

PILOT EVALUATION OF SAILPLANE  
HANDLING QUALITIES\*

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Presented at the XVth OSTIV Congress  
Chateauroux, France 1978

ABSTRACT

Seven test pilots flew six sailplanes in a round-robin evaluation of sailplane handling qualities. An evaluation was made of the qualitative handling qualities over the sailplane operational envelope using the Cooper-Harper Rating Scale and pilot comments as the evaluation instrument. The sailplanes were chosen to represent the range of handling and performance characteristics of high performance sailplanes in current use.

The evaluation sailplanes were found generally deficient in the area of cockpit layout. The pilots indicated general dissatisfaction with high pitch sensitivity especially when coupled with inertially-induced stick forces. While all sailplanes were judged satis-

factory for centering thermals and in the ease of speed control in circling flight, pilot opinions diverged on the maneuvering response, pull-out characteristics from a dive, and phugoid damping. Lateral-directional control problems were noted mainly during takeoff and landing for most sailplanes with the landing wheel ahead of center of gravity. Pilot opinion of inflight lateral-directional stability and control was generally satisfactory. Five of the evaluation sailplanes exhibited a very narrow airspeed band in which perceptible stall warning buffet occurred. However, this characteristic was considered not objectionable when stall recovery was easy. The pilots objected to the characteristics of a wide airspeed band of stall warning followed by a stall with yawing and rolling tendency and substantial loss of altitude during the stall. Glide path control for the evaluation sailplanes was found to be generally objectionable.

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\*This study was supported by NASA Grant 1284  
Langley Research Center, Hampton, Virginia.

INTRODUCTION

There has been some concern voiced about the trends in high performance sailplane handling qualities. Poor handling qualities generally result in increased pilot workload which may compromise flight safety. Thus there is a strong interest in determining whether the current trends in sailplane performance improvement can continue while at the same time a high level of flight safety be maintained. The primary objective of this study was to make a qualitative evaluation of all aspects of high performance sailplane handling qualities and to define areas which require further study. To accomplish this objective at a modest cost, a round-robin flight evaluation of six sailplanes by seven test pilots was conducted. The Cooper-Harper Rating Scale and pilots' comments were to be used to evaluate the sailplane handling qualities. The specific objectives of this study were:

1. Using the Cooper-Harper Rating Scale and pilot comments investigate the handling qualities of high performance sailplanes.
2. Obtain pilot opinion of handling quality characteristics to assist the formulation of airworthiness standards.
3. Develop a data base of pilot opinion which would be of value in the design of future sailplanes.
4. Delineate areas which warrant more quantitative study.

The development of high performance sailplanes has evolved in discrete states with several sailplanes vying for the market at each stage. Thus it was determined that if the sailplanes developed since the early 60's were arranged into groups, then one sailplane from each group should be chosen for the evaluation session. The sailplane grouping logic is given as follows:

- Group 1: Borderline between utility and racing class,  $L/D_{max}$  mid 30's.
- Group 2: First sailplanes to use fiberglass structures. Represents technology in the late 60's. Most have camber changing flaps and/or drag chute.
- Group 3: Sailplanes developed in early 70's. Most numerous class in USA today, hence important.
- Group 4: Sailplanes developed during mid 70's. Just becoming available in substantial numbers. Most have landing flaps.

- Group 5: Very high performance,  $L/D_{max} \approx 50$ . Effect of large span on handling can be established by this class.
- Group 6: High performance two-place. Used in transition to high performance singleplace sailplanes.

Test pilots for the flight session were chosen from NASA, FAA and the soaring community to ensure that a wide range of pilot backgrounds would be brought to bear upon the sailplane handling quality evaluations.

Due to length limitations this paper is restricted to a summary of the investigation of sailplane handling qualities. A more complete description of this study is given in Reference 1. Reference 1 contains a complete listing of the pilot ratings and comments for the interested reader.

SAILPLANE FLIGHT

SESSION DESCRIPTION

Evaluation Sailplanes

Within the previously mentioned groups of sailplanes, a ranking was made to determine which one within each group had characteristics of most interest to this investigation. At the same time, only sailplanes with standard approved type certificates were considered. The soaring community was most cooperative in supporting the acquisition of the evaluation sailplanes.

Sailplane 1. This sailplane was chosen since it represents a transition to higher performance ships. It has a fixed horizontal stabilizer with a fairly large-chord elevator. The fixed gear is ahead of the center of gravity. The sailplane is equipped with Schempp-Hirth type divebrakes.

Sailplane 2. This sailplane is equipped with camber changing flaps which are interconnected with the ailerons. The landing gear is retractable and is ahead of the center of gravity. The sailplane has Schempp-Hirth type divebrakes, and a very short, straight control stick. The sailplane is placarded against intentional spins.

Sailplane 3. This sailplane was selected from Group 3. It has an all-movable horizontal tail and a control stick which curves slightly toward the pilot. The ship is equipped with retractable landing gear ahead of the center of gravity, and has upper-surface divebrakes. Intentional spins are prohibited with this sailplane.

Sailplane 4. This sailplane has a con-

ventional fixed stabilizer and movable elevator. The retractable landing gear is located slightly behind the center of gravity. The camber-changing flaps, interconnected with the ailerons, can be positioned up to 90 degrees for landing.

Sailplane 5. This ship had the largest wing span among the evaluation sailplanes. The horizontal tail, control stick and landing gear arrangement was identical to that of sailplane 3. This ship is equipped with camber-changing flaps interconnected with the ailerons, and with upper-surface dive brakes.

Sailplane 6. This sailplane represented a typical, fairly high performance two seater. It features a fixed landing gear, an all-movable horizontal tail equipped with anti-servo tab and large counterbalanced dive brakes.

A three-view drawing of each sailplane is shown in Figures 1 through 6, and the principal geometric characteristics are presented in Table 1. Since in some of the ships intentional spins were prohibited and/or some of the ships were not equipped with water ballast or drag chutes, the effect of these three factors on the overall sailplane handling qualities was not evaluated.

#### Evaluation Pilots.

Each evaluation pilot is affiliated with one of the following organizations: Soaring Society of America, Inc., the Federal Aviation Administration and the National Aeronautics and Space Administration. Table 2. indicates the number of flight hours as pilot in command of each pilot. Two of the pilots were professional experimental test pilots and had considerable experience with the Cooper-Harper rating scale. Four of the seven pilots had considerable sailplane cross-country and competition flying experience. Preceding the flight test sessions, these four pilots were asked to describe in detail to other pilots what they conceived to be the flight role or mission of a high performance sailplane. Thus, all of the pilots had a clear understanding of the broad mission for which this class of aircraft is designed.

#### Pilot Opinion Sampling Instruments and Data Presentation

The most cost effective method to accomplish the objectives of this study was to stage a round-robin flight session in which seven test pilots

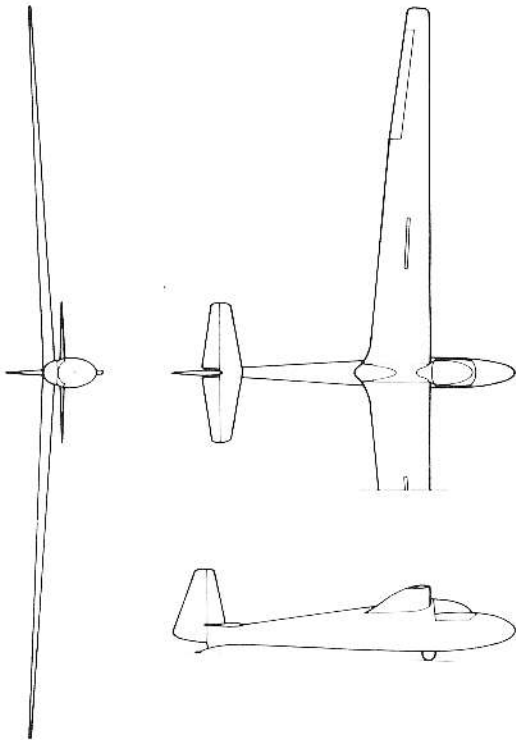


Figure 1. Three-view of Sailplane 1.

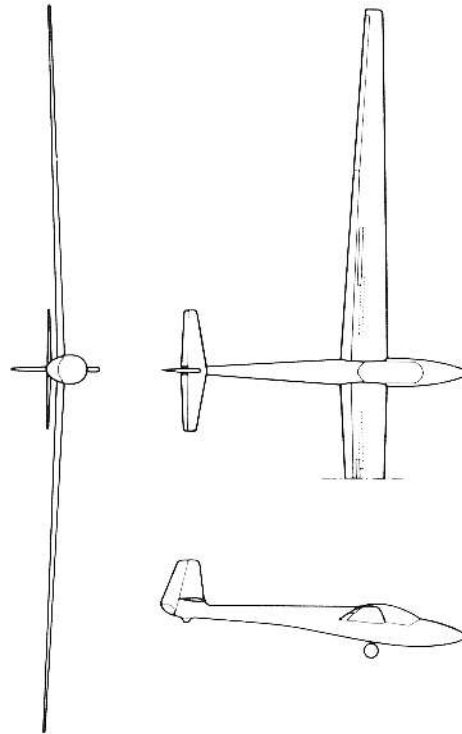


Figure 2. Three-view of Sailplane 2.

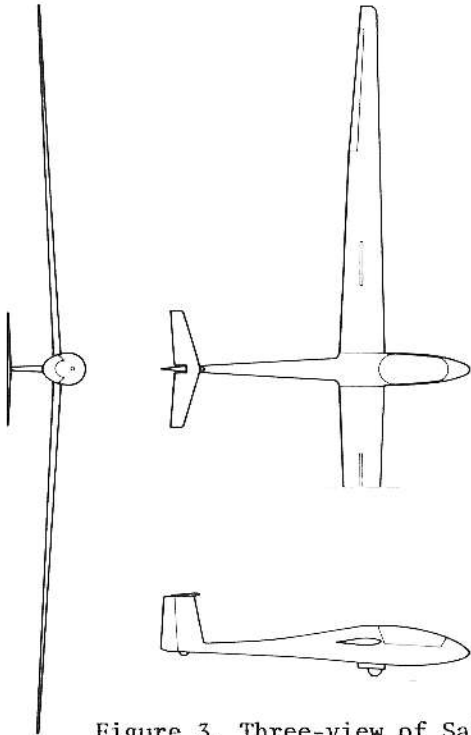


Figure 3. Three-view of Sailplane 3.

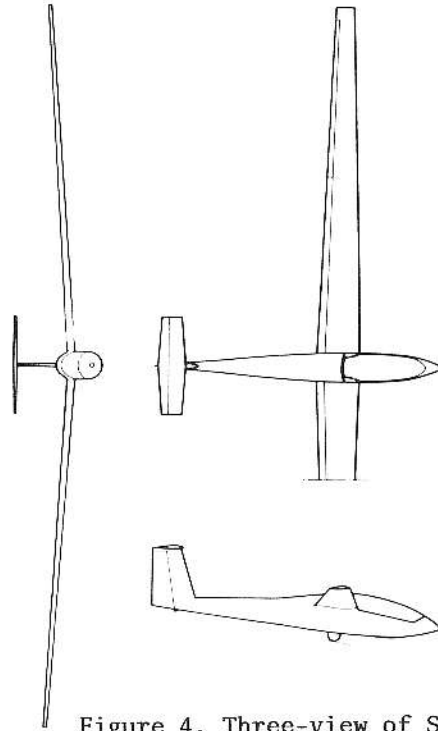


Figure 4. Three-view of Sailplane 4.

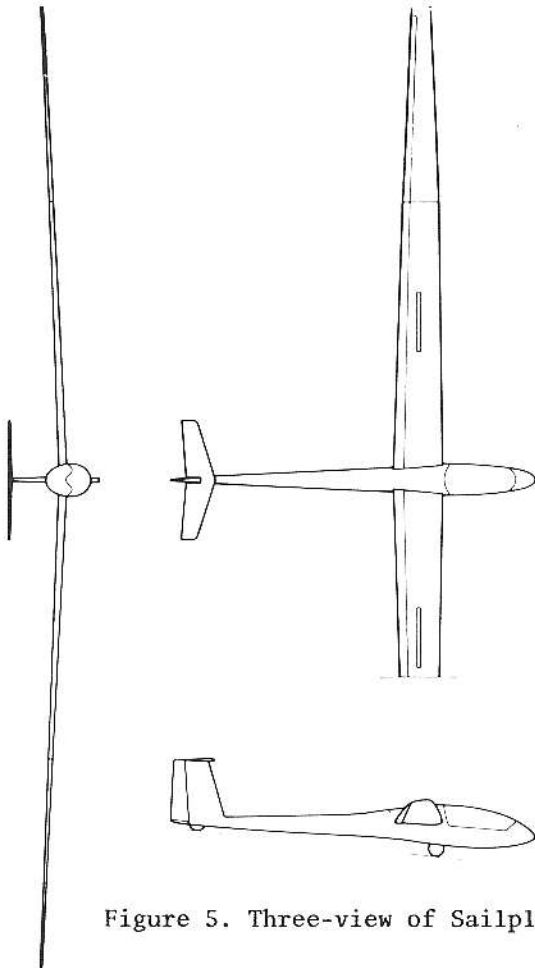


Figure 5. Three-view of Sailplane 5.

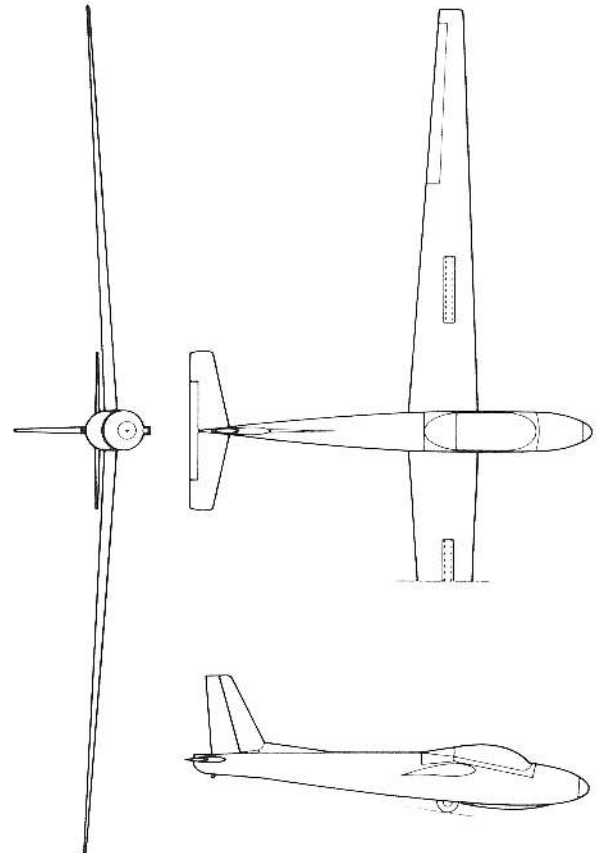


Figure 6. Three-view of Sailplane 6.

Table 1  
Sailplane Dimensional Parameters

Parameters	Units	Sailplane					
		1	2	3	4	5	6
Wing Span	m	15.0	15.0	15.0	15.0	20.3	17.4
Wing Area	m <sup>2</sup>	12.40	9.48	10.00	9.64	14.40	16.72
Aspect Ratio		18.1	23.6	22.5	23.3	28.6	18.0
MAC	m	0.885	0.687	0.704	0.681	0.756	1.069
Max Weight	kg	299	300	300/390	299/422	445/580	649
Wing Loading	n/m <sup>2</sup>	234.6	311.2	325.6/383	306.4/430.9	301.6/392.6	378.3
Root Chord	m	1.232	0.940	0.955	0.914	0.980	1.483
Tip Chord	m	0.394	0.343	0.368	0.373	0.350	0.483
Fuselage Length	m	6.680	6.198	6.350	5.842	7.290	8.153
Fuselage Width	m	0.584	0.610	0.635	0.584	0.610	0.813
Hor. Tail Area	m <sup>2</sup>	1.65	1.04	0.99	1.00	0.99	2.03
Hor. Tail Span	m	2.819	2.395	2.408	2.032	2.408	3.200
Elevator $c_f/c$		0.42	0.28	1.00	0.56	1.00	1.00
Vert. Tail Area	m <sup>2</sup>	1.13	1.06	0.84	0.78	---	1.43
L/D max (Handbook)		32	39	35.2	37	49	34
Fwd C.G.	% $\bar{c}$	20	25	26	27.8	29	25
Aft C.G.	% $\bar{c}$	40	52	47	38.2	45	38
$I_{yy}$ (Approx.)	kg m <sup>2</sup>	186	186	204	186	407	1178

Table 2  
Evaluation Pilot Flight Experience

Aircraft Type	Pilot						
	1	2	3	4	5	6	7
Sailplane	6500	1500	700	30	20	1500	20
SEL	500	500	200	600	200	1000	2450
MEL		1800		2600	3800	5000	1250
Jet Fighter		2500			1000		1500
Jet Transport		450		7000	3500	4000	550
Helicopter		50					250

evaluated six sailplanes representing distinct groups. The detailed sailplane handling quality pilot opinion data was obtained with a questionnaire which used the Cooper-Harper Rating Scale and pilots comments.

A questionnaire was designed to record the pilot's rating and comments of the sailplanes' handling qualities, design and cockpit layout. Each test pilot completed the questionnaire for each sailplane that he flew. The questionnaire was configured to evaluate the pilot's opinion of the sailplane handling qualities over the entire operating envelope from takeoff to landing. Specifically, each flight consisted of a tow to an altitude of 2700 or 3300 meters (AGL) depending on the pilot's preference. Evaluation tasks in smooth air were carried out before the flight reached lower altitudes (1000-1200 meters AGL) where convective conditions were usually encountered. On the average, the duration of each flight was 45 minutes, although some thermaling flight evaluations lasted as long as two hours.

Evaluations were made in both smooth air and in thermaling flight to determine if there were any significant pilot opinion differences between the smooth air test conditions and the usual operational environment, that is under convective conditions. A set of maneuvers listed in Table 3 was flown by each pilot to provide a basis for the evaluations. The pilots made comments on cassette recorders during each flight and these comments were transcribed by the pilots to the questionnaires.

A total of ninety-eight flights were made for a total of 80 flying hours. The session was very flight intensive, yet all objectives were accomplished without any mechanical or safety problems.

The Cooper-Harper Rating Scale (Reference 3), widely used in the evaluation of handling qualities of powered aircraft, was adopted for this questionnaire. The attractive feature of the Cooper-Harper Rating Scale, Figure 7, is the decision tree structure which guides the pilot to

Table 3. Evaluation Flight Tasks

A. Smooth Air Maneuver List

1. Evaluate take-off roll.
2. Evaluate tow-characteristics; box tow plane.
3. Release, slow flight, stall entry, general characteristics.
4. Attain and maintain constant IAS:50-70 kts. Evaluate trim capability over speed range. Note friction, noise, and vibration level.
5. Evaluate return to trim at 60 and 90 kts IAS.
6. Evaluate stick free stability. Trim at 60 and 90 kts. Introduce 5 kts airspeed perturbation and release stick. Note rate of convergence or divergence, time period of oscillation.
7. Evaluate stick position and force gradients over speed range. Trim at 75 kts, decelerate slowly to near stall then accelerate to 100 kts.
8. Evaluate pitch altitude response to small stick pulses over speed range especially at high speed (may be combined with Item 7).
9. Evaluate stick forces during pull up from high speeds.
10. Time roll rate during turn reversal (from 45<sup>0</sup> to 45<sup>0</sup> bank) at min. sink speed and at 65 kts. Evaluate ease of maintaining constant airspeed and coordination. (zero

sideslip).

11. Evaluate steady sideslip. Note force levels during rudder overbalance.
12. Evaluate constant g turn, 45<sup>0</sup> bank, 60 kts, L and R.
13. Evaluate constant g turn, 60<sup>0</sup> bank, 70 kts, L and R.
14. Evaluate flight path control system, pattern, flare characteristics, ease of touchdown control, landing roll.

B. Convective Flight Maneuver List

1. Evaluate takeoff, possibly crosswind effects, and tow characteristics in turbulence.
2. Evaluate stall/spin (incipient spin only) characteristics. Note onset of pre-stall buffet.
3. Thermaling characteristics
  - a. Low speed turns
  - b. Stall-spin susceptibility, recovery
  - c. Control characteristics near other aircraft.
4. Interthermal flight evaluation. Fly at max L/D speed plus 10 kts and at rough air airspeed or 100 kts IAS (whichever is lower).
5. Evaluate handling during secondary task.
6. Evaluate glide path control, touchdown and rollout characteristics in turbulence.

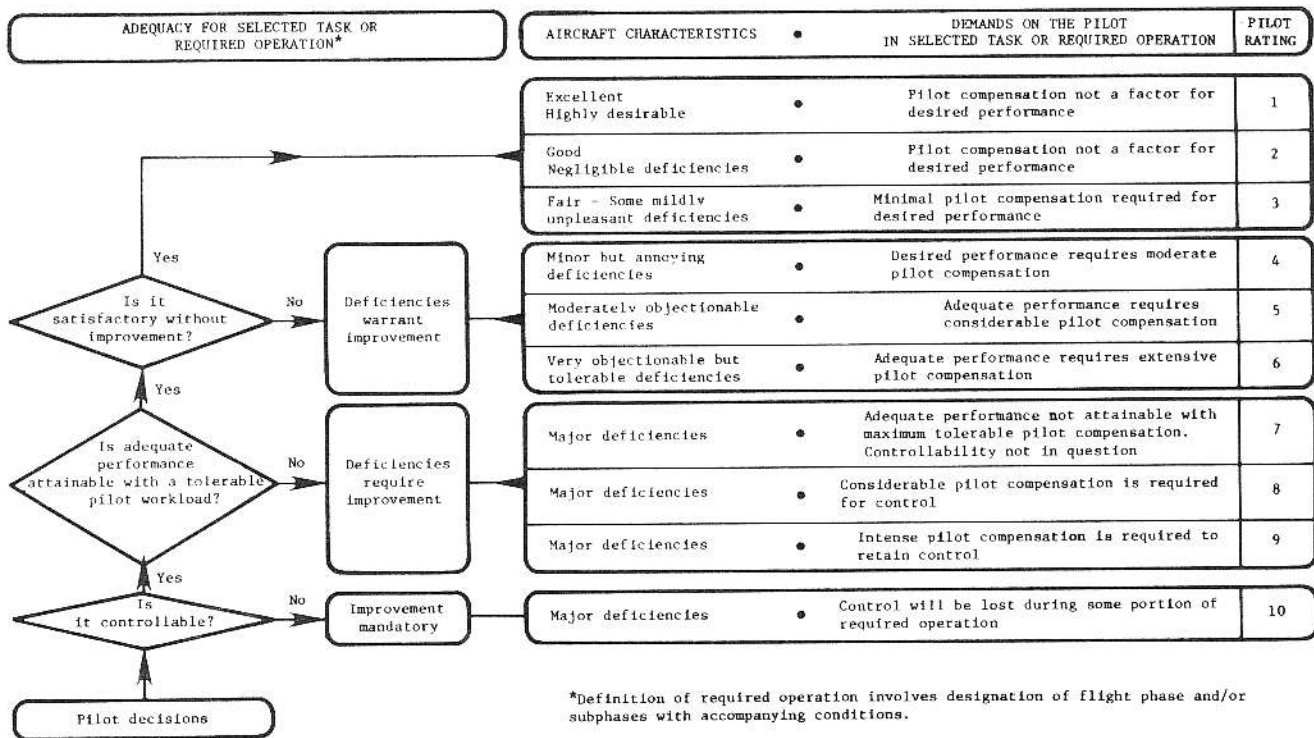


Figure 7. Cooper-Harper Rating Scale

a number for his rating value. For this initial study, the interpretation of the rating scale was broadened to be used in the evaluation of such sailplane characteristics as ease of assembly, inspection, and cockpit layout. The key to this interpretation was the assumption that the pilots would compensate for deficiencies in the design as they would for deficiencies in flight stability and control.

After the flight session was completed, the Cooper-Harper ratings and pilots' comments for each task of the questionnaire were transcribed into a data file on the University mainframe computer to facilitate the analysis and presentation of the data. The Cooper-Harper Rating Scale, is not a linear scale, thus statistical techniques do not strictly apply. However, averages and standard deviations were computed to gain some measure of the consensus of pilot opinions. An average and standard deviation of all sub-tasks for each pilot were computed to allow correlation of the average of the sub-tasks ratings with the major task rating. Extreme caution should be exercised in drawing conclusions from the numerically averaged ratings.

RESULTS AND DISCUSSION

Pilot Rating Summaries

The Cooper-Harper Rating Scale is a valuable tool in the evaluation of aircraft

handling qualities. To provide a measure of the variability of the pilot's assignment of ratings, averages and standard deviations for each task were computed for each sailplane. Again, it must be emphasized that the Cooper-Harper Rating Scale is non-linear and thus statistical methods do not strictly apply. Table 4 presents a summary of the average and standard deviation of all pilot ratings of a task for each sailplane. These average readings should not be directly compared with the levels of acceptability shown on the Cooper-Harper scale, but are rather a gross indication. Average Cooper-Harper ratings greater than 3.5 (with no specific meaning attached) have been underlined to delineate areas where problems were noted by most of the pilots. The standard deviations are a measure of the variation in the pilot's rating of a particular task.

Pilot rating numbers without their accompanying pilot comments are of very little value. The individual pilot ratings and comments furnished in Reference 1 are rather formidable in their volume and scope. The numerical summaries of Table 4, rather than being accepted by the reader at their Cooper-Harper rating scale face value, should be used as a guide to point out sections of particular interest in the complete pilot rating data base.

Sailplanes 4 and 6 received poor ratings in construction and rigging. Sailplanes 4 and 5 rated down in cockpit layout, sailplanes 3 and 5 in longitudinal handling qualities, and sailplane

Table 4. Rating Summary for Sailplanes

TASK	SAILPLANE											
	1		2		3		4		5		6	
	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV	AVG	STDEV
1	2.50	.50	2.00	.71	2.00	.71	<u>5.00</u>	1.00	2.00	.00	<u>4.50</u>	2.50
2	2.00	1.00	1.37	.41	2.25	.43	<u>4.50</u>	.50	1.88	.22	<u>5.50</u>	1.50
3	3.00	.82	1.50	.50	2.75	1.30	2.50	.50	1.75	.43	3.00	.00
4	2.00	.00	2.50	1.12	1.75	.43	3.50	1.50	1.75	.43	2.00	.00
5	2.33	.47	1.25	.43	1.75	.43	<u>5.00</u>	1.00	2.00	.00	<u>6.00</u>	1.00
6	3.60	.49	2.60	.80	1.80	.75	<u>4.25</u>	1.48	1.70	.60	2.00	1.00
7	3.29	.88	2.14	.99	1.14	.35	2.33	.75	1.40	.49	1.67	.75
8	3.29	1.39	2.71	.70	3.00	1.41	<u>4.80</u>	1.60	2.75	1.48	2.67	.94
9	2.57	.49	2.33	1.11	1.50	.50	2.00	.63	1.60	.49	2.80	.75
10	3.29	.88	1.43	.73	1.86	.83	1.83	1.07	2.00	.89	1.67	.47
11	3.75	.83	3.50	.50	3.50	1.12	1.60	.49	3.75	1.30	1.00	.00
12	1.12	.22	2.40	.49	2.33	.47	2.00	.00	3.00	1.26	1.25	.43
13	1.67	.94	2.75	.99	2.57	.73	2.67	1.60	1.20	1.17	1.80	.75
14	1.60	.49	2.17	.69	2.33	.94	1.17	.37	2.40	1.02	2.00	1.00
15	1.79	1.19	3.14	.99	2.57	.73	2.00	.58	3.20	1.17	1.83	1.07
16	1.37	.41	2.20	.75	2.50	.50	2.20	.40	<u>3.50</u>	1.26	1.50	.50
17	1.43	.73	2.29	.70	2.29	.70	2.00	.00	2.80	1.33	1.67	.75
18	<u>3.50</u>	1.34	2.57	.73	2.43	.49	2.50	1.26	2.20	.40	2.40	1.02
19	1.43	.73	2.14	.64	1.86	.64	2.17	.37	2.50	1.12	2.00	1.00
20	1.50	.50	1.67	.47	2.17	.69	1.80	1.80	1.75	.43	1.83	.69
21	1.25	.43	2.60	.49	<u>4.10</u>	1.11	3.20	.75	<u>4.20</u>	1.33	2.67	.94
22	1.57	.90	2.43	.73	2.29	.45	2.67	.47	2.40	.80	2.00	.58
23	<u>3.86</u>	.64	3.00	.53	2.33	1.25	2.33	.94	2.60	1.20	2.60	1.02
24	1.29	.45	2.29	.45	2.71	.70	2.17	.69	3.20	1.17	1.67	.47
25	1.57	.49	2.14	.99	2.29	1.03	3.17	1.07	2.80	1.17	2.33	1.25
26	1.25	.43	1.50	.50	2.25	.43	2.00	.00	2.00	.00	2.00	.63
27	1.17	.37	2.29	1.16	3.43	2.77	2.17	.69	<u>4.20</u>	2.93	2.20	.40
28	1.83	.69	3.17	1.07	3.80	3.19	1.40	.49	<u>4.25</u>	3.42	1.80	.75
29	1.29	.45	2.86	.35	2.71	.88	2.17	.90	<u>3.60</u>	1.62	2.00	.58
30	1.60	.49	2.83	.69	<u>5.29</u>	2.60	2.40	.49	<u>5.40</u>	2.58	2.00	.00
31	1.71	.45	2.71	.88	<u>4.00</u>	2.00	2.20	.98	3.30	1.78	2.00	.00
32	1.00	.00	2.80	.75	2.20	.51	2.20	.40	2.60	.80	2.00	.00
33	1.43	.49	2.14	.64	1.86	.64	2.17	.37	2.20	.40	2.00	.00
34	1.43	.49	1.86	.83	2.29	1.03	2.17	.37	2.60	.49	2.17	.37
35	2.00	.93	2.14	.35	1.86	.64	2.58	.45	3.30	1.08	2.50	.76
36	2.00	.76	2.83	.69	2.86	.64	2.17	.90	2.80	.75	2.60	.49
37	1.29	.45	2.71	.70	1.86	.64	2.00	.58	2.60	1.02	2.20	.75
38	2.00	.58	2.67	.75	2.17	.69	2.40	.80	3.00	1.55	2.50	.50
39	2.00	.63	3.40	.49	2.20	.75	2.25	.83	2.00	.00	2.33	.94
40	1.43	.73	1.86	.64	1.64	.69	2.00	1.00	1.20	.40	2.58	1.24
41	1.57	.73	2.14	.64	1.93	.78	2.00	1.00	1.60	.49	2.83	1.07
42	1.88	.74	2.20	1.60	2.40	1.00	3.00	.63	2.20	.75	<u>4.33</u>	1.25
43	2.00	.53	1.86	1.12	1.86	.64	2.33	.75	2.00	.63	<u>3.00</u>	1.15
44	2.43	.49	2.71	1.39	2.43	.90	2.50	.76	2.20	.98	2.33	1.25
45	2.00	1.00	2.14	1.73	2.57	.90	3.00	.58	2.70	.98	<u>4.00</u>	1.15
46	1.57	.73	2.00	.76	2.57	.73	2.00	1.00	2.60	.49	2.33	1.25
47	1.33	.47	1.67	.75	2.14	.64	1.80	.75	1.80	.75	3.67	1.89
48	1.75	.83	3.00	1.41	2.33	.94	2.67	.47	2.00	.71	<u>4.50</u>	1.12
49	1.00	.00	1.50	.50	2.00	1.00	1.50	.50	2.50	.50	2.00	1.00
50	1.50	.50	1.86	1.12	1.67	.47	2.25	1.09	2.00	1.10	<u>4.00</u>	2.52
51	1.70	.40	2.75	1.30	3.20	.40	<u>3.50</u>	.50	2.90	.66	2.33	.47
52	2.57	.90	1.43	.73	1.43	.49	1.50	.50	1.40	.49	1.00	.00
53	1.57	.73	3.00	.93	2.57	.49	2.67	.47	2.40	.49	1.33	.75
54	2.14	.99	3.14	.99	3.14	.35	<u>4.08</u>	.61	2.60	.49	1.60	.80
55	1.57	.49	2.57	.73	2.57	.73	<u>3.87</u>	.40	2.40	.49	1.50	.50
56	1.50	.50	2.29	.88	2.43	.49	2.54	.85	2.40	.49	1.80	.40
57	1.43	.73	2.57	.73	<u>4.00</u>	2.38	1.67	.47	<u>4.00</u>	1.26	1.33	.47
58	1.00	.00	2.50	.71	2.60	.49	2.62	.41	3.20	1.17	3.00	1.22
59	1.50	.76	2.42	.84	2.42	.61	2.00	.00	<u>3.87</u>	1.43	2.25	.43
60	1.33	.75	2.50	.96	2.50	.50	2.00	.00	3.00	1.22	2.00	.00
61	1.83	.69	2.50	.50	2.83	.69	2.00	.00	2.50	.50	2.00	.00
62	1.80	.40	1.75	.43	2.00	.63	2.33	.47	2.00	.82	2.00	.00
63	1.00	.00	2.40	.97	2.00	.00	2.87	.74	2.30	.75	<u>4.33</u>	2.62
64	1.17	.37	2.83	.90	2.00	.58	2.75	.83	2.40	.49	5.00	2.16
65	1.75	.38	2.33	1.37	2.00	.58	2.37	.41	1.60	.49	<u>5.33</u>	2.87
66	1.83	.69	2.33	.75	2.00	.58	2.75	.43	2.75	1.09	3.33	.47
67	1.50	.50	2.17	1.21	2.33	.47	3.25	1.09	2.20	.98	<u>4.33</u>	1.25
68	1.60	1.20	2.20	.98	2.60	.97	2.37	.65	2.20	.98	1.67	.47
69	1.67	1.11	2.17	.69	2.33	.94	2.37	.65	2.60	1.36	1.50	.50
70	1.67	.47	2.00	1.15	2.00	.82	2.87	.89	2.00	.63	2.50	1.50
71	1.50	.50	2.50	1.12	3.00	.82	2.50	.50	3.20	1.94	1.50	.50
72	2.17	.80	2.17	.37	2.25	.56	2.75	.43	1.80	.75	2.50	.50
73	1.40	.49	2.33	1.11	1.50	.50	1.75	.43	1.60	.80	1.75	.43



6 in stall/spin characteristics. Sailplanes 3, 4, and 5 were given poor ratings in landing characteristics, and sailplane 6 in circling flight. Sailplane 1 received consistently higher ratings than all other aircraft, in every rating category, and was often cited as a benchmark of excellence for sailplane handling qualities. To gain more than this superficial information, the reader must refer to the individual pilot comments in the above areas, which provide an understanding of the reasons for the ratings.

#### Pilot Evaluation of Ease of Assembly, Inspection and Cockpit Layout

Although these factors are generally not regarded as an essential part of handling qualities, as, say, longitudinal stability, all three characteristics do influence the ease and precision with which the pilot is able to perform tasks for the overall mission of the sailplane. Three of the pilots did not rate the ease of assembly and inspection since they have very limited contact with sailplanes before the flight session. The pilots found visibility was adequate in all ships. They singled out poor ventilation, the use of curved control sticks, confusing or unhandy secondary control handles (such as trim and flap handles), and poor pilot protection as areas of concern. The variety of adverse comments indicates the need for standardization of the location, shape, and color of the secondary control handles.

#### Pilot Opinion of Longitudinal Characteristics

Takeoff. Average pilot ratings ranged from 1.8 for sailplanes 1 and 6 to 3.2 for sailplanes 2 and 5. Sailplanes 1 and 6 were generally the most stable, had the highest stick forces, and had strong damping of the short period pitching oscillation. Pilots commented that sailplane 2 was more sensitive in pitch than they liked, and that they tended to overcontrol in pitch during takeoff. On sailplane 5, pilots reported disliking the stick bobbing fore and aft when rolling over bumps. Although he gave a pilot rating of 2, one pilot noted that on sailplane 4, the longitudinal stick feel-and-trim spring system had high and unsymmetric breakout forces which caused him to overcontrol.

Tow. Again, pilot ratings were best for sailplanes 1 and 6, averaging 1.4 for 1 and 1.5 for 6. The worst average rating was 3.5 for sailplane 5. Pilots strongly objected to inertially-induced stick forces, and reported overcontrolling, and a feeling that a serious

PIO could occur. Sailplane 2 was reported easily upset in rough air, requiring frequent small control corrections, thus receiving several pilot ratings of 3. Sailplane 4 was reported sensitive and easy to overcontrol, receiving pilot ratings of 2 and 3.

Establishing and Maintaining Airspeed. Establishing and holding speed was rated satisfactory for all sailplanes. For sailplane 5, one pilot reported that a pitch correction tended to continue past the intended point and had to be arrested by a checking control input (his pilot rating was 4).

Longitudinal Trimming. The trim system on sailplane 1 was rated unsatisfactory. The trim system of every sailplane was reported as inconvenient to use, but only sailplane 1 was rated unsatisfactory.

Pitch Sensitivity. Sailplanes 3 and 5 received some pilot ratings of 4 and 5 for oversensitivity. Sailplanes 2, 3, 4, and 5 were described as sensitive, but 2 and 4 did not receive poor pilot ratings for sensitivity.

Stick Force Gradient, Stick Fixed Stability, and Stick Free Stability. These were not tasks, but rather a request for opinions on the suitability of the listed characteristics. In the absence of quantitative data and since the pilot comments were rather general, the responses to these three requests for pilot opinion are broadly summarized: sailplane 1 was well-liked; sailplanes 2, 3, and 5 were characterized as having light stick forces, bordering on too light, while sailplanes 4, and, even more so, 6, were judged to have too-heavy stick forces.

Return to Trim. The pilots were satisfied with the return-to-trim characteristics of all sailplanes, giving pilot ratings of 2 to 3. Two pilots felt the task had no relevance to their opinion of a sailplane's handling qualities.

Maneuver Response. Opinions diverged on the maneuvering responses of the six sailplanes. Sailplanes 1, 4, and 6 were well-liked by all pilots, receiving mostly 1 and 2 pilot ratings. Sailplane 2 received mostly 3 ratings and comments giving the impression it was more responsive than the pilots liked. Sailplanes 3 and 5 got mixed opinions. Sailplane 3 was rated 4 and sailplane 5 rated 5 due to low or nil stick-force-per-g by some pilots.

Phugoid Characteristics. Pilots were satisfied with the lightly damped or neutral stick-free phugoids of sailplanes 1, 2, 4, and 6, while some pilots objected to the strongly divergent stick-free phugoids of sailplanes 3 and 5. The divergent motions appeared to be caused by a dynamic interaction between the sailplane

phugoid mode and the pitch control system.

Dive Recovery Sailplanes 1, 4, and 6 were regarded as satisfactory. Sailplane 2 was given satisfactory pilot ratings, but several comments suggested that it was more sensitive than desired. Sailplanes 3 and 5 were rated unsatisfactory by some pilots who commented that the stick forces were too light, and sometimes reversed during pull-outs.

Ease of Centering Thermal, and Speed Control in Circling Flight. All sailplanes were rated satisfactory for these tasks. Comments indicated that the high stick forces and heavy stability of sailplane 6 caused an undesirably high workload in circling at varying bank angles as is typically done in thermaling flight. On sailplane 3, comments noted that the very low or negative stick-force-per-g was very pleasant to fly and felt immediately natural and comfortable during the thermaling task. On sailplane 5 the same comments were made, and additionally that in an established thermaling turn the stick could be moved as much as 7 cm aft without appreciably affecting the turn. This later characteristic was not felt objectionable.

Table 5 summarizes the longitudinal stability and control characteristics of the sailplanes evaluated and Table 6 summarizes the pilot opinion of longitudinal handling qualities for primary flight tasks. Table 6 shows that longitudinal characteristics best liked for thermaling are less well liked for takeoff,

tow, maneuvering, and dive pull-out. From Table 5 it appears that increased stability and reduced sensitivity are beneficial to the first three tasks while lower stability and greater sensitivity are desirable for the last task. Table 6 shows that all the sailplanes had satisfactory or better longitudinal handling qualities for normal flying and thermaling, and that all but one were also satisfactory for maneuvering and dive pull-out. This was not surprising since all of the evaluation sailplanes were commercially successful in series production.

Sailplane Lateral-Directional Handling Qualities

Sailplane performance growth has not influenced lateral-directional handling qualities, although both have been degraded. The only serious lateral-directional problem apparent in current high performance sailplanes is in takeoff and landing, where low roll control and rudder power can lead to loss of directional control, especially in crosswinds. One cause is the placement of the landing wheel ahead of the C.G., which increases weather-cock tendencies. Another is a raised C.G. coupled with a further aft and lower placement of the tow line attach point, which introduces a significant rolling moment with sailplane heading/tow line misalignment. This problem warrants further study to better define controllability during takeoff and landing.

Although pilot comments did not reflect any serious inflight problems, improvement in lateral-directional handling qualities, such as roll response quickening, increased roll control power, and reduction in rudder coordination requirements, would enhance performance in soaring flight, due to the importance of quickly acquiring and centering the thermals and of reducing pilot workload.

Sailplane 1 was "excellent" to "good" (Pilot rating 1 to 2) in almost every area. Pilot comments emphasized the good control harmony between rudder and aileron and ease of rudder-aileron coordination.

Sailplane 2 pilot ratings ranged from 2 to 4, with many comments about high rudder coordination workload in maintaining ball-in-the-center flight, both in turns and turn entries as well as level flight. Lateral-directional characteristics for this sailplane could be summarized as distracting and irritating.

Sailplane 3 lateral-directional control harmony and coordination was good. A comment

Table 5. Sailplane Longitudinal Stability and Control Characteristics

Sailplane	Control Forces	Trim	Static Longitudinal Stab.	Stick-Free Short Per. Damping	Stick Force Per G	Perceived Sensitivity
1	Aerodynamic + Spring	Spring	Moderate	High	Moderate	Moderate
2	"	"	Lo	"	Lo	High
3	Spring + Bobweight	"	"	"	Nil	"
4	Aerodynamic + Spring	"	"	"	Lo	"
5	Spring + Bobweight	"	"	"	Nil	"
6	Aerodynamic	Tab	High	"	Moderate	Moderate

Table 6. Summary of Opinions on Longitudinal Handling Qualities

Sailplane	Takeoff and Tow	Straight Flight	Maneuvering & Dive Pull-Out	Thermaling
1	Well Liked	Well Liked	Well Liked	Well Liked
2	Satisfactory	Satisfactory	Satisfactory	Satisfactory
3	Satisfactory	Well Liked	Satisfactory	Well Liked
4	Satisfactory	Satisfactory	Satisfactory	Satisfactory
5	Satisfactory	Well Liked	Unsatisfactory	Well Liked
6	Well Liked	Well Liked	Well Liked	Satisfactory

for sailplane 3 on aileron effectiveness was that ailerons remained very effective even below stall speed.

The only complaints for sailplane 4 were due to the requirement for considerable top aileron in turning flight and mild objection to coordination workload in lateral maneuvering.

Sailplane 5 received good to excellent ratings for its ease of control in maintaining desired bank angles in turning flight. Several pilots objected to its low maximum roll rate of about 0.25 rad/sec, about 0.1 rad/sec less than that of all the other sailplanes.

Sailplane 6 was judged as a training sailplane, suitable for transitioning into high performance ships. In this context, it received very good ratings, except for ease of maintaining desired bank angles and for control near the stall.

Rudder overbalance, or "rudder lock" was a characteristic common to sailplanes 2, 3, and 5. The pilots did not find this unsafe or even annoying, except on sailplane 5; one pilot gave sideslips a rating of 4 due to this feature, noting that about 180 N. pedal force was required to "unlock" the rudder and that large sideslip angles were possible. Control, however, remained good and very little buffeting occurred at the high sideslip angles. It is concluded that although proportionally increasing rudder pedal force with rudder deflection is a desirable characteristic, rudder overbalance is not unsafe unless very high pedal forces or other overruling characteristics are involved.

#### Sailplane Stall/Spin Characteristics

Cross-country soaring flight sometimes involves steep turns at low altitudes to take advantage of whatever lift may be available, avoiding landing unless absolutely necessary. Since optimum airspeed for thermaling flight is near the stall speed, stall and incipient spin characteristics are of prime importance in safety of flight.

Stall warning characteristics of the evaluation sailplanes were described as mild for sailplanes 1 through 5 and too much for sailplane 6. The airspeed stall warning band varied from 1 to 3 kt for the first 4 sailplanes, and were often in a form that could be masked by atmospheric turbulence. However, once the stall was recognized, recovery in most cases was easily and quickly effected by merely relaxing aft stick pressure and flying out of the stalled condition with little altitude loss. Sailplane 6, on the other

hand, had a wide stall warning airspeed band of 10-12 kt, which caused stall buffet to occur frequently at thermaling flight airspeeds. The pilots noted that this is an undesirable characteristic because familiarity with the stall warning buffet degrades its effectiveness and tends to cause the pilot to ignore the warning.

As to stall, incipient spin, and recovery characteristics, sailplanes 1, 2, 3, and 5 generally received good to excellent ratings with sailplane 1 being foremost. Good aileron control was noted, even below stall speed, and abused, cross-controlled stalls did not reveal undesirable qualities. Sailplane 4 recovered immediately with relaxation of aft stick force, but two pilots noted a definite autorotative (spin) tendency if recovery was not executed promptly with wing drop. Sailplane 6 showed a tendency to yaw and roll to the left and to pitch down from a cross-control stall and received lower ratings due to this characteristic toward spinning.

#### Sailplane Approach and Landing Characteristics

Once committed to landing, sailplanes cannot go up; it follows that one of the primary considerations in evaluating approach and landing characteristics is ease of glidepath control. Precision in touchdown control is paramount for landing in unprepared and restricted areas, a situation often encountered in cross-country soaring flight. It is therefore not surprising that most of the evaluation sailplanes were criticized for lack of spoiler, flap, or airbrake effectiveness and precision.

Sailplane 6 received the best ratings, in the fair to good category, largely because of the effectiveness of spoilers in controlling glidepath. For instance, one pilot noted that due to dive brake effectiveness, it was easy to make "difficult" landings.

Sailplane 1 again received the best rating of all except sailplane 6, although it was noted that the divebrakes were somewhat ineffective. The same comment was made about sailplanes 2, 3, and 5. Sailplane 4 relied only on flaps for glidepath control. This concept was criticized on two points: large changes in pitch attitude with varying degrees of flap extension made precise glidepath control more difficult, and awkward placement, high force requirements, and complex flap control positioning requirements degraded precision of glidepath control.

Pilot Opinion and Certification Criteria

Pilot opinion specifies the characteristics pilots like in sailplanes. Certification criteria specify the characteristics thought by the certifying authority to be essential to their safe operation. There is no reason to expect that pilots will invariably prefer a safer characteristic to one less safe. The contribution to safety of a given characteristic sometimes being recognizable only by a complex analysis or demonstrated in accident patterns. However, in the absence of such analysis or evidence, it would seem sensible that criteria should conform in general to favorable pilot opinion.

General and specific examples of conflicting criteria and pilot opinion follow:

In general, pilots were willing to accept sailplanes that were somewhat more sensitive and less stable in pitch than they liked for takeoff, tow, and dive recovery in order to get easy longitudinal maneuvering and low stick forces for soaring flight--the mission of a sailplane. In particular, the criteria specifying a return-to-trim within, say, 10 percent of trim speed was felt to be of no benefit, and when achieved through increased stick centering forces considered to be a harassment. In what way such a criterion is essential to safety is not clear.

The only undesirable characteristic exhibited by some of the high performance sailplanes was marginal control during takeoff and landing. Current certification requirements are vague in this area. A requirement of controllability during takeoff and landing in crosswinds up to a prescribed level would be appropriate.

The requirement that no rudder overbalance occur was considered by some pilots to be overly restrictive. They argued that the natural instinct to straighten out would be sufficient to cue the pilot to overcome the mild overbalance that commonly occurs on gliders at large sideslip angles.

The sailplanes flown illustrated the ways in which stalling behavior desirable for sailplanes differs from that desirable for power planes. First pre-stall warning was found to be of little or no value because of the normal course of thermaling, the stall boundary is commonly exceeded. Because occasional stalls must be accepted, it is important that only the least reduction in angle-of-attack be sufficient to achieve an immediate unstall, and that very little loss in altitude and very minor upset

accompany the stall. For deeper or more prolonged or abused stalls, traditional criteria appeared acceptable. Thus, a modification to the traditional criteria such that the initial stall replaces buffet as a warning, and the deeper or aggravated stall be treated as the stall for purposes of certification.

The drag modulation observed on the test sailplanes was felt to be generally insufficient and the operating forces for the drag devices were felt to be generally undesirable for both flaps and airbrakes. Additionally, the variation of divebrake or flap effectiveness during the flare, float and touchdown phase was felt to degrade the pilot's ability to control his landing accuracy. In view of the importance of accurate landings for sailplanes, it was felt that a rational basis should be established for future criteria.

Future Study Areas

The present study shows the need for a more quantitative investigation of the factors influencing pitch control sensitivity such as precise measurements of stick forces due to both the aerodynamic hinge moments and the bobweight effects arising from the different horizontal tail configurations. Further study is required of lateral-directional control during takeoff and landing. More quantitative information should be gathered also on the various glide path control systems and the interaction of glide path controls with primary flight controls.

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