

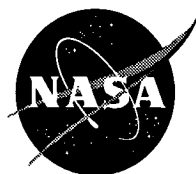
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NASA Contractor Report 198055

Flight Evaluation of an Aircraft with Side and Center Stick Controllers and Rate-Limited Ailerons

P. R. Deppe, C. R. Chalk, and M. F. Shafer

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National Aeronautics and
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NASA Contractor Report 198055

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Flight Evaluation of an Aircraft with Side- and Center-Stick Controllers and Rate-Limited Ailerons

Abstract

As part of an ongoing government and industry effort to study the flying qualities of aircraft with rate-limited control surface actuators, two studies were previously flown to examine an algorithm developed to reduce the tendency for pilot-induced oscillation when rate limiting occurs. This algorithm, when working properly, greatly improved the performance of the aircraft in the first study. In the second study, however, the algorithm did not initially offer as much improvement. The differences between the two studies caused concern. The study detailed in this paper was performed to determine whether the performance of the algorithm was affected by the characteristics of the cockpit controllers. Time delay and flight control system noise were also briefly evaluated. An in-flight simulator, the Calspan Learjet 25, was programmed with a low roll actuator rate limit, and the algorithm was programmed into the flight control system. Side- and center-stick controllers, force and position command signals, a rate-limited feel system, a low-frequency feel system, and a feel system damper were evaluated. The flight program consisted of four flights and 38 evaluations of test configurations. Performance of the algorithm was determined to be unaffected by using side- or center-stick controllers or force or position command signals. The rate-limited feel system performed as well as the rate-limiting algorithm but was disliked by the pilots. The low-frequency feel system and the feel system damper were ineffective. Time delay and noise were determined to degrade the performance of the algorithm.

Introduction

Background

This evaluation was part of an ongoing government and industry effort to study the flying qualities of aircraft with rate-limited control surface actuators. Prompted by recent aircraft accidents involving control surface rate limiting, several software algorithms have been developed to reduce the tendency for pilot-induced oscillations (PIO) when rate limiting occurs.

One such algorithm, the Rate Limit Concept (RLC) algorithm, was developed by R. A'Harrah of NASA and by C. Chalk under Calspan Internal Research and Development Program Number 85-892. The results of this study are presented in Reference 1. The RLC algorithm was evaluated in the Calspan Variable-Stability Learjet 25 in February 1993, sponsored by NASA, and showed good potential for reducing rate-limiting-induced PIO during landing tasks. The test configurations included rate limiting in pitch and roll, and were limited to a center stick controller and a flight control system with no augmentation. The results of this "Phase I" evaluation are presented in Reference 2.

The RLC algorithm was further evaluated in the USAF/FIGD NT-33 Variable-Stability aircraft in July 1993 with both center and side stick controllers and with an augmented flight control system. In addition to landing tasks, aggressive HUD tracking tasks were performed. During this USAF-sponsored program, the performance of the algorithm was less than satisfactory in most configurations tested, due in part to the slower computer cycle time and increase noise of the older NT-33 simulation system. Flight control system augmentation was shown to negate the effects of the algorithm in some cases, depending on the placement of the algorithm in the system. The results of the "Phase II" evaluation are presented in Reference 3.

The "Phase III" evaluation described in this report was sponsored by NASA Dryden Flight Research Center, Edwards, California, and was designed to answer questions raised in Phase II concerning RLC algorithm performance with side versus center stick controllers, sensitivity to noise and computer cycle time, and to evaluate alternatives to the RLC scheme. The RLC algorithm used in this experiment incorporated improvements based on the results of the NT-33 program.

Purpose

The purpose of this test was to evaluate the flying qualities of an aircraft with a low roll actuator rate limit. Variables introduced included: side- and center-stick controllers, force and position command signals, flight control computer cycle time, noise on command signals, rate-limited feel system, low frequency feel system, and a feel system damper.

Experiment Mechanization

Description of Test Aircraft

The test aircraft was the Calspan Variable-Stability Learjet 25, registration number N102VS. The aircraft is a production Learjet Model 25B airplane which has been modified with a three-axis variable stability system, including electro-hydraulic variable-feel center and side stick controllers. The simulation computer consists of an 80486 PC host with three Texas Instruments TMS320C30 digital signal processors performing the model and model-following calculations. A detailed description of the Learjet 25 simulation system is presented in reference 4.

Roll Feel System

The roll feel system was mechanized as a digital model-following system as shown in Appendix A, Figure A1. Force from the pilot's control was used to drive a digital second-order model complete with variable frequency, damping, force/position gradient, preload, friction, and rate limiting. The model position, rate, and acceleration signals were combined to drive the 70 rad/sec feel servo to follow the model. The feel system computer cycle time was 0.5 msec (2,000 Hz).

Roll Flight Control System

The roll flight control system was mechanized as a Simulink block diagram as shown in Appendix A, Figure A2. Simulink is a block diagram-oriented modeling and simulation package from The Math Works, Inc. of Natick, Massachusetts. Real-time code was produced using the Simulink C Code Generator to run on the digital signal processors in the Learjet simulation computer. The simulation computer cycle time was 10 msec (100 Hz).

The random noise generator produced normally-distributed pseudorandom sequences at the same frequency as the flight control system (50 or 100 Hz). The noise was scaled using the gain *vss_da_noise_gain* and was recorded as *da_noise*. The following code was used:

```
/* nrand - Normal random number generator */
static double nrand (unsigned int *seed)
{
    double sr, si, t;
    do {
        sr = 2.0 * urand (seed) - 1.0;
        si = 2.0 * urand (seed) - 1.0;
        t = sr * sr + si * si;
    } while (t > 1.0);
    return (sr * sqrt((-2.*log(t))/t));
}
/* urand - Uniform random number generator */
static double urand (unsigned int *seed)
{
    unsigned int hi, lo;
    log test;

#define IA 16807 /* magic multiplier = 7^5 */
#define IM 2147483647 /* modulus = 2^31 - 1 */
#define IQ 127773 /*IM div IA */
#define IR 2836 /* IM modulo IA */
#define S 4.656612875245797e-10 /* reciprocal of 2^31-1 */
```



```

hi = *seed / IQ;
lo = *seed % IQ;
test = IA * lo - IR * hi;

*seed = ((test < 0) ? (unsigned int)(test + IM) : (unsigned int)test);

return ((double) (*seed * S));
}

```

The RLC algorithm was turned on and off by setting the variable *vss_da_rlc_switch* to 0 or 1.

The actuator rate limit was simulated by placing a software rate limit immediately before the command sent to the Learjet surface actuators. The Learjet surface actuators have a 70 rad/sec bandwidth with a rate limit in excess of 180 degrees per second (total aileron surface travel).

An FCS computer cycle time of 0.02 second was simulated by calling the FCS code every other cycle of the simulation computer, which continued to run at 100 Hz.

Rate Limit Concept Algorithm

The RLC algorithm was mechanized as shown in Appendix A, Figure A3. Significant differences from the algorithm used in the phase I Learjet simulation are as follows:

1. The RLC was implemented in C language generated from a Simulink block diagram; in Phase I the algorithm was hand-coded.
2. A rate limit was placed on the bias removal function to prevent large command biases from building up with full-travel pilot inputs. The value of the bias removal rate limit was the same as the algorithm rate limit (and the surface rate limit for this experiment). This function was implemented based on results from the Phase II NT-33 program (reference 3).
3. The bias removal constant K_f was increased to improve the dynamics of the bias removal with the rate limit added. The following formula for K_f was empirically derived from analysis of Simulink models:

$$K_f = \frac{\dot{\delta}_{lim}}{0.05 \delta_{lim}} \quad \text{where } \dot{\delta}_{lim} = \text{rate limit (deg/sec) and } \delta_{lim} = \text{surface limit (deg)}$$

4. Flags were implemented to allow recording of the algorithm state. In Appendix A, Figure A3 the variable *da_bias_rm* is 1 if bias removal is active (input signal rate below the threshold), and 0 otherwise. The variable *da_track* is 1 if the input signal rate is less than the rate limit and 0 if greater than or equal to the rate limit.

The rate limit value used in the algorithm was 20 °/sec, the same as the value used in the simulated actuator.

Experiment Configurations

The experiment configurations are presented in Table 1.

Table 1 - Experiment Configurations

CFG #	DESCRIPTION	ROLL FEEL SYSTEM	POS'N CMD GAIN (°/in)	FORCE CMD GAIN (°/lb)	TIME DELAY ADDED (msec)	RLC	RATE LIMIT (°/sec)
000	Baseline Level 1 aircraft with center stick - Learjet with no rate limit	Center Stick	-10	0	0	OFF	none
300	Baseline "PIO-prone" aircraft with center stick and position command	5 lb/in	-15	0	50	OFF	20
301	CFG 300 plus RLC	$\omega_n = 16$ rad/sec	-15	0	50	ON	20
302	CFG 300 plus force command	$\zeta = 0.7$	0	-3	50	OFF	20
303	CFG 302 plus RLC		0	-3	50	ON	20
308	Baseline Level 1 aircraft with side stick - Learjet with no rate limit	Side Stick	-35	0	0	OFF	none
304	Baseline "PIO-prone" aircraft with side stick	8 lb/in	-35	0	50	OFF	20
305	CFG 304 plus RLC	$\omega_n = 25$ rad/sec	-35	0	50	ON	20
306	CFG 304 plus force command	$\zeta = 0.7$	0	-4.375	50	OFF	20
307	CFG 306 plus RLC		0	-4.375	50	ON	20
320	Rate limited feel system, center stick, $\omega_n = 16$ rad/sec, $\zeta = 0.7$	3.5 lb/in, max rate = 1 in/sec ⁽¹⁾	-10.5	0	50	OFF	20 ⁽¹⁾
323	CFG 320 plus increased stick motion	max rate = 2 in/sec ⁽¹⁾	-5.25	0	50	OFF	20 ⁽¹⁾
321	Low frequency feel system, $\omega_n = 4$ rad/sec, $\zeta = 0.7$	Center Stick, 3.5 lb/in	-15	0	50	OFF	20
322	Feel system damper, $\omega_n = 16$ rad/sec, $\zeta = 3.5$	Center Stick, 3.5 lb/in	-15	0	50	OFF	20

Note (1): Feel system rate limit was incorrectly mechanized, resulting in an effective surface rate limit of 10.5 °/sec instead of the desired 20 °/sec.

The baseline rate-limited configurations for both center and side stick were developed on the first evaluation flight as follows:

1. Command gain and feel system characteristics were set to those used in the Phase I Learjet evaluation (reference 2).
2. Command gain was adjusted until the pilot (Johnston) reported a reasonably quick but not objectionable response.
3. The aileron rate limit was set to 20 °/sec (total aileron travel, left plus right) and 50 msec time delay was added to make the aircraft PIO-prone.
4. The rate limit was removed and the aircraft evaluated to confirm that the PIO was due to the rate limit and not the time delay alone.

The baseline rate-limited configurations differed slightly from the Phase I baseline configurations due to differences in pilot opinion as to what constituted a “reasonably quick but not objectionable” aircraft. In all cases, however, the baseline rate-limited configurations had clear handling qualities “cliffs” where PIO tendencies would appear only when high-gain or aggressive inputs were used.

Scope of Tests

The evaluation was conducted during four flights totaling 6.5 hours. Crew assignments and flight durations are shown in Table 2.

Table 2 - Crew Assignments and Flight Durations

FLT #	FLT TIME	EVALUATION PILOT	SAFETY PILOT	SYSTEMS ENGINEER	FLIGHT TEST ENGINEER
446	1.8	LT. COL. R. Johnston	P. Deppe	S. Buethe	M. Shafer
447	1.6	LT. COL. R. Johnston	P. Deppe	S. Buethe	M. Shafer
448	1.6	R. Smith	S. Buethe	P. Deppe	M. Shafer
449	1.5	J. Ball	P. Deppe	S. Buethe	M. Shafer

The aircraft configuration was Powered Approach, with landing gear extended, flaps 20°, spoilers retracted, and power as required for the approach. The aircraft was loaded with 5,100 pounds of fuel. In order to minimize variations in roll inertia during the flight, fuel was transferred from the tip tanks into the fuselage tank immediately after takeoff, leaving the tip tanks empty for all but the first five minutes of flight.

All approaches were flown to runway 10L at Niagara Falls International Airport, Niagara Falls, New York. Weather conditions were daytime VFR with little to no turbulence. Winds were moderate with no significant gusts or crosswind component.

Method of Tests

Test Procedures

The test maneuver was the standard offset visual approach as shown in Appendix A, Figure A4. Evaluation pilots were not informed of the configurations they flew until after the flight.

Instrumentation & Data Recording

Sixty-four channels of parametric data were recorded at 100 Hz on hard disk cartridges using the simulation computer. Data were recorded in MATLAB Level 1.0 data file format as 16-bit scaled integers. A list of recorded parameters and scalings is presented in Appendix B, Table B1. A list of

the records taken and maneuvers performed on each flight is presented in Appendix B, Tables B2 through B5.

Forward-looking video and cockpit audio were recorded on 8mm video cassettes.

Handling Qualities Ratings (HQR) were assigned in accordance with the Cooper-Harper scale published in reference 5 and summarized in Appendix A, Figure A5. Performance criteria for the offset landing task are listed in Table 3. Pilot-Induced Oscillation (PIO) Tendency Classifications, also called PIO Ratings (PIOR) were assigned in accordance with the scale published in reference 6 and summarized in Appendix A, Figure A6.

Table 3 - HQR Performance Criteria for Offset Landing Task

AXIS	DESIRED	ADEQUATE
Longitudinal	Desired touch-down point -0 +500 ft	Desired touch-down point -0 +1000 ft
Lateral	Runway center-line between Learjet main gear (± 4 ft)	Runway center-line between Learjet tip tanks (± 17 ft)

Results and Discussion

Pilot comments, pilot ratings, and time histories for each evaluation are presented in Appendix C along with an index on page C-1.

Baseline Learjet

The baseline Learjet with a position command center or side stick and no time delay or rate limiting was evaluated ten times and received level 1 (satisfactory without improvement) pilot ratings without exception. There was no clear preference for center or side stick in the pilot rating data. Pilot comments consistently included phrases such as "smooth and predictable." This configuration was evaluated at least twice per flight to provide the pilots with a baseline level 1 aircraft for comparison to other configurations. Pilot rating data are summarized in Figure 1.

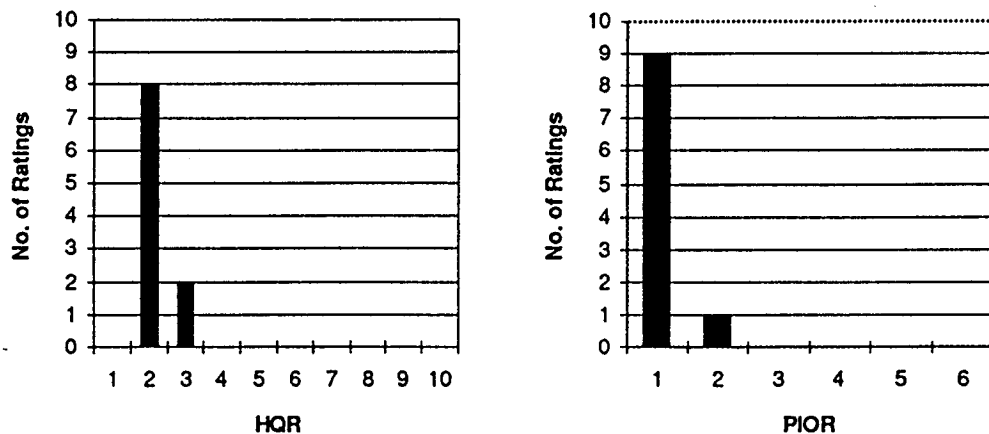


Figure 1 - Pilot Ratings for Baseline Learjet with No Rate Limiting

Rate-Limited Aircraft

The Learjet with 50 msec time delay and 20°/sec aileron rate limit was evaluated nine times and received level 3 ratings in all but one case. In most cases the aircraft exhibited no undesirable characteristics in the approach turn, but PIO occurred immediately after initiating the lineup correction. The one pilot who was able to land this configuration with the center stick (HQR 5, PIOR 3) did so by making smooth, slow control inputs and thereby avoiding the rate limit for the majority of the time as shown in the time histories on pages C-24 and C-25. All other pilots made comments including, "grievous," "terrible," and "I don't blame you for taking it" and assigned level 3 pilot ratings. There was no clear preference for center or side stick in the pilot rating data. Pilot rating data are summarized in Figure 2.

Rate-Limited Aircraft With RLC Added

The rate-limited Learjet with the RLC added was evaluated eleven times and received level 1 or 2 ratings in all but one case. The data are presented in Figure 2, compared with the non-RLC configurations.

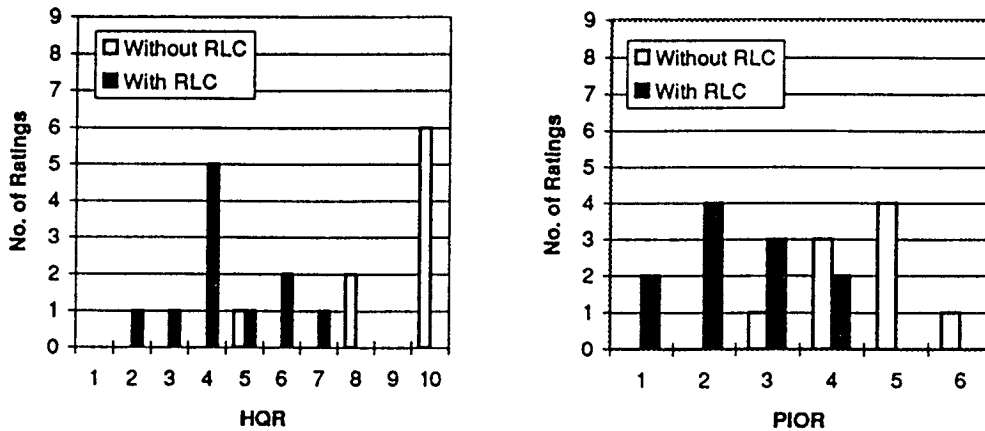


Figure 2 - Pilot Ratings for Learjet with 50 msec Time Delay and 20 °/sec Aileron Rate Limit With and Without RLC Algorithm

The RLC algorithm turned the essentially un-landable rate-limited aircraft into a landable aircraft, although with some minor (compared to the rate limit) undesirable characteristics. While some pilots reported "some peculiarities" with the roll response, the large amplitude PIOs due to the actuator rate limit were not present and controllability was not in question in any of the evaluations. On several approaches pilots reported apparent lateral out of trim conditions occurring, particularly with side stick and/or force command. In most cases the out of trim conditions were of short duration and no actions were required of the pilot. In several cases, however, the out of trim conditions persisted throughout the approach and touchdown, as shown in Appendix C, page C-66.

Effects of Noise and Sample Time

The effects of noise on the RLC algorithm were evaluated by adding random noise to the pilot commands. The amount of noise to add was determined in flight by increasing the noise gain until handling qualities anomalies were observed. The value used for the approaches was only 0.01° RMS, almost imperceptible on the time histories. The addition of noise prevented the proper operation of the RLC bias removal algorithm by toggling the RLC in and out of bias removal in cases where bias removal should have remained on. This effect is clearly shown in Appendix A, Figure A-7 which shows the RLC algorithm response to a pilot step input.

removal should have remained on. This effect is clearly shown in Appendix A, Figure A-7 which shows the RLC algorithm response to a pilot step input.

The effects of longer sample times on the RLC algorithm were not clear due to the small number of evaluations performed.

Feel System Cueing

A rate-limited feel system was mechanized in an attempt to provide the pilot with tactile cues that the flight control system was in rate limiting. The data are presented in Appendix C, pages C-112 to C-124. The idea was that the pilot would know exactly what the airplane was capable of through the movements of the stick. Although the feel system was designed to move at a maximum rate which matched the surface rate limit, a mechanization error resulted in only half of the desired rate. The data therefore cannot be directly compared with data from the other evaluations.

With the rate-limited feel system, pilots reported extremely poor roll performance (due to the unrealistically low rate limit) but no PIO. This is significant because one would expect more PIO with a lower rate limit. Pilots also objected to the nonlinear force feel and heavy forces when they tried to speed up the aircraft response, particularly with smaller stick motion as in configuration 320.

Low frequency and highly damped feel systems were also evaluated as potential methods for providing the pilot with tactile cues that the flight control system was in rate limiting. The data are presented in Appendix C, pages C-106 to C-111. Both configurations were rated level 3 and all pilots agreed that the handling qualities were worse than with the baseline feel system.

Conclusions

1. The fly-by-wire Learjet, with yaw damper on and beta feedback to the rudder, with center stick or side stick and position or force commands in roll was a solid level 1 airplane for the offset landing task.
2. The fly-by-wire Learjet was made into a solid level 3, PIO prone airplane for the offset landing task by increasing the roll command gain, adding time delay to the roll command path, and limiting the aileron deflection rate available.
3. The level 3, PIO prone airplane was improved to a good level 2 airplane with little PIO tendency by adding the Rate Limit Concept (RLC) to the roll command path.
4. The bias removal feature of the RLC tested caused (1) attenuated response to abrupt inputs, (2) reduced predictability of the aircraft response, and (3) out-of-trim conditions to develop.
5. The undesirable effects noted in conclusion (4) were exacerbated by noise or high frequency content in the RLC input signal.
6. Command signals from the side stick with force or position command and the center stick with force command tended to exhibit higher frequency content than those from the center stick with position command.
7. Flying the PIO prone airplane in roll with position commands from a rate limited feel system greatly reduced the PIO tendency. In this case the ailerons are always in phase with the stick position. PIO tendency was reduced even though the feel system rate limit was inadvertently set to roughly half the rate that would correspond to the 20 °/sec surface rate used in the majority of the configurations.
8. The pilots complained about the nonlinear roll control force and lack of roll performance with the rate limited feel system but were able to land the airplane without PIO.
9. Attempts to approximate the feel cues of the rate limited feel system through increased stick damping or through reduced feel servo natural frequency were unsuccessful and did not reduce the PIO tendency.

11. The evaluation pilot tended to be a more significant variable than the controller type or the command signal used. Ball and, in some cases, Johnson tended to be more severe in their ratings than Smith. This trend was probably related to the aggressiveness with which the offset correction was executed.

Recommendations

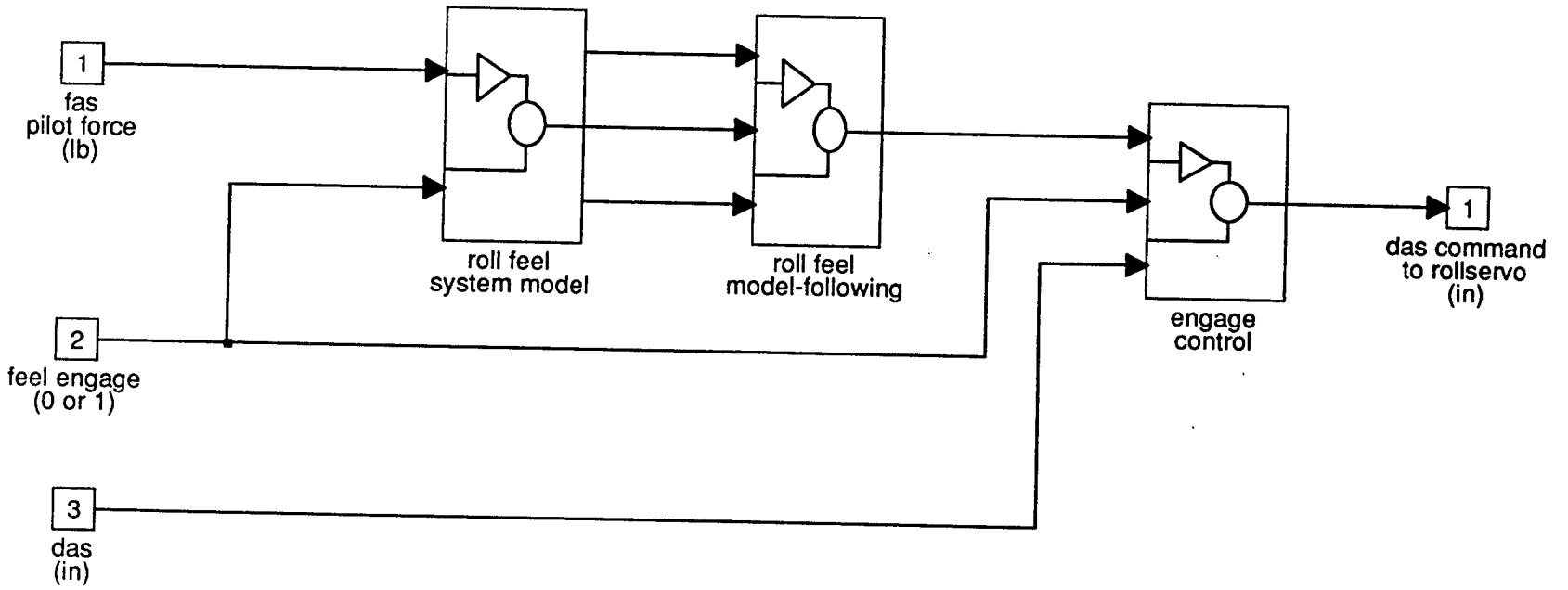
1. The bias removal feature of the RLC should be redesigned to eliminate the switching logic and to reduce the sensitivity of the bias removal feature to noise in the RLC input signal.
2. The rate limited feel system should be further evaluated as a potential method for reducing PIO tendency.

References

1. Chalk, C. R., "Study of a Software Rate Limit Concept," Calspan Flight Research Memorandum No. 636, October 1992.
2. Deppe, P. R., "Flight Evaluation of a Software Rate Limiter Concept," Calspan Report No. 8091-1, March 1993.
3. Ohmit, E. E., "Final Report - NT-33A In-Flight Investigation Into Flight Control System Rate Limiting," Calspan Report No. 7738-24, February 1994.
4. Buehe, S. A. and Deppe, P. R., "A Rapid Prototyping System for Inflight Simulation Using the Calspan Learjet 25," AIAA Paper No. 93-3606, presented at the AIAA Flight Simulation Technologies Conference, Monterey, CA, 1993.
5. Cooper, G. and Harper, R. P., "The Use of Pilot Rating in the Evaluation of Aircraft Handling Qualities," NASA Technical Note D-5153, April 1969.
6. "PIO Tendency Classification Scale," Proposed by C. Chalk at PIO workshop held at NASA Dryden Flight Research Facility on 18-19 November 1980.

Appendix A - Figures

Figure A-1 ROLL FEEL SYSTEM



1
fas
pilot force
(lb)

2
feel engage
(0 or 1)

3
das
(in)

roll feel
system model

roll feel
model-following

engage
control

1
das command
to rollservo
(in)

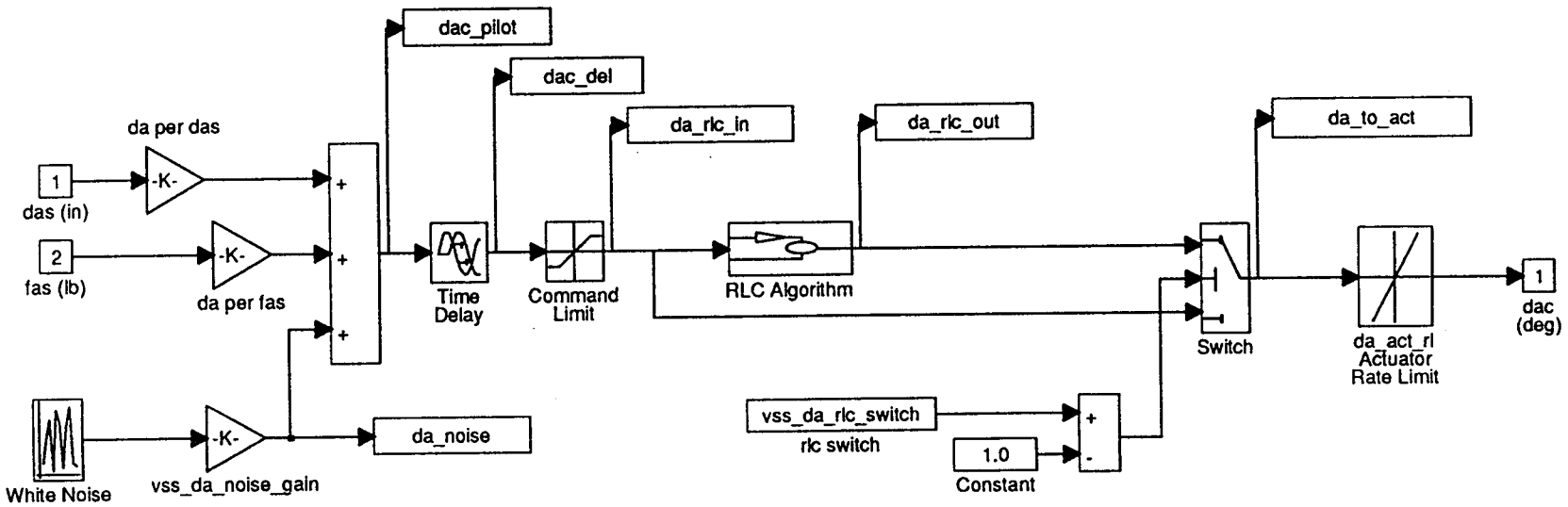
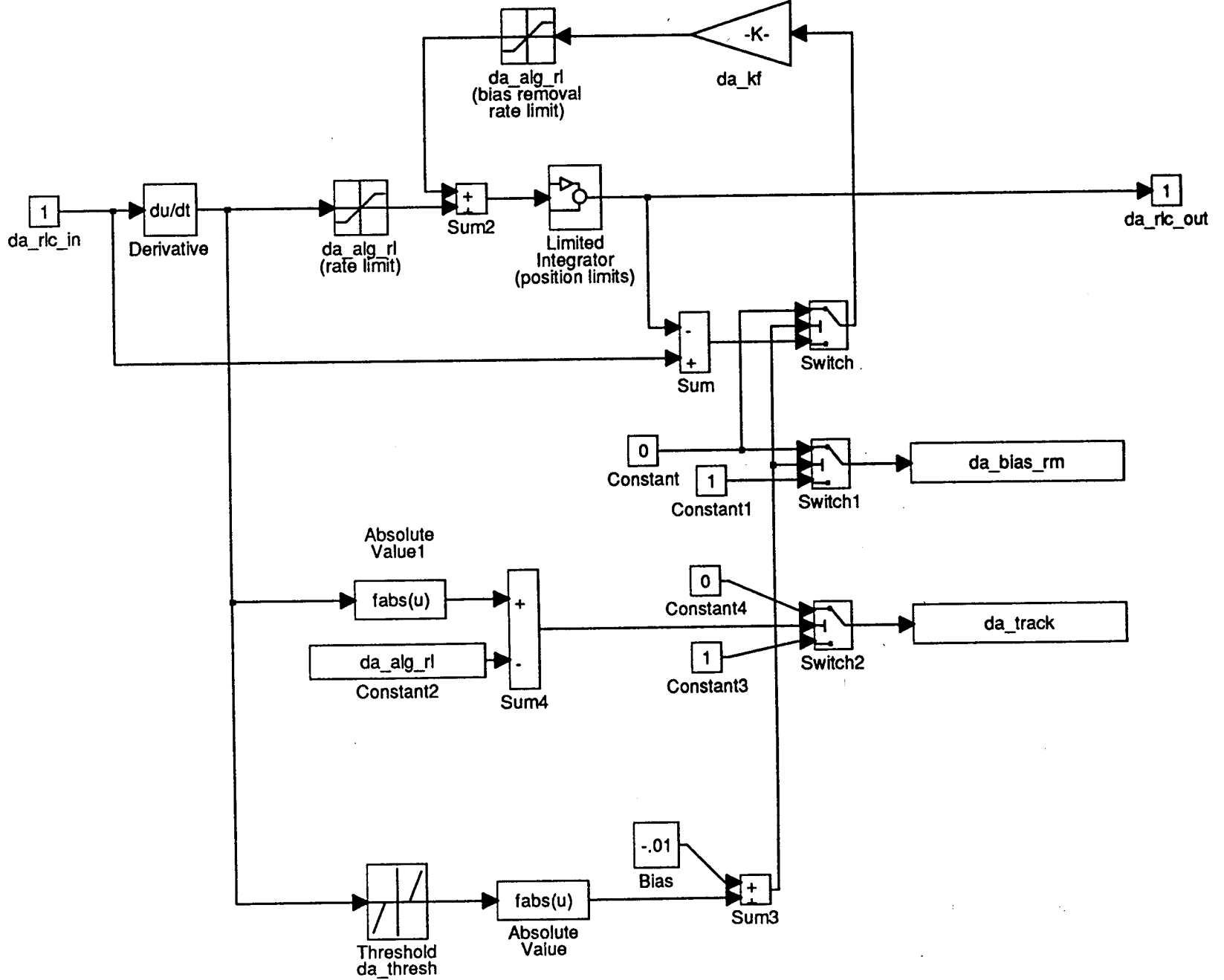


Figure A-2 ROLL FLIGHT CONTROL SYSTEM

Figure A-3 RATE LIMIT CONCEPT MECHANIZATION



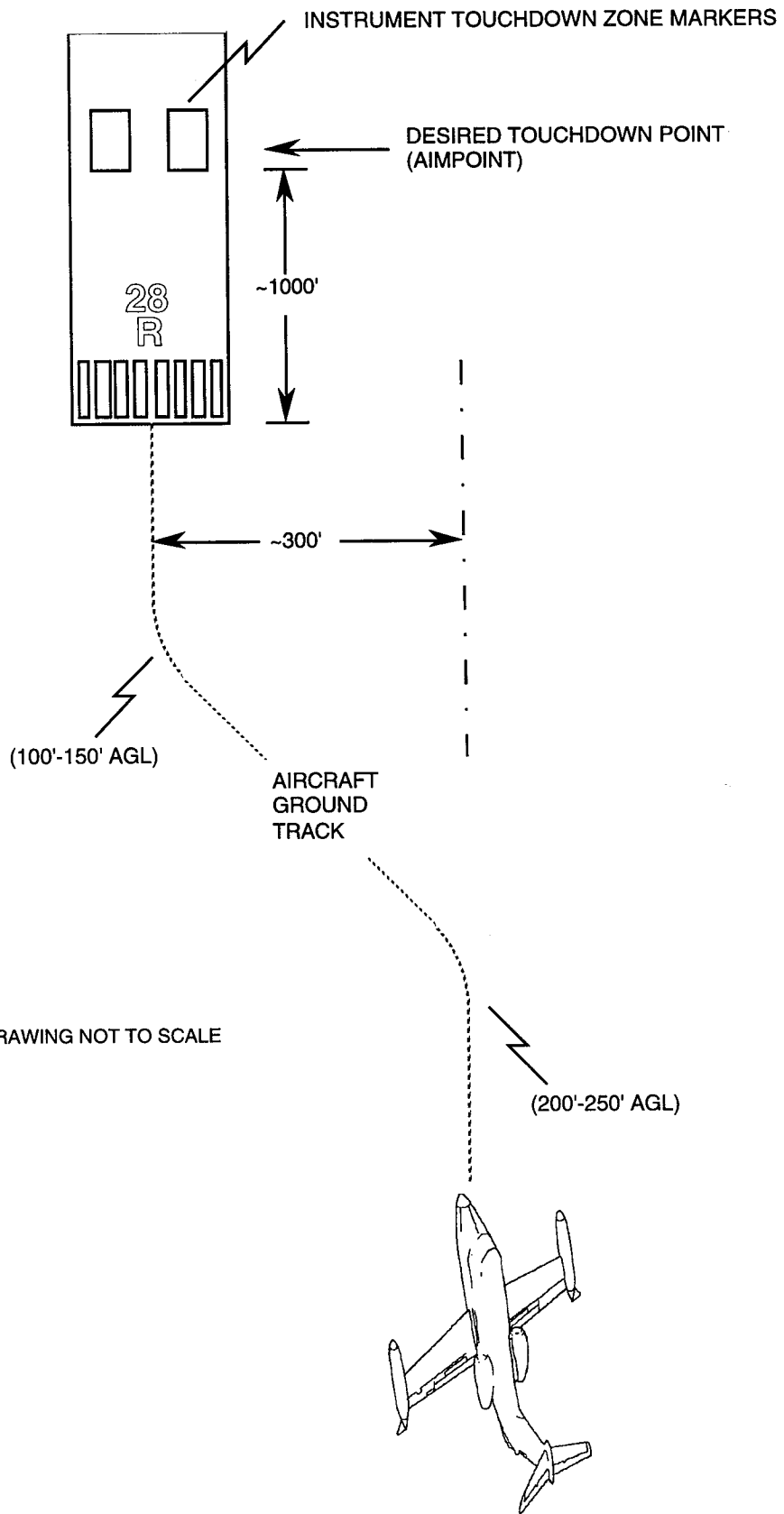
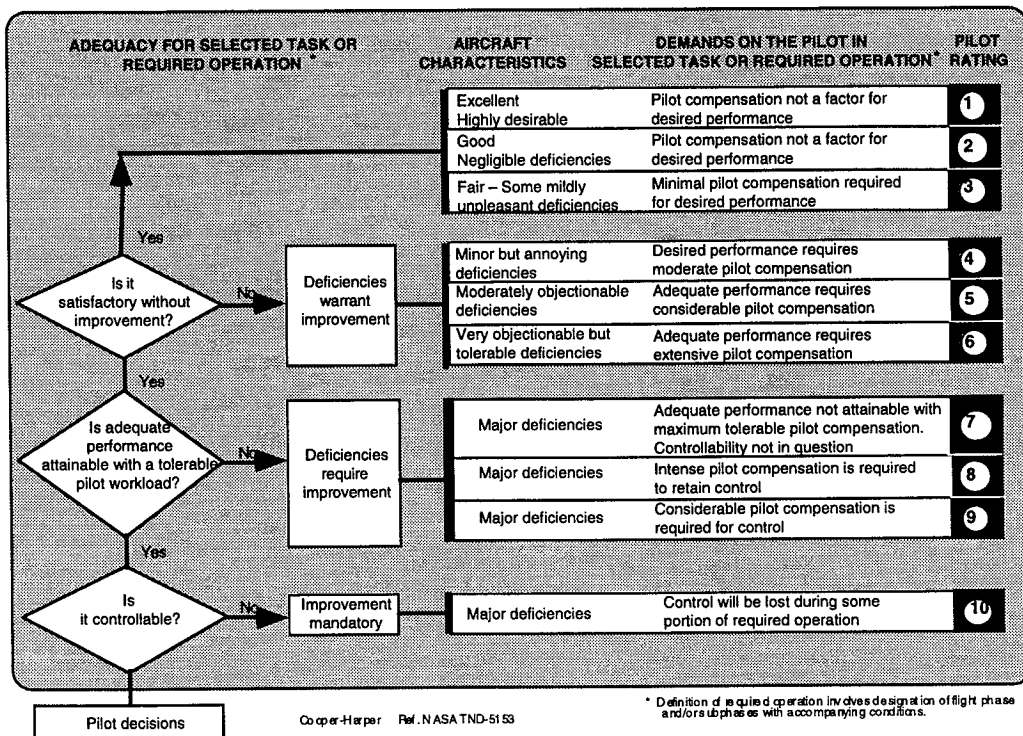


Figure A-4 OFFSET APPROACH (LEARJET)

HANDLING QUALITIES RATING SCALE



DEFINITIONS FROM TN-D-5153

COMPENSATION

The measure of additional pilot effort and attention required to maintain a given level of performance in the face of deficient vehicle characteristics.

HANDLING QUALITIES

Those qualities or characteristics of an aircraft that govern the ease and precision with which a pilot is able to perform the tasks required in support of an aircraft role.

MISSION

The composite of pilot-vehicle functions that must be performed to fulfil operational requirements. May be specified for a role, complete flight, flight phase, or flight subphase.

WORKLOAD

The integrated physical and mental effort required to perform a specified piloting task.

PERFORMANCE

The precision of control with respect to aircraft movement that a pilot is able to achieve in performing a task. (Pilot vehicle performance is a measure of handling performance. Pilot performance is a measure of the manner or efficiency with which a pilot moves the principal controls in performing a task.)

ROLE

The function or purpose that defines the primary use of an aircraft.

TASK

The actual work assigned a pilot to be performed in completion of or as representative of a designated flight segment.

Cooper-Harper Ref. NASA TND-5153

Figure A-5 HQR SCALE

COMMENT CARD

AIRSPEED/FLIGHTPATH CONTROL IN PATTERN

PREDICTABILITY IN FLARE

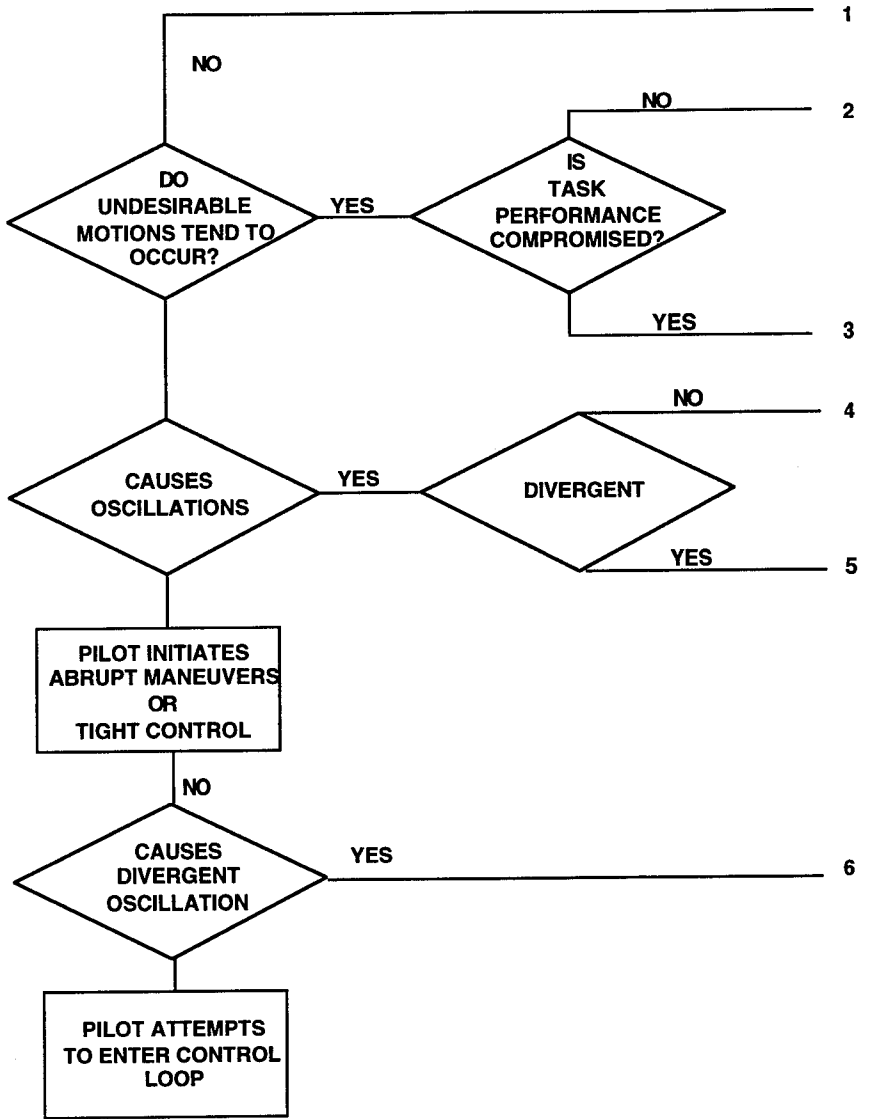
PIO TENDENCY ?

SPECIAL COMPENSATION TECHNIQUES

STICK FORCES

OUTSIDE INFLUENCES (WIND, TRAFFIC, ETC.)

C-H RATING



PIO TENDENCY CLASSIFICATION

Figure A-6 PIO TENDENCY CLASSIFICATION SCALE

FLT 449 REC 5 RL = 20 deg/sec THRESH = 2 KF = 10.5

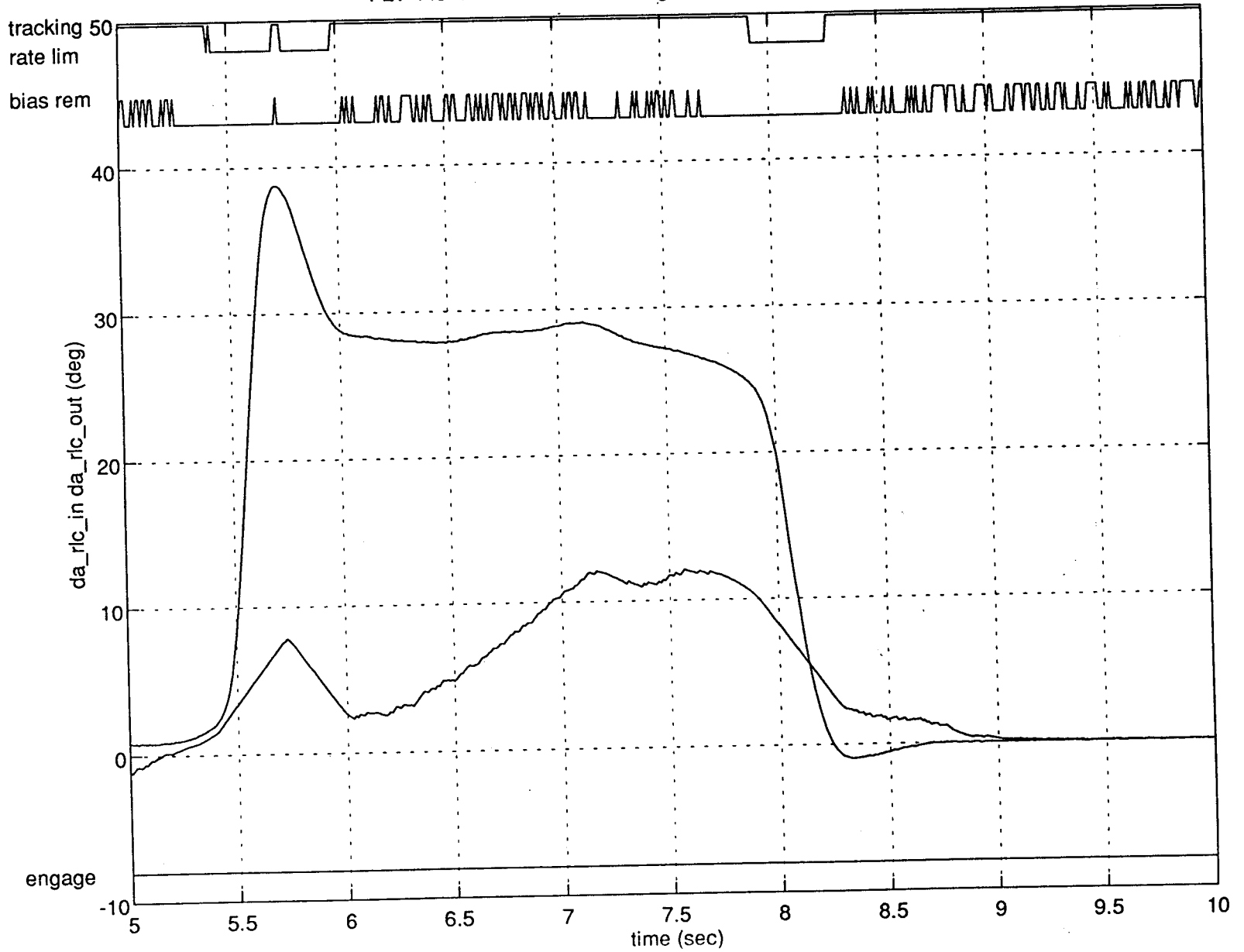


Figure A-7 EFFECT OF NOISE ON RLC ALGORITHM RESPONSE TO PILOT INPUT

Appendix B - Data Recording

Table B1 - Data Recording List

NAME	DESCRIPTION	UNITS	RANGE (16 BITS)	
			MIN	MAX
HOURS	Local time	hours	-24	24
MINUTES	Local time	min	-60	60
SECONDS	Local time	sec	-60	60
MSECONDS	Local time	msec	-1000	1000
engaged	VSS surface engage discrete	0 or 1	-10	10
fes	Elevator stick force	lb	-100	100
fas	Aileron stick force	lb	-100	100
frp	Rudder pedal force	lb	-200	200
des	Elevator stick position	in	-10	10
das	Aileron stick position	in	-10	10
drp	Rudder pedal position	in	-10	10
dec	Elevator servo command	deg	-50	50
dac	Aileron servo command	deg	-50	50
drc	Rudder servo command	deg	-50	50
de	Elevator position	deg	-50	50
ds	Stabilizer position	deg	-50	50
da	Aileron position (total L + R)	deg	-50	50
dr	Rudder position	deg	-50	50
theta	Pitch angle	deg	-50	50
phi	Roll angle	deg	-180	180
p	Roll rate	deg/sec	-100	100
q	Pitch rate	deg/sec	-40	40
r	Yaw rate	deg/sec	-40	40
nx	Longitudinal acceleration at CG	G	-1	1
ny	Lateral acceleration at CG	G	-1	1
nz	Normal acceleration at CG	G	-5	5
vi	Indicated airspeed	knots	0	400
h	Complementary-filtered (CF) altitude	ft	-20000	20000
oat	Total outside air temperature	deg_K	200	400
alpha_cf	CF Angle of attack	deg	-20	20
beta_cf	CF Angle of sideslip	deg	-20	20
dac_pilot	Aileron command after command gain	deg	-200	200
dac_del	Aileron command after time delay	deg	-200	200
da_rlc_in	Aileron RLC input	deg	-200	200
da_rlc_out	Aileron RLC output	deg	-200	200
da_to_act	Aileron command to rate-limited actuator	deg	-200	200
da_act_rl	Aileron actuator rate limit	deg/sec	-1000	1000
da_noise	Aileron added noise	deg	-10	10
da_rlc_sw	Aileron RLC switch position	0 or 1	-10	10

Table B1 - Data Recording List, continued

NAME	DESCRIPTION	UNITS	RANGE (16 BITS)	
			MIN	MAX
da_alg_rl	Aileron RLC algorithm rate limit	deg/sec	-1000	1000
da_kf	Aileron RLC algorithm Kf		-100	100
da_thresh	Aileron RLC algorithm threshold	deg	-100	100
da_bias_rm	Aileron RLC bias removal flag	0 or 1	-10	10
da_track	Aileron RLC tracking flag	0 or 1	-10	10
dec_pilot	Elevator command after command gain	deg	-200	200
dec_del	Elevator command after time delay	deg	-200	200
de_rlc_in	Elevator RLC input	deg	-200	200
de_rlc_out	Elevator RLC output	deg	-200	200
de_to_act	Elevator command to rate-limited actuator	deg	-200	200
de_act_rl	Elevator actuator rate limit	deg/sec	-1000	1000
de_noise	Elevator added noise	deg	-10	10
de_rlc_sw	Elevator RLC switch position	0 or 1	-10	10
de_alg_rl	Elevator RLC algorithm rate limit	deg/sec	-1000	1000
de_kf	Elevator RLC algorithm Kf		-100	100
de_thresh	Elevator RLC algorithm threshold	deg	-100	100
de_bias_rm	Elevator RLC bias removal flag	0 or 1	-10	10
de_track	Elevator RLC tracking flag	0 or 1	-10	10
fuel_tot	NOT USED			
fuel_fus	NOT USED			
cg	NOT USED			

Table B2
Data Record List for Flight 446
Evaluation Pilot: MAJ R. Johnston

REC #	CONFIG	MANEUVER	HQR	PIO
1	300	General maneuvering (high work)		
2	300	Approach turn (high work)		
3	300	Bank angle captures (high work)		
4	300 plus da/das = -25	General maneuvering (high work)		
5	304	Aileron steps and general maneuvering with side stick (high work)		
6	000	Landing - center stick, baseline Learjet		
7	000	Landing - center stick, baseline Learjet	2	1
8	300	Landing attempt - center stick, position command, rate limit		
9	300	Landing attempt - center stick, position command, rate limit	10	6
10	320	Landing - center stick, rate limited feel system		
11	320	Landing - center stick, rate limited feel system	5	slight
12	304	Landing attempt - side stick, position command, rate limit		
13	304	Landing attempt - side stick, position command, rate limit	10	4
14		None		
15		None		
16	305	Landing - side stick, position command, rate limit, RLC		
17	305	Landing - side stick, position command, rate limit, RLC	4	2
18	301	Landing - center stick, position command, rate limit, RLC		
19	301	Landing - center stick, position command, rate limit, RLC	4	2
20	308	Landing - side stick, baseline Learjet		
21	308	Landing - side stick, baseline Learjet	3	2
22	301	Landing - center stick, position command, rate limit, RLC	2	1
23	000	Landing - center stick, baseline Learjet	2	1

**Table B3
Data Record List for Flight 447
Evaluation Pilot: MAJ R. Johnston**

REC #	CONFIG	MANEUVER	HQR	PIO
1	321	General maneuvers with low frequency feel system		
2	322	General maneuvers with feel system damper		
3	301	General maneuvers with 20 msec cycle time		
4	000	Landing - center stick, baseline Learjet	2	1
5	303	Landing - center stick, force command, rate limit, RLC		
6	303	Landing - center stick, force command, rate limit, RLC	6	4
7	302	Landing attempt - center stick, force command, rate limit	10	5
8	305	Landing - side stick, position command, rate limit, RLC		
9	305	Landing - side stick, position command, rate limit, RLC	4	3
10	306	Landing - side stick, force command, rate limit		
11	306	Landing - side stick, force command, rate limit	8	4
12	307	Landing - side stick, force command, rate limit, RLC		
13	307	Landing - side stick, force command, rate limit, RLC	4	2
14	322	Landing attempt - center stick, rate limit, feel system damper	10	5
15	321	Landing attempt - center stick, rate limit, low frequency feel system	10	none given
16	321	Landing attempt - center stick, rate limit, low frequency feel system	9	4
17	301 with 20 msec cycle time	Landing - center stick, position command, rate limit, RLC		
18	301 with 20 msec cycle time	Landing - center stick, position command, rate limit, RLC	5	3
19	000	Landing - center stick, baseline Learjet	3	1

Table B4
Data Record List for Flight 448
Evaluation Pilot: R. Smith

REC #	CONFIG	MANEUVER	HQR	PIO
1	300	Bank angle captures with rate-limited aircraft		
2	301	Bank angle captures with rate-limited aircraft and RLC		
3	320	General maneuvers with rate limited feel system		
4	320 plus improved gains	General maneuvers with rate limited feel system improvements		
5	304	General maneuvering with rate-limited aircraft		
6	305	General maneuvering with rate-limited aircraft and RLC		
7	000	Landing - center stick, baseline Learjet		
8	000	Landing - center stick, baseline Learjet	2	1
9	301	Landing - center stick, position command, rate limit, RLC		
10	301	Landing - center stick, position command, rate limit, RLC	4	2
11	300	Landing - center stick, position command, rate limit		
12	300	Landing - center stick, position command, rate limit	5	3
13	320	Landing - center stick, rate limited feel system		
14	320	Landing - center stick, rate limited feel system	7	2
15	308	Landing - side stick, baseline Learjet		
16	308	Landing - side stick, baseline Learjet	2	1
17	306	Landing - side stick, force command, rate limit		
18	306	Landing - side stick, force command, rate limit	8	4
19	307	Landing - side stick, force command, rate limit, RLC		
20	307	Landing - side stick, force command, rate limit, RLC	3	1
21	000	Landing - center stick, baseline Learjet	2	1

Table B5
Data Record List for Flight 449
Evaluation Pilot: J. Ball

REC #	CONFIG	MANEUVER	HQR	PIO
1	323	General maneuvering with rate limited feel system		
2		None		
3	301 with 20 msec cycle time	General maneuvers		
4	301 with 20 msec cycle time plus noise	General maneuvers, <i>vss_da_noise_gain</i> = 0.01		
5	301 plus noise	General maneuvers, <i>vss_da_noise_gain</i> = 0.01		
6	000	Landing - center stick, baseline Learjet		
7	000	Landing - center stick, baseline Learjet	2	1
8	301	Landing - center stick, position command, rate limit, RLC		
9	301	Landing - center stick, position command, rate limit, RLC	5	3
10	300	Landing attempt - center stick, position command, rate limit	10	5
11	301 with 20 msec cycle time plus noise	Landing - center stick, position command, rate limit, RLC		
12	301 with 20 msec cycle time plus noise	Landing - center stick, position command, rate limit, RLC	4	2
13	301 plus noise	Landing - center stick, position command, rate limit, RLC		
14	301 plus noise	Landing - center stick, position command, rate limit, RLC	9	4
15	306	Landing attempt - side stick, force command, rate limit	10	5
16	307	Landing - side stick, force command, rate limit, RLC		
17	307	Landing - side stick, force command, rate limit, RLC	6	3
18	323	Landing - center stick, rate limited feel system		
19	323	Landing - center stick, rate limited feel system	8	4
20	304	Landing attempt - side stick, position command, rate limit	10	5
21	305	Landing - side stick, position command, rate limit, RLC		
22	305	Landing - side stick, position command, rate limit, RLC	7	4
23	000	Landing - center stick, baseline Learjet	2	1

Appendix C - Time Histories and Pilot Comments

Index to Center vs. Side Stick and Force vs. Position Command Experiments

CONFIG	PILOT CONTROLLER	FCS COMMAND	RATE LIMIT (°/sec)	RLC ALGORITHM	PAGE
000	Center Stick	Position	none	OFF	C-2
300	Center Stick	Position	20	OFF	C-19
301	Center Stick	Position	20	ON	C-28
302	Center Stick	Force	20	OFF	C-41
303	Center Stick	Force	20	ON	C-43
308	Side Stick	Position	none	OFF	C-47
304	Side Stick	Position	20	OFF	C-54
305	Side Stick	Position	20	ON	C-60
306	Side Stick	Force	20	OFF	C-72
307	Side Stick	Force	20	ON	C-81

Index to Noise and Sample Time Effects Experiments

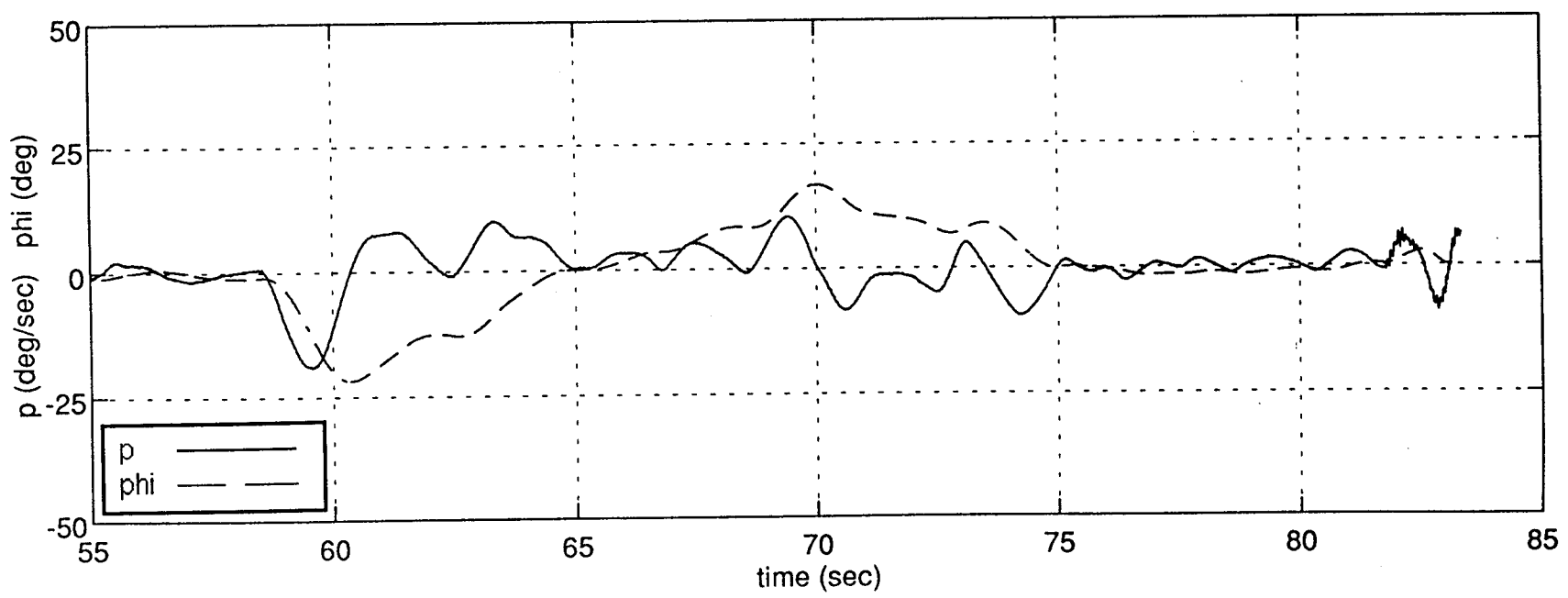
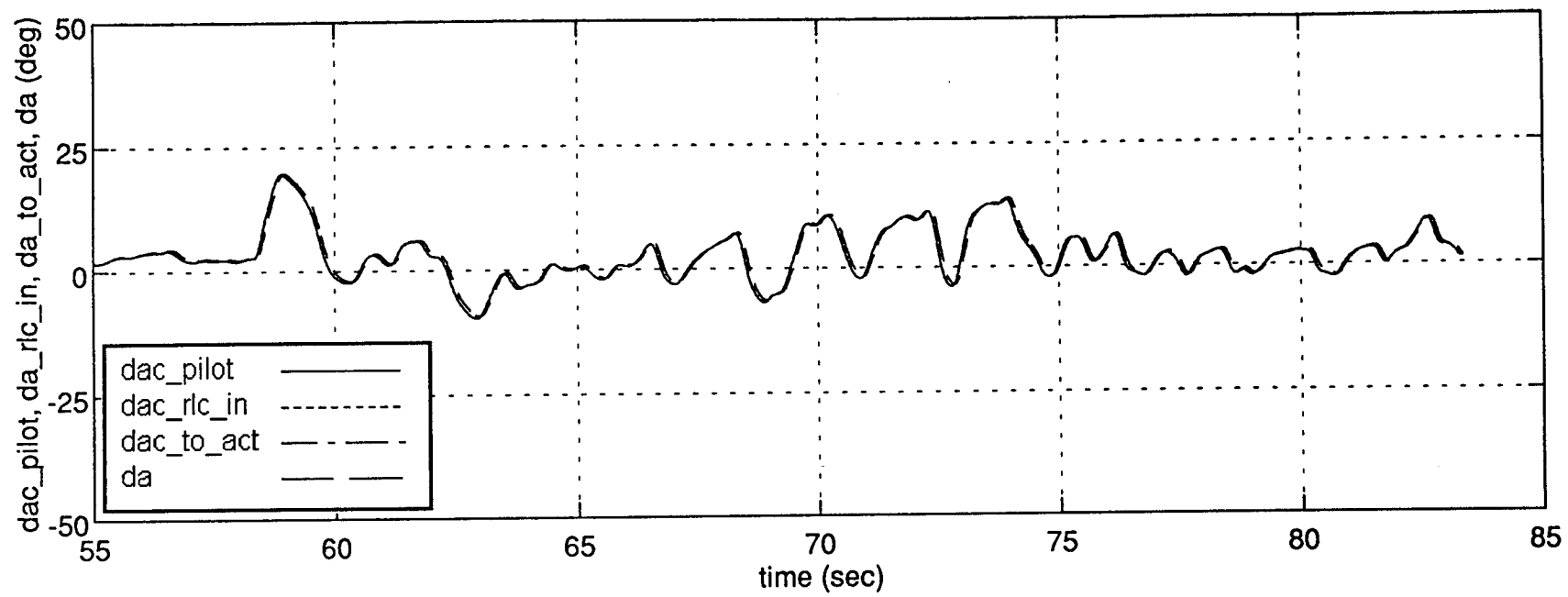
BASE CONFIG	RATE LIMIT (°/sec)	RLC ALGORITHM	NOISE ADDED	SAMPLE TIME (sec)	PAGE
000	none	OFF	NO	0.02	C-92
301	20	ON	NO	0.02	C-95
301	20	ON	YES	0.01	C-99
301	20	ON	YES	0.02	C-102

Index to Feel System Cueing Experiments

CONFIG	RATE LIMIT (°/sec)	FEEL SYSTEM CUEING	PAGE
321	20	Low frequency stick	C-106
322	20	Stick damper	C-110
320	10.5 ⁽¹⁾	Rate-limited feel system	C-112
323	10.5 ⁽¹⁾	Rate-limited feel system with increased motion	C-121

Note (1): Feel system rate limit was incorrectly set to produce a 10.5 °/sec surface rate limit instead of the desired value of 20 °/sec.

FLT 446 REC 6 NO RATE LIMIT

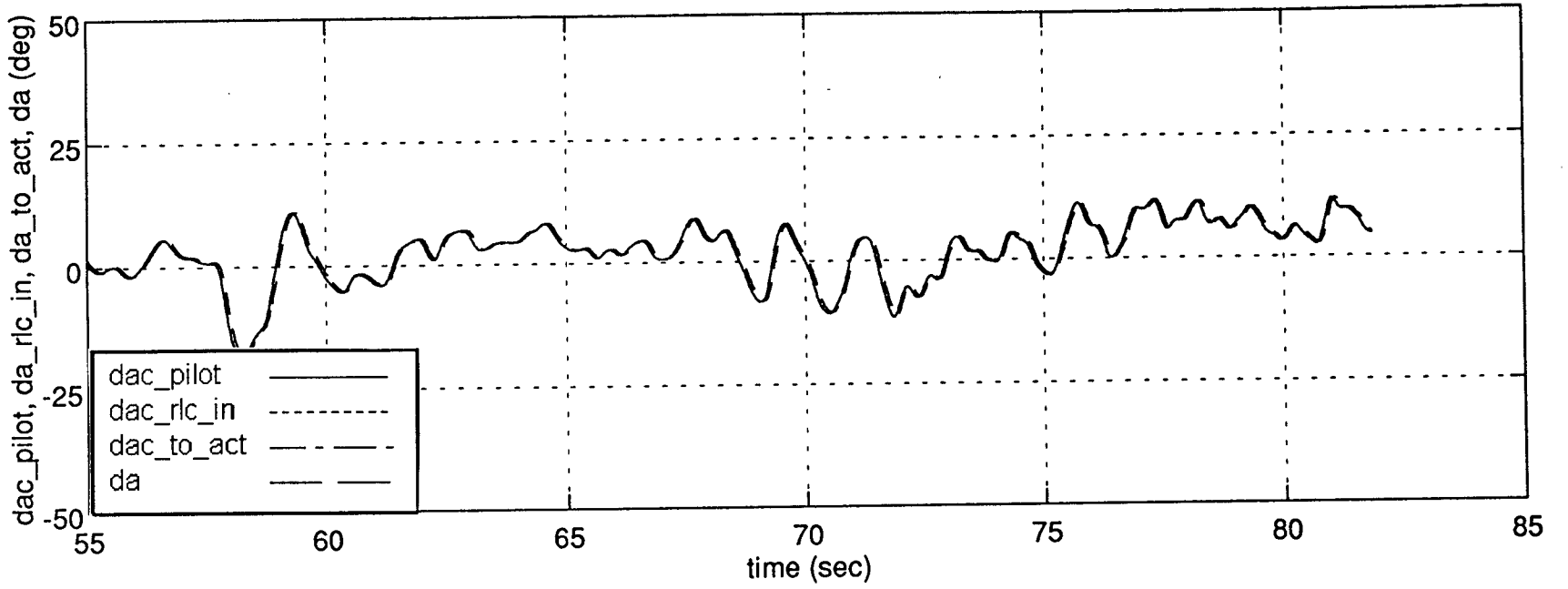


C-3

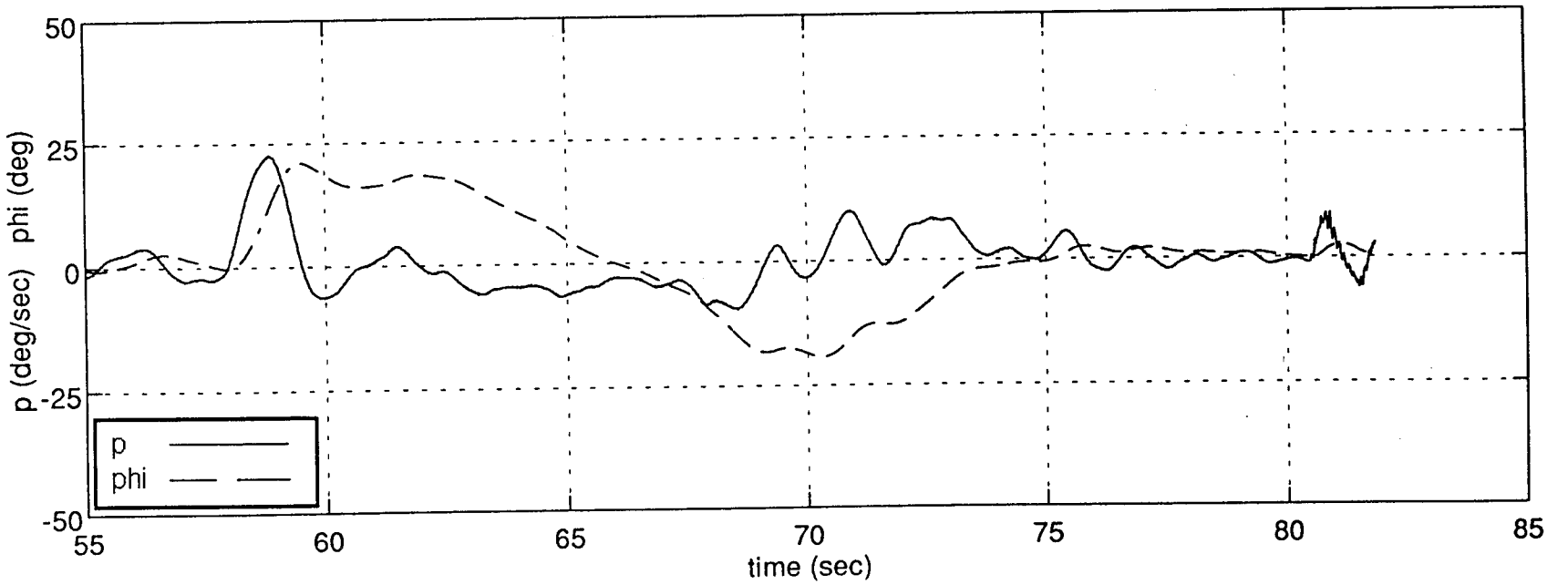
Calspan Report No. 8091-2
APPENDIX C

FLT 446 REC 7 NO RATE LIMIT

Calspan Report No. 8091-2
APPENDIX C



C-4



Evaluation 9 Flight 446/1 Flight Evaluation No. 9 Event 1

Configuration 000 Stick Center Type Position Rate Limit None

Pilot Johnston Safety pilot Deppe Computer operator Buethe Flight test engineer Shafer

Algorithm None Passes 1 Runway 05

Pass Record Offset Wind Performance
1 23 Right 060/9 Desired

CHR 2 PIOR 1

Inflight comments

1st pass:

EP: I think we've got ILS now. I show myself slightly high.

EP: Got a little low. Doesn't look like we're low, though.

EP: Now we're on glide path, coming back down. A little bit of light turbulence.

SP: Correct

EP: Air speed control's good. Aggressive. I can definitely be more aggressive than I was before with the last one that we did. It's definitely better.

EP: PIO 1, Cooper-Harper 2. Felt just like it did before. The last one I did was just slightly--if I had to rate it, I'd give the last one a 2.5 and that one a 2, if you guys will let me give 0.5s in the level. It was slightly worse, but not much.

Postflight comments

[See postflight comments on previous evaluation]

Remarks

Full-stop landing at Buffalo International

EP: There was very little turbulence, I would say. Turbulence had no effect at all, all day long today, and the winds, at least the winds that they were calling from the tower, stayed real constant all day long. Atmospheric conditions were extremely repeatable on each of the runs.

My overall impressions from it, I've been more closely involved with the actual configurations than I was in the NT-33, flying them, I could definitely tell when the rate limiting algorithm was in there when we made the final correction. Up until that point when we made the final correction, I could not tell. It was basically the level of PIO proneness that we were seeing. Also, the rate limited feel one--as soon as I made the correction, I knew exactly what we were flying, what the configuration was. There was no doubt in my mind.

Mike Parrag: But that says something for it, as opposed to having things happen behind your back, having something that you understand.

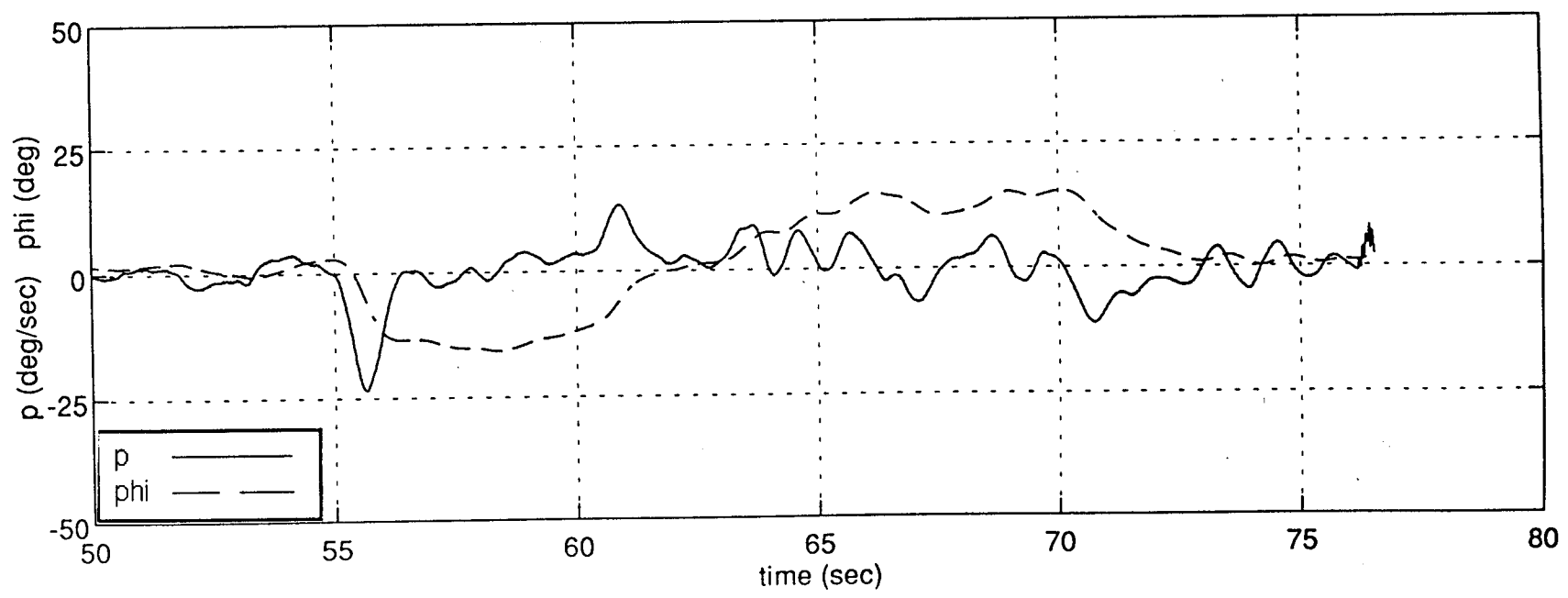
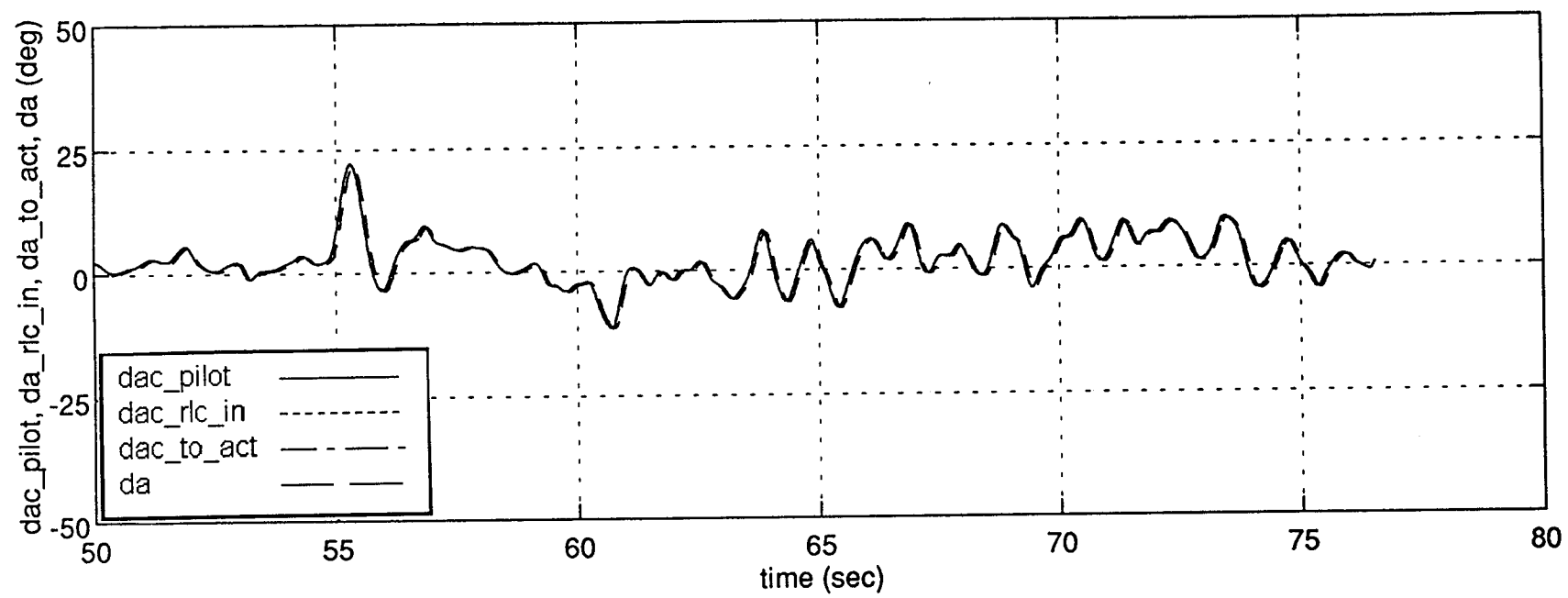
EP: Putting on my human factors hat, it uses one more of those cueing available to the pilot that we often don't think about. We are overloaded in the sight and the hearing.

Mike Parrag: We feel very strongly that tactile cueing is of the utmost importance.

EP: Airplanes shouldn't rate limit in the first place.

FLT 446 REC 23 NO RATE LIMIT

Calspan Report No. 8091-2
APPENDIX C
C-6



Evaluation 10 **Flight** 447/2 **Flight Evaluation No.** 1 **Event** 6

Configuration 000 **Stick** Center **Type** Position **Rate Limit** None

Pilot Johnston **Safety pilot** Deppe **Computer operator** Buethe **Flight test engineer** Shafer

Algorithm None **Passes** 1 **Runway** 10L

Pass Record **Offset** **Wind** **Performance**
1 4 Left 070/5 Desired

CHR 2 **PIOR** 1

Inflight comments

1st pass:

SP: Correct

EP: No PIO tendencies. Feels good. Got myself just slightly slow. Coming back

EP: Desired. Cooper-Harper 2. PIO 1. Absolutely no PIOs noticed. Easily controlled. Felt like I could be as aggressive as I wanted to be.

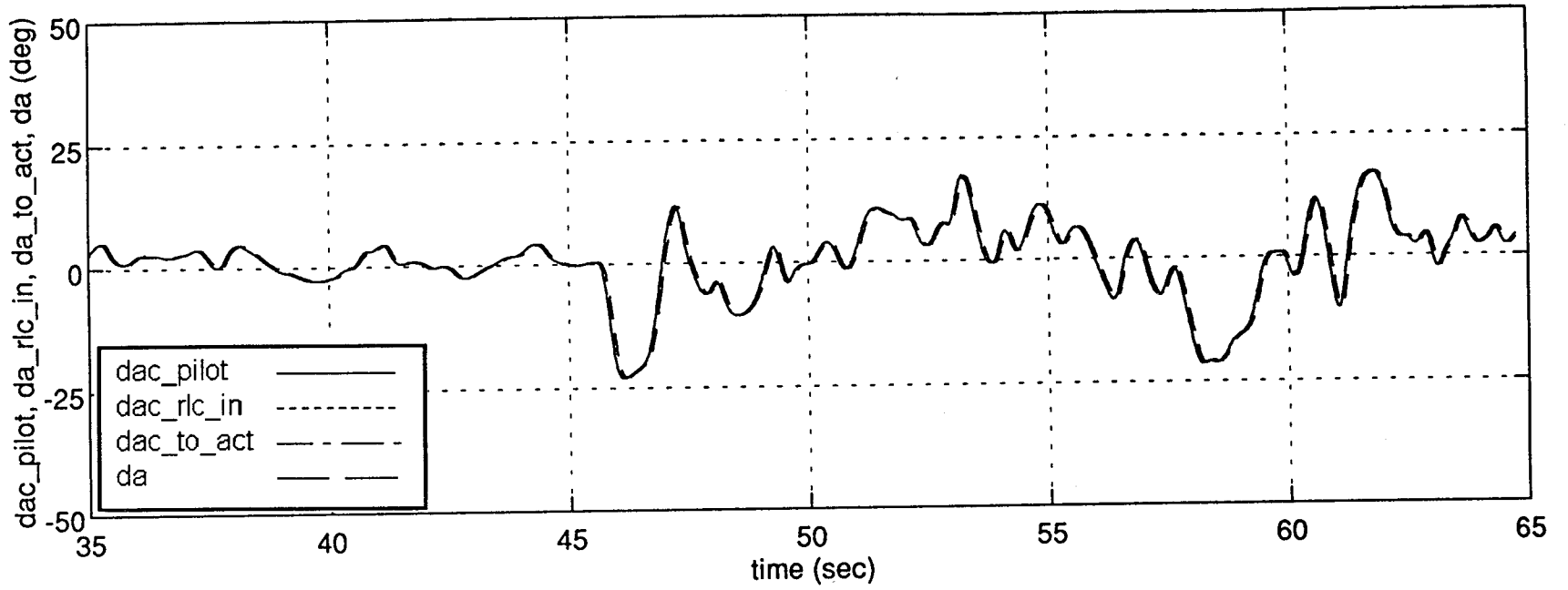
Postflight comments

EP: Baseline Lear jet felt just like it did yesterday. I gave it a Cooper-Harper 2, PIO of 1. I felt like I was readapted to the Lear with a good sitting height again. Throughout the day I didn't feel like doing just one--yesterday we did two--I didn't feel like just doing one affected anything else. I felt like I was flying the Lear fine. I knew what it flew like. It seemed like it flew the same to me today as it did yesterday

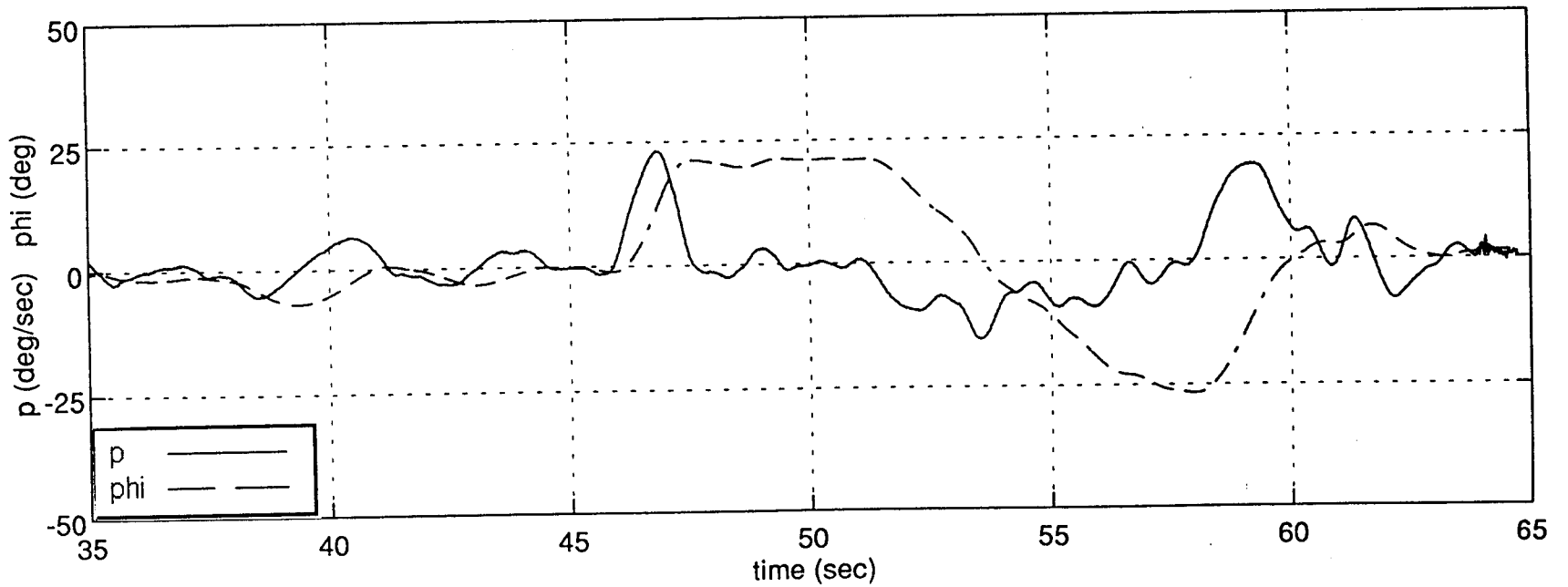
Remarks

FLT 447 REC 4 NO RATE LIMIT

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C-8



Evaluation 20 **Flight** 448/3 **Flight Evaluation No.** 1 **Event** 8

Configuration 000 **Stick** Center **Type** Position **Rate Limit** None

Pilot Smith **Safety pilot** Buethe **Computer operator** Deppe **Flight test engineer** Shafer

Algorithm None **Passes** 2 **Runway** 10L

Pass	Record	Offset	Wind	Performance
1	7	Right	050/8	Desired--offset laterally, to the right
2	8	Left	020/8	Adequate--long

CHR 2 **PIOR** 1

Inflight comments

1st Pass:

EP: No difficulties with the airplane. Just the performance a little off laterally, which was all of just getting organized in the task. Nothing to do with the airplane. The airplane was smooth and responsive, with good control in both axes.

2nd Pass:

EP: I like left corrections better.

The aircraft is smooth in both axes. The initial and final response is good. It's just a question of getting the task organized to hit the key points to be able to get on the ground in the right place. The little lateral excursion on the first one was not quite desired and the second one was debatable but I don't think there's anything wrong with the airplane.

EP: Acceptable? Yes. Satisfactory without improvement? Yes. The roll response was smooth and predictable. No deficiencies noted. 2 rating. PIO rating scale is a 1.

Postflight comments

CO: HQR 2, PIO 1.

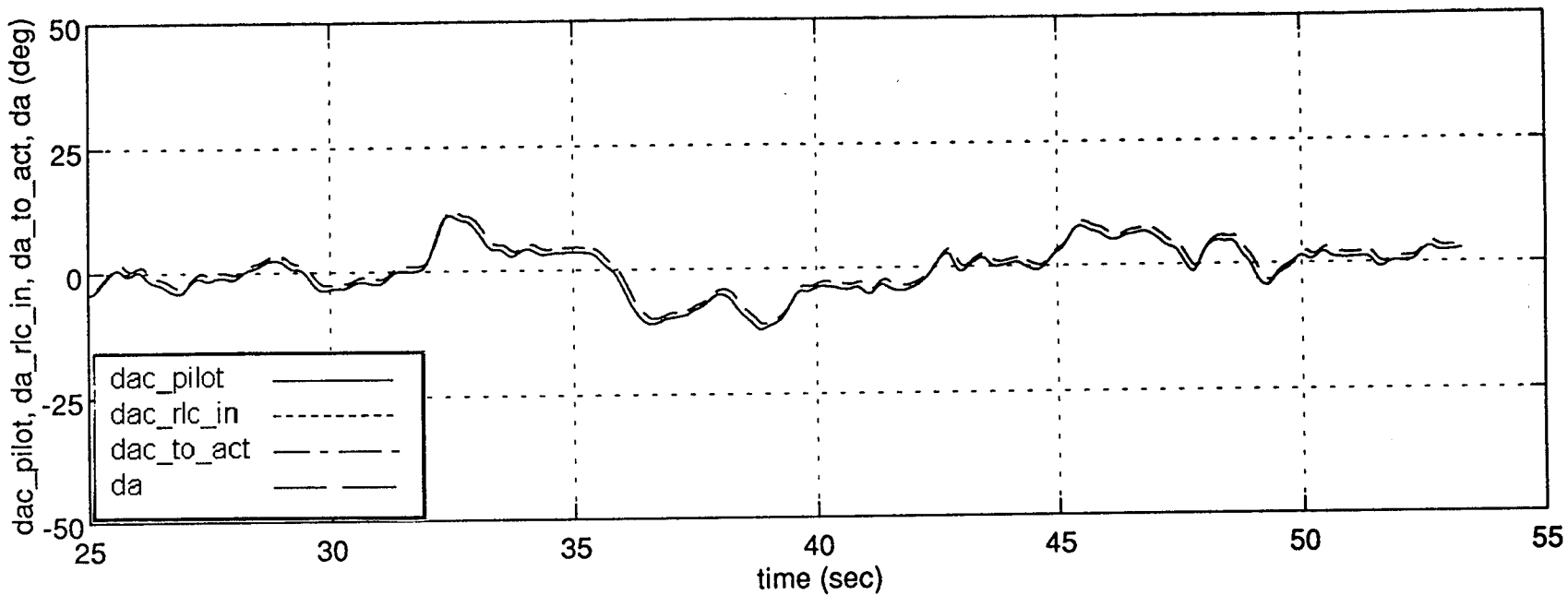
EP: Good airplane. I didn't have any problems.

Remarks

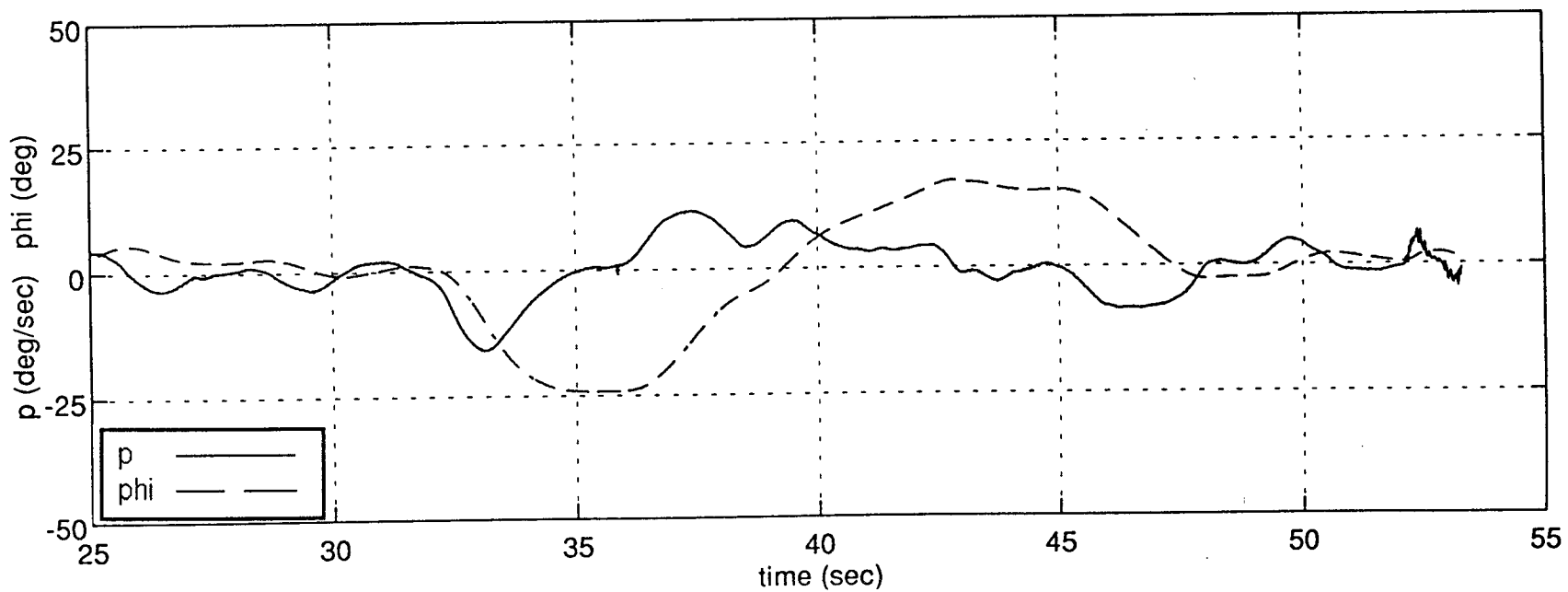
EP: Just make a comment on the pitch--I could see nothing wrong with the pitch and I won't comment again unless I have something special.

FLT 448 REC 7 NO RATE LIMIT

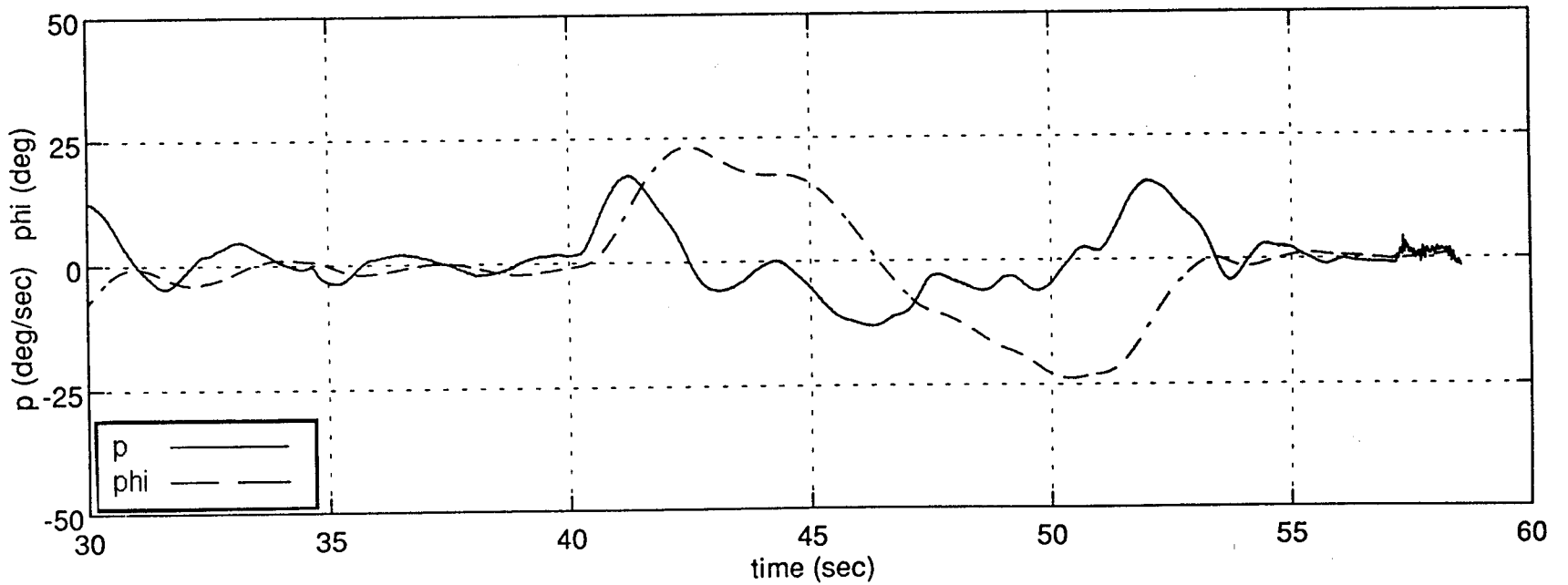
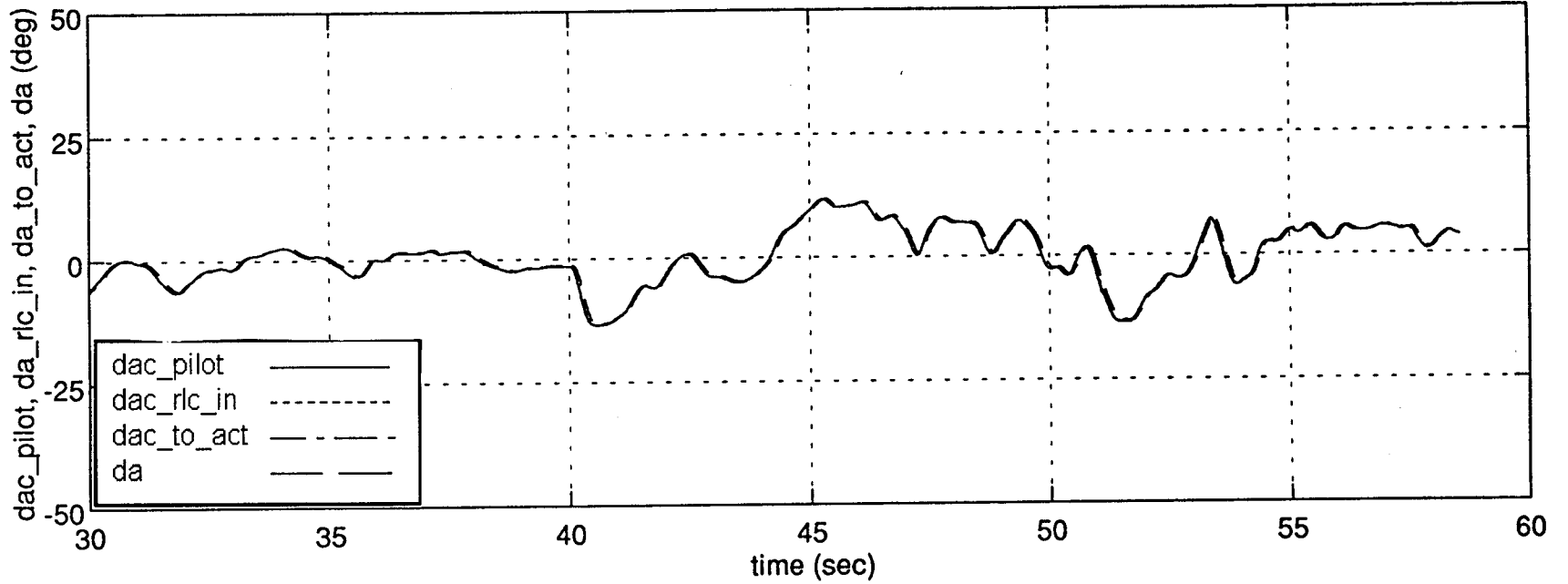
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C-10



FLT 448 REC 8 NO RATE LIMIT



C-11

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Evaluation 27 **Flight** 448/3 **Flight Evaluation No.** 8 **Event** 16

Configuration 000 **Stick** Center **Type** Position **Rate Limit** None

Pilot Smith **Safety pilot** Buethe **Computer operator** Deppe **Flight test engineer** Shafer

Algorithm None **Passes** 1 **Runway** 05

Pass Record **Offset** **Wind** **Performance**
1 21 Right 050/6 Desired

CHR 2 **PIOR** 1

Inflight comments

1st pass:

EP: It's controllable, certainly. Adequate performance? I had confidence in the airplane. Satisfactory without improvement? I'd say yes. The only thing I was almost questioning is whether I noticed a little glimmer of overcontrol, just a slight thing, so I'm debating between a 2 and a 3. I'm going to say it's a 2 with a 1. I really have no concerns about flying that airplane.

Postflight comments

CO: You didn't have much to say. You gave it a 2 and a 1.

EP: Yeah, I gave it a 2 and I felt like I overcontrolled just a little tiny bit, coming in close, and I was mumbling about whether there was something there.

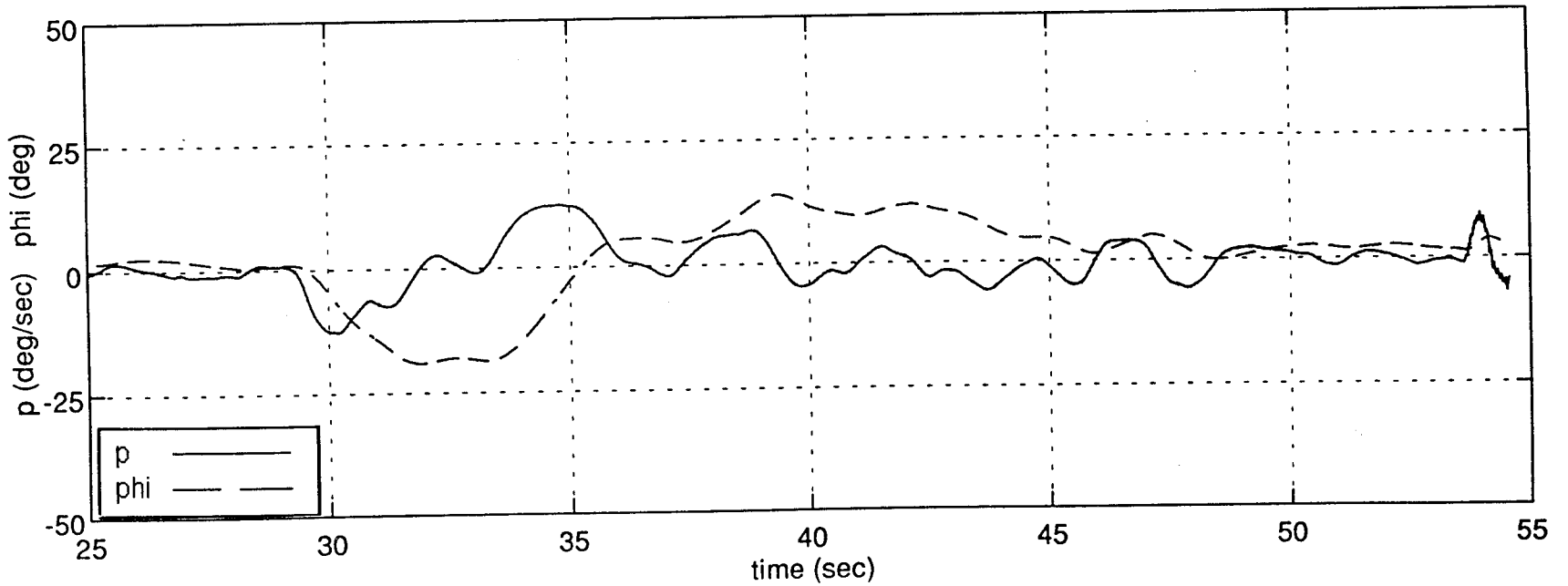
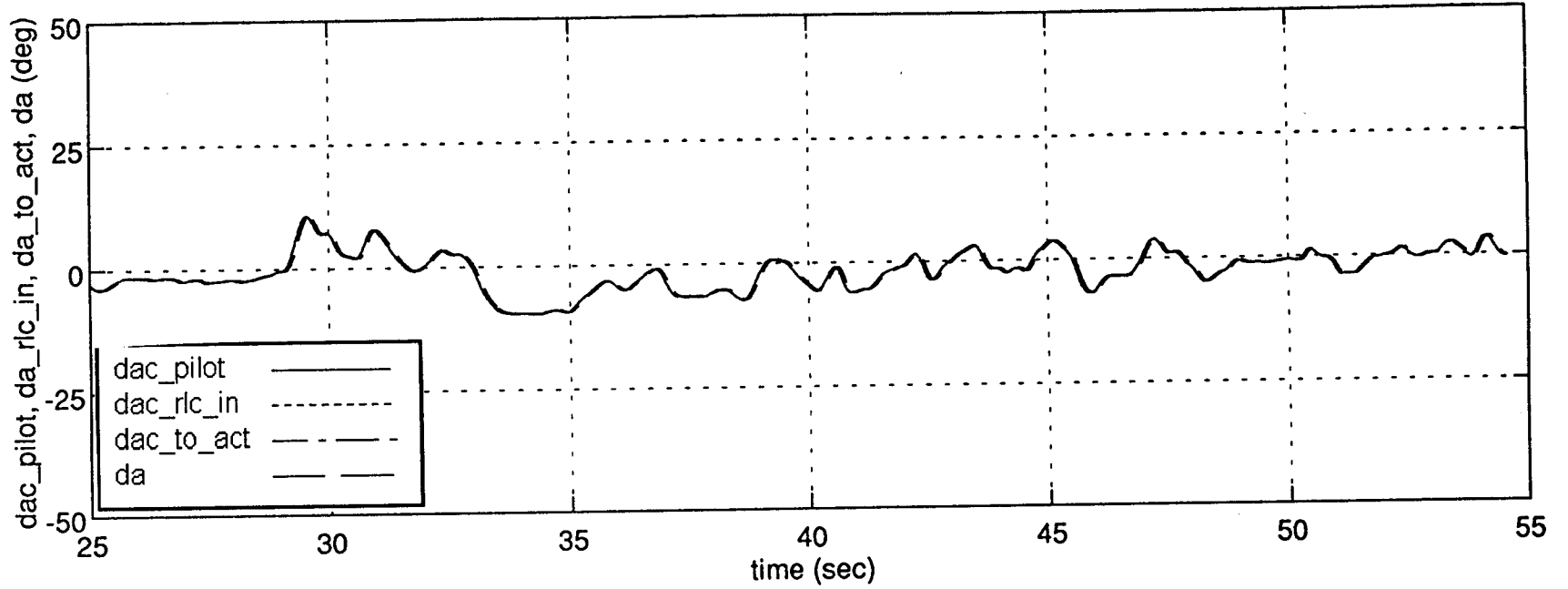
CO: That's the lowest roll inertia in the flight.

EP: That was not a factor.

Remarks

Full-stop landing at Buffalo International

FLT 448 REC 21 NO RATE LIMIT



C-13

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Evaluation 28 **Flight** 449/4 **Flight Evaluation No.** 1 **Event** 8

Configuration 000 **Stick** Center **Type** Position **Rate Limit** None

Pilot Ball **Safety pilot** Deppe **Computer operator** Buethe **Flight test engineer** Shafer

Algorithm None **Passes** 2 **Runway** 10L

Pass	Record	Offset	Wind	Performance
1	6	Right	080/13	Adequate
2	7	Left		Desired

CHR 2 **PIOR** 1

Inflight comments

1st pass:

EP: Feels like a Lear jet. Floats a little bit because it's got 20 flaps, most likely, but as far as the rolls goes, what we're interested in, it's very smooth and predictable. I don't have any real complaints with it. Forces were fine.

2nd pass:

EP: OK, no, no, yes. To be consistent with everything else I do, it'll be a 2 and a 1. Of course, no PIO. The same comments as before, this feels better. It's just uncomfortable--I didn't make a sharp enough offset, so I was getting too low, and that's one reason why I floated on the first one, I suspect. But this is good. When they're that good, there isn't much to say.

Postflight comments

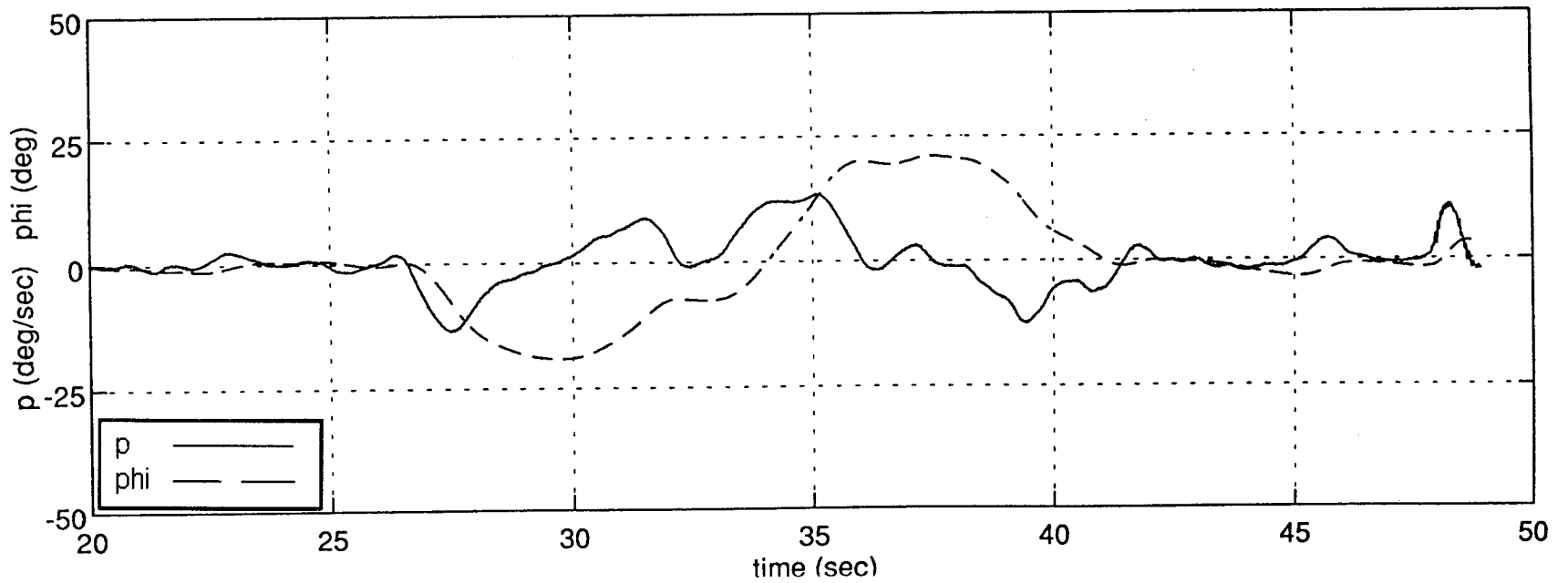
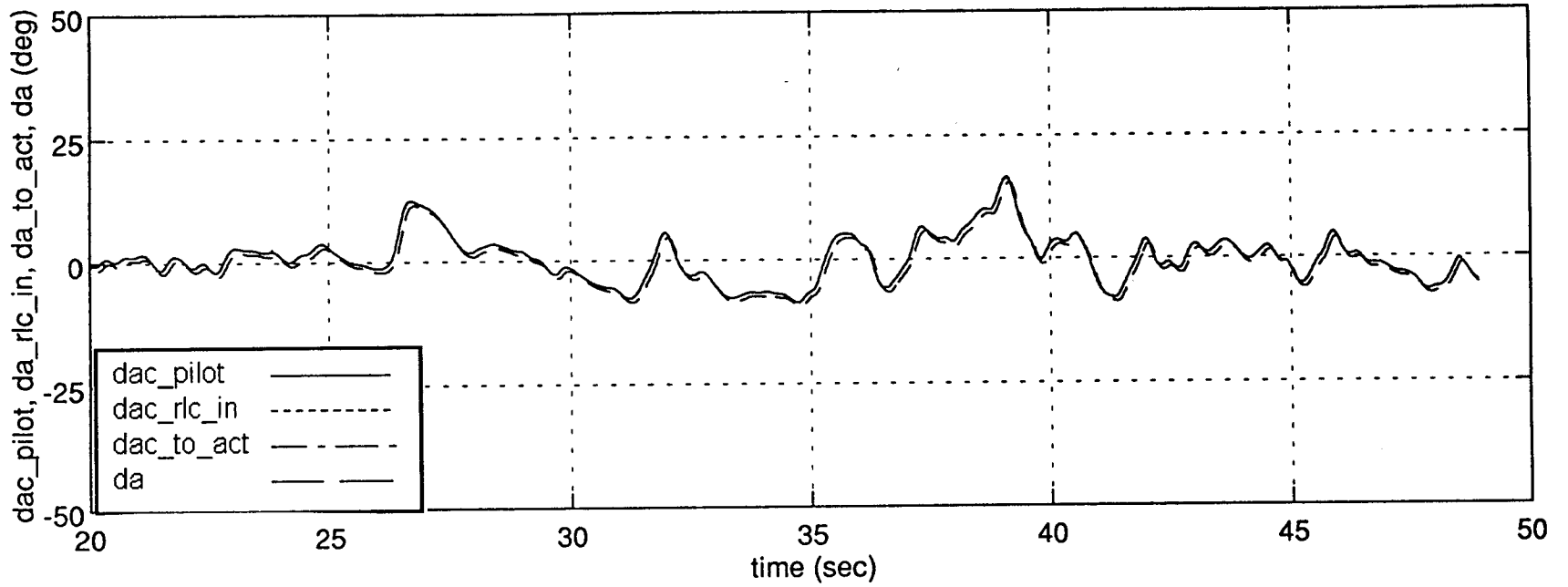
SP: For consistency, a 2 and a 1.

EP: When you've got calm conditions, that's likely where it's going to be. 90%.

Remarks

I had to dump it down and had that one wing down low making the last corner so I'll make the first one a little bit healthier and not be so low.

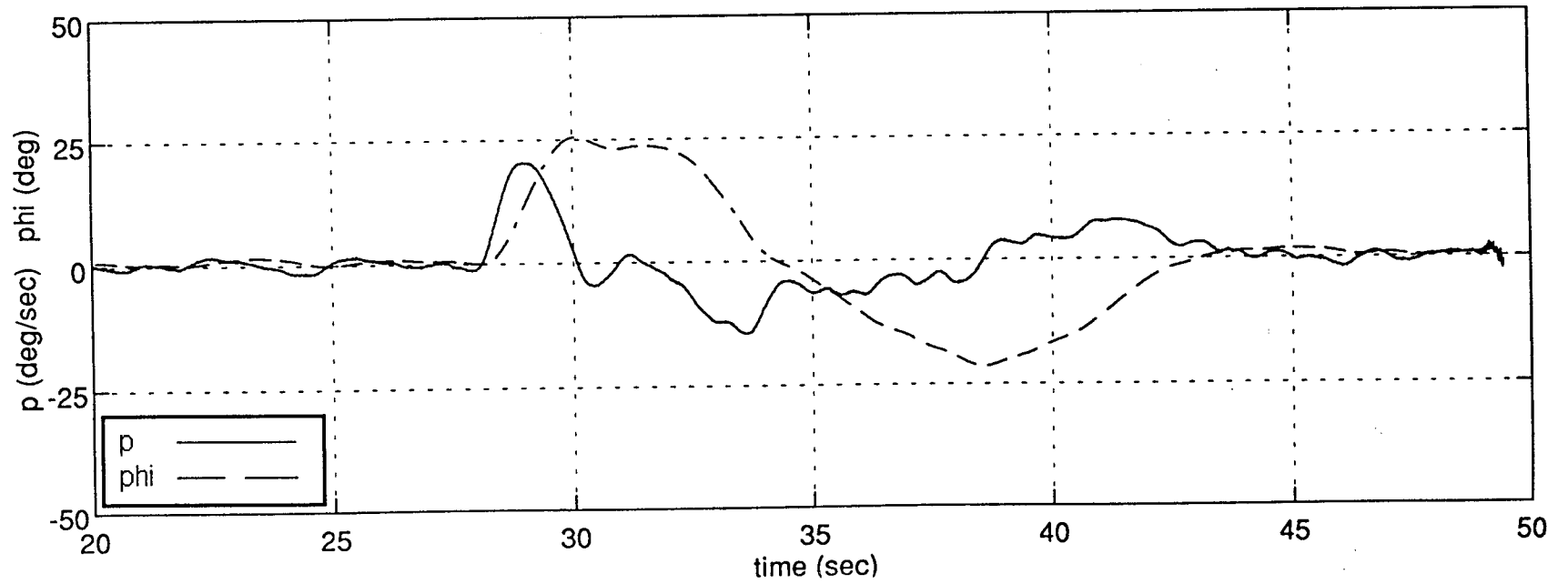
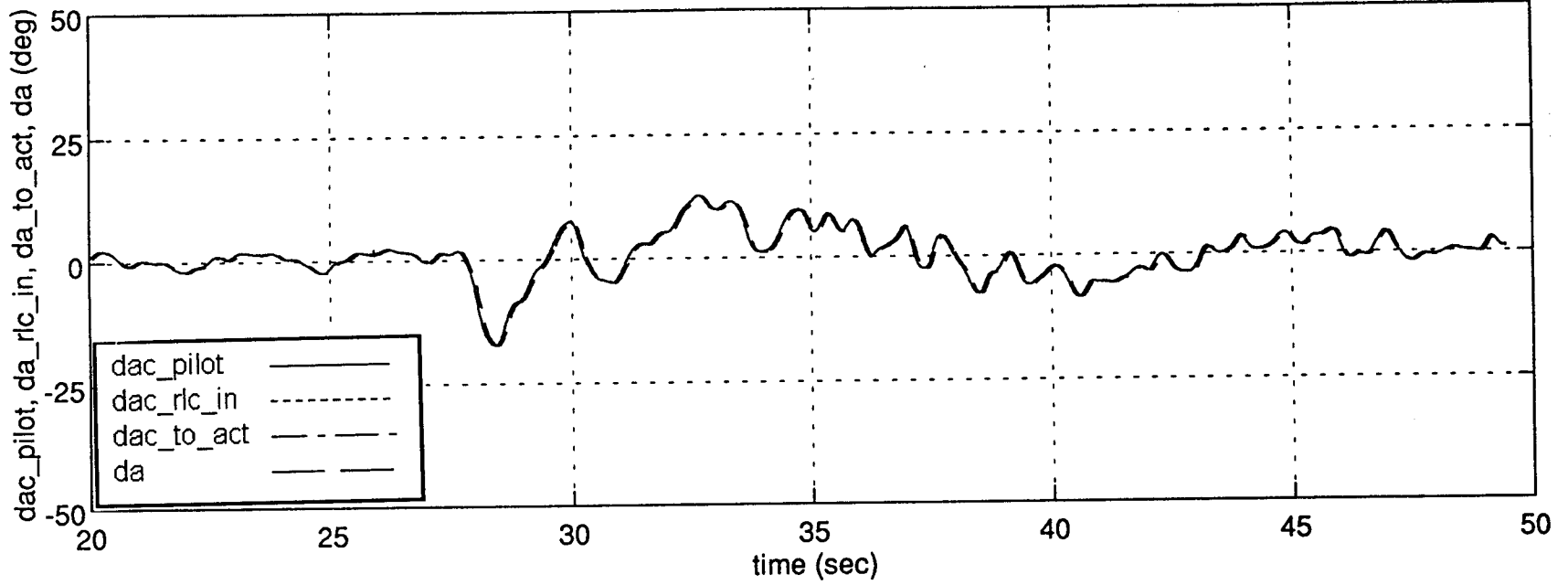
FLT 449 REC 6 NO RATE LIMIT



FLT 449 REC 7 NO RATE LIMIT

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APPENDIX C

C-16



Evaluation 38 **Flight** 449/4 **Flight Evaluation No.** 11 **Event** 16

Configuration 000 **Stick** Center **Type** Position **Rate Limit** None

Pilot Ball **Safety pilot** Deppe **Computer operator** Buethe **Flight test engineer** Shafer

Algorithm None **Passes** 1 **Runway** 05

Pass Record **Offset** **Wind** **Performance**
1 23 Left 090/12 Desired

CHR 2 **PIOR** 1

Inflight comments

1st pass:

EP: Looked like a 2 and a 1 to me. Seems like a piece of cake after all that other crap I was flying.

Postflight comments

FTE: A 2 and a 1.

EP: After all that other stuff I was flying, it was a really good 2 and a 1.

Remarks

Full-stop landing at Buffalo International

In flight:

EP: The biggest difference I saw in all of them was the workload varied all over the place on those. And the compensations that were necessary, some of them were really colossal. Very few of them looked alike. If you'd have said how many different ones did I look at, you may have shown me one more than once but there were very distinct differences in them.

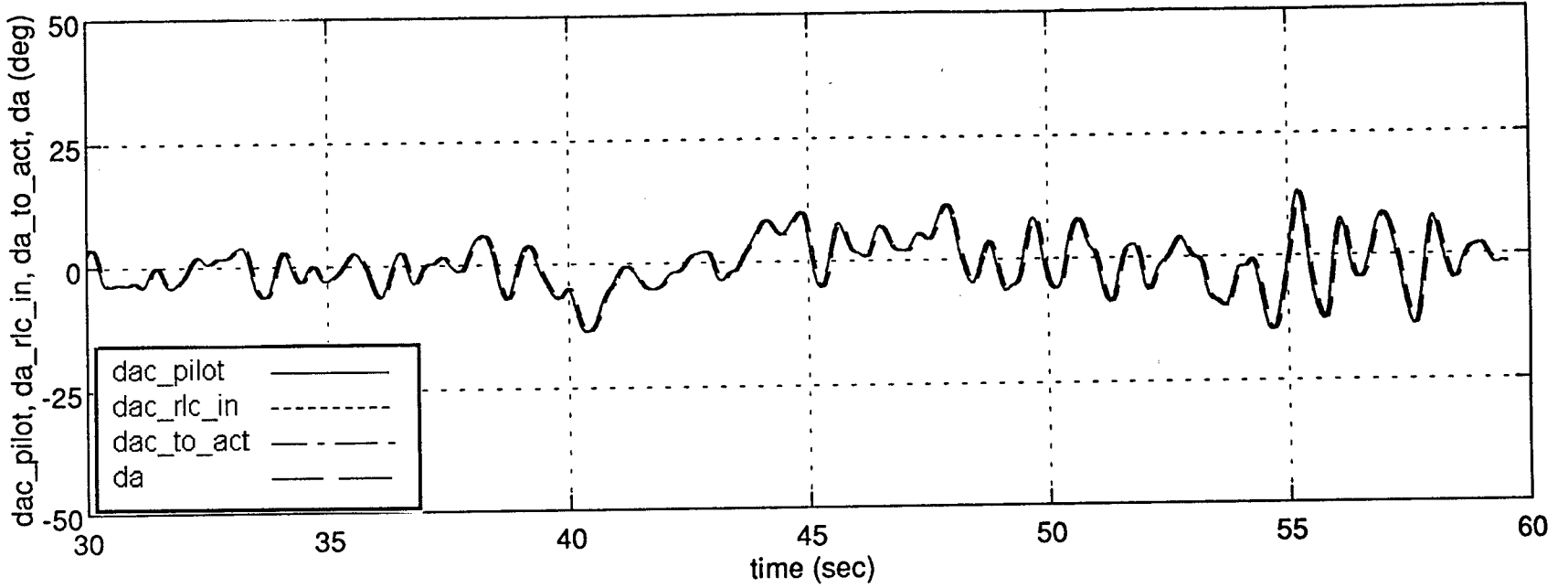
In postflight:

SP: It's interesting--on all four flights we started out with a 000 for the first landing and ended with a 000, every pilot, on the last landing, over controlled in roll a little bit. Still gave it a god rating, but there was a little bit of overcontrol. We're going from the heaviest roll inertia we had to the lightest roll inertia we had, that's the difference. Every time you saw that, but they all gave it a 2.

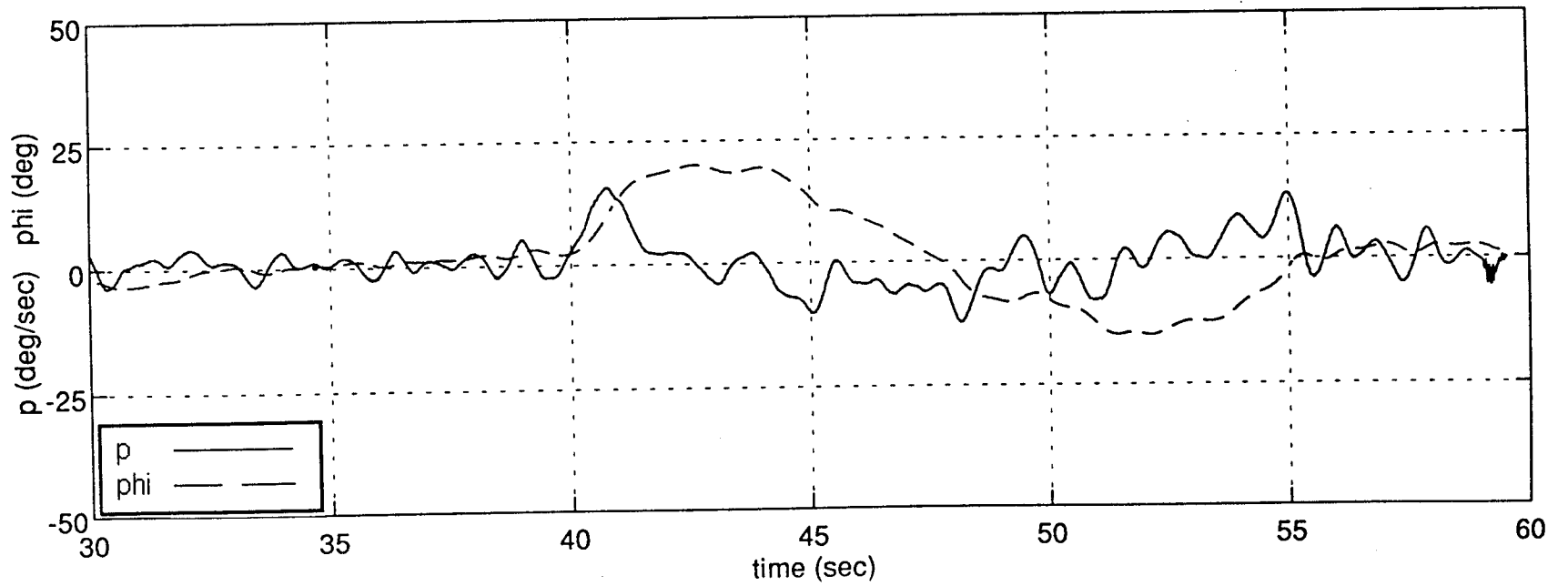
EP: The problem with any of those that have the algorithm in it, it takes the feel of the airplane away. There's something between you and the airplane. You never have a nice, tight, one-to-one feel--I put in an input and here's what I get, it's nice and predictable. All I had was varying degrees of predictability throughout. I guess even, in some ways, the one that had the rate-limited stick--it still wasn't a one-to-one and maybe what I was keying was the force, I wasn't getting one-to-one response per unit force, and that was the thing that I was keying on as I was flying that one.

FLT 449 REC 23 NO RATE LIMIT

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C-18



even with nearly full left input. On that second one, I actually tried to be less aggressive than I was before, slightly. It exhibited no tendencies on down wind or on the base turn that I was going to hit the cliff that I hit.

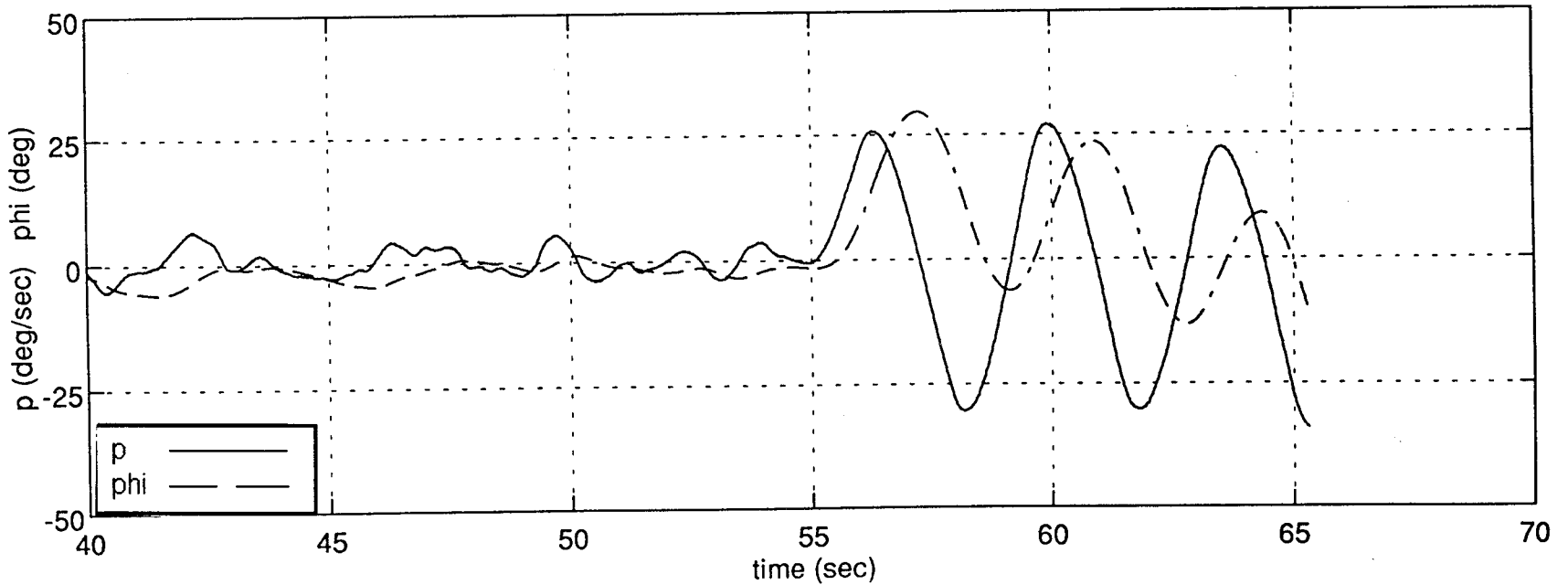
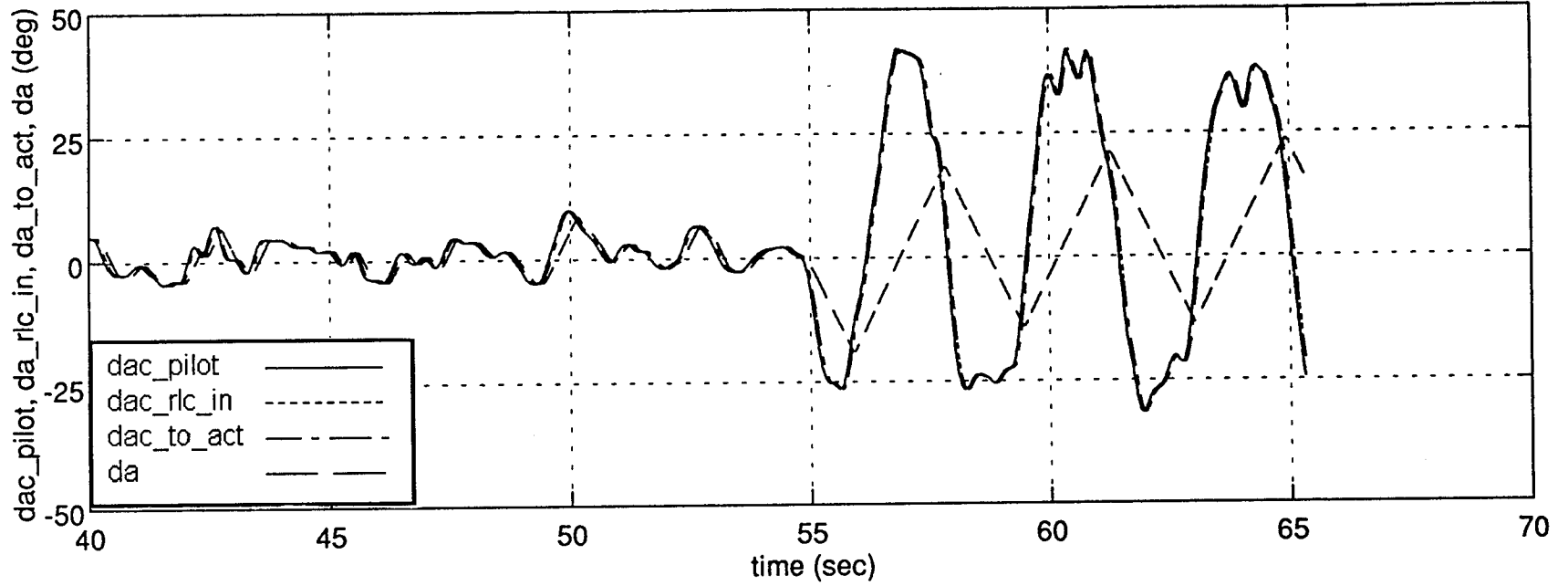
Postflight comments

EP: First of all, in the pattern the airplane felt fine. I saw no PIO tendencies, I could hold what I wanted to in the base, I could concentrate on working on holding airspeed and getting my glide path correct, and the airplane exhibited no bad handling qualities up to the point when [SP] called correct. At the point [SP] called correct I put in what I felt was the same input I had been using on the baseline and it was obvious from the very, very first correction that we were going to be getting into a PIO. At that point I attempted to back out slightly out of the loop, but not totally take my self out of the loop, just be less aggressive as a compensation technique. There was no chance for any landing on *that* runway. I kept flying the airplane and assuming that I was going to land the airplane, hoping that [SP] was going to take it. And he did.

SP: As soon as he made the correction, he made the exact same comment that I made when I tried it the first time and Rogers Smith made when he flew it the first time, which was , "Whoa!"

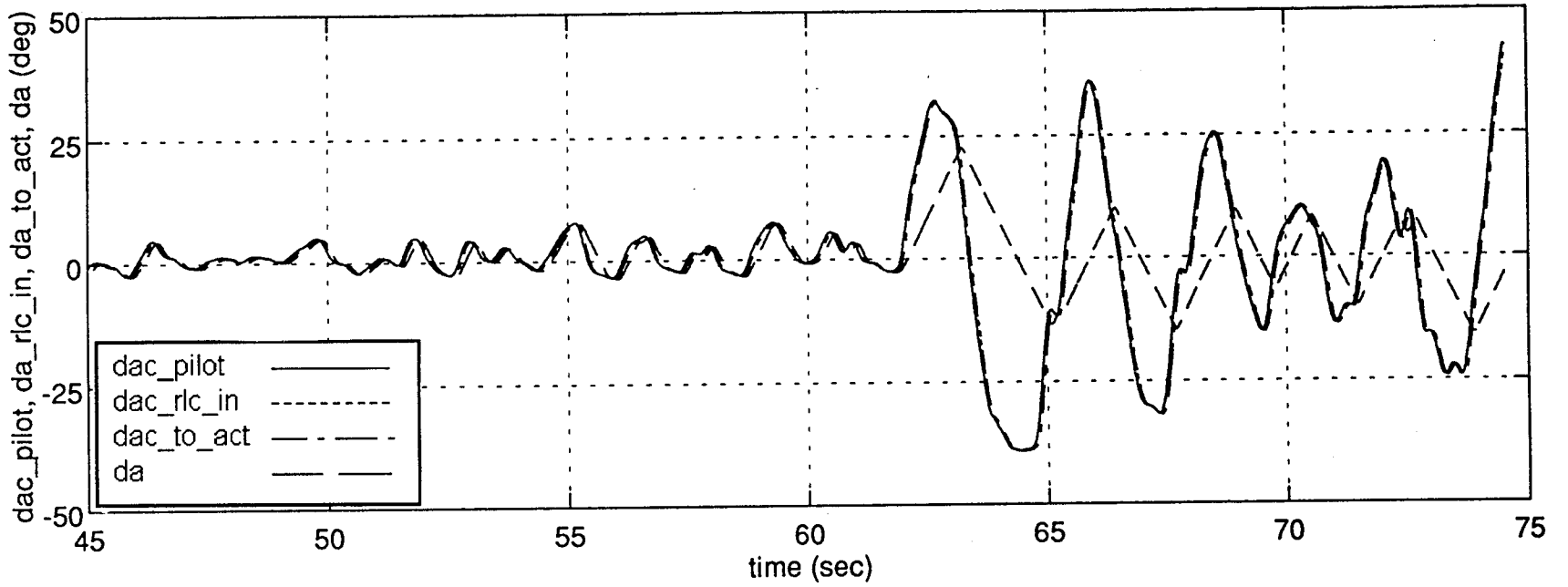
EP: There was no landing possible. The second one was exactly the same as the first. On the second attempt at it, I did not try to change my level of aggressiveness. I just went for the same level. It just felt like a very nice-flying airplane around the final turn.

Remarks

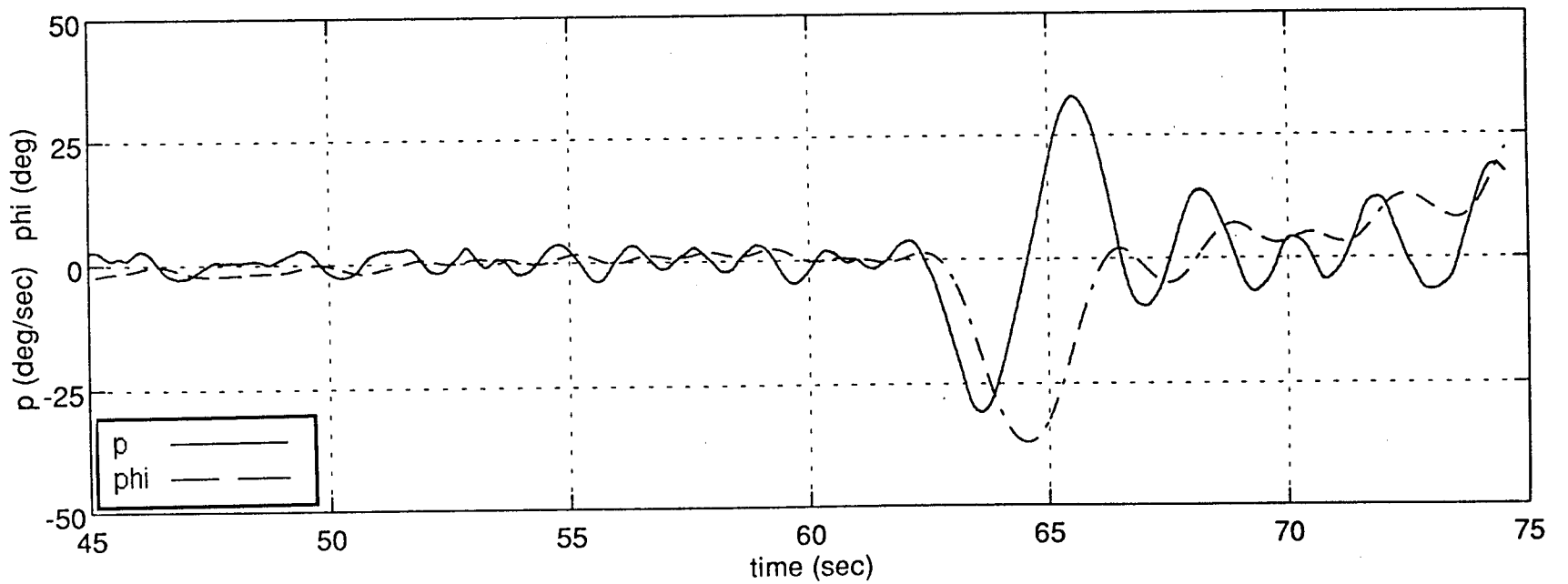


FLT 446 REC 9 RL = 20 deg/sec RLC OFF

Calspan Report No. 8091-2
APPENDIX C



C-22



Evaluation 22 Flight 448/3 Flight Evaluation No. 3 Event 10

Configuration 300 Stick Center Type Position Rate Limit 20 deg/sec

Pilot Smith Safety pilot Buethe Computer operator Deppe Flight test engineer Shafer

Algorithm None Passes 2 Runway 10L

Pass	Record	Offset	Wind	Performance
1	11	Right	030/8	Desired
2	12	Left		Desired

CHR 5 PIOR 3

Inflight comments

1st pass:

EP: That was not a pleasant airplane in the sense that on the initial correction for the offset I had this very uncomfortable feeling that you weren't going to be able to stop the bank. I was able to stop it but I had a glimmer of concern there. I was able to do the remainder of the offset and the final stage without getting into any real overcontrol but I was very cautious about the airplane after the first input. I'll try to do the opposite-side offset with the same aggressiveness and see what we get.

2nd pass:

EP: That was a very confusing set of [tower] instructions. I was surprised that without compensating a little bit, on the first one, if you make that abrupt initial input and overcontrol, you get the feeling of not being able to recover as crisply as you would like. In the context of the second, I was able to barely get around and land without difficulty.

EP: I think I can achieve adequate performance, not satisfactory without improvement, really has deficiencies that warrant improvement. I think the objectionable deficiencies are still there, so I'm going to give it a 5. PIO rating scale--oscillations? No, I didn't see oscillations. Undesirable motions? Yes. Task compromised? I think it was, on the basis of my first one--I did back off from the airplane a little bit--call it 3. 5 overall, 3 PIO rating.

Postflight comments

CO: Has some PIO, continuous PIO. "Not nice", you said. You gave it a 5 and a 2.

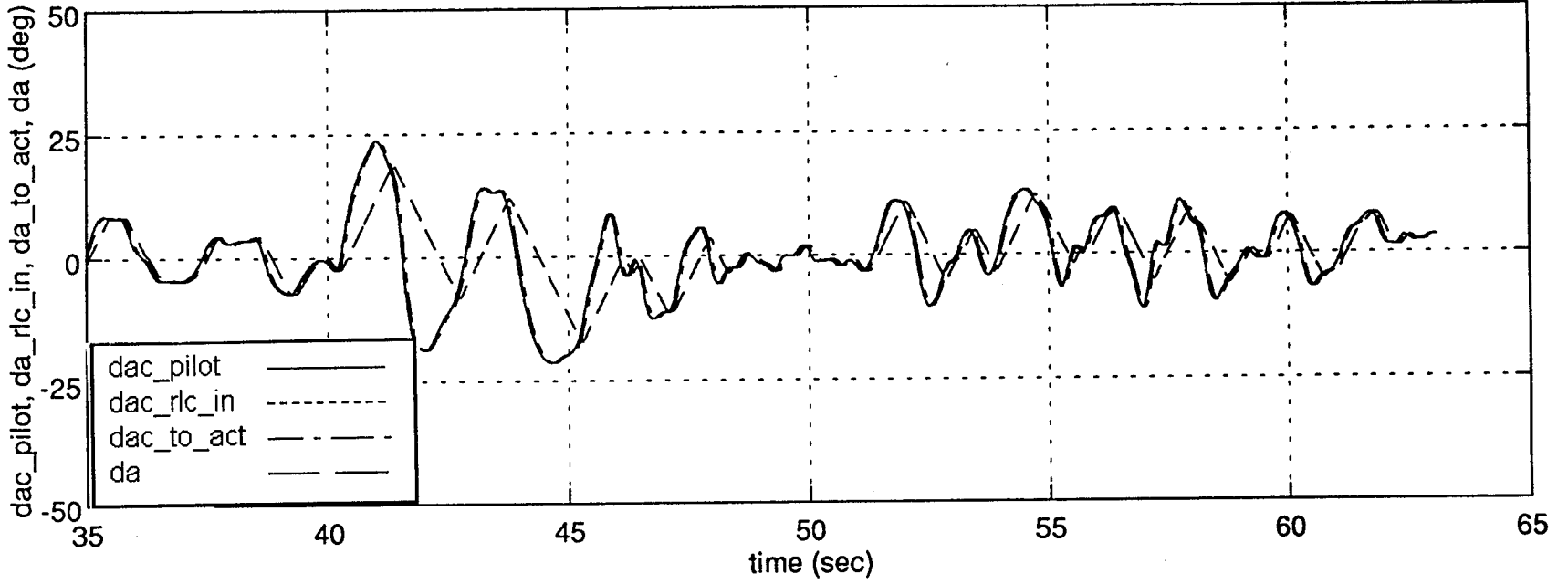
EP: What I remember there was that there was an overcontrol tendency but it was not significant. It was just, to use the word, "moderately objectionable". I put the airplane where I wanted. I got desired performance, but it was objectionable.

Remarks

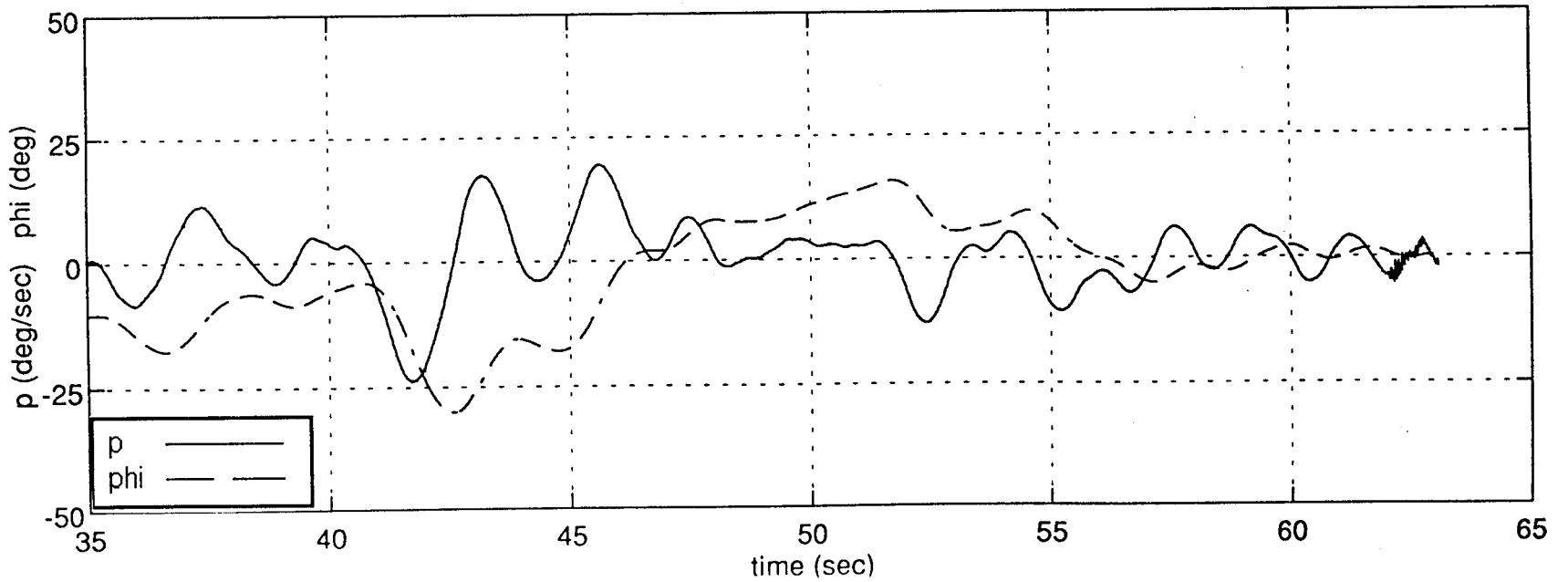
Second pass was a full-stop landing at Niagara (traffic)

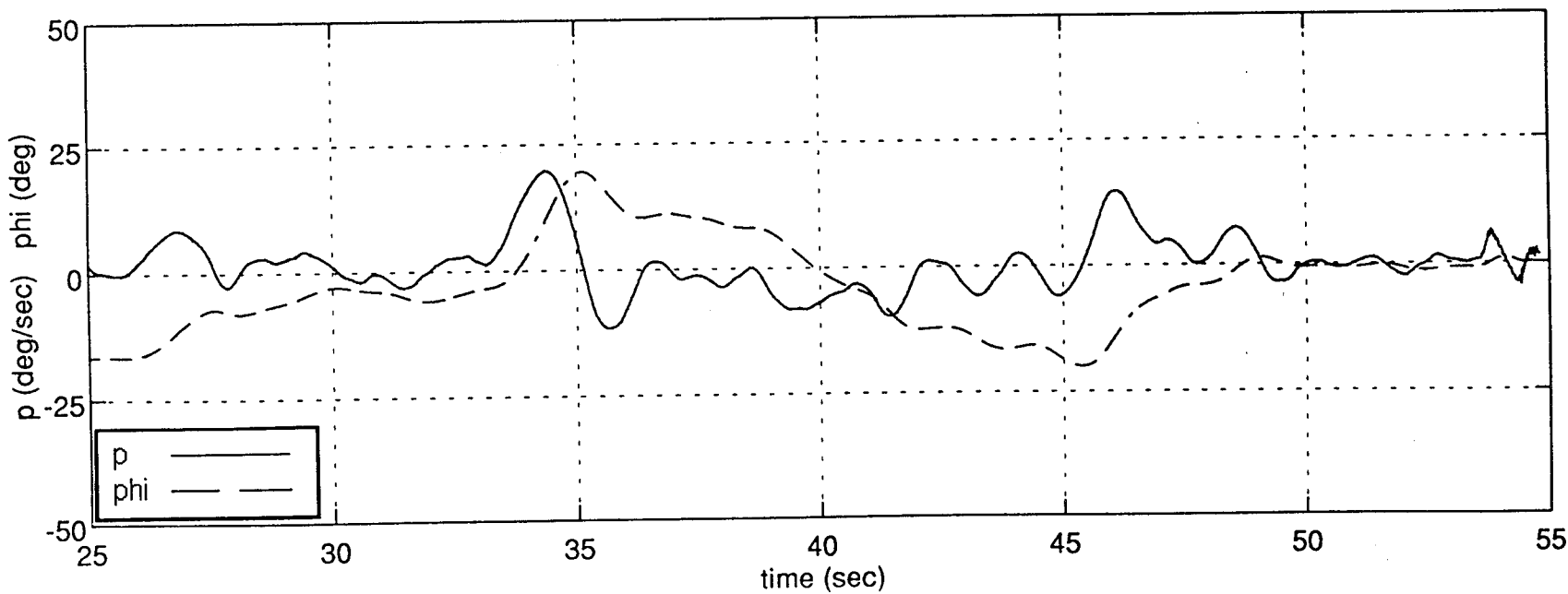
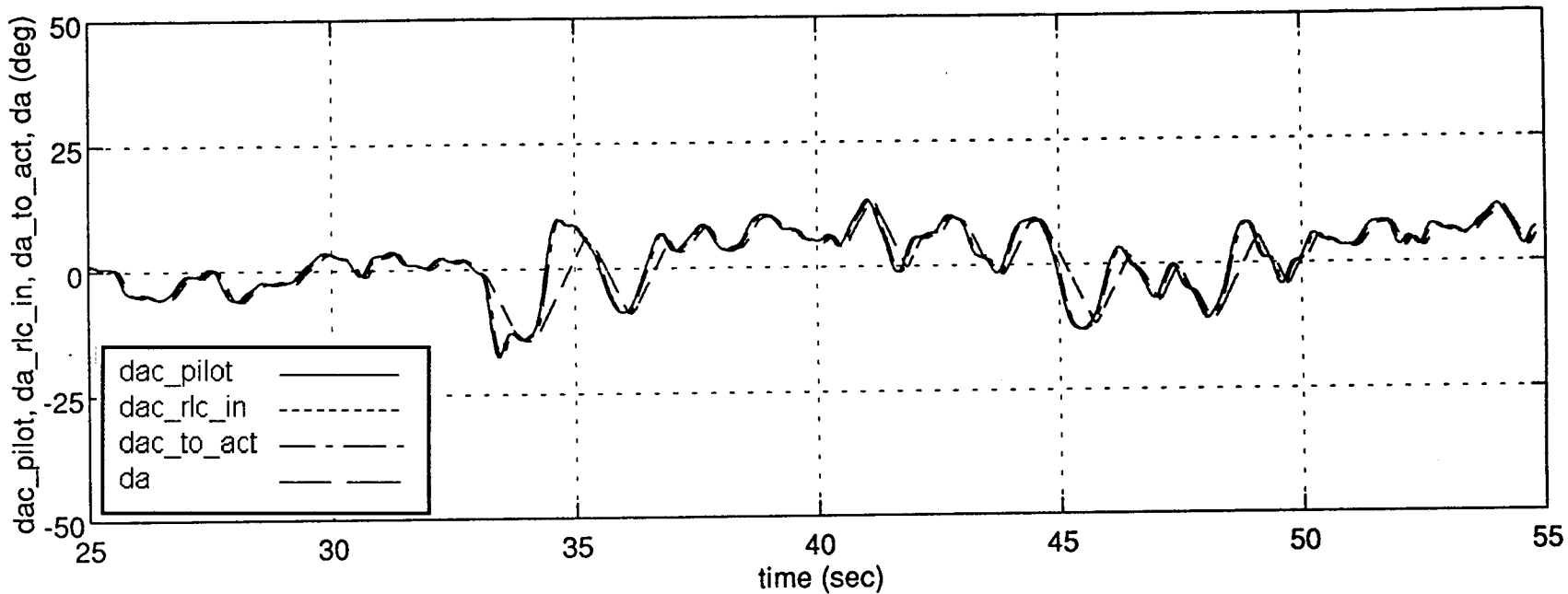
FLT 448 REC 11 RL = 20 deg/sec RLC OFF

Calspan Report No. 8091-2
APPENDIX C



C-24





C-25

Evaluation 30 **Flight** 449/4 **Flight Evaluation No.** 3 **Event** 10

Configuration 300 **Stick** Center **Type** Position **Rate Limit** 20 deg/sec

Pilot Ball **Safety pilot** Deppe **Computer operator** Buethe **Flight test engineer** Shafer

Algorithm None **Passes** 1 **Runway** 10L

Pass Record **Offset** **Wind** **Performance**
1 10 Left No landing

CHR 10 **PIOR** 5

Inflight comments

1st pass:

Turning base:

EP: Well, I put in a couple of quick inputs there and got a little overshoot that was unanticipated.

On final:

EP: As I get closer to the ground, I'm making more small inputs and a bigger PIO coming in. Not huge, yet, but I don't like the looks of it. It's going to be a beaut.

SP: Correct

EP: OK, over there, not too far, try to stop it, did. [Garbled] special techniques.

SP: I've got to take that one

EP: OK, I can understand that.

EP: That was pretty bad. I'm likely going to see the same thing again. It's going to end up to be a 10 most likely, if you want me to look at it to make more comments. The biggest thing I see close to the ground, though, is getting the more I noticed it and I had to start using a special technique. I'd put in, and then hold what I had, until I'd almost got it and then take some of it out and then the rest of it out. That was the only way I could stop it anywhere near where I wanted to. That's a 10. On the PIO scale, it's grievous. Oscillations? Once I got in it, yes. I didn't do it long enough to tell whether it's divergent, so that's why it's hard to tell if it's a 4 or a 5, but it's very, very bad in any case. It likely would be a 5. There would be times when it was a 5, if I had to do any [moved hand rapidly]

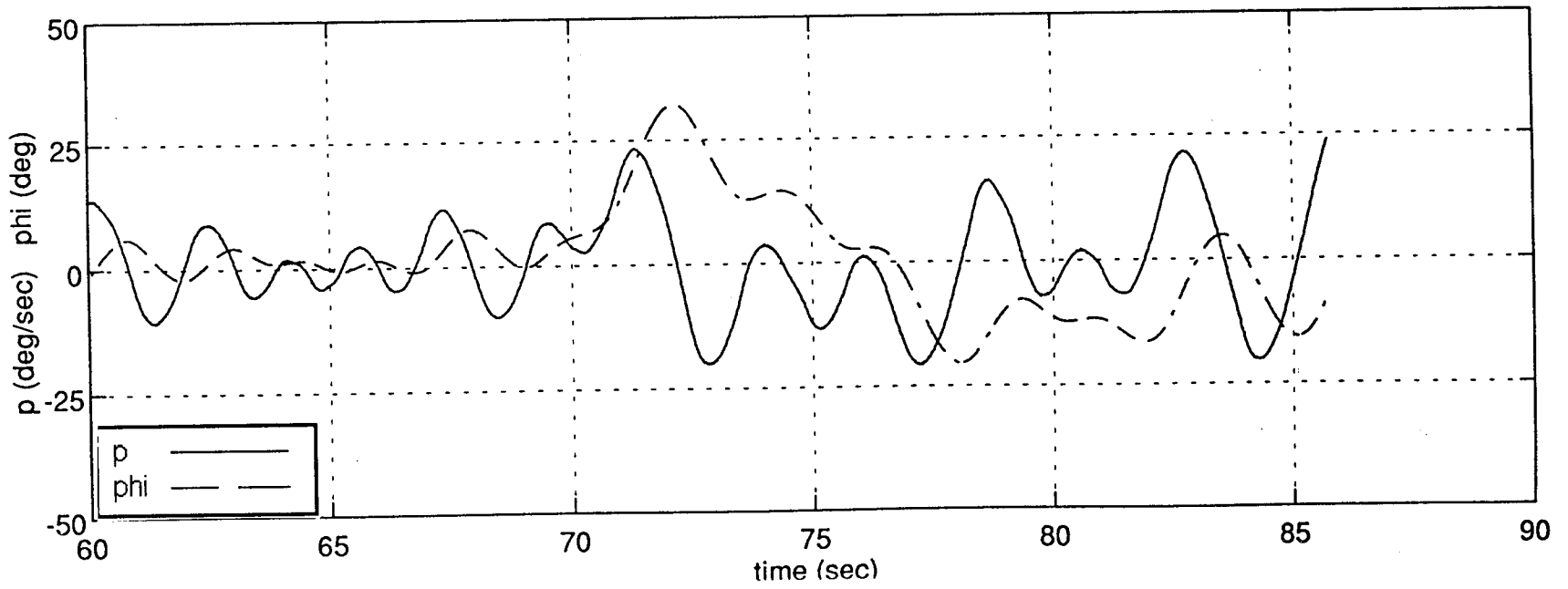
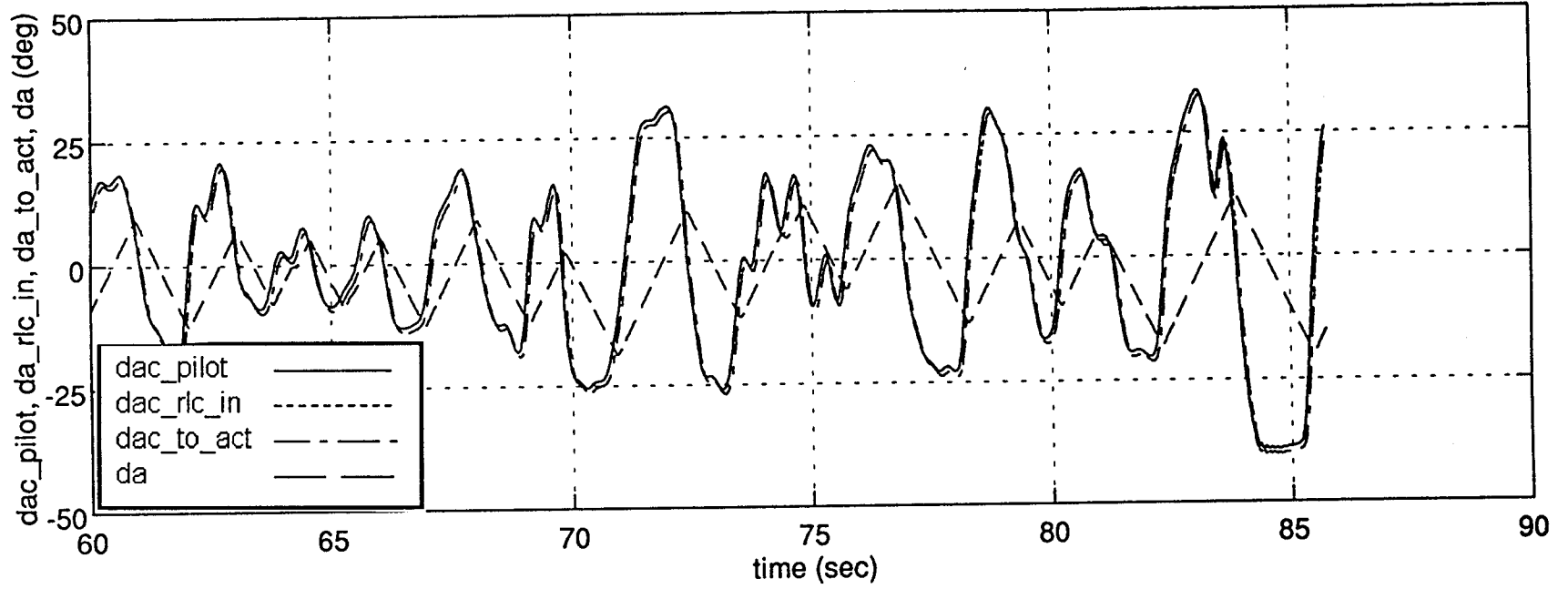
Postflight comments

FTE: A 10 and a 5.

EP: I think that was the one that, it's a common tendency, I've heard it a hundred times, and I tend to do it, too--you keep thinking, "Well, just a little bit more, I think I would have caught that one". I think I just got it back wings level when you took it, and I said, "I don't blame you for taking it." I kept thinking that maybe I had that one. I'll say that if I didn't lose control of it, I would have if I'd done it enough times, guaran-damned-teed. That's a terrible airplane.

Remarks

FLT 449 REC 10 RL = 20 deg/sec RLC OFF



C-27

Calspan Report No. 8091-2
APPENDIX C

Evaluation 6 Flight 446/1 Flight Evaluation No. 6 Event 3

Configuration 301 Stick Center Type Position Rate Limit 20 deg/sec

Pilot Johnston Safety pilot Deppe Computer operator Buethe Flight test engineer Shafer

Algorithm RLC Passes 2 Runway 10L

Pass Record Offset Wind Performance

1	18	Left	050/9	Desired
2	19	Right		Desired

CHR 4 PIOR 2

Inflight comments

1st pass:

Turning final:

EP: Roll control right now is fine. I have no tendencies to overshoot. I do find out that I'm putting in small inputs to keep it where I want it, more so than before in the baseline airplane.

SP: Just a shade low out here.

EP: Yes.

SP: Correct

EP: Initial move is slightly sluggish, but not bad. Well controlled. No PIO tendencies noted. Rolling out on final, airspeed's good. Lineup's good.

EP: Well controlled and in the desired box. Didn't see any cliffs and didn't feel like there was anything out there, PIO tendencies were very benign. For some reason the stick's starting to feel a little sluggish to me, I don't know whether it's switching back from the side controller to the center stick or exactly what it is. I'm not sure that that comment is even worth documenting, but it does feel just slightly sluggish to me. It doesn't feel like it's in cement, but it....

SP: I think that's a very good comment. They're all valuable, and I think that one is very germane and we can talk about it afterwards. I know exactly what you mean.

2nd pass:

EP: Initial bank angle, on the roll in, here felt fine. Noticing just a little bit more tendencies to have minor control inputs to maintain desired bank angle, but nothing I would call PIO or even call objectionable, just noticeable.

SP: We're a shade low here [on final]

EP: Still slightly low. Airspeed's good. No turbulence noted.

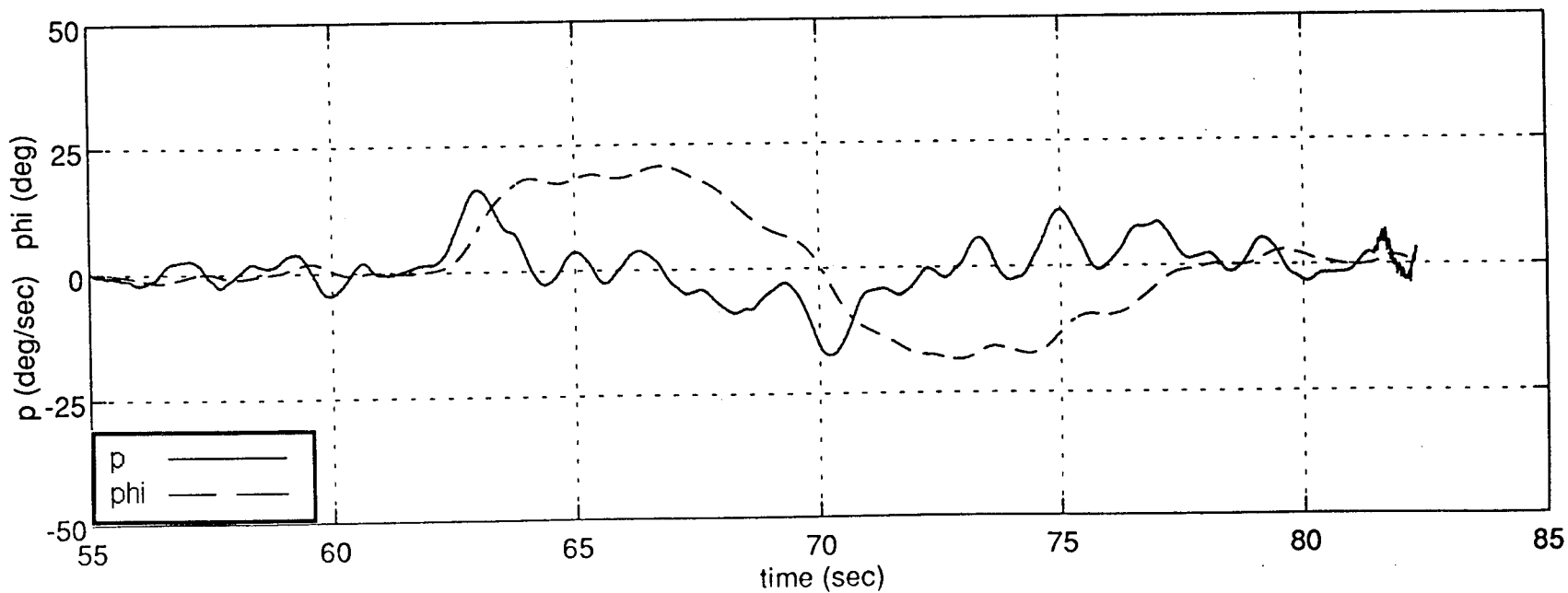
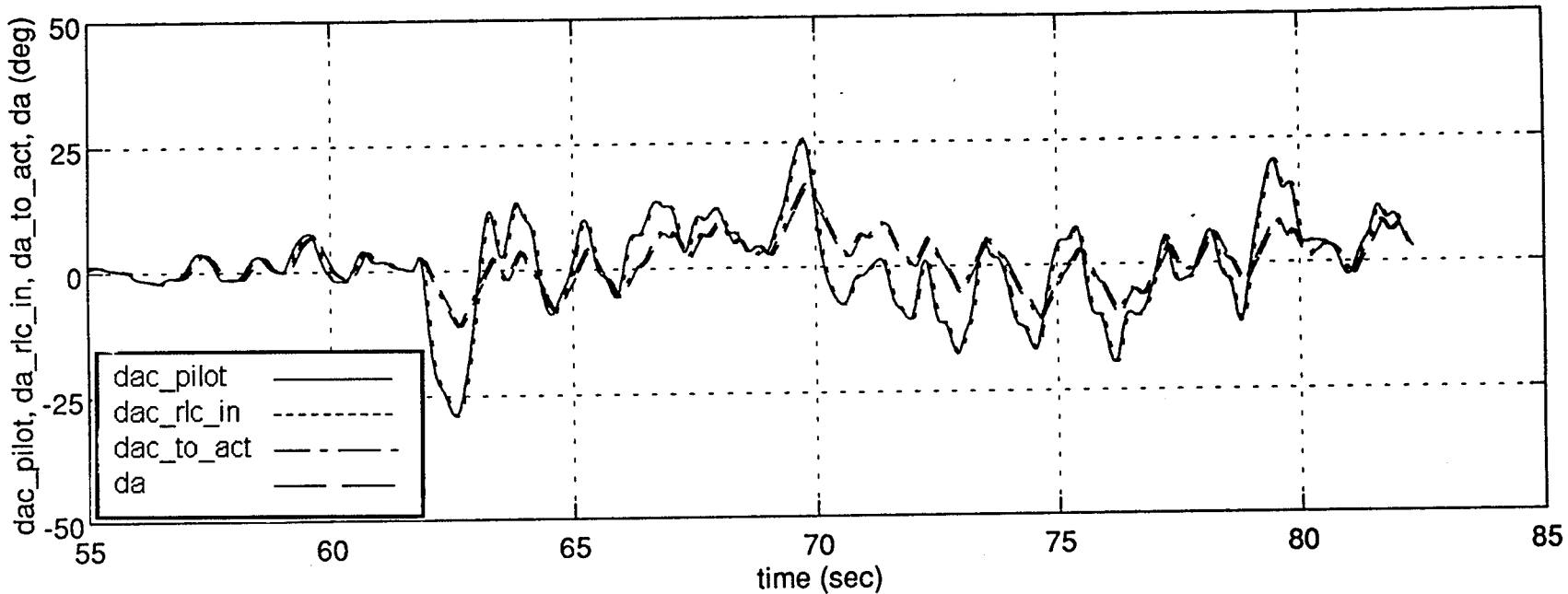
SP: Correct

EP: Sluggish--had to put in a little bit more input than what I originally would put in. Rolling out. Doing it in steps and I don't know why. Slight overshoot. Correcting back. Working on pitch. Got everything stable and right where I want it.

EP: It is controllable. Adequate performance attainable with a tolerable pilot workload. Is it satisfactory without improvement? No. I'm going to give it a Cooper-Harper 4 with minor but annoying deficiencies and that annoying deficiencies is a slight sluggish feeling. A PIO rating of 2. A Cooper-Harper 4 and a PIO of 2.

Postflight comments

EP: This time, we were still doing fairly normal patterns here. I gave it a Cooper-Harper 4 with a PIO of 2. It felt the same as the one before, except a slight more sluggishness. I achieved desired criteria both times. The real reason I think I downgraded this one was the sluggishness, plus it felt like I was close to the edge of the cliff. I don't know why, it just felt like if I gave this thing just a little more, it was going to push it over the edge. I do not feel like I was backing off my gains much to compensate for that, but something in the control system just felt like it didn't want to go any further than what I pushed it. I don't think my gains were much lower than what I did on any of the other ones.

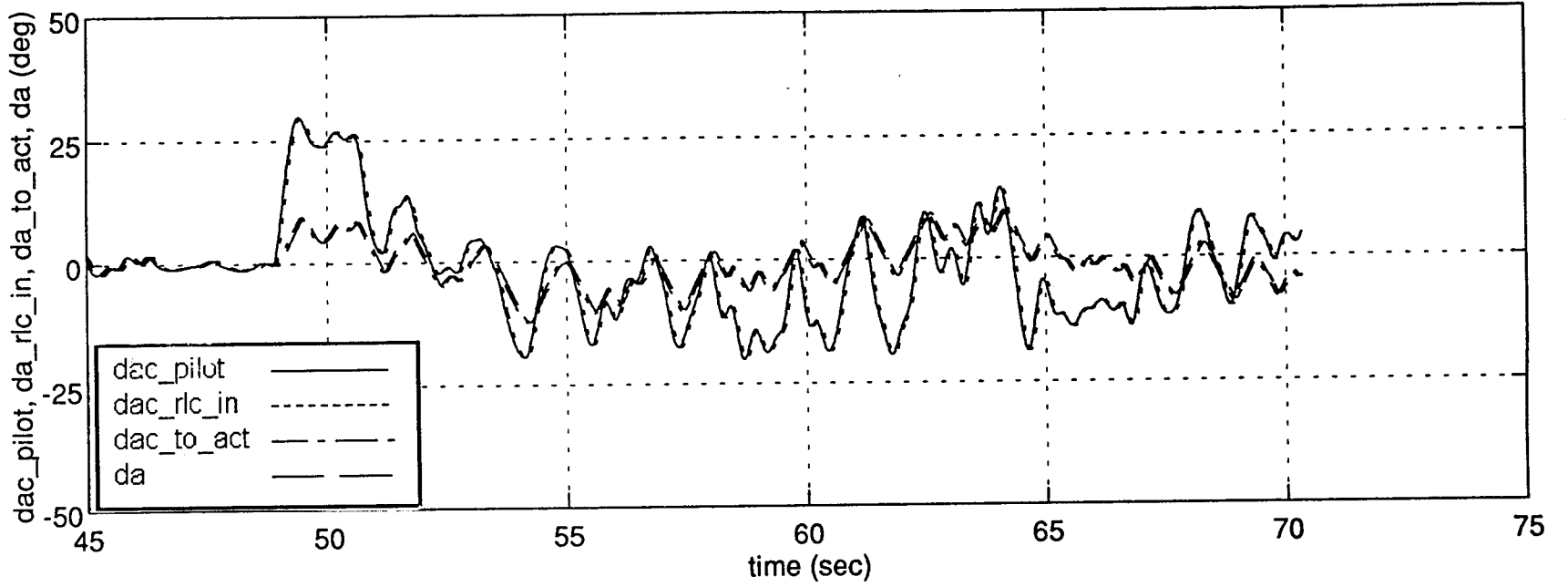


C-29

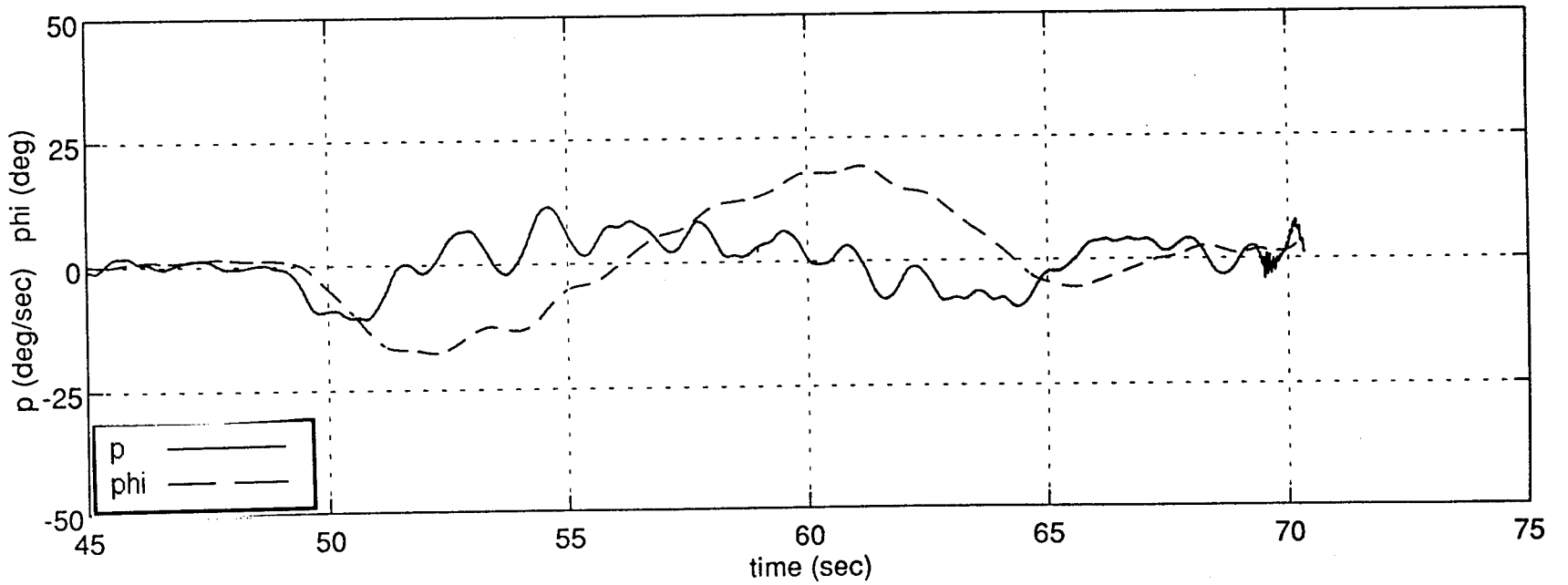
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APPENDIX C

FLT 446 REC 19 RL = 20 deg/sec RLC ON

Calspan Report No. 8091-2
APPENDIX C



C-30



Evaluation 8 Flight 446/1 Flight Evaluation No. 8 Event 10

Configuration 301 Stick Center Type Position Rate Limit 20 deg/sec

Pilot Johnston Safety pilot Deppe Computer operator Buethe Flight test engineer Shafer

Algorithm RLC Passes 1 Runway 10L

Pass Record Offset Wind Performance
1 22 Left Desired

CHR 2 PIOR 1

Inflight comments

1st pass:

On final:

EP: No PIO tendencies yet. Bank angle captures were good. Nice crisp flying airplane. Airspeed's where I want it. Glide path's where I want it. Offset's where I want it. All are stable. 747 approach out here.

SP: Correct

EP: Aggressive correction. Bank angle capture was good on the correction. Angling over. Rolling out. Bank angle capture was good there. Rolling back. Sliding across the center. Nice and crisp. Good corrections. Right where I want it. Fighting a little tendency in here. We're going to nail that one.

EP: One eval limited on that one, but I'm going to give it a Cooper-Harper 3. No, no, I'm going to give it a Cooper-Harper 2. PIO 1. I handled that one as aggressively as I've handled any other and, I felt, as aggressively as I've handled the baseline. We'll see if I change that after I do the baseline again. That was a limited evaluation, only.

Following next evaluation:

EP: The last one I did was just slightly--if I had to rate it, I'd give the last one a 2.5 and that one a 2, if you guys will let me give 0.5s in the level. It was slightly worse, but not much.

Postflight comments

EP: We only got one on this, due to traffic at Niagara, we had a very, very long final. We got everything trimmed up and set. The correct back to centerline was given at the same time it always had been. Assigned a Cooper-Harper of 2 and PIO 1 on this one. We had been doing a number of evaluations and I thought it was definitely better than 5 on this time. I didn't feel any sluggishness. I didn't feel any edge of the cliff type of feeling on this one. It was better than event 5, I thought.

Chick Chalk: Any comments on out of trim?

EP: No, no comments whatever. This was what felt to be a very good airplane to me. Then we did the baseline coming back in here to Buffalo again and so I have kind of a back-to-back comparison. I only had one shot at that one, because of the fuel and daylight. Back here at Buffalo, we flew the baseline again, 000 with the center stick, and direct comparison of those two, the baseline was definitely better.

[?] What did you give the baseline?

EP: A 2 and a 1. And that's why, when I was rolling off the runway, I said, "Well, if I had to do it all over again, I'd give Cooper-Harper 2.5 to the event 10." Then [FTE] started beating me up because she won't accept a half.

FTE: We did event 10, which was the repeat of event 3.

EP: We did it twice and I gave it a 4 and a 2. Then we did just one shot at it with a real long final right at the end and I gave it a 2 and a 1.

FTE: Do you think the long final was part of that?

EP: think the long final was part of that. I think the learning curve was part of that.

[?]: Was it an offset?

EP: Yeah, it was an offset. The only difference was--I strongly believe, and you guys may not--you feel like you get to that point in the sky, then it doesn't matter how you got there. I feel if you turn a tighter base and if you were working real hard right when you got to that point in the sky, that workload carries over into your offset. This one, I was not working that hard at all. I had it basically trimmed up and sitting there and just

waiting. Some of the other one, you know, I got to the same point in the sky at the same airspeed, but my workload that I started out with at the correction was more than that one was. So that was the lowest workload I had on any at the start of the correction--I was ready, waiting, keyed, primed.

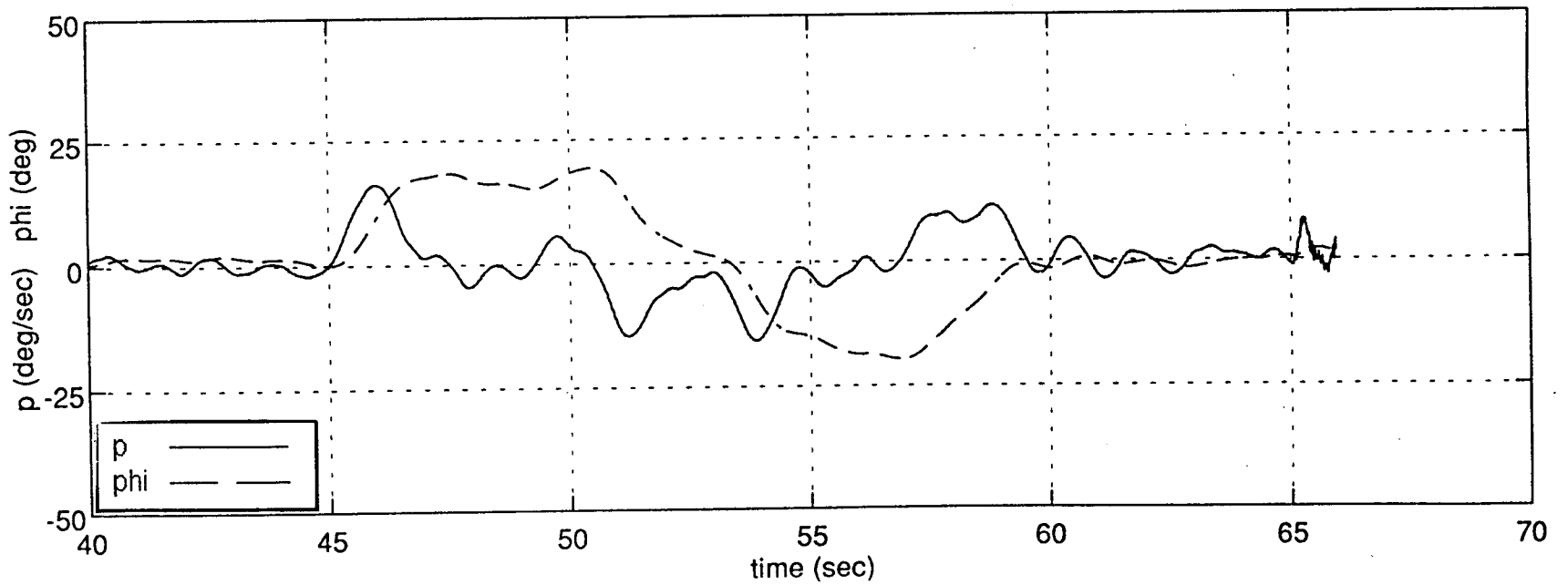
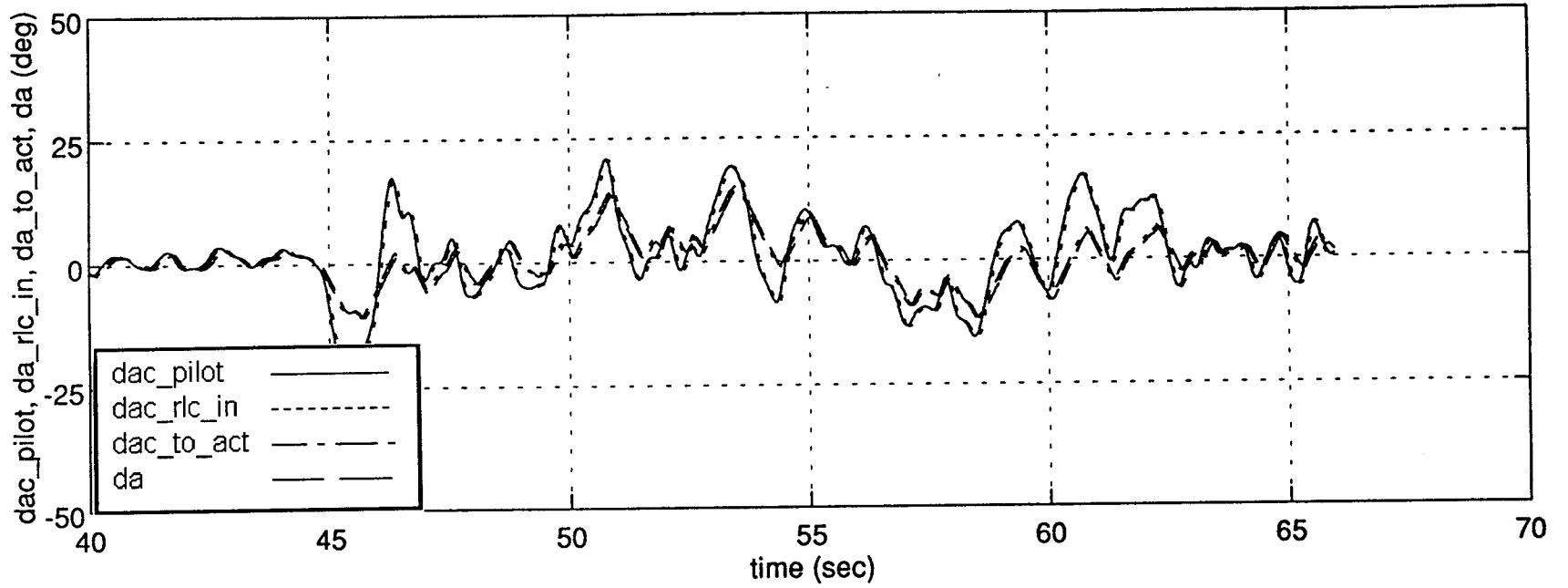
CO: I agree with you that the airplane may be in the same state but you aren't necessarily in the same state. You may have just checked all of your parameters....

EP: That may be a wrong comment to say that you guys don't feel that way. I don't know how you guys feel. That was why I was asking for those 360's instead of going for the long final, to keep them all starting base at the same point, rolling out at the same time. That one, because of that, that one wasn't the same. That's my excuse for not being consistent. But still, I could not notice anything wrong with the airplane. Also, the only other thing I could see about that one, if I remember right, was that was a left offset in a left, quartering crosswind, which helps on the correction.

Remarks

Rating corrected to a 2.5 after subsequent evaluation

FLT 446 REC 22 RL = 20 deg/sec RLC ON



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APPENDIX C

Evaluation 21 **Flight** 448/3 **Flight Evaluation No.** 2 **Event** 9

Configuration 301 **Stick** Center **Type** Position **Rate Limit** 20 deg/sec

Pilot Smith **Safety pilot** Buethe **Computer operator** Deppe **Flight test engineer** Shafer

Algorithm RLC **Passes** 2 **Runway** 10L

Pass	Record	Offset	Wind	Performance
1	9	Right	020/8	Desired
2	10	Left		Desired

CHR 4 **PIOR** 2

Inflight comments

1st pass:

EP: The airplane had a tendency to overcontrol. I think this time I can be a little more aggressive in the offset. I think I compensated and did the offset in small increments and, as a result, I did not see any real tendency to overcontrol in the course of the final stages of the approach. I did not have a lot of confidence in the airplane, just feeling it around the base turn. So this time we'll do an offset and I'll be a little more aggressive. I'll try to keep my aggressiveness about the same and not subconsciously compensate.

2nd pass:

EP: It was better than I expected. I was a little hesitant on the first one, a little more aggressive on the second. I'm not real happy with the final response but it was not going to get away from me, even with some aggressive inputs near the end of the lineup.

EP: I think it's adequate performance. Yeah, we did achieve desired performance. I don't think it's satisfactory without improvement, however. I just think there's something peculiar about the response that I'm not happy with. I think I did achieve desired performance and I would give it a 4. A 4 rating. Undesirable motions tend to occur? Yes. Compromised? No. A PIO rating of 2. An overall 4 rating, being better than I thought it was going to be, with a 2 on the PIO.

Postflight comments

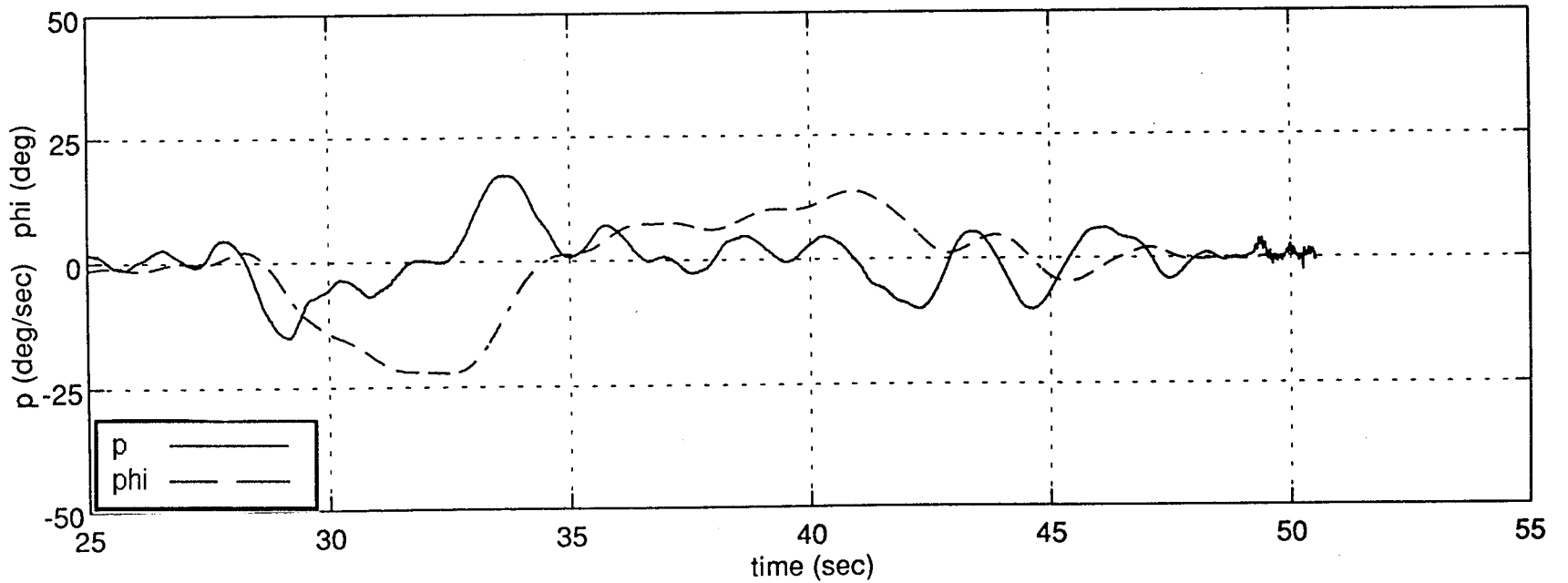
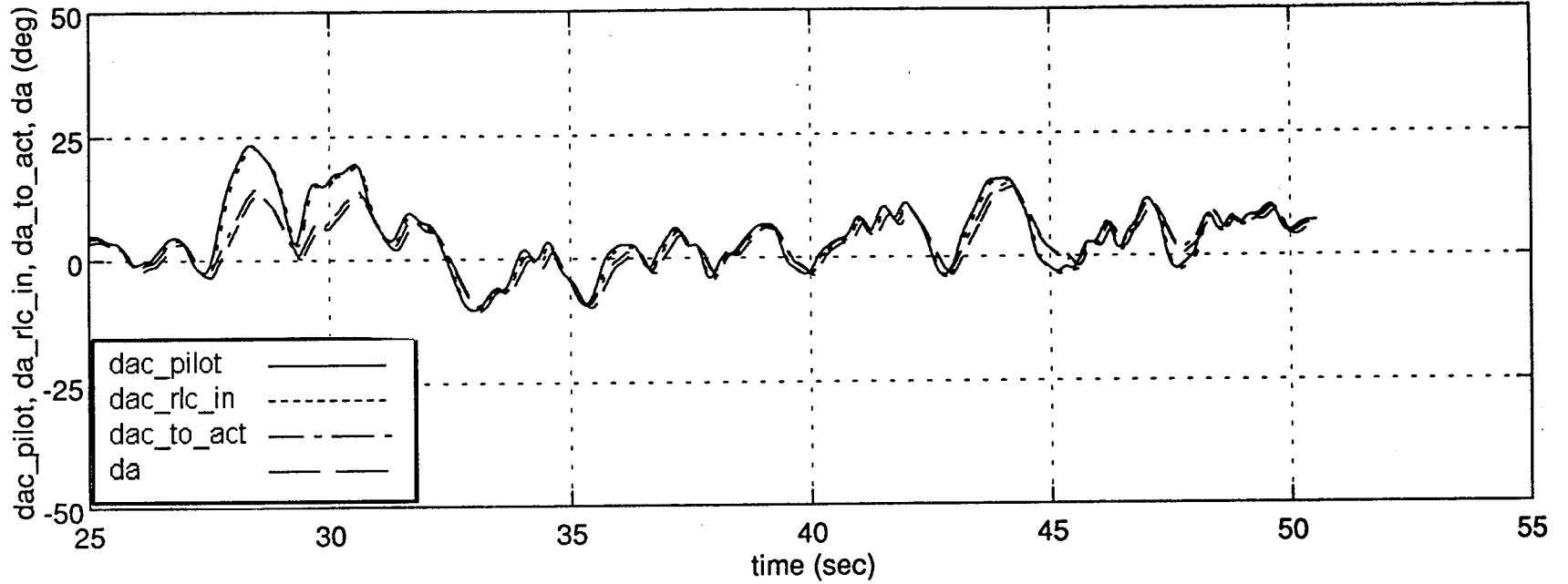
CO: Higher workload. You gave it an HQR 4 and a PIO 2.

EP: I can't remember specifically, but there was a tendency to overcontrol.

Remarks

Extensive discussion of desired and adequate relative to the runway markings.

FLT 448 REC 9 RL = 20 deg/sec RLC ON

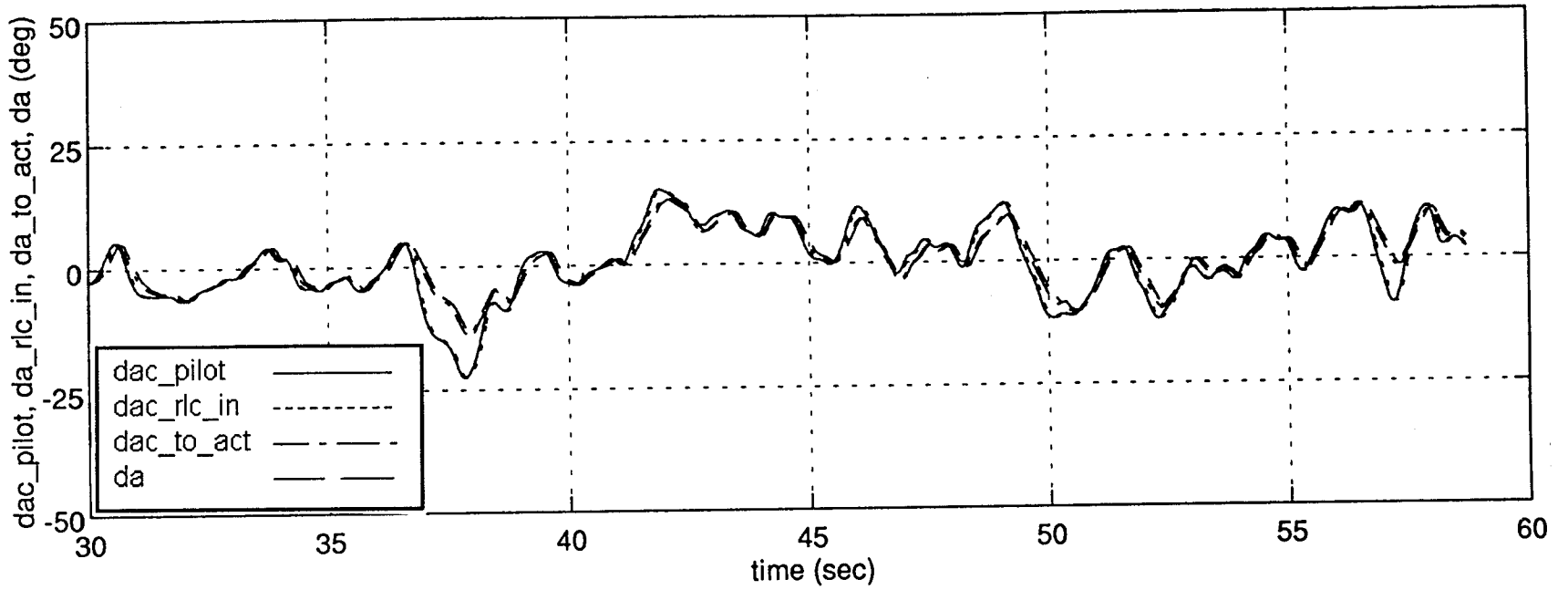


C-35

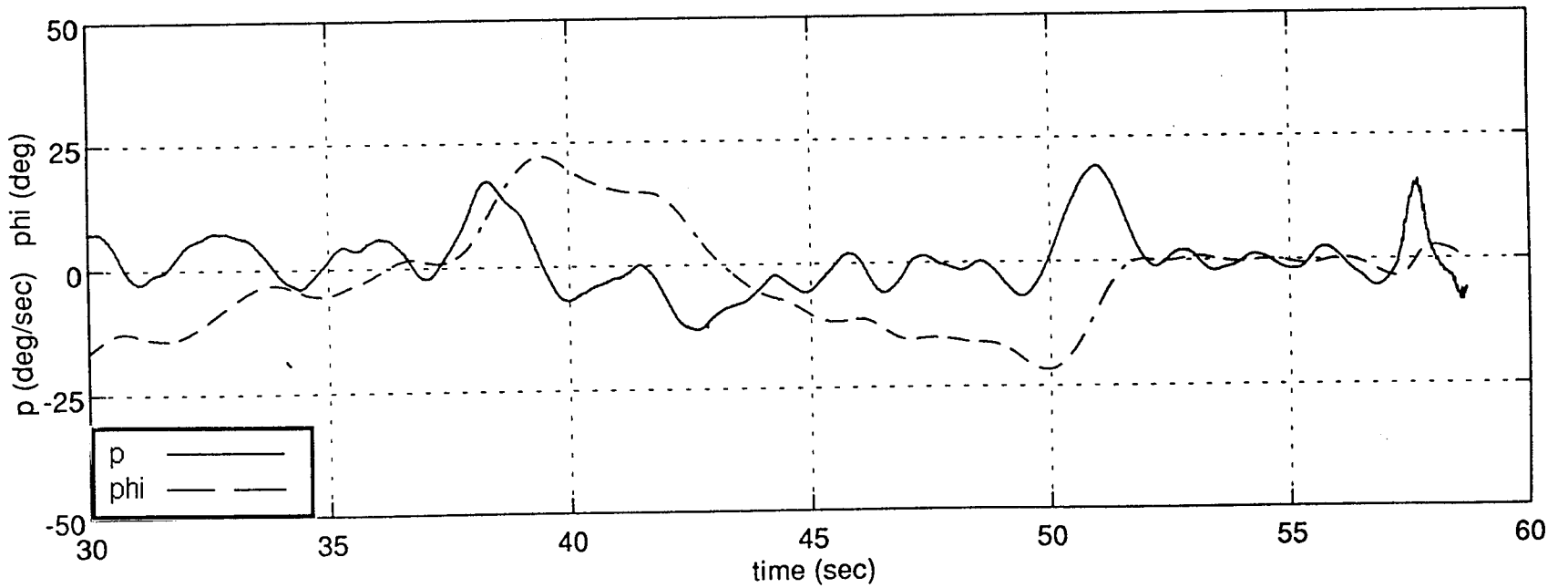
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APPENDIX C

FLT 448 REC 10 RL = 20 deg/sec RLC ON

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APPENDIX C



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Evaluation 29 Flight 449/4 Flight Evaluation No. 2 Event 9

Configuration 301 Stick Center Type Position Rate Limit 20 deg/sec

Pilot Ball Safety pilot Deppe Computer operator Buethe Flight test engineer Shafer

Algorithm RLC Passes 2 Runway 10L

Pass	Record	Offset	Wind	Performance
1	8	Left		Adequate--long and right
2	9	Right		Desired

CHR 5 PIOR 3

Inflight comments

1st pass:

Turning final:

EP: It's not as tight a feeling, just in the roll, out there. I had a tendency to overshoot the bank angle some.

On final:

EP: Forces feel just a little bit higher in roll.

SP: Correct

EP: A little sluggish--a little hard to get it as fast as I want it to over there. The sluggishness is the biggest complaint I have at the moment. I'm lined up.

EP: The biggest thing I noticed was slight sluggishness and then right at the very end there was just a little PIO, it'd overshoot, and the more I worked with it, I really couldn't put in an input as fast as I wanted to. Put in an input and the aircraft is a little slow catching up with my input

SP: You were in the adequate box but long and adequate but to the right of the centerline.

EP: If I was going to land, I just had to accept that. I was most concerned with the lateral-directional. You get working that hard, why then you tend to lose the longitudinal, too. I just don't feel as connected with the airplane as I did with the basic, the first one I flew.

2nd pass:

On final:

EP: I may be having a little turbulence here, not much, but every time I have to put an input in, I kind of overdo it.

SP: Correct

EP: It didn't start anywhere near where I expected it to that time.

EP: My feeling is, it's a crap shoot whether you're going to get desired or not, is the only bad part.

EP: OK, all that stuff, but it's not satisfactory without improvement and considerable--something on the order of a 5, probably, for HQR. Oscillation--I don't think it got to the oscillation part; undesirable motions--definitely, but--compromise? I think it probably did. That was a 3. A 5 and a 3. The comments I made before are still there.

Postflight comments

FTE: A 5 and a 3.

EP: As I recall, one of those was desired and one was adequate and even the desired one was a little bit long. In working the roll, I kind of let the pitch go. A little bit sluggish starting in and then you could just tell that if you wait until you get all the way over there and then try to come back quickly, it's going to take too long, you're not going to want to do that. So, just as a compensation, I'd take a pretty good cut off and then start and then ease off the turn on the way around, so that's just extra compensation I'm talking about there. As I say, one was desired and one was adequate. The desired just happened to work out well, but I know that was one I was having to concentrate more on the pitch. It's sluggish to get going. Then once it gets going, you're all squared away, say, "Hey, this isn't so bad" but every time you make this big input, you kind of question

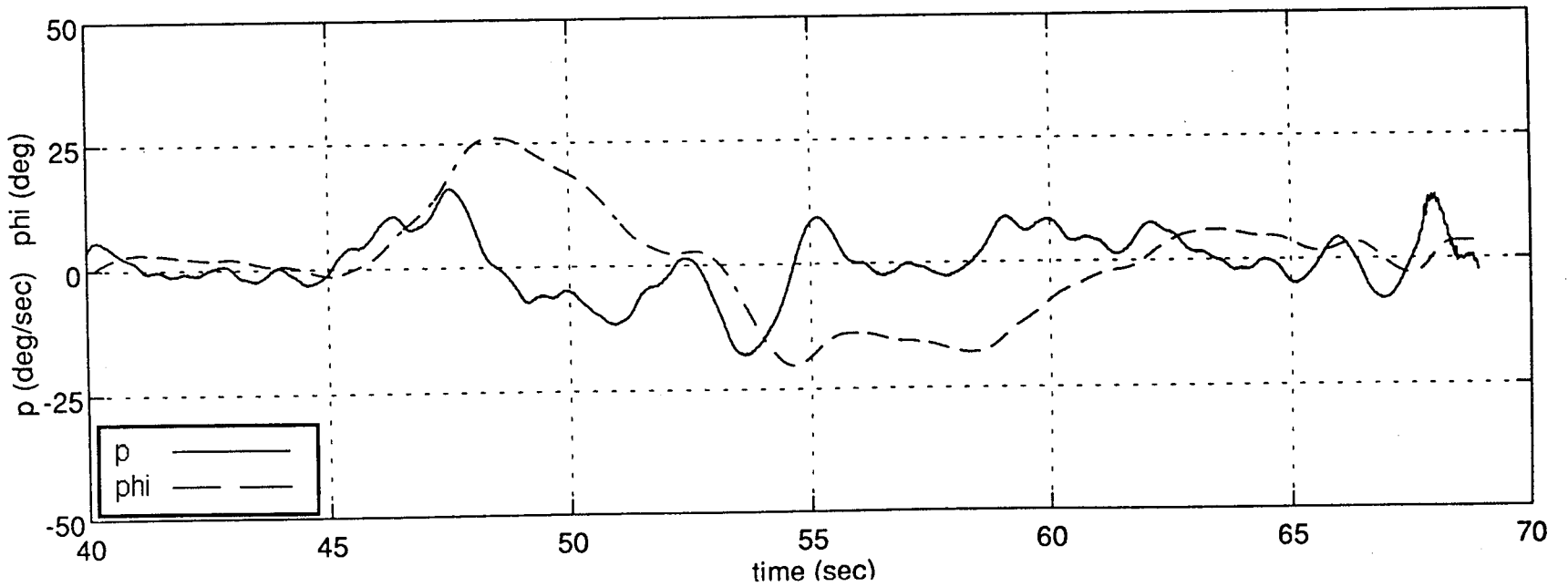
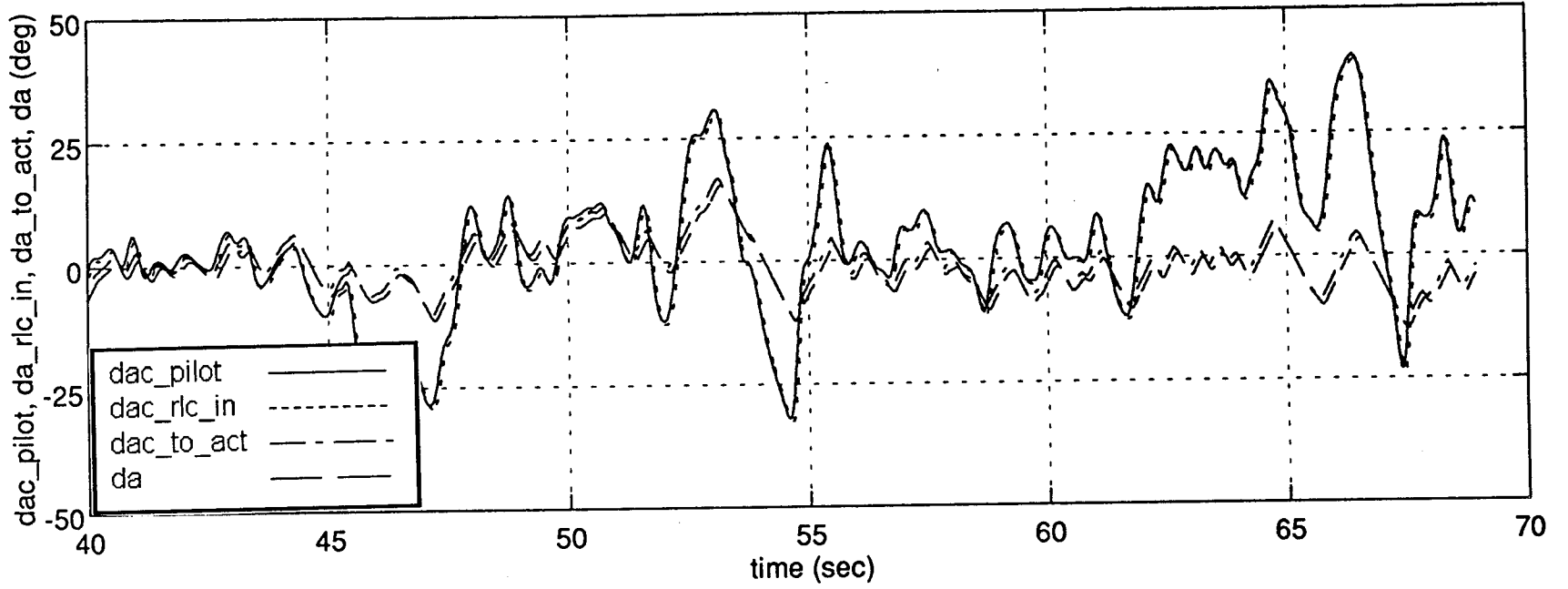
whether it's going to get around in time. As I recall, I didn't see any wing rocking on this.

CO: You got a 3 on the PIO.

EP: Let's see, what does that mean? Oscillations, non-divergent. All that means is that I got at least one cycle of the nose. I'm trying to get the thing stopped where I want to. When it's that sluggish, it's kind of ugh to get it. I finally got it where I wanted it and I could get the thing down. It's one of those things where, if you did it often enough, you'd probably be getting 4s out of it, you could get desireds out of it. Since I had one adequate and the other one was marginal, and that was a lot of compensation--in fact, that's more than 4's amount of compensation, in my book. You see, you get awfully wrapped around on just locking in on performance. You think just because you get desired, therefore it's got to be a 4 or better, and there was a case where the compensation, as far as I was concerned, took it out of the 4. That happened on one or two of them today.

Remarks

FLT 449 REC 8 RL = 20 deg/sec RLC ON

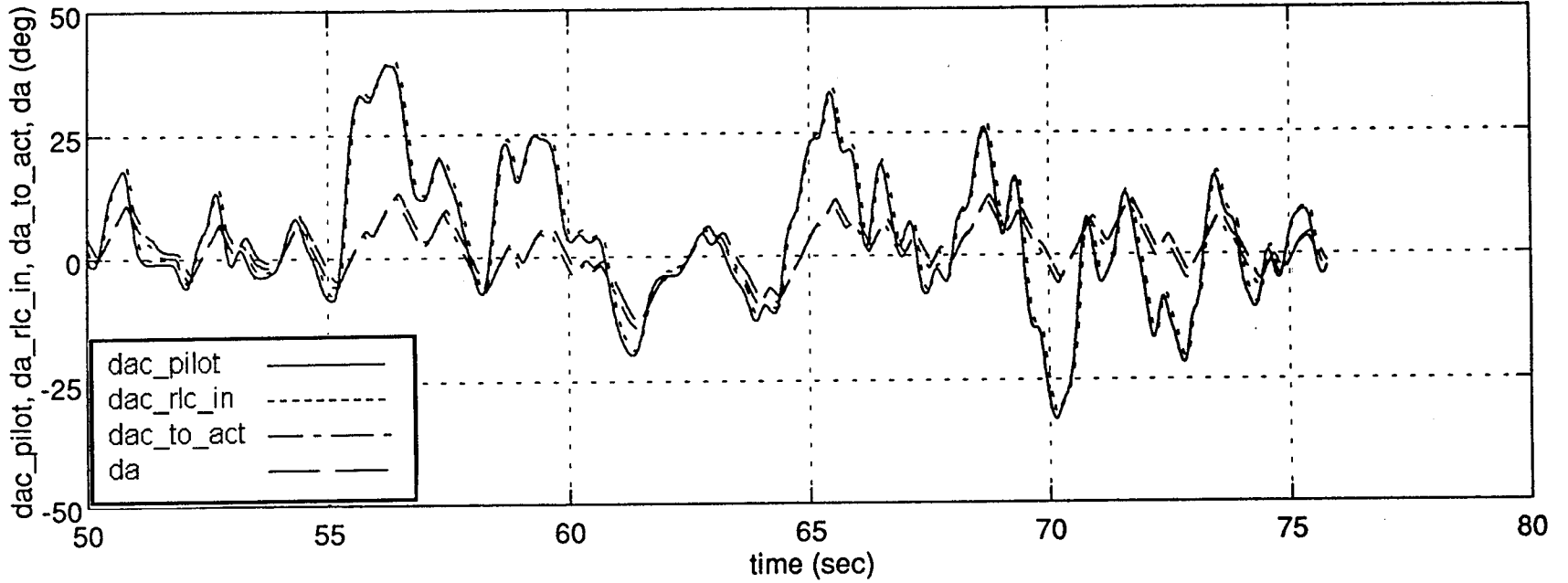


C-39

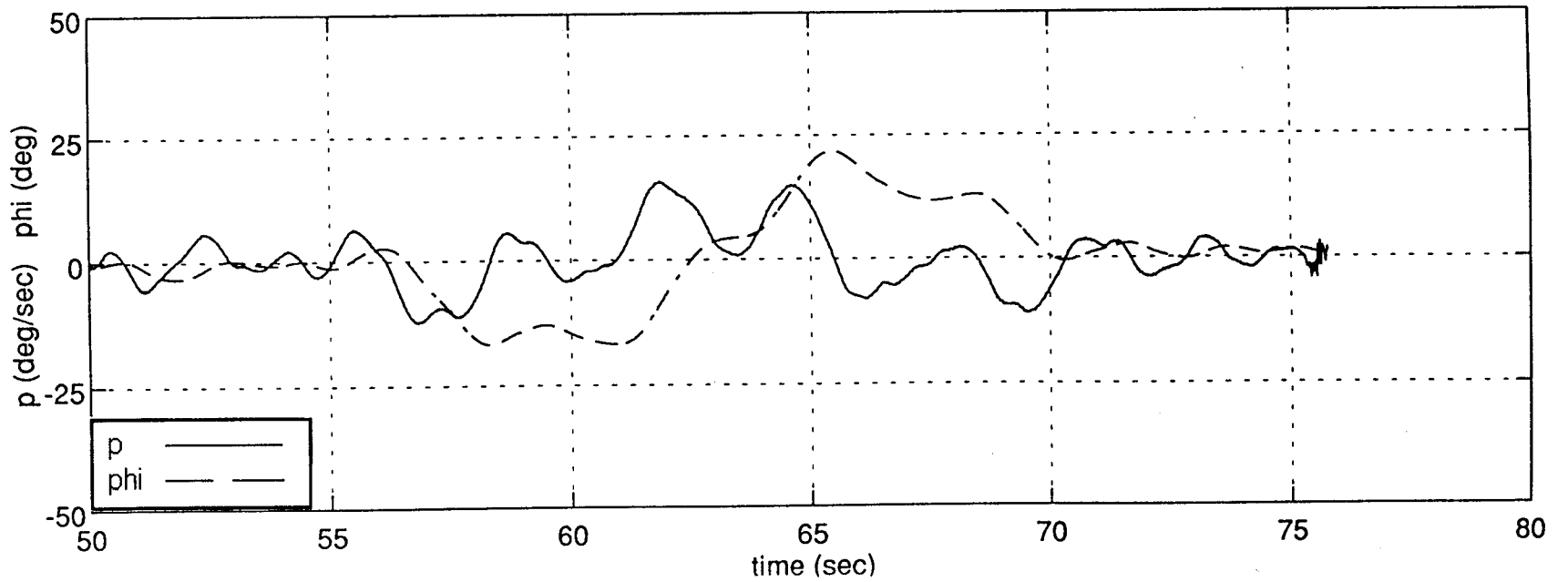
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APPENDIX C

FLT 449 REC 9 RL = 20 deg/sec RLC ON

Calspan Report No. 8091-2
APPENDIX C



C-40



Evaluation 12 **Flight** 447/2 **Flight Evaluation No.** 3 **Event** 8

Configuration 302 **Stick** Center **Type** Force **Rate Limit** 20 deg/sec

Pilot Johnston **Safety pilot** Deppe **Computer operator** Buethe **Flight test engineer** Shafer

Algorithm None **Passes** 1 **Runway** 10L

Pass Record **Offset** **Wind** **Performance**
1 7 Right 050/8 No landing

CHR 10 **PIOR** 5

Inflight comments

1st pass:

EP: The initial feel of the airplane feels fine. Minor roll commands.

Initial roll in. It's OK. Doesn't feel quite the same as the baseline Lear. Little bit, not quite as responsive, but it's not bad, it's not far off. Airspeed control's adequate. About the same amount of time available to look at it. Holding my bank angle on the base turn without any unnecessary pilot inputs. Doesn't try to wander and it feels like it has good spiral stability. This is a one turn to final, easy turn. Just playing it to roll out where I want.

On final:

EP: Sense myself slightly high.

SP: Correct

EP: Full stop control. PIO. Still in the PIO but it's convergent, not divergent.

SP: [Taking control] That was going somewhere we don't want.

FTE: Ooh.

EP: I don't think we need to go any further on that one. That's a Cooper-Harper 10. Let me come up with a PIO on that. 10, 4. I'd say PIO of 5. 10,5.

Postflight comments

EP: It was a 10 and a 5. We attempted it once and I got punched off--I was happy to be punched off--in the flare. I believe my comment was, even going into the flare, "I don't think I'm going to make this." I never felt confident that I even had a chance at this.

SP: That was a pretty wild one.

EP: Didn't like it.

FTE: That one was a little scary in the observer seat.

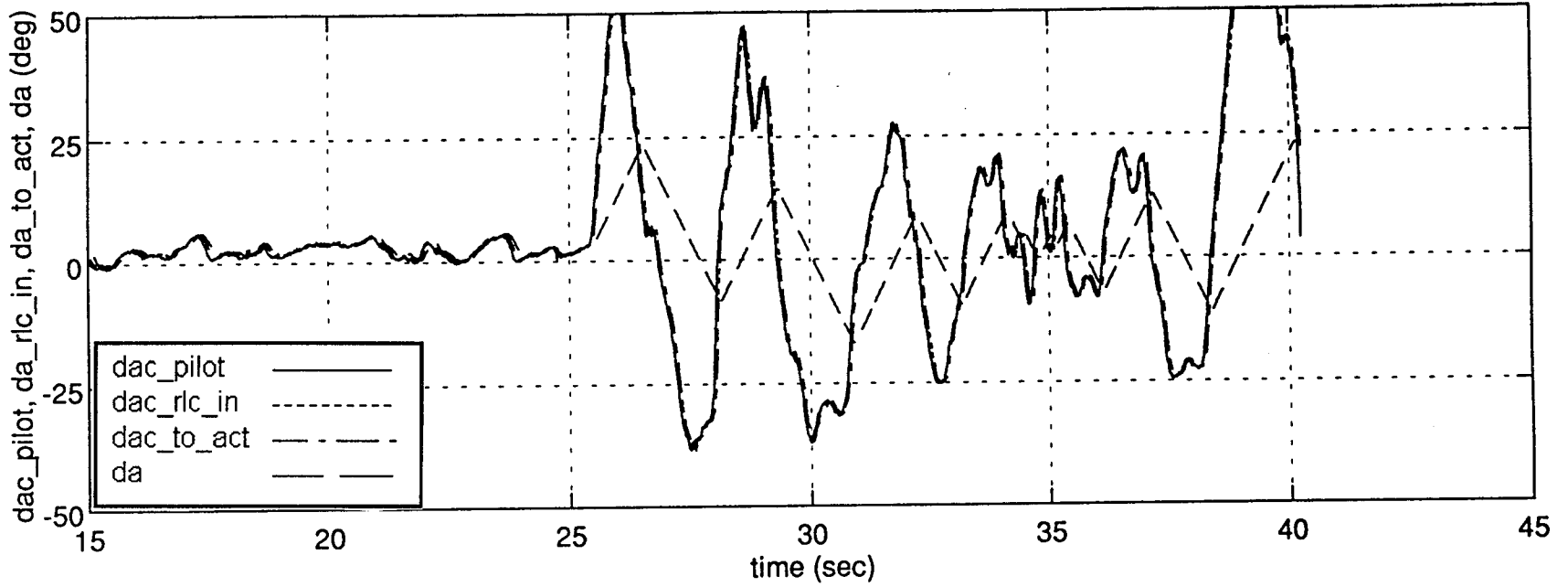
EP: Yes, I thought I felt a sigh of relief when [SP] punched me off.

CO: I wasn't scared; I had my eyes closed.

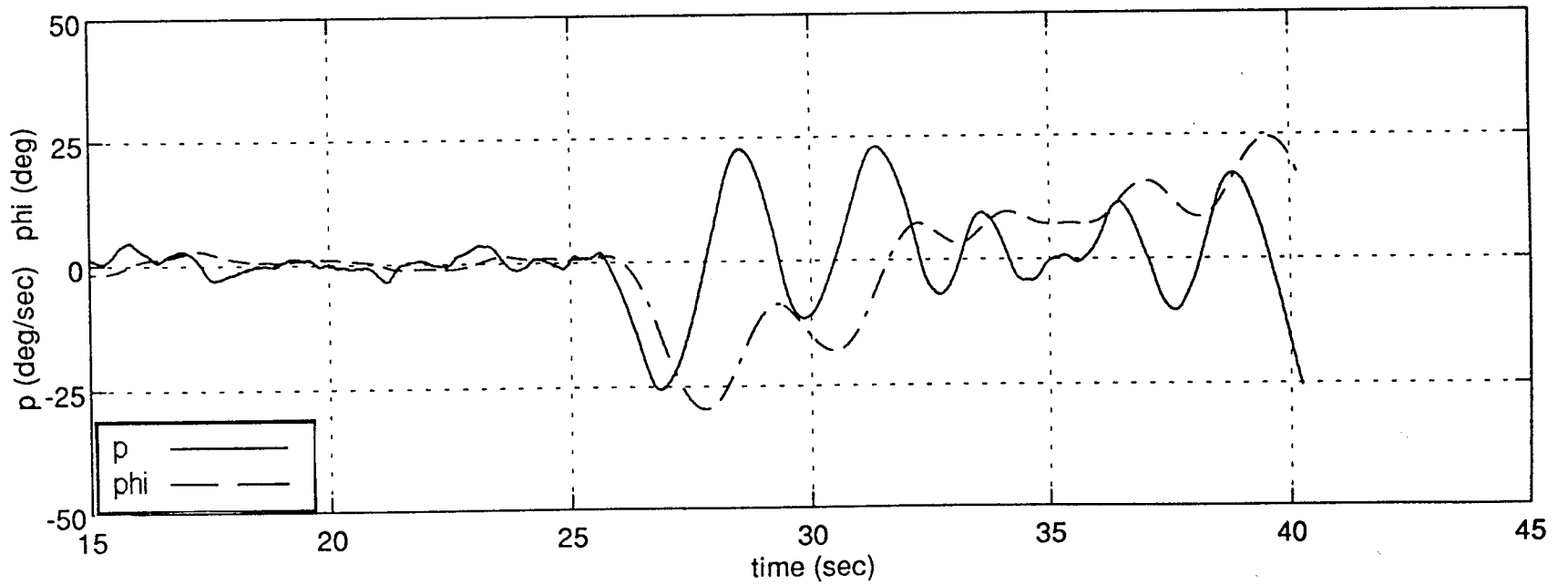
Remarks

FLT 447 REC 7 RL = 20 deg/sec RLC OFF

Calspan Report No. 8091-2
APPENDIX C



C-42



Evaluation 11 Flight 447/2 Flight Evaluation No. 2 Event 7

Configuration 303 Stick Center Type Force Rate Limit 20 deg/sec

Pilot Johnston Safety pilot Deppe Computer operator Buethe Flight test engineer Shafer

Algorithm RLC Passes 2 Runway 10L

Pass	Record	Offset	Wind	Performance
1	5	Left	050/7	Desired
2	6	Right	050/7	Adequate--long

CHR 6 PIOR 4

Inflight comments

1st pass:

EP: On downwind, event 7, everything feels fine. Easy to hold zero bank with small, minor inputs. Feels like a good-flying airplane.

Through the base turn, holding bank angle. Feels good. No problems.

I'm having a little problem holding airspeed today, I don't know why. Noticed that on my first one.

Lining up on final. No PIO tendencies rolling out. Small minor corrections. Negative turbulence. Feel like I'm on glide path, with the offset that I want.

SP: Correct

EP: Sluggish. No PIO but very sluggish on the initial thing. Can't be as aggressive as I want to. Now I got into PIO. Sluggish response.

EP: Call it a one-overshoot PIO. I put in the opposite response well before I thought I needed it and it turned out to be about the right spot. Have to correct for the roll rate as soon as it starts with opposite aileron, to roll it out where you want it. But it was predictable.

The harmony between when you're just flying with just small input and then when you're making more major inputs--it's not predictable, it doesn't give you the same response.

2nd pass:

EP: Around the base turn, we're achieving predictable bank angles and the airplane does not feel sluggish. Feels similar to the baseline Lear. I can hold my desired angle of bank.

On final:

EP: Got my desired offset. Maybe slightly wide, but not much.

SP: Correct

EP: Full input. Very sluggish response. Roll out predictable. Slight PIO. Find myself putting in bang-bang controls. Full input. Little bit of rudder to help.

EP: Long and I was using rudder at the very end, which I haven't been using before, to try to inch my way over to the left to get the wheels within the desired criteria. I felt like we had the wheels within the desired, the distance within adequate. First time during this experiment I've been stop-to-stop on the ailerons control and I was stop-to-stop there.

EP: Is it controllable? Yes. Is adequate performance attained with tolerable pilot workload? No. I'd say adequate performance was attainable with tolerable pilot workload. Satisfactory without improvement? No. Deficiencies warrant improvement? Yes. Very objectionable but tolerable deficiencies is what I came up with. Adequate performance requires extensive pilot compensation or considerable? I'm between a 5 and a 6 here. What I'm coming up with is a 6. I'm reading the first one, aircraft characteristics, more than demands on the pilot. It's very objectionable but tolerable deficiencies. Leads me to a 6 and the deficiency that I don't like is stop-to-stop and having to lead the rollout quite a bit. On the PIO scale, causes oscillations? Yes. Divergent? No. PIO 4. 6, 4.

Postflight comments

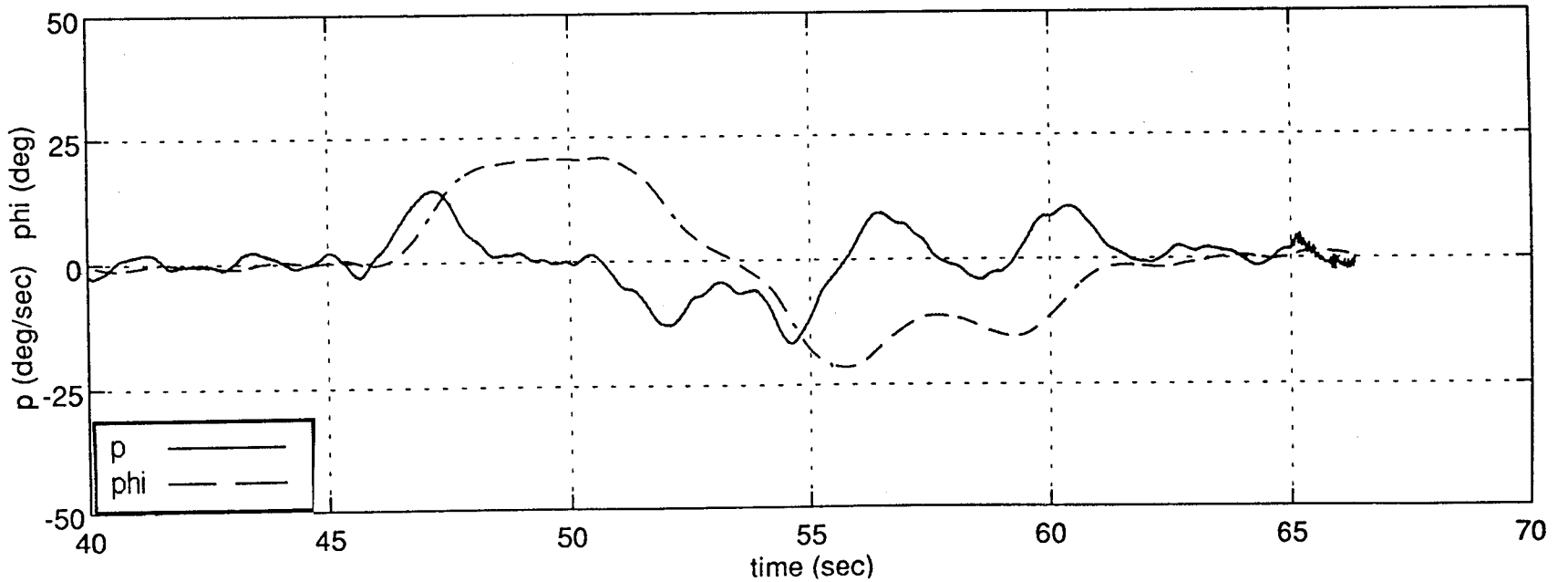
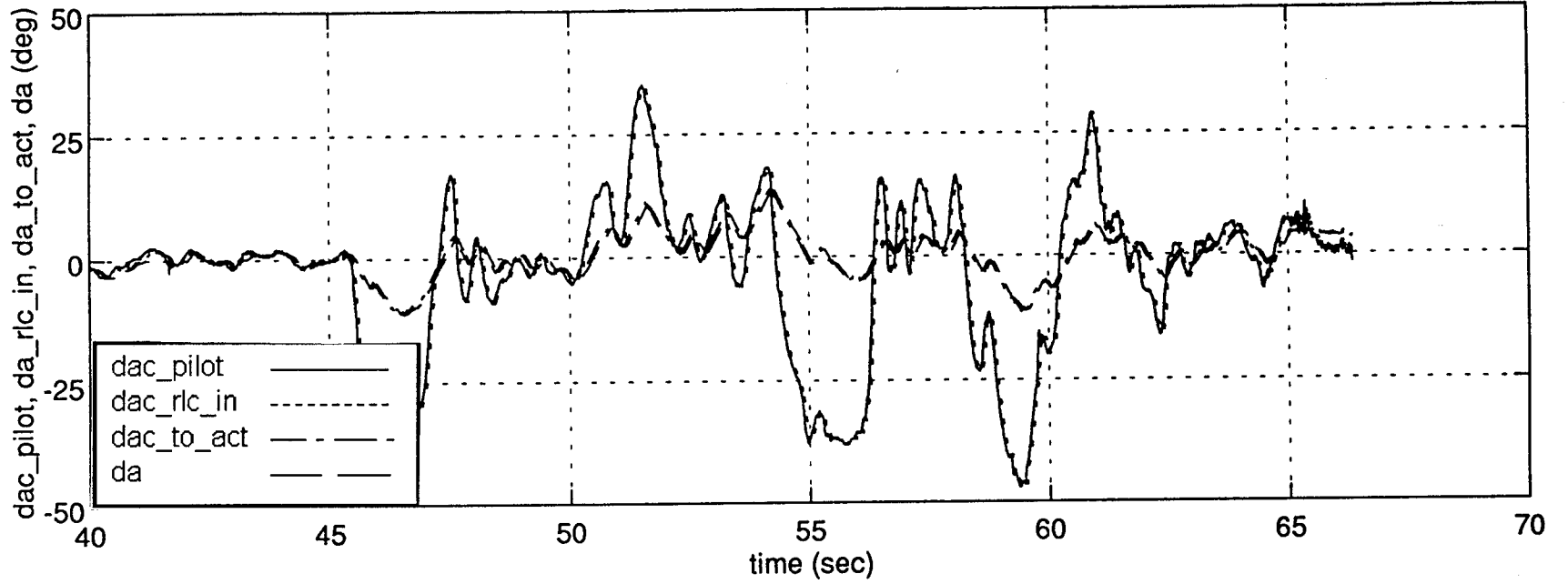
EP: Cooper 6, PIO rating 4. When aggressive maneuvers were attempted, the aircraft was sluggish to respond and typically achieved one overshoot into what I'd call a well-damped PIO. So I'd get a little bit of unpredictable roll response, I'd overshoot past where I wanted to go, and then I'd back up and get what I wanted. It wasn't a constant PIO where the roll angle's constantly changing, just overshoot and back, overshoot and back.

[?] Did you notice any out of trim? Any biases building up?

SP: No, there was one landing later where you ended up holding stick when you were landing, but this wasn't it. We did this one twice.

Remarks

FLT 447 REC 5 RL = 20 deg/sec RLC ON

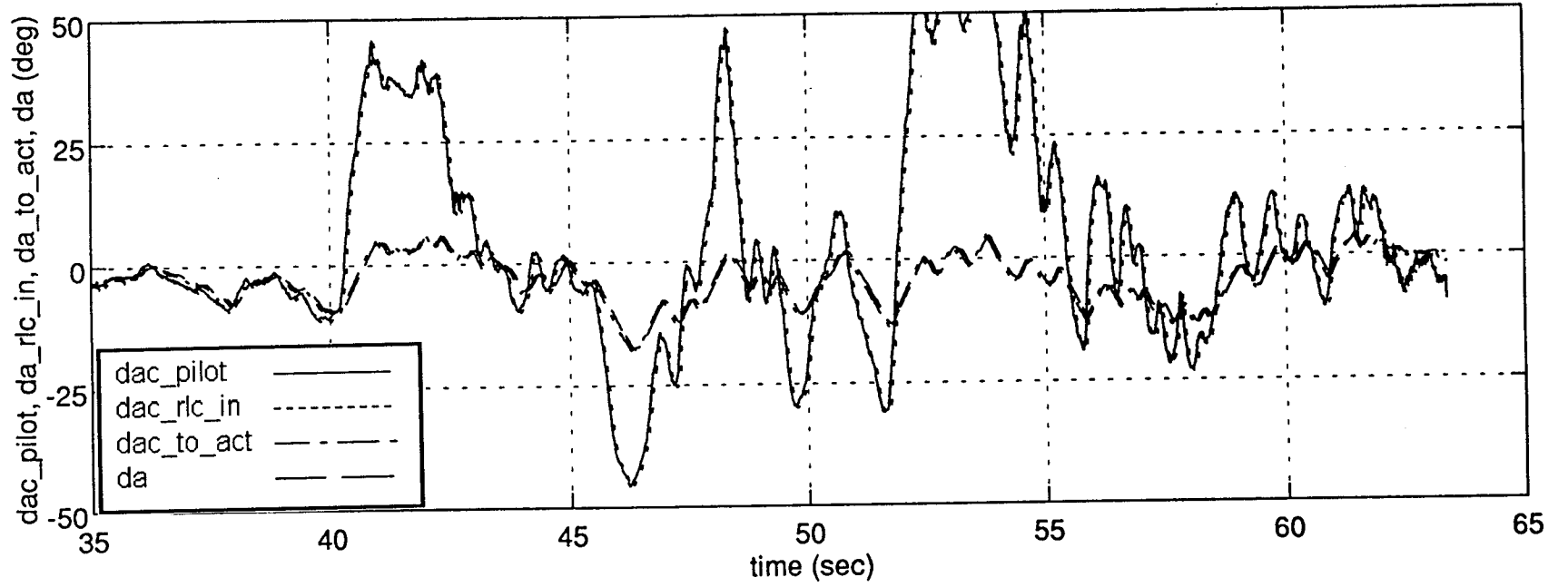


C-45

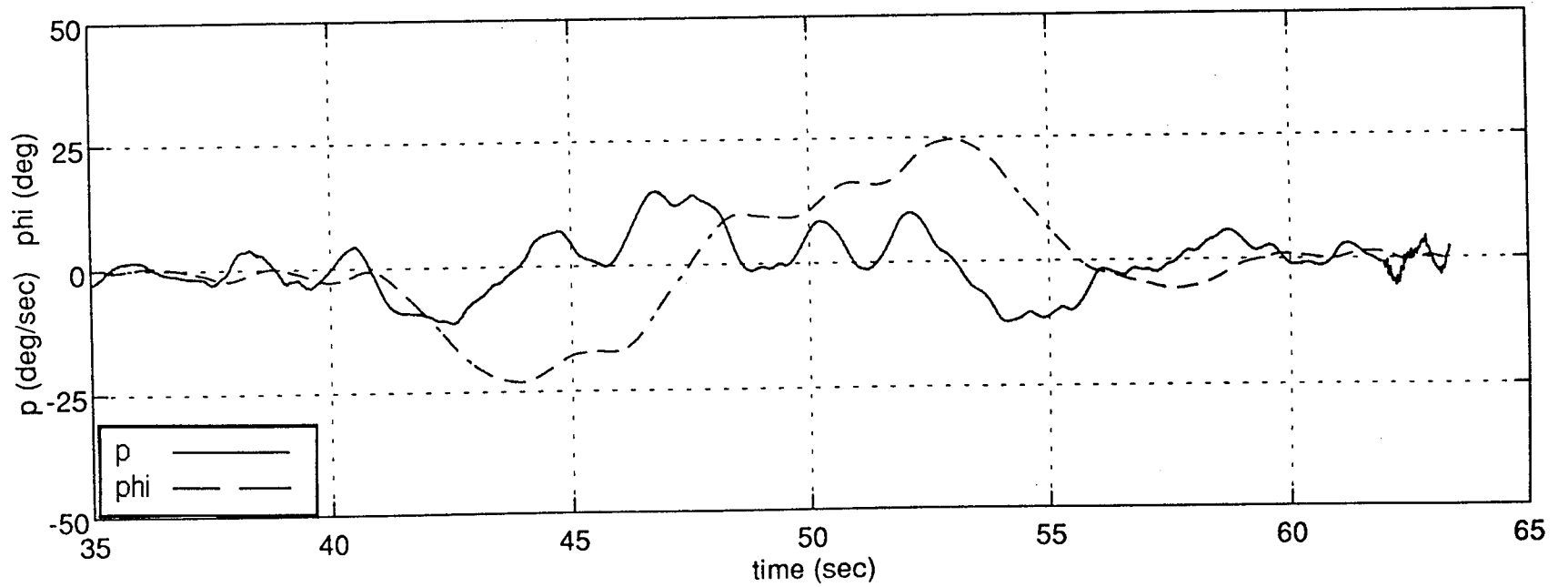
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FLT 447 REC 6 RL = 20 deg/sec RLC ON

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Evaluation 7 Flight 446/1 Flight Evaluation No. 7 Event 5

Configuration 308 Stick Side Type Position Rate Limit None

Pilot Johnston Safety pilot Deppe Computer operator Buethe Flight test engineer Shafer

Algorithm None Passes 2 Runway 10L

Pass Record Offset Wind Performance

1	20	Left	080/10	Desired
2	21	Right		Desired

CHR 3 PIOR 2

Inflight comments

1st pass:

EP: Start the turn. Doesn't feel as sluggish as the airplane has before. Nice and crisp. Felt good. Bank angle capture in the base turn feels nice. Right now I feel like I'm flying a good-flying airplane.

EP: Rolling out what I feel is slightly high on final. I'll be correcting on down and ease in the bank to roll out with the offset. Angling. I'll correct in here in a moment. Glide path is what I want. Air speed is what I want.

Offset is what I want.

SP: Correct

EP: Correcting back. Nice initial response. A little jerky in here, but not bad. Not bad. Feels crisp. Good.

EP: I'd like to look at the tapes on that. It felt like I had a lot of inputs in there to keep it under control, but I didn't feel like there was any PIO. It just felt like it took a lot of small, minor inputs to keep it adjusted. I did not have a sense that a cliff was near. It was just a crisper-flying airplane than what I've had before--or what I felt like I've had before.

2nd pass:

Turning final:

EP: Due to traffic, this was a right-hand pattern instead of a left-hand pattern. Still not sensing any turbulence out here. The only turbulence we've gotten today has been so light, I don't think it's been much of a factor. Since I'm slightly high here--I'm not coming across the VASIs, so I'm not getting the VASIs as early--I'm angling in to where I would like to be.

On final:

EP: Still slightly high, but correcting on down. Still angling in. Bank angle control--I haven't sensed any roll PIOs. I've always gotten the desired bank angle that I've wanted. Still angling slightly. Not the best pattern that I've flown. Feel like I'm on glide path and airspeed's where I want it.

SP: Correct

EP: Initial, aggressive correction tendency. No PIO noted on the roll out. Correcting back. Come on, baby, right there.

EP: Desired criteria met. Cooper-Harper 3, PIO tendency of 2. The undesirable motions was a slight tendency to overshoot, just so slight, but no real tendency, from what I felt, to PIO. I did not feel that that cliff was near. I felt like I could even be slightly more aggressive than what I have.

Postflight comments

EP: Cooper-Harper 3, with a PIO of 2. Desired criteria both times and the only minor, annoying deficiency. The reason for the PIO 2 was slight tendency to overshoot then from what I desired to achieve.

SP: One thing I noticed different about this, clearly, was with the center stick, he'd put in a roll input and it was almost like there was lead in there. I know there was none, but he'd put in a little input like that to start the banking in--he was flying differently--he'd just kind of pulse the stick like this and my stick would go wham, just like that.

CO: You commented "Ulp" once or twice--it was a little jerky in roll.

SP: Well, I don't know. I'd look over there and he was just, the airplane was just sort of flying around and he was making comments like "pretty low workload", "pretty predictable", "very sharp", "crisp", "here I'm in the desired box, level 1" but every now and then he'd put in a sharp input. I think it's sensitivity. But the result was

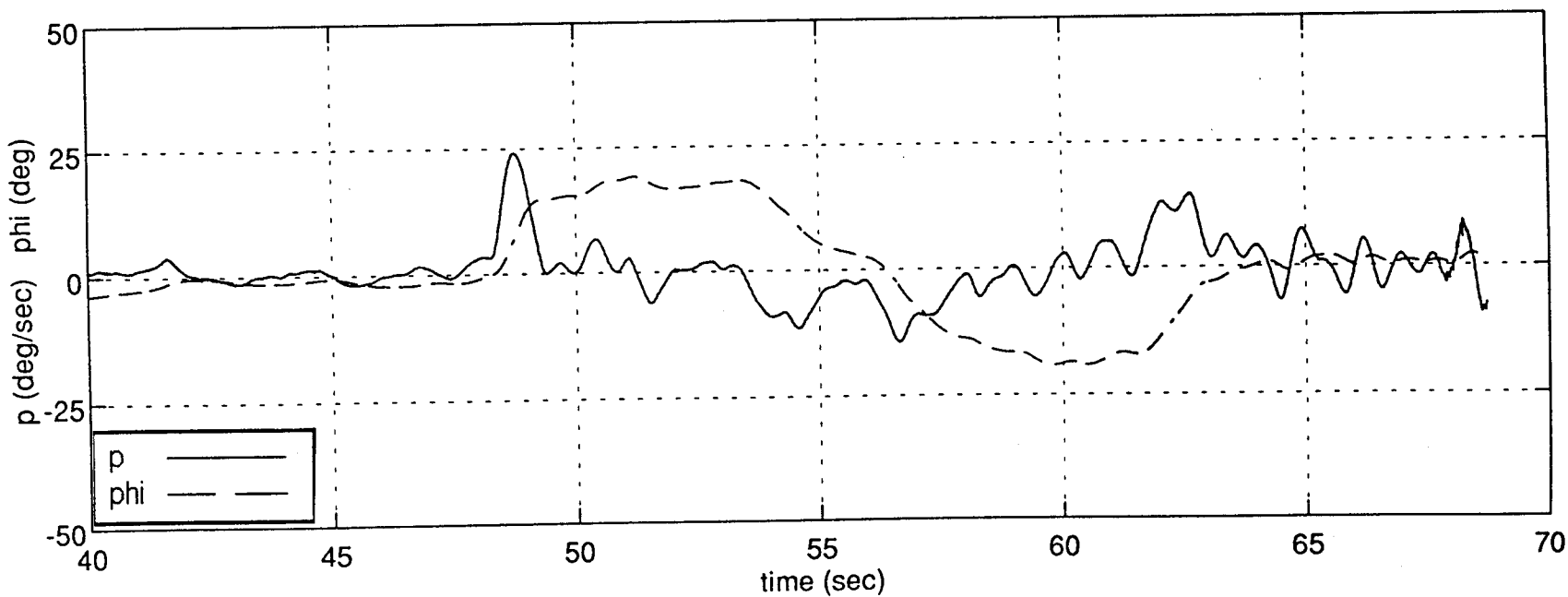
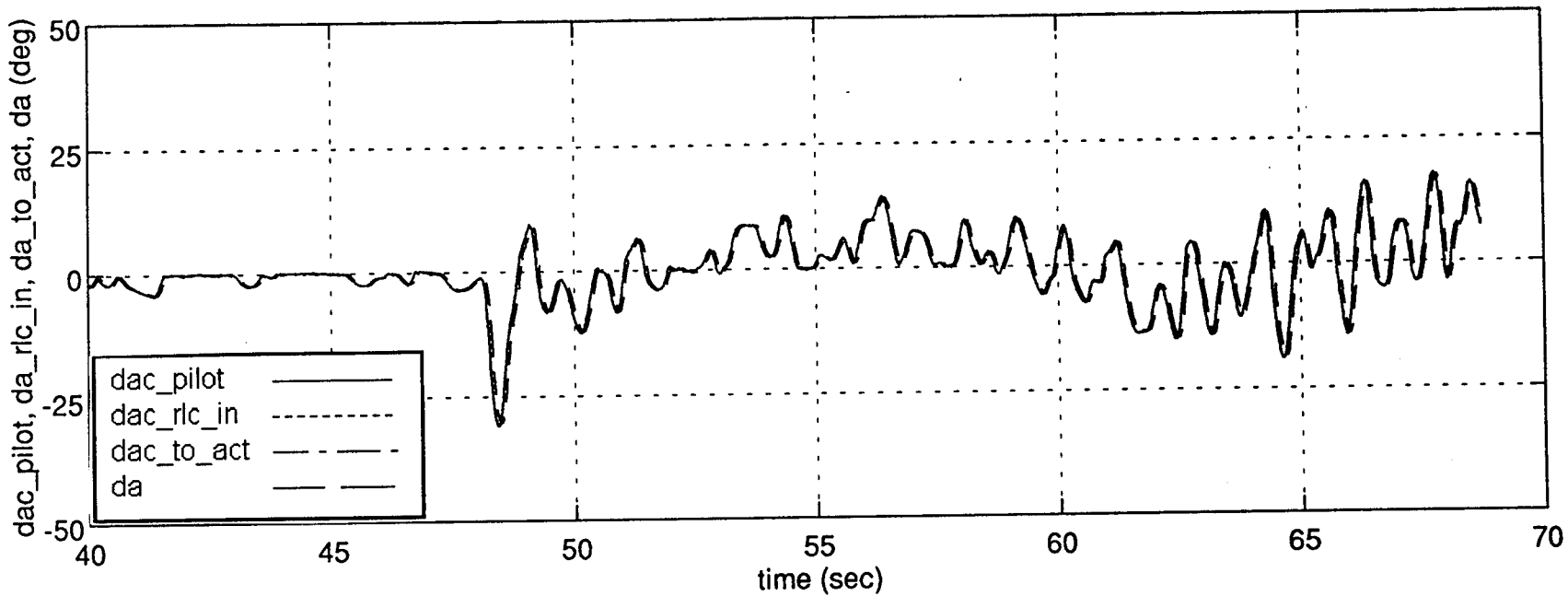
Chick Chalk: There's obviously the ability to move the stick faster.

SP: It is a 25 radian side stick.

EP: It could be flopping back and forth between the center and the side sticks. We were doing that fairly regularly, just back and forth.

Remarks

FLT 446 REC 20 NO RATE LIMIT



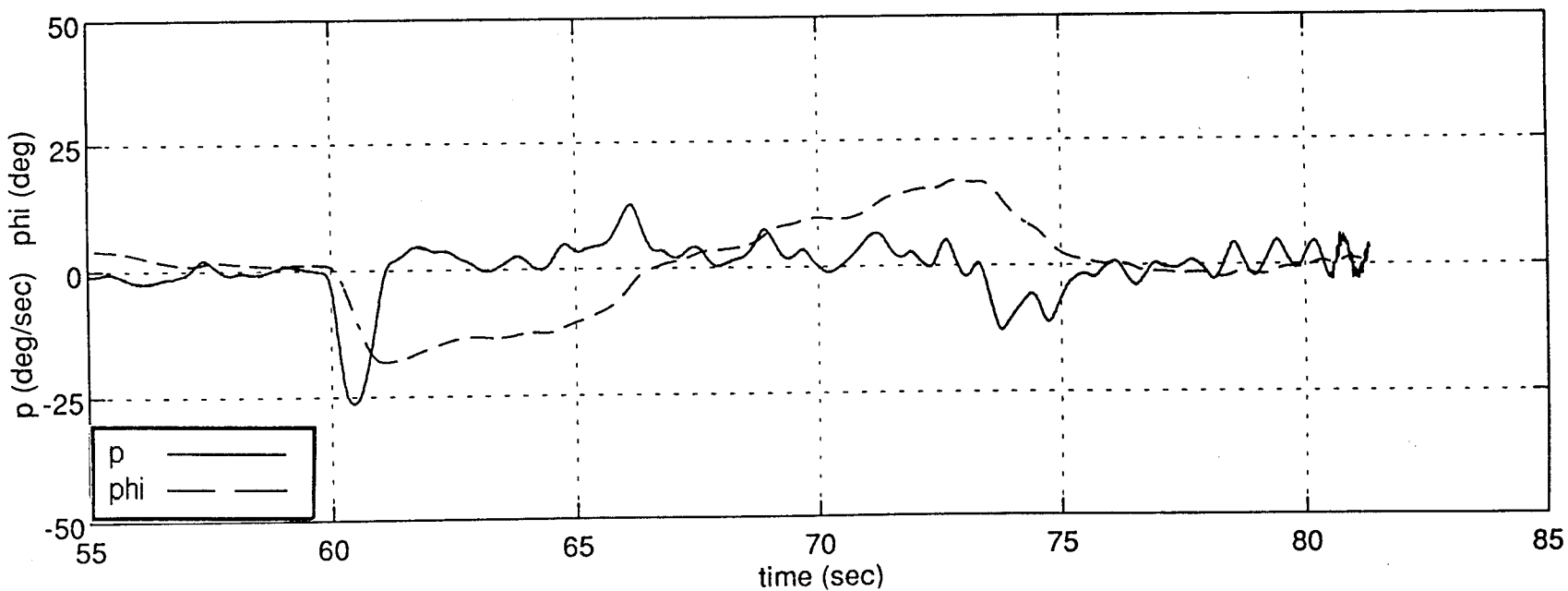
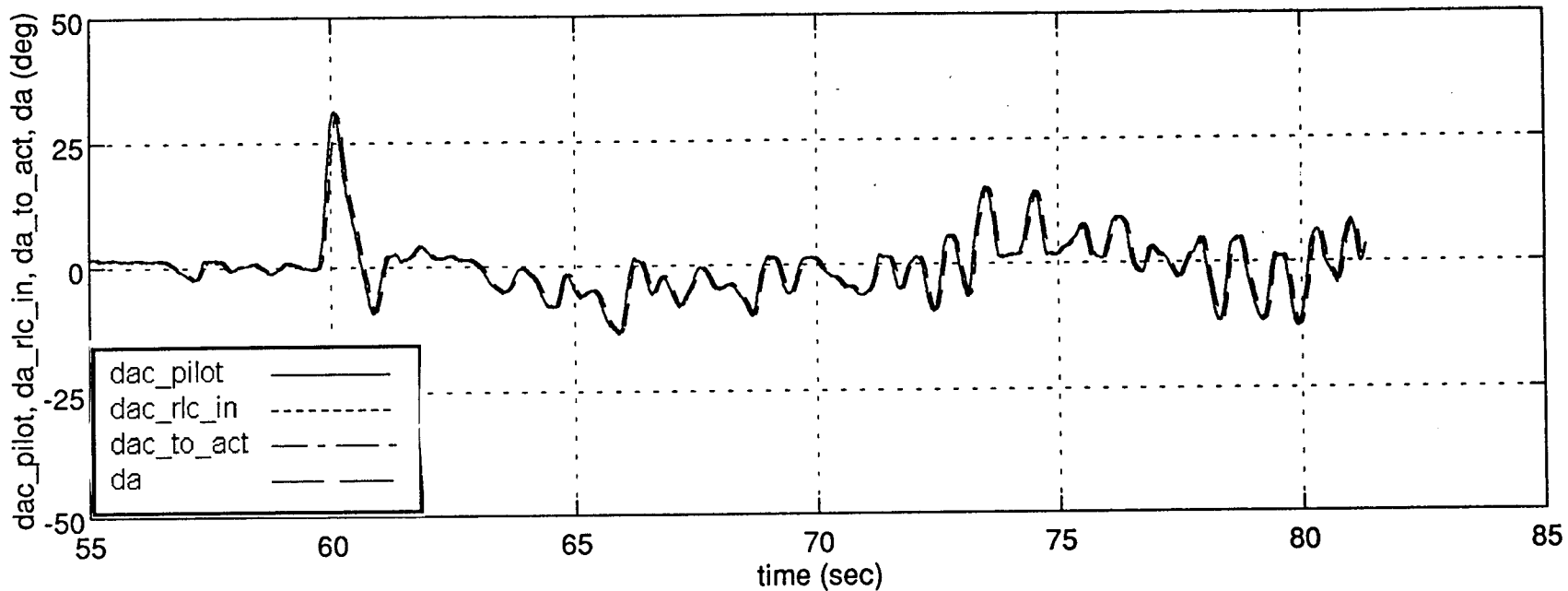
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FLT 446 REC 21 NO RATE LIMIT

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C-50



Evaluation 24 Flight 448/3 Flight Evaluation No. 5 Event 12

Configuration 308 Stick Side Type Position Rate Limit None

Pilot Smith Safety pilot Buethe Computer operator Deppe Flight test engineer Shafer

Algorithm None Passes 2 Runway 10L

Pass Record Offset Wind Performance

1	15	Left		Desired
2	16	Right	050/8	Desired--Short

CHR 2 PIOR 1

Inflight comments

1st pass:

EP: This is a responsive airplane. Initial response is faster than I felt in the others-- I guess I've been watching the wheel respond on the left. I didn't feel any sense of overcontrolling.

2nd pass:

EP: Agh. Side stick, I can't pull back, I ran out...

SP: You ran out?

EP: Well, I started to pull back and then I couldn't get the nose up. Otherwise I would have stopped that one. Quick comments on that--I hit a little short, but I ran out of aft control on the side stick. Though I felt like I was perfectly in charge of it, I was going to put it where I wanted it, but I needed to get the nose up a little more. I should have maybe used the trim, I guess.

EP: OK, I'm going to say I achieved desired performance there. I find the aircraft satisfactory. It's responsive but no tendency to overcontrol. I like the airplane. I could be increasingly aggressive with it. Satisfactory without improvement? Yes. I'm going to just talk about the roll. I found the roll response was good. Initial response was quick and final response was no problem. I would give it a 2. The pitch control was maybe a little sluggish and certainly at the final stages I couldn't get the nose up. I'm not going to include that in the rating. If I did I would downgrade it maybe to a 4 in pitch. It's a 2 and a 1 PIO in roll.

Postflight comments

CO: You gave it a 2 and a 1. Your comments were that it was "responsive", "fast", "predictable".

EP: Yes, to me the side stick baseline, I like that. It was as responsive as I wanted it but I could back off. I never got into situations where it was overly responsive, so I really liked that. I basically like side sticks. I like them. You could almost tell by how I was flying the airplane. You can fly a little more aggressively, come around the corner more aggressively.

Remarks

EP: You can likely call the offsets a little later because I have a little bit of time to just crab over, angle over there.

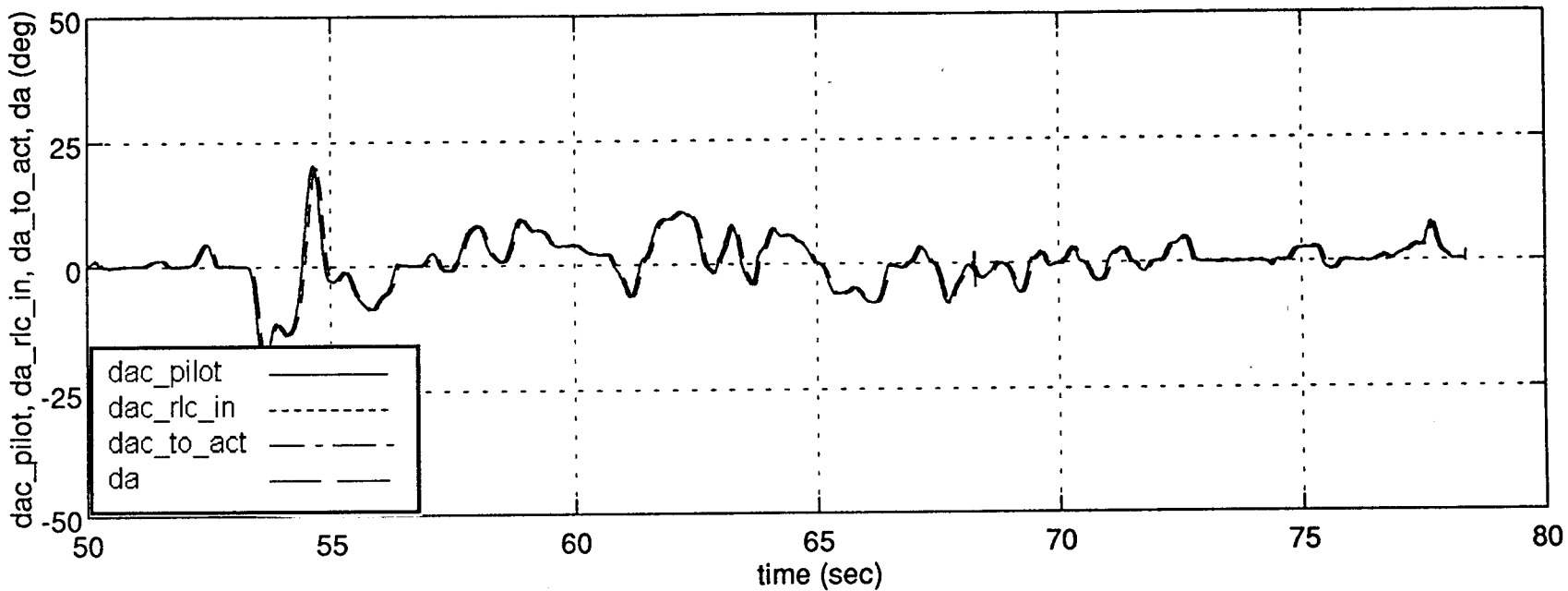
SP: I called that one at exactly 200 feet radar altitude., slightly lower.

EP: I thought we were a little lower than we had been.

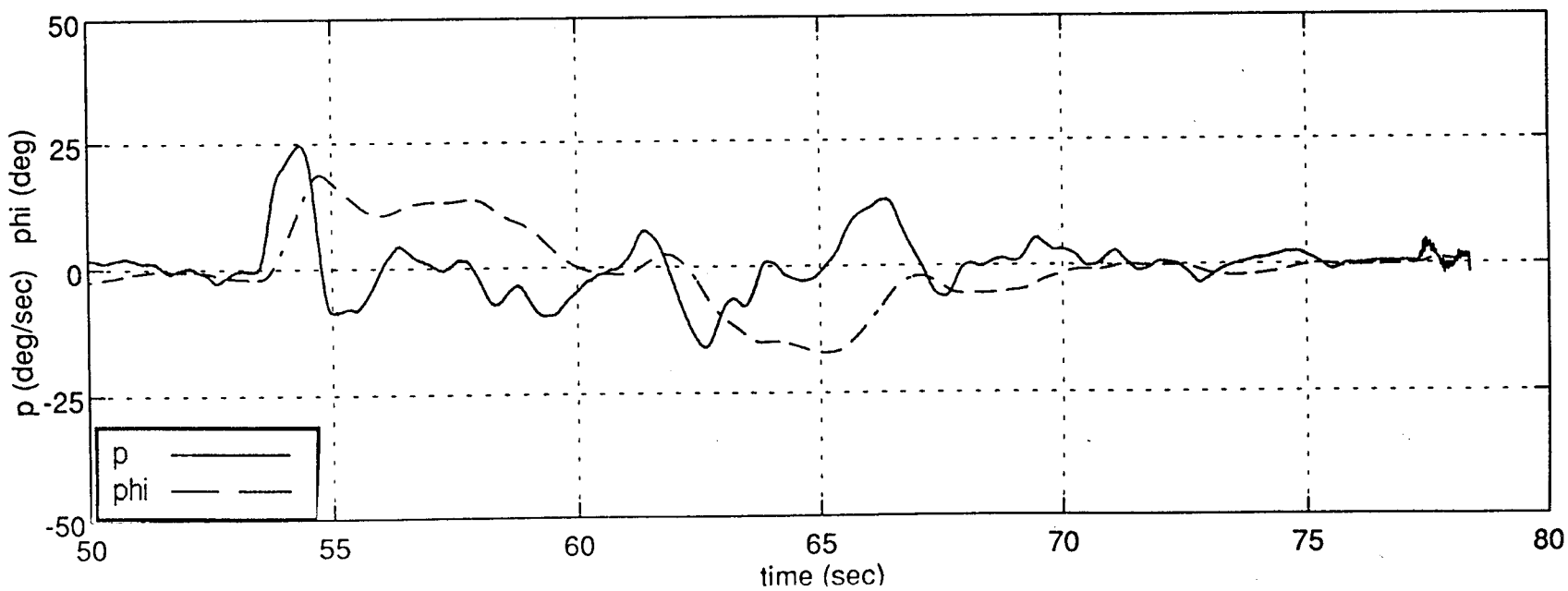
SP: So I gave you more time.

FLT 448 REC 15 NO RATE LIMIT

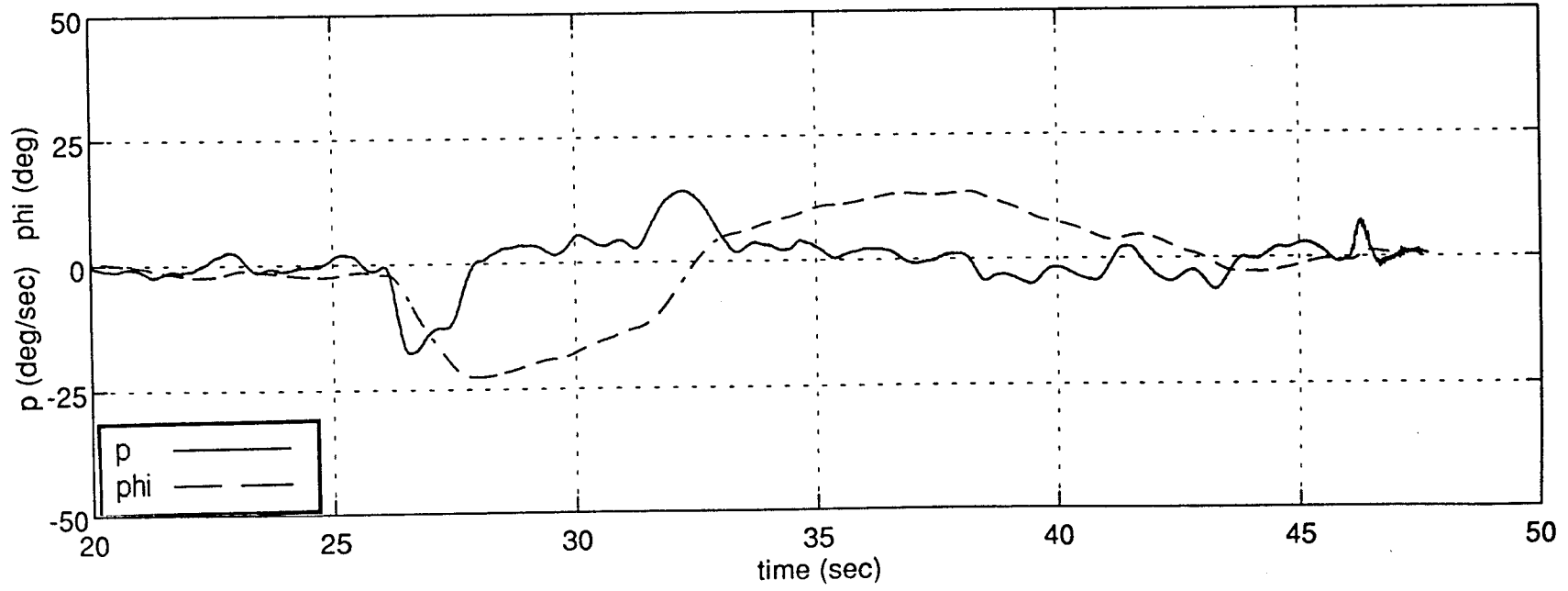
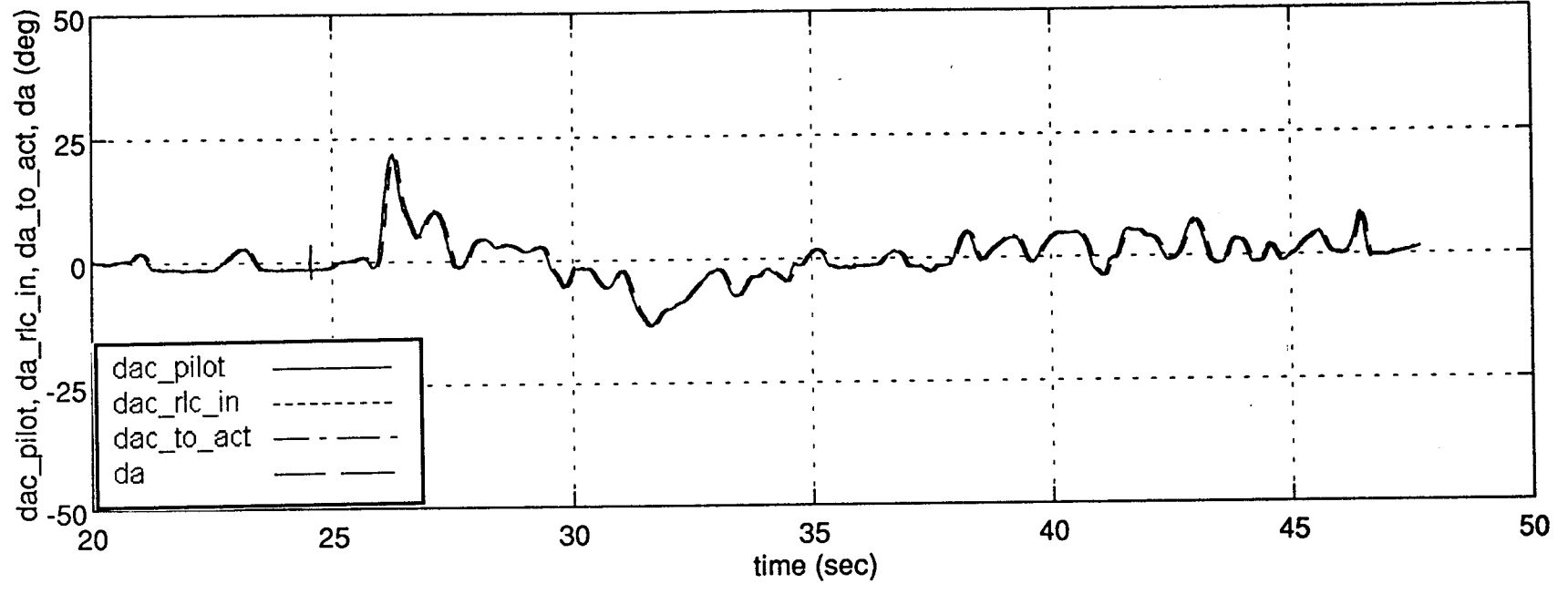
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FLT 448 REC 16 NO RATE LIMIT



C-53

Calspan Report No. 8091-2
APPENDIX C

Evaluation 4 **Flight** 446/1 **Flight Evaluation No.** 4 **Event** 6

Configuration 304 **Stick** Side **Type** Position **Rate Limit** 20 deg/sec

Pilot Johnston **Safety pilot** Deppe **Computer operator** Buethe **Flight test engineer** Shafer

Algorithm None **Passes** 2 **Runway** 10L

Pass Record **Offset** **Wind** **Performance**

1	12	Left	060/9	No landing
2	13	Right	060/9	No landing

CHR 10 **PIOR** 4

Inflight comments

1st pass:

On downwind:

EP: Initial feel is nice.

EP: Rolling into the base turn, got the bank angle that I wanted with no tendencies to overshoot. Airspeed control's getting a little fast.

EP: Rolling out 10 knots hot on final, I'm trying to figure out why. I guess I'm still holding my 140 or 135.

Angling slightly over. There's on speed. On glide path.

SP: Maybe a little flat here. Not too bad. Correct.

EP: Slight PIO tendencies. Having to back out of the loop just slightly but I'm still trying to aggressively obtain, I'm still in the loop, not totally out of it.

SP: I've got it. I felt a little uncomfortable with that left wing down there.

EP: I sensed also that we were going sideways down the runway there.

EP: I noticed slight PIO tendencies and it was when I started the correction, immediately I could see that when I initially rolled into the bank, I couldn't get the bank that I wanted set and that started the PIO. Backed out of the loop just slightly, staying with the airplane, I never just centered the stick and let it go, I stayed with the airplane, and I got to what I thought was reasonable until the final one there had a slight left bank with right stick and it just didn't seem to be responding too quickly.

2nd pass:

EP: Rolled out, got my ground track established where I want it. Glide path's where I want it. Airplane feels fine right now.

SP: Correct

EP: Coming with the correction. PIO tendencies right away. Countered with some sharp inputs to knock it off. I've got 3 knots slow and a little bit drag in here. Concentrating on the roll degrades my ability in pitch.

SP: [Takes the airplane] I'm sorry. We're just getting those tips down too close there.

SP: I don't think you've really got the roll under control there.

EP: No, I don't. And every time I try to work on pitch, the roll goes out. Cooper-Harper 10. The PIO I did not feel was divergent. It was there but I didn't feel like it was increasing in amplitude. I felt like I just could not get it to settle down.

SP: When you couldn't back out of the loop, it was there.

EP: Yes. I got a PIO tendency of 4. So a Cooper-Harper 10, PIO of 4. No landings possible. And the reason we couldn't land was inability to level the wings. I didn't feel like this configuration was as bad as the other one that we had a Cooper-Harper 10 on. I got closer, at least. That may be learning curve effects.

CO: So this is a better 10 than the other 10?

EP: Yes, this is a better 10 than the other 10.

FTE: The observer would have rated it that way, too.

Postflight comments

EP: This didn't have the 10+ in that I actually thought that maybe I could get this thing down. I knew that I was

in a slight PIO but I did not feel it was divergent and I felt that I was getting fairly close to something that I would have been willing to land with. On the earlier ones, on event 2, configuration 300, I did not feel that I would have even attempted the landing had I not been tasked to go ahead and do it and [SP] would save us. This one I felt like, yeah, I might be able to get this one but [SP] did not feel comfortable and that was fine.

SP: I think the roll oscillations as we got closer to the ground were more than we could--we would have hit a tip tank--and they weren't getting any closer as we got closer to the ground. They weren't getting bigger, but they weren't getting smaller. I took it because if we had continued that, we would have hit a tip tank. I thought that clearly you did not have roll under control at that point.

EP: Yeah, I agree with you. My perception was that they were getting slightly smaller and they were getting a little bit more under control. But it was not a good flying airplane. Even if I had been able to get the airplane on the ground it would not have been much better than an 8 and probably still a 10. And the PIO got a 4 because from my perceptions they were not divergent. I thought that there was PIO there but I felt like I had it coming slower.

Remarks

After first pass:

EP: Am I flying two feet on the floor or do you feel that coordination is OK?

SP: I think the coordination is OK

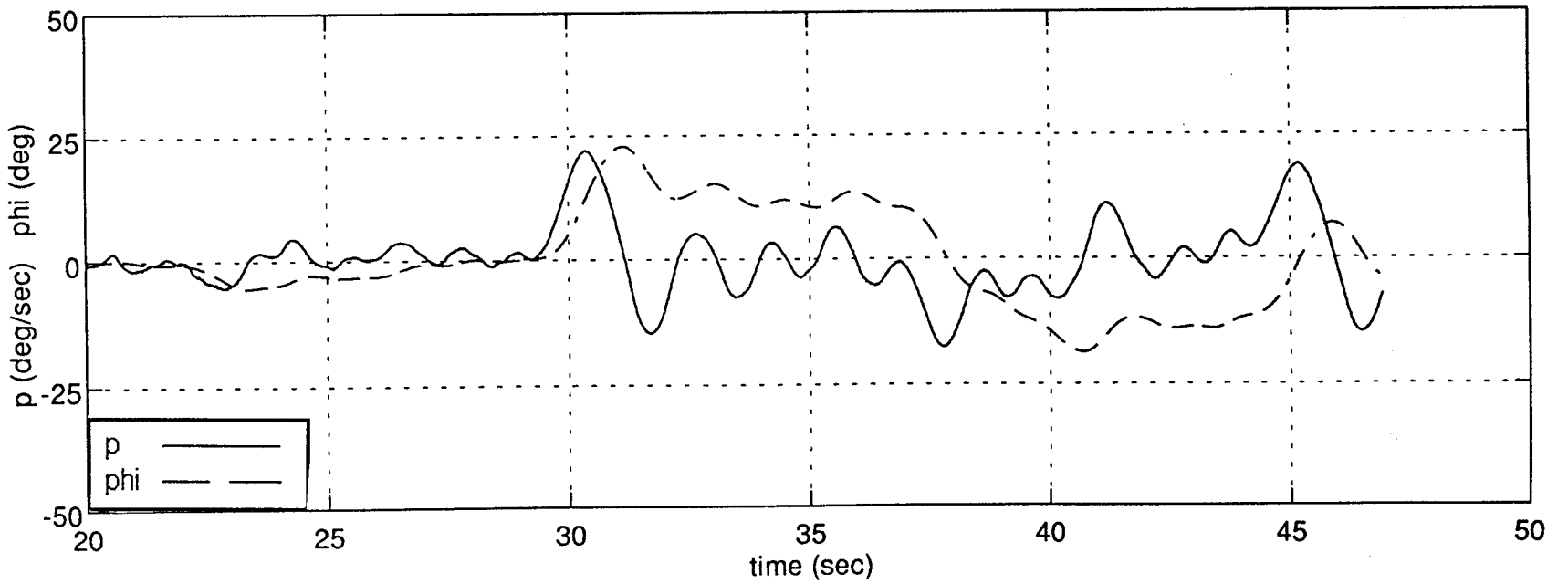
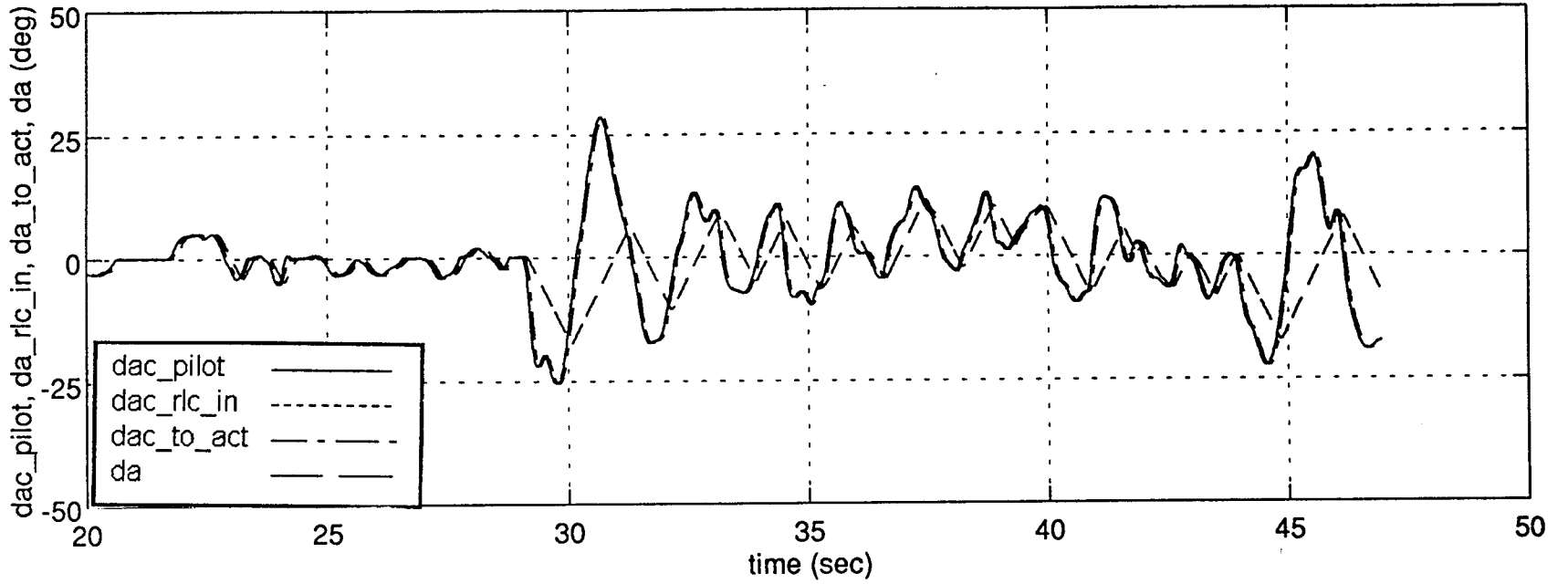
Turning base on second pass:

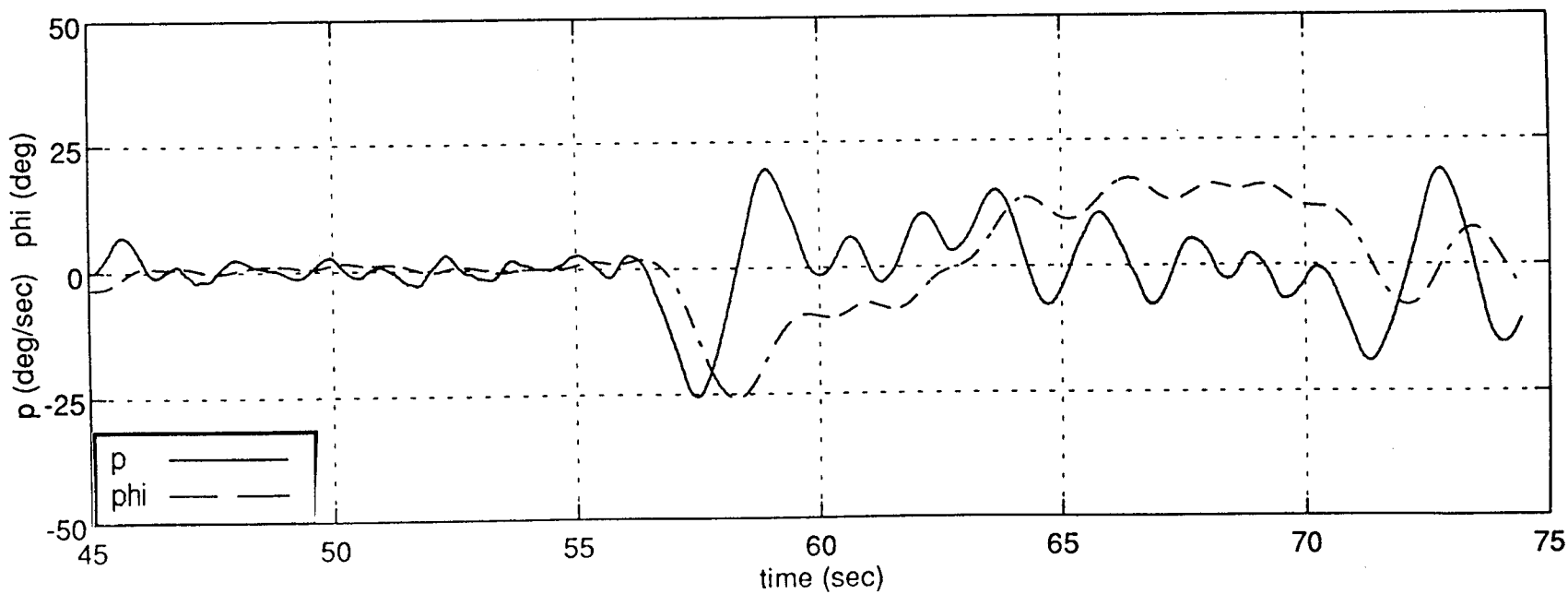
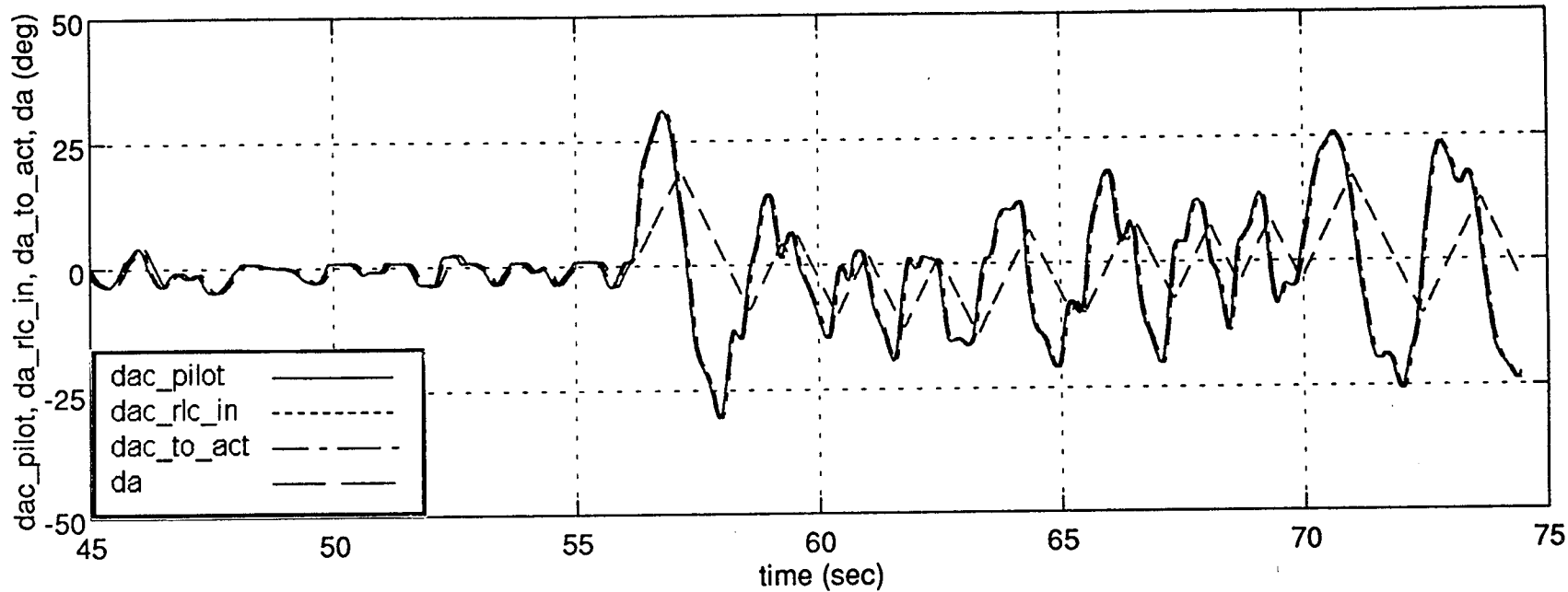
EP: The airplane handling qualities are compatible with the side stick and the center stick, from what I've seen before. They're not quite the same. It's a little bit different stick feel and command gain. They aren't perfectly matched, but it's close enough, I think.

FLT 446 REC 12 RL = 20 deg/sec RLC OFF

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APPENDIX C

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Evaluation 36 **Flight** 449/4 **Flight Evaluation No.** 9 **Event** Alt 1

Configuration 304 **Stick** Side **Type** Position **Rate Limit** 20 deg/sec

Pilot Ball **Safety pilot** Deppe **Computer operator** Buethe **Flight test engineer** Shafer

Algorithm None **Passes** 1 **Runway** 10L

Pass Record **Offset** **Wind** **Performance**
1 20 Left 080/14 No landing

CHR 10 **PIOR** 5

Inflight comments

1st pass:

On downwind:

EP: A little wing waggle way out here.

Turning base:

EP: I'm getting some wing rock way out here.

Turning final:

EP: Oh, boy, I don't like the looks of this already. I'm not sure I'm going to be able to....

SP: Correct

EP: Ah, ah, ah.

SP: I've got it.

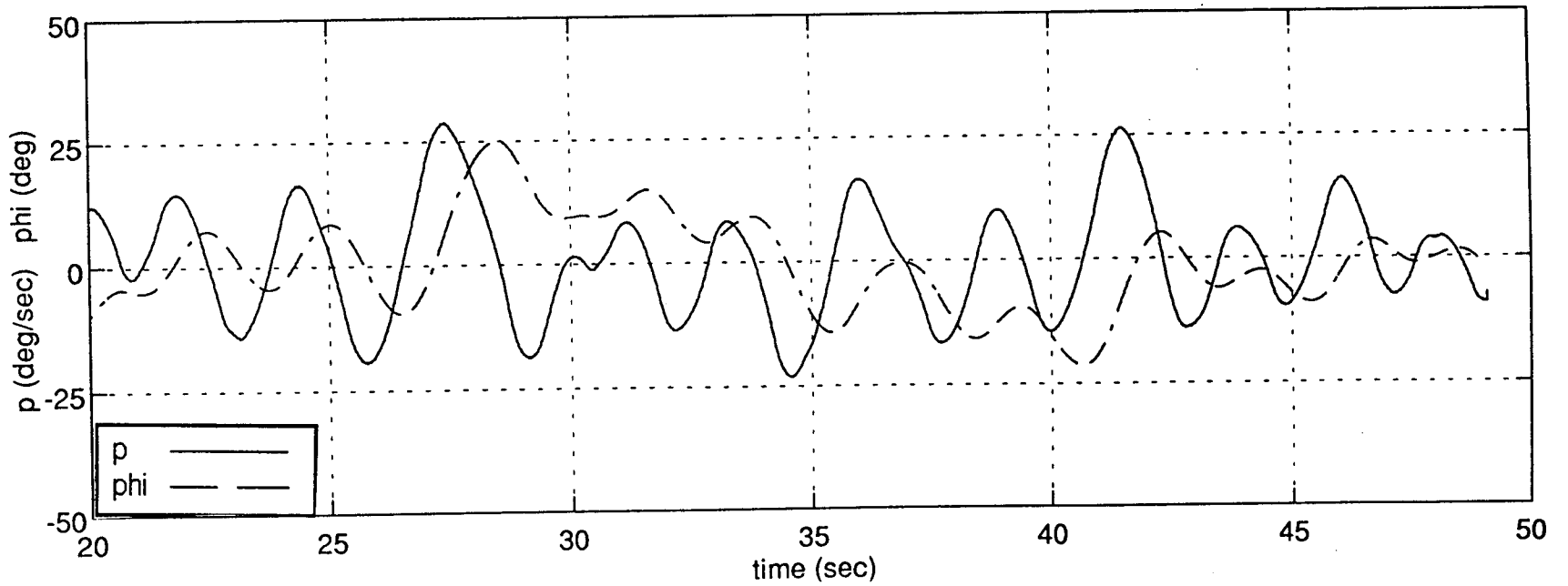
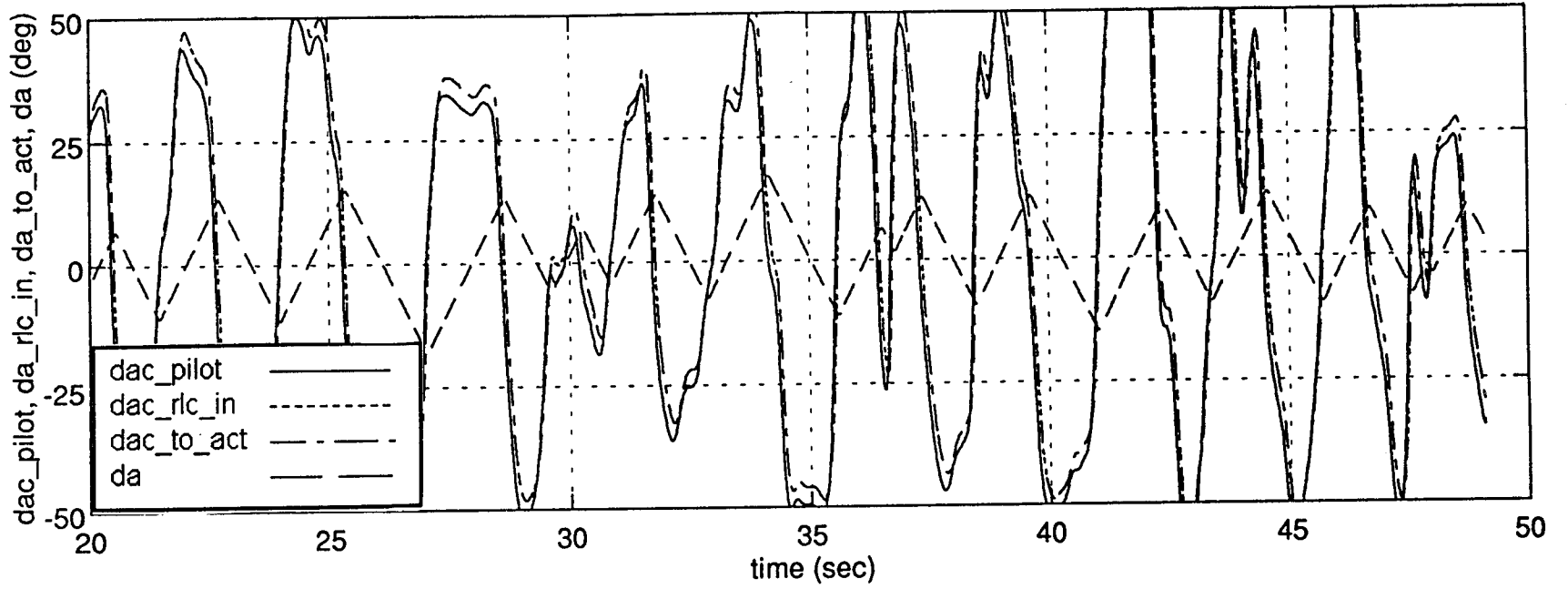
EP: Oh, yeah, it's about the power.

EP: That's plenty, I don't need any more on that one. I think I could likely give that one a 10 without seeing any more. I was just lucky I didn't hit something that time. In fact, I was that far from just telling you to take it because I just don't feel like I'm going to be able to catch it. Boy, that's not a long ways from a 6. Well, it wasn't divergent, I guess. There's an oscillation as soon as I took control, but I don't think it was divergent at that point, so that would be like a 5, probably, on the the PIO. It wouldn't take much to make that a 6 on the PIO. Just as soon as you try to do almost anything, you begin to get this wing rock

Postflight comments

FTE: a 10 and a 5. We only did that once. We did not make a landing and we were quite high when [SP] took it away.

Remarks



C-59

command, if you will.

Postflight comments

EP: It was assigned a Cooper-Harper 4 and PIO of 2. There was a slight tendency for a non-divergent PIO and that was the objectionable--not a PIO, undesirable motions. Let me make sure that's straight. I did not feel like it was a PIO. It felt like undesirable motions that I had to compensate for. Mainly a little bit of overcontrol. I got desired both time that we attempted this one.

Chick Chalk: Notice any out of trim?

EP: I did not feel that way in the base turn. In the base turn I think what my comment was some slight having to stay in the loop here, but it wasn't an out-of-trim, it was more of a roll angle wandering. I mean real slight. I'm not sure if they really perceived it

SP: I was watching the stick and this morning you could clearly see that the bias removal was not working. The stick would just stay over there and [CO] was going "we're out of trim here" . That did not happen here.

CO: I suspect it's the gain change.

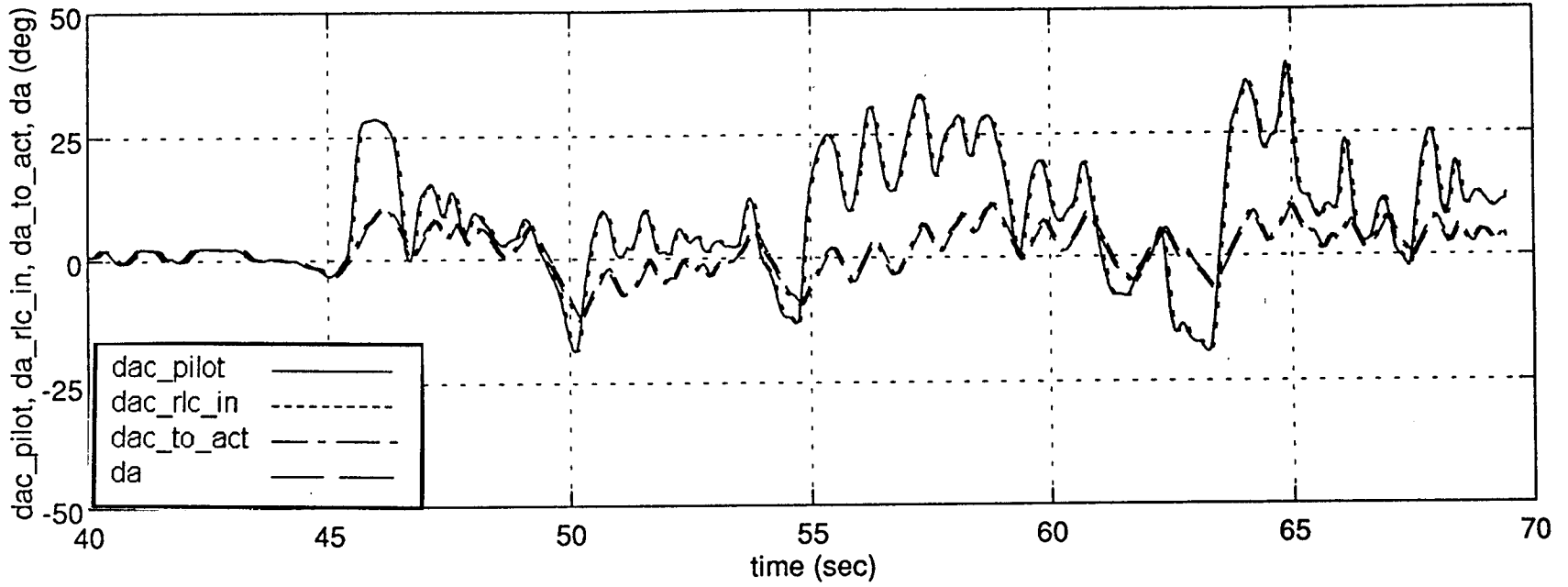
SP: Yes, I think so.

Remarks

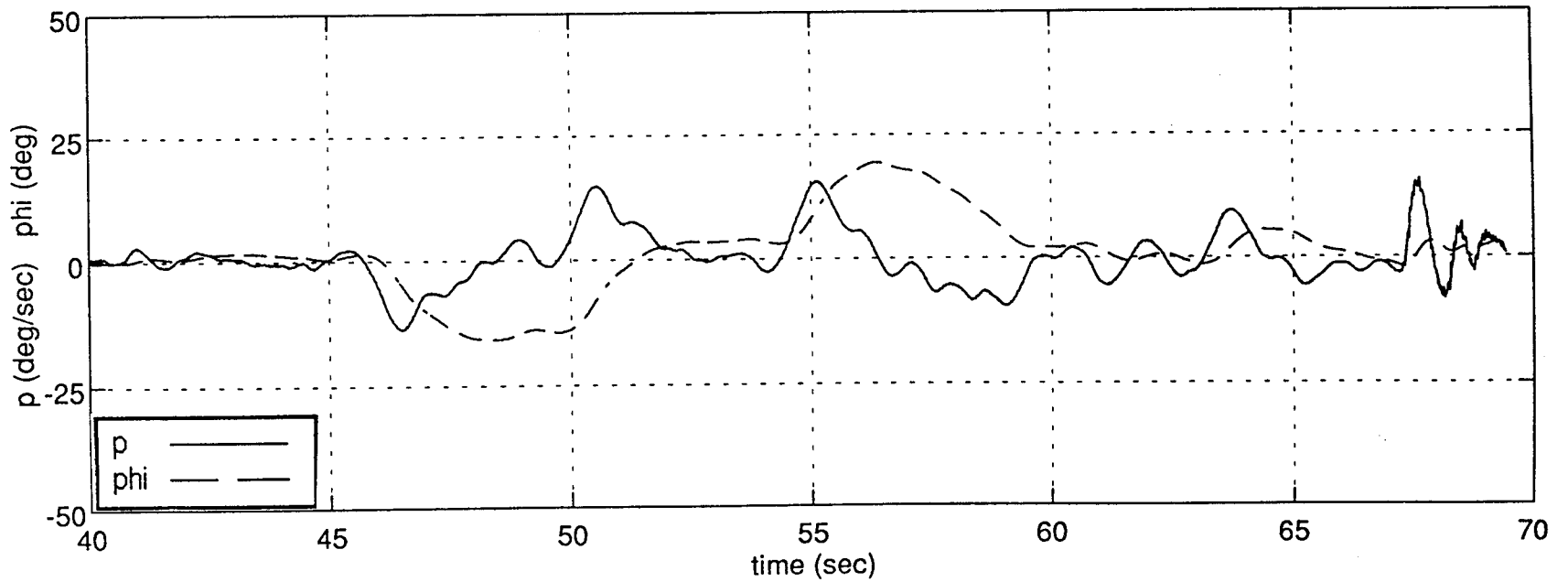
Initial pass converted to low approach by tower because of traffic.

FLT 446 REC 16 RL = 20 deg/sec RLC ON

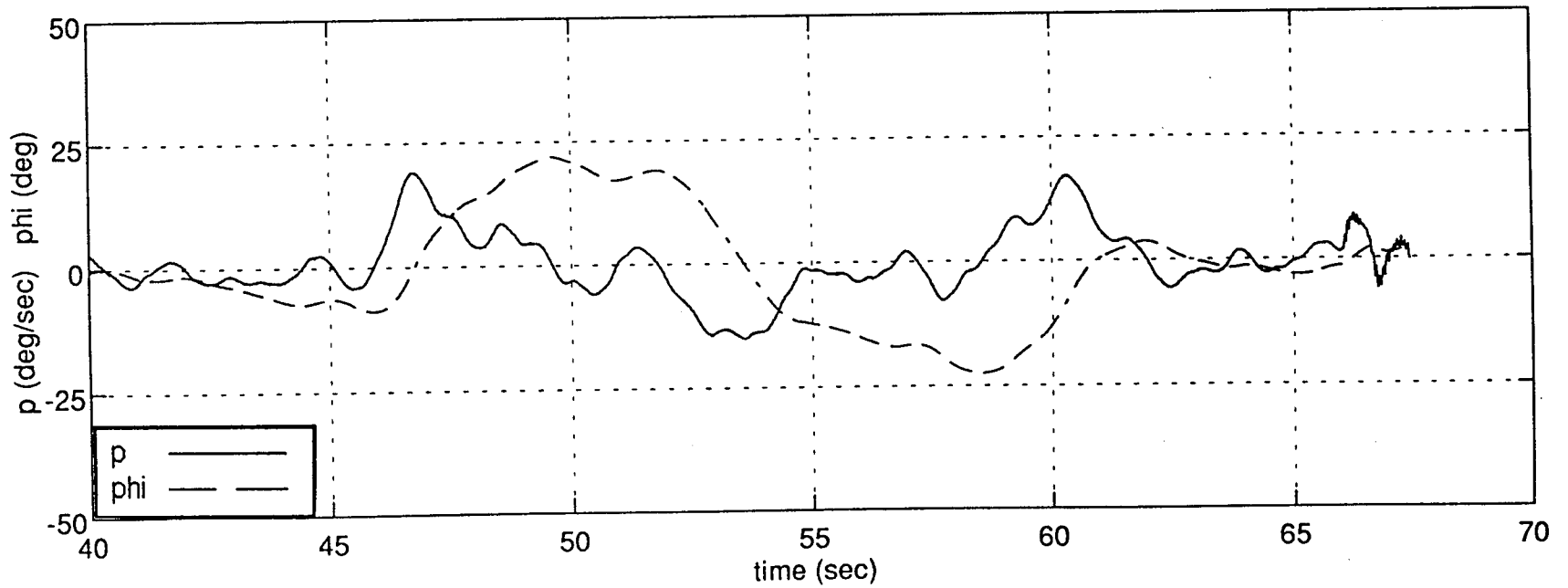
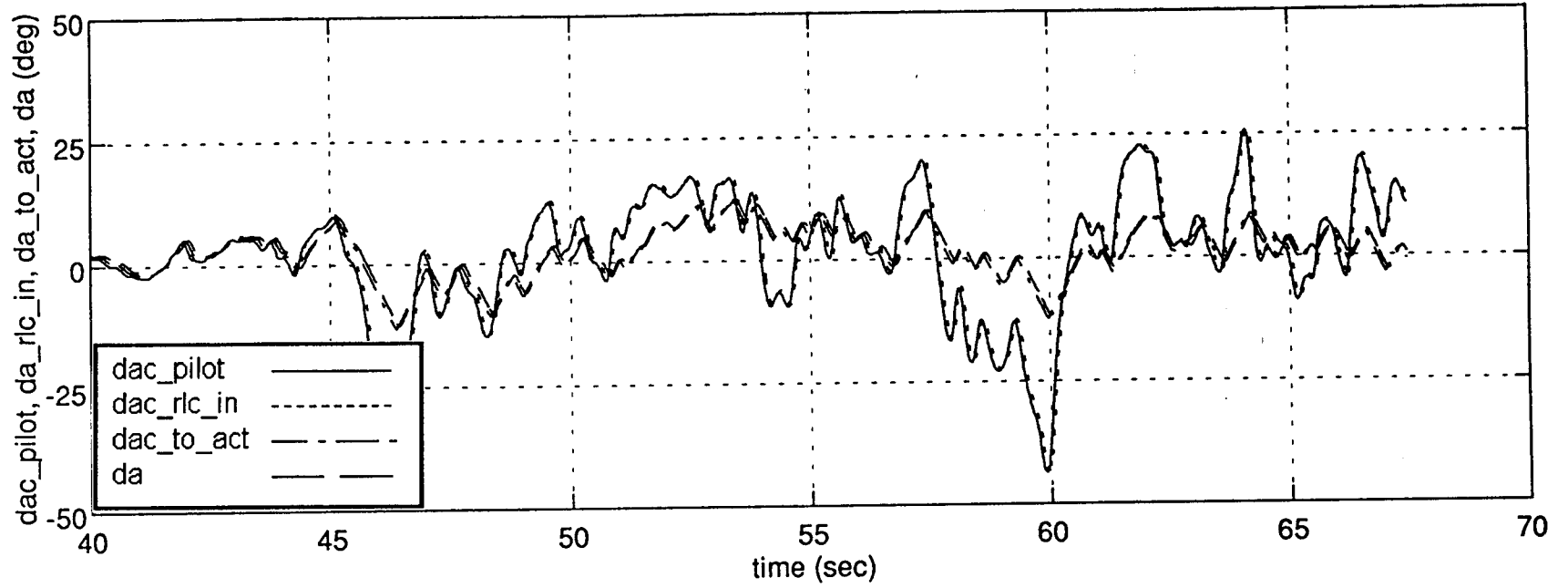
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FLT 446 REC 17 RL = 20 deg/sec RLC ON



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Evaluation 13 Flight 447/2 Flight Evaluation No. 4 Event 9

Configuration 305 Stick Side Type Position Rate Limit 20 deg/sec

Pilot Johnston Safety pilot Deppe Computer operator Buethe Flight test engineer Shafer

Algorithm RLC Passes 2 Runway 10L

Pass Record Offset Wind Performance

1 8 Left 050/5 Desired

2 9 Right 050/9 Desired

CHR 4 PIOR 3

Inflight comments

1st pass:

On downwind:

EP: This one is kind of--let me see if I can trim it out. This one will hold the wings level with the same force. Like this has a variable spiral mode.

Crisp turn. Lot more inputs to hold wings level.

SP: More than what, the center stick?

EP: More than the center stick, more than the baseline Lear. Spiral mode feels OK here, though. Real stable.

On final:

EP: A little wide on my offset, just a shade. where I want to be. Airspeed's under control. Airplane feels fine. I feel like I can be aggressive with it.

SP: Correct

EP: Correcting now. Slightly sluggish. Overcontrolled slightly on the first correction. Coming back. Leading it a little bit because of that. Overshooting slightly. Pull right. Still rolling left. Got it lined up. Now just keep it there, keep it there. Coming out of the loop just a little bit.

SP: It was in the desired box.

EP: Including the wingtips?

SP: Yes. I think we just made desired. I think we had the main gears on the centerline. At least for the touchdown point, the other stuff--maybe it was an accident.

EP: Desired criteria was met, but it wasn't very easy on that one. Working quite a bit to get it there. Find myself trying to, instead of working for exactly the nosewheel on the thing, I'm willing to accept getting the main gear there. I feel like if I continue to try to make it very, very tight, it would PIO and I'd be off to the races, so that was why I was accepting less than perfect but within desired.

2nd pass:

EP: Once again, airplane flies good, but it feels like the spiral stability is wandering. Occasionally you put in a little bit of right bank and you feel like it has negative spiral stability and then you roll out and it feels positive.

SP: There might be a little drift in the force sensor. If you can trim it out and it's happy from then on, we might just have a little drift in the force sensor.

EP: Yeah, it trimmed out last time. Right now I've got a little bit of negative spiral stability.

SP: We don't know if it's spiral or if it's just out of trim one way or the other.

EP: I'll roll out here. Now here the airplane's flying fine. I feel like I can be aggressive with it. I don't feel like there's any....

SP: Correct

EP: Correcting now. Large input. Predictable response. Rolling out. Sluggish now. Not getting the inputs I want. Rolled out, right in the box.

EP: Adequate performance attained with tolerable pilot workload? Yes. Satisfactory without improvement? No. Deficiencies warrant improvement. Moderately objectionable deficiencies; adequate performance requires considerable pilot compensation? That's not true, I got desired times 2. I'm still going to go with

Cooper-Harper 4. Minor but annoying deficiencies. Can't tightly control the task in the very final end, have to accept in the desired but not perfect parameters and sluggish response is my minor but annoying deficiencies.

CO: It's only moderate compensation? Just because you got desired doesn't mean it's necessarily a 4 or better.

SP: You can downgrade it because of the workload, if you want

EP: No, I think moderate pilot compensation. And the reason I say that is because I think I can get adequate with very little pilot compensation. PIO rating--do undesirable motions tend to occur? Yes. Is task performance compromised? Yes. So a 4, 3.

Postflight comments

FTE: This is a repeat from yesterday.

EP: This may give us some input into how repeatable I was. I had overshoots on this. I attained desired performance both times but it was not easy at all. I was backing out of the loop and it was sluggish, with tendencies to overshoot. PIO rating of 3, Cooper-Harper of 4.

What did I give it yesterday?

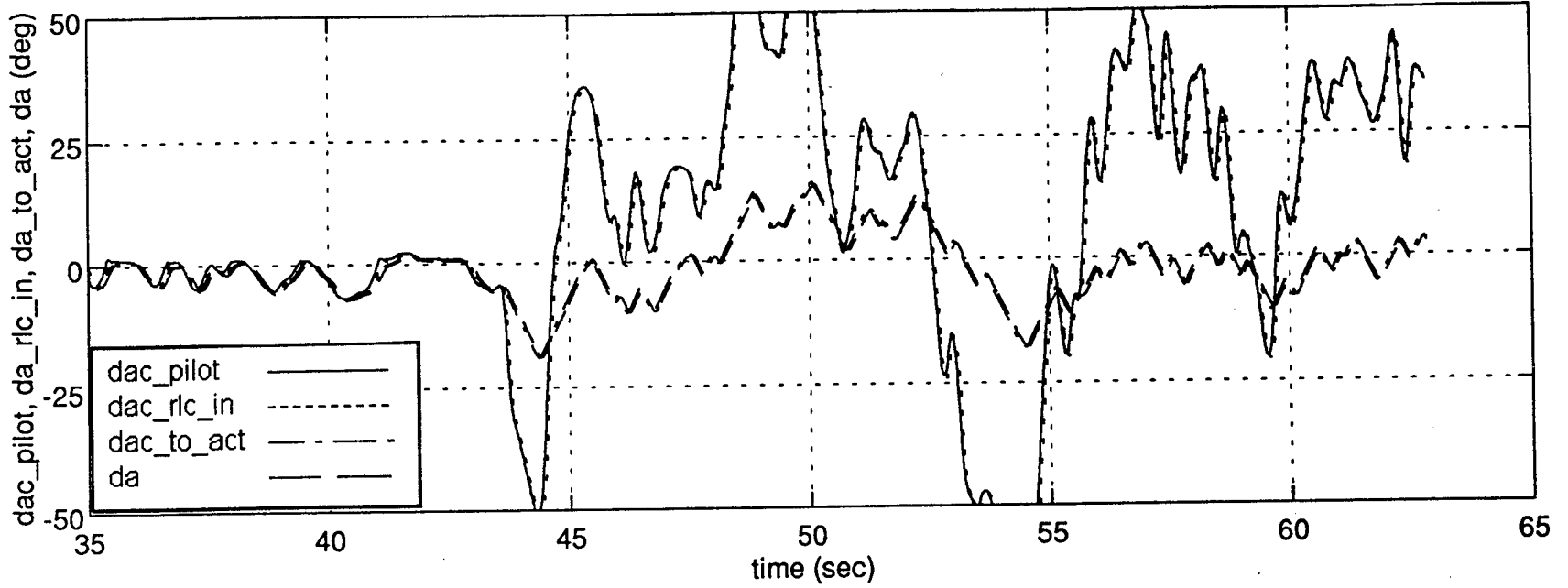
FTE: A 4 and a 2.

EP: So, fairly consistent. I think then the two days would be fairly consistent ratings.

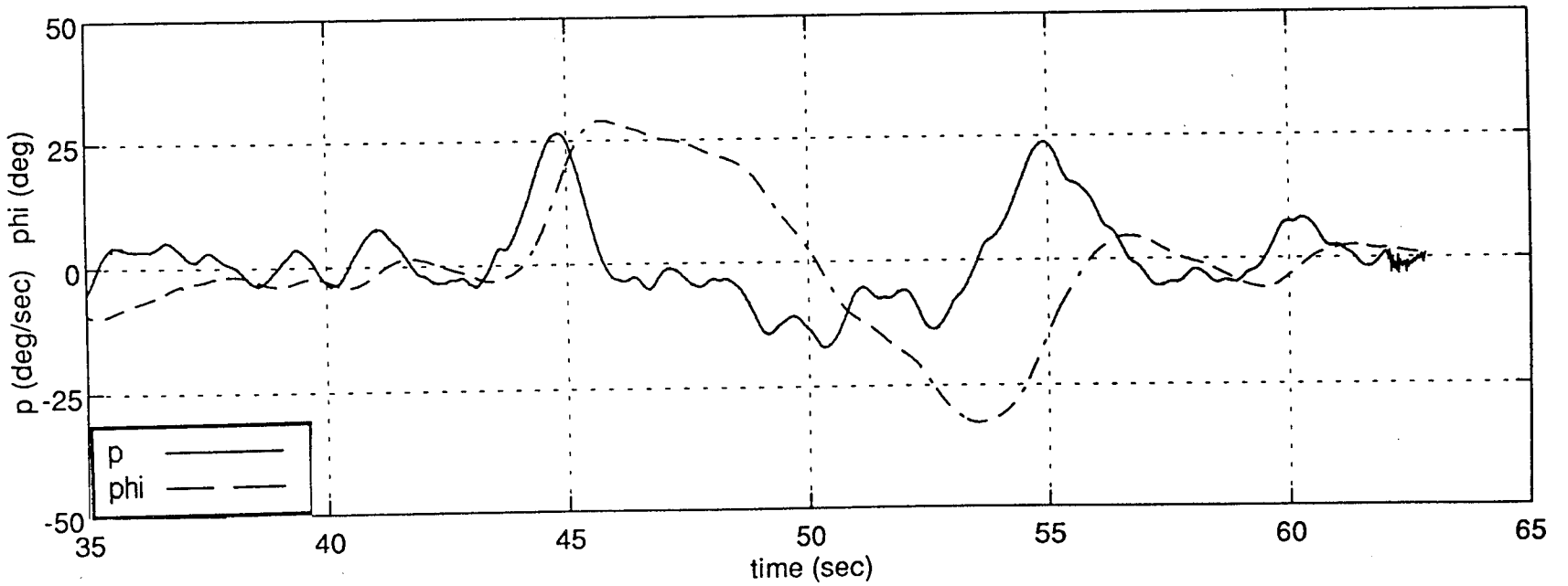
Remarks

FLT 447 REC 8 RL = 20 deg/sec RLC ON

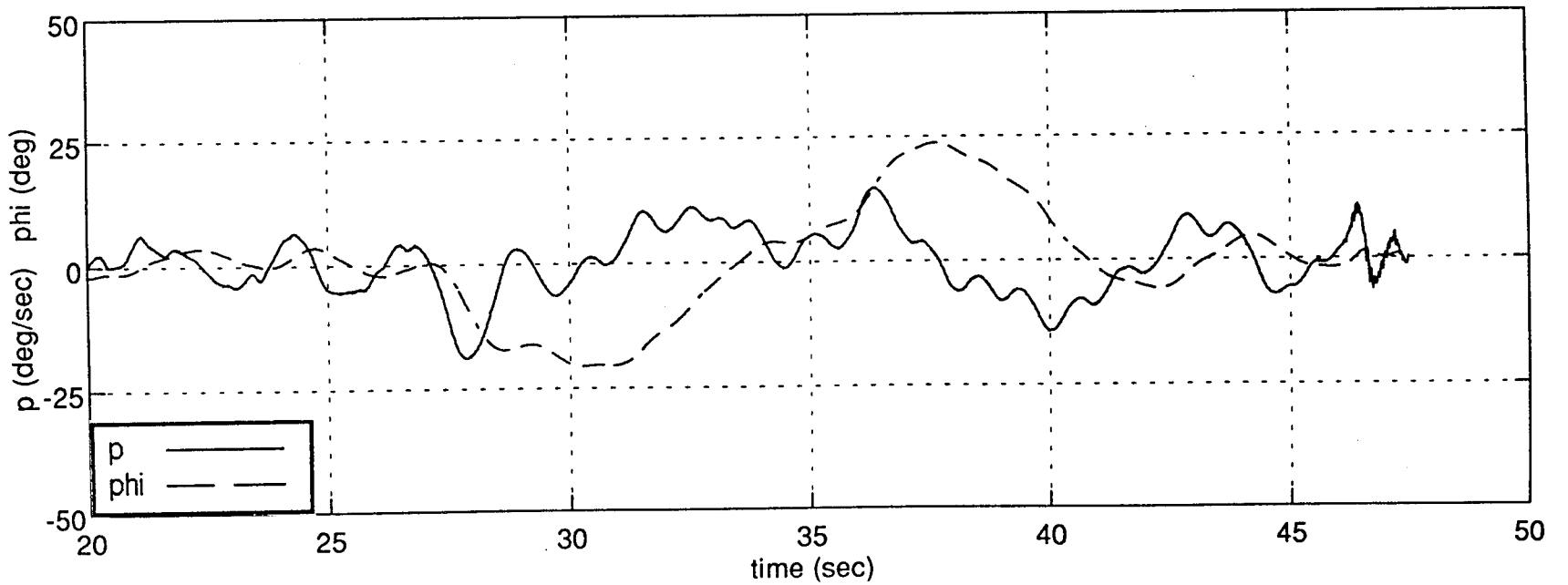
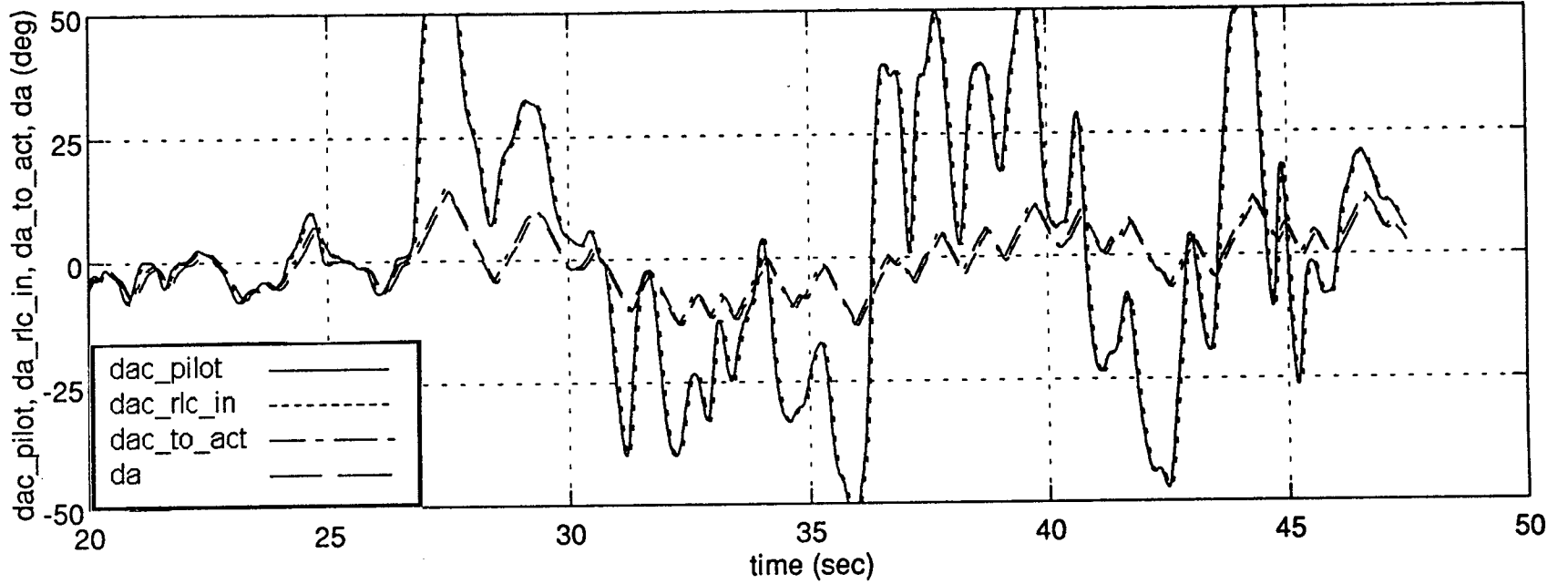
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FLT 447 REC 9 RL = 20 deg/sec RLC ON



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Calspan Report No. 8091-2
APPENDIX C

Evaluation 37 **Flight** 449/4 **Flight Evaluation No.** 10 **Event** Alt 2

Configuration 305 **Stick** Side **Type** Position **Rate Limit** 20 deg/sec

Pilot Ball **Safety pilot** Deppe **Computer operator** Buethe **Flight test engineer** Shafer

Algorithm RLC **Passes** 2 **Runway** 10L

Pass Record **Offset** **Wind** **Performance**

1 21 Right 090/13 Desired

2 22 Left 090/13 Desired

CHR 7 **PIOR** 4

Inflight comments

1st pass:

On base:

EP: The forces feel a little higher than they did before. I probably shouldn't be comparing one to another one. Because this one starts so light, the fact that it gets a little heavier doesn't bother me. It went from being quite light, [?]. And I don't have nearly as much wing rock--just a little tendency there, but not much, to rock the wings.

SP: Correct

EP: Now the force is getting pretty heavy. Tendency to overshoot there. It's one of those that doesn't feel like I'm hooked to the airplane very much. I kind of put an input in and wait and see what I get.

EP: That one didn't have as many surprises as, for instance, the one before it. I don't know if you're trying to compare it, but that one has the higher force and, for the correction-type size inputs, forces felt pretty high and the airplane just didn't respond as quickly as I'd like. A little tendency to overshoot. One thing might have to do with the forces that I'm starting with, but it doesn't feel out of trim nearly as much as some of those that I was putting in, that had a similar feel to this one, but when they were out of trim it was way out of trim. This one, like I say, I don't know if it's the baseline forces or not, but while I'm holding some pressure it didn't bother me. I wouldn't complain strongly about that force that I had to hold.

2nd pass:

SP: Correct

EP: Seems like I've got to put in some more inputs than I feel like I should have to.

EP: And that's another one of those that, at touchdown, I have odd forces in, holding a lot more roll force to keep the wings level than certainly would be nice. Adequate performance? The performance I got was desired, my tolerable pilot workload--I'm not real happy with that. Adequate performance--well, it was more than adequate, but the tolerable pilot workload blows it out of the water. I think that, for an airplane I was going to fly all the time, it would require improvement. I don't think I could set that on without everything working. I really wasn't too concerned about the control on that as much as it was just taking a lot of compensation to get what I wanted. So I'd say a 7 on that one. Divergent oscillation? No. Oscillation at all? I'd say no. Undesirable motion? Definitely. As far as the PIO rating I think I'd give it a 2. Let me think a second. Is task performance compromised? Undesirable motion--let me back up. My concern here is between an oscillation or an undesirable motion. I don't know, I guess I may have gotten a cycle or two in there, which would make it an oscillation, but it definitely wasn't divergent. That's a tough one, a tough call. We'll keep this in the comments, then. If there was an oscillation it was only a one cycle type of thing. It was almost just an undesirable motion and that's what I'm debating over even jumping up into that area. But if I say it was an oscillation, it definitely wasn't divergent, and that's a 4. And if I were to say it was just an undesirable motion, then I'd probably bring it into a 3 that way. Since I've got to give it one, though, I'll give it a 4. That one definitely needs the comments with it.

Postflight comments

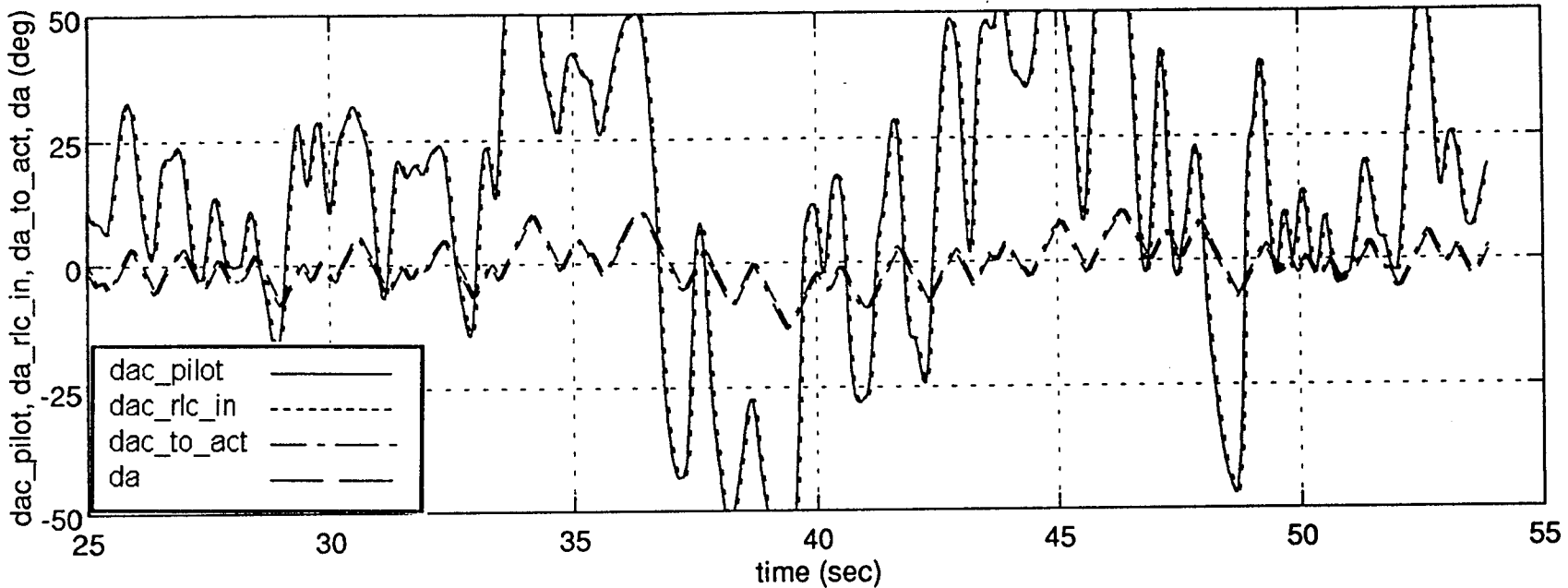
FTE: A 7 and a 4.

EP: That one was one I think I mentioned--the thing that made that usable was that, while it did get a little bit out of trim, it starts with lighter forces. You end up with not holding some humongous force on the thing. So by starting with a more sensitive roll control, the fact that it got a little bit heavier and was out of trim--it wasn't that much out of trim. It wasn't good. I was holding some of that "weird" force, but it was much lower just because the control power was higher.

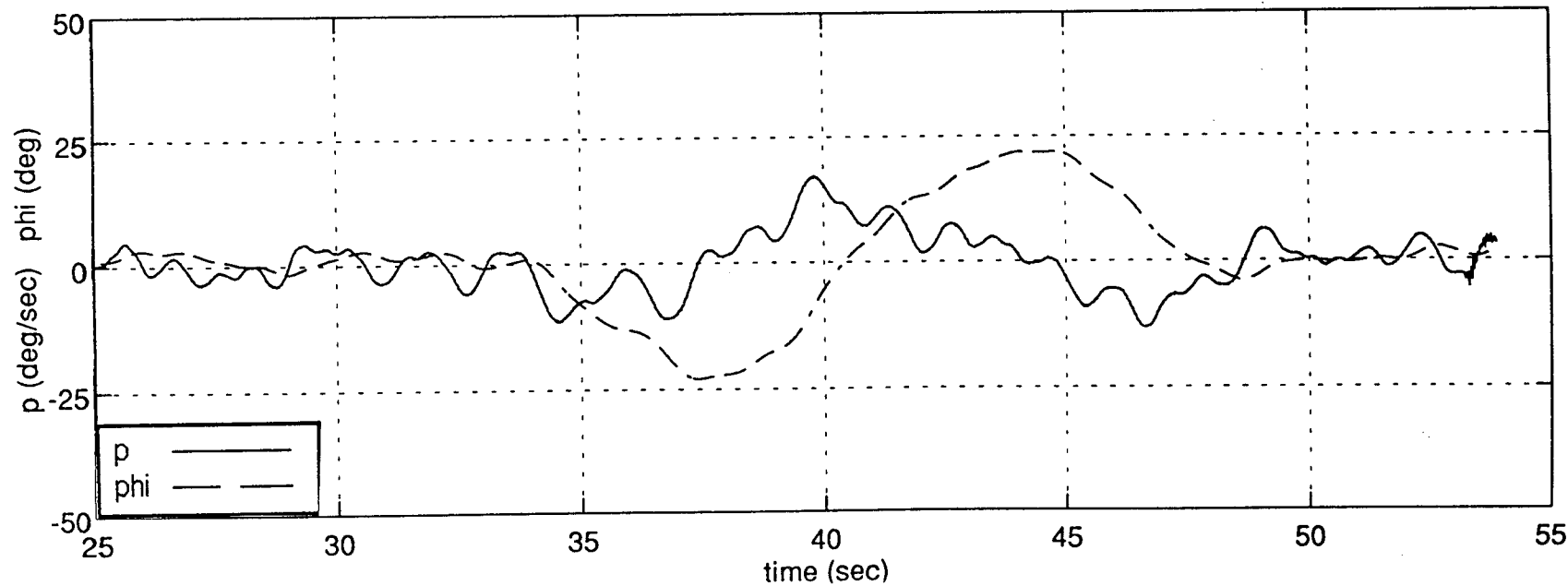
Remarks

FLT 449 REC 21 RL = 20 deg/sec RLC ON

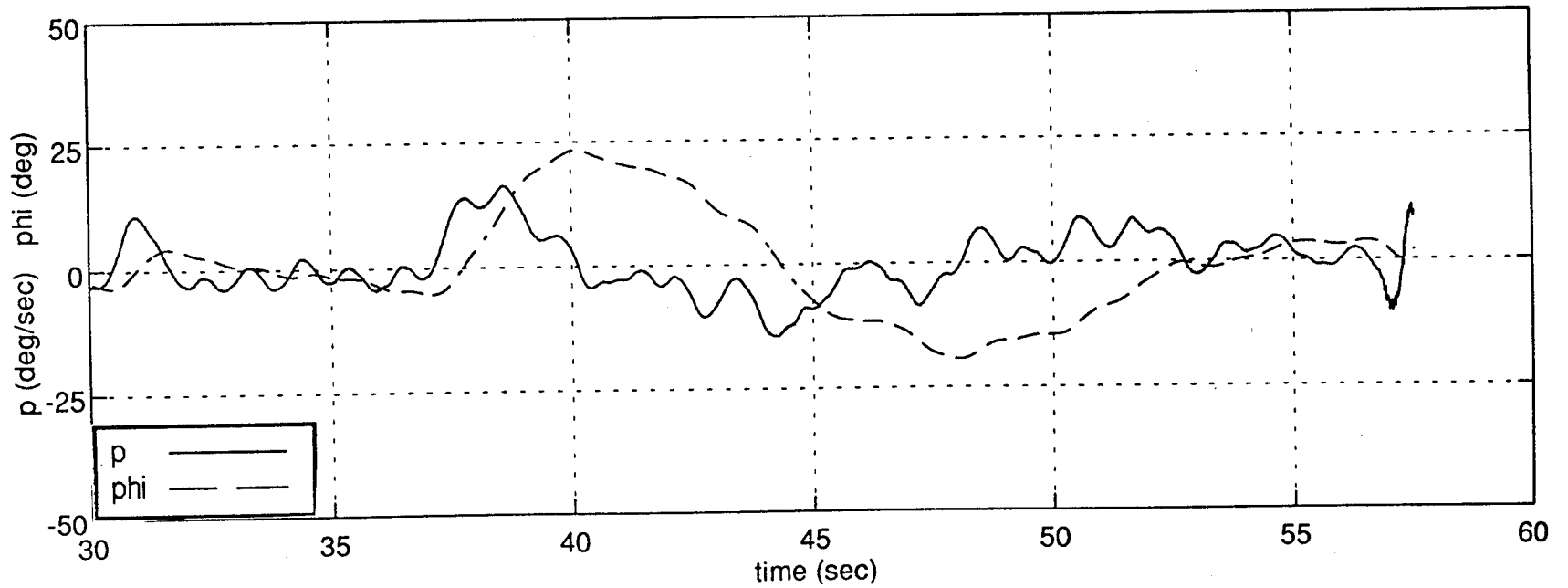
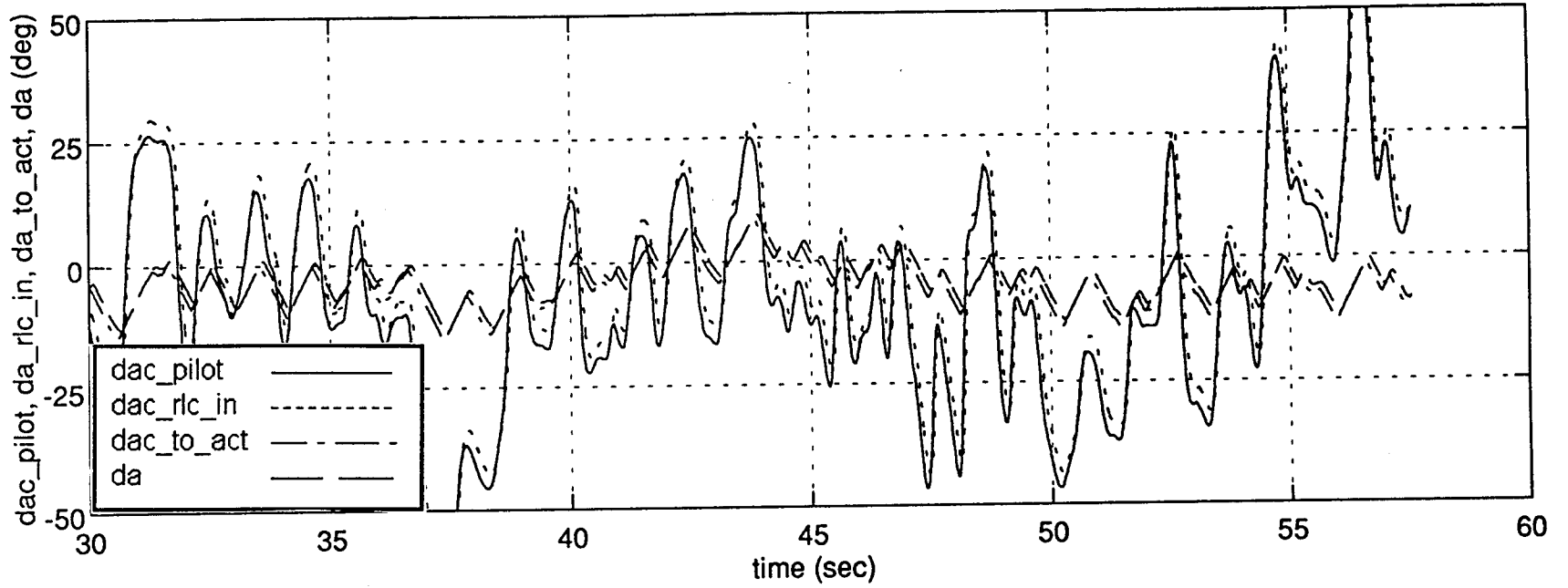
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C-70



FLT 449 REC 22 RL = 20 deg/sec RLC ON



C-71

Calspan Report No. 8091-2
APPENDIX C

Evaluation 14 Flight 447/2 Flight Evaluation No. 5 Event 10

Configuration 306 Stick Side Type Force Rate Limit 20 deg/sec

Pilot Johnston Safety pilot Deppe Computer operator Buethe Flight test engineer Shafer

Algorithm None Passes 2 Runway 10L

Pass	Record	Offset	Wind	Performance
1	10	Right	050/9	No landing
2	11	Left	040/6	Desired--SP took control at touchdown

CHR 8 PIOR 4

Inflight comments

1st pass:

Turning base:

EP: Feels good and I feel like I can be aggressive with the airplane. Same comment with the spiral stability. May be a trim. I didn't get this one on downwind much.

Lined up. The air speed's under control. I'm about on the glidepath I want, out on the offset that I want.

SP: Correct

EP: Correcting. Whoa. Big overshoot there from what I wanted to get. Having to back on on my gains just slightly, but I'm still working it and I still feel like I can do the task. Overshoots. PIO.

SP: [Takes control] I wasn't sure about that wing tip coming down there.

EP: I'd like to take that one one more time.

SP: We'll give you a little downwind here to look at that trim thing, too, if you want

EP: I don't think that affected me on the trim here, though.

2nd pass:

On downwind:

EP: [Takes hands off controls] Roll off to the left. It's been doing that fairly consistently.

SP: I think that's the trim, coming up just a little out of trim, maybe a little force offset or something.

EP: About 3 to 4 clicks.

Turning base:

EP: A lot of positive spiral stability in both directions there at zero bank. The same in the turn at 25. Goofing around with that, got myself way past. Not even halfway through the turn, though, and I think we can recover. Right now the airplane's feeling fine. I feel I can be aggressive with it.

On final:

EP: Not quite getting the desired roll rate out of it when I do something. It's slightly unpredictable. Tending to be a little timid with it. Major power correction to make an airspeed and glide slope correction.

SP: Correct

EP: Correcting now. Sluggish initially. Way more than I wanted. Dampened out the PIO. It was a definite PIO but I dampened it out. I think I can do this task. PIOed again. Dampened it out. I think I can do this task. Got it lined up.

SP: [Takes control]

EP: Well, tough.

EP: I do not like that at all. As we touched down, I was getting back into a PIO. You saw that the left wheel hit first, with roll rate on it, and then the right wheel hit.

SP: We were still in the oscillation when we hit.

EP: I did not like it at all. Even though we got adequate once and kicked off on the second one, I'm going with a combined rating of about a Cooper-Harper 7. I just want to give one rating for the whole thing.

CO: Controllability was not in question?

SP: It's your call but I don't know....

EP: Yeah, you're right. Considerable pilot compensation is required for control. I agree, let's go with an 8.

PIO 4. Non-divergent. I say that because we got in the PIO on the correction. I felt like I dampened out two fairly major PIOs. That's why I feel that they were non-divergent.

Postflight comments

EP: In the first attempt, the safety pilot knocked it off. It was in a PIO from the first correction. It was non-divergent. On the first one, I thought I had a chance to land it. It wasn't like the first time [event 8] where I got knocked off, when I was, "Thank you very much for knocking off". This one was more like, "I think I could have got it", but he didn't like the way the airplane was going and that's fine.

Second attempt. This one, you knocked me off both times. But the second attempt, I really felt like I could of gotten it on the runway.

SP: And I made the comment, "I think you could have made that one but it would have been real close on the tip tanks."

EP: I felt like I had a landable but marginally controllable airplane. So even though he punched me off two times, so we gave it an 8 and 4. The PIOs were definitely non-divergent and I was damping them out as we got in closer. Whether we were going to complete the maneuver at all was, at times, marginally in doubt. I always felt like yes, I'm going to be able to land this. I never felt like I was going to be able to get it in the desired box.

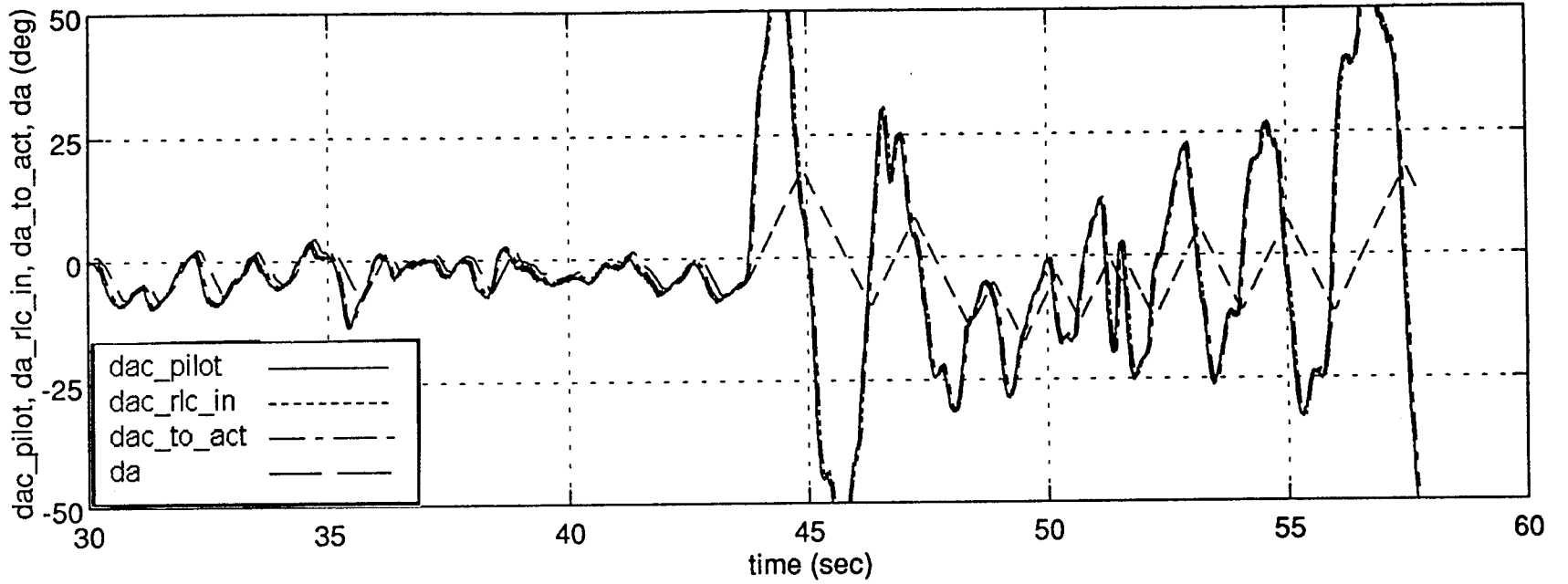
SP: Controllability in question?

EP: Yeah, it was marginally in question. I think each time I was thinking yeah, I can get this on the ground, I think I can get this on the ground, I think I can continue to do the task to the adequate or, maybe, outside the adequate but on the runway and walk away from it. I agree with you, I felt like I might kind of nick a wing tank but we're not going to ding a wing. The first one that we had a 10 [event 8] I was probably going to ding a wing and cartwheel down the runway. This one I felt like at worst I'd scrape a tip tank, at best I'd come in and say not a problem. That's why I got an 8 and a 4, even though I got kicked off both times.

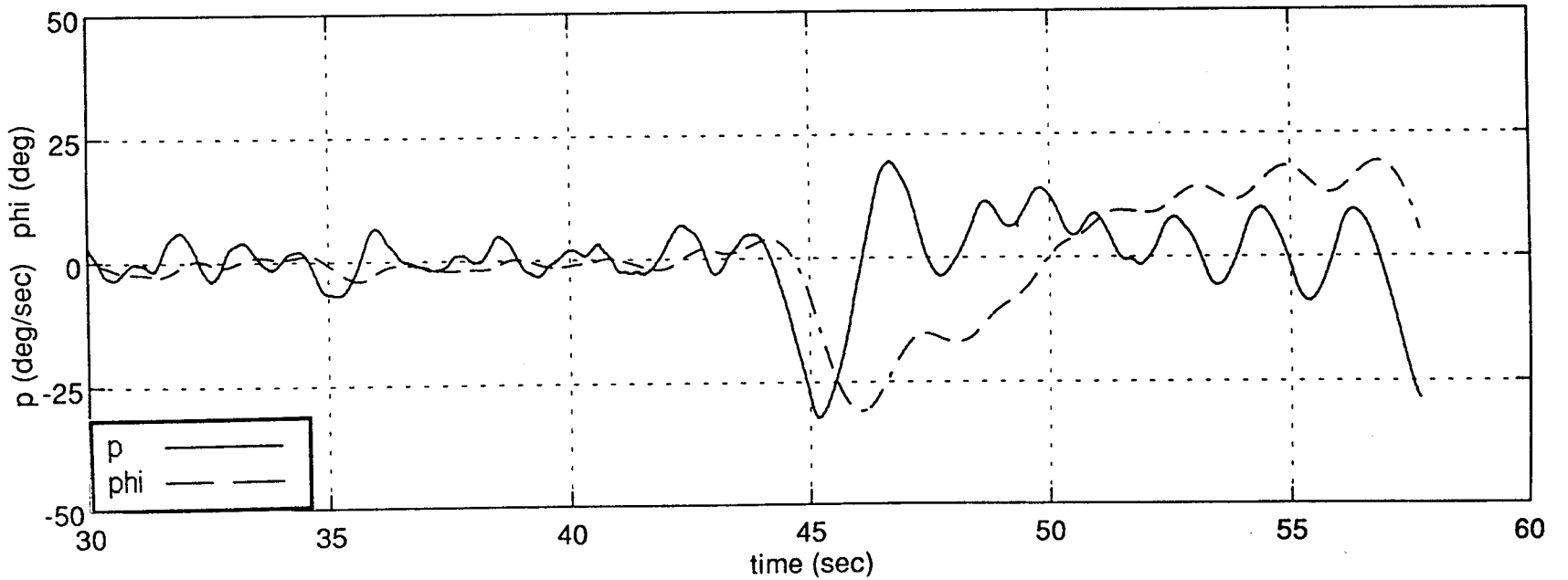
Remarks

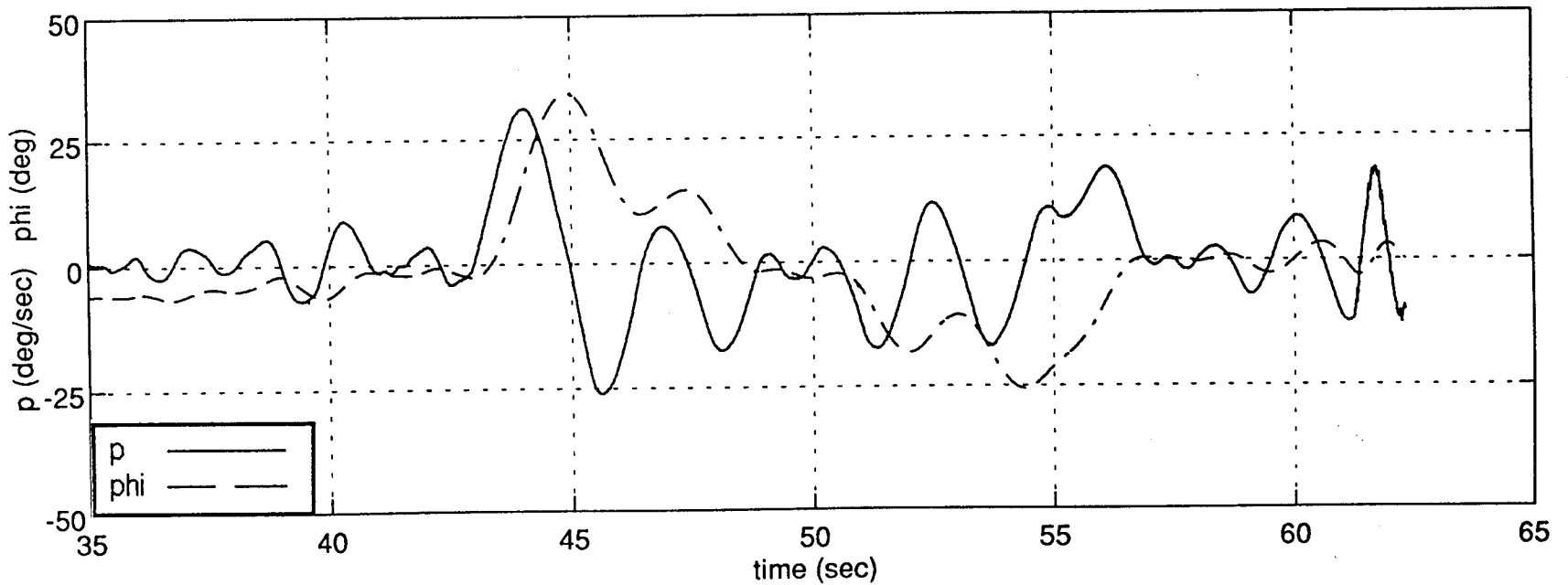
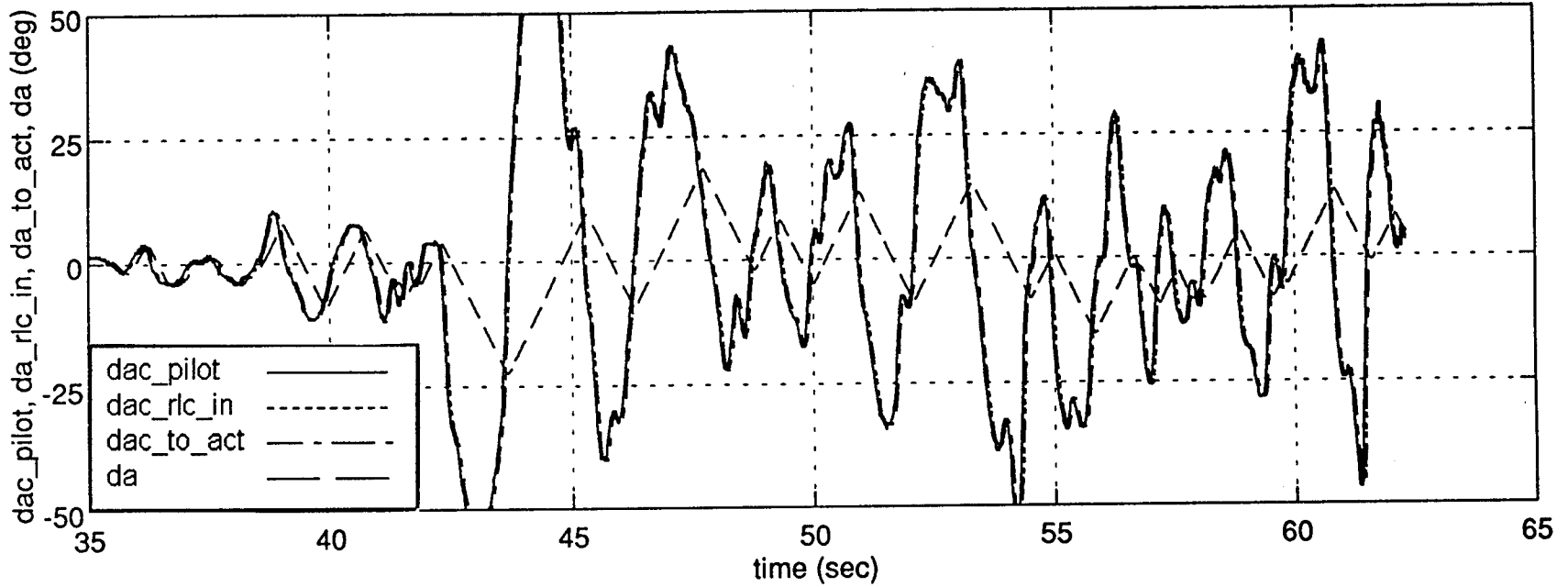
FLT 447 REC 10 RL = 20 deg/sec RLC OFF

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APPENDIX C



C-74





Evaluation 25 Flight 448/3 Flight Evaluation No. 6 Event 13

Configuration 306 Stick Side Type Force Rate Limit 20 deg/sec

Pilot Smith Safety pilot Buethe Computer operator Deppe Flight test engineer Shafer

Algorithm None Passes 2 Runway 10L

Pass Record Offset Wind Performance

1 17 Right 040/5 Desired

2 18 Left 040/4 Desired

CHR 8 PIOR 4

Inflight comments

1st pass:

On final:

EP: I'm not going to like this one.

SP: Correct.

EP: Agh.

FTE: Ooh.

SP: That was right on the edge.

EP: Yes, it was.

SP: Every time I was about to take it, it reversed.

EP: I think that was a good comment for this one, that it was right on the edge. It was on the edge of really losing control. Very dangerous airplane, very easy to overcontrol. The initial response, I was trying to maintain my initial move to be about the same and I even grunted because I wasn't sure I was going to get the wing up. Then in close we were in an almost continuous oscillation. I managed to get down on the ground in approximately the right place, but it wasn't really a good thing about the airplane. That was not a good airplane--insidious, dangerous, and we'll try one more here.

2nd pass:

SP: Same thing.

EP: It's controllable, barely. Adequate performance? I can't judge just where I hit the ground. I think we did get adequate performance but it's certainly a bad airplane, almost any kind of closed loop task, there's a constant oscillation. Very dangerous with rapid inputs. I think it has major deficiencies and considerable pilot compensation required for control, I'm going to say it's somewhere between an 8 and a 9 if anybody cares. I'll say it's an 8 over all. Oscillations are certainly caused. Are they divergent? No, but they're certainly there and it's a 4.

Postflight comments

CO: You called this one "dangerous", "on the edge", "a lot more PIO", "a lot of PIO". You touched down in a PIO, actually, both times. You called this one an 8, PIO 4.

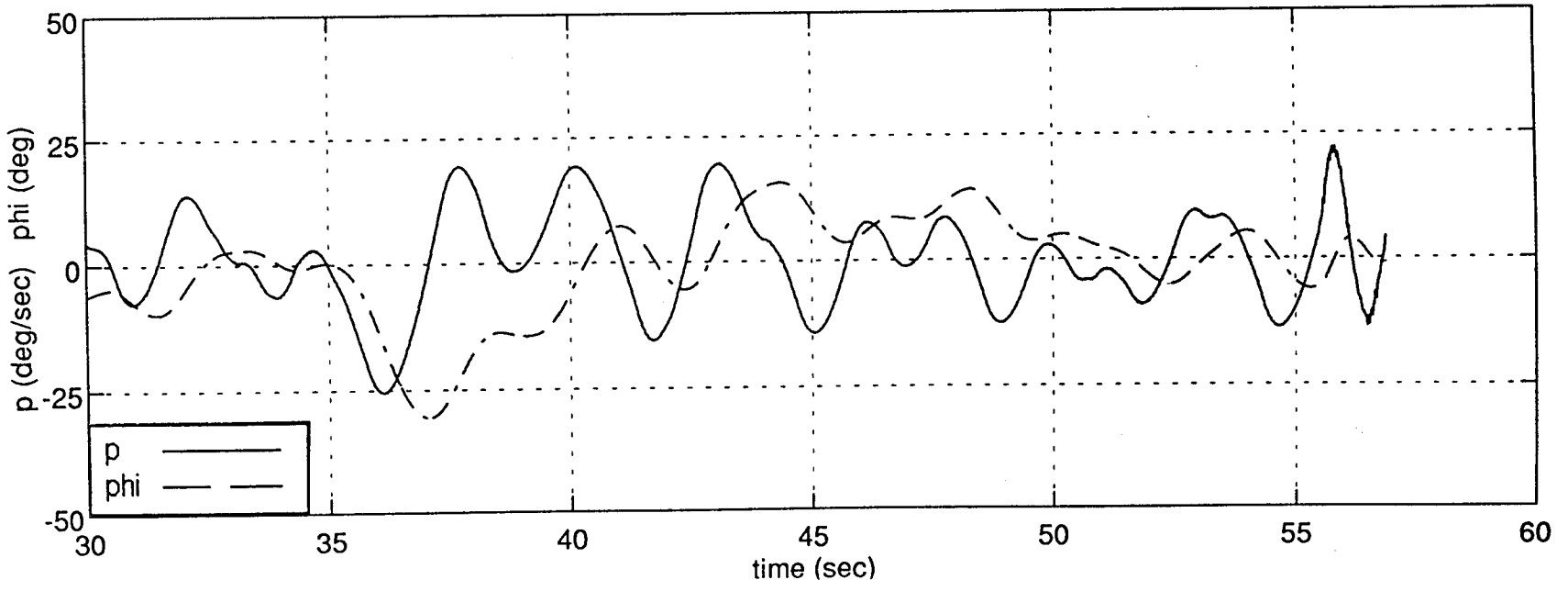
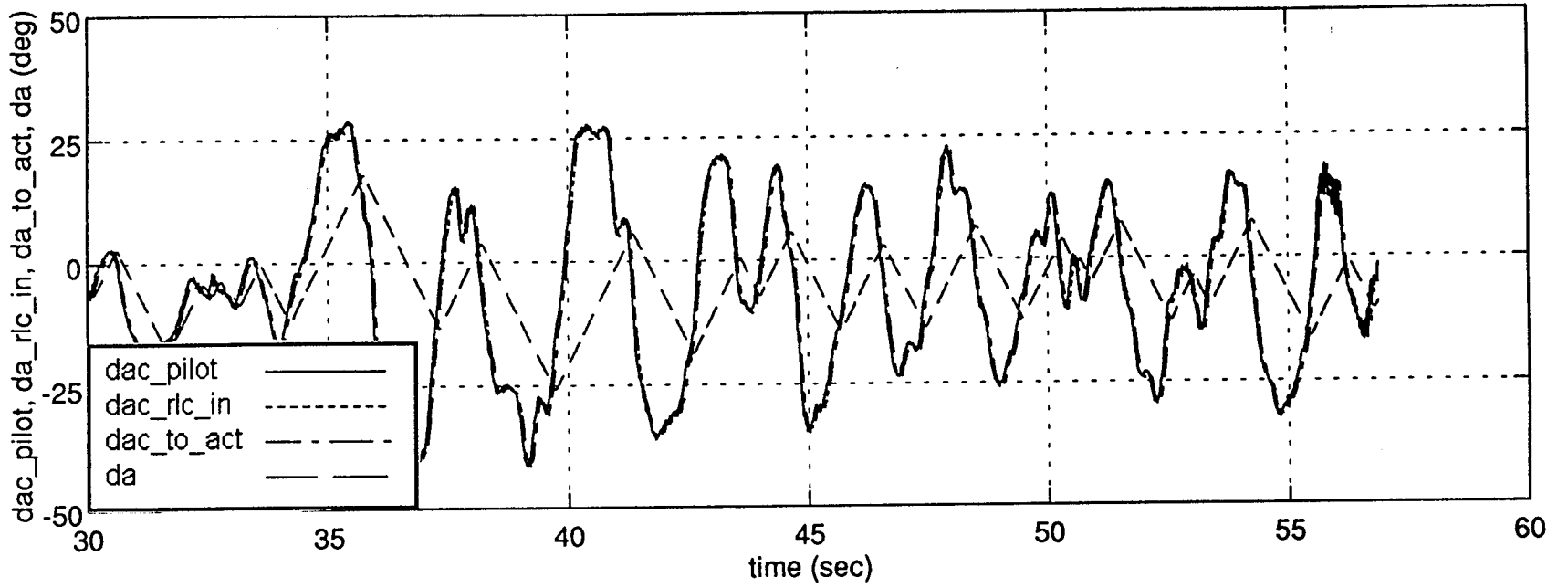
EP: Yes, I was debating 8s and 9s, but who cares? It was not divergent. It was neutral and it was on the edge in the sense that [SP] mentioned several times, that the first time, when he was about ready to take it, I did get it to respond in the right direction.

SP: He was just about at his bank angle limits for touchdown.

EP: It's a lousy airplane.

Remarks

FLT 448 REC 17 RL = 20 deg/sec RLC OFF



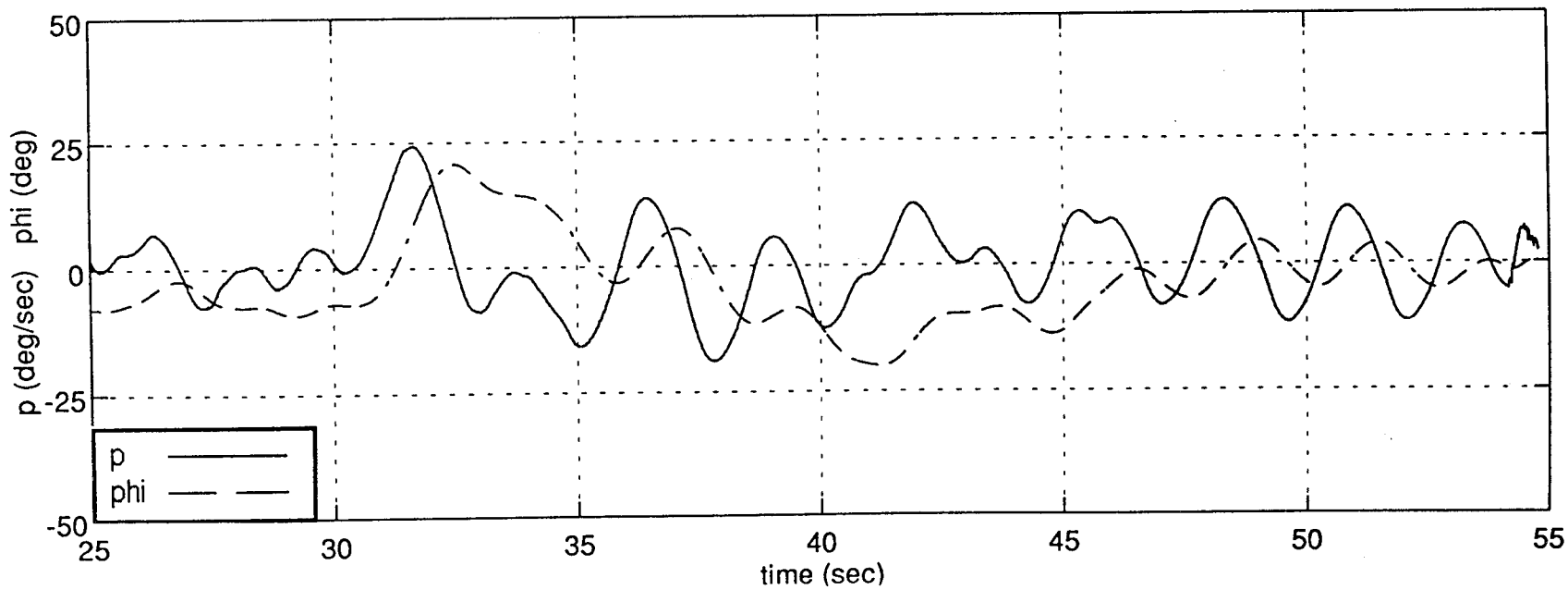
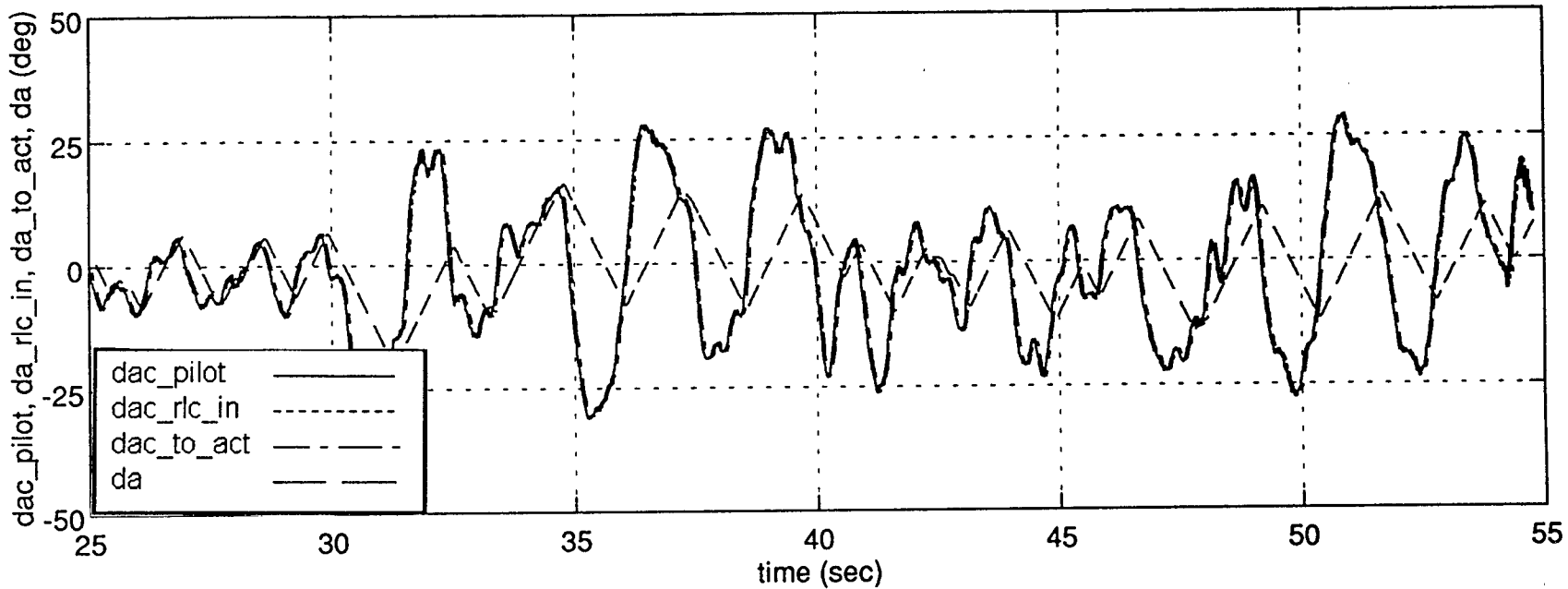
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FLT 448 REC 18 RL = 20 deg/sec RLC OFF

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APPENDIX C

C-78



Evaluation 33 **Flight** 449/4 **Flight Evaluation No.** 6 **Event** 13

Configuration 306 **Stick** Side **Type** Force **Rate Limit** 20 deg/sec

Pilot Ball **Safety pilot** Deppe **Computer operator** Buethe **Flight test engineer** Shafer

Algorithm None **Passes** 1 **Runway** 10L

Pass Record **Offset** **Wind** **Performance**
1 15 Left 100/14 No landing

CHR 10 **PIOR** 5

Inflight comments

1st pass:

Turning base:

EP: This may be a one pass does everything for you here.

Turning final:

EP: Well, get the light-touch gloves out here now. This is a beaut. Just holding a bank angle I've got a bit of a PIO going or oscillation which it's hard to believe isn't a PIO.

On final:

SP: I show you wide here and fast.

EP: And everything else. Part of that's because I'm trying to stay alive. OK, down a little bit would be a lot better. And slow.

SP: Correct

EP: You ready? I don't think this one's going to get close to the ground. That one was going to diverge. I could tell that just by the feel of it. OK, that's plenty.

EP: 10 HQR. Well, I didn't have a divergent oscillation when I just took control but I had an oscillation every time I just breathed on it and it was divergent, a 5. So a 10 and a 5.

Postflight comments

FTE: 10, with a PIO rating of 5 and a comment, "The worst I've seen by quite a bit." That's a 10+.

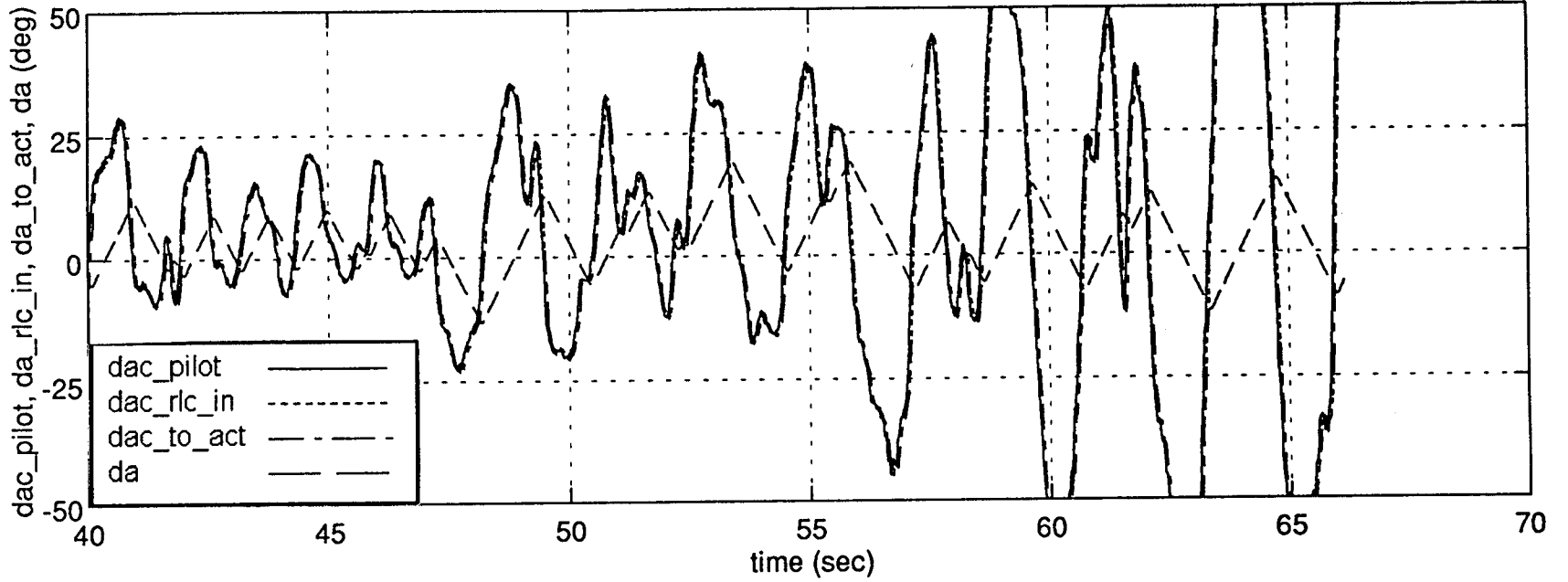
EP: Part of it is the sensitivity is much higher in roll. I mean, it really gets you going much faster. That could have even been a 6. As soon as I'd take a hold of it, you'd see the oscillation, but it wasn't getting bigger, and just by my own backing out and so on, I could keep it from diverging. But it very easily could have been a 6. Terrible.

Remarks

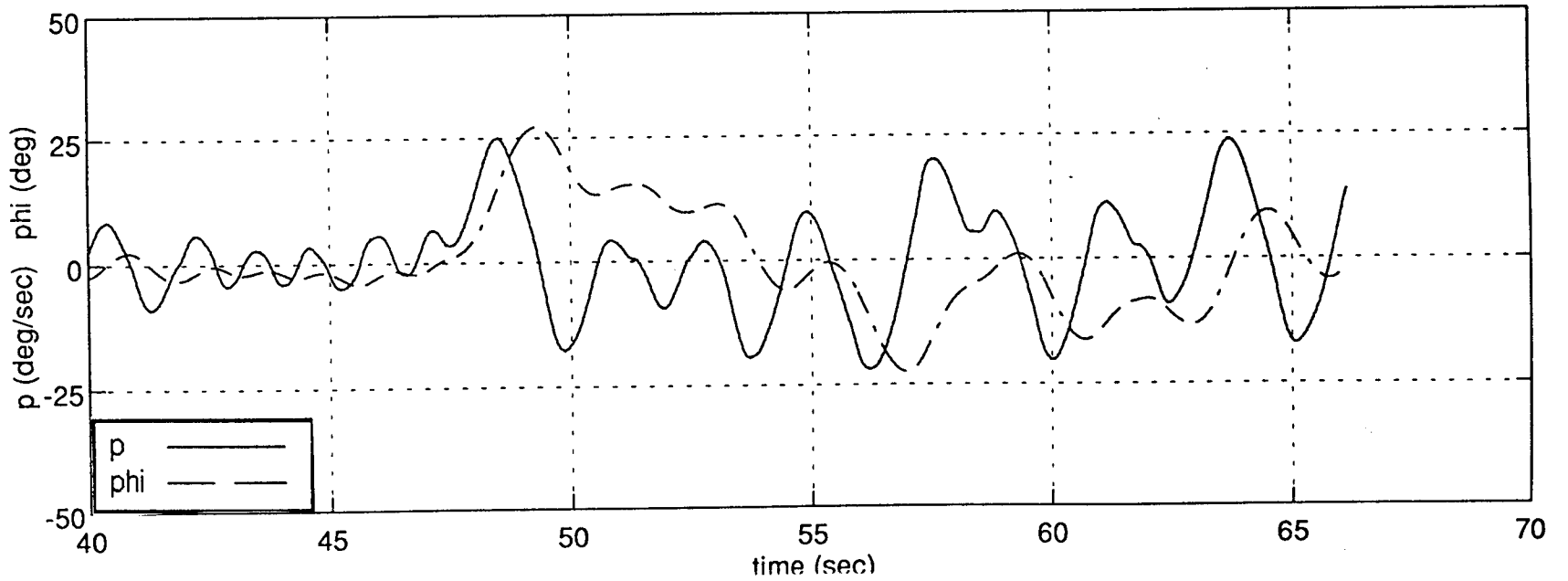
On several of these, they're all taking about the same kind of compensation. You put an input in and you may not get what you want, but when you get close to what you want, you take about half of it out and then ease the rest of it out. That's the only way and I couldn't even do that on that one and get it on the ground where I wanted it, meaning on the asphalt or concrete, let alone on the rest. And that was the worst one I've seen, by quite a bit. Part of that might have been sensitivity--you know, the roll rate, you kind of like it OK, but not when it does that to you.

FLT 449 REC 15 RL = 20 deg/sec RLC OFF

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APPENDIX C



C-80



Evaluation 15 **Flight** 447/2 **Flight Evaluation No.** 6 **Event** 11

Configuration 307 **Stick** Side **Type** Force **Rate Limit** 20 deg/sec

Pilot Johnston **Safety pilot** Deppe **Computer operator** Buethe **Flight test engineer** Shafer

Algorithm RLC **Passes** 2 **Runway** 10L

Pass Record **Offset** **Wind** **Performance**

1 12 Right 040/6 Desired

2 13 Left 060/5 Desired

CHR 4 **PIOR** 2

Inflight comments

1st pass:

Turning base:

EP: Flying it now. Feels fine. I'll square the base here just to get a little bit more wings-level evaluation of it before we take it in. Right now I feel like I can be about as aggressive as I want with it. It's still kind of rolling off to the left.

Turning final:

EP: Overshooting my desired offset slightly. Slightly fast on final.

SP: Correct

EP: Correcting. Sluggish. Very sluggish response.

SP: Starting a little low on this one, by the way.

EP: Put it right in the box.

SP: A little bit of a skid there. I think we hit in the box.

EP: Quite a bit of a skid going over it.

EP: That one was different than anything else I've flown before. It really felt sluggish in there and it just felt like I lost my crisp airplane and all of a sudden I was flying an airplane that was sluggish and non-responsive. Not like it was rate-limiting me like I've seen before, but the flying qualities have just gone to pot. Desired performance attained. Considerable, close to intense pilot compensation. You noticed that once I started correcting, I was no longer talking, no longer trying to do anything but just get it there.

SP: The gains may have been up a little bit on that one because we were lower than the rest of the approaches when we started that. I know my gains were up on that one.

2nd pass:

On downwind:

EP: On the engage, wants to roll to the right slightly. I mean, to the left. Towards the throttles.

SP: Say again about the throttles?

EP: It wants to roll towards the throttles. I didn't bring my painted gloves.

SP: Maybe that's part of it. It is pretty sensitive to differential power in roll.

EP: On the base turn I feel like I have a good-flying airplane and that I can be aggressive. Minor pilot inputs to keep the bank angle and the turn radius that I'm desiring.

On final:

EP: OK, I'm looking like I'm on the glide path that I want.

SP: Correct

EP: Sluggish initial response. It's going over there, though. Rolling out. Coming back. This one, I feel right now that I can make it without a problem. Sluggish. It builds up like a bias. Wants me to roll out, I'm still in to hold right and going left.

EP: Two slightly different approaches there. The first one, I think it might have been just because we were low. I felt a lot better on that one once we rolled out and I felt like we had more wings-level time coming in and I had more time to make decisions, make corrections, and handle the airplane.

[Desired] both times. Is it satisfactory without improvement? No. Deficiencies warrant improvement? I would

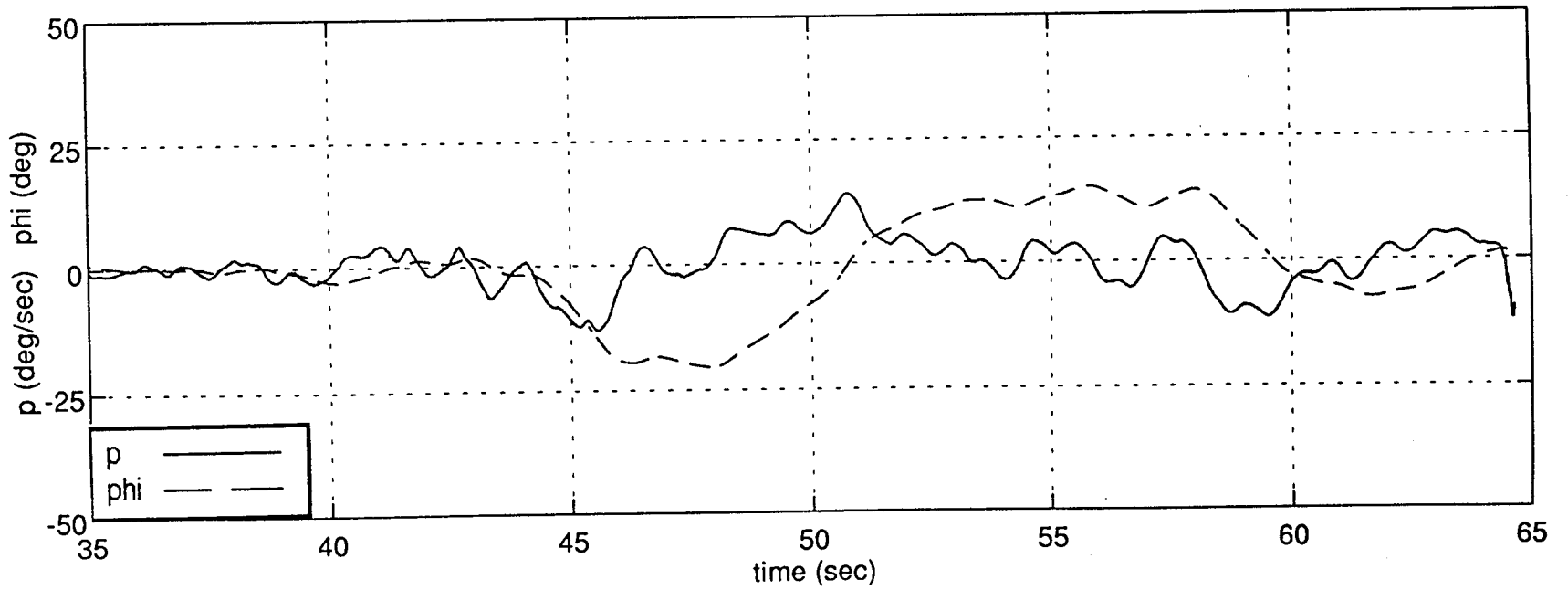
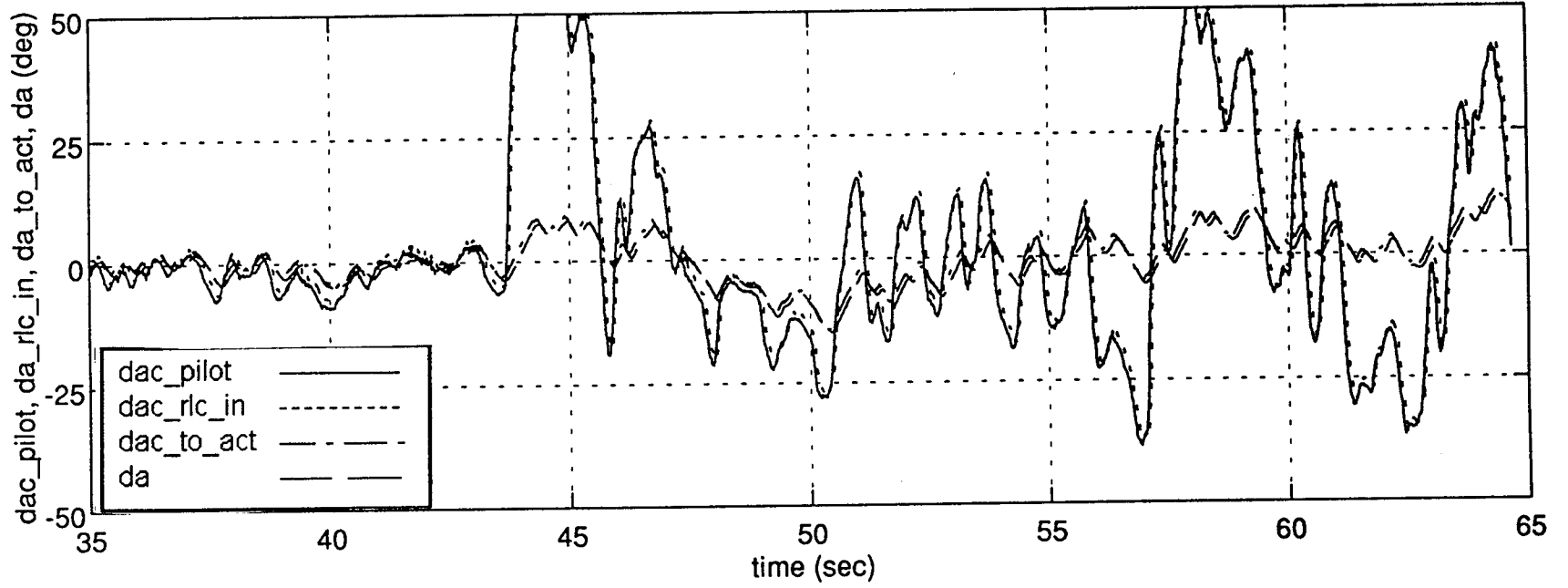
call the compensation I used last time moderate and I felt like, on the last approach, I'm giving it a higher rating, or more weight in my rating, because of the first approach being low. You may want to repeat this one later on because of that, especially if you just have one to do. I'm coming up with a Cooper-Harper of 4--desired performance requires moderate pilot compensation, considerable at times. Undesirable motions do occur. PIO rating of 2.

Postflight comments

EP: Got desired both times. The first time, we started out low on the approach. The first one, I didn't like very much at all. I think it was a bad pilot setup on the start. We were just too low and therefore we were making all our corrections too low to the ground, which upped the gains quite a bit. The second one achieved desired. I thought it was moderate. The undesired motions were slight overshoots, I think. I'd have to listen to the tape on this, but I think the undesired motions which caused the PIO rating of 2 were slight overshoots. 4,2.

Remarks

FLT 447 REC 12 RL = 20 deg/sec RLC ON



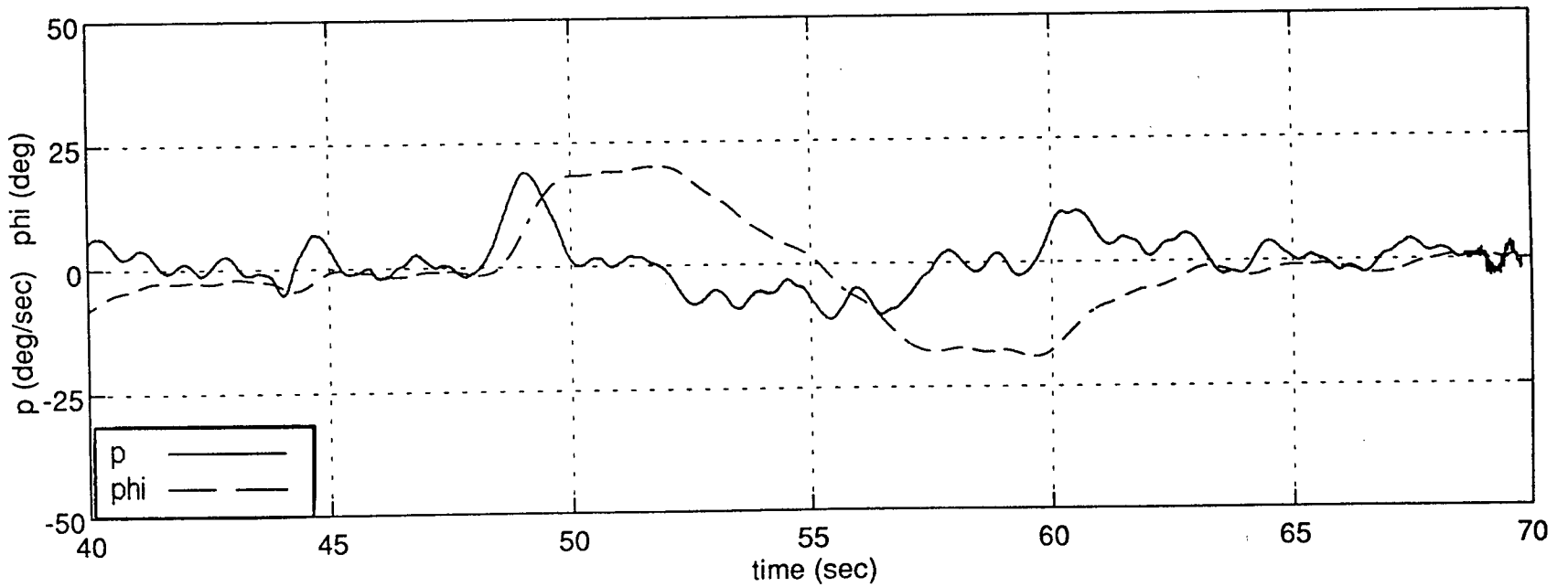
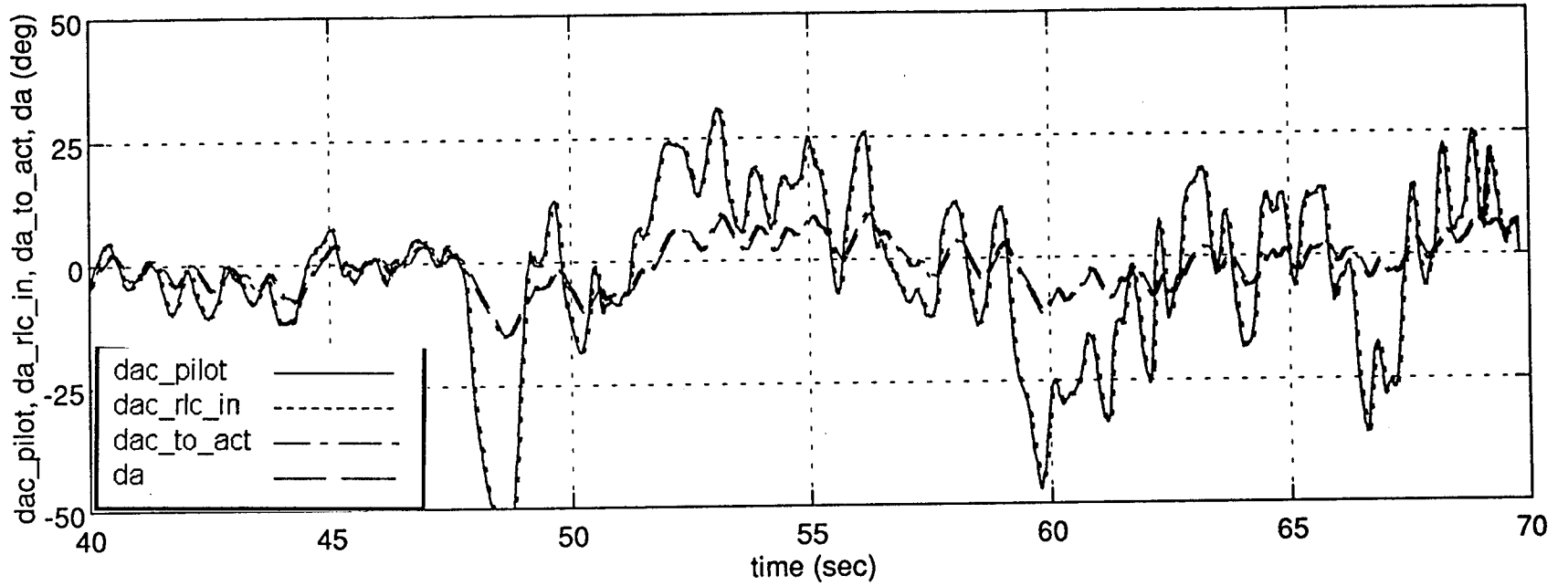
C-83

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FLT 447 REC 13 RL = 20 deg/sec RLC ON

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APPENDIX C

C-84



Evaluation 26 Flight 448/3 Flight Evaluation No. 7 Event 14

Configuration 307 Stick Side Type Force Rate Limit 20 deg/sec

Pilot Smith Safety pilot Buethe Computer operator Deppe Flight test engineer Shafer

Algorithm RLC Passes 2 Runway 10L

Pass	Record	Offset	Wind	Performance
1	19	Right		Desired
2	20	Left		Desired

CHR 3 PIOR 1

Inflight comments

1st pass:

EP: Easy airplane to control. It has some deficiencies that I'll talk about more later. I can't really identify them here. It's just not totally smooth in its response but it's predictable. I guess mainly the forces are modulated somewhat--not totally linear in the lateral. But I'm able to fly with confidence and with the same degree of aggressiveness and get the performance.

2nd pass:

EP: I actually got a little more aggressive in close. I made a little aggressive last-minute correction which I was able to, started to get a little slow, was able to contend with that and get around it and touch down just about the beginning of the area. So I had a lot of confidence in this airplane that it wasn't going to go anywhere. It just has a little lack of, I don't know, perfect smoothness in the forces but again, the word is confidence. The airplane's responsiveness is diminished somewhat. I can then compensate and be a little more--I guess if I compared it to some of the other ones it's not as responsive but I can put in the responsiveness with confidence.

EP: OK, adequate performance? Yes. Satisfactory without improvement? Yes. I'm going to give it a 3 rating. Mildly unpleasant deficiencies I think satisfies me at the moment. A 1 on the PIO rating scale. So that's a 3 and a 1.

Postflight comments

CO: You made good comments on that. You said you were "confident of the airplane". You gave it an HQR 3, PIO 1.

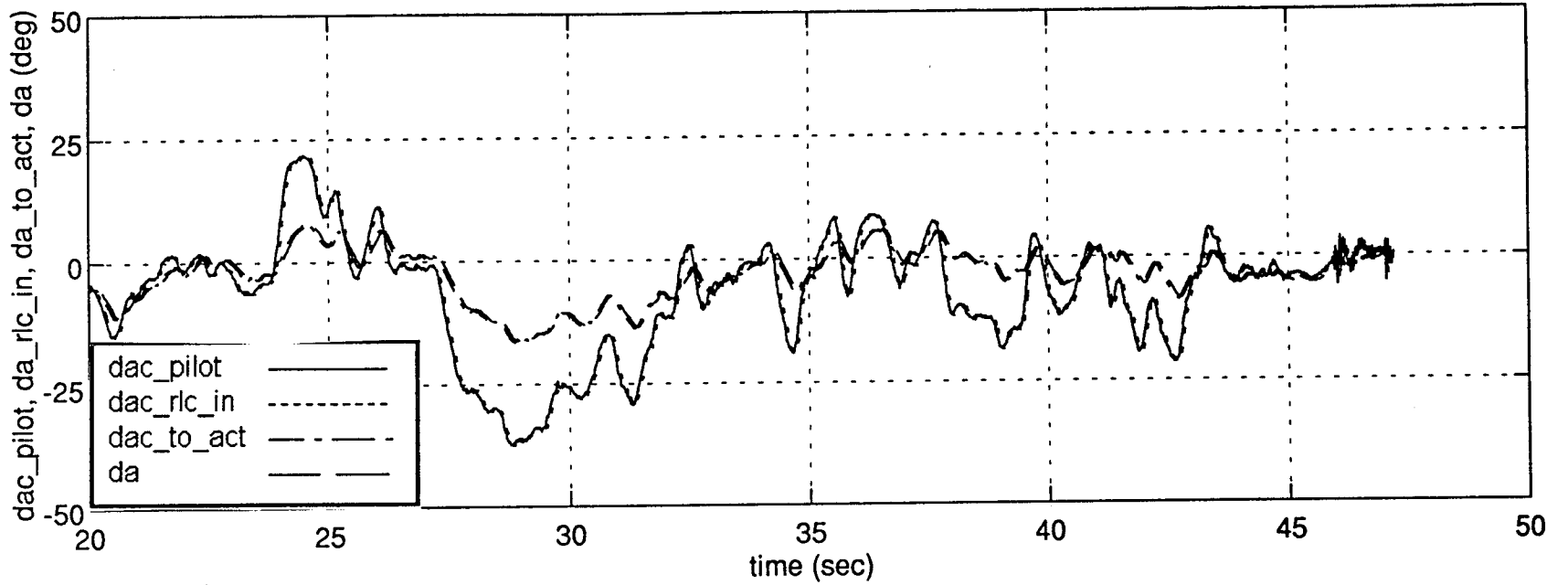
EP: I think that one I do remember. I think the key word there is confidence. I had confidence that I could fly that airplane where I wanted, but there was something was bothering me, whether it was a 3 or a 4. It was something I wanted to comment on, that I couldn't quite define. I think it was just wasn't smooth, there was something, nonlinearities in the force. There was no question in my confidence. I could do what I wanted. Chick Chalk: Have you had any that developed a bias that you were conscious of, in the force?

EP: No. I made a comment on that, early on, when I was climbing out up and away. Compared to the T-33, I could make biases at will, by just oscillating the airplane, but I no sense of that here. With the T-33, if I came around the corner, we did it a couple of times, we'd just make a high base and a little dithering of my own practice, just checking the response--if I did that in the T-33, with many of the configurations, I would end up with a really noticeable offset. I did not ever feel any of that characteristic today, which was very strong at times in the T-33. It wanted muscle just to hold large stick displacements, more muscle. I didn't feel that. Up and away, when we were playing with it, I was kind of looking for that. I was making inputs to see if I'd get an offset. At one time I thought I got different response rates, seemingly, coming out or going in, but I never felt like I got an offset.

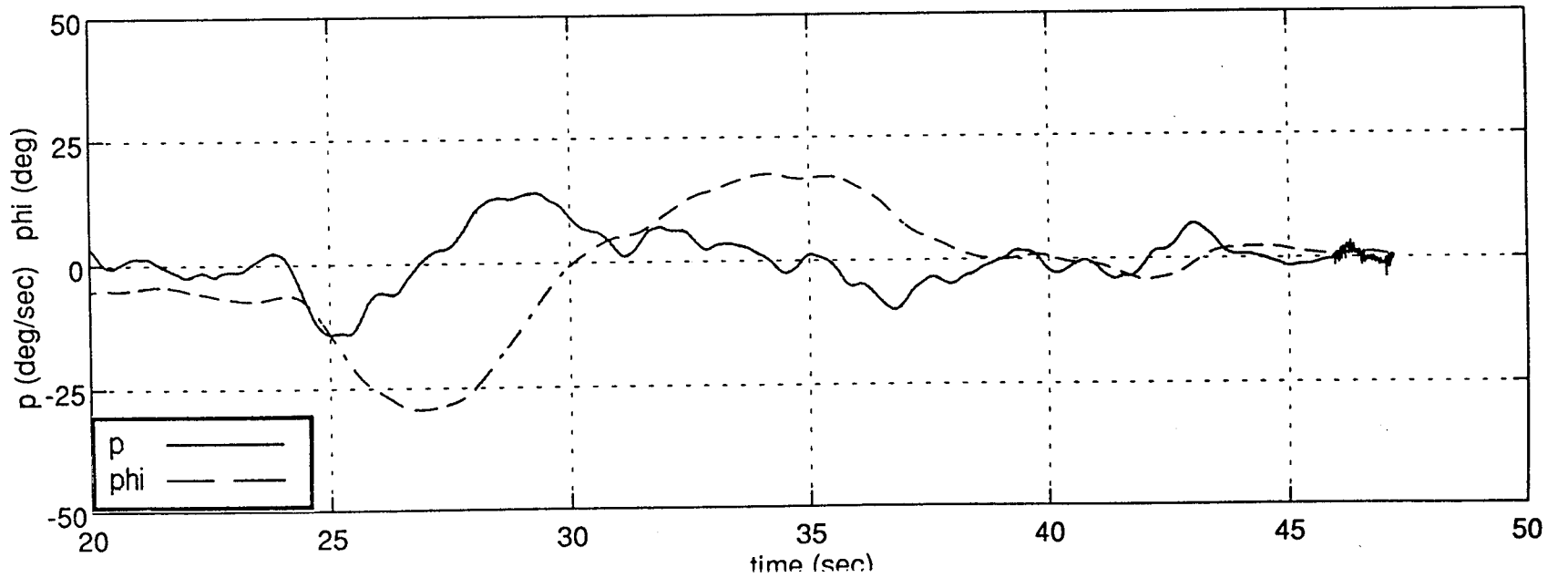
Remarks

FLT 448 REC 19 RL = 20 deg/sec RLC ON

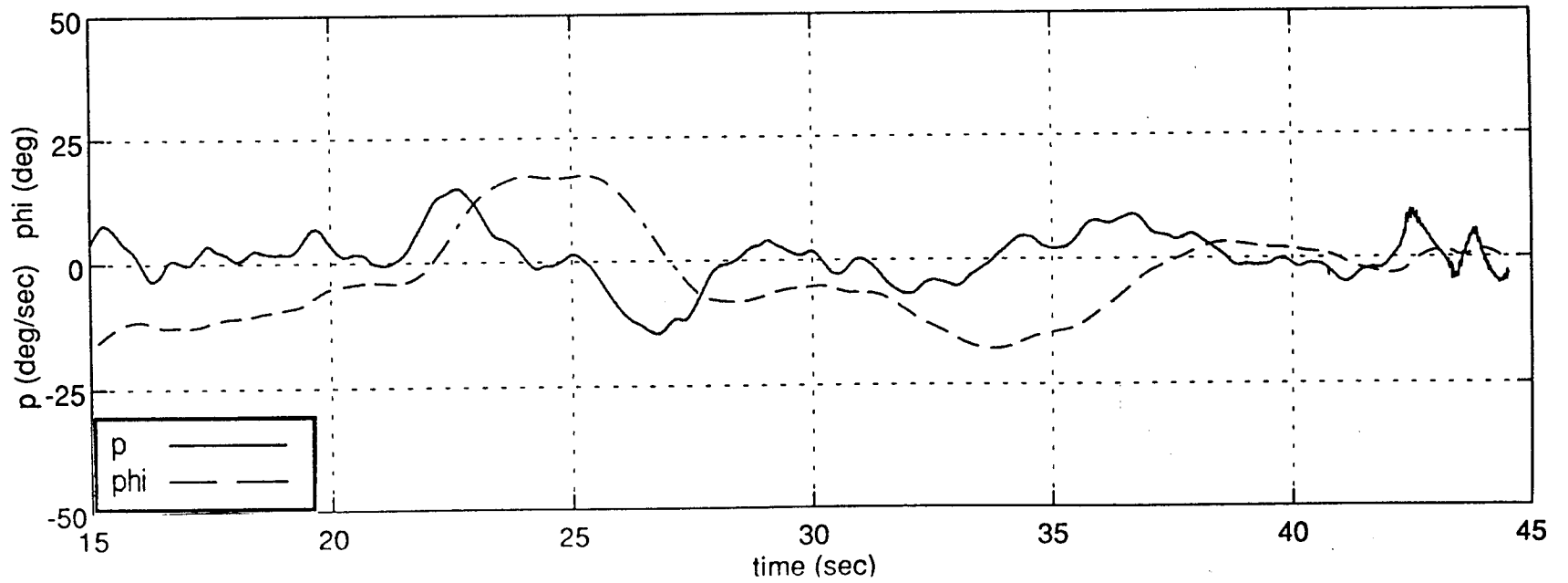
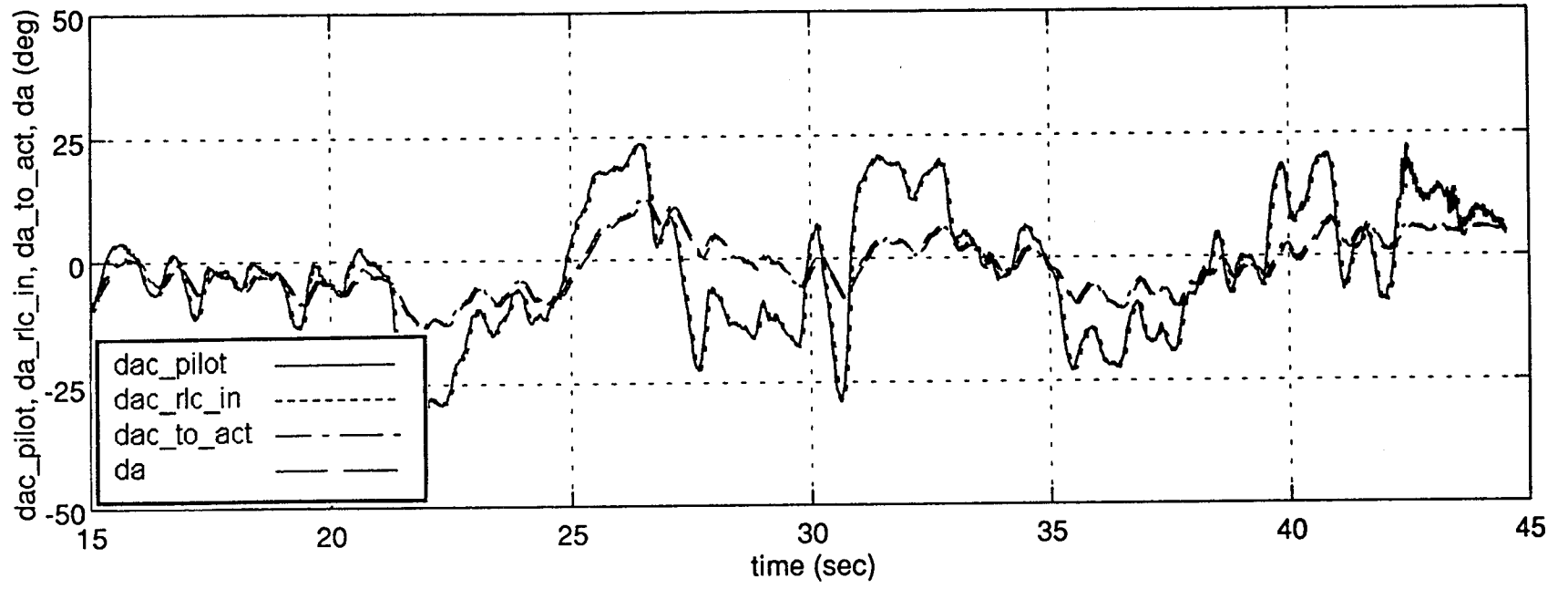
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APPENDIX C



C-86



FLT 448 REC 20 RL = 20 deg/sec RLC ON



C-87

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APPENDIX C

Evaluation 34 Flight 449/4 Flight Evaluation No. 7 Event 14

Configuration 307 Stick Side Type Force Rate Limit 20 deg/sec

Pilot Ball Safety pilot Deppe Computer operator Buethe Flight test engineer Shafer

Algorithm RLC Passes 2 Runway 10L

Pass	Record	Offset	Wind	Performance
1	16	Right	100/13	Adequate--long
2	17	Left	090/14	Desired

CHR 6 PIOR 3

Inflight comments

1st pass:

Turning base:

EP: This one feels a little, it's interesting. It's slow to get started but once it gets started then it feels like it's got quite a roll rate coming up So it's one of those that some people would call a little sensitive and some people would call sluggish, whether they're talking about the initial response or a later response.

Turning final:

EP: A little turbulence there. A little undesired motions in there, but nothing scary, just a pain in the neck and I'd rather not have it. It's getting a little fast.

On final:

EP: Forces feel heavy now that I try to pick wings up a little bit faster.

SP: Correct

EP: Force feels real heavy trying to make a big correction. I'm probably going to be fast; I was concentrating on the roll. Again, the forces are quite a bit higher.

SP: That was in the adequate box, long but on the centerline.

EP: I suspect the long was because I was paying so much attention to the roll. You just can't forget about the roll. You're concentrating on the roll all the time and then what's left over you're using in the pitch.

2nd pass:

On downwind:

EP: It's starting faster.

Turning base:

EP: When I go to a bank angle, I don't end up at the one I expect. Predictability in bank angle control isn't good. And then to get it to where I want it and hold it, I have to hold the pressure to keep it there. That's that out of trim feeling that I've been talking about on some of these.

SP: Correct

EP: I'm kind of sneaking in on this one, I'm not squaring the resulting final corner off. Part of my problem is I've got a longer aim point than I should have, although...

SP: Just got desired, just on the edge there.

EP: That doesn't surprise me, that's about the way the thing feels.

EP: Definitely it's not satisfactory without improvement. Due to that lack of predictability and everything which, as you were saying, I was adding extra power and so on just because I didn't feel comfortable getting down close to the ground and requiring a sharp turn, took a lot of compensation. One of them was get the turn in as fast as I could and then just be easing it out rather than trying to make a last-minute correction, because those are almost impossible. No more than adequate, I don't care where they landed.

Considerable...well, 5, I guess. These are kind of--with that one I did get adequate. I'm going to give it a 6. That's one you can argue for a 5 or a 6 but I'll go with a 6. I didn't see an oscillation. Definite undesirable motion and it did hurt the task--3. 6 and 3.

Postflight comments

FTE: A 6 and a 3. The first landing was adequate, the second was desired. He started out giving it a 5 and

then he changed his mind and made it into a 6.

EP: It was just how hard. That was one of those, I think, that I end up in the flare, holding these very strange forces. It gets out of trim and you're maneuvering and then, as you flare, you end up holding all this side stick one way or the other. So the compensation was quite a bit.

Chick Chalk: That's about the first comment of out of trim with the algorithm, right?

SP: No, sporadically there's been other mentions of that in that particular configuration, with the force side stick.

FTE: All three flew 306 [ratings were: Johnston, 8 and 4; Smith, 8 and 4; and Ball, 10 and 5]

EP: That ought to be one that's very sensitive to technique, I think, because if you've got somebody who's working it a lot, is it not possible that it's to be getting out of trim more than if somebody is trying to finesse the whole thing?

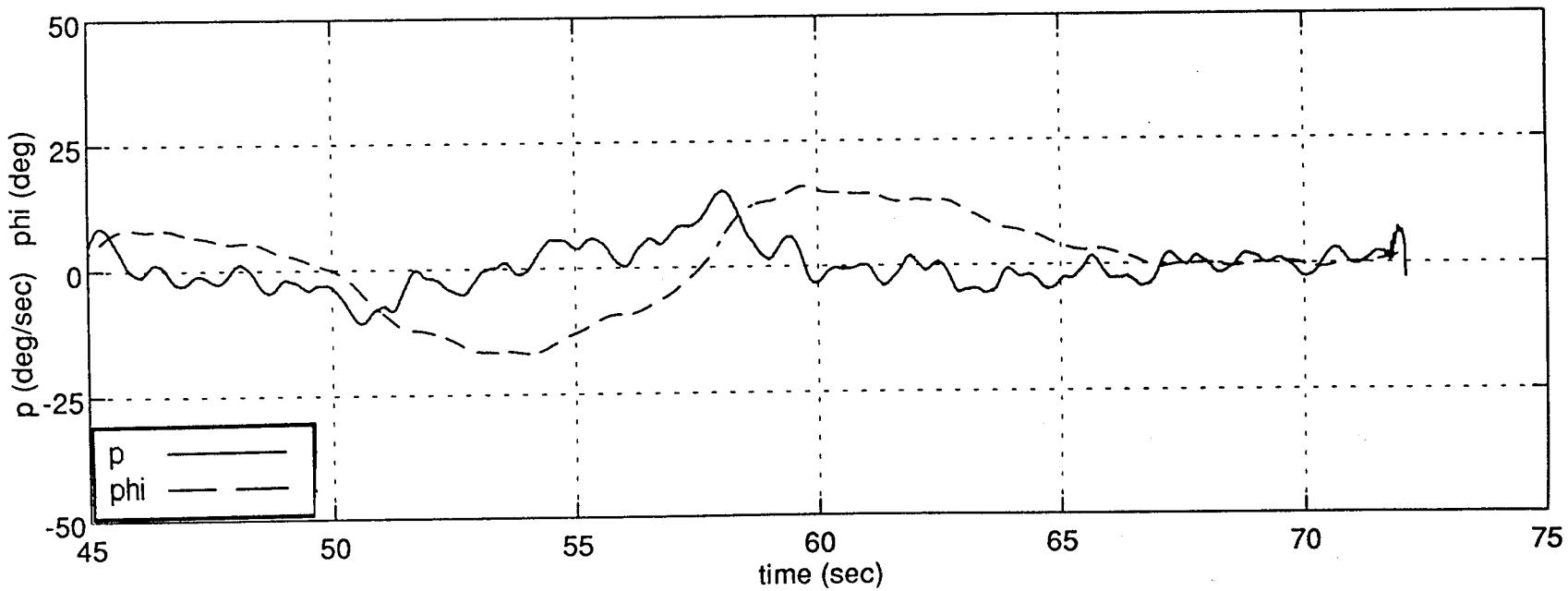
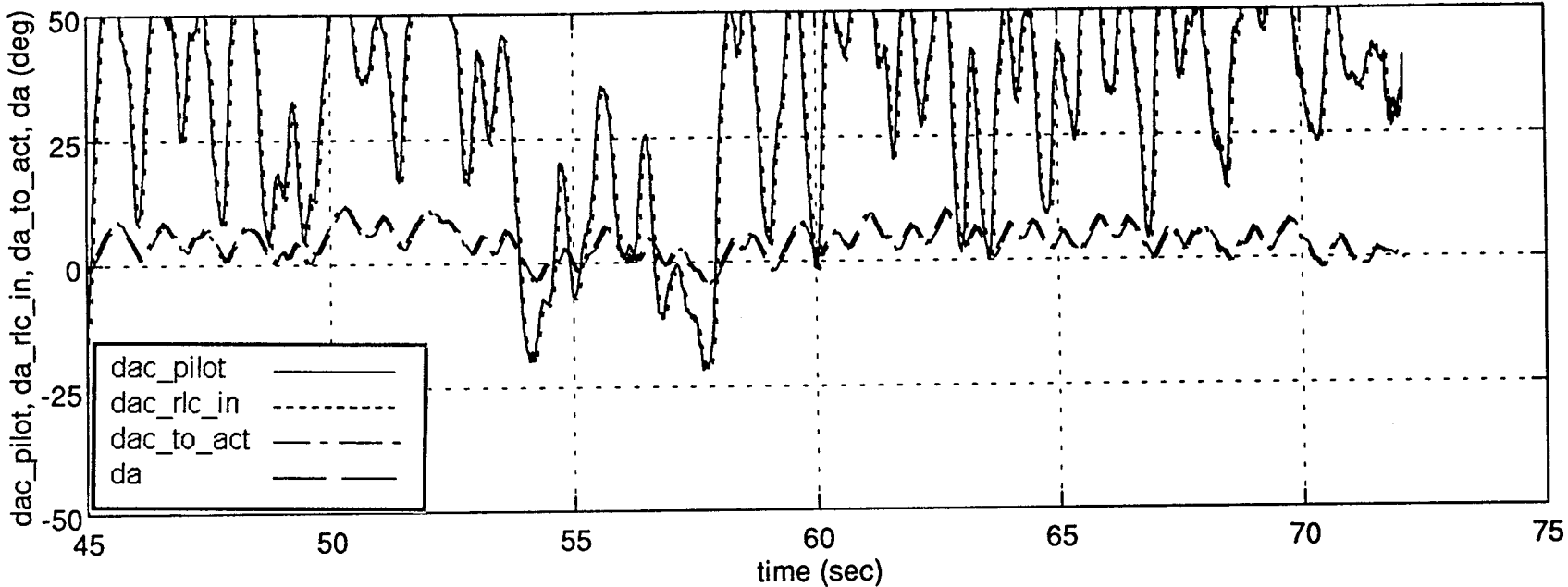
Chick Chalk: I was listening carefully for comments about "It gets out of trim on me". When they didn't say it, I specifically asked them about it. And none of them....

SP: Generally, yes, but I saw it happening in flight, occasionally, in the force sticks, particularly the side stick, there would be occasions where there would be some funniness there when we had the algorithm on, even with no noise added at all. It wasn't very often and it wasn't very noticeable, but it was there.

Remarks

After 1st landing: One thing I've noticed that you're doing, John, on all the configurations where you make an input and it's sluggish, the first thing you do is add power and you end up high and fast and diving for the deck. I'm not saying change your technique, I'm just observing. When you're working like that, your instinct is to add a little power because you're worried about, you know, those kinds of things EP. Yeah, that's right.

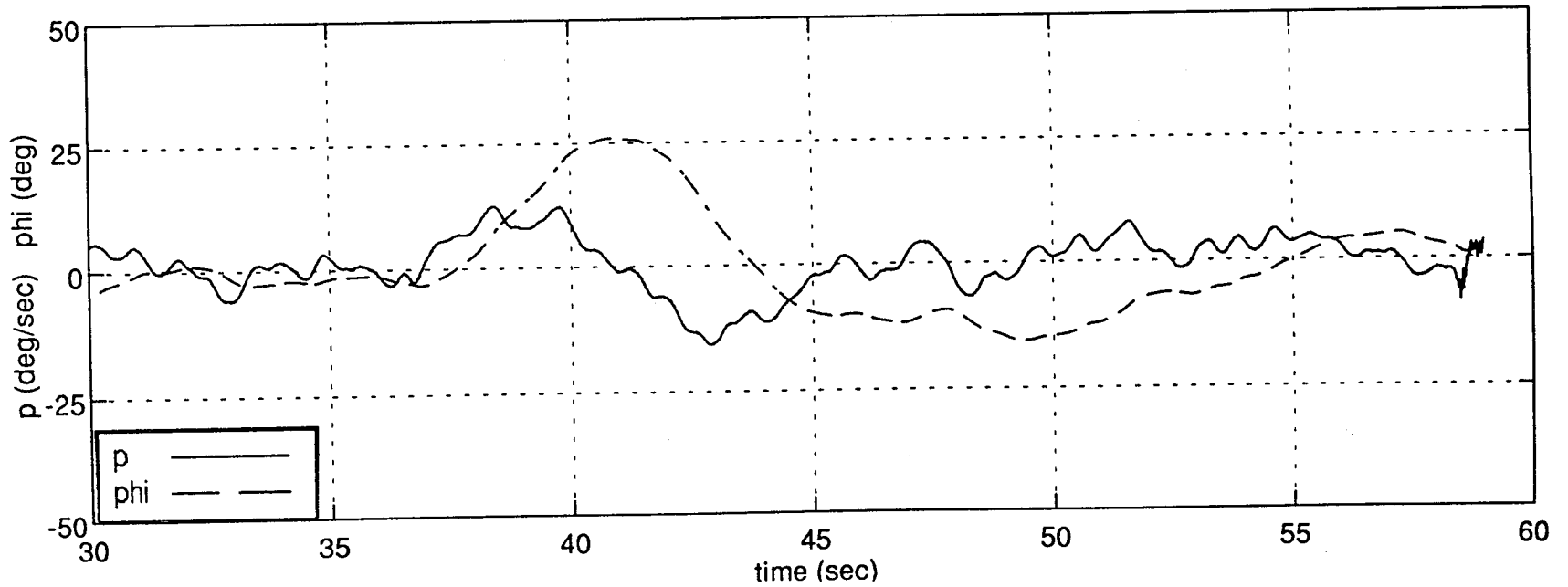
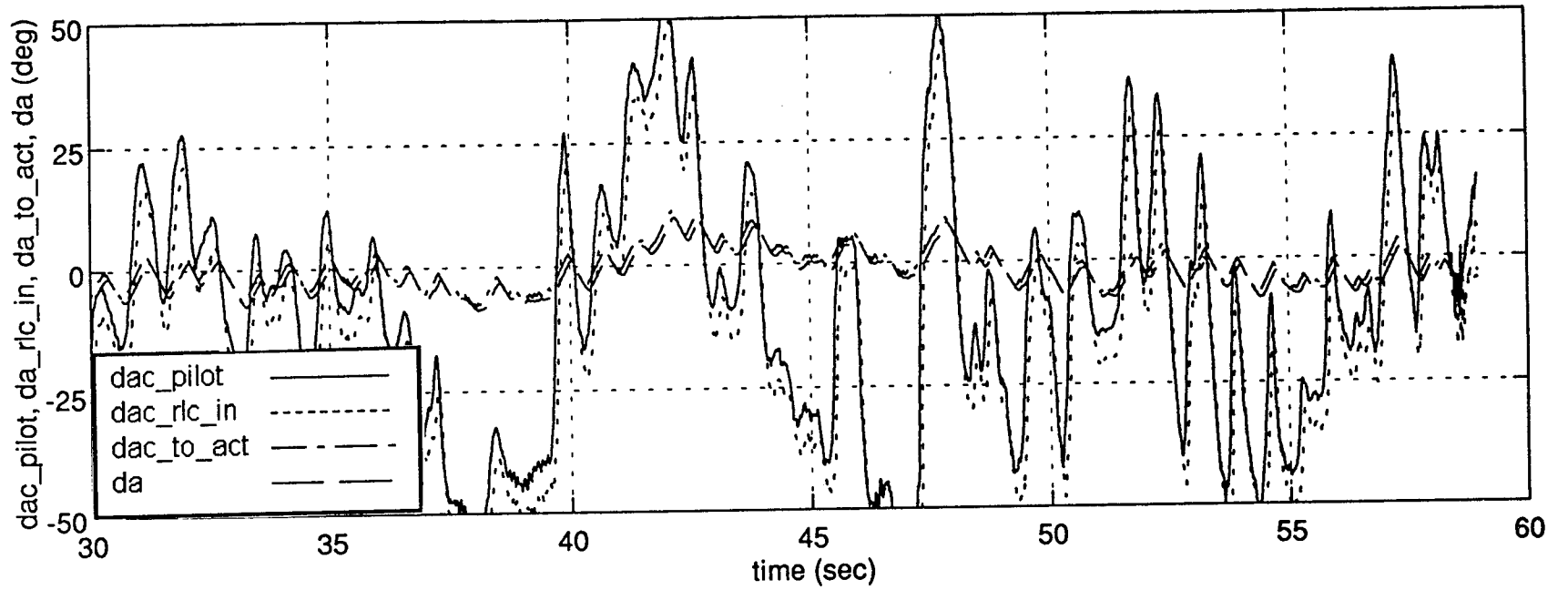
FLT 449 REC 16 RL = 20 deg/sec RLC ON



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C-90

FLT 449 REC 17 RL = 20 deg/sec RLC ON



C-91

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Evaluation 19 **Flight** 447/2 **Flight Evaluation No.** 10 **Event** 14

Configuration 000 + 20 **Stick** Center **Type** Position **Rate Limit** None

Pilot Johnston **Safety pilot** Deppe **Computer operator** Buethe **Flight test engineer** Shafer

Algorithm None **Passes** 1 **Runway** 05

Pass Record **Offset** **Wind** **Performance**
1 19 Right 030/3 Desired

CHR 3 **PIOR** 1

Inflight comments

1st pass:

CO: This is a mystery configuration.

SP: We really built up some fuel imbalance here, doing the same way pattern every time. About 300 pounds, in the wings.

On final:

EP: Good flying airplane. Feels fine. Not having to do any undue roll command corrections. On glide path. Starting on down. On final setup. Feel like I can be aggressive with the airplane. Got a little off.

SP: Correct

EP: Correcting now. Good initial input. No PIO tendencies. Easily controlled bank angle.

EP: It was easily controllable. I just didn't take a big enough bite and then come back. I thought it was going to be a little bit better than what I did. I felt like we got in within desired--probably our left main was right on the centerline, is where I thought it was.

SP: I agree.

EP: I give it a Cooper-Harper 3, with a PIO of 1.

Postflight comments

EP: Back here, to tell you the truth, I didn't realize we had a 20 millisecond update rate. It was a slightly different landing airplane. I did not feel that my performance back here was the same as the first landing up at Niagara Falls. I did not feel tired, I didn't feel like I was overtasked. As a matter of fact, I had a long break as we were flying back. I didn't take the airplane until 2 or 3 miles out on final, a comfortable time. I was just sitting there, we were talking about thing, so I felt like I was fairly relaxed, not overworked, not overstressed. I did not think that the landing was as good as my very first landing up at Niagara Falls. I think that we barely achieved desired there. I think that my Cooper-Harper rating was a 3, where I'd given it a 2 before.

Dave Leggett: I don't think I'd worry about the difference between a 2 and a 3, especially landing in two different places.

FTE: Same place. You did a full stop back here yesterday and gave it a 2 and a 1. Same runway.

EP: Yes, same runway, same place, about the same setup. To me it was definitely different.

FTE: Your comments were that it was different. There's no question.

EP: I was puzzled because I didn't realize you guys had done that to me. I thought I was flying the same basic airplane.

SP: I didn't either.

EP: Before, on the other landings, I always felt like--the hardest thing that I worked on, on the baseline Lear, was getting the main wheels to touch down in the length of the runway. The width I never, I mean that was always easy. I could get the centerline between the wheels very easily. On this one, I was working harder to get the centerline between the wheels. It was in doubt, up to the last little bit, whether I was going to achieve that or not.

SP: Crosswind? Runway 05 versus runway 10, the wind was from 080. It would have been from a different direction.

EP: That could have been it.

Remarks

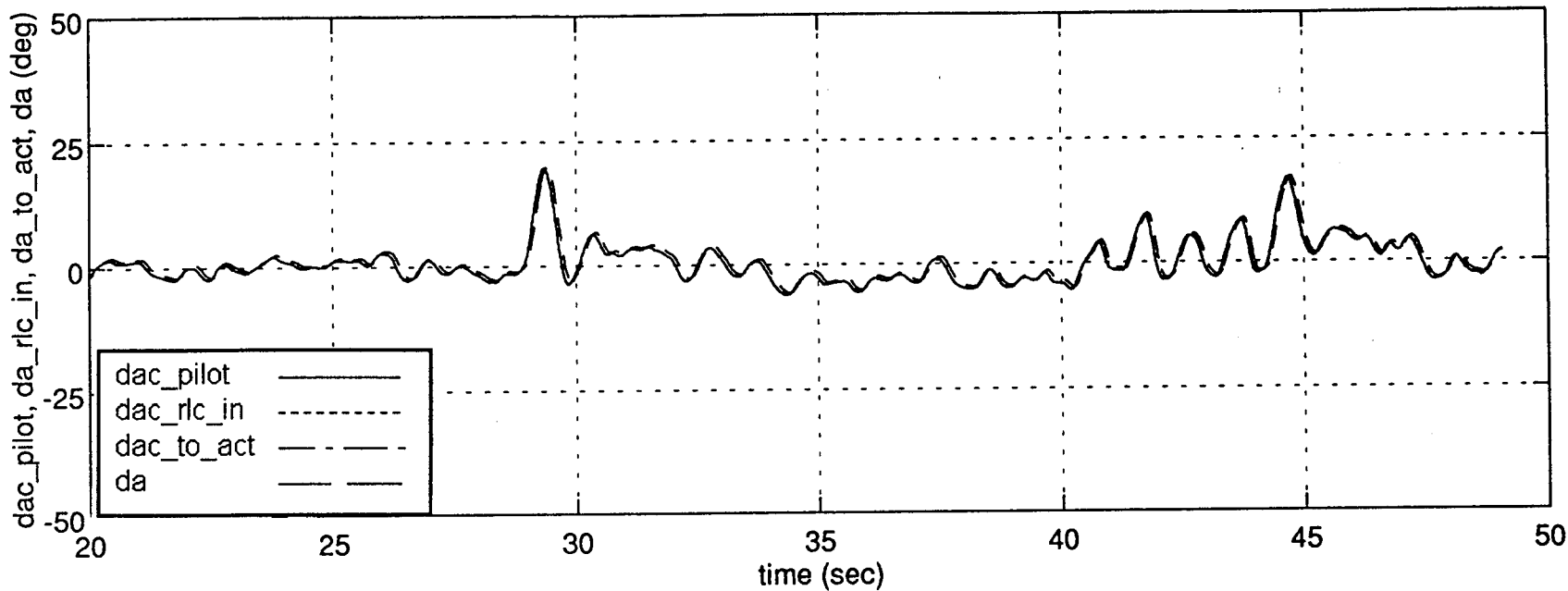
Full-stop landing at Buffalo International

Postflight:

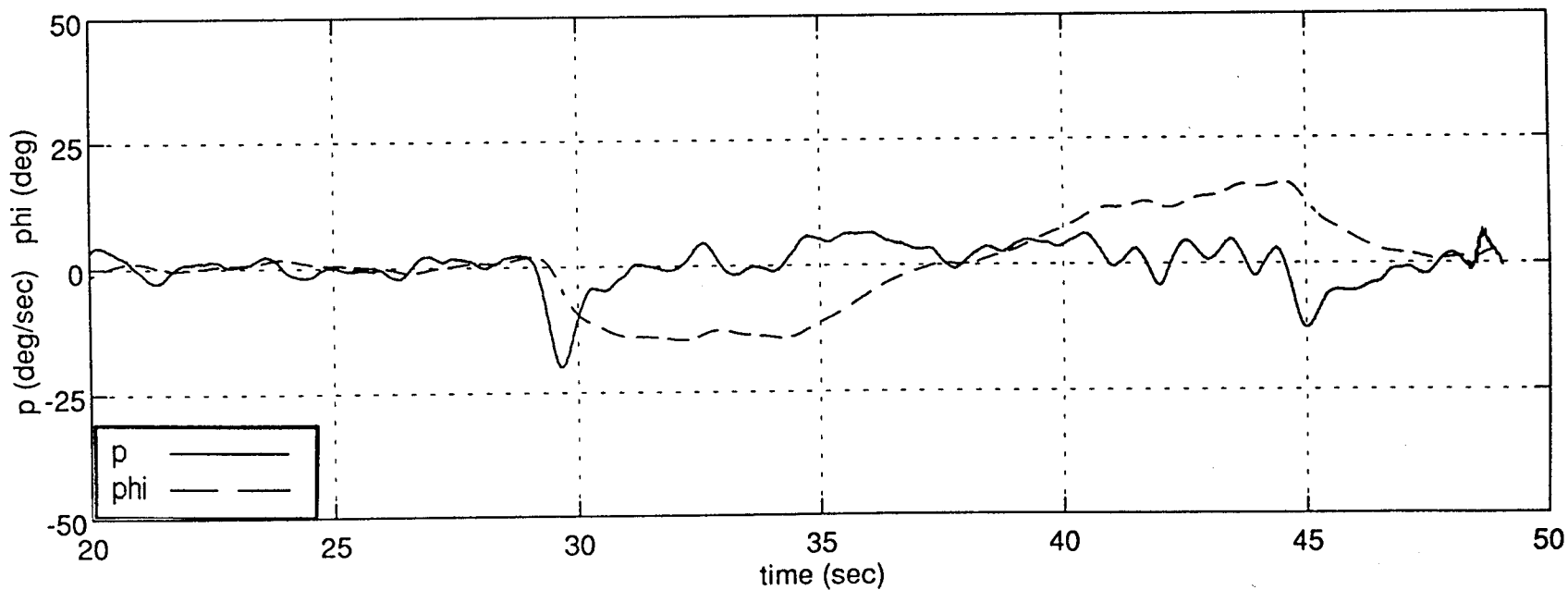
I never sensed anything today in the pattern that was trying to tell me that the airplane was rate limited. There was nothing that I felt through the controls that I could say, "Ooh, I'm rate limited" like yesterday when we got the cement stick, I could definitely say, "OK, I know exactly what the airplane's trying to tell me. It is feeding back information to me like a rate limit light would have just come on." Today in the pattern--nothing.

FLT 447 REC 19 NO RATE LIMIT

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C-94



Evaluation 18 Flight 447/2 Flight Evaluation No. 9 Event Alt 1

Configuration 301 + 20 Stick Center Type Position Rate Limit 20 deg/sec

Pilot Johnston Safety pilot Deppe Computer operator Buethe Flight test engineer Shafer

Algorithm RLC Passes 2 Runway 10L

Pass	Record	Offset	Wind	Performance
1	17	Right		Adequate--a little long
2	19	Left		Desired

CHR 5 PIOR 3

Inflight comments

1st pass:

Turning base:

EP: Airplane feels fine and flyable. A little sensitive, but not bad in roll. Pitch, it's fine. I haven't been talking much about pitch, but in pitch all of them have been just fine, it's well damped.

SP: It's pretty transparent, then. That's what we've been hoping for.

EP: Going for a right offset, easing out my bank to do that. Got a lot of time, not much pilot compensation.

Looking over at Niagara Falls. Airspeed's holding within 5. Looks like I'm a little high here, correcting on down. I feel like I can be aggressive with this airplane. Not spending too much time working bank angle problems, so I can spend more time holding the airspeed and looking at glide path.

On final:

EP: It's not real stable in bank, though.

SP: We're a shade low here.

EP: Bit of turbulence.

SP: Correct

EP: Correcting. Sluggish initial input. Works out fine. Kind of stair stepping out, I'm not sure why. The thing's flying fine, I don't notice any definite PIO tendencies, just sluggish. Real sluggish trying to get back. Come on, come on.

SP: You were working so hard, you forgot the power. A little bit long, in the adequate box. You seemed to be working there and when you got it sorted out, you said, "Oh, I had too much power."

EP: Yes, I was trying to figure out why I was

ATC: Keep it in real close. Your traffic is a KC-135.

EP: That won't be a problem.

2nd pass:

Turning base:

EP: Turning this one in a little bit tighter due to traffic. It's a fine flying airplane up here, so I'm not feeling uncomfortable with it.

SP: This is definitely a more sporty approach, but hopefully we'll come out smelling like a rose. Glide path looks good, offset looks good, good setup there

On final:

EP: We're stable here.

SP: Correct

EP: Sluggish there. Real sluggish. No PIO, just sluggish. In the box.

EP: Cooper-Harper 5, PIO 3. The moderately objectionable deficiencies is the sluggish roll response when you're commanding a higher roll rate. I had to have intense or considerable pilot compensation to keep from having undesirable motions, going into what I felt was going to be a PIO. I felt like I could overcontrol it fairly easily and I was compensating by using stair step approaches or stair step inputs. I was rolling it, rolling it, rolling it and not letting the roll rates build up too large. That's why the undesirable motions did tend to occur and they did compromise task performance.

Postflight comments

EP: I felt the airplane flew crisp. We got one adequate in there and one desired, is the only comments I have. A Cooper-Harper of 5 and 3.

SP: This is the one where you ended up with a bias, right? You ended up holding stick? You made several comments during both of these landings about how "I've got a bias in here now" . I'm pretty sure this is the one.

EP: I didn't write anything on that.

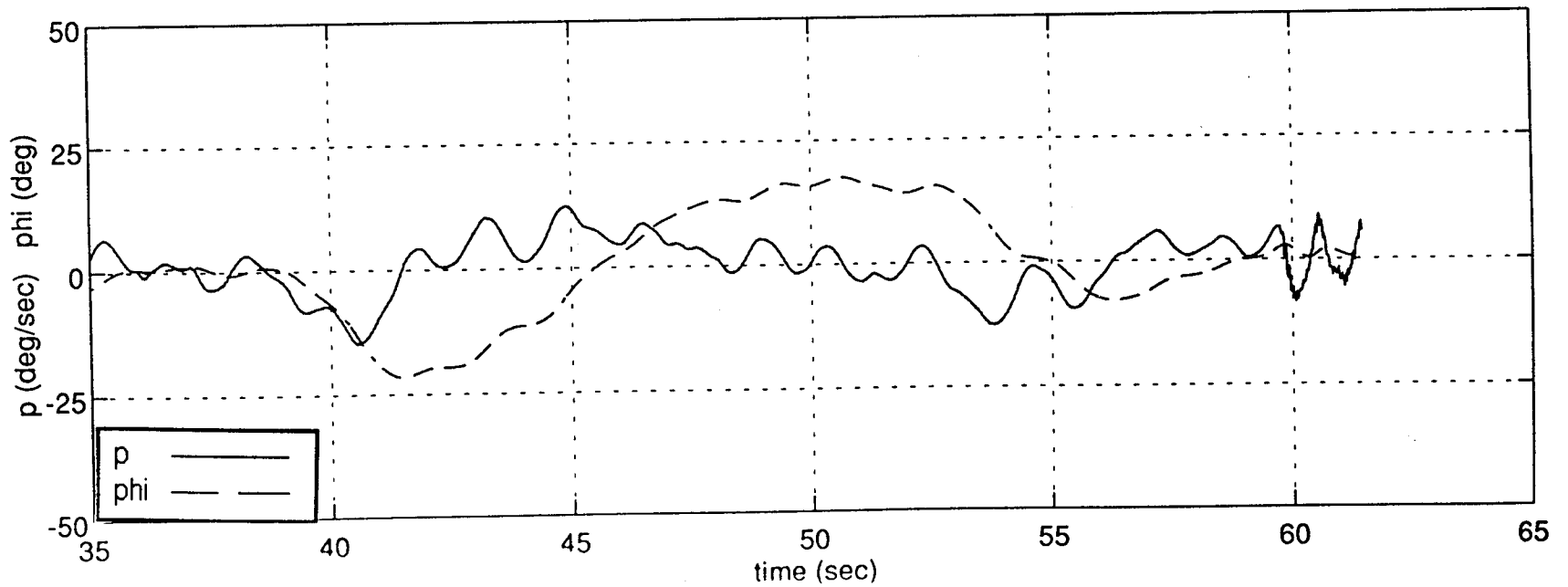
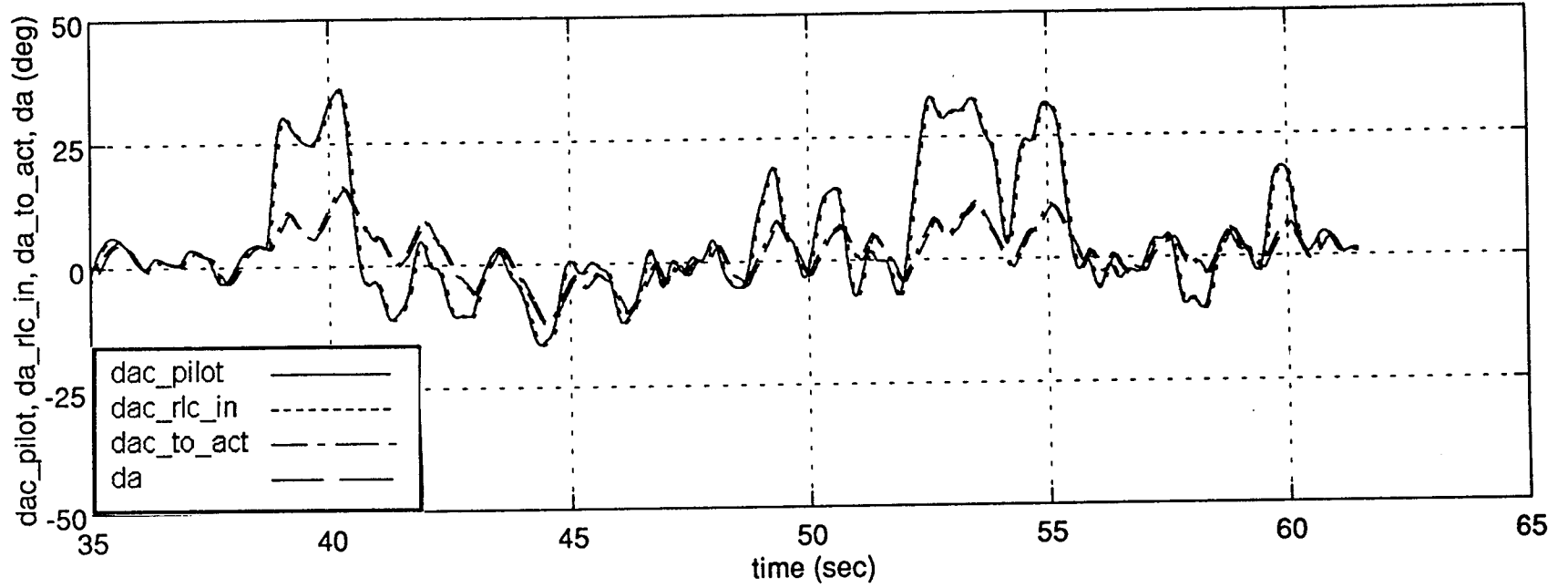
SP: We can check the touchdowns on these to see the angle and stick force. I'm pretty sure this was the one where the bias didn't come out.

EP: I flew a 301 yesterday, center stick, position, with a 10 millisecond update rate on it and it got a 4, 2 the first time and a 2, 1 the second time. So if anything, you might see a little bit of an effect there of update rate on the stick. A change of 1 on the Cooper-Harper isn't a real significant thing.

SP: The comments were different. Well, some of them were the same, but we had some additional things, like about the bias.

Remarks

FLT 447 REC 17 RL = 20 deg/sec RLC ON

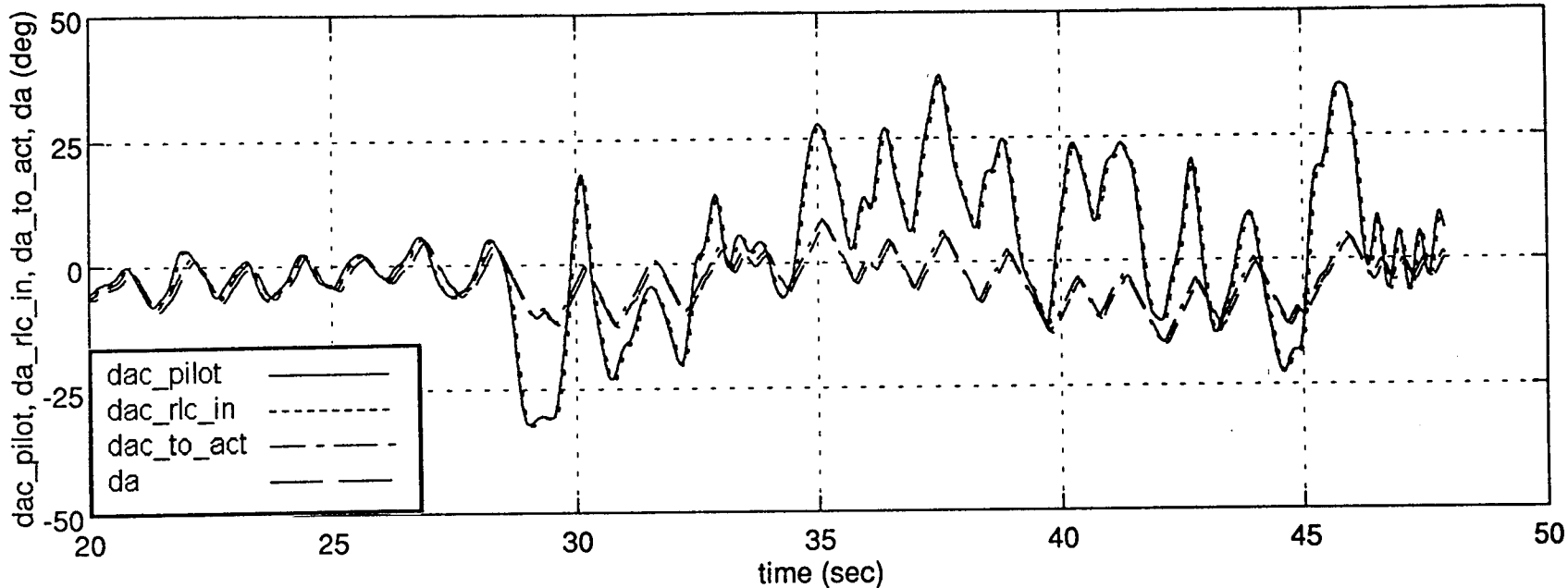


C-97

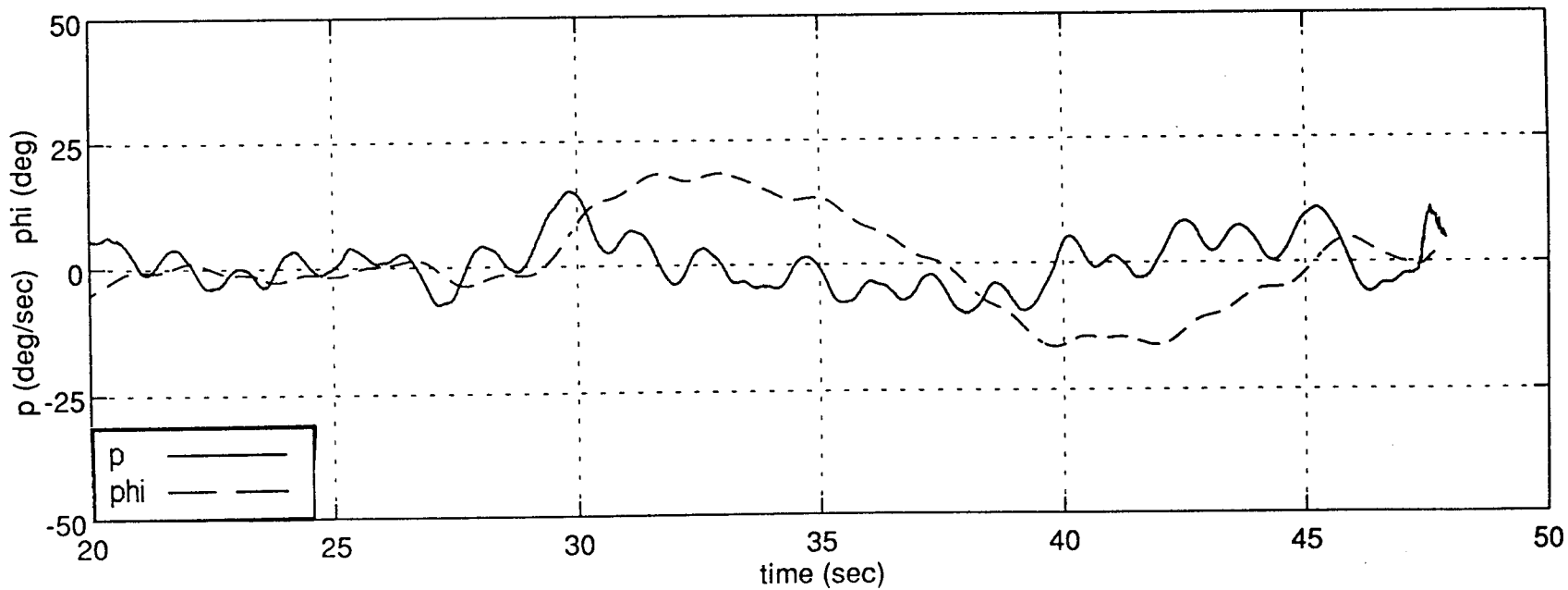
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FLT 447 REC 18 RL = 20 deg/sec RLC ON

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APPENDIX C



C-98



Evaluation 32 Flight 449/4 Flight Evaluation No. 5 Event 12

Configuration 301 + N Stick Center Type Position Rate Limit 20 deg/sec

Pilot Ball Safety pilot Deppe Computer operator Buethe Flight test engineer Shafer

Algorithm RLC Passes 2 Runway 10L

Pass	Record	Offset	Wind	Performance
1	13	Left		No landing
2	14	Right	090/15	Adequate

CHR 9 PIOR 4

Inflight comments

1st pass:

On final:

EP: I seem to be a little busier trying to keep the wings level this time than I have been before. Just little corrections but putting in a lot of them. And they might be getting bigger the closer to the ground I get.

SP: Correct

EP: Ooh, I don't think I'm going to like this.

SP: I think that would have been OK but I wasn't quite sure about that right wingtip there.

EP: Yeah, there certainly seems to be a series of disconnections there, just varying degrees of looseness. That's another one that takes a lot of compensation to keep from getting into real trouble with.

FTE: You felt disconnected from the airplane?

EP: Yeah, you put an input in and nothing and then it kind of comes sweeping in. It isn't like you've got this control that's hooked right to the airplane. It's like you're flying it through a big rubber band or something.

2nd pass:

On final:

EP: The same thing I saw before, the closer to the ground I get, the busier it gets. Busier meaning stick inputs, a lot of them. Tends to overshoot.

SP: Correct

EP: I'm purposely backing out my aggressiveness there. Ow, all of a sudden it's a real beaut. More aggressive rollout there. Last time I was able to compensate a little better, but this time.

SP: Adequate

EP: You couldn't prove it by me. Workload way too high and sooner or later you're going to catch that one out. That takes a lot of compensation to keep that thing going. I think I may have lucked out a couple of times on it.

EP: OK, I'd have to say it's controllable with a lot of--you have to be very careful with it. Definitely not good performance. Tolerable pilot workload? I was concerned for control, very much, and the first time it was probably more like considerable [input?] but much less input but this time it was [garbled]. I'm going to give that one a 9. An oscillation? Yeah, it was but I wouldn't say it was divergent. A 4 on the PIO scale.

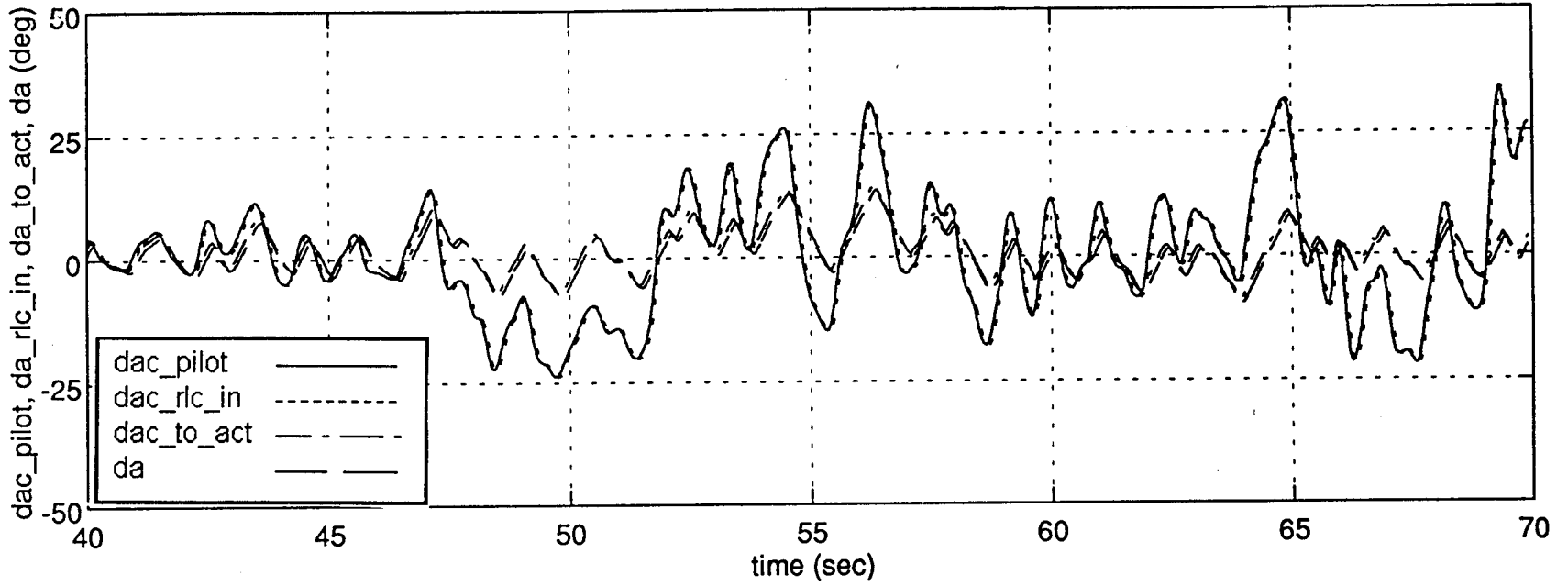
Postflight comments

[See postflight comments for evaluation 31]

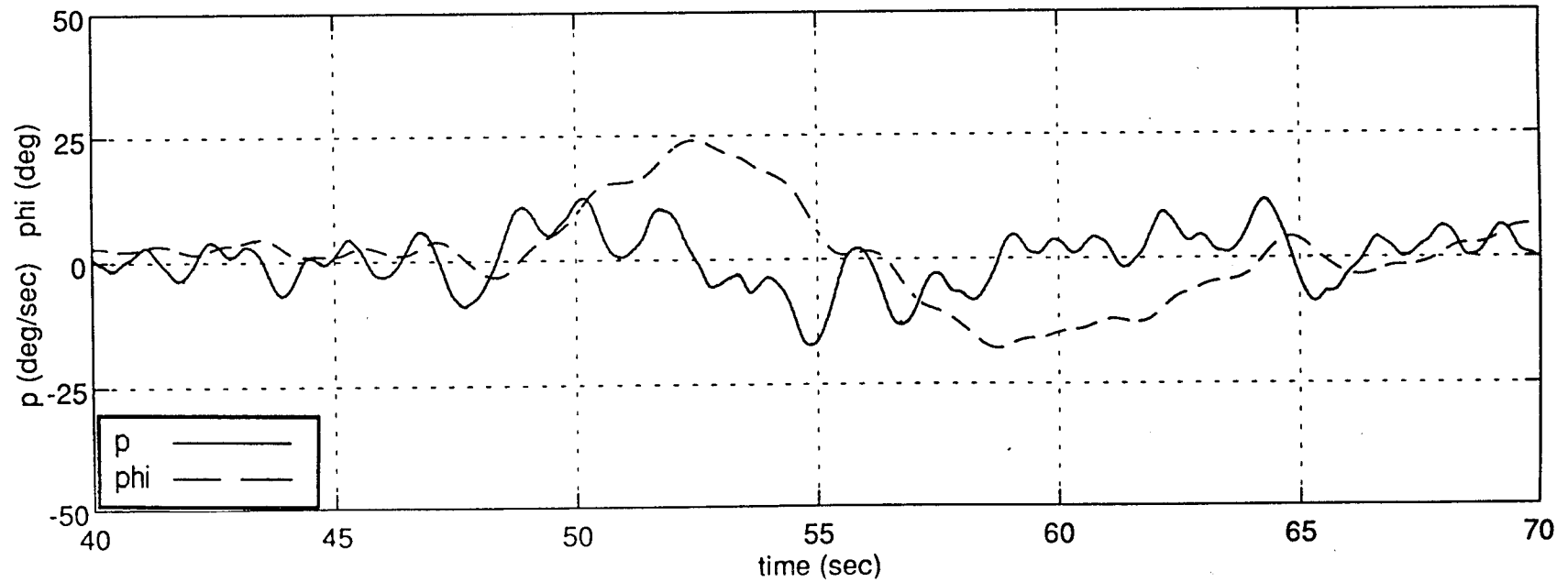
Remarks

FLT 449 REC 13 RL = 20 deg/sec RLC ON

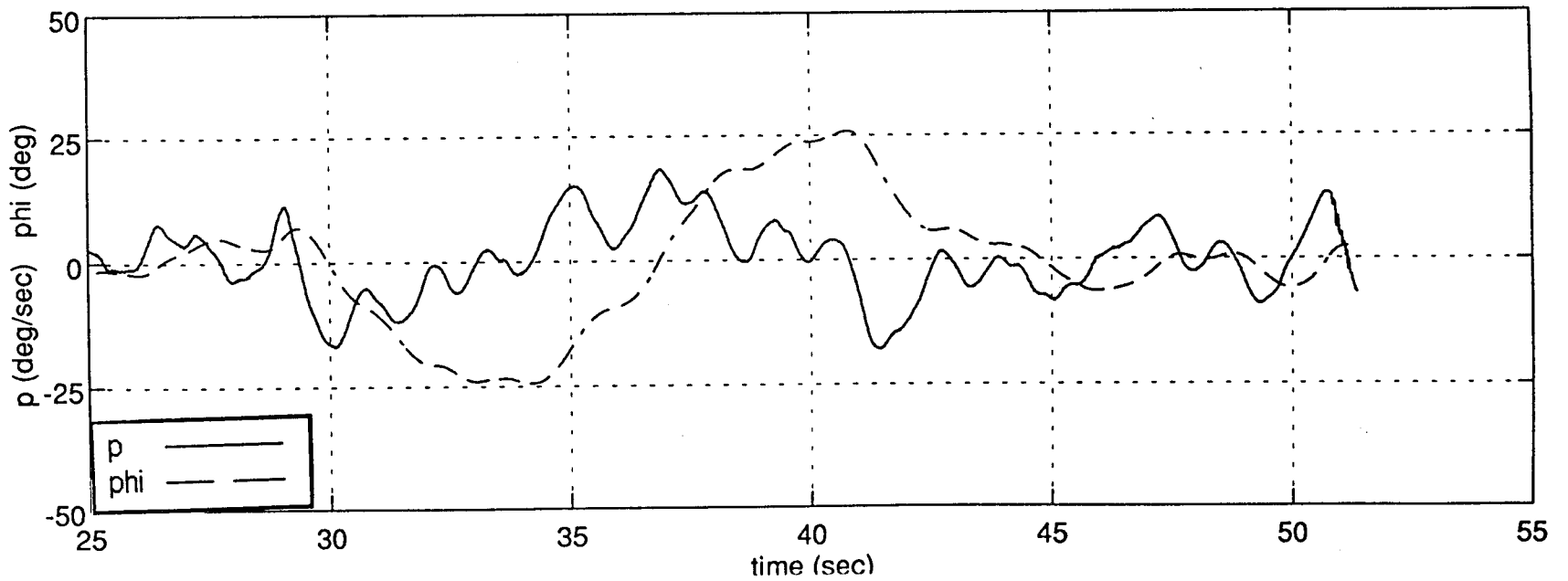
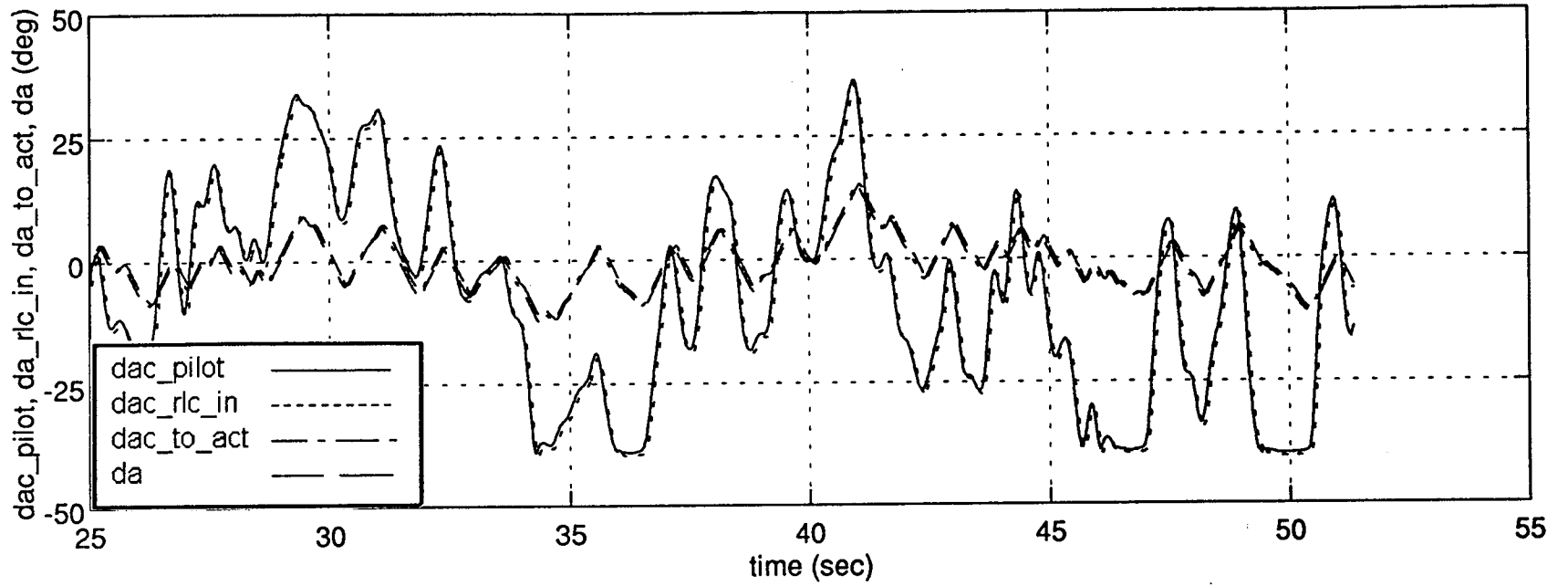
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C-100



FLT 449 REC 14 RL = 20 deg/sec RLC ON



C-101

Calspan Report No. 8091-2
APPENDIX C

Evaluation 31 **Flight** 449/4 **Flight Evaluation No.** 4 **Event** 11

Configuration 301+N+20 **Stick** Center **Type** Position **Rate Limit** 20 deg/sec

Pilot Ball **Safety pilot** Deppe **Computer operator** Buethe **Flight test engineer** Shafer

Algorithm RLC **Passes** 2 **Runway** 10L

Pass	Record	Offset	Wind	Performance
1	11	Left		Desired
2	12	Right	100/14	Desired--a little sideways, there

CHR 4 **PIOR** 2

Inflight comments

1st pass:

SP: Correct

EP: Get over there, you little devil. And it's out of trim, but it's settled out now.

EP: It tends to be sluggish and it overshoots just a a little bit. It doesn't have a nice, tight, connected feel. It doesn't take too much compensation to get it back to do what I wanted it to, but it wouldn't be my favorite.

2nd pass:

On final:

EP: After a couple of bank angle changes, I feel like I'm out of trim, I end up holding quite a force.

SP: Correct

EP: A little sluggish to get it started. I got this one started a little early so I wouldn't have to make a square corner.

EP: I had to hold some odd forces because of the trim in the flair. Were both of them in desired? They were. OK, well, I wouldn't call that satisfactory without improvement by any stretch. I'd give it a 4 on the HQR. I didn't see an oscillation, but I saw an undesirable motion. It's kind of on the edge of whether it really did the performance or not., but I guess, well, I did get the performance. I'll give it a 2 on the PIO. It easily could be a 3, though. I didn't put it exactly where I wanted it, like I could with the other ones, but I guess if I met the desired performance, that's what the thing's all about, so I'll say that it didn't. It had undesirable motion that was very undesirable and I wouldn't want an airplane to have that particular characteristic, if I had a choice.

Postflight comments

FTE: A 4 and a 2, with two desired landings.

EP: Well, I'm surprised at that one.

FTE: That's what you said at the time. You didn't want to rate it that well.

SP: You kept saying that you had some out of trim conditions for a little while there.

EP: But obviously I didn't. If I'd have had an oscillation--well, I didn't have an oscillation. I called it a 2.

FTE: You said that if you hadn't gotten the desired performance, you wouldn't have thought it was as good as it was, or something to that effect.

CO: The thing that makes it interesting is that on the next evaluation, where we cut the cycle time in half, you gave it a 9 and a 4.

EP: That's hard to believe, but I did.

[Intense discussion of noise spectrum and other issues deleted]

EP: But to go from a 4 to a 9 and back-to-back, now. There isn't any kind of contamination.

FTE: But if you go back and look at his comments, he hated the 4. He felt that he had to give it a 4 because he managed to get it in the desired box but he didn't think it deserved a 4.

EP: That's against the philosophy that I've been expounding here that just because it's in the box doesn't necessarily mean that it's good.

FTE: Well, we'll listen to the tapes.

EP: That's what really surprised me, back-to-back. If one of those had been at the beginning of the flight and

the other one at the end, I'd have said, "Well, OK" I couldn't have changed the task that much.

[Much more discussion of noise spectrum]

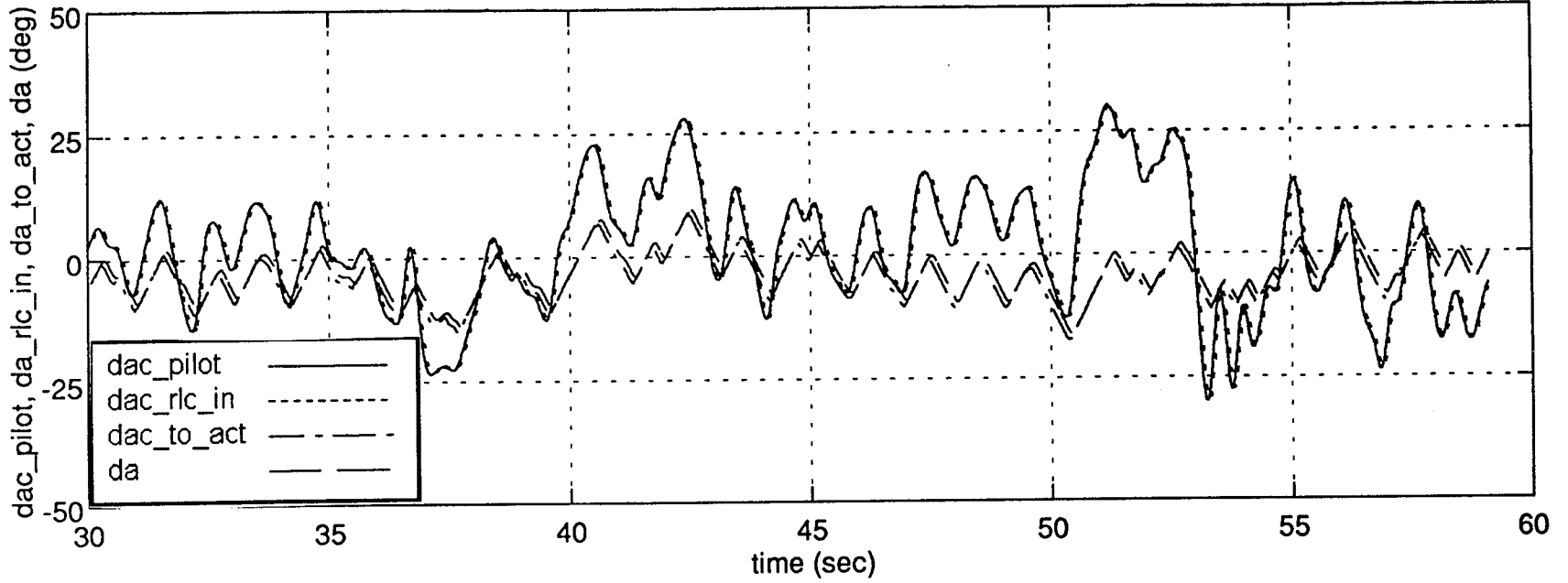
EP: I am just amazed. That is not just a misstatement, the difference between 4 and 9. I mean, one of them I'm really worried about controllability and the other one, it's not even close. I don't understand that.

SP: Up and away, the comments were different. You had different impressions.

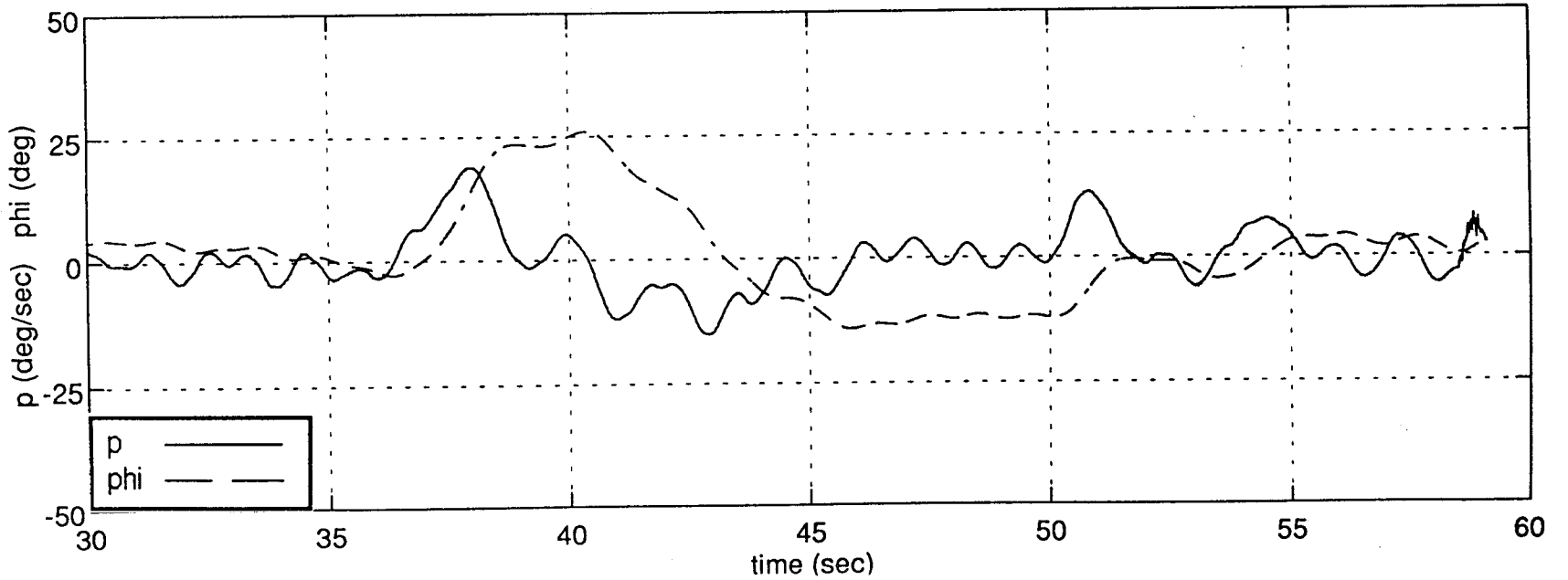
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FLT 449 REC 11 RL = 20 deg/sec RLC ON

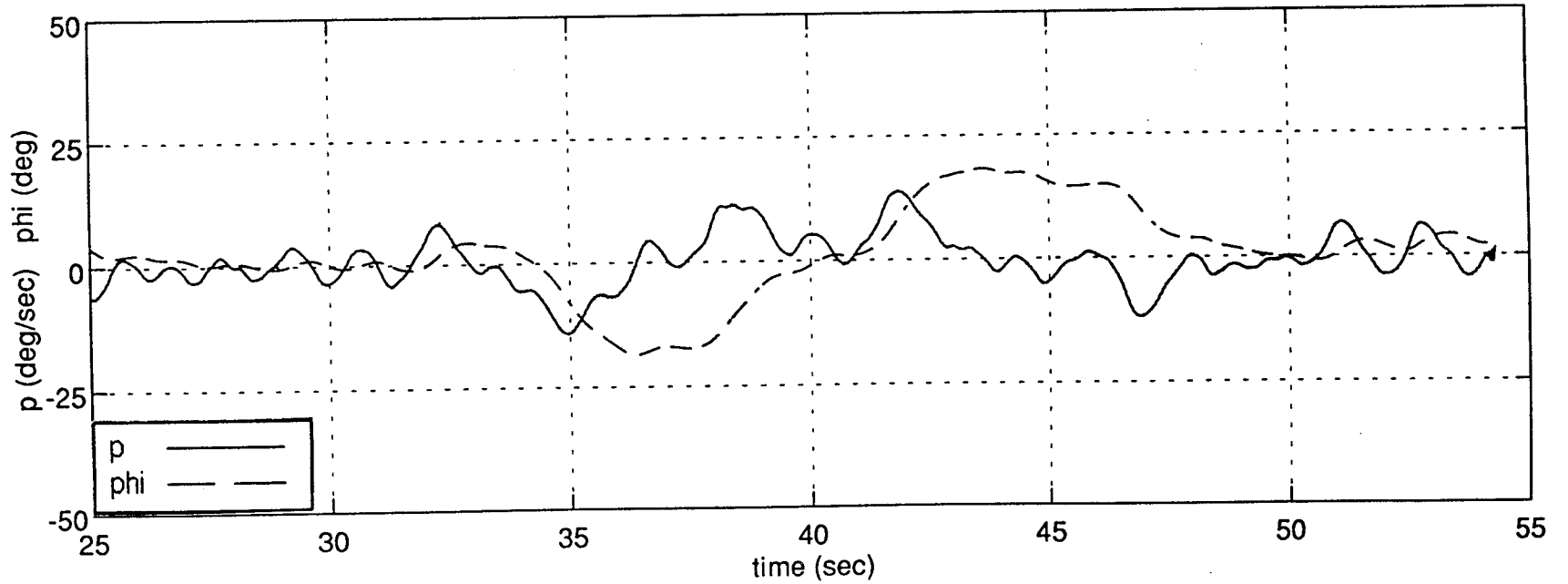
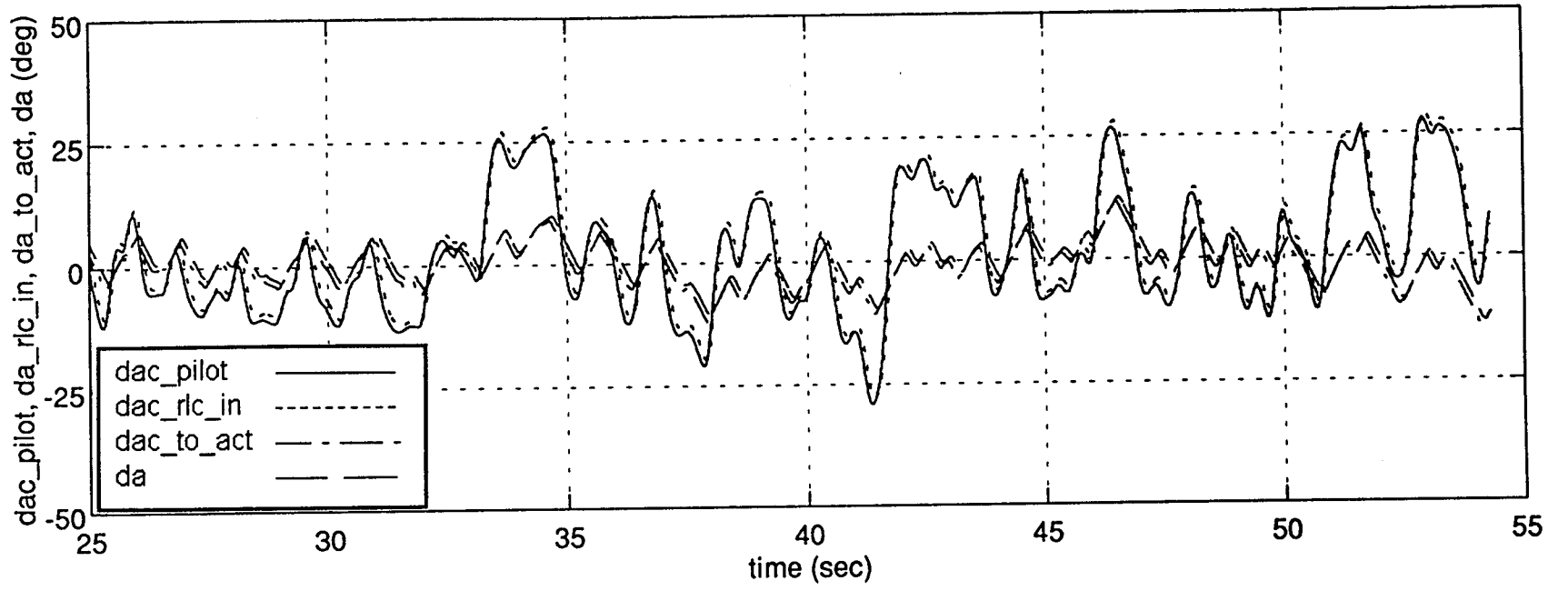
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C-104



FLT 449 REC 12 RL = 20 deg/sec RLC ON



C-105

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Evaluation 17 Flight 447/2 Flight Evaluation No. 8 Event 13

Configuration 321 Stick Center Type Position Rate Limit 20 deg/sec

Pilot Johnston Safety pilot Deppe Computer operator Buethe Flight test engineer Shafer

Algorithm Low frequency stick Passes 2 Runway 10L

Pass	Record	Offset	Wind	Performance
1	15	Right		No landing
2	16	Left		

CHR 9 PIOR 4

Inflight comments

1st pass:

EP: This is a little bit squirrely on downwind. I'm having quite a bit of inputs just to hold wings level.

Turning base:

EP: Right now, I'm not feeling like this is all that good of a flying airplane.

SP: We turned a little earlier, too.

EP: OK, I'll shallow this out. You're right, we did turn early. It's like stick talk back. The stick will move without me even doing much. It wants to center itself. Strong centering force. It feels like it's just kind of wallowing in my hand. Slight PIO here, very minor. Definitely PIO.

Rolling out on final, maybe a little low. Correcting back.

SP: Correct

EP: Sluggish. Whoa, buddy. Trying every thing I can to keep from getting in a divergent PIO. We're definitely in a PIO, it was not divergent.

SP: [Takes control] Sorry, I wasn't happy with the plane going down like that.

EP: That's OK. Fine by me.

EP: That was a Cooper-Harper 10.

Something's different in the stick on that. It wants to kind of move in my hands, back and forth. It's kind of wandering. I did not feel anything that the stick was talking back to me or giving me any clues of when it was rate limiting, however. There was something going on there I was totally oblivious to it.

2nd pass:

On downwind

EP: Got a very stable, now. Let go. Rolls off slightly left. Watch this in here walk. I want to keep putting in inputs. It's like I'm in a minor roll PIO right from the, just holding wings level.

Turning base:

EP: It's so minor, it's just slightly annoying. You're just kind of saying, yeah, this thing just doesn't feel like it has much stability. I don't know why, but it feels like it has heavy centering forces on the stick but at a very low frequency. It wants to drive the stick back to neutral when I put in an input, but it's such a low frequency it tends to feel like it almost overshoots and drives a little bit past. That may be what's feeding the slight roll PIO--I'd call it less than a degree, it's just barely visible from the front.

On final:

EP: Suddenly I've got time to talk, time to look at airspeed, look at glide path. I feel good, comfortable about it. Not sure how aggressive I can be with the airplane. Minor turbulence. Not a factor. Slightly low, but not a problem.

SP: Correct

EP: Correcting. Big input. Definite PIO. Trying to stabilize the PIO now as I'm driving towards the field. I do not feel the stick talking to me at all. Now I'm easing out on my gains. I'm going to try and stabilize this. I think I can make it but whether we do or not is in doubt.

SP: [Takes control] I think we would have, but it just--we probably would have, but we would have been close to a 10. We probably would have made that one.

EP: At best that's a Cooper-Harper 9, with a PIO of 4. I say they're not divergent. It took intense pilot compensation to keep them non-divergent.

Postflight comments

[See remarks from previous evaluation]

EP: 321 [event 13] was a 9, 4 for a rating. Kicked off both times, but both time I thought I could do it, especially the second time. The second time I thought I was going to get there, I thought it was OK.

SP: That's right. I kicked you off pretty late, real close to the ground because I just wasn't a 100% sure we were going to have a low enough bank angle, but I made the comment there that "Yeah, we probably could have made both of those." It was right on the edge, there.

EP: About the same comments for me as event 10. Might have dinged a wingtip a little bit

SP: Because we were still in it, we were in it the whole time. Didn't we touch down on one of those?

FTE: Isn't that the one that we touched down on the left wheel?

SP: Yes, we touched down while we were in a low-amplitude PIO there.

EP: The biggest thing to talk about on this one was this was where I felt like the stick was just moving around on me. I thought that was objectionable. I did not like it. It's like I'm trying to figure out why is this stick moving. What would happen is, you'd go to command a left roll, you'd put the stick to the left, the airplane would start rolling to the left, and then the stick would start wanting to come out. You'd almost have to hold continuing force to hold in that roll rate. Then, if you let go of the stick, the stick had strong centering tendencies and would want to center itself and actually even just overshoot a little bit. Coupled with what appeared to be a very positive spiral mode, that when the stick centered, the airplane wanted to roll out. Like the stick was always kind of wandering around in your hand. I tend to hold the stick very loose anyway, when I'm not maneuvering tightly, and it was like "Why is this stick trying to move on me?"

SP: On either one of those last two, you didn't see anything that really helped with the rate limit?

EP: I saw nothing in there that gave me tactile cues that there was rate limiting. I'm not sure that, even had I known--I feel very strongly that even if you had told me the configuration that we were flying, educated me on the flight control system in that when you were rate limiting, the stick will do this--I didn't see it, because even in small inputs the stick was kind of wandering.

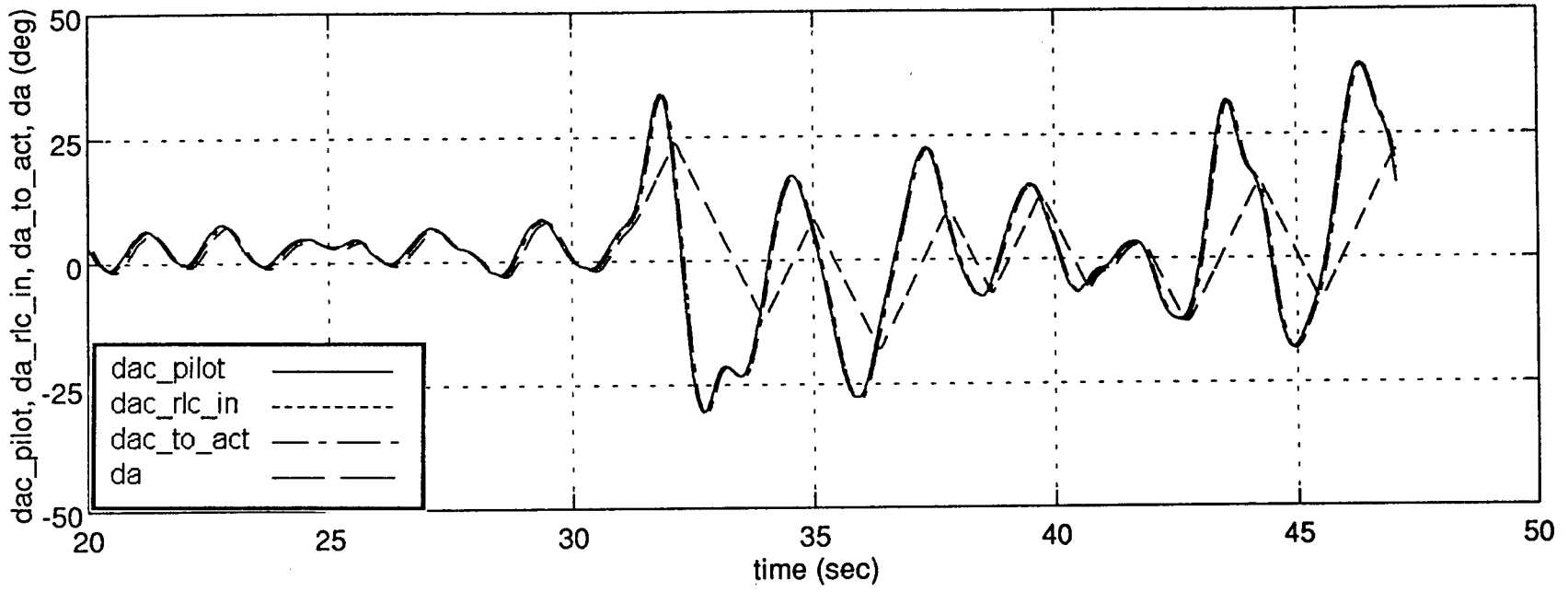
CO: The stick did that all of the time, whether you were rate limiting or not.

EP: Yes, whether I was rate-limiting or not. Even on final, making very small corrections very slowly, it was kind of doing it. Did not like it.

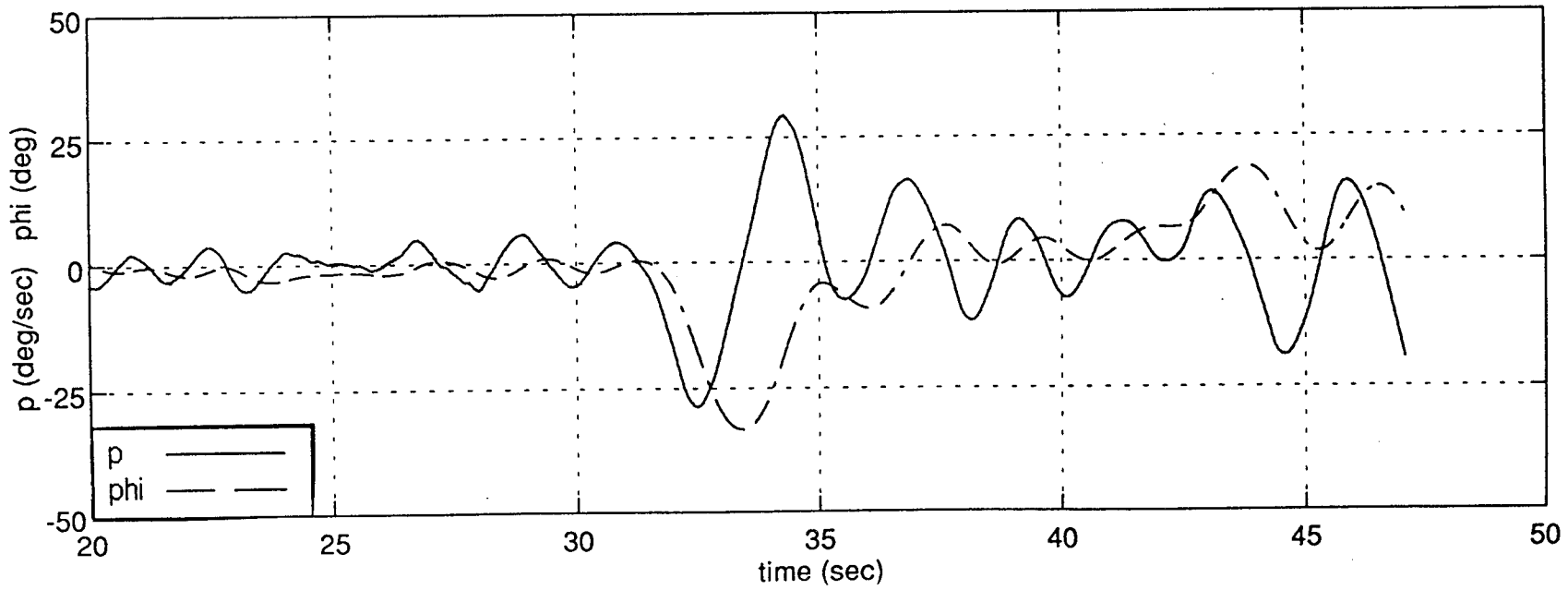
Remarks

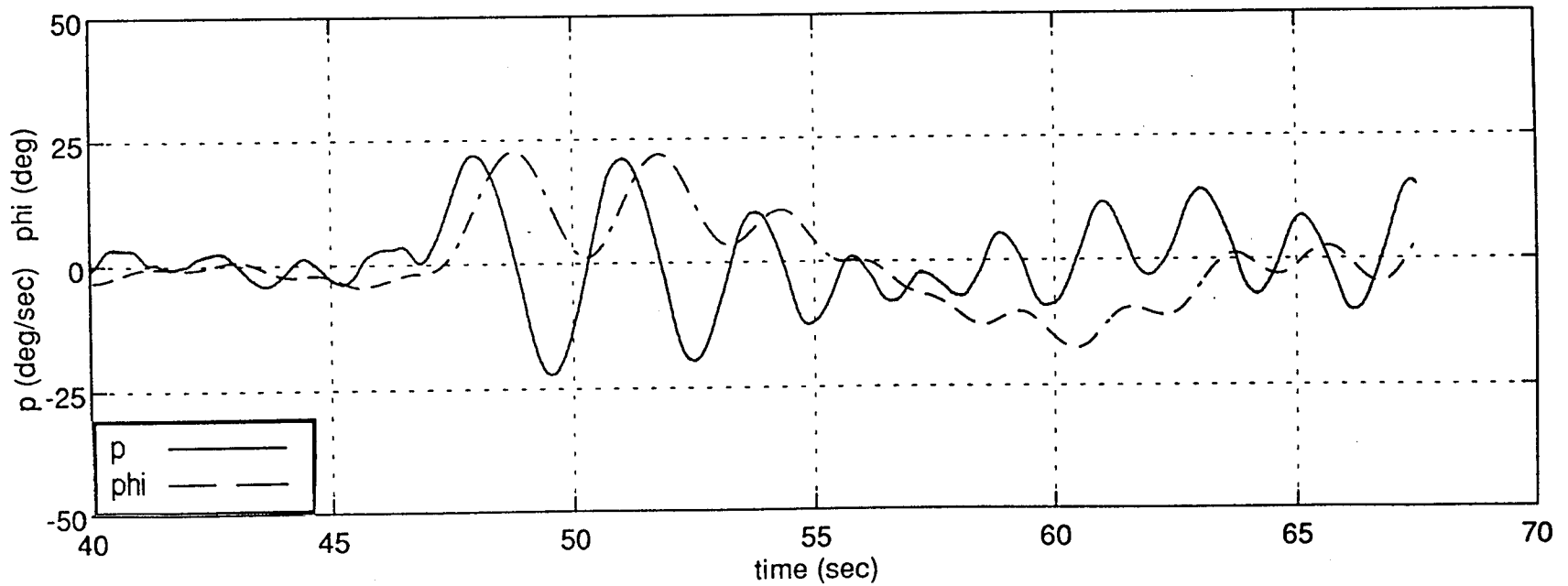
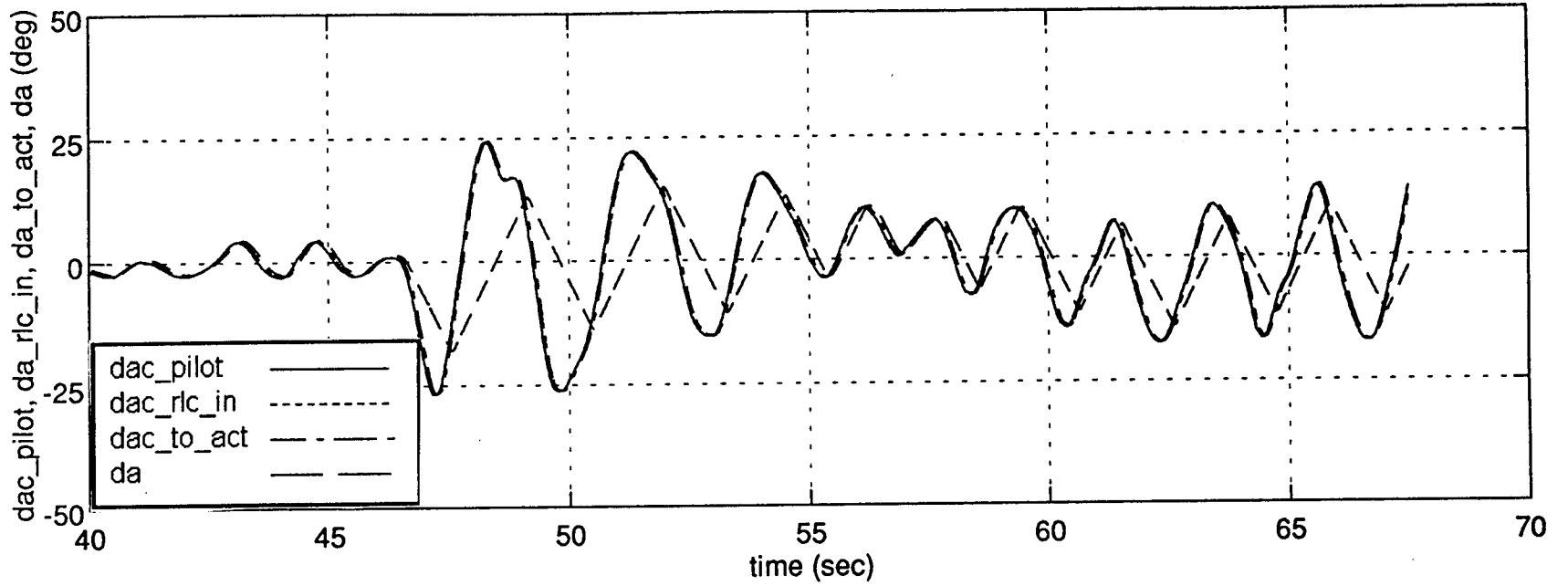
FLT 447 REC 15 RL = 20 deg/sec RLC OFF

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APPENDIX C



C-108





Evaluation 16 Flight 447/2 Flight Evaluation No. 7 Event 12

Configuration 322 Stick Center Type Position Rate Limit 20 deg/sec

Pilot Johnston Safety pilot Deppe Computer operator Buethe Flight test engineer Shafer

Algorithm Highly damped stick Passes 1 Runway 10L

Pass Record Offset Wind Performance
1 14 Left No landing

CHR 10 PIOR 5

Inflight comments

1st pass:

EP: Rolling in. Initial response from the airplane here is good. Feels fine. Bank angle capture is nice and I feel like I have a very good, aggressive airplane.

SP: Correct

EP: Correcting now. Sluggish. PIO prone. I'm not sure I can make this. I'm not sure I can do the task.

SP: Oh. Now we're out of here.

FTE: Ooh.

SP: That was interesting.

EP: I tried to back myself out of the loop to keep from PIOing after the first, initial PIO. There's no tendency on final to PIO until the correct and then the gains went up. I was not going stop to stop until the very end. In the very end I think I had full right to correct for that left. It was unpredictable and it was divergent PIO. Cooper-Harper 10, PIO 6. Let me make it PIO of 5. 10, 5. I may have given an inappropriate 6 yesterday, by not looking at that card. It was only when I entered tight control that it PIOed and it was divergent.

Postflight comments

EP: One try. You clicked me off really early. I never thought that it was even attemptable to do the task. I gave it a 10, 5. It was bad. Was this the one I was talking about the stick was talking back to me?

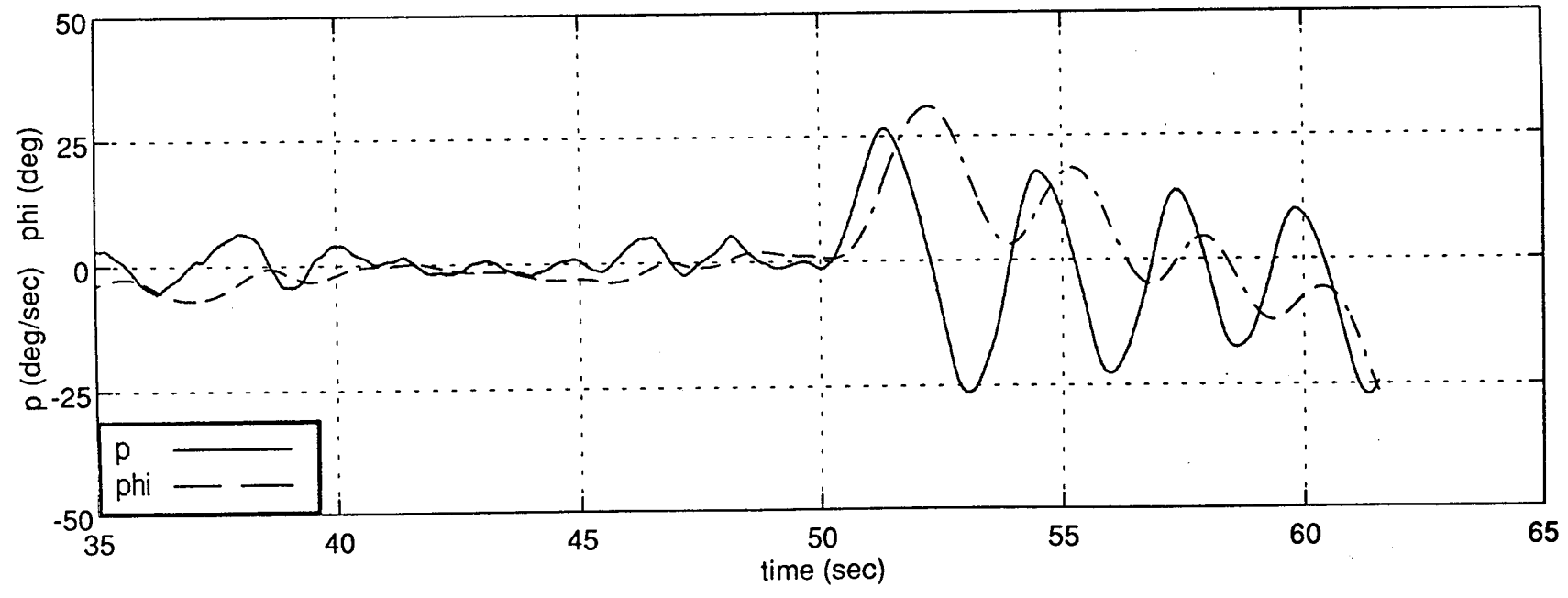
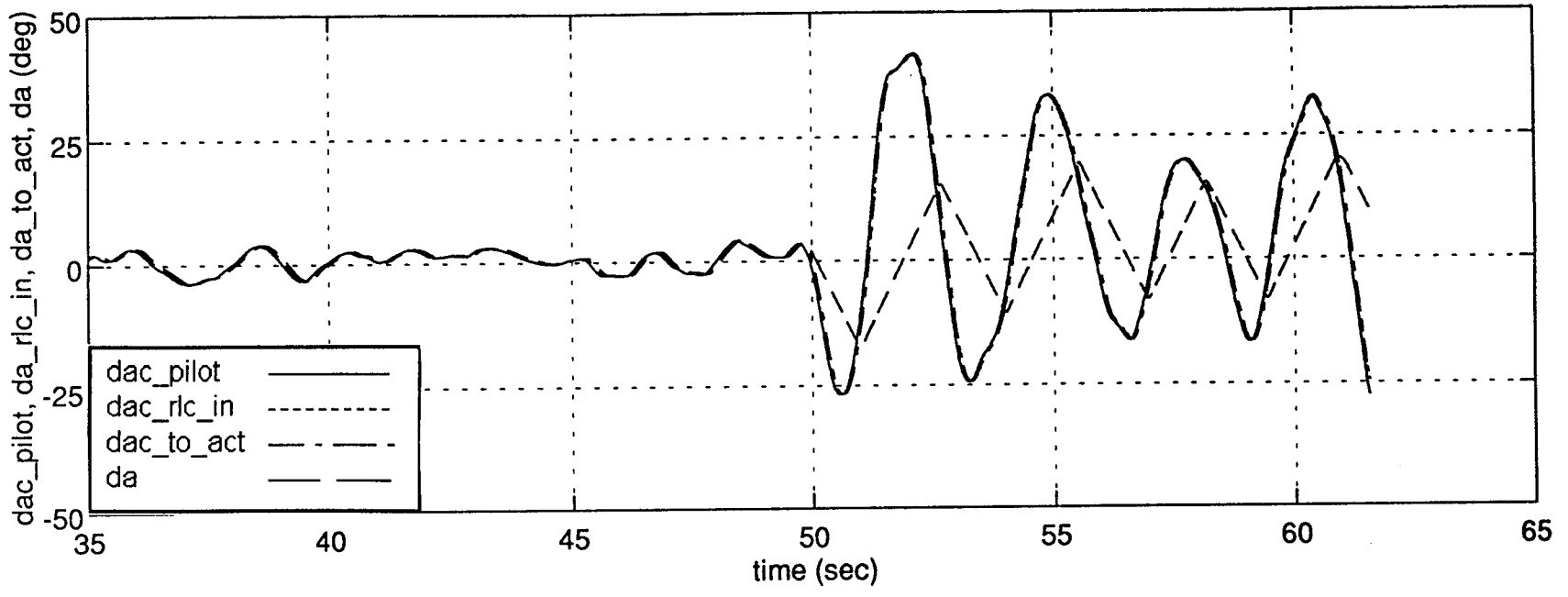
FTE: No, that was the next one, 321, the low-frequency stick and that stick kept taking back to you.

SP: On event 12 we just tried it once and it was a wave-off, right?

FTE: A *high* wave-off.

Remarks

EP: The center stick is a little bit better flying airplane than the side stick. Not just because I like center sticks better, it is actually a little bit better flying airplane. So in all of our evaluations, I hope that I'm repeating that enough to say that we have a better flying center stick airplane than a side stick airplane. I hope that doesn't bias anything in the results. I think as long as we can just compare center to center and side to side, we'll be OK on that. If you start making any comparison between center and side, of which is better, this isn't going to work with the command gains that we have.



C-111

Calspan Report No. 8091-2
APPENDIX C

Evaluation 3 Flight 446/1 Flight Evaluation No. 3 Event 4

Configuration 320 Stick Center Type Position Rate Limit 20 deg/sec

Pilot Johnston Safety pilot Deppe Computer operator Buethe Flight test engineer Shafer

Algorithm Rate-limited stick Passes 2 Runway 10L

Pass	Record	Offset	Wind	Performance
1	10	Right	060/12	Desired
2	11	Left	060/9	Adequate--long

CHR 5 PIOR

Note: Feel system rate limit was incorrectly set to produce a 10.5°/sec surface rate limit instead of the desired value of 20°/sec.

Inflight comments

1st pass:

EP: Downwind, once again, I'm feeling like there's more corrections to be had to keep wings level.
 EP: Rolling into base it feels fine. No tendencies to overshoot. I feel like it's well controlled. Holding bank angle nicely.
 EP: A little bit of turbulence that I haven't felt before, coming around the final turn. Still holding good. We're slightly high, but not bad. Correcting slightly. Airspeed control is good. Man, I hate that windshield.
 EP: Rolling out on final. Airspeed's good. Glide path's good. Just a little bit more turbulence than I've had before, but nothing real bad. Roll control on final here is fine, no problems, minor inputs.
 SP: Correct
 EP: Correcting now. Sluggish. Very sluggish. Telling me we're getting close to the rate limiting and it's making me back out of the loop. I can't be as aggressive as I'd like to.
 SP: Put it on the box, put it on the centerline, put it on the box.

EP: OK, that was 320. Beating the back end of of the stick is what it felt like it was doing.
 SP: We can neither confirm nor deny that.
 EP: OK. Adequate criteria was achieved. Is it satisfactory without improvement?
 CO: Tell us what it was that made you think that that was a certain configuration.
 EP: The stick forces changed on final and they changed abruptly. They were nice and light and they felt good until I went to make the final correction, was the first time I could feel anything at all different in the stick forces and at that time the stick felt like it was in cement. It felt sluggish and it required that I back out of the loop. It forced me to back out of the loop and immediately I knew I could not be as aggressive and I started, instead of correcting to final and making a fairly long, or trying to get as long as I can of a straightaway on final, I was forced to angle in, accept less of a straightaway on final than I would have liked to have.

2nd pass:

Turning base:
 EP: Even as aggressive as that turn was, I could not feel any difference in the stick dynamics than what we've had before.
 SP: It's really obvious that the gain goes up closer to the ground, doesn't it?
 EP: Oh, buddy. I would not have thought of it. I mean, I would have thought that I rolled in as aggressively there as when I made the corrections.
 On final:
 EP: Angling over. Getting slightly slow. A little bit of turbulence, not anything detracting from the--I could feel the stick getting stiff right there. So even that little bit of turbulence is enough to ...
 SP: Correct
 EP: Correcting, and the stick was stiff when I started. Slight PIOs. Still. Minute performance is in doubt whether I was really going to get that. Still angling.

EP: Is adequate performance attainable with a tolerable pilot workload? I perceived that that pilot workload was tolerable, so yes. Is it satisfactory without improvement? No. I got moderately objectionable deficiencies, so it leads me to a Cooper-Harper of 5. The moderately objectionable deficiencies I have is a slight PIO

tendency and the change in stick feel.

Postflight comments

SP: We should be clear that this is not exactly the same airplane with a rate-limited feel system. This has increased stick motion to make the rate-limited feel system do more for you and the command gain is a little bit lower.

CO: The command gain is 15.

SP: OK, it's the same, but the motion is higher.

EP: I will let you guys go back and look at that. I can tell you that the apparent flying qualities, from the base turn and everything else, were the same. I did not sense, if that is true, the pilot didn't sense any of that. So it felt like the same airplane that I had just flown around the base turn and lining up on final. I could not tell that anything was different in it. It was not until the correction, and as soon as I made the correction I could tell exactly what we were flying. It was what I called a cement stick. It was annoying to me, it was frustrating to me, but it caused me to back out of the loop and to be able to land the airplane. I do not like it, but it does make an unlandable airplane landable. The major objectionable handling qualities--why I've got a Cooper-Harper 5--is that I don't like the stick forces changing on me and airplane felt extremely sluggish because of it, so I'd go from a nice crisp-flying airplane to what is an apparent sluggish airplane, just because of the inability to move the stick. A slight PIO tendency was noticed, even with it in there, and I felt like that is possibly a dangerous one to look at or a dangerous one to put in without checking that same thing in turbulence, because if turbulence is there, there may not be anything I can do about it. I will hit the cliff and the cement stick isn't going to save me.

Chick Chalk: Is this an adaptive stick or is it always constant?

SP: It's a second-order feel system model, but it's rate limited, so you can't move it any faster than a certain rate. It's always rate limited.

EP: But if you asked me if it was an adaptive stick, I'd say yes. To the pilot's point of view it was an adaptive stick.

CO: It's what you'd get if the stick was mechanically connected to the rate-limited aileron. You cannot get ahead of the aileron.

SP: We set the stick up to match the aileron rate limit. You can look at the traces and they move exactly together.

Chick Chalk: So if you got into turbulence, you couldn't do any more.

EP: Correct. It corrects for a pilot-induced oscillation, it wouldn't correct for a turbulence-induced operation.

CO: I think your comment about turbulence applies to any rate-limited aircraft.

EP: On the first one I got desired criteria and on the second landing I got adequate criteria. It was controllable but there was a PIO tendency noted. I don't think I gave it a PIO rating in the air. That one was a frustrating one.

CO: It was a frustrating one--when you try to move the stick and it doesn't move, it's like "Come on!"

EP: Although it does give you feedback, if you're knowledgeable of the flight control system. It does give you feedback of what's going on in the flight control system and that you are rate limiting.

CO: Did you notice any learning curve on it?

EP: No. I could not feel for the edge there. There was no ability to do that. I knew the second time around I was flying the same exact thing and I did the same exact thing. I put in the input and from the very first correction, as soon as he called "Correct", I was flying a cement stick all the way to touchdown.

CO: Is it more informative than a light? The Gripen has a light to tell you that surfaces are going into rate limit.

EP: I think it's more informative than a light, but if you only apply it in one axis, you buy yourself bad control harmony.

CO: I think the bottom line on this is that it helps some. This has not been optimized at all, so the question would be, since it works to some degree, how good could you make it if you played with it a little bit more, optimized it. This first cut, we just wanted to see if it did anything good or not.

[?] It looks like it does.

EP: It went from an unlandable airplane to a landable airplane. I believe that's all we really changed. If we did change the command gain in there or any of those things, that would be interesting.

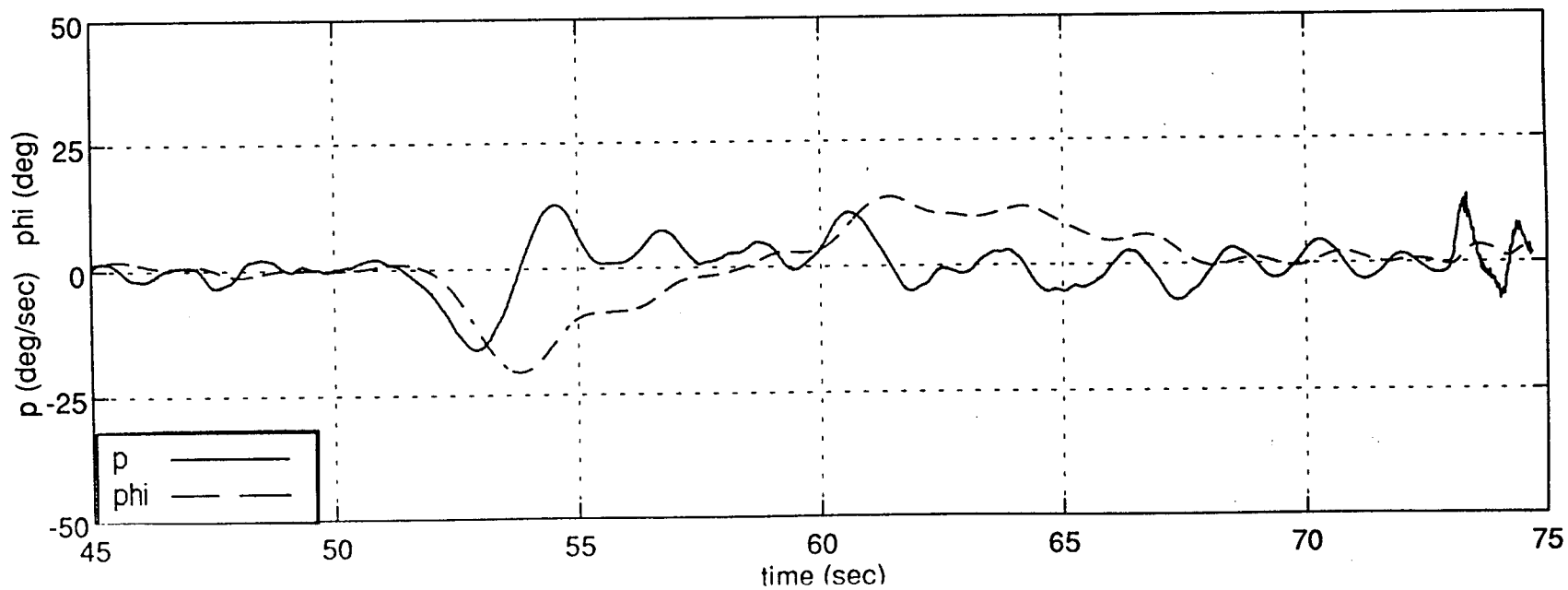
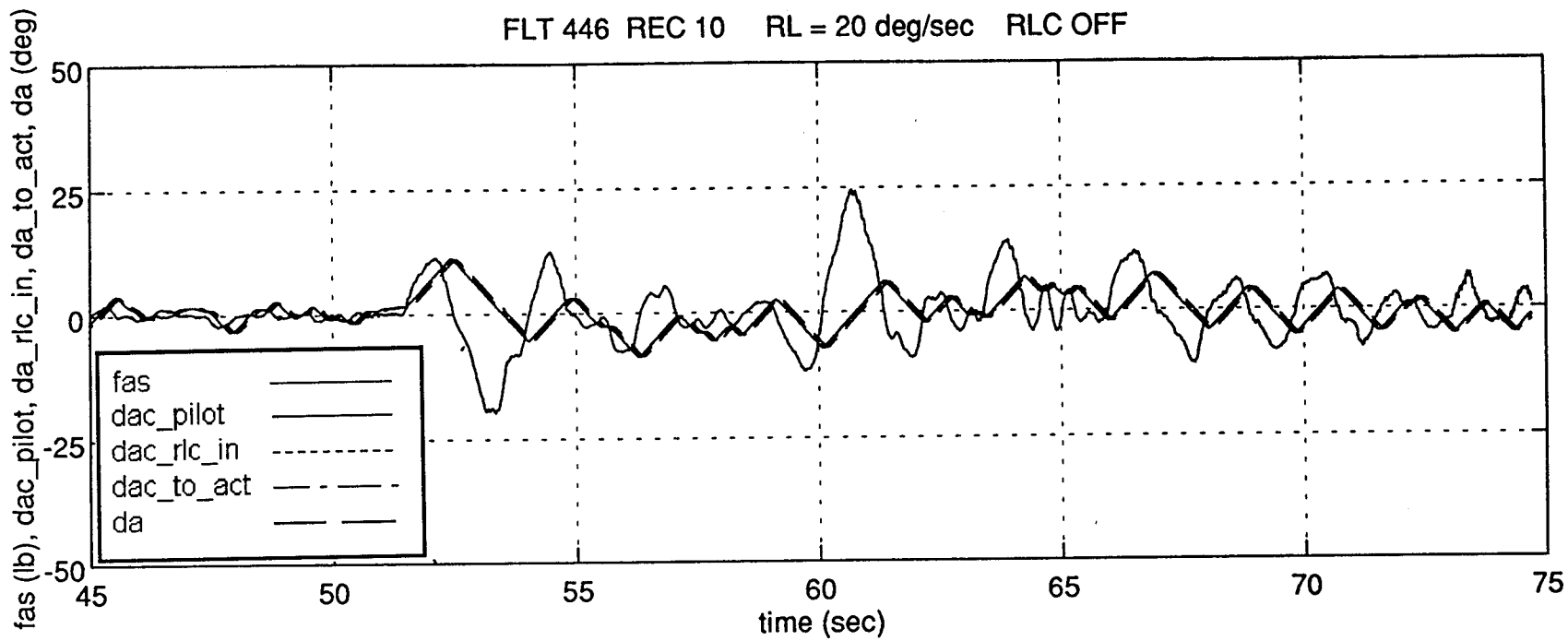
SP: We changed the stick motion. The baseline roll stick is 5 pounds per inch which is not a lot of motion. Our basic Lear is 3.5 pounds per inch, so this is a little bit stiffer stick. Remember that we tried this rate limiting thing and it was just like having a fixed stick, there was no feel at all, there was no improvement at all, so we said well, in order to get some feel, we're going to increase the motion.

CO: I would argue that we did not increase the motion. The command gain is the same, so for a given amount of motion, you get the same aircraft response. You just get that motion with a lighter stick force, which may not be optimal for what we're trying to do. Further development could be done.

EP: I need to make some comments here, out of sync and out of order, but I want to make sure I make them and don't forget to put them out. For the tape, I also participated in the NT-33 experiment and got quite different results and I think I can see why. Also, I do not think that, of the two Gripen accidents, if we want to refer to the Gripen accidents as rate-limited accidents, that maybe this algorithm can help. It could probably have helped with the landing accident; it would not have helped with the air show accident, I don't think, at all. And the reason for that is the smaller inputs that are made in the landing phase. The inputs that we were making to do the HUD tracking task, when Lou [Knotts] and I were flying in the NT-33--I was worried about the stops, we talked a lot about those. I was worried about the stick forces a lot more than I was in this. In this I don't think I ever got one-third deflection, maybe a half, and in the NT-33 we were oftentimes getting full deflections. My impression of it, having experienced both of those, is that the rate-limiting algorithm may help in a very narrow task, the landing task, but it will not help in most of the up-and-away fighter tasks. That is no different--I did not fly the NT-33 any differently than I fly the F-16 or the F-4 or any other fighter I've flown, like the F-14. I can remember a lot of times in those planes being stop-to-stop on the stick, not to control the PIO but to get the desired motion out of it, so I don't think it was overly aggressive in the NT-33.

Remarks

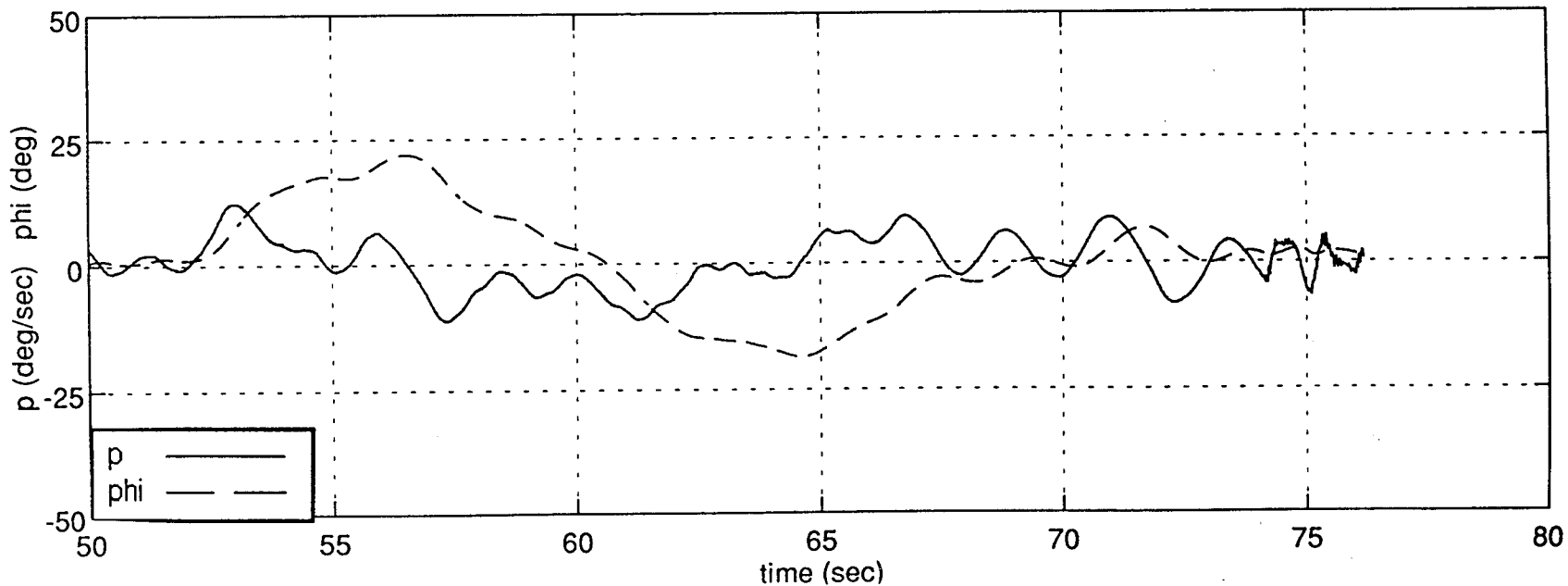
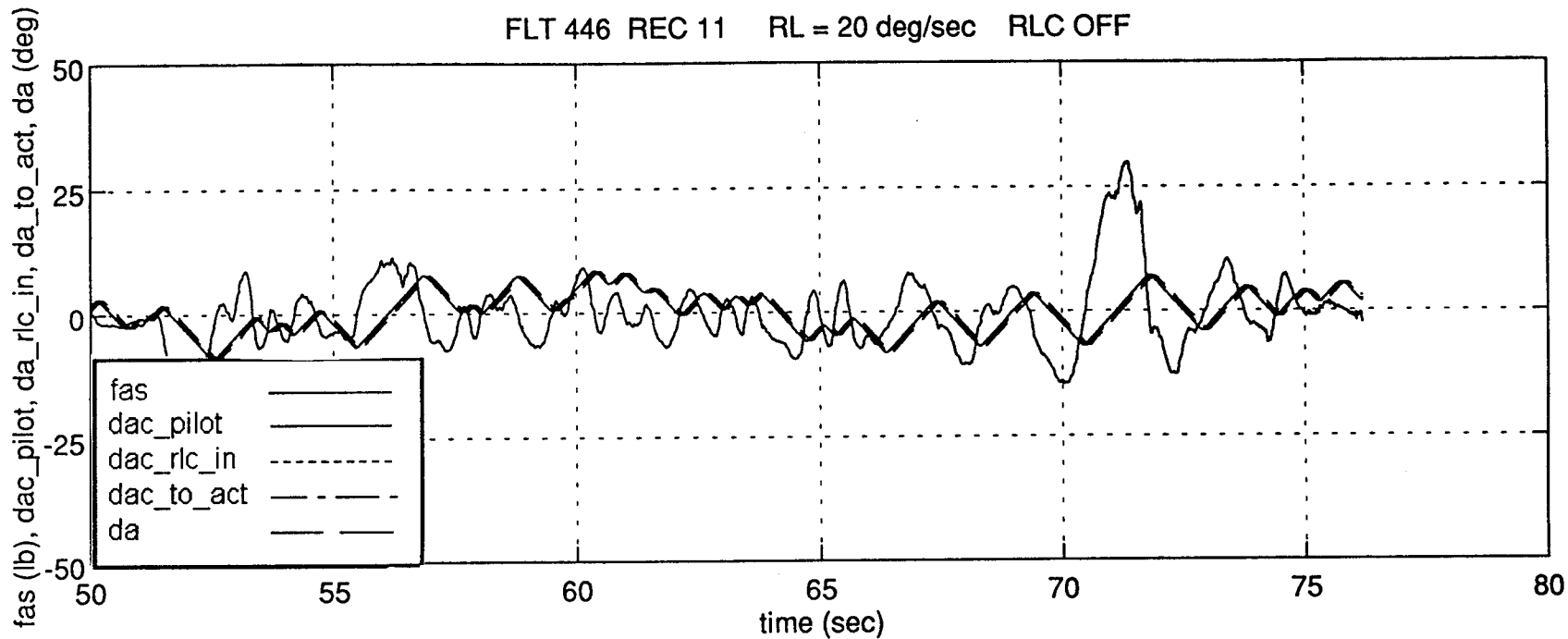
FLT 446 REC 10 RL = 20 deg/sec RLC OFF



C-115

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APPENDIX C

FLT 446 REC 11 RL = 20 deg/sec RLC OFF



Configuration 320 Stick Center Type Position Rate Limit 20 deg/sec

Pilot Smith Safety pilot Buethe Computer operator Deppe Flight test engineer Shafer

Algorithm Rate-limited stick Passes 2 Runway 10L

Pass	Record	Offset	Wind	Performance
1	13	Left	050/9	Desired
2	14	Right		Adequate

CHR 7 PIOR 2

Note: Feel system rate limit was incorrectly set to produce a 10.5°/sec surface rate limit instead of the desired value of 20°/sec.

Inflight comments

1st pass:

EP: Wow, that was a struggle. Somebody else back there was flying the airplane.

SP: You were pretty slow with that one.

EP: I was distracted--the stick forces are very high at the edges of initial inputs. In close, making the corrections, I was really concentrating totally on trying to get the muscle in to get the response I wanted. The airspeed was degraded. I think I barely hit the desired but it was more good fortune than good management. I didn't get in to any oscillatory problems but I had really conflicting initial forces that interfered with my ability to do the job.

2nd pass:

EP: It's controllable, yes. Adequate performance attainable? I would say I could achieve the performance but it wasn't tolerable to me. It's got deficiencies that require improvement--any kind of input manifests itself in a large force that gets you into a loop where you have that several times and while the aircraft doesn't oscillate, it's very difficult to control. Major deficiencies? It would be a 7 because of the initial forces that come with rapid inputs. The initial part of the second one, to the offset, came around relatively smoothly because I didn't use a rapid input. I went to stop it rapidly and got into several oscillations that I see more than outside because of the heavy forces. It's just a little awkward to understand whether you're going to be able to control it properly. The last one I think I hit just beyond the desired because I really was wrestling with the forces, so it does interfere with the task significantly

EP: Oscillations? Don't occur. Undesirable motions? This is a hard one to call because it's mainly the forces that I'm worried about. The motions that result are not really significant, but I really never know whether I'm going to contain it, so I'll say there is some overcontrolling but it doesn't interfere with the task in the sense of the external motions but the internal fight with the forces certainly do, if that makes any sense, so it's a 7 with a 2.

Postflight comments

CO: This was the stick of cement. You complained about the stick forces and gave it a 7 and a PIO of 3.

EP: That was an airplane, I think we got the job done and so on but I look at does it warrant improvement or does it require improvement. To me, it requires improvement. That's why I gave it a 7, because it's just not acceptable to have that force interference.

Mike Parrag: You gave it a 2 on the PIO.

EP: That's true. There was some overcontrolling, but not oscillations.

Dave Leggett: It was objectionable, but the primary objection was something other than PIO.

EP: Yes, it's basically the forces that I said were the reason that I said it was a 7.

Chick Chalk: That configuration has the rate limit and the time delay, but no algorithm to help you. Did the rate-limited feel system replace that? That was another fix for the PIO.

EP: That's likely then a case where the PIO part of it, overcontrol/oscillations, was not there, but the cure was itself strange.

Chick Chalk: It cured the PIO to an extent but the cure was a bit worse than the problem.

EP: Right.

Remarks

CO: I think, compared to the other two flights, [Smith] is not working as hard as [Johnston] was. I think he's having more time during his corrections, so maybe I was calling them a little later than you are. That's my impression.

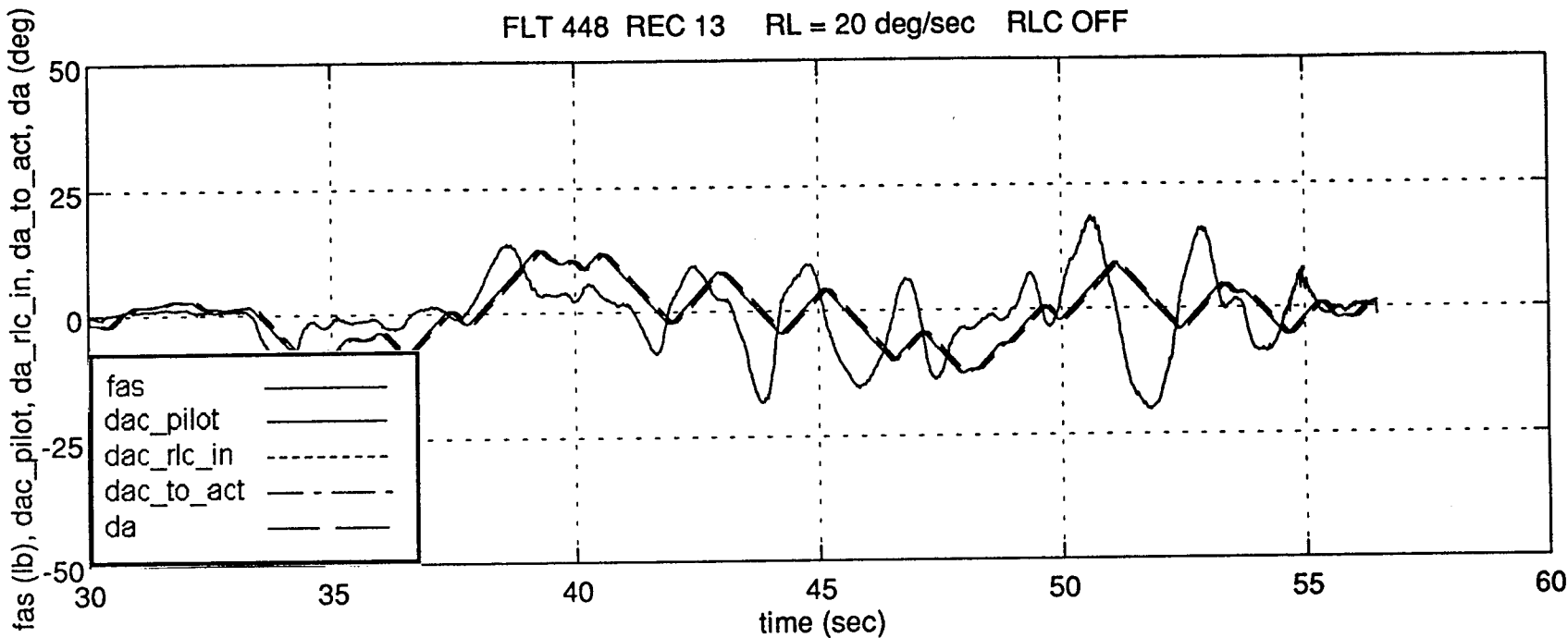
SP: I think his flying technique is less aggressive.

CO: Could be, too. I just think he has more time during the correction.

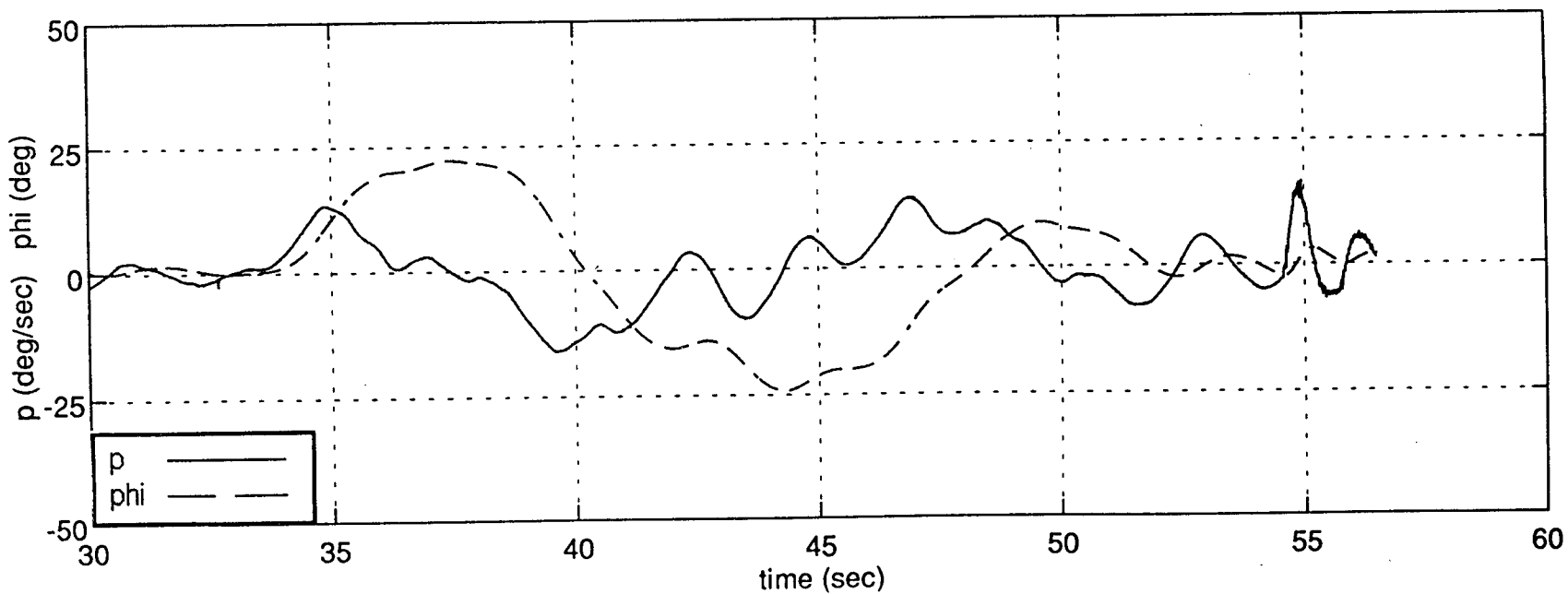
SP: I think he's doing it more gently.

CO: Could be.

FLT 448 REC 13 RL = 20 deg/sec RLC OFF



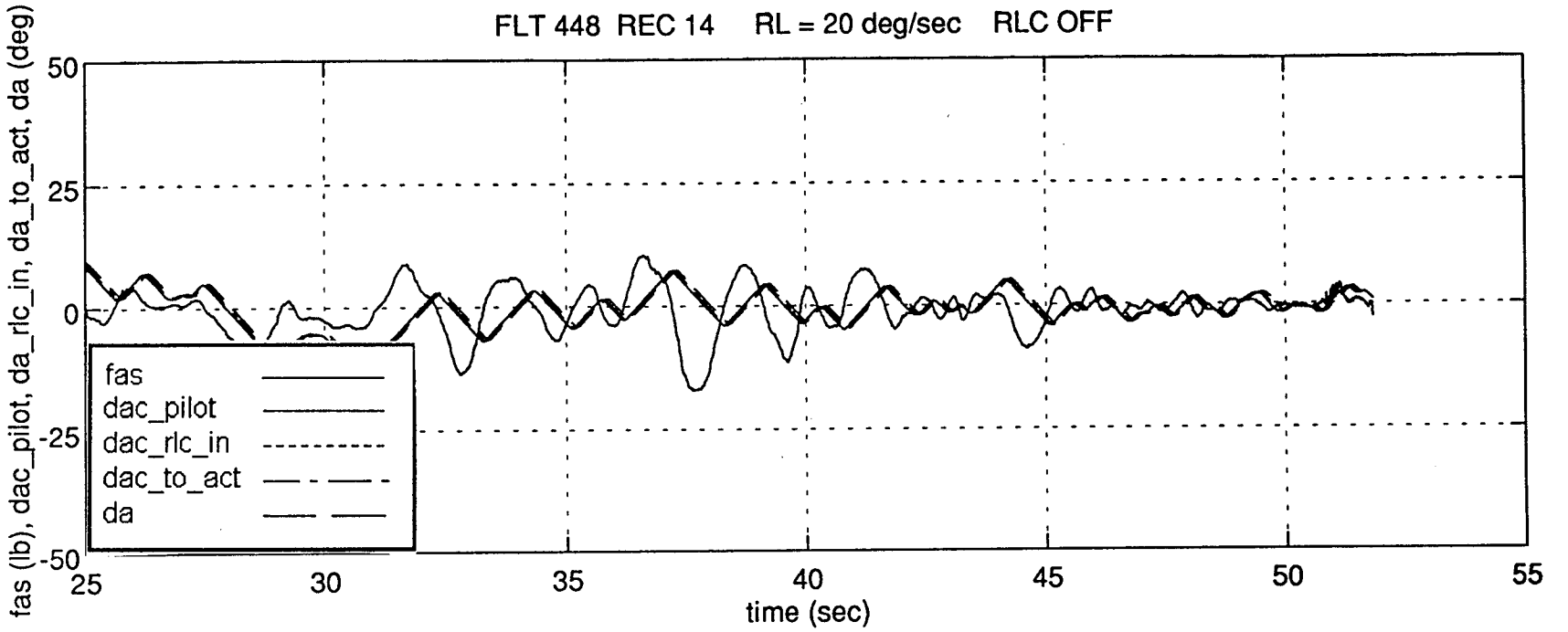
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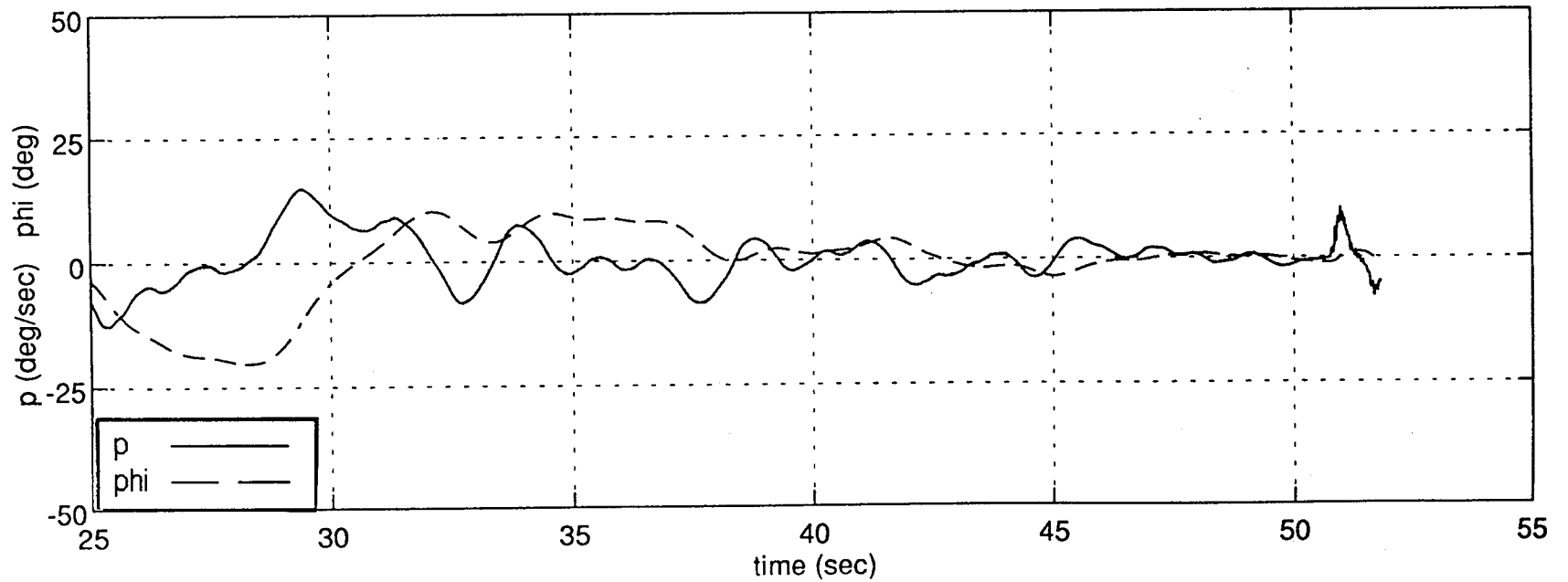
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FLT 448 REC 14 RL = 20 deg/sec RLC OFF

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APPENDIX C



C-120



Evaluation 35 Flight 449/4 Flight Evaluation No. 8 Event 15

Configuration 323 Stick Center Type Position Rate Limit 20 deg/sec

Pilot Ball Safety pilot Deppe Computer operator Buethe Flight test engineer Shafer

Algorithm Rate-limited stick (modified from 320) Passes 2 Runway 10L

Pass	Record	Offset	Wind	Performance
1	18	Left	090/14	Desired
2	19	Right	110/13	Desired

CHR 8 PIOR 4

Note: Feel system rate limit was incorrectly set to produce a 10.5°/sec surface rate limit instead of the desired value of 20°/sec.

Inflight comments

1st pass:

Turning base:

SP: This is the rate-limited stick.

CO: Can you feel it?

EP: It's definitely in there. All I've got to do is kind of shake the stick and it feels like a fixed stick.

On final:

EP: At the level of this, it's getting into almost controllability here. It is getting into controllability, I can't move the stick and get the input that I want. Oops, a little fast--slow it down to start with.

SP: Correct

EP: I didn't know what--whoa--I didn't know what to expect on this one. I thought it would be very tough, in fact it may be...I don't know, I may be able to salvage it here.

SP: In the desired, right in the middle.

EP: I'm happy for it. Just in making would normally be just a normal roll input during landing, I'm into the heavy force feel and that's limiting the roll I can get. There for a minute...if you really had an upset there, you'd bang it. I know we don't have turbulence and I'm going to rate it for what I saw but I can tell you ahead of time that you'd want to look at that one in turbulence if you had an airplane that was even close to that because I think you'd have a real problem. Given our conditions today I could get by, but it's certainly not good.

2nd pass:

On downwind:

EP: You have to fly like a big airplane, in other words, just nothing fast, and that's fine until you get where you have to put in a big input just to pick a wing up or something and then it's a little scary.

Turning final:

EP: A little learning curve on this one, being real delicate with it.

SP: Correct

EP: Every time I end up with what I want, I say "Whew, boy, am I glad it worked out." Some of the stuff is just--

EP: A lot of work on that one. No, no, adequate performance with tolerable workload? I don't even think that's--even though I got desired performance, the workload on that is way too high. I can't even say that one. Requires improvement? I definitely wouldn't want an airplane to fly like that. Even in the offset, I'm a little concerned about the controllability on that one. It's at least an 8. If and when I've got--nope, 8 will be fine. Divergent? Causes oscillations? Never saw any that would get divergent, so a 4. 8 and 4.

Postflight comments

FTE: An 8 and a 4. Two desired landings.

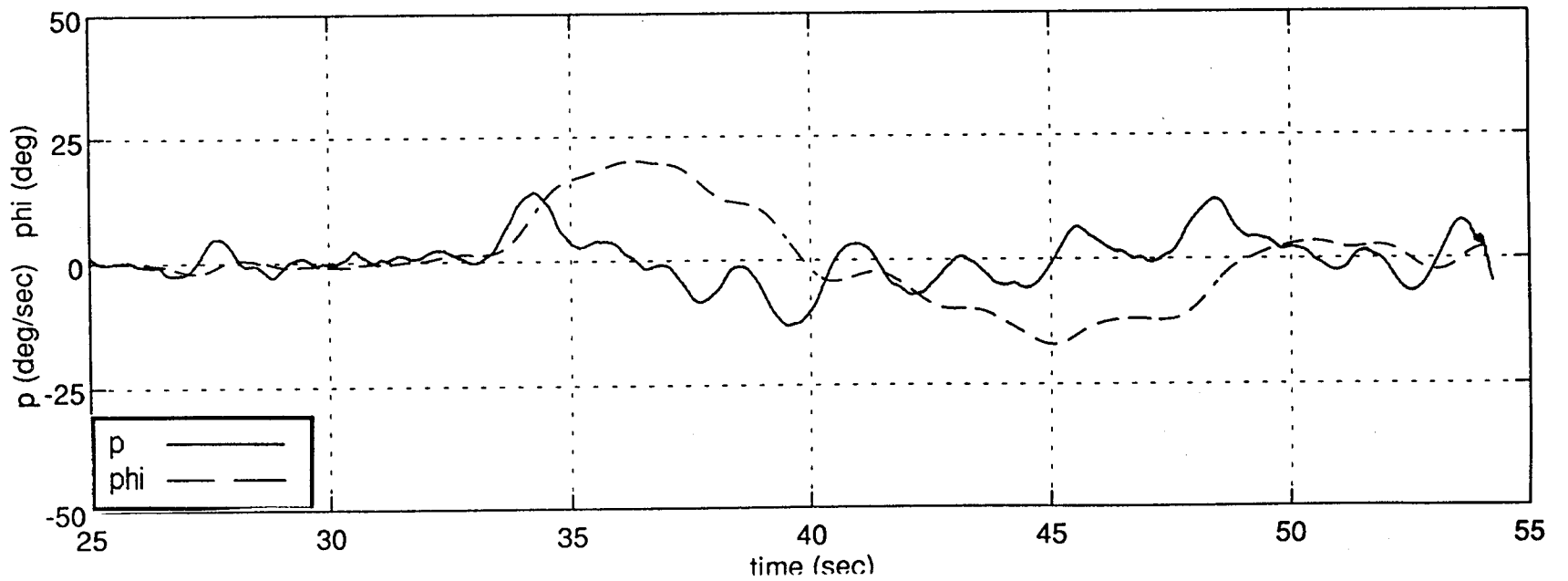
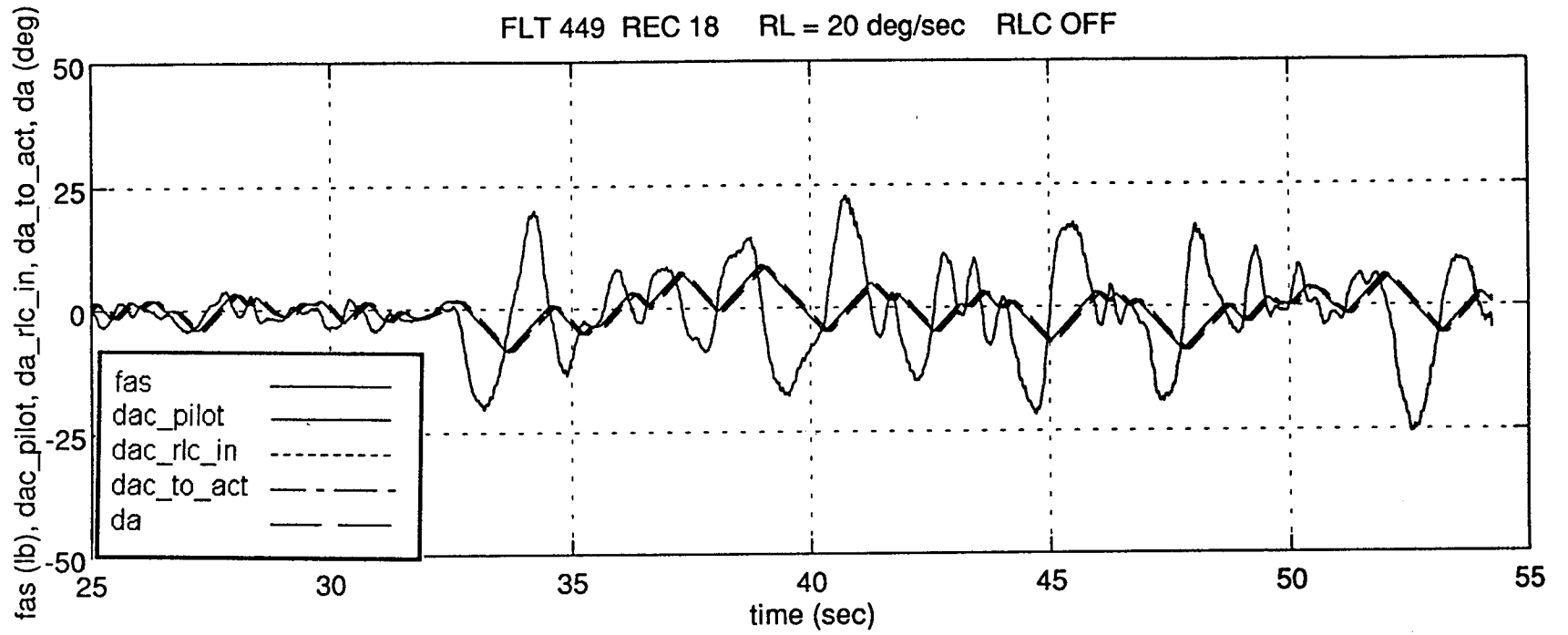
EP: What's available just feels like it's too low, can't move it as fast as you want to. On this one, for small inputs it seemed fine. Once you got what you wanted and came out, you could make that last little bitty correction without any problem. It's felt much solidier than some. But the thing that gave it the 8 was just what was available to me. It jumps at you how little you have available.

Remarks

From postflight:

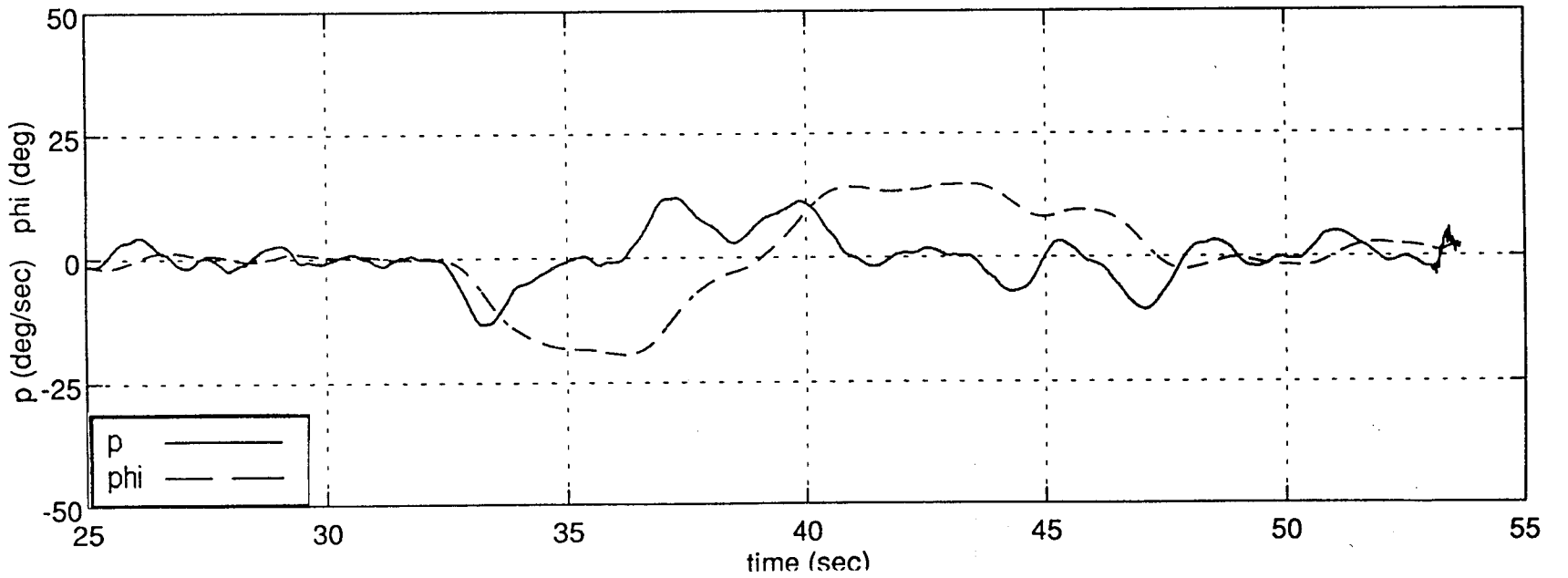
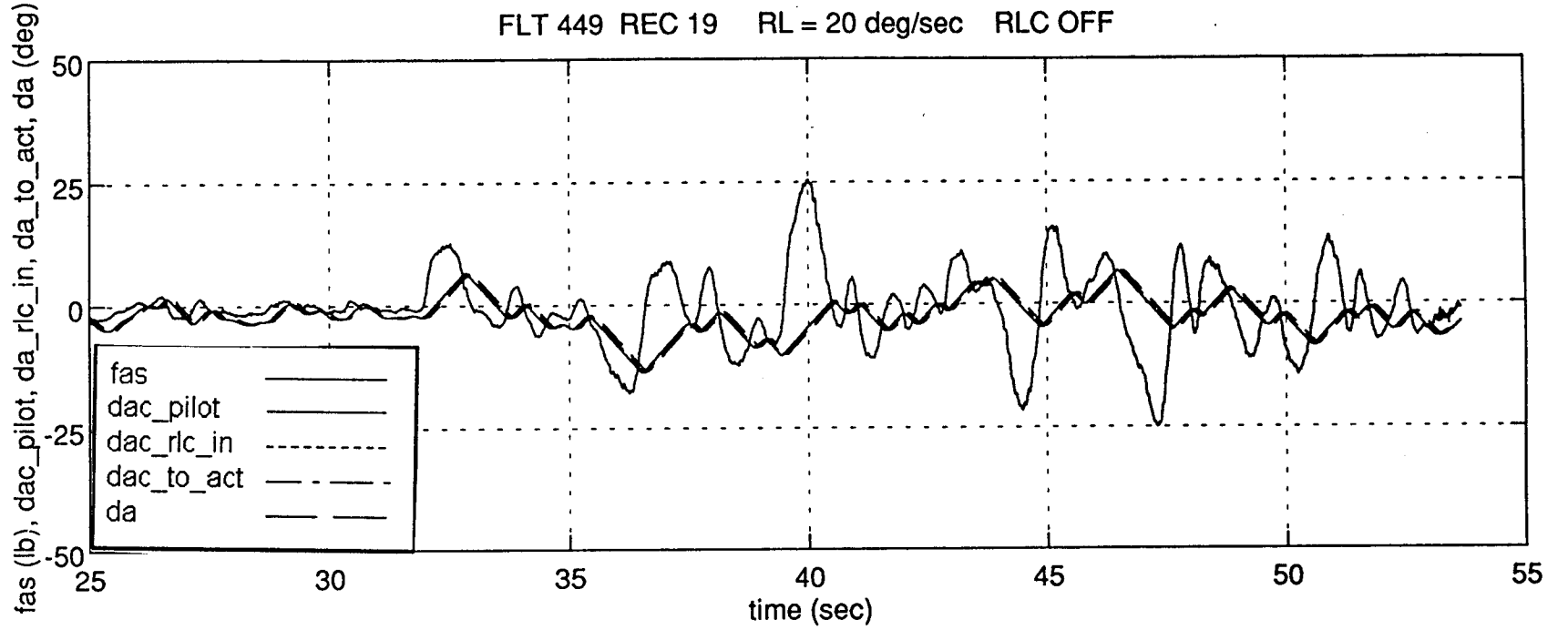
Somewhere in here, you mentioned that any time I'd get to a sluggish stick, I added power. The reason is that I'm still coming down. If I have some concern about being able to get around and lined up, I'm going to tend to try to stop that descent a little bit until I get this thing under control. As a result, I tend to get fast and be long on some of these. That was one of them. What I was trying to do most of the time was get a fairly good turn in and get all the maneuvering done high enough so that I had some sort of a final left. On any of these, when I didn't get the roll rate that I really wanted, it gave me some concern whether I was going to get this thing turned around without making a real low altitude, wing way down turn at the end. In fact, something like that could even explain something like a 9, if I were doing that lower, I was concerned about getting down in.

FLT 449 REC 18 RL = 20 deg/sec RLC OFF



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REPORT DOCUMENTATION PAGE

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13. ABSTRACT (Maximum 200 words) As part of an ongoing government and industry effort to study the flying qualities of aircraft with rate-limited control surface actuators, two studies were previously flown to examine an algorithm developed to reduce the tendency for pilot-induced oscillation when rate limiting occurs. This algorithm, when working properly, greatly improved the performance of the aircraft in the first study. In the second study, however, the algorithm did not initially offer as much improvement. The differences between the two studies caused concern. The study detailed in this paper was performed to determine whether the performance of the algorithm was affected by the characteristics of the cockpit controllers. Time delay and flight control system noise were also briefly evaluated. An in-flight simulator, the Calspan Learjet 25, was programmed with a low roll actuator rate limit, and the algorithm was programmed into the flight control system. Side- and center-stick controllers, force and position command signals, a rate-limited feel system, a low-frequency feel system, and a feel system damper were evaluated. The flight program consisted of four flights and 38 evaluations of test configurations. Performance of the algorithm was determined to be unaffected by using side- or center-stick controllers or force or position command signals. The rate-limited feel system performed as well as the rate-limiting algorithm but was disliked by the pilots. The low-frequency feel system and the feel system damper were ineffective. Time delay and noise were determined to degrade the performance of the algorithm.			
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