow the airspeed down, but then my altitude goes up, so, this is approaching a configuration that you can control airspeed with your angle of attack, through your elevator dynamically I mean, but not quite because you get too much lift.

DRAG CASE: BACK SIDE

General Comments on Control Technique

A. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
6	48	2 (Cont.)	So, with the throttle response that we have (and I have a fairly large amount of motion required to change the power) it was difficult. Now I like the throttle better up around 90% because you get a fair change in rpm and thrust with throttle position. Below 90% the change in rpm and thrust with throttle is very small. Also there is a tremendous time lag and this starts to be a problem.
			So, I'm sure this is why a high and fast is a difficulty on approach. I'm down to 80-81% depending on the airspeed and if I get a high and fast, I've got to come way back to about 70% and this isn't a tremendous change in thrust. Hence, the airspeed doesn't really bleed off very fast and I don't want to come back any further because it takes so long to get my thrust back. I'm afraid of sinking below the glide slope.
6½	72	2	The secret in flying this one is to attack any airspeed errors or altitude errors rapidly with throttle.
			Glide Slope - Flew as tight as possible. I made pretty large throttle corrections when an airspeed error started to occur. So, I was watching airspeed, glide path and attitude.
			Technique - You have to put in throttle corrections and you have to pick up the effects of those throttle corrections rapidly, so you can readjust the throttle and not let the airspeed get too far off.

B.

Rating	Flt.	Conf.	Pilot Comments
5½	82	2	Descent - I started to reduce my rate of descent and there I got in trouble. It was partly my fault because the throttle was all the way back to idle and I started my nose attitude up too soon and the throttle response was very slow and consequently I lost 10 kt airspeed. It points up the fact that you do lose airspeed awful fast if you don't coordinate the throttle.
			Glide Slope - I could not correct a high and fast situation. I pulled the power way back to 60% or so but the airspeed only came back very slowly. This is undesirable to have the throttle way back. You have the long engine acceleration time and if you start to sink with the throttle way back you would have to stop the sink with attitude and then the airspeed loss would be very, very rapid and then you would be in real trouble.

DRAG CASE: BACK SIDE

General Comments on Control Technique

B. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	68	1	Principal difficulty was maintaining airspeed. There was a slow insidious change in airspeed and/or rate of sink, you never were in trim steady state. Airspeed always seemed to be going someplace that you didn't intend it to go and it was always going at a very slow rate.
$5\frac{1}{2}$	75	1	Airspeed Problems.
6	76	2	If I'm at the right airspeed when I approach the glide slope and if I put the right power on to maintain the glide slope; some airplanes will pretty much help themselves push over and seek the steady state angle of attack going down the glide slope. That kind of defines your attitude for you and then you hold it and watch the mirror to see what it does. Well, it doesn't quite go that way - you don't let it seek it itself, you put it down or help it down and find out where it wants to sit with minimum stick force. You do have to worry about the stick force change with power or the pitching moment change with power, but basically the airplane tends to seek an angle of attack. Well this configuration and those that are slow like it do not tend to seek angle of attack; so you have to push them down to an estimate of the attitude and then hold that attitude and see what happens to glide slope. If you don't do it perfectly you won't know until you start off of the glide slope. By the time you make a correction, you are definitely off so you have to make an extra correction. For example, if I set the throttle and assume an attitude and start down the glide slope and nothing happens for a while and then gradually it starts to get high; I can't just make an attitude and/or power correction and start from that high, i.e., stay high but parallel to glide slope. I have to nose over and take off power and then get back on the glide slope and establish a new power, new attitude and see how it does. (I nose over first because it takes so long to get the nose over.)

DRAG CASE: BACK SIDE

General Comments on Control Technique

B. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
6	61	1	Airspeed Control - During IFR portion had errors ±10 kt and there wasn't a heck of a lot I could do about it.
			Glide Slope - I had to be very tight on my airspeed and put in throttle due to airspeed errors as well as glide slope errors. My throttle inputs were probably equally divided between altitude errors and airspeed errors. I had a pretty tight throttle loop. Checked airspeed errors down to 1/4 mile trying to keep throttle closure on airspeed.
8	82	1	Descent - Took 1000 ft to establish rate of descent, lost 10 kt.
7	53	1	Level Flight - If the airspeed starts to bleed and I want to stop it with power, this always gets me out of trim and makes it difficult to hold altitude. If I make a small correction with power and a correction in angle of attack, then I start to sink and the altitude goes off but you don't sink as far as you might think because getting the angle of attack down helps the speed increase and the extra power does too. Also you don't get so far out of trim if smaller throttle changes are used.
			Turns - Throttle necessary for angle of attack and airspeed. If you enter a turn and change angle of attack, you add what you think is the right amount of power but it never is exactly right. The airspeed starts to change and if you try to maintain flight path with elevator and the airspeed is diverging, then you have to use throttle to get airspeed back.
			Elevator - Attitude control of airspeed isn't good enough here mostly because if you use attitude to control airspeed, you get too large flight path deviations.
			Landing Approach - As long as I assume and make the loop closures that I'm capable of making under continuous closed-loop control, then this airplane is flyable. But you can't make the assumption that I can always be continuous closed loop, and under those circumstances this airplane is going to kill people. This airspeed difficulty was very predominant.

DRAG CASE: BACK SIDE

General Comments on Control Technique

B. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
7	53	1 (Cont.)	Wave-off - I had considerable airspeed difficulties. I would set up an attitude and throttle setting to get the airspeed I wanted, then the airspeed would start off and I'd change attitude a little and get the airspeed about back and look away a second and come back and the airspeed would be high maybe 10 kt and that's a substantial error but not unusual one for this configuration.
			Mirror Approaches - Started off in quite a good position, i.e., no gross corrections to be made, but I got fast with an ON glide slope indication and I couldn't get rid of the speed. I kept pulling the power off and the speed got 8 kt fast; then it seemed all of a sudden, the airspeed started to come back and back and I really had to come on with power and I think right at the end I went a little high because of the power coming back on. I didn't have precise control of airspeed.
			Two Control Airplane - When you have an airplane which requires the use of both elevator and throttle for safe control, then you have to have the means for closing the second loop. So when I'm IFR I have the airspeed indicator in a good position and I'm able to close that loop. When I'm VFR it requires a lot of looking down and I'm afraid I'd have my head in the cockpit a lot more than is desirable. On the mirror approach, you have to give me a means for closing this loop. I don't think Navy airplanes have an airspeed which is any more visible than the one I have. Under poor visibility conditions with attention focused outside the cockpit, I'm afraid you would neglect the airspeed indicator and the closure would not be precise. Then this becomes dangerous.
			Performance of Task - To achieve a fairly good job I was closing a good tight throttle loop on airspeed errors. Those errors were substantial before I recognized them as errors, they didn't go away in a hurry after I recognized them and started to do something about them. I had to continue to devote attention to them after I initiated the corrective action. Also the rate of divergence at the time I recognized them as errors was large enough that if I had not recognized them I would be in deep trouble in few seconds.

DRAG CASE: BACK SIDE

General Comments on Control Technique

C.

Rating	Flt.	Conf.	Pilot Comments
5	63	2	High and Fast - That high and fast is a real one to combat with this configuration. When you got high and fast all you could do was pull the throttle off and try to keep from going any higher and control attitude so you didn't go any higher and try to get the airspeed to bleed off, gradually sinking back onto the glide slope and then when the airspeed was right and you were on the glide slope then come on with the power.
			Well I had enough attitude control to do this so that was no problem. It was just the airspeed response to throttle was not there. Now obviously that must take into account the angle of attack changes too.
			So, I was checking airspeed and actually I think I saved that approach. I quit checking airspeed 1/4 mile or little less from mirror.
			IFR - If your airspeed is high and your rate of descent is up, you pull the throttle off and hold or minimize the attitude change because nose down will only increase your airspeed so I had altitude and airspeed problems.
4½	74	2	Glide Slope - I pulled the throttle off and the airplane would kind of nose down holding airspeed and then I just correct the attitude as necessary and add a little throttle or take off to keep on the glide slope. (Smooth Air).
4	48	1	Throttle and Elevator - Elevator is used to control attitude and -- well -- airspeed, but once again, if you have attitude requirements in order to control flight path, well, airspeed I had to get with the throttle. Throttle was more airspeed on this configuration, except in the descent portions of the thing where attitude was used to control airspeed. Then on the glide slope, I think the altitude command to my pitch attitude control was pretty significant. In other words, if I was high, I had to push the nose over and really come off the throttle, and I tended to get fast in this situation.
			Glide Slope - Was made with throttle used to control airspeed errors and throttle used to control altitude errors and pitch attitude changed accordingly, with the elevator controlling the attitude. Throttle is also used to control airspeed very tightly. Checked airspeed as long as possible.

DRAG CASE: BACK SIDE

General Comments on Control Technique

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	56	1	As long as you fly this airplane closed-loop, throttle and elevator, you will not have trouble with it. But it's an airplane that will bite you real hard if you open up the throttle loop, and let the airspeed or rate of sink get away from you. I object to the magnitude of the throttle closure that is required. It's not just a little throttle closure, it's a large throttle closure that is required and must be done properly or unwanted changes in the flight path occur. Where I get into trouble with this configuration is when I change the flight path, it's really a two control operation with good closed-loop on airspeed required. You just can't avoid that and when this is required, you can't devote as much time to heading, track, etc. If you assume it is a two control airplane it doesn't exhibit particularly bad characteristics, as long as you flew it two-control. Only time you get in trouble is when you open one of the control loops (and this will happen to almost every pilot, either through necessity or lack of attention) and under this situation, this can become somewhat dangerous airplane. You have to be right on top of it with power, if you are it flies fairly well.
6	39	1	Throttle and Elevator - Throttle adjustments are necessary to compensate for airspeed errors. I use attitude in conjunction with throttle to control airspeed but I can't use attitude as much as with most configurations because when the airspeed is low and you have to maintain the flight path, then you can't fool around with the attitude, you have got to go after it with power. Also, throttle adjustments are obviously used to control rate of climb IFR and altitude on the glide slope.
5	68	2	Glide Slope - I started on-course fairly well. I stayed on course altitude wise but my airspeed built and built. I was coming off with throttle more and more. So, I was definitely up on the glide slope and if anything correcting to keep the altitude from going high and trying to do it without jiggling the throttle -- just flying attitude head out of the cockpit. Every time I checked airspeed it was up another knot or two and I'd make a correction on throttle but they didn't seem to do any good because I ended up 6 kt fast. Airspeed was a general problem.

DRAG CASE: BACK SIDE

General Comments on Control Technique

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
3	65	1	It is one of those configurations that you just have to be there with power. But, if you use the throttle it doesn't take a superman to keep the airspeed right. The airspeed didn't seem to be too bothersome (in this real smooth air) as long as you keep after it with reasonable amounts of power. But, this throttle closure does require attention on the part of the pilot and if he doesn't carry this out, it can pick up some pretty healthy sink rates.
8	76	1	Glide Slope - I was high and fast and had to make an awful large correction to start it down and when I did, I couldn't stop it. Had a very difficult time stopping the rate of sink. I went quite low and would have had to wave-off. So, correcting a high and fast is a difficult thing and you end up (the thing I've been afraid of all along) taking too much power off and then you pick up a rate of sink that you are unaware of and you sink too fast and you can't stop it (smooth air and calm).

D.

Rating	Flt.	Conf.	Pilot Comments
$6\frac{1}{2}$	79	1	Descent - Seemed like the airspeed mode is unstable. I was chasing it and I had to make substantial attitude changes to correct for airspeed errors. The reduced rate of sink portion I had great difficulty establishing a reduced rate of sink. I lost 10 kt in the process in the time it took me to look over at the RPM and move from 65% - 82%, maybe about 6 seconds I lost 10 kt.
			Glide Slope - Started fast and couldn't correct in time it was on the approach.
8	60	1	Special Technique - Real high-gain throttle closure with angle of attack and a pretty effective closure with airspeed on the throttle. And all the time, trying to do what seemed right with the elevator to keep the flight path under control.
			Glide Slope - Got fast on the glide slope by about 10 kt and I had one heck of a time losing it. I pulled the throttle way off and then it would finally come back on airspeed, there you are with hardly any throttle on and the nose pointed pretty far down and you rotate the nose back up, come on with throttle and try to stop it on the glide slope.

DRAG CASE: BACK SIDE

General Comments on Control Technique

D. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
7	49	1	Use throttle to control rate of climb and altitude on the glide slope and very definitely airspeed. If you are high and fast you got to back off a lot of throttle. Elevator used to control attitude and through attitude-airspeed, then on glide slope -- altitude also.
7	65	2	Changing Rate of Descent - I added the power first and then gradually brought the attitude carefully so that I didn't change the attitude before I had the right amount of throttle on and this worked fine. I found that I had guessed the RPM right. Glide Slope - I pulled the power back to what seemed right, kept cross-checking the airspeed and pointed the airplane nose at the lights and it looked real good (perfect smooth air). I had apparently transitioned just perfect. When I got down to about 200 ft altitude I started to go a little low so I added a little power and rotated the nose just a little bit and about that time I hit a gust (this is where turbulence started) the airplane just kind of heaved up off the glide path, I tried to push it back down and I tried to pull the throttle off but it just heaved right on up and I don't think I would have made it on a carrier. Turns - In making a couple of turns I was able to keep my attitude about where I wanted it and the altitude tended to stay about where I wanted it, but the airspeed was going rapidly divergent. These were quick turns and I'm sure that with the airspeed going off that far and me late coming in with power that probably I would pick up a sink rate. Instruments - Tended to use the throttle position a lot with this configuration (TPM) because if you set something that was close to right it sure helped a whole lot -- I mean you couldn't be continuous closed-loop controller setting the throttle according to the errors. If you waited long enough for there to be errors, you would be way behind the airplane airspeed wise. Throttle adjustments are necessary for angle of attack changes but with this one it's difficult to sense angle of attack. It takes so long after you indicate an elevator input for the angle of attack to change, you

DRAG CASE: BACK SIDE

General Comments on Control Technique

D. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
7	65	2 (Cont.)	don't feel you have changed it. This kind of fouls you up on how to add the throttle. So when I put on elevator input in to change the flight path I put in some throttle and then monitor airspeed, a real tight loop, to see if I have the right throttle input.

DRAG CASE: BACK SIDE

Question No. 1 Is the Airplane Difficult to Trim?

A.

Rating	Flt.	Conf.	Pilot Comments
5	49	2	No -- except airspeed is sensitive to angle of attack.
4	74	1	No, easy attitude-wise but little trouble finding power.
4½	72	1	Easy in pitch but hard to find power setting for level flight.
4½	75	2	No, but little problem finding throttle setting.
4½	58	1	No, quite easy.
4	79	2	No, easy.
6	48	2	Somewhat, because of attitude control problems and large changes in drag with α .
4	63	1	Erased for Harper's SST Report.
6½	72	2	Extremely, could control attitude ok but couldn't get the right combination power, attitude, etc. to maintain zero R/C.

B.

Rating	Flt.	Conf.	Pilot Comments
5½	82	2	No, very easy.
4½	68	1	Yes, a little difficult.
5½	75	1	Yes, a little. Hard to find right throttle setting. (No horizon today.)
6	76	2	Didn't get good look at it, but not too bad.
6	61	1	Yes, somewhat -- because of the long response time in pitch.
8	82	1	Yes, very difficult.
7	53	1	Attitude-wise no, airspeed-wise yes.

C.

Rating	Flt.	Conf.	Pilot Comments
5	63	2	Erased for Harper's SST Report.
4½	74	2	No, easy attitude-wise but little difficulty to find power setting.
4	48	1	No.
4½	56	1	No.
6	39	1	Yes, on airspeed, no, on attitude.

DRAG CASE: BACK SIDE

Question No. 1 Is the Airplane Difficult to Trim? (Cont.)

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
5	68	2	Yes, a little difficult.
3	65	1	No, easy.
7	83	1	No, fairly easy in smooth air.
8	76	1	Had little trouble finding throttle setting. (No horizon)

D.

Rating	Flt.	Conf.	Pilot Comments
6½	79	1	Yes.
8	60	1	Yes, just a little on the difficult side.
7	49	1	Yes, doesn't have much trim stiffness.
7	65	2	Yes, quite difficult.

DRAG CASE: BACK SIDE

Question No. 2 Is the Elevator Control Gain Satisfactory?

A.

Rating	Flt.	Conf.	Pilot Comments
5	49	2	Yes, was easy to pick.
4	74	1	Compromise between initial and steady response. Final response little slow compared to initial response.
4½	72	1	Good, no trouble choosing.
4½	75	2	Compromise
4½	58	1	Yes, quite comfortable
4	79	2	Yes.
6	48	2	Yes.
4	63	1	Erased for Harper's SST Report.
6½	72	2	Compromise BF = 60 Initial response little quick or loose. BF = 55 not enough control. Picked BF - 58.

B.

Rating	Flt.	Conf.	Pilot Comments
5½	82	2	I think so. Noted stick force lightening on up steps and stick force increase on down steps.
4½	68	1	Compromise BF = 60 - Initial response too sensitive Steady forces were good. BF = 55 - Initial response ok, steady forces not too bad, but in turns he didn't seem to have enough control. BF = 58 - Compromise. Ok.
5½	75	1	Compromise. Airplane was slow in pitch but increasing gain resulted in loose pitch control.
6	76	2	Slow and sluggish so tried high gain, BF = 58, but lacked steady forces. BF = 55 had fairly good sense of force required to maintain steady angle of attack. Thus I could judge what was necessary to command a response after overdriving it to get it started.
6	61	1	Yes, best compromise.
8	82	1	Yes, good choice.
7	53	1	Yes.

DRAG CASE: BACK SIDE

Question No. 2 Is the Elevator Control Gain Satisfactory? (Cont.)

C.

Rating	Flt.	Conf.	Pilot Comments
5	63	2	Erased for Harper's SST Report
4½	74	2	Compromise, picked low to slow down initial response and lessen bobble tendency. Steady forces little heavy.
4	48	1	Yes, rather heavy steady state forces to get rid of the sensitive initial response.
4½	56	1	Yes.
6	39	1	Yes.
5	68	2	Selected BF = 58. BD = 55 too heavy, can't overdrive. BF = 60 too sensitive initially.
3	65	1	Yes, used BF = 58.
7	83	1	Yes, picked high value to get steady forces down, results in little oversensitive in maneuvers.
8	76	1	Compromise. Tended to pick low value to minimize tendency to excite short period. But not real low because of heavy steady forces.

D.

Rating	Flt.	Conf.	Pilot Comments
6½	79	1	Yes.
8	60	1	Yes, good compromise.
7	49	1	Yes, best available.
7	65	2	Started with BF = 75 and had PIO. BF = 53 too hard to overdrive, selected BF = 55, permits overdriving. But forces are quite variable. Heavy initially then lighter during transient.

DRAG CASE: BACK SIDE

Question No. 3 Is Attitude Control Satisfactory?

A.

Rating	Flt.	Conf.	Pilot Comments
5	49	2	Yes, quite good.
4	74	1	(No specific comment) may be a little too stiff and a shade light in damping.
$4\frac{1}{2}$	72	1	Quite good.
$4\frac{1}{2}$	75	2	Little sluggish.
$4\frac{1}{2}$	58	1	Yes, quite good, excellent.
4	79	2	Yes, slightly low in damping.
6	48	2	No, unsatisfactory -- a real problem when coupled with the airspeed and drag problem. Probably could have handled it if the other two problems weren't present.
4	63	1	Erased for Harper's SST Report.
$6\frac{1}{2}$	72	2	Satisfactory.

B.

Rating	Flt.	Conf.	Pilot Comments
$5\frac{1}{2}$	82	2	Yes, little sluggish.
$4\frac{1}{2}$	68	1	Little slow in starting, then goes fast then stops then goes on at reduced rate.
$5\frac{1}{2}$	75	1	No, too slow and too lightly damped.
6	76	2	No, too slow and sluggish.
6	61	1	No, sluggish response, but not unacceptable.
8	82	1	No, very poor. Also nonlinear pullup response (less stiff) quite different from pushover.
7	53	1	A little unsatisfactory (slow, sluggish, and a little objectionable, but not objectionable) (airspeed is the big problem).

C.

Rating	Flt.	Conf.	Pilot Comments
5	63	2	Slightly unsatisfactory.
$4\frac{1}{2}$	74	2	No, it is little unsatisfactory, tends to bobble.
4	48	1	Yes, slight tendency to bobble which would downgrade it slightly.
$4\frac{1}{2}$	56	1	Quite satisfactory and acceptable.
6	39	1	Good.
5	68	2	Damping little low and frequently little slow.

DRAG CASE: BACK SIDE

Question No. 3 Is Attitude Control Satisfactory? (Cont.)

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
3	65	1	Fair to good in the smooth air, definite overshoot.
7	83	1	Good stiffness but low damping.
8	76	1	No, nearly unacceptable due to low damping.
D.			
$6\frac{1}{2}$	79	1	Marginal, it's slow and a little loose in pitch.
8	60	1	No, absolutely not -- it's bad -- aggravated by air-speed mode -- not too bad in smooth air, but terrible in rough air -- gallops a little bit.
7	49	1	No, with these drag characteristics, it's unacceptable.
7	65	2	No, definitely not. Low frequency and low damping.

DRAG CASE: BACK SIDE

Question No. 4 Is Maintaining Altitude a Problem?
a) Straight and level
b) Turns

A.

Rating	Flt.	Conf.	Pilot Comments	
5	49	2	a) Not too much	b) Not too much.
4	74	1	a) Long response time to find power setting.	b) Requires lots of power in turns.
$4\frac{1}{2}$	72	1	a) Can't find right power setting	b) Takes lots of power in turns.
$4\frac{1}{2}$	75	2	a) Not so much.	b) Have to use lots of power in turns and if not properly set in altitude will not remain constant.
$4\frac{1}{2}$	58	1	a) No.	b) Yes, would have to add power and if power wasn't set just right, A/C would sink or climb.
4	79	2	a) Yes, a little.	b) Turns are a problem because of poor airspeed control. Attitude control is good and this is an advantage in maintaining altitude.
6	48	2	a) Yes.	b) Can't answer.
4	63	1	a) Erased for Harper's SST Report.	
$6\frac{1}{2}$	72	2	a) Extreme problem	b) Extreme problem

B.

Rating	Flt.	Conf.	Pilot Comments	
$5\frac{1}{2}$	82	2	a) Yes, when trying to level off after climb.	b) Yes, must coordinate power with angle of attack in turns.
$4\frac{1}{2}$	68	1	a) Somewhat, requires large power changes to correct altitude errors.	b) Not good.
$5\frac{1}{2}$	75	1	a) Yes, difficult to find right throttle setting.	b) Difficult to get proper throttle; airspeed seems unstable.
6	76	2	a) Yes, because of slow short period and drag characteristics.	b) Yes, must add lots of power accurately.

DRAG CASE: BACK SIDE

Question No. 4 Is Maintaining Altitude a Problem? (Cont.)
a) Straight and level
b) Turns

B. (Cont.)

Rating	Flt.	Conf.	Pilot Comments	
6	61	1	a) Yes.	b) Yes (A/C has very little stiffness).
8	82	1	a) Yes.	b) Yes, very difficult. Can't do it precisely.
7	53	1	a) Yes, because airspeed would keep going to "pot". &b)	
C.				
5	63	2	a) Yes, due to airspeed	b) Yes, misled on throttle required for drag rise.
$4\frac{1}{2}$	74	2	a) Little difficult due to long response time of flight path.	b) Took awful lot of throttle in turns and pilot had to try to coordinate properly. Airspeed departure was slow.
4	48	1	a) Yes, slight problem	b) Yes, didn't have enough power to hold the airspeed under control like wanted to.
$4\frac{1}{2}$	56	1	a) No.	b) Somewhat because a R/S develops rapidly with increased α .
6	39	1	a) Not much	b) Definitely yes.
5	68	2	a) Little difficult, maybe related to airspeed.	b) Could not do with precision.
3	65	1	a) No.	b) Only if throttle is properly coordinated.
7	83	1	a) (No comment)	
8	76	1	a) Somewhat	b) Requires strong throttle coordination.
D.				
$6\frac{1}{2}$	79	1	a) Yes	b) Very definitely.
8	60	1	a) Not too much.	b) Exceedingly difficult. (Unstable U).
7	49	1	a) Yes, galloped.	b) Yes, galloped.
7	65	2	a) Somewhat	b) Must coordinate power properly.

DRAG CASE: BACK SIDE

Question No. 5 Can You Establish a Specific Rate of Descent?

A.

Rating	Flt.	Conf.	Pilot Comments
5	49	2	Fairly well, but airspeed kept changing.
4	74	1	Seemed to go quite well.
4½	72	1	Fairly good.
4½	75	2	Yes, pretty well.
4½	58	1	Yes, fairly well.
4	79	2	Yes, good.
6	48	2	Yes.
4	63	1	Erased for Harper's SST report.
6½	72	2	No, partly because a different power setting was required from most of past configurations (low fuel)

B.

Rating	Flt.	Conf.	Pilot Comments
5½	82	2	Did not do very well. Was late in changing power setting when trying to level off descent. This caused airspeed loss.
4½	68	1	No specific comment.
5½	75	1	Went fairly well although not very quickly. Use tight attitude control to control airspeed and adjust power to get R/C.
6	76	2	Went well.
6	61	1	Yes, but had tight attitude control and throttle position.
8	82	1	No, very difficult. Ended up at lower altitude and slow speed when finally got R/D established.
7	53	1	No, because of airspeed troubles.

C.

Rating	Flt.	Conf.	Pilot Comments
5	63	2	Went fairly well.
4½	74	2	Went pretty well.
4	48	1	Yes, however airspeed would get away a little bit.
4½	56	1	Yes.
6	39	1	Yes.
5	68	2	Rather difficult. Fishing for attitude to maintain airspeed.
3	65	1	Yes, pretty well. However, I have optimum conditions; air is very smooth.

DRAG CASE: BACK SIDE

Question No. 5 Can You Establish a Specific Rate of Descent? (Cont.)

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
7	83	1	(No comment)
8	76	1	Quite Well.

D.

Rating	Flt.	Conf.	Pilot Comments
$6\frac{1}{2}$	79	1	Found it very difficult.
8	60	1	Yes -- fairly well.
7	49	1	(No comment).
7	65	2	Yes, by controlling attitude closely.

DRAG CASE: BACK SIDE

Question No. 6 Is Maintaining Airspeed a Problem?

A.

Rating	Flt.	Conf.	Pilot Comments
5	49	2	Yes, major problem; it's alright as long as you're tight on attitude and keep attitude right for the power setting and angle of attack.
4	74	1	Yes, but rate of change of airspeed is slow. Have to use lot of throttle.
$4\frac{1}{2}$	72	1	Yes, this is principal problem.
$4\frac{1}{2}$	75	2	Yes, when I was trying to maintain flight path. Could control with attitude quite well if I did not also have to control flight path.
$4\frac{1}{2}$	58	1	Yes, major problem -- had to fly very tight airspeed control -- airspeed response to airspeed was very sluggish.
6	48	2	Yes, hardest problem was flying high and fast, and trying to correct airspeed errors with throttles.
$5\frac{1}{2}$	82	2	Yes, very difficult. It's always changing. Can't find right power to hold airspeed.
4	63	1	Erased for Harper's SST report.
$6\frac{1}{2}$	72	2	Yes, you have to pay a lot of attention to throttle control and airspeed.

B.

Rating	Flt.	Conf.	Pilot Comments
4	79	2	Yes, tends to get away.
$4\frac{1}{2}$	68	1	Yes, always changing at a very slow rate.
$5\frac{1}{2}$	75	1	Yes, must use strong throttle with $\Delta\alpha$ and ΔU.
6	76	2	Yes, poor short period and requirement to add throttle with angle of attack.
6	61	1	Yes, had high and low airspeed errors (± 10 kt) and pilot couldn't do much about it.
8	82	1	Yes, very difficult. It's always changing. Can't find right power to hold airspeed.
7	53	1	Yes, just about unacceptable.

C.

Rating	Flt.	Conf.	Pilot Comments
5	63	2	Yes, had a strong tendency to get fast.
$4\frac{1}{2}$	74	2	Yes, you must use right closures to maintain airspeed.
4	48	1	Yes, not a gross problem, but it's serious enough to become objectionable.

DRAG CASE: BACK SIDE

Question No. 6 Is Maintaining Airspeed a Problem? (Cont.)

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	56	1	Just a little bit (airspeed errors required large changes in power settings).
6	39	1	Yes (major problem) under changing α conditions.
5	68	2	Yes, very definite problem. Could never pin it down. Tend to loose airspeed in maneuvers.
3	65	1	Yes, must compensate for drag rise with α . Don't think it is unstable in airspeed.
7	83	1	Have high drag rise with α .
8	76	1	Definitely yes. Almost impossible on glide slope.

D.

Rating	Flt.	Conf.	Pilot Comments
$6\frac{1}{2}$	79	1	Yes, the most critical problem, varied ± 10 kt.
8	60	1	Yes, a major difficulty -- unstable -- requires very large throttle corrections.
7	49	1	Yes, tendency to be too fast or too slow. Seemed to be a noticeable change in characteristics with fuel remaining.
7	65	2	Yes, an extreme problem.

DRAG CASE: BACK SIDE

Question No. 7 What Instruments are You Using Most?

Rating	Flt.	Conf.	Pilot Comments
A.			
5	49	2	
4	74	1	Attitude and airspeed; h , R/C, ψ and RPM.
$4\frac{1}{2}$	72	1	Attitude and airspeed; R/C, h , ψ , RPM when throttle is changed.
$4\frac{1}{2}$	75	2	Attitude and airspeed; R/C, h , ψ , RPM.
$4\frac{1}{2}$	58	1	1st attitude, airspeed, 2nd R/C, altimeter, throttle, heading.
4	79	2	Attitude (airspeed, h , R/C), RPM and ψ .
6	48	2	Attitude and airspeed; 2nd, R/C, altitude, throttle, RPM and heading.
4	63	1	Erased for Harper's SST Report.
$6\frac{1}{2}$	72	2	Attitude and airspeed with lots of attention on airspeed.
B.			
$5\frac{1}{2}$	82	2	Attitude and airspeed, h , R/C, ψ , RPM.
$4\frac{1}{2}$	68	1	Attitude and airspeed, R/C, h , RPM, and ψ .
$5\frac{1}{2}$	75	1	Attitude and airspeed, h , R/C, ψ , RPM.
6	76	2	Attitude. It doesn't stay put in attitude. Airspeed strong check. Then R/C, h , ψ , and RPM.
6	61	1	1st attitude and airspeed, 2nd R/C, altimeter, throttle, and α .
8	82	1	Attitude and airspeed, R/C, h , ψ , RPM.
7	53	1	Attitude, airspeed, R/C, altitude; 2nd RPM, throttle, (didn't have much time for heading).
C.			
5	63	2	1st airspeed and attitude, 2nd R/C, altitude.
$4\frac{1}{2}$	74	2	Airspeed and attitude, h , R/C, ψ and RPM.
4	48	1	1st attitude and airspeed, 2nd R/C, altimeter, heading, power (not much on heading).
$4\frac{1}{2}$	56	1	
6	39	1	Attitude and airspeed, R/C, altimeter, heading, power.
5	68	2	Attitude and airspeed, R/C, h , RPM and ψ , Check RPM when throttle is changed.

DRAG CASE: BACK SIDE

Question No. 7 What Instruments are You Using Most? (Cont.)

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
3	65	1	Attitude and airspeed, R/C, h, RPM, ψ.
7	83	1	(No comment).
8	76	1	Attitude and airspeed, R/C, h, ψ, RPM.
D.			
$6\frac{1}{2}$	79	1	Attitude and airspeed, h, R/C, ψ, RPM.
8	60	1	1st attitude and airspeed, 2nd R/C, altimeter, throttle heading.
7	49	1	Attitude and airspeed; and R/C, altitude, throttle, RPM and heading.
7	65	2	Attitude and airspeed, together with throttle controlling ΔU. Cross check R/C, h, RPM and ψ. Use throttle position a lot.

DRAG CASE: BACK SIDE

Question No. 8 Is a Special Control Technique Required?

A.

Rating	Flt.	Conf.	Pilot Comments
5	49	2	Good attitude control and good coordination of throttle and attitude in angle of attack.
4	74	1	Smooth elevator inputs. Strong throttle with α .
$4\frac{1}{2}$	72	1	Strong throttle closure with α and airspeed errors.
$4\frac{1}{2}$	75	2	Throttle with $\Delta\alpha$ and ΔU .
$4\frac{1}{2}$	58	1	High gain throttle closure with angle of attack.
4	79	2	Coordinate throttle with $\Delta\alpha$ and for airspeed errors.
6	48	2	Tight throttle loop on airspeed.
4	63	1	Erased for Harper's SST Report.
$6\frac{1}{2}$	72	2	Throttle with $\Delta\alpha$ and ΔU .

B.

Rating	Flt.	Conf.	Pilot Comments
$5\frac{1}{2}$	82	2	Large throttle with $\Delta\alpha$ and strong throttle with ΔU .
$4\frac{1}{2}$	68	1	Tend to overdrive in pitch and watch airspeed.
$5\frac{1}{2}$	75	1	Overdrive it in pitch. Use strong throttle with $\Delta\alpha$ and ΔU .
6	76	2	Overdrive in pitch. Throttle with $\Delta\alpha$. Although it is pretty slow in airspeed divergence.
6	61	1	Overdrive A/C in pitch -- varied throttle proportionately to $\Delta\alpha$.
8	82	1	Overdrive in pitch. Throttle with $\Delta\alpha$ and ΔU .
7	53	1	None (tended to slightly overdrive).

C.

Rating	Flt.	Conf.	Pilot Comments
5	63	2	Smooth inputs.
$4\frac{1}{2}$	74	2	Smooth elevator inputs. Close throttle loop with $\Delta\alpha$.
4	48	1	Real tight airspeed control
$4\frac{1}{2}$	56	1	Have to close loop on the throttle by making throttle corrections proportional to $\Delta\alpha$ changes, due to airspeed errors; and to set up R/C and R/S.
6	39	1	Cross checked α a little.
5	68	2	Tend to overdrive and use tight attitude control.
3	65	1	Throttle with α .

DRAG CASE: BACK SIDE

Question No. 8 Is a Special Control Technique Required? (Cont.)

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
7	83	1	Smooth input and provide damping. Throttle with angle of attack.
8	76	1	Must smooth inputs and provide short period damping. Add strong throttle with $\Delta\alpha$.

D.

Rating	Flt.	Conf.	Pilot Comments
$6\frac{1}{2}$	79	1	Yes, overdrive it in pitch. Lots of throttle corrections with airspeed errors.
8	60	1	Yes, real high gain throttle closure with $\Delta\alpha$ and an inefficient closure with airspeed errors on the throttle. Controlling flight path angle with elevator.
7	49	1	Have to smooth the elevator inputs and be tight on airspeed.
7	65	2	Very tight throttle closure and good attitude control. Overdrive it in pitch.

DRAG CASE: BACK SIDE

Question No. 9 Are Throttle adjustments Necessary?
Are They Used to Control: Attitude? R/C? Other?
Altitude? Airspeed?

A.

Rating	Flt.	Conf.	Pilot Comments
5	49	2	Yes, R/C, airspeed, angle of attack, altitude on glide slope.
4	74	1	Coordinate with $\Delta\alpha$, R/C, h on glide slope and ΔU.
$4\frac{1}{2}$	72	1	Coordinate with $\Delta\alpha$, R/C, h and ΔU on glide slope.
$4\frac{1}{2}$	75	2	Coordinate with $\Delta\alpha$, R/C, h on glide slope and ΔU.
$4\frac{1}{2}$	58	1	Angle of attack, airspeed errors, R/C, altitude errors on glide slope.
4	79	2	Coordinate with $\Delta\alpha$, ΔU, R/C, h errors on glide slope.
6	48	2	Yes, for R/C and airspeed.
4	63	1	Erased for Harper's SST Report.
$6\frac{1}{2}$	72	2	Coordinate with ; Adjust for R/C and airspeed.

B.

Rating	Flt.	Conf.	Pilot Comments
$5\frac{1}{2}$	82	2	Coordinate with $\Delta\alpha$. Adjust for R/C, h on glide slope and ΔU.
$4\frac{1}{2}$	68	1	Coordinate with $\Delta\alpha$. R/C, h on glide slope and airspeed.
$5\frac{1}{2}$	75	1	Coordinate with $\Delta\alpha$, and ΔU, adjust for R/C, h on glide slope.
6	76	2	Coordinate with $\Delta\alpha$, ΔU, h errors on glide slope, R/C.
6	61	1	Yes, α changes, altitude errors on glide slope. Airspeed errors.
8	82	1	Coordinate with $\Delta\alpha$ and ΔU. Adjust for R/C, U, h on glide slope.
7	53	1	R/C, airspeed and altitude on glide slope.

C.

Rating	Flt.	Conf.	Pilot Comments
5	63	2	For controlling R/C, airspeed error, altitude errors, α errors.
$4\frac{1}{2}$	74	2	Coordinate with $\Delta\alpha$, adjust for R/C, h on glide slope and ΔU.
4	48	1	Yes, R/C (always), airspeed (very tightly), altitude on glide slope.

DRAG CASE: BACK SIDE

Question No. 9 Are Throttle Adjustments Necessary? (Cont.)
Are They Used to Control: Attitude? R/C? Other?
Altitude? Airspeed?

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
$4\frac{1}{2}$	56	1	R/C, for α changes, and control altitude on glide slope.
6	39	1	Absolutely - airspeed, R/C, altitude errors on glide slope.
5	68	2	Coordinate with $\Delta\alpha$; R/C, h on glide slope and airspeed.
3	65	1	Coordinate with $\Delta\alpha$; Adjust for R/C, U , h on glide slope.
7	83	1	(No comment)
8	76	1	Coordinate with $\Delta\alpha$ and ΔU , adjust for R/C. h on glide slope working throttle all the time.

D.

Rating	Flt.	Conf.	Pilot Comments
$6\frac{1}{2}$	79	1	Coordinate with ΔU . R/C, h errors on glide slope.
8	60	1	Yes, R/C, airspeed errors, α changes, altitude errors on glide slope.
7	49	1	Yes, R/C and altitude on glide slope and airspeed (especially when you are high and fast).
7	65	2	Coordinate with α . However, difficult to know when α is changing with this one. R/C, h on glide slope.

DRAG CASE: BACK SIDE

Question No. 10 Is Elevator Used to Control: Attitude? R/C? Other? Altitude? Airspeed? n_z ?

A.

Rating	Flt.	Conf.	Pilot Comments
5	49	2	Yes, attitude and thru attitude, airspeed-altitude on glide slope.
4	74	1	Attitude and through attitude, altitude and velocity.
4½	72	1	Attitude and attitude changes are made to control attitude and airspeed.
4½	75	2	Attitude, through attitude altitude and airspeed.
4½	58	1	Attitude, airspeed, attitude errors due to throttle changes.
4	79	2	Attitude. Inputs to the attitude command computer are several and depend on situation. Can be angle of attack, altitude, airspeed.
6	48	2	Yes. 1st attitude, 2nd through attitude, it controlled airspeed and altitude (especially on glide slope).
4	63	1	Erased for Harper's SST Report.
6½	72	2	Attitude and through attitude, altitude and airspeed.

B.

Rating	Flt.	Conf.	Pilot Comments
5½	82	2	Attitude. Make attitude changes for altitude and airspeed errors.
4½	68	1	Attitude and attitude used to control airspeed and altitude.
5½	75	1	Attitude and altitude and airspeed on glide slope.
6	76	2	Attitude - attitude corrections for airspeed and airspeed errors.
6	61	1	1st attitude; 2nd altitude on glide slope and airspeed errors.
8	82	1	Attitude and try to correct airspeed, altitude errors with attitude.
7	53	1	Attitude, airspeed; 2nd, altitude on glide slope.

C.

Rating	Flt.	Conf.	Pilot Comments
5	63	2	Yes, attitude; 2nd, airspeed and altitude.
4½	74	2	Attitude. Airplane noses over or up when the throttle is changed such that airspeed tends to hold.
4	48	1	Attitude and airspeed; altitude on glide slope.

DRAG CASE: BACK SIDE

Question No. 10 Is Elevator Used to Control; Attitude? R/C? Other? (Cont.)
Altitude? Airspeed? n_z ?

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
4½	56	1	1st airspeed; 2nd airspeed, altitude through attitude.
6	39	1	Yes, pitch attitude and with throttle control airspeed.
5	68	2	Attitude and through attitude -- altitude and airspeed.
3	65	1	Attitude, airspeed and altitude on glide slope.
7	83	1	(No comment).
8	76	1	Attitude and secondarily, altitude and airspeed. Pretty good change of stick force with airspeed in jet penetration but not noticeable on glide slope.

D.

Rating	Flt.	Conf.	Pilot Comments
6½	79	1	Attitude and through it altitude and airspeed. Didn't have to use much elevator with throttle.
8	60	1	Attitude, 2nd airspeed, altitude error on glide slope.
7	49	1	Yes, attitude and through attitude, airspeed -- altitude on glide slope.
7	65	2	Attitude and attitude use to control airspeed and altitude.

DRAG CASE: BACK SIDE

Question No. 11 Could You Make an Instrument Landing Approach with this Configuration at this Speed?

A.

Rating	Flt.	Conf.	Pilot Comments
5	49	2	Yes, but you have to watch it all the time.
4	74	1	Yes, but air was quite smooth. It may respond too much to gusts.
4½	72	1	Yes, but must watch airspeed and use throttle with angle of attack.
4½	75	2	Yes, but don't like drag characteristics.
4½	58	1	Yes and in an acceptable manner, but requires two-control operation by the pilot.
4	79	2	Yes, problems are mainly in turns.
6	48	2	Yes.
4	63	1	Erased for Harper's SST Report.
6½	72	2	Yes, but I don't like it. Eventually gets you in trouble.

B.

Rating	Flt.	Conf.	Pilot Comments
5½	82	2	Yes, have to watch airspeed.
4½	68	1	Yes, but may have airspeed troubles.
5½	75	1	Yes, but I don't like this airplane.
6	76	2	Yes, but not happy with it.
6	61	1	Yes, marginally.
8	82	1	Only under ideal conditions.
7	53	1	Yes, but it's got a built-in characteristic for killing people.

C.

Rating	Flt.	Conf.	Pilot Comments
5	63	2	Yes, it's acceptable.
4½	74	2	Yes, would have to teach pilots to close throttle loop.
4	48	1	Yes, a pretty good one -- but had to watch airspeed.
4½	56	1	Yes, but it's a two-control configuration in pitch.
6	39	1	Yes, airspeed indicator a must.
5	68	2	Yes, but should caution pilot to watch airspeed.
3	65	1	Yes, acceptable and satisfactory.
7	83	1	Turbulence dumped system. Would have oscillation problems in turbulence.

DRAG CASE: BACK SIDE

Question No. 11 Could You Make an Instrument Landing Approach with this Configuration at this Speed? (Cont.)

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
8	76	1	You could do it but I don't like it at all.
D.			
$6\frac{1}{2}$	79	1	Yes, but there will probably be accidents.
8	60	1	Not under all circumstances -- could gallop it right into runway.
7	49	1	Yes, but sooner or later, it would get you.
7	65	2	Yes, under favorable conditions but would probably kill a lot of people if it was used a lot.

DRAG CASE: BACK SIDE

Question No. 12 — What Happens When You Transition to Visual Flight? How do You Fly the Visual Approach, Particularly Regarding Glide Slope Control? Are You Checking Airspeed and/or Angle of Attack? If so, When do You Quit?

A.

Rating	Flt.	Conf.	Pilot Comments
5	49	2	Tended to have airspeed control difficulties.
4	74	1	Pretty good, had poor visibility.
$4\frac{1}{2}$	72	1	First one went well. Checked airspeed all the way. Second one, got high and fast and it was extremely difficult to correct.
$4\frac{1}{2}$	75	2	Off on centerline due to ADF trouble. Difficult to correct high and fast.
$4\frac{1}{2}$	58	1	Transition (poor visibility caused trouble in interpreting the lights) Visual (everything - including airspeed - went well hardly no glide slope control was required) Airspeed all the way.
4	79	2	Smooth air. Poor visibility. Strobe lights on. Approaches went very well. Started fast on second one and corrected quite nice in smooth air.
6	48	2	Transition - high and fast; airspeed - $\frac{1}{2}$ to $\frac{1}{4}$ mile.
4	63	1	Erased for Harper's SST Report.
$6\frac{1}{2}$	72	2	Could stay on glide slope but control of airspeed was difficult.

B.

Rating	Flt.	Conf.	Pilot Comments
$5\frac{1}{2}$	82	2	Not very good, got fast both times. High and fast first time and had difficulty trying to correct. Don't like to have to pull power way back because of engine acceleration.
$4\frac{1}{2}$	68	1	Trouble correction "low".
$5\frac{1}{2}$	75	1	Never felt very good with it. It never seemed right. Tended to get fast both approaches.
6	76	2	Airplane does not tend to seek pitch attitude. You have to direct it, then wait to see if you are on glide slope and speed. Has little stick force feel with airspeed.
6	61	1	Transition (right on) visual (had to be tight on airspeed, had to use tight throttle loop for both airspeed error and glide slope errors). Airspeed $\frac{1}{4}$ mi.

DRAG CASE: BACK SIDE

Question No. 12 What happens When You Transition to Visual Flight? How do You Fly the Visual Approach, Particularly Regarding Glide Slope Control? Are You Checking Airspeed and/or Angle of Attack? If so, When do You Quit? (Cont.)

B. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
8	82	1	Never could nail it down. The whole approach was series of corrections.
7	53	1	Transition (had to make slight lining-up corrections) Good approach.

C.

Rating	Flt.	Conf.	Pilot Comments
5	63	2	Transition -- go high and fast; glide slope control when high, pull off throttle; airspeed - $\frac{1}{4}$ mile or less.
$4\frac{1}{2}$	74	2	Fairly comfortable transition. Pretty good on glide slope in smooth air.
4	48	1	Transition -- moderately smooth, got light indications pretty well. Glide slope -- throttle controlled air-speed errors, altitude and elevator controlling attitude. Airspeed -- as long as he could.
$4\frac{1}{2}$	56	1	Transition (took power off and R/S developed quite rapidly) visual (able to make corrections easily without large airspeed changes) Airspeed to $\frac{1}{2}$ or $\frac{1}{4}$ mile.
6	39	1	Much better (trouble due to wind shear) Airspeed $\frac{1}{2}$ mile.
5	68	2	Must use tight attitude control. Airspeed tends to get off desired value.
3	65	1	Tended to be high -- corrected by easing off power. Went well.
7	83	1	Turbulence dumped system.
8	76	1	Poor visibility, got high and fast very hard to correct. Heaved off glide slope on second one and would have had to wave-off.

D.

Rating	Flt.	Conf.	Pilot Comments
$6\frac{1}{2}$	79	1	Poor visibility. Airport approach and strobe lights were on. Had to make lateral correction on first approach. Fast condition hard to correct.
8	60	1	Transition (trouble seeing and interpreting lights) Visual (airspeed would get 10 kt high and felt like you are half out of control trying to get it back) Airspeed -- $\frac{1}{4}$ mile out.

DRAG CASE: BACK SIDE

Question No. 12 What Happens When You Transition to Visual Flight? How do You Fly the Visual Approach, Particularly Regarding Glide Slope Control? Are You Checking Airspeed and/or Angle of Attack? If so, When do You Quit? (Cont.)

D. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
7	49	1	Didn't have good transition characteristics -- couldn't control the flight path near as accurately as was desired. Had trouble with airspeed on glide slope; oscillated in pitch about mean, flet half out of control. Airspeed -- almost to the wave-off.
7	65	2	Went well in smooth air but then gust heaved it off glide slope and pilot had very little ability or success in correcting back to glide slope.

DRAG CASE: BACK SIDE

Question No. 13 Comment on the Wave-Off.

A.

Rating	Flt.	Conf.	Pilot Comments
5	49	2	Satisfactory.
4	74	1	O. K.
4½	72	1	O. K.
4½	75	2	O. K.
4½	58	1	Went Well -- got a little high on speed (8 kt).
4	79	2	Good.
6	48	2	Had adequate control.
4	63	1	Erased for Harper's SST Report.
6½	72	2	O. K.

B.

Rating	Flt.	Conf.	Pilot Comments
5½	82	2	O. K. -- response little sluggish.
4½	68	1	O. K.
5½	75	1	O. K.
6	76	2	O. K. Got fast in climb.
6	61	1	Went well -- got a little fast -- tight airspeed control.
8	82	1	O. K.
7	53	1	Good control, but had airspeed problems.

C.

Rating	Flt.	Conf.	Pilot Comments
5	63	2	Tended to get fast.
4½	74	2	Comfortable, airspeed control good.
4	48	1	Control seemed quite good except pilot wants more excess thrust even though this was a light configuration.
4½	56	1	Little cumbersome, but made satisfactory wave-off.
6	39	1	Alright except didn't have enough R/C or thrust available.
5	68	2	Airspeed control was poor, lot of turbulence.
3	65	1	Comfortable -- could look for traffic without bleeding airspeed.
7	83	1	Turbulence dumped system.
8	76	1	O. K. Bobbled a little.

DRAG CASE: BACK SIDE

Question No. 13 Comment on the Wave-Off (Cont.)

D.

Rating	Flt.	Conf.	Pilot Comments
$6\frac{1}{2}$	79	1	No comment.
8	60	1	Got fast -- poor airspeed control -- had to watch attitude too close.
7	49	1	O. K., but had difficulty accounting for trim changes with elevator (A/C tended to oscillate).
7	65	2	System disengaged in wave-off.

DRAG CASE: BACK SIDE

Question No. 14 Comment on the Visual Circling Approach

A.

Rating	Flt.	Conf.	Pilot Comments
5	49	2	Substantial R/S, but had good attitude control.
4	74	1	Went fairly well.
4½	72	1	Difficult to find power setting. High sink rate in down-wind turn.
4½	75	2	Not too bad.
4½	58	1	High R/S in turns.
4	79	2	High drag rise in turns make level turns difficult.
6	48	2	Acceptable -- didn't have the precise tightness of control that the other one had.
4	63	1	Erased for Harper's SST Report.
6½	72	2	Difficult to find power setting.

B.

Rating	Flt.	Conf.	Pilot Comments
5½	82	2	Have to fiddle with throttle to get setting that will keep airspeed.
4½	68	1	Trouble finding correct throttle setting.
5½	75	1	Trouble establishing altitude, high sink rate turn. Always tend to make mistakes.
6	76	2	O.K.
6	61	1	Went well probably because of no turbulence.
8	82	1	Established altitude and airspeed very gradually. High sink rate in turn. Airspeed gets off if attention to closed-loop control is interrupted.
7	53	1	Didn't pull off much power, so aircraft didn't have a large R/S.

C.

Rating	Flt.	Conf.	Pilot Comments
5	63	2	Got fast down-wind; no high sink rate when turning base.
4½	74	2	Little altitude problem; have to keep after turns.
4	48	1	Went well -- was even able to pull up gear and handle trim changes.
4½	56	1	Rapidly developed R/S when power was reduced.
6	39	1	Alright except for airspeed -- bleeds.

DRAG CASE: BACK SIDE

Question No. 14 Comment on the Visual Circling Approach (Cont.)

C. (Cont.)

Rating	Flt.	Conf.	Pilot Comments
5	68	2	Sink rate in turns was pretty high.
3	65	1	You have to be there with power during maneuvers. If use proper coordination of power, airspeed is not a problem.
7	83	1	Turbulence dumped system.
8	76	1	Very high sink rate on down wind turn very difficult to control.
D.			
6½	79	1	High drag rise in turns.
8	60	1	Had high R/S -- lose a lot of airspeed in turns, then when starting down, would get too fast. It was a real handful.
7	49	1	Went alright except couldn't take off power below 90% because of R/S.
7	65	2	Airspeed got down to 150 kt. Got high sink rate in turns. Not good.