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PSYCHOPHYSIOLOGICAL EFFECTS OF AGING - DEVELOPING A FUNCTIONAL AGE INDEX FOR PILOTS: III. MEASUREMENT OF PILOT PERFORMANCE

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16. Abstract
If a functional age index for pilots is to be developed that can be used as a criterion for extending or terminating an aviator's career, means for the assessment of pilot proficiency must be available or devised. There are two major approaches used for this purpose today, namely, the qualitative evaluation of performance based mainly on subjective ratings, and the quantitative assessment of performance through objective recordings of pilot action and aircraft response. The qualitative rating procedure, which is still the official method authorized by the Federal Aviation Administration and other Government agencies abroad, is still popular, generally accepted, and operationally rather effective. The most advanced concept of measuring pilot performance is based on automated data recording and processing independently of or in conjunction with the judgment and interpretation of an instructor, examiner, or inspector. With all the computers and automatic data processing equipment around, pilot performance indeed can now be measured automatically, accurately, and rather reliably. Measurements already obtained this way discriminate effectively among different levels of operational requirements, demands, skills, and proficiency and are accepted by the pilots. Owing to the capability of simultaneously monitoring the performance of the human operator and the aircraft, automatic inflight monitors are the ultimate in systems design and application. Their implications for the development of a functional age index for pilots are discussed.

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PSYCHOPHYSIOLOGICAL EFFECTS OF AGING - DEVELOPING A FUNCTIONAL AGE INDEX FOR PILOTS: III. MEASUREMENT OF PILOT PERFORMANCE

Introduction.

In two earlier reports on this subject, a literature survey and a taxonomy of psychological factors which are age-related and essential to pilot performance were presented (13,14). It was observed that the 14 factors, identified by our taxonomic survey do meet the basic criteria of theoretical and operational applicability in regard to the assessment of aviator proficiency (7). We also concluded from our previous work that there are performance differences between younger and older pilots and, based on available statistical criteria, that the rules which govern the statistical distribution of abilities, skills, and the underlying psychophysiological functions may or may not work in individual cases. It is well known that individuals who are of the same chronological age differ significantly as to their functional or performance capabilities. Any attempt to develop a functional age index for pilots must, therefore, deal with the means and methods available to measure group and individual pilot performance.

We would like to point out that, based on statistical data published over the years by the National Transportation Safety Board (NTSB), performance and performance failures appear to be more important to safety-related pilot proficiency than are health or medical disability in flight. The number of fatal and nonfatal general aviation accidents, in which the pilot-in-command is listed as the cause or a contributing factor during the 5-year period from 1970 to 1974, is shown in Table 1. In analyzing these data, Jensen and Benel of the University of Illinois (23) established three behavioral categories, namely, Procedural Activities, Perceptual-Motor Activities, and Decisional Activities, and they included accidents which involved medical causative factors into this last category (factors numbered 23 and 24 in the table). After summing the incidences for these latter two factors, we find that they account for less than 5 percent of the total fatal and less than one-fourth of 1 percent of all nonfatal accidents (25). One reason for this particular relationship observed in general aviation may be that the private pilots must be medically examined and certified at regular intervals, whereas there are no regular performance checks required. But the dominance of nonmedical human factors over medical factors also exists in air carrier accidents in which illness and sudden physical incapacitation of the pilot play a relatively minor part (33). This makes the analysis and measurement of pilot performance an even more important issue.

Research on Aviator Performance.

There has been extensive research on aviator performance determinants as part of the various aviation psychology programs in this country and abroad.

TABLE 1 Number of Fatal and Nonfatal General Aviation Accidents in Which the Pilot in Command is Listed as the Cause or a Factor for all Data Between 1970 and 1974 for Three Behavioral Categories (23)

	Procedural Activities	5-Year Totals Fatal	Nonfatal
1.	Failed to extend landing gear	1	255
2.	Failed to retract landing gear	4	14
3.	Failed to use or incorrectly used miscellaneous equipment	14	62
4.	Improper IFR operation	110	66
5.	Improper fuel management	105	1,231
6.	Improper starting procedure	1	30
7.	Failed to assure gear down and locked	1	207
8.	Misused or failed to use flaps	27	235
9.	Inadvertently retracted landing gear	0	104
10.	Retracted gear prematurely	1	26
	Total for Procedural Activities	264	2,230
	Percent of total pilot-caused accidents	4.6	8.6
	Perceptual-Motor Activities		
1.	Delayed action in aborting takeoff	5	236
2.	Delayed in initiating go-around	32	380
3.	Failed to see and avoid other aircraft	178	196
4.	Failed to see and avoid object	166	757
5.	Failed to maintain flying speed	846	1,625
6.	Misjudged distance, speed, altitude, clearance	351	2,864
7.	Failed to maintain adequate rotor RPM	16	153
8.	Improper operation of power plant controls	5[illegible]	685
9.	Improper operation of brakes/flight controls	1	688
10.	Improper operation of flight controls	164	569
11.	Improper level-off	10	1,596
12.	Improper compensation for wind	12	550
13.	Control interference	0	1
14.	Improper recovery from bounced landing	5	811
15.	Spatial disorientation	528	60
16.	Failure to maintain directional control	13	1,978
17.	Premature liftoff	11	302
18.	Failed to abort takeoff	26	257
19.	Failed to initiate go-around	8	637
20.	Exceeded design stress limits of aircraft	121	16
	Total for Perceptual-Motor Activities	2,496	14,561
	Percent of total pilot-caused accidents	43.8	56.3
	Decisional Activities		
1.	Operation of aircraft with known deficiencies	84	201
2.	Operation beyond experience/ability	170	368
3.	Continued VFR into known adverse weather	717	343
4.	Continued flight into known severe turbulence	18	7
5.	Improper inflight decisions/planning	236	597
6.	Exercised poor judgment	235	767
7.	Operated carelessly	7	36
8.	Selected unsuitable terrain	22	1,230
9.	Initiated flight into adverse weather	[illegible]	61
10.	Psychological condition	11	4
11.	Selected wrong runway	11	341
12.	Failed to follow approved procedures	145	425
13.	Inadequate preflight planning or preparation	511	2,341
14.	Lack of familiarity with aircraft	121	611
15.	Started without proper assistance	6	89
16.	Became lost/disoriented	68	248
17.	Taxied, parked without proper assistance	0	67
18.	Left aircraft unattended	1	8
19.	Diverted attention from operation of aircraft	111	501
20.	Inadequate supervision of flight	62	610
21.	Spontaneous improper action	15	119
22.	Misunderstood orders/instructions	3	20
23.	Incapacitation	50	7
24.	Physical impairment	203	65
25.	Inadequate training	0	5
26.	Direct entry	9	14
	Total for Decisional Activities	2,940	9,[illegible]7
	Percent of total pilot-caused accidents	51.6	35.1

Historically, interest in the assessment of pilot proficiency dates back to the work on military aviation problems during World War I. This effort was greatly accelerated in World War II, and it continues at this time by generally following the methodological principles, techniques, and operational procedures of the earlier period. Generally speaking, performance has been assessed against a definite task specification that had been obtained by either operational analysis, subjective judgments by experts in this particular field, or numerous performances sampled from adequate populations (25). There are two major approaches in which pilot performance assessment can be categorized. The earliest method used in aviation was the qualitative evaluation of performance based on subjective ratings by flight instructors or inspectors, flight examiners, or check pilots. Today, the rater may use some form of quantitative verification technique such as descriptions of action taken, record sheets, or quantitative rating scales or score cards.

The second method of performance assessment consists of the objective and/or automatic recording of the major performance criteria and evaluation against standardized criterion measures. The goal of this effort is to arrive at an objective system that leaves no margin for human error. At present the method most commonly used consists of various mixed techniques, whereby the subjective ratings of an observer are complemented and correlated with the data obtained by an objective recording system or, vice versa, where these two methods are designed to supplement each other. In this way, more complete information on pilot performance in a more or less realistic situation can be obtained.

As part of a feasibility study dealing with the automated performance assessment of military pilots, Knoop and Welde (26) discussed the significant problems inherent in the development of an objective pilot performance measurement system. They rightly point out the many difficulties involved in such an attempt. In accordance with the concept described by Glaser and Klaus in 1963, they consider the environment in which performance is measured as a major source of variability (16). Other sources of variance are the fluctuations inherent in the system that is used to measure performance. Sensors, sample selection, software, system operators, and response-evaluating instruments contribute to system variability.

Of the human factors directly involved in performance measurement, the complexity of the behavior being evaluated and the individual differences affect the consistency and reliability of the measures. Since an individual's performance level may change measurably from one occasion and one dimension to the next, each component element in a sense represents a new condition of a somewhat different level of difficulty. Also, the psychological and physiological conditions of the pilot himself are a source of performance variations, but we must assume a certain amount of system stability or homeostasis in our measurement process. Even so, the variations in the scores or data obtained do reflect a certain degree of bias and random fluctuations caused by system instability, intra-individual variability, and other remnant factors.

Conceptually, performance measurements of the kind we are interested in must, regardless of the degree of subjectivity involved, therefore, be designed to minimize or eliminate fluctuations and variability to produce reliable results. Of primary importance, as formulated by Knoop and Welde (25) is the necessity to apply realistic conditions and criteria in the measurement of pilot performance, so that the technique and the results obtained are accepted by the pilot.

In 1952, Smith, Flexman, and Houston of the Human Resources Research Center, Air Training Command, developed a technique for, as they called it, "objectively" recording pilot performance (35). They admitted, however, that the "Performance Record Sheets" which were used in the experiment were designed to describe but not to rate pilot performance. It was thought essential to develop procedures which would permit recording inflight performance and to allow for reliable descriptions which could be repeated by several flight observers. The first step in this procedure was to examine all maneuvers required in the Primary Training Syllabus and to break down each maneuver into its components. This item breakdown was accomplished by a team of flight instructors and psychologists and aimed at the isolation of the critical flight elements.

The Performance Record Sheets mentioned before were then tried out on the specified maneuvers to assure that the record procedure was efficient and practical. In addition, observer reliability studies were conducted to determine the degree of agreement between the two instructors who observed the same pilot performance. There were two direct products of this effort: First, the maneuver analysis was made to cover all important pilot activities and second, the technique was rendered reliable and standardized for obtaining pilot proficiency measures. The authors concluded that this research represented the first successful attempt to minutely describe and "objectively" record actual performance for both contact and instrument maneuvers.

Subjective Pilot Performance Assessment.

Pilot performance assessment is required by law. At present, in accordance with Part 61 of the Federal Aviation Regulation (FAR), the applicant for a civil pilot certificate must pass the appropriate written and practical tests and medical examination, must have the necessary flight instructions and in the case of a request for an air transport rating, be able to perform satisfactorily a line check which includes the duties and responsibilities as specified in FAR 121.440. His ability to perform the required pilot operations is generally judged by the way he:

1. Executes procedures and maneuvers within the aircraft's performance capabilities and limitations, including the use of the aircraft's system or systems;

2. Executes emergency procedures and maneuvers appropriate to the aircraft;

3. Pilots the aircraft with smoothness and accuracy;

4. Exercises judgment;

5. Applies aeronautical knowledge;

6. Shows masterful handling of the aircraft with the successful outcome of the procedure or maneuver never seriously in doubt.

The syllabus or scenario of the inflight performance check (which can be partially taken in an approved flight simulator) varies, of course, in accordance with the type of certificate; but it contains such items as preflight preparations, aircraft performance analysis, handling of the aircraft on the ground and in the air, compliance with safe operation procedures, checklists, and so on.

The flight instructor, examiner, or inspector who conducts the pilot operations or flight tests or the proficiency check, judges or rates the applicant in accordance with acceptable performance guidelines. These guidelines include the factors which will be taken into account by the examiner in deciding, whether the applicant, student, or pilot being checked has met the objective of the intended operation. Emphasis is placed on knowledge, procedures, and maneuvers which are most critical to a safe performance as a pilot. For example, the demonstration of fast stall recognition, adequate control action, and recovery techniques receive special attention. Other areas of importance include spatial orientation, collision avoidance, vigilance, and wake turbulence hazards.

The Practical Tests Guide for Airline Transport Pilots (FAA AG-61-49)(11) contains a few remarks about the rating procedure. It states that throughout the maneuvers, if appropriate, good judgment commensurate with a high level of safety must be demonstrated. In determining whether such judgment has been exercised, the inspector/examiner who conducts the check considers adherence to approved procedures, actions based on the analysis of situations for which there is no prescribed or recommended practice, and qualities of prudence and care in selecting a particular course of action. As already mentioned, these actions must be based on knowledge of the airplane, its systems and components, and compliance with approved en route, instrument approach, missed approach, ATC, or other existing and applicable procedures (11).

Notwithstanding the amount of thought, experience, and care that is and has been invested in the present pilot rating procedure, one has to admit that it is subjective, based on more or less well defined and clear criteria, and--above all--catering to the concept of minimal standards. It is therefore well worth remembering what Knoop and Welde (25) stated in their study of an automated pilot performance assessment system developed for the United States Air Force. They listed the following sources of variance in subjective pilot ratings:

1. Judgments of this sort are made without reference to a definite standard since the same maneuver may be flown satisfactorily in a number of different ways.

2. Different standards of performance are usually employed due to differences in the examiner's knowledge, experience, and proficiency.

3. The examiner's operational skill, his personal assessment of the critical aspects of the maneuver or the job, and his own training may affect the perspective and judgment of the ratings.

4. The examiners differ in personal bias toward the student or pilot to be tested.

5. Raters have different concepts of the specific grading system in regard to the flight parameters involved, the knowledge tested, weights to be assigned, and the range of the qualitative categories.

6. It is difficult to compare actual performance with the conceptual performance and with what the average proficiency level should be at the time of the check ride.

Since our study program is essentially psychophysical and psychological in nature, the behavioral factors should be pointed out that Knoop and Welde (25) assigned to the examiner for evaluation:

1. Ability to plan effectively.
2. Decision making capability.
3. Sensorimotor coordination and smoothness of control.
4. Ability to share attention and efforts appropriately in an environment of simultaneous activities.
5. Knowledge and systematic performance of tasks.
6. Confidence proportionate to the individual's level of competence.
7. Maturity, i.e., the willingness to accept responsibility, the ability to accomplish stated objectives, judgments, and reaction to stress, unexpected conditions, and aircraft emergencies.
8. Motivation (attitude) in terms of the manner in which it affects performance.
9. Coordination with others (crew members).
10. Fear of flying.

11. Motion sickness.

12. Air discipline, i.e., adherence to rules, regulations, assigned tasks, and command authority (25).

These behavioral factors are in very close agreement with the 14 factors which were identified in our previous taxonomic survey (14). They are rather independently found in studies concerning military or civilian airmen, and they are consistently associated with successful and nonsuccessful pilot performance regardless of the level of skill, experience, technology, and automation. The main problem in this context does not concern the validity of the identified psychological and psychophysiological factors in measuring pilot proficiency, but the techniques, methods, and means with which these factors can be assessed with the least error variance possible.

There are many examples in the literature about attempts to improve subjective rating systems (e.g., 3,13,15). They mostly deal with the problem of obtaining quantitative measures that are free from personal or emotional bias, as well as being reproducible and permanent. In this context, Grunhofer and Gerbert questioned the validity of proficiency records obtained from pilots of the German Air Force (17). Reporting their findings at the AGARD Conference on Physical Fitness in Flying, Including the Aging and the Aged Aircrew, they concluded that only objectively measured or assessed flying performance reflects intra- and interindividual differences, age-specific changes and, possibly, insufficiences. And they state: "It is only with measurements of this nature that we could diagnose when a man has reached the point where he will be unable to compensate for performance decrements in this or that particular ability and in a certain flight task, and where the reduced degree of reliability of inflight behavior will endanger flying safety."

The authors reflected seriously on how to assess significant aspects of performance and they recommended, as a first step, the upgrading of the flight performance ratings from the two-grade system "Satisfactory" and "Unsatisfactory" to a five-grade flying proficiency statement, which would be prepared by the Wing Commander for every pilot whenever he is due for his annual physical examination. Such a system would differentiate between proficiency levels, reduce gross errors in judgment, demand a more analytical approach by the rater, and provide better quantifiable results. It would also be suitable for longitudinal studies and permit correlations with flying experiences, training status, type of aircraft flown, physiological and psychological data, and age. The authors concluded that in this way it may be possible to recognize in time "critical symptoms of aging," identify certain "syndromes of aging," and determine "Verhaltensalter," meaning functional age, which could be used as a criterion for reassignment or retirement from flying.

In Holland, Van der Laan (35) assessed the behavior, of which human performance is a derivative, of 99 KLM pilots in the cockpit. During the regular proficiency checks, pilot behavior was graded by means of an elaborate rating scale. An analysis of the main factors that could be isolated as a

FLIGHT EVALUATION RECORD

			HOBBS	TACH
SUBJECT ______				
INSTRUCTOR ______		FINISH	____	____
AIRCRAFT ______		START	____	____
FLIGHT ______		TOTAL	____	____
QUIZ GRADE ______		DATE	______	
OVERALL GRADE ______				

	Procedures Retention & Recall	Judgment & Problem Solving	Motor Coordination
FLIGHT PLANNING & FILING			X
AIRCRAFT PREFLIGHT		X	X
START, TAXI & RUNUP		X	X
TAKEOFF & DEPARTURE		X	
SLOW FLIGHT	X	X	
STALLS		X	
VOR ORIENTATION & TRACKING			X
SIMULATED ENGINE OUT	X		
SIMULATED LOSS OF HORIZON			
PILOTAGE & DEAD RECKONING			X
CHANGE IN FLIGHT PLAN			X
RADIO PROCEDURES			X

LANDINGS

	Pattern	Accuracy
1st		
2nd		
3rd		
4th		
5th		
6th		

1 3 5 4 3 2 1 0

Figure 1. Flight evaluation record developed by Hollister and LaPointe (20).

result of the check ride yielded the following loadings: (i) work efficiency (r=0.42), (ii) emotional stability (r=0.23), and (iii) sociability (r=0.17).

In an attempt to identify and determine skill degradation in private and commercial pilots, personnel from the Massachusetts Institute of Technology (MIT) conducted flight performance tests for the FAA in 1972/73 (20). Five experienced pilots were assigned as evaluators for the flight test program conducted in a Cessna 150 aircraft. Their evaluation procedure was "standardized" on a Flight Evaluation Record Form (see Figure 1) through discussion periods, standardized flights, and the following guidelines:

"Skill grades were assigned as indicated on the Flight Evaluation Record Form for major subareas of each flight, plus an overall grade and written quiz grade, when taken. A grade was entered in all boxes for which the subject's performance was observed and a dash, if the box was not applicable to the flight or the maneuver was not performed. Grades were assigned on the basis as follows: 5 = perfect, 4 = above average, 3 = average, 1 = unacceptable, and 0 = dangerous.

"For all flights, grades were given on the following: (1) Aircraft preflight, (2) start, taxi, and run-up, (3) takeoff and departure, (4) simulated engine-out, (5) radio procedures, (6) landings, and (7) overall grade. For the first and last flights, additional grades were included on slow flight and stall and landings. The cross-country flight included additional grades on: (a) Flight planning and filing, (b) VOR orientation and tracking, (c) simulated loss of horizon, (d) change in flight plan, and (e) landings at several airports (if feasible).

"In general, the criteria for "average" was that established by the FAA Private Pilot Flight Test Guide AC 61 (11). Individual grades were assigned on observed performance in three areas; and an overall grade was recorded. The graded areas were:

1. Procedure, retention, and recall. The subject was expected to be knowledgeable concerning FAR, Part 61 - Certification: Pilots and Flight Instructors, and Part 91 - General Operations and Flight Rules. Written quizzes were administered to each subject prior to the first two flights, but evaluators were expected to ask questions and observe the subject's adherence to specific rules and procedures as required for safety of flight.

2. Judgment and problem solving. Grades in this area were based on the subject's ability to use whatever information was available to him and to apply it as would be expected for his level of pilot certification. Especially important was the subject's judgment and actions as related to flight safety.

3. Motor coordination. The "average" pilot was expected to demonstrate the ability to maintain the aircraft in a safe flight attitude under all normal conditions. For all maneuvers it was required that airspeed be

UNITED AIRLINES

PILOT PROFICIENCY

SEE PROFICIENCY SECTION OF AIRCRAFT MANUAL

ROUTE TO
1. HOME DOMICILE
2. DEN-W/TK FILE
3. FLIGHT OFFICER

CAPTAIN (CIRCLE ONE)	DOMICILE	FILE NUMBER
F/O		
S/O		

AIRCRAFT TYPE & NUMBER	BLOCK TIME	FLIGHT TIME	SIMULATOR TIME

☐ AIRPLANE ☐ VISUAL SIM ☐ SIMULATOR ☐ ORAL ☐ (209-1/2) ☐ (CAT II)

☐ P/C ☐ P/T ☐ RECHECK ☐ RATING ☐ SPECIAL ☐ EVAC ☐ PREFLIGHT

GRADING LEGEND

S - Satisfactory

U - Unsatisfactory

I - Incomplete (Other than proficiency)

REMARKS

This flight crew member has been checked/trained as indicated above. Applicable provisions of all Federal Air Regulations and the UAL Flight Training Manual have been met when satisfactorily completed.

EVACUATION TRAINING INSTRUCTOR SIGNATURE	DATE / /	CHECK FLIGHT ENGINEER SIGNATURE	DATE / /
PART 121 APPROVED INSTRUCTOR	DATE / /	BRIEF TIME · TRNG. TIME · ADF · ILS · BK CRS · VOR	RADAR APP
[illegible]	DATE / /	FLIGHT OFFICER SIGNATURE	
CHECK AIRMAN (A/C) SIGNATURE	DATE / /	REVIEWED BY MANAGER/DIRECTOR OF FLIGHT OPERATIONS	
CHECK AIRMAN (ORAL) SIGNATURE	DATE / /		

[illegible] PRINTED U.S.A.

Figure 2. Reproduction of United Airlines Pilot Proficiency Record.

ORIGINAL-EMPLOYEE'S FILE
DUPLICATE-TO EMPLOYEE

UNITED AIR LINES
FLIGHT CREW ENROUTE PROFICIENCY CHECK
SEE REGULATIONS 25-4

CAPTAIN	PLANE TYPE	PLANE NUMBER	FLIGHT NUMBER	DATE / /
FIRST OFFICER	FROM		TO	
SECOND OFFICER	FLIGHT TIME DAY		NIGHT :	
NAVIGATOR	OVER-ALL EVALUATION ☐ SATISFACTORY ☐ UNSATISFACTORY		☐ INITIAL FLIGHT ASSIGNMENT (See No. 7 below)	

1. FLIGHT PREPARATION — COMMENTS
   - Uniform and Equipment
   - Flight Planning
   - Cockpit Preparation
2. PRE-TAKEOFF — COMMENTS
   - Inspection and Cockpit Setup
   - Engine Starting
   - Taxi Procedure
3. TAKEOFF AND CLIMB — COMMENTS
   - Takeoff Technique
   - Observation of V1, VR, V2
   - Gear and Flap Management
   - Speed and Altitude Control
   - Traffic and Anti-noise Procedures
4. ENROUTE — COMMENTS
   - Cruise Control
   - Traffic Alertness
   - Communications
   - Use of Radar
5. APPROACH — COMMENTS
   - Descent and Speed Control
   - Approach Procedures
   - Use of Auto Pilot and Flite Director
   - Landing Technique
   - Reversing, Braking and Engine Shutdown
6. GENERAL — COMMENTS
   - ATC Procedures
   - Knowledge of Takeoff and Landing Limitations
   - Equipment Knowledge
   - Adherence to S.O.P.
   - Use of Navigation Equipment
   - Public Relations - PA System
   - Command Ability and Cockpit Management
   - Use of Challenge and Response Lists

7. This completes Initial Flight Assignment requirements for ______ type aircraft in accordance with FAR as follows.

TRIP NO.	DATE	FROM	TO	LANDINGS	OBSERVED FLT TIME	OBSERVER (OOC) TIME
	/ /					
	/ /					
	/ /					
	/ /					
	/ /					
	/ /					
	/ /					
			TOTAL			

8. REMARKS AND RECOMMENDATIONS

CREW MEMBER (SIGNATURE) | CHECK F/M (SIGNATURE) | REVIEWED BY DIR./MGR. OF FLIGHT OPERATIONS (SIGNATURE)

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Figure 3. Reproduction of United Airlines Flight Crew Enroute Proficiency Check form.

UNITED AIRLINES FLIGHT TRAINING CENTER
PILOT FLIGHT TRAINING RECORD

Capt
F/O________________________________

Domicile__________ Class #__________ 197__

Int ( ) Initial
Tr - ( ) Transition
( ) Upgrade - F/O to Capt
( ) Upgrade - S/O to F/O

( ) Currency
( ) Special

B-727 ( )
B-737 ( )
B-747 ( )
DC-8 ( )
DC-10 ( )

1	2	3	4	5	6	7	8		9	10	
							LANDINGS			INSTRUCTOR	
DAY	SIM/AC # OR OTHER ACTIVITY	BLOCK TIME SIM/ACFT	TOTAL BLOCK TIME (ACCUM)	AS PILOT @ CONTROLS SIM/ACFT	TOTAL AS PILOT @ CONTROLS (ACCUM)	AS S/O	DAY	NITE	GROUND TRAINING HOURS	FILE #	SIGNATURE

INSTRUCTIONS

COLUMN #
1. Day & Month
2. Sim or A/C number, CPT, CTS or Class, (CR)
3,5,7. Enter Hours & Minutes Daily
4, 6. Accumulate Columns #3 & #5 (Sim & A/C)

COLUMN #
8. Ldgs: Include T&G & Full Stop as One Total
9. Grnd. Trng. Time - Hrs. & Minutes for All.
10. Instructor File # & Signature for Each Work Assignment

REMARKS:

UDMA

87../6
Page 1

Figure 4. Reproduction of United Airlines Pilot Flight Training Record. (Continued on next page.)

SIMULATOR	DATE	AIRPLANE
	1. [illegible]	
	A. Acft. Visual Insp	
	B. Preflight Start Procedures	
	C. Taxiing	
	D. Pre-takeoff Checks	
	2. TAKEOFFS	
	A. Normal	
V	B. Instrument (100')	
	C. Crosswind	
TrV	D. Engine Failure before V2	
*	E. Night - 1 Req'd	
	F. Rejected	
	3. FLIGHT MANEUVERS & PROCEDURES	
	A. [illegible] Control	
	B. [illegible] Buffet	
	C. [illegible] Stabilizer (Except DC10)	
	D. Jammed Stabilizer	
	E. Approach to Stalls	
Tr	(1) Clean	Also Int
Tr	(2) Takeoff (15° Bank)	In A/C Int
Tr	(3) Landing	3O to FO Int
Tr	F. Flt. Characteristics	Up-Grd Int
Tr	G. Steep Turns (Capt. only)	Int
	H. Max Endurance & Max. Range	
	I. Panel Trng. (Not Reqd SO-FO Upgrd)	
	J. Anti-icing & De-icing Pr	
	K. Area Arrival/Departure	
	L. Use of Nav/Comm. Equip.	
	M. Holding	
	4. INSTRUMENT APPROACHES	
	A. ILS F/D	
	B. ILS Autocoupler (Autoland 747/DC10)	
TrV	C. ILS F/D, Engine Inop	Int
	D. VOR	
	E. ADF	
	F. ASR	
	G. ILS Back Course	
V	H. Non Precision (One Req'd)	
	5. MISSED APPROACHES	
TrV	A. From ILS	Int
TrV	B. With Engine Inop	Int
V	C. From Non-Precision (One Req'd)	
	D. Complete Published M/A Proc.	
	6. LANDINGS & APPROACHES TO LANDINGS	
	A. Normal	
TrV	B. From ILS	Int
	C. Engine Inop	
	D. Crosswind	
#V	F. 50% Power-4 Eng. A/C (Capt. Only)	Int
TrV	F. Zero Flap Approach (Capt. Only)	Int
TrV	G. Circ. Apprch & Lndg (737 Capt Only)	Int
TrV	H. Rejected Landing	Int
*	I. Night - 1 Req'd	
TrV	J. Stab Out Trim[illegible] Arnd (Capt. Only)	Int
#V	K. 1-Eng Lndg. 3-Eng A/C (Capt. Only)	Int
[illegible] 727 747	7. EMERGENCY & IRREGULAR PROCEDURES	
	A. Engine Fire, Damage or Separation	
	B. Rapid Depress. & Emerg. Descent	
	C. Electrical Smoke or Fire	
	D. Radio/Flt. Instrument Failures	
	E. Jammed Stab. Lndg. (Sim. Only)	
	F. Loss of Hyd. Fluid or Pressure	
V	G. Manual Flt. Cont. Approach (Land DC8)	
	H. 2-Eng. Missed Aprch. (Sim. Only-Capt)	
	I. Landing, No Spoiler Press. (Sim. Only)	
	J. Landing-PTC Extend. (Sim. Only)	
	K. Pneumatic Manifold Over-Temp.	
	L. Manifold Fail Light On	
	M. Manifold Air Pressure Light On	
	N. Loss of All Generators	
	O. Cargo Cabin Compt. Smoke or Fire	
	P. Ditching (Oral)	
	Q. Wheel Well Fire in Flight	
	R. APU Fire	
	S. Alternate Flap Extension	
	T. Manual Gear Extension	
	U. Asymmetrical T.E. Devices	
	V. Asymmetrical L.E. Devices	
	X. Strut/Body Overheat	
	Y. One Generator Operation	
	Z. Loss of all Engines	
	AA. Yaw Damper Inoperative	
	BB. Inadvertent Thrust Reversal	
	CC. 1-Eng. Missed Aprch. (Sim Only-Capt)	
	8. COMMAND	
	9. JUDGMENT	
	10. FLIGHT INSTRUCTOR'S INITIALS	
	11. PILOT'S INITIALS	

GRADING LEGEND

ACFT & SIM	VISUAL SIM
S	SV - Satisfactory Progress
S	SV - End Level Proficiency
U	UV - Unsatisfactory Progress

SYMBOLS

V --Visual Sim. authorized to end level prof. If done, A/C trng. not required.

TrV--Visual Sim } Visual to End Level Prof. for Trans & UpGrd. If done A/C Trng. not Required.
Tr --No Vis. Sim }

Int--End Level Prof. in A/C for Init. Trng.

#V --Req'd in A/C for Capt. Init. & F/O to Capt UpGrd. unless maneuver previously performed by F/O. All others to End Level Proficiency in Visual Sim

FV--Auth. in Vis. Sim. May be done in non Vis. for Trans. Trng. from eng. mounted in similar position, or from wing mounted to aft mounted engines. Vis. Sim allowed for all other categories.

* --Night T/O & Ldg. -For Trans. Capt Accomplish if practical, but may be deferred and done while meeting line operation experience requirements. Required during trng. for all other cat.

Figure 4 (Continued)

UNITED AIR LINES FLIGHT TRAINING CENTER - PILOT FLIGHT TRAINING RECORD
DC-8 Equipment

S/O__________ File No.__________ Domicile__________ Class No.________ 197______

1	2	3	4	5	6	7	8	9	10	11	
DATE	SIM/AC # OR OTHER ACTIVITY	DAILY TOTAL BLOCK TIME				ACCUMULATIVE			EXTRA GROUND HOURS	INSTRUCTOR	
		AS PIC	AS F/O	AS S/O	AS OBSVR	TOTAL PIC	TOTAL	SIM/AC		SIGNATURE	FILE NO.

Column #
1. Day & month
2. Sim. or Acft. # - Additional Training (Tutoring, Extra CTS, Extra Oral Review)
3,4,5,6. Hours and Minutes
7. Accumulate Column #3
8. Accumulate Column #5
9. Accumulate Totals of Columns 3, 4, 5, 6.

NOTE: Accumulate A/C Total separate from Sim. Total.

Column #
10. Additional Training: Hours & minutes for tutoring, extra CTS, extra oral review training for rating, oral or certification failures.
11. Signature and file number.

1/12/78

U-26-8

CPT 1	2	3	4	5	6	7	8	9		Item		SIMULATOR 1	2	3	4	5	6	7	8	CK	AIRPLANE 1	2	3	CK
										Cracked Windshield	D													
										Windshield Heat Inop	D													
										Tail De-Ice System Lite On Cont.														
										Eng. Anti-Ice Valve Lite On														
										Door Warning Lite On														
										Abnormal Fuel Burnout Report	#													
									*	Hydraulic Fail Lite On														
									*	Press. Relief Valve Open Lite On														
									*	Radio Rack Overheat Lite On														
									*	Freon Compressor Overheat Lite On														
									*	Cabin Compressor Overheat Lite On														
									*	Cabin Comp. Stall, Surg. or Noisy.														
									*	Cabin Compressor RPM Abnormal or Gage Inop.														
									*	Automatic Press. Inop After Takeoff														
									*	Animal Comp. Overheat/Underheat (-61 & -62)	D													
										Two-Eng. Approach & Landing	#													
										Two-Eng. Go-Around	#													
										Three-Eng. Approach & Landing	#													
										Jammed Stabilizer Landing	#													
										Landing w/ Pitch Trim Comp. Extended	#													
										Landing w/ Partial Gear	#													
										E. MISCELLANEOUS														
									*	-61 Differences														
										-62 Differences	D													
									*	Additional Procedures (All Exc. INS)														
										Refueling Procedure	#													
									*	Circuit Breaker Panel Fam.														
										Radio, Nav, & Flite Inst. Malfunctions	#													
									*	Ice Detection vs. PT2 Heat & EPR Ind.														
									*	T/O Horn, Land. Horn, Cabin Alt. Horn														
									*	A/C Pneumatic Start														
										Bulletins	D													
										Cabin Familiarization & Preflight														
										Exterior Inspection														
										Use of Radios														
										Log Book Entries														
										8-F Cargo Door	D													
										Visual Gear Check														
										Manual Pressurization														
										Hydraulic Replenishment														

GRADING LEGEND
✓ - Accomplished - Not Graded
S - Satisfactory
(S) - End Level Proficiency
U - Unsatisfactory
* - In CPT
# - In Simulator
D - Supplemental Discussion
@ - Discussion if -8F Unavailable

Figure 5. Reproduction of United Airlines Flight Training Center - Pilot Flight Training Record (DC-8 Equipment). (Continued on next page.)

CPT 1	2	3	4	5	6	7	8	9				SIMULATOR 1	2	3	4	5	6	7	8	CK	AIRPLANE 1	2	3	CK
									A.	NORMAL OPERATIONS - S.O.P.														
									*	Cockpit Familiarization														
									*	Cockpit Preparation														
									*	Engine Start														
									*	Taxi-out														
									*	Takeoff Card														
									*	Takeoff														
									*	Climb														
									*	Cruise														
									*	Descent														
									*	Landing Card														
									*	Landing														
									*	Taxi-in														
										Fuel Management	#													
									*	Use of Check Lists														
									B.	PERFORMANCE														
									*	Limitations														
									*	Partial Flap Card														
									*	Zero Flap Card														
									*	Gross Weights/Takeoff & Landing														
									C.	EMERGENCY PROCEDURES														
									*	Loss of All Generators														
									*	Flameout or Engine Fails to Accelerate														
									*	Irregular Starts														
									*	Starter Valve Fails to Close														
										Passenger Evacuation	D													
										Ditching - Unplanned	D													
									*	Eng. Fire. Severe Eng. Damage or Eng. Sep.														
										Cargo Cabin Comprt. Smoke or Fire (8F)	@													
									*	Loss of Hyd. Fluid (w/wo Loss of Pressure)														
										Undesirable Aileron or Rudder Operation	D & #													
									*	Emergency Descent														
									*	Rapid Depressurization														
									*	Manifold Air Over Temp Lite On														
									*	Manifold Air Press Lite On														
									*	Manifold Fail Lite On (-61 & -62)														
									D.	IRREGULAR PROCEDURES														
									*	Erroneous Mach/Airspeed Indications														
									*	Inop Equip. Result from Elec Bus Fail														
									*	Elec. System Smoke or Fire														
									*	Bus Power Fail Lite On														
									*	Generator Unparallel Lite On														
									*	All Gen Unpar. Lites on & No Bus Pwr. Fail Lites On														
									*	High or Rising Gen. Drive Oil Temp.														
									*	Gen Drive Oil Warn Lite On														
									*	Gen Drive Fails to Disconnect														
									*	Loss of More Than One Gen.														
									*	Battery Start														
									*	Hung Start														
									*	Inflight Engine Shutdown														
									*	Flameout Report														
									*	Inflight Engine Start														
										Fuel Flow Abnormally High	#													
									*	High Engine Oil Temp.														
									*	Oil Press. Warn Lite On														
									*	Engine Stuck in Reverse - JT4														
									*	Operation w/Ejector Extended														
									*	Engine Stuck in Reverse - JT3D														
										Eng. Thrust Brake Lite Flash, Cont. (-62)	D													
									*	Engine Doors Open Light On														
										Prep. for Passenger Evac.	D													
										Ditching - Planned	D													
										Fuel Dumping	#													
										Alt. Qty. Low Lite On (Exc. -62)	#													
										Fuel Tank Boost Pump or Feed Pump Inop	#													
										Alt. Qty. Low Lite to Flash (-62)	D													
										Fuel Qty. Gage Inop.	#													
									*	Hyd. Oil Temp. Lite On														
									*	Loss of Hyd. Press. (No Fluid Loss)														
									*	Hyd. System Press High (3300 PSI)														
									*	Ind. Loss of Hyd. Fluid (No Pressure Loss)														
									*	Aux. Pump Press Low														
										Stabilizer Creeping	#													
										Jammed Stabilizer	#													
										Pitch Trim Comp. Inop or Malfunction	#													
										Rudder Control Manual Lite On	D & #													
										Aileron Control Manual Lite On	D & #													
										Wing Slots Lite On	#													
										Unable to Arm Spoilers	#													
										Inbd Spoil. Extnd or Do not Retract Inflight	#													
									*	Main Gear Spoil Inop Lite On (-61, -62 & 8F)														
										No Drop in Spoil Press After Gear Retract.	#													
										Spoil Press Low after Gear Extension	#													
									*	Lndg. Gear Unlatch Chk. Fail or Doors Lite On														
									*	Lndg. Gear Lever Can't be Raised After Takeoff														
									*	Lndg. Gear Lever Can't be Moved to Dn. Pos.														
									*	Lndg. Gear Lever Dn. & Lndg. Gear Unsafe Lt. On														
									*	Anti-skid Fail Lite On														

Figure 5 (Continued)

maintained within ± 5 mph, altitude within ± 100 ft, and heading within ± 10°. In addition, the subject was expected to be able to quickly recognize unsafe flight conditions and to take proper action when needed.

4. Overall grade. This concerned the evaluation of the overall skill and knowledge demonstrated on each flight. The subject was given comments on his performance, but no information on grades or the rating system.

In a similar way but using a more sophisticated format, United Airlines (UAL) makes a concerted effort to use "objective" test procedures for assessing pilot proficiency. The grading system now in use is a pass/fail system, and the evaluation criteria used are contained in the airplane flight manuals which were established under the "Specific Behavioral Objectives" system. The pilot proficiency rating is given in a more general way in Figure 2. It documents how the pilot has been trained and checked and that the United Airlines flight training requirements were met and completed.

Figure 3 is a reproduction of a UAL form which shows the systematic arrangement of crew rating requirements in an operational sequence from the flight preparations to the final approach and landing procedure at the end of a flight. In addition, Box 6 on that form contains criteria for comments on general requirements which the crew member must meet during the en route proficiency check. There also is space for remarks and recommendations concerning shortcomings, retraining, and flight or crew assignment.

Figures 4 and 5 are reproductions of UAL forms which contain very detailed information on the pilot's record for simulator and inflight training as requested by the company's flight training center. The training record and grading standards are given in a very general form in Figure 6.

It should also be pointed out in this context that all pilots-in-command operating FAA aircraft must satisfactorily complete periodic proficiency checks; and the results of these checks are recorded on FAA Form 4040-2 (see Figure 7). The Record of Check Flight includes 12 categories containing items of significance to the safe operating and piloting an aircraft as shown in Figure 7. The check pilot will mark only those items that are applicable to a particular check ride or proficiency test, and the grading on each item is either "satisfactory" or "unsatisfactory." Compared to some of the other examples given in this report, this system of rating pilot proficiency is rather unsophisticated and does not lend itself to a more differentiated assessment of performance.

The proficiency ratings of British airline pilots as directed by the Civil Aviation Authority (CAA) is similar to that of its American counterpart. Methods of assessment generally vary with the individual airlines, and most of them also apply a simple pass/fail criterion; with a few requesting a somewhat expended scale providing for remarks like "very good," "good," "satisfactory," and "unsatisfactory," or like the European Division of

UNITED AIRLINES
TRAINING RECORD AND GRADING STANDARDS

__Certificate of Training (UF 2403)__

1. **PURPOSE.** To serve as the permanent record of an airman's (pilot, or dispatcher) training. Along with the UO109, it satisfies the requirements of FAR 121.401(c) and FAR 121.683 for certification of proficiency after training and evidence of previous training pre-requisite for ensuing approved training courses.

NOTE: See Flight Dispatcher's Training and Competency Record in 25-2. This is the permanent domicile record of a Dispatcher's training and qualifications.

2. **THE CERTIFICATE OF TRAINING** is executed and signed by the Training Manager when the airman (pilot or dispatcher) has satisfactorily completed ground and/or flight training. State the grade as "S" (satisfactory), or "U" (unsatisfactory).

3. **TERMINATION.** If an airman's (pilot or dispatcher) training is terminated before successful completion of the course, enter a note to this effect under "Remarks" including the date and the phase in which training was discontinued. The Training Manager signs it.

4. **ROUTING.** Forward the original of the UF 2403, along with the original of the UO 109 to the domicile to be included in the airman's (pilot or dispatcher) file, keep the duplicate, attached to the second copy of the UO 109, at DENTK. Forward all other training records associated with the subject course, including records of activities and grades of the day-to-day training, to the airman's Director/Manager of Flight Operations who discusses the records with the airman before giving them to him for his disposition.

UNITED AIRLINES
TRAINING RECORD AND GRADING STANDARDS

__Flight and Simulator Training Grade Standards__

5. **USE THE FOLLOWING GRADING** in flight training and simulator training. Daily grades should reflect a pilot's progress toward the level of proficiency required for certification. Add a "V" to the grade symbol if the maneuver is performed in a visual simulator.

S – Satisfactory Progress—Proficiency in execution of maneuver is progressing satisfactorily toward the desired level.

Ⓢ – Satisfactory Level or Proficiency—Proficiency in execution of maneuver is consistently at a satisfactory level.

U – Unsatisfactory Progress—Proficiency in execution of maneuver has not reached a satisfactory level, the performance thereof is highly erratic or inconsistent, or progress is not being made. Enter the specific deviation from satisfactory level of performance supporting lack of progress in the remarks section of the grading form; reference the maneuver by number.

__Written Examination Grade Standards__

6. **OPEN-BOOK EXAMINATIONS 80%** or better is passing.

7. **CLOSED-BOOK EXAMINATIONS 70%** or better is passing.

Figure 6. Reproduction of United Airlines Training Record and Grading Standards for (left) Certificate of Training (UF 2403) and (right) Flight and Simulator Training Grade Standards.

RIS [illegible]

PILOT/FLIGHT ENGINEER/NAVIGATOR FLIGHT RECORD AND RECORD OF CHECK FLIGHT

INSTRUCTIONS – This form will be utilized and processed as required in Handbook [illegible]

NAME OF EMPLOYEE TO BE CHECKED *(Last, First, M.I.)*	ORGANIZATION LOCATION	DATE OF BIRTH *([illegible])*

AIRMAN CERTIFICATES HELD

TYPE	CERTIFICATE NO
AIRLINE TRANS. PILOT	
COMMERCIAL PILOT	
PRIVATE PILOT	
FLIGHT INSTRUCTOR	
MECHANIC	
AIR TRAFFIC CONTROL TOWER OPERATOR	
FLIGHT ENGINEER	
FLIGHT NAVIGATOR	
OTHER *(Specify)*	
TYPE RATINGS *(Specify)*	

RATING RECORD

- SINGLE ENGINE ☐ LAND ☐ SEA
- MULTI ENGINE ☐ LAND ☐ SEA
- AIRPLANE
- AIRFRAME
- INSTRUMENT
- POWER PLANT
- ROTORCRAFT
- HELICOPTER
- GLIDER
- GYROCOPTER
- FLIGHT INSTRUCTOR ☐ AIRPLANE ☐ INSTRUMENT
- OTHER *(Specify)*

AGENCY *(FAA)* DESIGNATIONS

- CHECK PILOT
- INSTRUCTOR PILOT
- CHECK FLIGHT ENGR
- INSTRUCTOR FLT ENGR
- CHECK NAVIGATOR
- INSTRUCTOR NAVIGATOR
- PILOT
- NAVIGATOR
- FLIGHT ENGINEER
- OTHER *(Specify)*

CURRENT AIRMAN MEDICAL CERTIFICATE HELD

CLASS ☐ FIRST ☐ SECOND ☐ THIRD

ISSUE DATE

PREVIOUS FLIGHT CHECK

TYPE A/C

CHECK DATE

FLIGHT EXPERIENCE (FAR 61.39, 61.41, 61.47, 63.37, 67.55; Handbook 4040.9)

NOTE – Complete Items 2 through 7 below ONLY if no previous FAA Form 4040-2 is on file at the office administering check flight.

LINE NO.	ITEM	HOURS: FLT NAVIGATOR	HOURS: FLT ENGINEER	HOURS: PILOT
1	TOTAL FLIGHT TIME			
2	MULTI ENGINE TIME OVER 12,500 LBS			
3	MULTI ENGINE TIME 12,500 LBS OR LESS			
4	ROTORCRAFT TIME			
5	TOTAL INSTRUMENT TIME			
6	TOTAL NIGHT TIME			
7	PRINCIPAL AIRCRAFT BY TYPES FLOWN DURING PAST 5 YEAR PERIOD *(Limit to 5 entries—combine comparable types)*			
	(1)			
	(2)			
	(3)			
	(4)			
	(5)			

FLIGHT COURSES COMPLETED PAST 12 MONTHS

LOCATION		TYPE AIRCRAFT	LENGTH	COMPLETION DATE
FAA ACADEMY	OUT OF AGENCY			
FAA ACADEMY	OUT OF AGENCY			

TYPE FLIGHT CHECK REQUIRED

			TYPE AIRCRAFT
PILOT	INITIAL QUALIFICATION	CATEGORY II	
FLT. ENGINEER	REQUALIFICATION	ACADEMY INSTRUCTOR	
NAVIGATOR	PROFICIENCY	AFTER ACCIDENT	
OTHER *(Specify)*			

REQUEST DATE	SIGNATURE OF EMPLOYEE TO BE CHECKED	ROUTING SYMBOL ORG

AUTHORIZATION FOR APPLICANT TO BE FLIGHT CHECKED

APPROVAL DATE	SIGNATURE OF APPROVING AUTHORITY	ROUTING SYMBOL ORG

FAA Form 4040-2 (1-73)

Figure 7. Reproduction of Pilot/Flight Engineer/Navigator Flight Record and Record of Check Flight (FAA Form 4040-2). (Continued on next page.)

RECORD OF CHECK FLIGHT(S) (Cont'd)

Check Pilots/Flight Engineers/Navigators shall mark only items accomplished, grading each category and item as Satisfactory—S Unsatisfactory—U or Not Applicable—NA. Items marked with an asterisk (*) are to be accomplished with reference to instruments only, when appropriate. Entry in Remarks is also required.

PILOT ITEMS

CATEGORY	ITEM	GRADE
A	REGULATIONS AND PUBLICATIONS	
	1 FLT/OPERATIONS MANUAL	
	2 FAR S	
	3 FLIGHT PLANNING	
	4 4040 5	
	5 WEIGHT AND BALANCE	
	6 CHECK LIST	
B	PREFLIGHT	
	1 WALK AROUND INSPECTION	
	2 EQUIPMENT INSPECTION	
	3 COCKPIT KNOWLEDGE	
	4 TAXIING AND ENGINE RUN-UP	
C	AIRCRAFT SYSTEMS	
	1 POWER PLANT	
	2 FUEL AND OIL	
	3 HYDRAULIC AND ELECTRICAL	
	4 COMM AND NAV	
	5 DE-ICING AND ANTI-ICING	
	6 FIRE WARNING AND EXT	
D	TAKE-OFF	
	1 NORMAL, V1, VR, V2	
	2 CROSS WIND	
	3 SIM ENGINE FAILURE	
	4 SIM ENGINE FAILURE PRIOR V_1	
	5 SIM ENGINE FAILURE AFTER V_1	
E	LOCAL AIRWORK	
	1 SLOW FLIGHT *	
	2 APPROACH TO STALL *	
	3 STALL RECOVERY *	
	4 UNUSUAL ATTITUDE *	
	5 STEEP TURNS *	

CATEGORY	ITEM	GRADE
F	AIRWORK ENROUTE	
	1 AIRSPEED AND ALTITUDE CONTROL *	
	2 HEADING CONTROL *	
	3 TRAFFIC CONTROL PROCEDURE *	
	4 USE OF COMM/NAV EQUIP *	
G	EMERGENCIES	
	1 SIM ENG FAILURE IN FLIGHT *	
	2 SIMULATED ENGINE FIRE	
	3 FEATHERING/UNFEATHERING	
	4 JET AIR START	
	5 SIM. CABIN/COMPART. FIRE	
	6 SIM. HYDRAULIC FAILURE	
	7 SIM. ELECTRICAL FAILURE	
	8 EMERGENCY DESCENT	
H	APPROACHES	
	1 HOLDING *	
	2 VOR ILS ADF PAR ASR RNAV *	
	3 MISSED APPROACH *	
	4 JET PENETRATION *	
I	LANDING	
	1 TRAFFIC PATTERN	
	2 NORMAL	
	3 SIM ENGINE OUT	
	4 CROSS WIND	
	5 REJECTED LANDING	
J	KNOWLEDGE OF A/C SURV EQUIP	
K	SMOOTHNESS AND COORDINATION	
L	JUDGMENT AND TECHNIQUE	
	1 FLIGHT TIME (*Hours & Tenths*)	
	2 LANDINGS (*Number*)	

FLIGHT ENGINEER ITEMS

CATEGORY	ITEM	GRADE
A	EQUIPMENT EXAMINATION (*Oral*)	
B	PREFLIGHT INSPECTION	
C	NORMAL OPERATING PROCEDURES	
D	ABNORMAL OPERATING PROCEDURES	
E	PERFORMANCE DATA & CRUISE CONTROL	
F	TROUBLE SHOOTING	
G	EMERGENCY PROCEDURES	
H	FORMS AND RECORDS	
I	POST FLIGHT	
J	CREW COORDINATION	
K	JUDGMENT	
L	FLIGHT TIME (*Hours & Tenths*)	
M	DATE	

FLIGHT NAVIGATOR ITEMS

CATEGORY	ITEM	GRADE
A	EQUIPMENT EXAMINATION (*Oral*)	
B	EQUIPMENT CHECK	
C	PREFLIGHT PLANNING	
D	NORMAL NAVIGATION PROCEDURES	
E	KNOWLEDGE OF NAVIGATION METHODS	
F	COORDINATION OF NAVIGATION METHODS	
G	EMERGENCY PROCEDURES	
H	COORDINATION OF DUTIES	
I	CREW COORDINATION	
J	JUDGMENT	
K	FLIGHT TIME DAY/NIGHT	
L	ROUTE OF FLIGHT FROM / TO	
M	DATE	

APPLICANT HAS BEEN FLIGHT CHECKED AND FOUND QUALIFIED:

- ☐ IN ACCORDANCE WITH PROFICIENCY REQUIREMENTS
- ☐ AS PIC IN COMMAND FOR CATEGORY II OPERATIONS IN ____ TYPE AIRCRAFT
- ☐ AS PILOT IN COMMAND OF AGENCY AIRCRAFT (*Type* ____) FOR IFR/VFR FLIGHT
- ☐ FLIGHT ENGINEER IN ____ TYPE AIRCRAFT
- ☐ AS PILOT IN COMMAND OF CATEGORY ____ RENTAL AIRCRAFT
- ☐ AS FLIGHT NAVIGATOR
- ☐ OTHER (*Specify*)
- ☐ AS ACADEMY INSTRUCTOR IN TYPE ____ AIRCRAFT
- ☐ NOT QUALIFIED (*Recommend additional time training*)

REMARKS (*Explain each unsatisfactory entry and identify strong and weak points. Attach additional sheets as necessary.*) ENTRY IS REQUIRED

SIGNATURE OF CHECK PILOT/FLIGHT ENGINEER/NAVIGATOR

AUTHORITY TO ACT IN THIS CAPACITY | DATE

Figure 7 (Continued)

British Airways, "above average," "average," etc. Usually, the biannual competency checks are treated as refresher training as well, and the rating is of the pass/fail type with most of the pilots passing this affair. The judgment of the inspector is, of course, subjective and the CAA does not require or specify detailed evaluation criteria. However, certain ground rules and standards are available in the "Notes for the Guidance of Authorized Instrument Rating Examiners" published by the CAA in London (CAP 170), since it is normal practice to combine the instrument rating and competency check. A combined instrument rating and competency check form is available for this purpose; and all items annotated on that form as being relevant to the instrument rating renewal must be rated at least "satisfactory" in order to pass the proficiency check.

The German Lufthansa has outdone the German Air Force in developing a "Pilot's Proficiency Report" which permits a rater to specify in great detail pilot performance during the training and overall proficiency assessment procedure. The report form (Figure 8) contains five main areas of competence, which describe distinct and observable modes of behavior (criteria). By using a numerical grading system from 1 to 5 (1 indicating "unusually effective," 5 indicating "unsatisfactory"), the instructor or flight inspector may rate the pilot in regard to the required level of performance. But the system is even more differentiated in that the grades 2, 3, and 4 are subdivided, so that actually 9 levels of competence are available to choose from. Moreover, the five main areas contain the following items:

1. Knowledge (Knowledge of Flight Rules, Regulations, and Mechanical Principles).

   Criteria: Is familiar with aircraft performance characteristics; can explain aircraft systems and knows their locations and limitations; understands the technical relationships of aircraft systems and their normal operations; is familiar with emergency procedures; knows the operational rules and flight procedures.

2. Use of Checklist (Philosophy and Application).

   Criteria: Uses the checklist conscientiously and conducts all necessary control actions in a systematic and timely fashion.

3. Flying Ability.

   3.1 Aircraft Handling (Use of Controls)

   Criteria: Controls the aircraft with sensible and good coordination; does not overcontrol during corrections; demonstrates steadiness in the control actions.

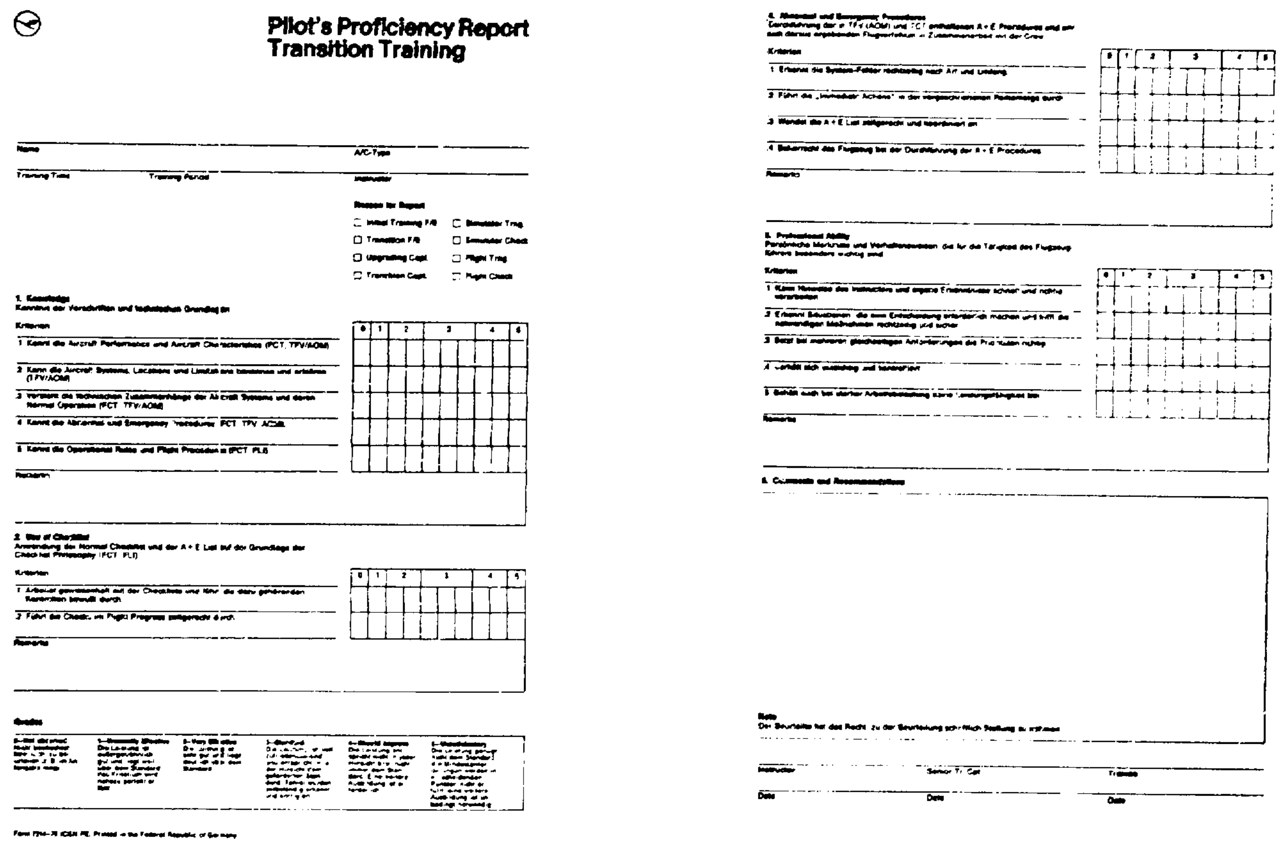


Figure 8. Reproduction of German Lufthansa Pilot's Proficiency Report Transition Training (front and back pages). (Continued on next page.)

3. Flying Ability

3.1 Aircraft Handling
Bedienen der Controls

Kriterien	0	1	2	3	4	5
1 Bedient die Controls koordiniert und feinfühlig						
2 Vermeidet Übersteuern bei Korrekturen						
3 Zeigt Stetigkeit in der Flugzeugführung						

Remarks

3.2 Basic Flying
Koordination aller fliegerischen Aufgaben zur Flugdurchführung

Kriterien	0	1	2	3	4	5
1 Hat jederzeit die Orientierung über die Fluglage und Position im Raum						
2 Erkennt die Trends in den Anzeigen durch gezieltes Instrument Scanning und reagiert rechtzeitig darauf						
3 Kann den gewünschten Flugzustand stabilisieren						
4 Macht gezieltes und situationsgerechtes Instrument Scanning						
5 Hält die Toleranzen ein						

Remarks

3.3 Take-Off and Climb-Out
Durchführung des Take-Off und Climb-Out entsprechend der vorgegebenen Trainingssituation

Kriterien	0	1	2	3	4	5
1 Beherrscht den Normal Take-Off unter verschiedenen Bedingungen (Gewicht, Crosswind, unterschiedliche Klappenstellungen, Anti-Noise)						
2 Trifft Entscheidung zum Startabbruch rechtzeitig und richtig und bringt das Flugzeug sicher zum Stillstand						
3 Beherrscht den Engine Failure after V_1 und fliegt nach dem Engine Failure Procedure						
4 Hält den Flap Speed Schedule ein						

Remarks

0—Not observed 1—Unusually Effective 2—Very Effective 3—Standard 4—Should Improve 5—Unsatisfactory

3.4 Instrument Approaches
Durchführung von Anflügen unter Instrumentenflugbedingungen

Kriterien	0	1	2	3	4	5
1 Kennt die für den Approach relevanten Daten und macht ein situationsgerechtes Briefing						
2 Fliegt die nach Art des Anfluges erforderlichen Procedures genau, koordiniert und unter Beachtung der ATC Clearance						
3 Hält die nach Flugzeugtyp vorgeschriebenen Verfahren ein						
4 Macht ein gutes Timing unter Berücksichtigung aller verfügbaren Informationen						
5 Kann im Final Approach den Flugzustand stabilisieren und bleibt im Slot (FLI)						
6 Beherrscht den Übergang zum Sichtflug						
7 Entschließt sich gegebenenfalls rechtzeitig zum Go-Around						

Remarks

3.5 Visual Approaches
Durchführung von Anflügen nach Sichtflugbedingungen

Kriterien	0	1	2	3	4	5
1 Hält die Verfahren bei den verschiedenen Platzrunden (Normal, Low Circling, Different Flap Settings) ein						
2 Kann Flugweg auf Down-Wind und Base-Leg unter Beachtung von Configuration und Windbedingungen für ein sauberes Eindrehen auf Final im Slot bestimmen						
3 Kann das Flugzeug on Final mit gezielten Korrekturen auf Centerline und Glide Path bezogen auf die Touch Down Area stabilisieren (FLI)						
4 Erkennt rechtzeitig die Notwendigkeit für einen Go-Around						

Remarks

3.6 Landing
Durchführung der Landung nach Instrumenten- und Sichtanflügen einschließlich der After Touch Down Procedure oder Go-Around

Kriterien	0	1	2	3	4	5
1 Leitet die letzte Landephase (break) zum richtigen Zeitpunkt ein						
2 Setzt auf der Centerline und in der Touch Down Area kontrolliert und sicher auf						
3 Beherrscht die After Touch Down Procedure						
4 Beherrscht die Landetechnik auch unter erschwerten Bedingungen (Seitenwind, Nacht, mit Abnormal Configurations)						
5 Leitet den Go-Around richtig ein (attitude, power) und führt die erforderlichen Aktionen in der richtigen Reihenfolge durch						

Remarks

0—Not observed 1—Unusually Effective 2—Very Effective 3—Standard 4—Should Improve 5—Unsatisfactory

Figure 8 (Continued) (middle two pages of form)

3.2 Basic Flying (Integration of Flight Procedures)

Criteria: Maintains orientation and position in space; reads instruments correctly and corrects unwanted deviations; intermittently scans airspace; anticipates changes in flight conditions; maintains course and desired flight path; keeps systems within tolerances.

3.3 Takeoff and Climb-out (Execution of Prescribed Maneuvers)

Criteria: Executes normal procedures under various conditions (weight, crosswind, flap position, noise abatement); when required, aborts takeoff in time and safely stops aircraft; compensates for engine failure after V_1 and proceeds in accordance with regulations; stays within flap speed schedule.

3.4 Instrument Approaches (Landing Approaches Under IFR Conditions)

Criteria: Knows all relevant subjects and conducts appropriate briefings; files in accordance with the approved procedures and observes ATC clearance; proceeds in a timely manner considering all available information; stabilizes flight conditions and stays in slot; transitions well from IFR to VFR; decides to abort approach and to go around, if indicated.

3.5 Visual Approaches (Landing Approaches Under VFR Conditions)

Criteria: Observes the various VFR landing procedures (normal, low circling, different flap settings); accurately determines downwind and base-leg approach under the prevailing flight conditions and configuration for proper line-up in slot; makes glidepath and centerline corrections and stabilizes the aircraft relative to touchdown area; decides to abort approach and to go around, if indicated.

3.6 Landing (Execution of Landing the Aircraft After IFR or VFR Approach Including Touchdown Procedure or Go Around)

Criteria: Initiates flare at the appropriate time; touches down on centerline and within touchdown area; observes after-touchdown procedures; lands aircraft under unfavorable conditions (crosswind, darkness, unusual configurations); initiates go around at the right time (attitude, power) and takes timely and adequate actions to land the aircraft.

4. Abnormal and Emergency Procedures (In Accordance With Flight Manuals and Crew Participation).

   Criteria: Recognizes kind and amount of system failures; takes appropriate and immediate action; uses Abnormal and Emergency Procedure List in a timely and coordinated way; keeps aircraft under control.

5. Professional Ability (Abilities and Behavior Important to the Pilot's Task).

   Criteria: Knows how to combine instructional advice and personal experience; recognizes situations which demand decisions and takes timely and appropriate actions; establishes the right priorities; acts calm and controlled; performs effectively under stress.

There is additional space left below each of the competence areas to supplement remarks about the behavior of the candidate or about special features of his performance which deserves attention; and such statements can be expanded on the last page of the performance report form under "Comments and Recommendations" (see Figure 8).

The total form, including the observations, grades, and recommendations, is shown to the trainee or rated individual at the end of the procedure; and the rated person has the right to a written reply or rebuttai in case of disagreement. There is also an attempt made by Lufthansa to provide the instructor or rater with a kind of standardized rating procedure.

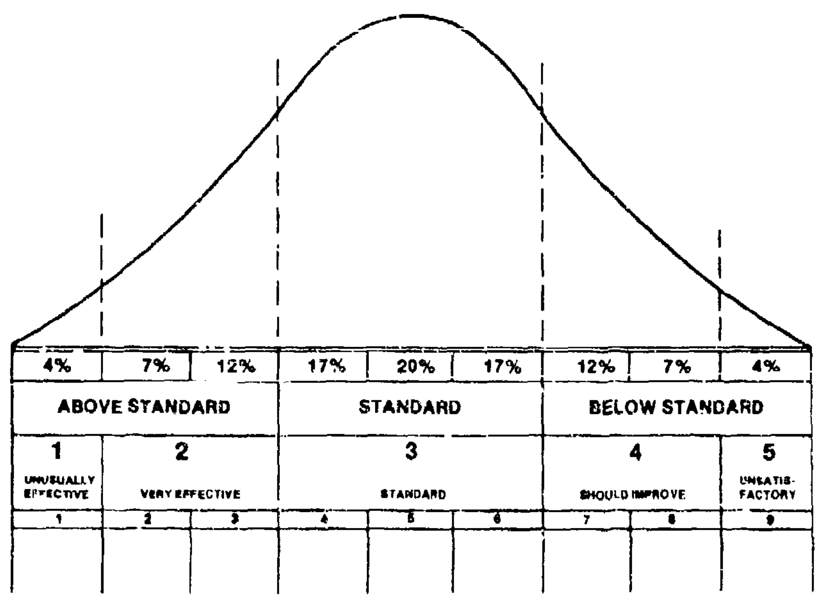


Figure 9. Normal distribution curve.

The Lufthansa rater is advised to use, if possible, the normal distribution curve as the basis of his grade assignments (see Figure 9). In this process, he should determine if (i) a rating within a certain area and on a specific criterion is indicated, (ii) the grade 3 is an adequate rating, (iii) a grade 2 or 4 would be more appropriate, or (iv) a grade 1 or 5 can be justified. A satisfactory performance is mandatory either as a measure of normal progress during transition training or as an accepted standard of pilot performance. A flight training test or a proficiency check is considered as passed, if all graded criteria are rated as at least standard performance.

In the United States, the FAA is aware of substantial variations in the manner in which inflight performance is assessed, and in the reports which reflect the evaluation, judgment, ratings, and results of the flight tests conducted by FAA examiners. The official performance guidelines, descriptive and detailed as they are, do not presently provide for a real objective assessment of the procedures, maneuvers, and operations, and even less for the behavioral characteristics, abilities, and skill of the applicant or pilot to be tested. As a remedy, the FAA is conducting seminars, training courses, and workshops for inspectors and examiners. Within the present system, this will help to increase the reliability, accuracy, and consistency of the subjective ratings.

By and large, it can be stated that there are many subjective systems available and in use which have been proven practical and efficient for assessing pilot performance. They can be adapted to any operational situation, expanded to provide needed or desired information, and kept on record during the professional life of a pilot. Although the dynamics of the flight environment, the complexity of the phenomena to be observed, and the speed with which they occur impose a heavy burden on the examiner, quantitative rating scales for the manual recording and grading of procedures are still very popular with the airlines and official organizations. They permit the examiner to evaluate those qualitative behaviors reflecting on the examinee's ability to cope effectively and safely with the various demands, requirements, and potential hazards of the total flight environment.

Objective Measurements Using Flight Simulators.

A. Fixed-Wing Aircraft. There have been several past efforts undertaken to design, develop, and use simulator systems for objectively measuring pilot performance (9,10,11,12). For example, part-mission simulation performance measures were aimed at the landing procedure, statistically the source of most aircraft accidents. In the course of various studies, starting with a comparison of center sticks versus side control sticks in 1970, the Crew Station Design Facility at the Aeronautical Systems Division, Wright-Patterson AFB, Ohio, had a need for an objective and quantitative method of evaluating pilot performance during Instrument Landing Systems (ILS) approaches and landings. To meet this requirement, a numerical scoring system was designed and tested which yielded relatively consistent and reliable measures of landing performance (22). In various studies and comparisons with other measures, it demonstrated its usefulness to the intended purpose.

In 1971, Hill and Goebel (19) developed automatic measures of pilot performance for a General Aviation Trainer (GAT-1). Two years later, they expanded their investigation through a re-analysis of their earlier statistics and the addition of a compensatory tracking task. The approach was based on two separate experiments carried out by using the GAT-1: A basic experiment with 326 measurements on each of 30 subjects in three different experience groups, and an expanded experiment with 2,436 measurements on each of 30 subjects from the same three groups. The first experiment included four different flight tasks lasting about 10 minutes each; the second experiment consisted of these and six additional tasks (18).

The results of the experiments showed that there is little difficulty in obtaining measurements that correlate with experience. Tables of more than 400 important data elements were prepared by the authors with group means, standard deviations, and further cross-tabulations that showed which tasks and measurements were best at discriminating among pilots. The outcome of the study also indicated that the statistical approach used by Hill and Eddowes (19) was not effective for the development of a practical pilot performance measurement system; and that different procedures, equipment, and means had to be used to achieve the intended goal.

Shipley, Gerlach, and Brecke (32) recorded, analyzed, and discussed the data obtained from student pilots while flying a T 4-C simulator. Two somewhat different methods of collecting data were considered. The first one was the use of a checklist by an expert observer. The observations could have been made during the subject's actual performance or they could have been made by inspecting a video-recording sometime after their performance. The second method considered, and ultimately adopted, was the use of an electronic analog-to-digital recording device to record the several electrical impulses emanating from and/or entering the simulator's control and instrumentation systems. A ten-channel, recording device was used to obtain information about flight instruments, such as altimeter, airspeed, rate of descent, heading, attitude, power, and throttle activation.

The records were coded, transferred to tape, and treated to indicate experimental details. The tapes were then evaluated using a three criterion scoring procedure; namely, time on "target," bit rate, and error amplitude. Summary scores of the performance of each subject were computed and subjected to two different analyses of variance to test for differences in performance. Single observation of response time and maximum altitude for each trial were also analyzed. The graphic performance plots revealed significant group differences, among other things.

Four sets of graphic representations of the data were used as an alternative for judging the validity of the output of the statistical computations. One result of the program for generating the graphic displays was the discovery of two easily observed and computed measures of performance quality, namely, performance time or time on target and maximum altitude of the vertical S-A maneuver. (The Vertical S-A consisted of a series of alternating climbs and descents flown at a constant rate of speed (1,000 ft/min) and heading.) These two measures were potentially useful as estimators of general differences in performance in subsequent research.

Another study was recently conducted by Carter (5,6), who used the Northrop LAS/WAVS air combat simulator for automated performance measurements (APM). He identified a set of measures for the evaluation of air-to-air combat tactics and various statistical techniques adequate for this process. The effort consisted of nine major different tasks; namely, maneuver selection, development of appropriate and valid evaluation methods, measure analysis, measure definition, software development, data collection, data reduction, and measure selection.

The maneuvers selected for the APM study were the barrel roll attack, the high yo-yo, and the lag roll. While data were initially collected on all three maneuvers, problems with the autopilot bogey on the latter two maneuvers resulted in a subsequent decision to limit the study to the barrel roll attack.

Highly detailed behavioral objectives were developed for each of the maneuvers contained in the introductory phase of the Navy F4J RAG syllabus (14). The methodology and results of this task are documented in Carter (5). The detailed understanding of air combat maneuvers gained in this task provided an important basis for all subsequent tasks in the APM study.

Special scoring forms were developed to provide a much more detailed and systematic instructor evaluation of student performance than the grading techniques normally used in flight training. The approach of this problem was based on the critical incident technique originally developed by John Flanagan in the 1950's (for a short description of this technique, cf. 14). The rating form was designed to record instructor observations and judgments relating to the following in each run: (i) critical errors occuring during the run; (ii) the qualitative value of critical parameters at each of several points during the run; (iii) the quality of the end-position achieved; and (iv) an overall grade for the run. These data were ultimately reduced to punched cards by assigning numerical values to the judgment categories in the qualitative scales developed for use with the form.

Seven F4J student pilots and six F4J instructor pilots flew 16 barrel roll attacks against an autopilot-controlled bogey, for a total of 208 simulator runs. A total of 552 objective performance measures and an average of 35 subjective performance measures were obtained on each run. Using the simulator's replay capability, 64 of the original 208 runs were evaluted independently by three different instructors to obtain estimates of inter-observer reliability. Sixteen of these 64 runs were evaluated a second time by the same three instructors to obtain estimates of intra-observer reliability. A master tape was constructed which contained all of the subjective and objective measures obtained for each run in a format that permitted statistical analyses of any desired subset of subjects, evaluators, or performance variables. Several different univariate and multivariate analyses were performed on selected subsets of the data.

In general, results of the measure selection analysis yielded several objective measures which were used to augment and facilitate instructor evaluation and diagnosis in introductory air-to-air tactics (6). Several sets of automated measures were identified which had high-multiple correlations with both instructor judgments and value of critical objective parameters at later points in the maneuver.

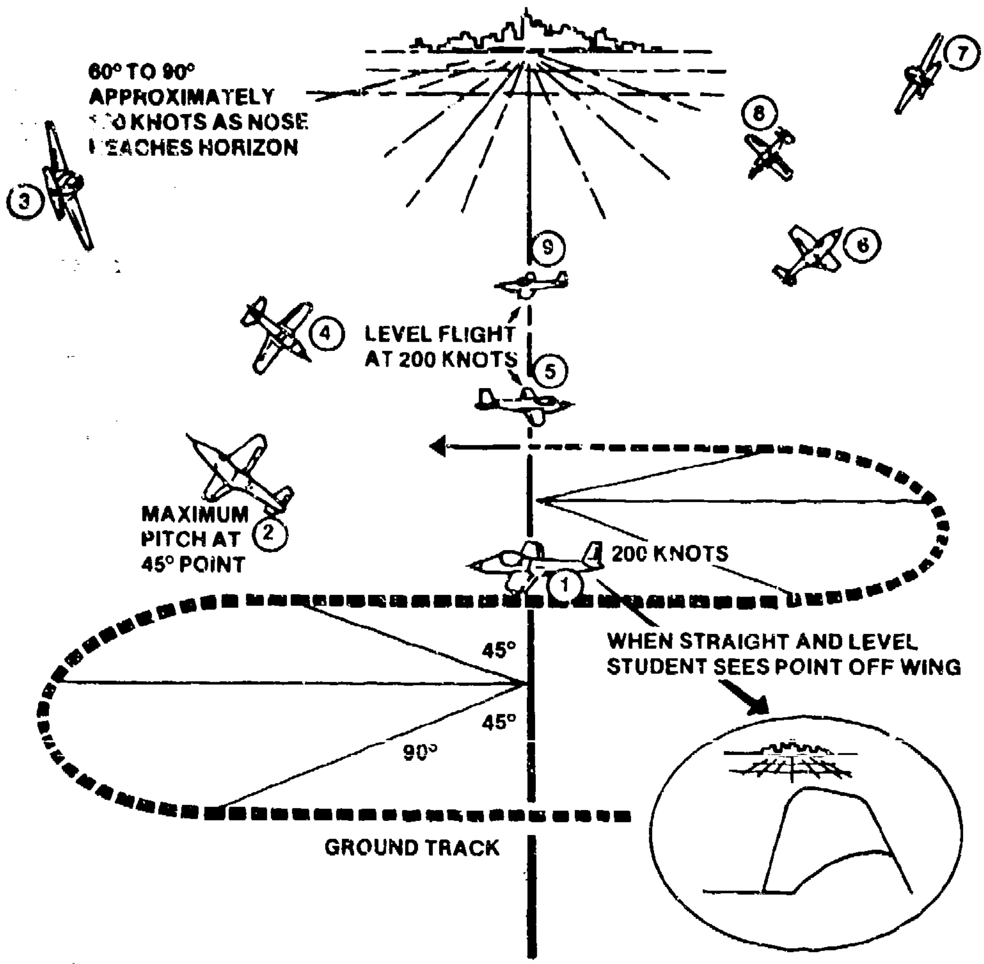
B. Rotary Wing Simulator. Vreul and Obermayer (37) studied helicopter crew performance through the analysis of 12 maneuvers in a "Jaycopter." This effort consisted of time history measures (e.g., time on target, time out of tolerance), amplitude distribution measures (e.g., mean and median values of the control movement deviation), and frequency domain measures, which included such things as autocorrelation functions, power spectral density functions, and transfer model parameters. Their interest rested more with the mathematics and modeling techniques for total system response than with the human factors involved. Vreul and Obermayer concluded that the engineering hardware and the behavioral research methods are available to provide objective pilot/system performance measurements of sufficient accuracy. The major constraints appeared to be primarily related to the amount of time and effort required to define the parameters and to test the validity of the method and results, but data collection and handling are easily accomplished by computers and automatic data processing (ADP). In order to reduce the costs of obtaining performance information and to maximize their utility or applicability, the authors suggested that methods and software should be improved.

Specifically, the cost of empirical data collection for obtaining quantifiable information on performance parameters can be reduced if: (i) attempts are made to collect only the type of results which can be generalized, and (ii) only such information is collected that can be standardized and catalogued for use by others.

The data collected by Vreul and Obermayer (37) meet these criteria. They discriminate very well among their selected parameters. In addition, the authors made some measurements in actual flight.

Table 2. T-37 Flight Variables Recorded by Knoop (26)

Variable	Units	Samples per Second
Airspeed	knots	100
Pitch	deg.	100
Roll	deg.	100
Stick Position (Long.)	deg.	100
Stick Position (Lat.)	deg.	100
Rudder Position	deg.	100
Heading	deg.	10
Altitude	feet	10
Vertical Acceleration	g's	10
Pitch Rate	deg./sec.	10
Roll Rate	deg./sec.	10
Yaw Rate	deg./sec.	10
RPM (both engines)	percent	10
Throttle Positions	deg.	10
Flap Position	percent	10
Landing Gear	discrete	10
Speed Brakes	discrete	10
Thrust Attenuator	discrete	10
Trim Tab Movements	discrete	10
Time	hrs./min./sec.	10
Record Number	integer	10



Maneuver Elements

1 Maneuver entry
2 45° turn point
3 90° turn point
4 135° turn point
5 180° turn point (midpoint of maneuver)
6 135° turn point (direction opposite from 0.1-0.5)
7 90° turn point
8 45° turn point
9 Maneuver termination (straight and level flight)

Figure 10. Lazy 8 maneuver profile.

Inflight Performance Measurements.

A. Fixed-Wing Aircraft. Extensive inflight research in fixed-wing aircraft has been conducted by Knoop and Welde (26) and Knoop (25) in order to develop an objective performance measuring system for use in Undergraduate Pilot Training (UPT) in the U.S. Air Force (USAF). This was accomplished by an automated performance measurment system which was reliable, sensitive, and accurate. A T-37B was instrumented to record the flight variables listed in Table 2.

This effort was at first directed to investigate the feasibility of using quantitative measurement techniques for two of the flight maneuvers taught in the USAF UPT flight syllabus, namely, the Lazy 8 and the barrel roll. The Lazy 8 is a maneuver requiring simultaneous turning and climbing or descending in such a fashion that a regular horizontal figure 8 is described about a selected point of reference located on the horizon. Figure 10 illustrates the nine maneuver elements of the Lazy 8. The element numbers coincide with the circled task analysis number used. The barrel roll consists of an aerobatic roll maneuver of 360° bank about a selected reference point located ahead of the aircraft. The sensors and recording equipment were strictly off-the-shelf components that had proved to be reliable in previous flight test projects. An extensive computer software system was developed with which to reduce, calibrate, and analyze the recorded data from the Lazy 8 and barrel roll maneuvers, and to compute performance measures. Criterion values for the two maneuvers were developed by utilizing task analysis data, narrative descriptions, and recorded inflight maneuver performance of a highly qualified Air Training Command instructor pilot.

The data were systematically sampled, digitally encoded and recorded on magnetic tape. The calibrated records were then inspected to produce printouts, plots, and card copies of selected parameters for use in the data analysis procedure. Typical plots for the Lazy 8 and barrel roll are shown in Figures 11 and 12. By utilizing the recorded data obtained from 16 students and 4 instructors, experimental performance measures were derived through an iterative analytical approach.

Study results indicated that Lazy 8 performance assessment can be accomplished using the flight parameters of roll angle, pitch angle, and airspeed in a single, summary error measure. Barrel roll measurement is dependent upon roll and pitch angle, acceleration, and roll rate. A definite relationship between roll and pitch was critical to the measurements.

In a later report concerning the development of standardized techniques for deriving and validating measures of operator performance, Connelly, Bourne, Loental, and Knoop (9) described the theory, structure, and implementation of a processor (written in FORTRAN IV) that can accept data representing various levels of operator's skill and analyze performance measures and validation test results. The theoretical concept of their study and the computational techniques were thought to have great potential for this type of activity.

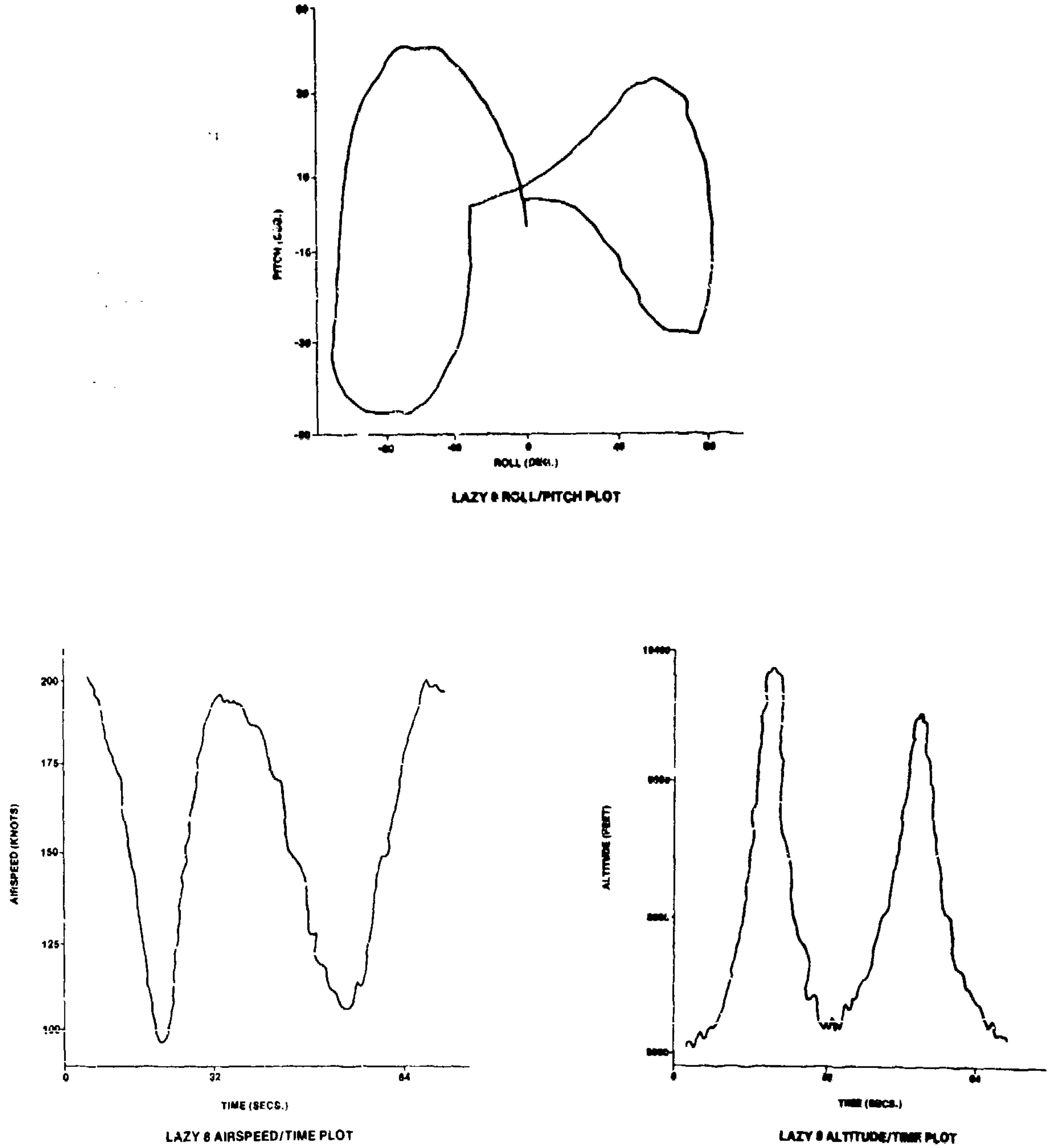
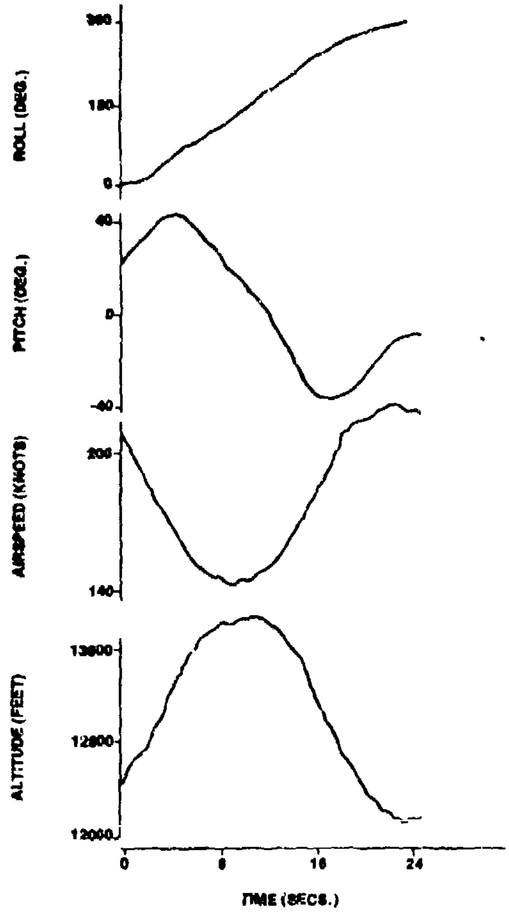
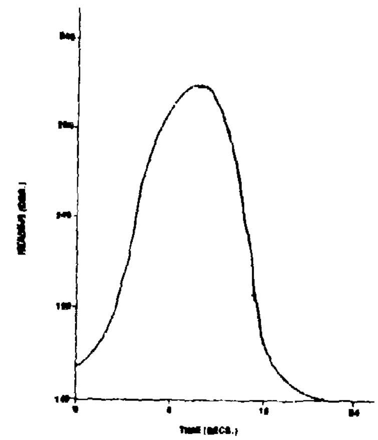


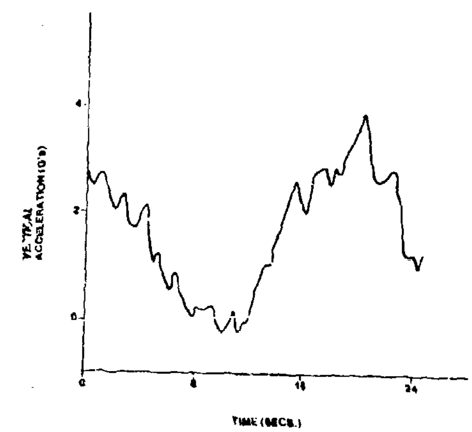
Figure 11. Lazy 8: roll/pitch, airspeed/time, and altitude/time plots.



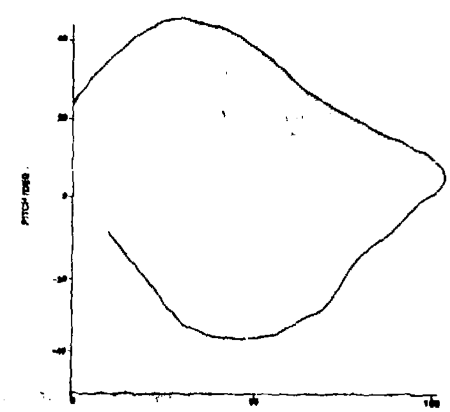
BARREL ROLL: ROLL, PITCH, AIRSPEED, AND ALTITUDE PLOTS



BARREL ROLL HEADING/TIME PLOT



BARREL ROLL ACCELERATION/TIME PLOT



BARREL ROLL ROLL/PITCH PLOT

Figure 12. Barrel roll: roll, pitch, airspeed, and altitude; heading/time; acceleration/time; and roll/pitch plots.

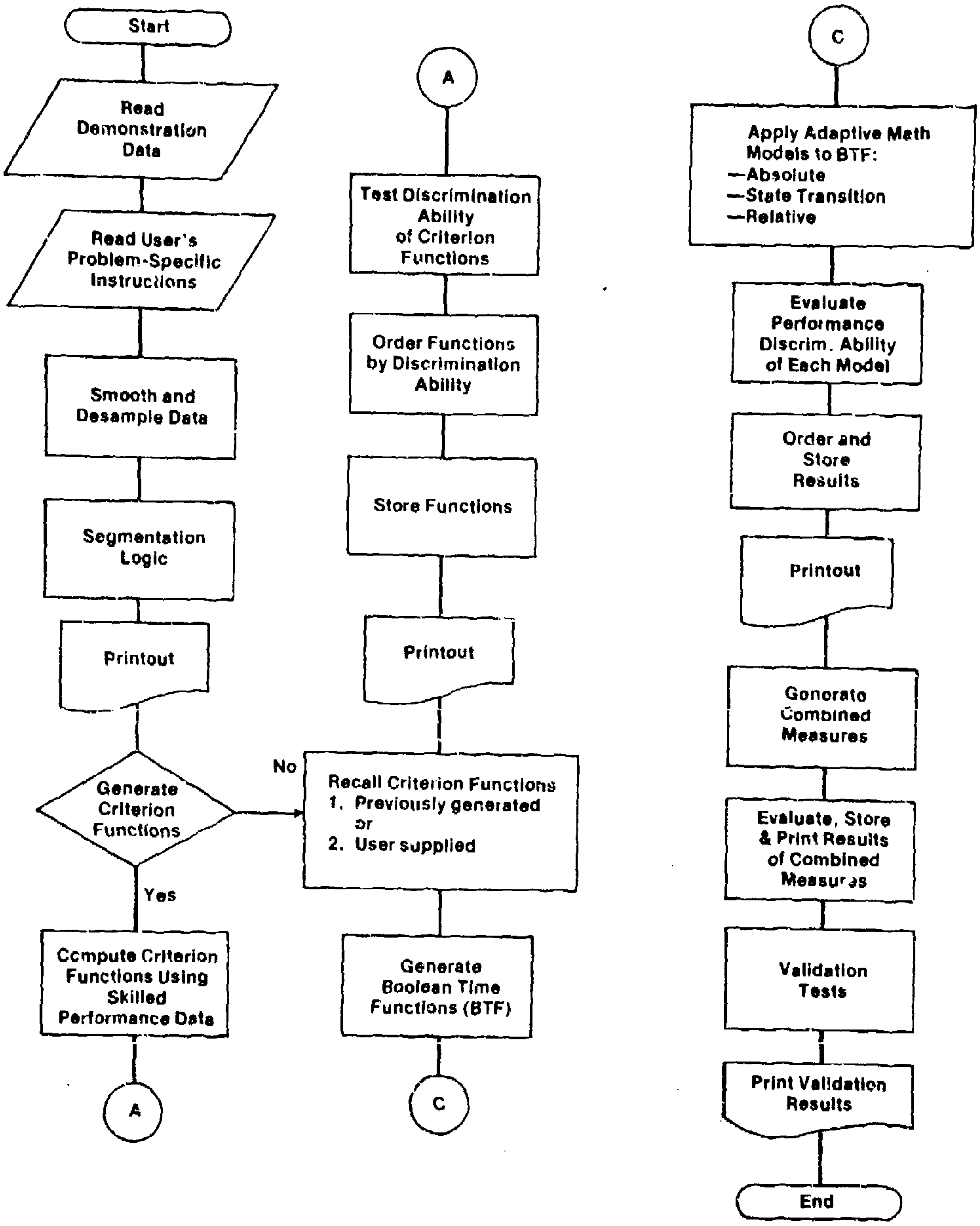


Figure 13. Flow diagram of processor.

Table 3. Possible Criterion and Performance Measure Factors Cited by Connelly et al. (8)

Type of Criterion	Possible Ways Deviation (Error) Is Related to Performance
Functions Relating Problem Variables (Reference Path)	• Amount of deviation from path • Max deviation • Time in a tolerance band • Convergence/divergence • Similarity to reference path • Shape of deviation • Time significant deviation occurs • Frequency of significant deviations • Rate of error correction • Way error is corrected • Number of errors that occur simultaneously
Differential Reference (*where criterion is specified by differential or difference equations*)	• Error in differential • Critical variable values exceeded • Time critical variables values are exceeded • Convergence/divergence to reference point on path trajectories • Shape of trajectory
Fixed (*variable*) tolerance at a specific time or at a specific value of another variable	• Variable out of tolerance • Amount variable is out of tolerance • Time variable is out of tolerance
Sequence of Operation	• Number of errors in sequence • Number of critical errors in sequence

The same processor was used for measurement problems associated with five UPT contact training maneuvers flown in the T-37 aircraft, namely, barrel roll, Lazy 8, Clover Leaf, Split S, and a normal landing (8). The activities necessary for obtaining the desired measurements included several steps, such as the development of criteria, the determination of the significance of deviation from these criteria, the search for candidate performance measures and their ADP transformation, their validation, and the design of an adequate data management process. A generalized flow diagram of the process is given in Figure 13. Some possible criterion and performance measure factors applied in this context are shown in Table 3. The analytical method included the identification of two types of function segments (locus and sequence) within a given control task, wherein the set of dominant measurement variables is consistent. In this way, portions of each individual task and portions of each task segment, in which the operator's primary control functions remained consistent, were identified. This suggested that the specific nature of the continuous or discrete measures was compatible with the intended performance assessment.

B. Rotary Wing Aircraft. Billing (1), Billings, Eggspuehler, Gerke, and Chase (2), and Billings, Gerke, Chase, and Eggspuehler (3) delineated a quantitative and objective method of evaluating pilot performance in a Hiller 12-E helicopter. The aircraft was instrumented for recording rotor velocity (rpm), cyclic and collective pitch control movements, and throttle position. After many tryouts and calibration, these parameters were found promising to measure pilot performance during low-level flights of varying demands and amounts of work, in particular during power line inspections. Several years later, the authors validated their previous results by conducting experiments with a mixed group of flight instructors and students, recording the student's electrocardiograms as indexes of workload and fatigue. The findings from this study supported their hypothesis that rotor rotations per minute (in terms of rpm variability) was a valid index of pilot skill in helicopter flight, and that methods used in these experiments are useful tools for assessing pilot performance.

Investigations by personnel of the U.S. Army Aeromedical Research Laboratory in Fort Rucker, Alabama, during the 1974/77 time period concerned pilot performance during nap-of-the-earth (NOE), low-level, and local area flights (13,24,29). Most of the experiments were centered about the assessment of helicopter crew performance, the nature of the flight and combat environment, the operational demands, perceptual problems, and the development of appropriate methods of workload measurements. Inflight measurements of the aviator and the recording of aircraft parameters provided results which were sensitive to workload and fatigue by extended flight durations.

Performance data were obtained through the use of the helicopter inflight monitoring system (HIMS). This research tool provided for the real acquisition of all major aircraft motion and pilot control parameters. It monitors

Table 4. Helicopter Flight Parameters Measured and Derived by Kimball et al. (24)

Parameters Measured	Derived Measures
Pitch	Pitch Rate
Roll	Roll Rate
Heading	Rate of turn
Position x	Constant Error, Average Absolute Error, RMS Error
Position y	Ground Speed, Constant Error Average Absolute Error, RMS Error
Acceleration x	
Acceleration y	
Acceleration z	
Roll Rate	Roll Acceleration
Pitch Rate	Pitch Acceleration
Yaw Rate	Yaw Acceleration
Radar Altitude	Rate of Climb, Average Absolute Error, Constant Error, RMS Error
Barometric Altitude	Rate of Climb
Airspeed	
Flight Time	
Rotor RPM	
Throttle	
Cyclic Stick (Fore-Aft) Cyclic Stick (Left-Right) Collective Pedals	Control Position, Absolute Control Movement Magnitude, Positive Control Movement Magnitude, Negative Control Movement Magnitude, Absolute Average Control Movement Rate, Average Positive Control Movement Rate, Average Negative Control Movement Rate, Control Reversals, Instantaneous Control Reversals, Control Steady State, Control Movement

and records aircraft motion in all six degrees of freedom as well as all pilot control movements. A list of the parameters measured and derived is shown in Table 4.

The helicopter pilot performance measurements were supported by industry developments in the area of pilot contribution to aircraft system operation. An example of this effort is a technique to gather empirical data on the inflight acquisition of task sequences and task times designed by the Vought Corporation in Dallas, Texas. Vought had demonstrated key features of the proposed system, using existing equipment, in a recent helicopter vision study contracted by the U.S. Army Aviation Systems Command. The visual/audio data can be supplemented, complemented, or verified with other system measures which are common to the instrumentation of all new military aircraft. These include: stick/rudder/throttle positions, rates of deflection, and forces; aircraft flight profile; aircraft subsystems moding and performance (15).

The measures are available to record what the pilot is doing to operate the aircraft within prescribed mission tolerance and how the aircraft is responding. Such data, when reduced and processed, as in the Vought Human Performance model, provide graphic/numeric readout of accuracy of performance to prespecified tolerances.

Advanced Inflight Monitoring Systems.

In retrospect, the concept of an automatically recording inflight monitoring system for air transport type aircraft emanated as a means to increase flight safety. As Ferrarese (12) pointed out, there exists a credibility gap when pilots report that any given flight is operated in accordance with established procedures, that the aircraft's systems function normally, and that there are no safety problems on the ground and in the air. System malfunctions, deviations from accepted practice, and pilot errors do occur. The causative factors, such as internal conditions and environmental forces having adverse safety effects, are most difficult to identify and it is sometimes impossible to assess their impact from the cockpit.

The means to close this inflight information gap is found in new, technically advanced flight recorder equipment. Modern logic systems and mathematical models can be employed to gather information concerning the performance of the aircraft and of the pilots; and means are available to reduce such information into some understandable and useful form. High-speed analysis systems can compare the obtained information to established norms. In order to measure and evaluate performance, one must compare "what should happen" to "what is actually happening." Flight recording and analyzing systems which can do this are a technical reality.

As to the possible use of automatic inflight recording for obtaining proficiency measures, Ferrarese (12) stated:

"A good example might be the practice of reaffirming pilot competence with respect to flying the instrument landing system (ILS) each six months. Is this really necessary if during actual operation the ILS flight is always conducted within the safe-flight envelope, and this is a matter of record? The system can identify those who do well. It is thereby possible for the individual and the operator to be relieved from certain portions of aircraft flight checks at fixed intervals. Likewise, those who depart from established norms because of proficiency problems may be given training as the situation dictates, rather than at some fixed period.

"In a typical system, safe-flight envelopes or programmed operating limits are described. Mathematical models of these envelopes or norms are programmed in computers. Flight data are fed into the computers and compared to the stored models. All excursions are identified and, where appropriate, given further qualitative and quantitative analysis. Part of the analysis will be to determine if the stored model is valid or in need of change, whether the variables are properly considered, and if the airborne data are adequate, as well as determine the adequacy of procedures, equipment and techniques. This operation is a most critical part of the system and requires input from all elements of the industry. Flight crews, engineers, medics, supervisors, ground personnel may all be brought into the picture."

Airline management has had a long standing interest in the improvement of proficiency assessment of airline pilots. Current sampling of a pilot's performance consists of one line check and two proficiency checks per year. A line check is an audit of pilot performance during a flight over a typical part of the route served by the airline, and it is normally made by an airline check pilot or an FAA inspector. Several major airlines use the flight simulator extensively for training and proficiency checks of their pilots. The simulator can be equipped with the necessary devices to obtain not only an aircraft type rating, but also for evaluating the adequacy of the pilot's line performance, if the performance is measured against professional flying standards on an adequate and factual basis. The question must now be asked whether such techniques can also be used under actual flying conditions.

Indeed, flight monitoring and analysis systems are available and are being used to assess pilot performance in objective and measurable terms. Such automated performance measurement systems inherently permit the assessment of pilot performance to be highly sensitive, valid and reliable, since performance can be recorded on-line for a large number of system variables. Greater accuracy regarding the performance of pilot and aircraft under the prevailing flight conditions is provided by an automated system than by a human observer, since more pilot actions, aircraft responses, and flight parameters can be recorded within a certain period of time. By automatically analyzing the data so obtained, a high degree of objectivity and reliability is guaranteed which cannot possibly be afforded by human observation.

Examples of these systems will now be described and their use for the measurement of pilot performance will be discussed. The selection of the two systems was based on their availability at the time this report was prepared; and it is not inferred that there are no other systems available or in the design stage, which could not be applied or modified for the purpose of automatically recording, analyzing, and measuring pilot or aircrew performance. At present, the two systems described below come very close to the concept of an advanced inflight monitoring system as envisioned by the FAA.

Concern about flight safety was essential for American Airlines (AA) to propose, develop, and use the "Astrolog" program (30). Based on operational experience, several desirable attributes of a safe, flight operation were described in words and then converted into specific numerical limits. This process delineated satisfactory flying performance in a workable digital form. The three parties that participated in the process of deciding on what the operational envelopes should be were the American Airlines piloting management, the Allied Pilots Association, and the FAA. In setting operational standards concerning the size of the various envelopes on speed, altitude, attitude, etc., the amount of deviation from those standards was recorded and analysed. Automatic data handling and processing techniques were extensively used in this process. The software could be adjusted to accommodate new information and changing requirements.

The "Aircraft Integrated Data System" was installed in the BAC-111 aircraft and employed for the intended purpose for several years. In order to keep the amount of data at a manageable minimum, the data processing method was based on the management-by-exception concept; i.e., only deviations from the "standards" were recorded, and a primary document known as an "Exception Report" was rendered.

Table 5. American Airlines Astrolog Exception Report

DATE 04 01 69 FLT 1014 LEG 1 ACFT 014 CAPT NO 12345

TIME FROM 200 FT AFL TO TOUCHDOWN 32 SEC CPT
TIME FROM 50 FT AFL TO TOUCHDOWN 21 SEC CPT

FUEL FLOW VARIATION BETWEEN 85 FT AFL AND 51 FT AFL 2100 PPH 2345 GMT CPT

OUT 2230 GMT OFF 2235 GMT ON 2346 GMT IN 2350 GMT

The Exception Reports were used by AA supervisory pilots to initiate corrective action appropriate to each specific situation. A sample of an Astrolog Exception Report is shown in Table 5. In case additional information was needed, two other kinds of machine-produced documents were available. They would provide trend information by exception type. When widespread instances of a particular deviation from the standards occurred, the operating procedures, training programs, or the operational envelope involved were examined. All of the recorded data and several calculated items were produced in the form of a printed list, known as a frame-by-frame printout.

An underlying assumption of the Astrolog program was that an excursion outside the established operational envelope is a warning of possible trouble, while operation inside the established range is demonstrated proof of satisfactory performance. The validity of this assumption has been proven by information obtained by the analysis of aircraft accidents and incidents. It is also compatible with our concept of measuring pilot performance in an age-related functional framework.

To assist the analysis of data further, or the study of a particular portion of flight, a third form of output was obtained by Astrolog. These are profiles of selected data drawn by a plotting machine. A sample plot is shown as Figure 14. This particular plot is a time history of several data items. Various types were available, drawn to scales appropriate to the study of takeoffs, landings, or entire flights (30).

The recorded data are also available for purposes other than flying safety evaluation. Other possible uses include engine and airplane performance measurement, automatic tracking for air traffic delay data, and analysis of compliance with optimum flight plans. In this context, the system can be used to record aircraft/pilot interaction, and it yields objective measurements of pilot performance. The "Astrolog" system was invented by Captain W. A. Braznell, American Airlines. The program was discontinued in 1971 when the BAC-111 aircraft, in which the system had been installed, were taken out of service.

Another example of an attempt to make use of existing technology for recording and assessing pilot performance automatically is the development and application of the advanced inflight monitoring system designed by Trans World Airlines (TWA), Incorporated (34). Since 1968, TWA has undertaken to monitor each approach and landing made by its crew members during their routine flight conditions. In September 1975, TWA recorded the two millionth monitored approach. An expanded inflight system was recently installed in the L 1011 aircraft. Rather than recording only seven parameters associated with the landing approach, the new system records 30 flight performance parameters throughout the entire flight range from engine start to engine shutdown. A detailed listing of the 13 trend modes and the 30 performance parameters to be recorded is given in Appendix A (see also Appendix A, Figure A-1).

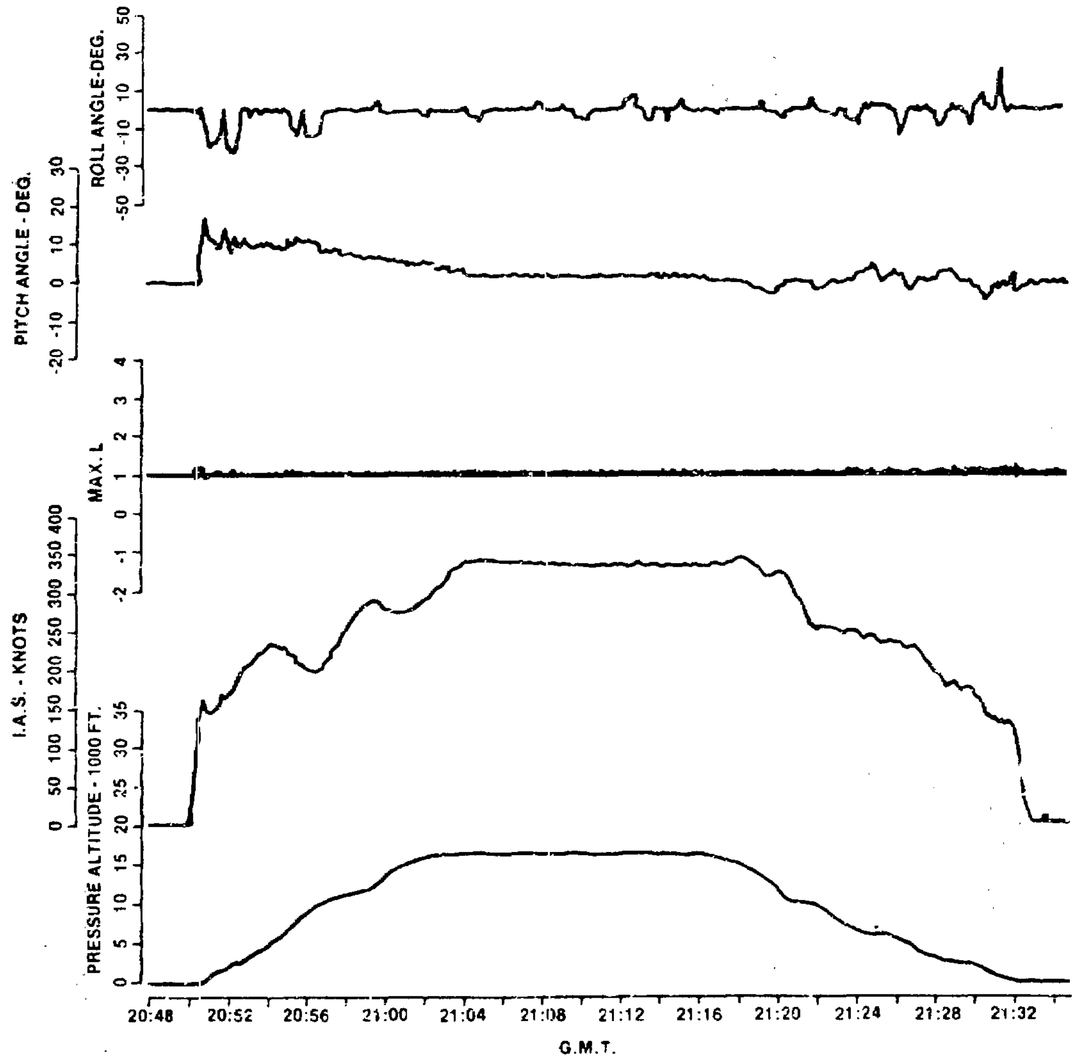


Figure 14. Sample plot of selected American Airlines data from Astrolog Inflight Monitor.

Data handling and analysis have been very well organized. The data are taken on magnetic tape, which is removed at layover points and then transmitted to TWA's Kansas City computer via data terminals and telephone lines. Any deviation from the limits established for the 30 flight crew performance parameters is recorded by the computer along with the flight number, date, and crew. Thus, each pilot's performance is monitored during each flight by an impartial recorder and the results are retained for later evaluation.

Details concerning the TWA AIDS/Inflight Monitoring System are given in Appendix A. In a brief entitled "Trend Modes" the modes are listed in which aircraft operations are sensed and recorded. There are three different reports generated when the system is in operation. Examples of these reports are also given in Appendix A. The first is an Exception Report obtained as the result of a "L 1011 Flight Analysis." It contains information about the route, flight crew, takeoff and landing weight of the aircraft, date, time, and mode of the flight as well as type of exceedence (localizer, glide slope, calibrated airspeed, and descent rate deviations) (See Appendix A, Figure A-2). The parameters listed in columns 7 through 11 in this report show the recorded values for the localizer, magnetic heading, radio altimeter, flaps, and glide slope deviations.

The second report is the "L 1011 Performance Summary by Captain" which contains information such as the total number of crew performance deviations during the entire month, the total number of flight legs monitored, instrument approaches, instrument approach exceedences, and the number of exceedences per flight leg (see Appendix A, Figure A-3).The third report is the "L 1011 Monthly System Summary" which provides operational trends and points out areas of particular concern (see Appendix A, Figure A-4). For example, exceeding V_2 by more than 15 knots consistently would need a closer observation and corrective action. TWA is convinced that this program will increase the safety of the operation and will provide more reliable and accurate performance and proficiency measures than the occasional observation in a stereotyped situation and by subjective judgment.

One has to consider, of course, some of the shortcomings or weaknesses of the fully automated performance measurement method, that have been pointed out by several investigators (4,12,25). First, it has been mentioned that automatic recordings of pilot performance does not show nor explain what is going on in the pilot's brain. There are many subtle aspects of judgment and decision making that do not lend themselves to recording; and automated performance measurement usually permits the assessment of only those actions by the pilot which directly affect the performance and motion of the aircraft. Hence, a sudden deviation from the glidepath or an unprogramed increase in speed may be caused by an unprogramed event, such as an unexpected obstacle on the runway, a failure in the lighting system, or a visual illusion. And the reason for the "undesired" deviation from the program may not become obvious from the records obtained during the pilot action, although the deviations were necessitated for safety reasons. Moreover, there may be psychological or psychosocial problems that affect pilot action and express themselves unconsciously and remain unexplained and may influence, only temporarily and with no lasting degradation, his performance. These factors can become important and some of them, in particular those generated by the environment in flight and observable to the inspector pilot, may be detected, explained, and analyzed by a subjective assessment technique. By and large, however, these flaws of the automated objective method do not diminish the overall value of this method, which provides data free from personal bias.

As a remedy for the possible negative features of the automatically recording objective assessment system, a multivariate method has been recommended by several scientists in this country and abroad (4,25). They suggest that subjective ratings, physiological recordings, and automated measurements be combined to yield a total performance score. However, this approach also has some inherent flaws, in particular since it is not always possible to attain these three scores concomitantly. Moreover, the physiological data obtained under test conditions are often ambiguous, and they may contribute more uncertainties and variance than improve reliability. For certain conditions of performance measurement, for example, during solo flights where there is no instructor pilot in the cockpit, the automatic recording seems to be the only accurate and reliable means to collect performance data, and in this case the recording of some physiological parameters can help to assess performance.

Knoop and Welde (26) suggested that pilot acceptability becomes a rather important point, when the time arrives for making the decision to implement an automated pilot performance measurement system. Apparently, there is evidence that pilots accept such a system if it has been proven to be sensitive, valid and fair (34). As far as the training situation is concerned, it can be argued that, whatever type or level of sophistication of advanced performance measurement is attained, the human observer should always be part of the system. But this is not the point here. The purpose of this survey was to find out whether or not there exist objective methods which can be used to obtain performance profiles usable for the assessment of pilot proficiency. This question can be answered affirmatively.

Summary and Conclusions.

The purpose of this study was to describe how pilot performance can be monitored and assessed, and what means, techniques, methods, and instruments are available to measure pilot performance accurately and reliably. Such measurements will have to be made if a functional age index or an objective proficiency standard for pilots is to be developed that can be used as a criterion for extending or terminating an aviator's career.

It has been shown in this context that the attempt to develop criteria and means for the assessment of pilot performance dates back to World War I. There were two major approaches taken in order to reach this goal; namely, (i) the qualitative evaluation of performance based mainly on instructor ratings and flight inspector judgments, and (ii) quantitative grading of performance based on numerical rating scales and recordings of pilot actions which reflect the quality of the performance. Several examples were given to illustrate these efforts.

Within the qualitative assessment system, which is highly subjective in nature, there are several steps of sophistication, ranging from a simple pass/fail rating to detailed, multi-faceted descriptions of the examinee's behavior, personality, and performance. It has been voiced by many researchers familiar with psychological assessment techniques that any attempt at manually recording inflight activities is highly questionable, since the rater is often unable to effectively time-share the task of observing and recording multiple parameters at an appropriate sampling rate. His judgment, primarily based on an overall impression of the examinee's effort, may be involuntarily biased, unreliable, and occasionally unfair. Actually, however, this method is still being used and is generally accepted and operationally rather effective.

The more advanced method of measuring pilot performance is based on the concept that data should be recorded objectively and independently of the ability, judgment, and standards of the examiner/inspector. The highest degree of accuracy and reliability can be attained when permanent records of actions and behavior of the pilot are furnished by an automated data acquisition system. Review of the pertinent literature suggests that the following steps are indicated in the development and use of an objective performance measurement system:

1. Performance analysis in order to establish quantifiable descriptors or criteria of performance (including the definition of errors, scales, and scoring techniques).

2. Raw data collection.

3. Selection of a unit of measurement in regard to human subsystem or operator performance.

4. Selection of the important, adequate, and useful measurable parameters.

5. Measurement system test and evaluation.

6. Calibration and standardization of the measurement system and its validation against the intended purpose and other available modes.

7. Calibration and standardization of the data and preparation of the information in a practical, manageable, and usable form.

It was shown in the course of this discussion that with all the computers and ADP available today, pilot performance can be measured objectively, accurately, and reliably. Such measurements discriminate effectively between different levels of operational requirements, demands, skill, and proficiency. If properly evaluated, such data should be useful not only for measuring pilot performance at a particular point in time, but also for predicting later or expected proficiency through the analysis of current performance and its comparison with past performance.

The military services, private industry, and the airlines have made great strides in the design and application of objective, automatically recording, inflight monitoring systems. While mostly developed for research purposes, they are now being viewed for application on a routine and regulatory basis. Owing to their capability of monitoring simultaneously the performance of the aircraft and the human operator, they are the ultimate in assessment systems design and application. They offer great possibilities for the establishment of a functional age index for pilots. Most probably, this development will first affect the air carriers; but the other groups, namely, the military and the general aviation pilots, will also utilize the advantages offered by progress in this area. The vertification of the concept and its validation is still a matter of future research.

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APPENDIX A

TWA INFLIGHT MONITORING SYSTEM

TREND MODES

Trend Mode No.	Title	Description of Cue Initiation
T1	ESU	Engine Start - No. 1, 2 or 3 Fuel/Ignition Switch On.
T2	TKOR	Takeoff Roll - No. 1 Engine Thrust Lever advanced to 70% power.
T3	V_2	Radio Altitude ≥ 35 Feet.
T4	CLB1	Climb 1 - Radio Altitude ≥ 1,600 Feet.
T5	CLB2	Climb 2 - Altitude Coarse ≥ 9,855 Feet.
T6	CLB3	Climb 3 - Altitude Coarse ≥ 12,000 Feet.
T7	CRZ	Cruise - Pitch Computer-Altitude Hold Mode is engaged for 15 minutes.
T8	DST1	Descent 1 - Pitch Computer-Altitude Hold Disengage and Altitude Coarse Decreases ≥ 1,000 Ft.
T9	DST2	Descent 2 - Altitude Coarse ≤ 9,450 Feet.
T10	APP1	Approach 1 - Radio Altitude ≤ 1,500 Feet.
T11	APP2	Approach 2 - Radio Altitude ≤ 500 Feet.
T12	ROLT	Rollout - Air/Ground Sensor - Aircraft on ground.
T13	ESD	Engine Shutdown - No. 1, 2 and 3 Fuel/Ignition Switches Off.

Logic is provided for alternate flow of trend mode progression as indicated on the following chart. Trend mode cue initiation is the same as above.

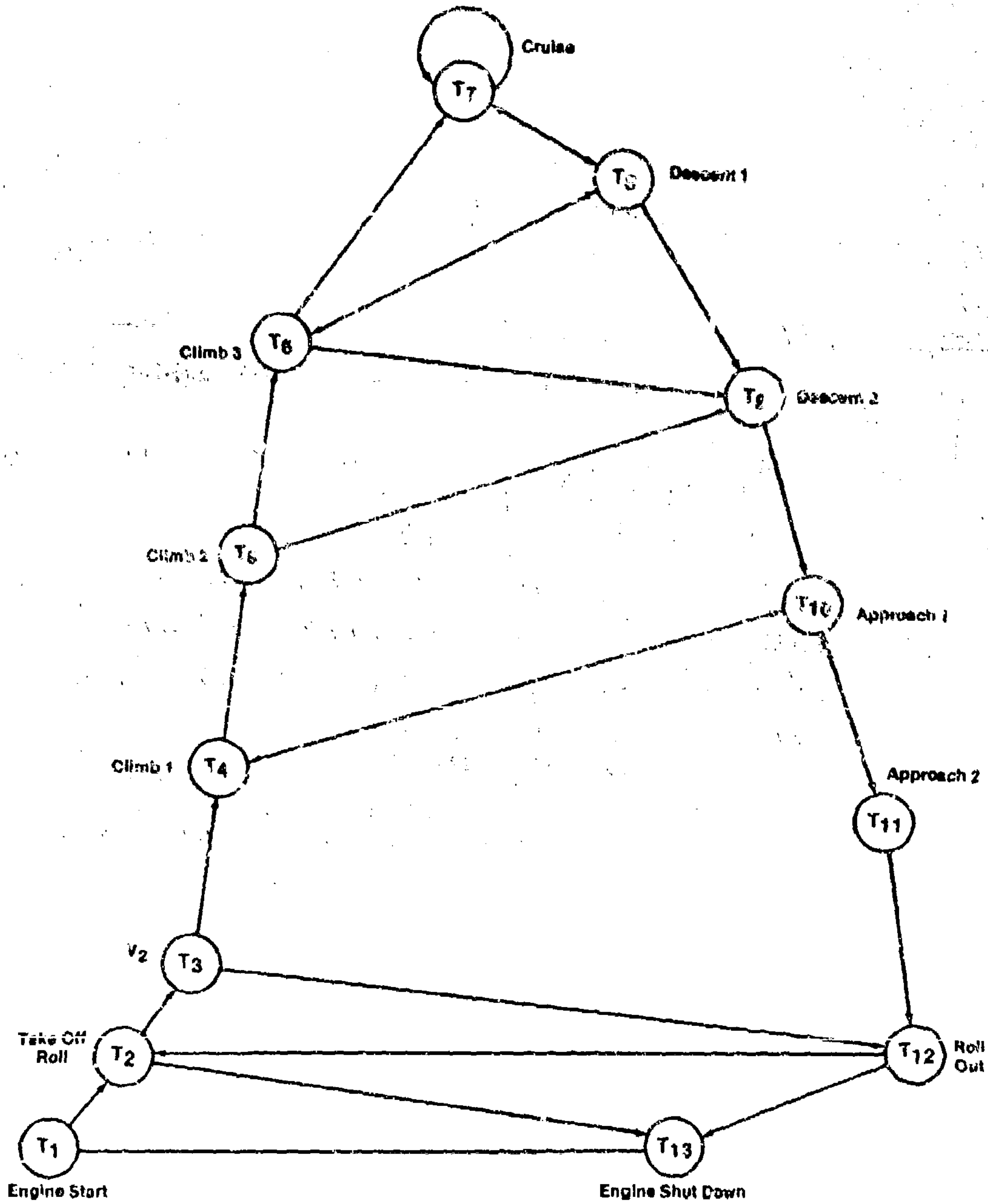

Figure A-1. Logic for alternate flow of trend mode progression.

FLIGHT CREW PERFORMANCE PARAMETERS

Number	Trend Mode	Description (Support parameter data to be printed)
1	2	At the start of the takeoff roll, flaps shall be set at 10° and pitch trim shall be set within -2.5° to -8°. (Pitch trim, C.G., gross weight, flaps.)
2	3	When the Radio Altimeter Altitude equals 35 feet (V_2), computed air speed shall be less than V_2 + 15 knots and greater than V_2 -5 knots (CAS)
3	3	At a Radio Altimeter Altitude of 200', pitch attitude shall be less than 19° and greater than 11°. (CAS, pressure altitude, radio altitude, pitch attitude.)
4	2, 3, 4, 5, 6, 7, 8, 9, 10, 11	Roll attitude shall be less than 35° and greater than -35°. (CAS, pressure altitude, radio altitude, roll attitude.)
5	2, 3, 4, 5, 6, 7, 8, 9, 10, 11	Vertical acceleration shall be less than 1.5G's and greater than 0.5G's. (CAS, pressure altitude, radio altitude, vertical acceleration.)
6	5, 6, 7, 8	The angle of attack shall be less than 18.3°. (CAS, pressure altitude, A.O.A., pitch attitude.)
7	2	Trend Mode 3 (V_2) shall be sensed one minute after the start of the takeoff roll. (Words: Abort Takeoff.)
8	3, 4	Computed air speed shall be within the following limits: Flaps 10° - CAS shall be less than 230 knots and greater than V_2 -5 knots. Flaps 4° - CAS shall be less than 250 knots and greater than V_2 +5 knots. Flaps 0° - CAS shall be less than 260 knots and greater than V_2 + 50 knots. (CAS, pressure altitude, radio altitude, flaps.)
9	3, 4, 5, 6, 7, 8, 9, 10, 11	Whenever the landing gear is being retracted, computed air speed shall be less than 230 knots. (CAS, pressure altitude.)
10	3	When the landing gear starts to retract, the rate of climb shall be positive. (CAS, pressure altitude, radio altitude, pitch attitude. Words: Alt Fine Decr.)
11	3, 4, 5, 6, 7, 8, 9, 10, 11	Pitch attitude shall be less than 19° and greater than -5°. (CAS, pressure altitude, pitch attitude, flaps.)
12	2, 11, 12	During the takeoff roll until liftoff and during approach below a radio altimeter altitude of 50 feet, pitch attitude shall be less than 12.5°. (CAS, pitch attitude, radio altitude, flaps, vertical acceleration.)
13	6	From a pressure altitude of 14,000 feet to 28,900 feet, computed air speed shall be less than 335 knots and greater than 305 knots. (CAS, pressure altitude.)
14	6	At a pressure altitude greater than 28,900 feet. Mach number shall be less than 0.85 and greater than 0.79. (Mach number, pressure altitude.)
15	7	In the Cruise Mode at pressure altitudes greater than 30,000 feet, Mach number shall be less than 0.87 and greater than 0.81. (Mach number, pressure altitude, altitude hold-yes/no.)
16	4, 5, 6, 7, 8, 9, 10, 11	There shall be no 'Altitude Select' deviation indications for more than two seconds. (CAS, pressure altitude, radio altitude.)
17	7	A VOR deviation greater than one dot for a period of ten minutes shall include a heading change of greater than 15°. (CAS, pressure altitude, VOR deviation, magnetic heading, Mach number.)
18	8, 9	During the descent mode, Mach number shall be less than 0.905 and computed air speed shall be less than 375 knots. (CAS, pressure altitude, Mach number.)
19	5, 10, 11	Computed air speed shall be within the following limits: Flaps 0° - CAS shall be less than 260 knots and greater than Vref + 50 knots. Flaps 4° - CAS shall be less than 250 knots and greater than Vref + 20 knots. Flaps 10° - CAS shall be less than 230 knots and greater than Vref + 10 knots. Flaps 22° - CAS shall be less than 205 knots and greater than Vref + 5 knots. Flaps 33° - CAS shall be less than 170 knots and greater than Vref - 3 knots. (CAS, pressure altitude, radio altitude, flaps.)
20	11	From a radio altimeter altitude of 500 feet to 100 feet, localizer and glide slope deviations shall be less than one dot. (CAS, localizer deviation, radio altitude, flaps, glide slope deviation, gross weight, magnetic heading.)
21	11	From a radio altimeter altitude of 500 feet to touchdown, the rate of descent computed over a six second period shall be less than 900 feet per minute. (CAS, pressure altitude, radio altitude, descent rate, magnetic heading.)
22	11	From a radio altimeter altitude of 500 feet to touchdown, the rate of descent computed over a six second period shall be positive. (CAS, pressure altitude, radio altitude, flaps, magnetic heading.)
23	11	From a radio altimeter altitude of 500 feet to 20 feet, computed air speed shall be less than Vref + 10 knots and greater than Vref - 5 knots. (CAS, pressure altitude, radio altitude, flaps, gross weight.)
24	3, 4, 5, 6, 7, 8, 9, 10, 11	While the landing gear is down, computed air speed shall be less than 250 knots and Mach number shall be less than 0.73. (CAS, pressure altitude, Mach number.
25	11	The time from a radio altimeter altitude of 50 feet to touchdown shall be less than 15 seconds (CAS, touchdown - yes/no, radio altitude.)
26	3, 4, 5, 6, 7, 8, 9, 10, 11	An exceedance recording will commence if the ground proximity pull-up light is illuminated and the ground proximity fault light is extinguished. (CAS, pressure altitude, radio altitude, flaps, Words: GPWS pull up, gear down - yes/no.)
27	12	Hard landing indications shall not exceed 117,000 pounds for the left and right main gears and 105,000 pounds for the nose gear. (CAS, left main, right main, nose, pitch attitude, roll attitude, vertical acceleration.)
28	12	The time to spoiler action after touchdown shall be less than 5 seconds. (CAS, touchdown - yes/no, spoiler - yes/no.)
29	12	The time to reverse thrust action on any engine after touchdown shall be less than 7 seconds. (CAS, touchdown - yes/no, thrust reverse - yes/no.)
30	12	From touchdown to touchdown + 12 seconds, brake metered hydraulic pressure shall be less than 1000 PSI. (CAS, touchdown - yes/no, brakes.)

Additionally, the AIDS Data Entry Panel has been modified to include a system selection labeled 'Instrumented Approach'. When this position is selected by the Flight Crew, prior to 1500 feet radio altimeter altitude, and the manual record button is depressed, the on-board computer will flag the data recorded after this event as being an instrument approach.

EXCEPTION REPORT

L1011 FLIGHT ANALYSIS

REPORT ID – AJ12910
MONTH – JUL
DOMICILE CURRENT – LAX-D
DOMICILE SEGMENT – LAX-D
CAPTAINS ID – 45678
CAPT – BROWN B C
F/O – GREEN G H
F/E – WHITE W Y
FLT – 137/29 JUL STL-LAX

REPORT DATE
8 13-77

REF NO –	731137201	OUT –	425
FLT-LEG –	137-2	OFF –	441
Z-DATE –	72977	ON –	601
PLANE NO –	11030	IN –	805
T/W IDENT –	45678	I/A –	YES

			OBAWS	
TAKEOFF WT	– 389300		TAKEOFF WT	– 389300
VREF WT	– 333500		VREF WT	– 333500
LANDING WT	– 330871		LANDING WT	– 330871
VR	– 147		VR	– 147
V2	– 157		V2	– 157
VREF	– 138		VREF	– 138

PERFORMANCE MODE RECORDED

E	T	V	C	C	D	A	R	E
S	K	2	L	R	S	P	C	S
U	O		3	Z	1	1	L	D
3	2	3	3	3	2	2	2	3

Z TIME	ATC	CFE MODE	CPE NO	I A	TYPE OF EXCEEDENCE	PARAM/VALUE	PARAM/VALUE	PARAM/VALUE	PARAM/VALUE	PARAM/VALUE
7 59 46	1	AP1	20	Y	LOC-GS DEV	CAS/143 GW/332965	LOC DEV/-1.211 MAG HDG/44	RDO ALT/687	FLAPS/33	GS DEV/1.331
7 59 51	1	AP1	20	Y	LOC-GS DEV	CAS/141 GW/332890	LOC DEV/1.331 MAG HDG/42	RDO ALT/636	FLAPS/33	GS DEV/1.331
7 59 55	1	AP1	20	Y	LOC-GS DEV	CAS/139 GW/332832	LOC DEV/1.331 MAG HDG/42	RDO ALT/578	FLAPS/33	GS DEV/1.331
7 59 59	1	AP2	20	Y	LOC-GS DEV	CAS/137 GW/332776	LOC DEV/-1.123 MAG HDG/41	RDO ALT/497	FLAPS/32	GS DEV/1.331
8 0 4	1	AP2	20	Y	LOC-GS DEV	CAS/137 GW/332663	LOC DEV/-0.723 MAG HDG/42	RDO ALT/403	FLAPS/33	GS DEV/1.315
8 0 8	1	AP2	20	Y	LOC-GS DEV	CAS/138 GW/332546	LOC DEV/0.787 MAG HDG/43	RDO ALT/190	FLAPS/33	GS DEV/0.816
8 013	1	AP2	20	Y	LOC-GS DEV	CAS/142 GW/332420	LOC DEV/-0.840 MAG HDG/44	RDO ALT/115	FLAPS/33	GS DEV/0.264
8 018	1	AP2	20	Y	LOC-GS DEV	CAS/145 GW/332306	LOC DEV/-0.976 MAG HDG/44	RDO ALT/37	FLAPS/33	GS DEV/0.776

Figure A-2. Reproduced TWA Exception Report: L-1011 Flight Analysis
(Continued on next page.)

EXCEPTION REPORT

L1011 FLIGHT ANALYSIS

REPORT ID – AJ12910 REPORT DATE – 8/13/77

Z TIME	ATC	CPE MODE	CPE NO	I A	TYPE OF EXCEEDENCE	PARAM/VALUE	PARAM/VALUE	PARAM/VALUE	PARAM/VALUE	PARAM/VALUE
7 59 59	1	AP2	21	Y	DESC RATE	CAS/137	PR ALT/ 375	RDO ALT/ 497	DESC RATE/****	MAG HDG/ 41
8 0 4	1	AP2	21	Y	DESC RATE	CAS/137	PR ALT/ 300	RDO ALT/ 403	DESC RATE/1021	MAG HDG/ 42
8 0 8	1	AP2	21	Y	DESC RATE	CAS/138	PR ALT/ 220	RDO ALT/ 190	DESC RATE/1120	MAG HDG/ 43
8 0 13	1	AP2	21	Y	DESC RATE	CAS/142	PR ALT/ 130	RDO ALT/ 115	DESC RATE/ 790	MAG HDG/ 44
8 0 18	1	AP2	21	Y	DESC RATE	CAS/145	PR ALT/ 100	RDO ALT/ 37	DESC RATE/ 329	MAG HDG/ 44
8 0 23	1	AP2	21	Y	DESC RATE	CAS/144	PR ALT/ 80	RDO ALT/ 12	DESC RATE/ 165	MAG HD 12
8 0 27	1	AP2	21	Y	DESC RATE	CAS/142	PR ALT/ 75	RDO ALT/ 2	DESC RATE/ 0	MAG H 42
8 0 31	1	ROL	21	Y	DESC RATE	CAS/138	PR ALT/ 80	RDO ALT/ -3	DESC RATE/****	MAG HDG/44

Figure A-2 (Continued)

EXCEPTION REPORT
CAPTAIN'S REPORT

L1011 FLIGHT ANALYSIS

REPORT DATE
8/13/77

REPORT ID – AJ12910
MONTH – JUL
DOMICILE CURRENT – LAX-D
DOMICILE SEGMENT – LAX-D
CAPTAINS :D – 87654
CAPT – SMITH S T
F/O – JONES J K
F/E – ADAMS A B
FLT – 904/29 JUL LAX–JFK

							OBAWS	
REF NO –	731904101	OUT –	1845	TAKEOFF WT –	420100	TAKEOFF ‹.T –	420100	
FLT-LEG –	904-1	OFF –	1858	VREF WT –	331700	VREF WT –	331700	
Z-DATE –	72977	ON –	3	LANDING WT –	328800	LANDING WT –	328800	
PLANE NO –	11028	IN –	10	VR –	152	VR –	152	
T/W IDENT –	87654	I/A –	NO	V2 –	162	V2 –	162	
				VREF –	137	VREF –	137	

PERFORMANCE MODE RECORDED

E	T	V	C	C	D	A	R	E
S	K	2	L	R	S	P	O	S
U	O		3	Z	1	1	L	D
3	2	3	3	3	2	2	2	3

Z TIME	ATC	OPE MODE	OPE NO	I A	TYPE OF EXCEEDENCE	PARAM/VALUE	PARAM/VALUE	PARAM/VALUE	PARAM/VALUE
18 58 22	1	V2	2	N	CAS AT V2	CAS/179			
18 58 04	1	TKO	3	N	ATT CLMOUT	CAS/136	PR ALT/ 15	RDO ALT/ -2	ATT CLMOU:T/ 0.3
18 58 08	1	TKO	3	N	ATT CLMOUT	CAS/150	PR ALT/ 10	RDO A.T/ -2	ATT CLMOUT/ 0.3
18 58 13	1	TKO	3	N	ATT CLMOUT	CAS/163	PR ALT/ 5	RDO ALT/ 0	ATT CLMOUT/ 4.2
18 58 17	1	TKO	3	N	ATT CLMOUT	CAS/175	PR ALT/ 20	RDO ALT/ 12	ATT CLMOUT/ 7.8
18 58 22	1	V2	3	N	ATT CLMOUT	CAS/190	PR ALT/ 140	RDO ALT/ 90	ATT CLMOUT/11.9
18 58 27	1	V2	3	N	ATT CLMOUT	CAS/183	PR ALT/ 265	RDO ALT/ 200	ATT CLMOUT/10.6
18 58 31	1	V2	3	N	ATT CLMOUT	CAS/179	PR ALT/ 385	RDO ALT/ 330	ATT CLMOUT/10.1
18 58 30	1	V2	3	N	ATT CLMOUT	CAS/177	PR ALT/ 540	RDO ALT/ 485	ATT CLMOUT/11.3

Figure A-3. Reproduced TWA Exception Report: *L-1011 Flight Analysis* (Captain's Report).

EXCEPTION REPORT

L1011 PERFORMANCE SUMMARY BY CAPTAIN (MONTHLY)

REPORT DATE 8-15-77

REPORT ID – AJ45010
MONTH – JUL
DOMICILE CURRENT – LAX-D
CAPTAINS ID – 45678
NAME – BROWN B C

CREW PERFORMANCE EXCEEDENCE NUMBER

REF. NO. SEGMENT	FLT/DTE	ATC	IA	A/C	1 FLAP/TRIM	2 CAS ATV2	3 ATT CLMOUT	4 ROLL ATT	5 VERT ACCEL	6 AOA	7 ABORT TO	8 CAS/FLAP	9 CAS/GEAR	10 GEAR/CLIMB	11 ATT IN FLT	12 ATT TO/LDG	13 CAS/CLIMB	14 MACH/CLIMB	15 MACH/CRZ	16 ALT SELECT	17 VOR DEV	18 MACH/DESC	19 CAS/FLAP	20 LOC-GS DEV	21 DESC RATE	22 GO AROUND	23 CAS/VREF	24 CAS/GEAR	25 5OFT TO TD	26 GPWS ACTIV	27 HARD LNDG	28 TD/SPOILER	29 TD/REVERSE	30 TD/BRAKES
705016201	CAPTDOM			LAX-D																														
LAX-EWR	16/04	1	N	028	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
705016301	CAPTDOM			LAX-D																														
FWR-BOS	16/04	1	N	028	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
711137101	CAPTDOM			LAX-D																														
BOS-STL	137/09	1	N	012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
711137201	CAPTDOM			LAX-D																														
STL-MCI	137/09	1	N	012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
711137301	CAPTDOM			LAX-D																														
MCI-LAX	137/09	1	N	012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
731016201	CAPTDOM			LAX-D																														
LAX-EWR	16/28	1	N	003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
731016301	CAPTDOM			LAX-D																														
EWR-BOS	16/28	1	N	003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
731137101	CAPTDOM			LAX-D																														
BOS-STL	137/29	1	N	030	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
731137201	CAPTDOM			LAX-D																														
STL-LAX	137/29	1	Y	030	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
				TOTAL	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0

TOTAL ALL EXCEEDENCES – 8
TOTAL FLT/LEGS MONITORED – 9
TOTAL INSTR APPROACHES – 1
TOTAL INSTR APPROACH EXCEEDENCES – 2
TOTAL FLT/LEGS FLOWN – 9
EXCEEDENCES PER FLT/LEG – 0.9

Figure A-4. Reproduced TWA Exception Report: L-1011 Performance Summary by Captain (Monthly).

L-1011 MONTHLY SYSTEM SUMMARY (MONTHLY)

REPORT ID – AJ45011
MONTH – JUL

REPORT DATE
8-15-77
PAGE 1OF2

	LAX-D	ORD-D	SFO-D	UNKN	TOTAL
CPE 1 – FLAP/TRIM	0	0	0	0	0
CPE 2 – CAS AT V2	42	26	24	4	96
CPE 3 – ATT CLMOUT	6	3	2	1	12
CPE 4 – ROLL ATT	0	2	1	0	3
CPE 5 – VERT ACCEL	3	1	0	1	5
CPE 6 – AOA	0	0	0	0	0
CPE 7 – ABORT TO	1	0	0	1	2
CPE 8 – CAS/FLAP	23	11	12	2	48
CPE 9 – CAS/GEAR	0	0	0	0	0
CPE 10 – GEAR/CLIMB	0	0	0	0	0
CPE 11 – ATT IN FLT	18	4	3	2	27
CPE 12 – ATT TO/LDG	1	0	0	0	1
CPE 13 – CAS/CLIMB	34	17	13	4	68
CPE 14 – MACH/CLIMB	32	18	18	4	72
CPE 15 – MACH/CRZ	38	20	18	6	82
CPE 16 – ALT SELECT	5	3	6	1	15
CPE 17 – VOR DEV	0	0	0	0	0
CPE 18 – MACH/DESC	0	0	0	0	0
CPE 19 – CAS/FLAP	46	23	24	4	97
CPE 20 – LOC-GS DEV	23	11	19	0	53

Figure A-5. Reproduced TWA L-1011 Monthly System Summary.
(Continued on next page.)

L-1011 MONTHLY SYSTEM SUMMARY (MONTHLY)

REPORT ID – AJ45011
MONTH – JUL

REPORT DATE
8-15-77
PAGE 2 OF 2

	LAX-D	ORD-D	SFO-D	UNKN	TOTAL
CPE 21 – DESC RATE	23	11	12	0	46
CPE 22 – GO AROUND	1	1	1	1	4
CPE 23 – CAS/VREF	49	21	27	2	99
CPE 24 – CAS/GEAR	0	0	0	0	0
CPE 25 – 50 FT TO TD	2	2	3	0	7
CPE 26 – GPWS ACTIV	0	0	0	0	0
CPE 27 – HARD LNDG	0	0	1	0	1
CPE 28 – TD/SPOILER	0	0	0	0	0
CPE 29 – TD/REVERSE	0	1	2	0	3
CPE 30 – TD/BRAKES	3	0	3	0	6
TOTAL ALL EXCEEDENCES	350	175	189	33	747
TOTAL FLT/LEGS MONITORED	1178	589	636	111	2514
TOTAL INSTR APPROACHES	83	42	45	8	178
TOTAL INSTR APPROACH EXCEEDENCES	6	3	4	1	14
TOTAL FLT/LEGS FLOWN	1178	589	636	111	2514
EXCEEDENCES PER FLT/LEG	0.3	0.3	0.3	0.3	0.3

Figure A-5 (Continued)