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CAPABILITIES, NECESSARY CHARACTERISTICS AND EFFECTIVENESS OF PILOT GROUND TRAINERS

PHASE II

VISUAL REFERENCE FLIGHT MANEUVERS

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16. Abstract

An experiment was conducted at the National Aviation Facilities Experimental Center (NAFEC) to determine the capabilities, necessary characteristics and effectiveness of pilot ground trainers required for developing primary aeronautical skills. Ten nonpilot subjects were trained to proficiency in presolo Visual Flight Rules (VFR) flight maneuvers using a fixed-base pilot ground trainer. A simplified visual display interconnected to the ground trainer, which provided the VFR environment, responded to flight control and power inputs simulating motion in the pitch, roll, and yaw axes. Subject flight performance capability achieved through ground trainer instruction was evaluated by a flight check in a single-engine aircraft. Project results indicate that a positive and effective transfer of training for performing a majority of VFR presolo maneuvers can be achieved with a ground trainer and visual presentation which provides the pilot pitch, roll, and yaw information with respect to a horizontal and directional referent. Attributes of the pilot ground trainer which contributed to positive transfer are defined. Maneuver situations which resulted in zero training transfer during aircraft validation flights are detailed. The characteristics deemed necessary for ground trainers to be effective for primary maneuver training are defined.

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INTRODUCTION

At the present time, there are no minimum criteria for pilot ground trainer use in Federal Aviation Regulation (FAR) 141 Pilot Schools and other certificated agencies. For example, as specified in FAR 141-61-a1, "An applicant for a primary flying school must provide (for airplanes) at least 35 hours of flight time or 30 hours of flight time and additional specialized approved instruction...." This FAR guidance leaves the acceptability of each pilot ground trainer to the discretion of the individual general aviation district offices.

PURPOSE.

The purpose of this project was to establish guidelines for the development of standards to determine the acceptability of pilot ground trainers used as primary pilot training devices in lieu of flight instruction in an aircraft.

BACKGROUND.

The variety and use of pilot ground trainers is expanding rapidly. Synonymously called simulators, flight trainers, flight duplicators, synthetic trainers and the like, these devices differ from the full-fledged certificated flight simulator because they simulate fewer aircraft characteristics or simulate them to a lesser degree of fidelity. They are used to provide practice in flight maneuvers and procedures that are common to a broad spectrum of general aviation aircraft. Because of their wide utilization, research on these types of flight simulators is needed so that the Federal Aviation Administration (FAA) may have a sound basis for developing regulations to authorize their use.

The ultimate goal of research on pilot ground trainers is to improve pilot training. To accomplish this goal it is necessary to determine what characteristics a ground trainer should have to be effective in various training situations. The information needed concerns the effects on the individual of flight training in the trainer. What features and characteristics need to be built into the ground trainer to provide an effective transfer of training between the learning situation on the ground and the later performance situation in the air?

In an effort to obtain the information necessary to establish adequate guidelines for authorizing the use of these devices, a contract was awarded in July 1970 to the Systems Technology Center, a subsidiary of Lear Siegler, Inc. The project, which constituted Phase I of the study, examined the performance of control and experimental groups performing a selective list of primary flight maneuvers defined in FAR's 61.37, 61.87, 61.117, and the appropriate Flight Test Guides. A control group trained solely in an aircraft, and an experimental group received flight instruction in a pilot ground trainer. Additional phases of the program tested subjects in similar maneuvers and procedures with varying levels of ground trainer capability including non-motion, motion, visual displays, audio cues, and radio navigation/communications simulation. (Reference Report No. FAA-RD-72-127, Vols. I, II; Study of the Capabilities, Necessary Characteristics and Effectiveness of Pilot Ground Trainers.)

The present project or Phase II, was initiated by the Aircraft Division of the Systems Research and Development Service, FAA, Washington D. C., and was conducted at the National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey.

Phase II, NAFEC project work, is a continuation of the Lear Siegler, Inc., program and investigates the effectiveness of a pilot ground trainer with a unique visual display. This visual system was not available for Phase I testing by Lear Siegler, Inc. Phase II was limited to the determination of the effectiveness of this system for training students in visual flight rule (VFR) presolo-type maneuvers.

DISCUSSION

GENERAL TEST PLAN.

The project was divided into three major parts. Part I was established to identify and document through live flight tests the basic and essential characteristics and trends of responses to flight control displacements in a typical primary training aircraft. A general description of these basic characteristics and trends was prepared for use in assessing the capabilities of any pilot ground trainer as being generally representative of typical training aircraft. Visual cues were identified, to the degree required, to perform specific presolo maneuvers and procedures.

Part II concerned the application of the information derived from Part I to assess the capabilities of a selected test pilot ground trainer.

Part III was an operational validation of the test pilot ground trainer as an effective training device for maneuver capabilities deemed acceptable in Part II.

PART I - DOCUMENTATION OF AIRCRAFT FLIGHT CHARACTERISTICS.

The documentation of aircraft flight characteristics was regarded as a basic "yardstick" against which any pilot ground trainer could be compared. To what extent these defined characteristics are absolutely necessary for the valid performance of visual flight maneuvers was to be determined in Part II and validated in Part III of the project work. A series of simple flight test procedures was developed and flown by an authorized flight test pilot in a Cherokee 180 aircraft (see Appendix). The documentation consisted of performing selected maneuvers in the aircraft and recording the external scene and the aircrafts' instrumentation on video tape. For example, to determine the effects of power changes on an aircraft trimmed for straight and level flight at normal cruise speed, power was increased/decreased by 200 revolutions per minute (r/min). The visual scene, as well as the instruments depicting variations in attitude, airspeed, heading, altitude, and rate-of-climb/descent were recorded with the video camera and tape recorder. The documentation also included a tape recording of observer and flight test pilot comments. Thus, a fairly accurate record was established of what actually occurred in the aircraft during these various flight test procedures.

To augment the definition of aircraft flight characteristics, a series of visual presolo flight maneuvers was flown in the aircraft and again documented by the video camera/tape recorder method (Table 1). This record, in most but not all cases, provided information concerning the basic visual aspects of pitch, roll, and/or heading changes associated with the flight maneuvers.

TABLE 1. DOCUMENTED PRESOLO FLIGHT MANEUVERS

1.	Taxi	12.	Power-off stall
2.	Takeoff	13.	Power-on stall
3.	Straight and level flight	14.	Flap usage
4.	Medium bank turn	15.	Slip/skid
5.	Shallow bank turn	16.	Crosswind tracking
6.	Steep bank turn	17.	Rectangular pattern
7.	Climb	18.	Airport traffic pattern
8.	Descent	19.	S turn
9.	Climbing turn	20.	Final approach
10.	Descending turn	21.	Landing
11.	Slow flight	22.	Rollout

The listing of these maneuvers did not mean necessarily that the ground trainer to be assessed in Part II had the capability of performing all of them; only through experimentation could this determination be made. However, these maneuvers were considered operational for presolo flight training, in that the grouping lends itself well to the real world of pilot training. Furthermore, these initial maneuvers were consistent, if not identical, with the maneuvers and procedures investigated by the Lear Siegler, Inc., study. Therefore, additional basic information for a comparative evaluation of ground trainer performance capability was available for analysis.

PART II - PILOT GROUND TRAINER ASSESSMENT.

In Part II, a pilot ground trainer simulating a civil primary training aircraft was subjected to the same series of flight tests and maneuvers as employed in Part I. No maneuvers or procedures were attempted in the ground trainer if there existed an obvious equipment, characteristic, or instrument deficiency. Obvious deficiencies were determined by referring to the general aircraft characteristics documented in Part I. Broad guidelines were formulated, a priori, as preliminary and general criteria, which established the basis for assessing the effectiveness of any pilot ground trainer. The guidelines (Table 2) related to ground trainer characteristics and trends which must be considered if some definition of acceptable ground trainer qualities for primary flight training is to be made.

PART III - PILOT GROUND TRAINER VALIDATION.

Selected zero-time subjects were trained to perform the specified presolo maneuvers and procedures within the scope of capabilities of the pilot ground trainer as determined in Part II.

Upon satisfactory completion of the presolo maneuvers, the subjects were flight checked for their ability to perform the maneuvers, learned in the ground trainer, in a typical civil primary training aircraft. The successful completion of a maneuver in one of three trials on a first flight encompassing these maneuvers was regarded and documented as an effective and positive transfer of training from the ground trainer to the aircraft. Conversely, pilot inability to perform a maneuver successfully was considered to be ineffective (zero) or negative transfer of training and suggestive of some deficiency in the ground trainer in terms of capability, characteristic, or equipment, which precluded an acceptable performance transfer.

PILOT GROUND TRAINER EQUIPMENT.

The flight simulation test environment consisted of a fixed-base pilot ground trainer representative of a single-engine general aviation aircraft with elevator, elevator trim tab, flap, aileron and rudder controls (Figure 1). Appropriate flight and engine instruments responded to movement of the flight and engine controls.

A simplified film strip projection system, enclosed in an overhead cabinet of the trainer, projected a colored sky-earth scene onto a vertical, white projection screen located above the trainer's instrument panel in front of the pilot. The visual scene responded to flight control and power inputs, simulating aircraft motion in the pitch, roll, and yaw axes. The system did not provide for a simulation of longitudinal or vertical closure movement or closure rates; however, lateral movement of the visual scene simulated turning motion, either left or right, through 360°.

A ground reference pattern screen inscribed with various geometric patterns (i.e., rectangles, squares, circles, figure eights, runways, and airport traffic entry, and departure patterns) could be substituted for the white projection screen. The projection of an airplane-shaped position light onto the screen and representing the aircraft responded to trainer airspeed and heading changes. This aspect of the visual system provided the pilot visual information of the aircraft's position, heading, flight path and drift relative to the ground reference patterns.

The ground trainer had provisions for simulating wind direction/force and engine noise. The latter varied in pitch with power changes. A "freeze" switch permitted the investigator/instructor to stop the flight at any time in order to analyze and discuss any errors made by the subject while performing a maneuver or procedure. A permanent record of aircraft track over the ground was accomplished automatically by a pen moving over a chart mounted on an external plotting board. Speed and directional movement of the pen were regulated by ground trainer airspeed and heading.

SUBJECTS AND TRAINING.

Ten zero-time subjects employed in Part III, the validation of the pilot ground trainer, were selected on a volunteer and availability basis from NAFEC personnel. They varied in age, occupational, and educational experience.

Subjects were trained in those presolo maneuvers and procedures within the scope of the capabilities of the pilot ground trainer as determined in Part II. Training sessions were conducted on a daily basis and each session consisted of a 10-minute preflight briefing, 45 minutes of ground trainer instruction, and a 15-minute post-flight debriefing. Instruction was limited to performing the selected maneuvers and procedures. Subjects did not receive any formal ground school training, nor was such intended. The FAA Flight Training Handbook, AC61-21 was the major document employed for flight instruction and was supplemented by the flight test guides for student and private pilots.

Once a subject achieved the desired proficiency level for performing a maneuver in the ground trainer, instruction proceeded on to the next maneuver. Review of the learned maneuvers was accomplished in the early part of each following session. There were no set number of lessons. Flight instruction was paced with the subjects' ability to demonstrate his performance capability in the ground trainer. Consideration was given to dropping a subject if he consistently failed to meet tolerances for the maneuvers (because of personal inability and not because of trainer deficiencies) but such occasions did not arise.

Upon successful completion of all tasks, subjects were given one final flight check in the ground trainer. This was a comprehensive flight which covered all the maneuvers and procedures learned in the ground trainer. After completing the ground trainer flight check, each subject received a similar validation flight check in the Cherokee 180 test aircraft. The subject occupied the left front seat, a Flight Operations safety pilot occupied the right front seat, and the investigator observed and recorded

TABLE 2. GUIDELINES FOR PILOT GROUND TRAINER ASSESSMENT

1.	Takeoff, climb, cruise, slow, descent, and landing flight.	The relationship of power, acceleration, attitude, vertical speed, configuration, deceleration, angle-of-attack, and flight path shall be appropriate for the general class of aircraft being used for pilot training.
2.	Turning flight.	The relationship of bank angle, airspeed, and turn rate during a coordinated turn shall be appropriate for the general class of aircraft being used for pilot training.
3.	Stalls.	The relationship of power, airspeed, angle-of-attack, attitude, vertical speed, configuration, and application of controls during approaches to stalls, stalls, and recovery from stalls shall be representative of the general class of aircraft being used for pilot training.
4.	Navigation and Communications.	If the pilot ground trainer is to be used (in lieu of instruction in flight) for navigation and communications on the civil airways or in controlled airspace, the pilot ground trainer shall be equipped to simulate those navigation and communications devices specified in accordance with FAR 91.33-d (1-9).
5.	Emergency Conditions.	If the pilot ground trainer is to be used (in lieu of instruction in flight) for emergency condition training, displays and controls shall be activated and operational in accordance with FAR 91.33-b (1-10).
6.	Pilot Ground Trainer Characteristics for VFR maneuvers.	The relationship of the visual scene as viewed by the pilot shall be synchronous with the flight path of the pilot ground trainer flight path and shall be representative of the visual cues normally used for instruction in flight during various maneuvers.

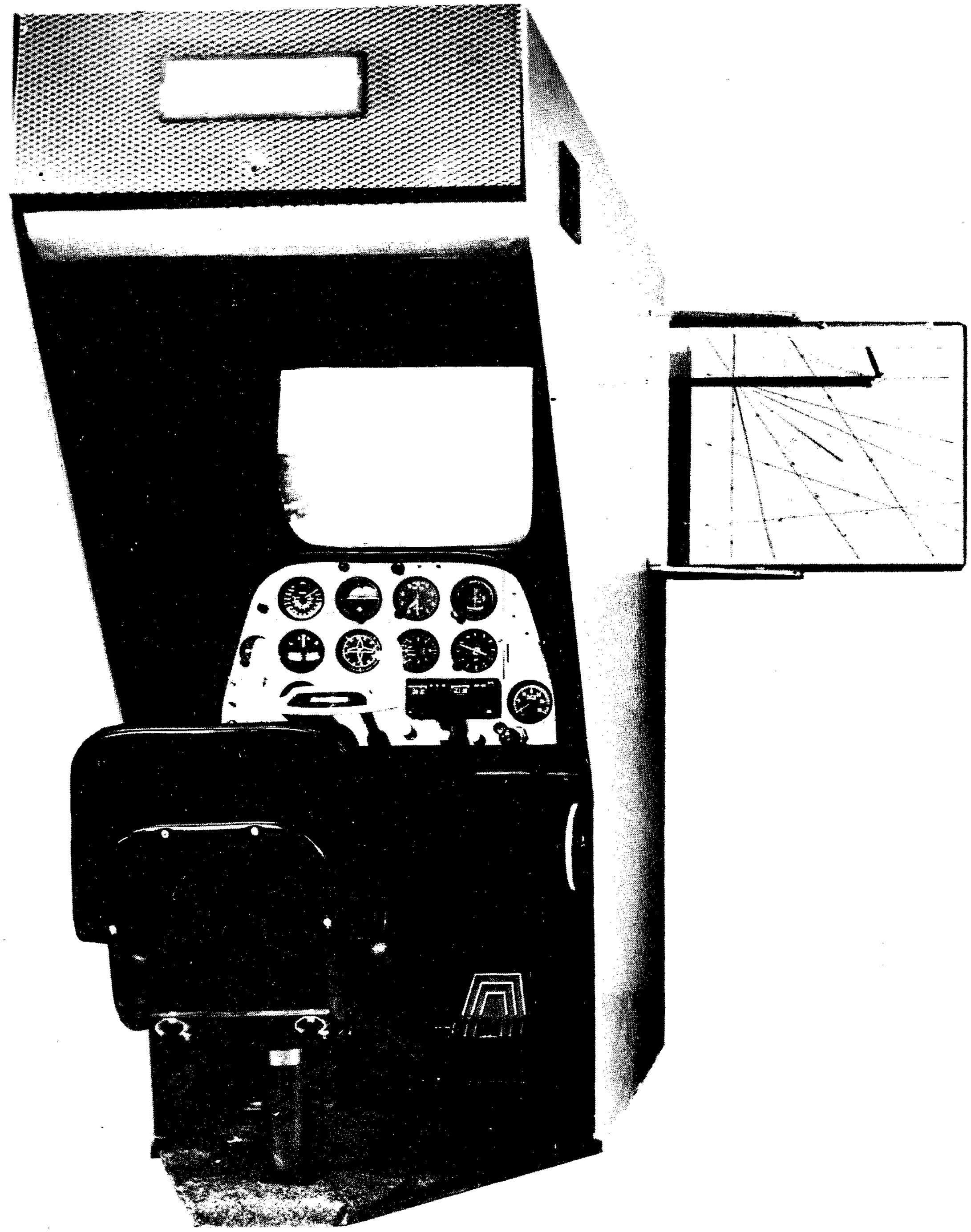

FIGURE 1. TEST PILOT GROUND TRAINER

TABLE 4. SUMMARY OF GROUND TRAINING TIME AND AIRCRAFT MANEUVER PERFORMANCE TRIALS

Subject	Ground Trainer Time	MANEUVER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
		NUMBER OF TRIALS																
A	7.2	1	2	3	-	1	1	2	1	1	-	3	2	3	-	1	2	-
B	6.1	1	1	3	-	1	1	2	1	1	3	2	1	3	-	1	2	3
C	7.3	1	1	2	3*	1	1	2	1	1	3	1	1	3	-	2	1	2
D	10.2	3	2	2	-	1	2	3	2	2	-	2	-	-	-	2	2	-
E	9.2	2	2	2	-	2	1	2	2	1	-	3	2	-	-	2	2	-
F	10.3	2	2	-	-	2	2	-	2	1	-	2	2	-	-	3	2	-
G	9.1	1	2	2	-	1	2	2	1	1	-	2	2	-	-	2	2	-
H	8.4	2	3	2	-	2	2	2	1	1	-	1	1	-	-	2	-	-
I	7.5	1	1	2	-	1	1	1	1	1	3	1	1	2	-	1	1	3
J	8.2	1	2	2	-	2	1	2	1	1	-	1	1	-	-	2	1	-
Average	8.4 hours	1.5	1.8	2.2	-	1.4	1.4	2.0	1.3	1.1	-	1.8	1.4	-	-	1.8	1.7	-

(-) Notation that maneuver was not completed successfully within three trials in the aircraft.
* Subject initially lost 250 feet but maintained altitude thereafter through 360° of turn.

Visual Aspects and Flight Characteristics. External horizon is used for pitch/roll information. External referent, building, road, etc., is used for straight flight (tracking). Pitch changes from level flight in terms of the horizon occur with:

- Elevator displacement.
- Elevator trim tab displacement.
- Power changes.
- Turbulence.

Power changes without trim produce:

- Nose up and yaw with increased power.
- Nose down and yaw with decreased power.

Excursions from wings level flight in terms of the horizon occur with:

- Aileron displacement.
- Rudder displacement.
- Turbulence.

Excursions from straight flight are influenced by:

- Wind effect (direction and force).
- Torque effect (the term torque is used in a broad sense to describe any yawing tendencies caused by varying aircraft attitude, power, or airspeed).
- Turbulence.

Other factors:

- Engine noise, vibration, stability, left/right visibility.

GROUND TRAINER REQUIREMENTS.

Controls: Elevator, aileron, rudder, elevator trim tab, throttle.

Instruments: Altimeter, airspeed indicator, heading indicator, tachometer.

Visual Aspects and Characteristics.

- External horizontal referent for level flight.
- External heading referent for straight flight.
- Internal frame of reference for straight and level flight (cowling, glareshield, or windshield divider).
- Pitch changes, either by elevator, elevator trim tab or power changes perceptible in terms of the horizontal referent.
- Roll excursions, either by aileron or rudder displacements perceptible in terms of the horizontal referent.
- Heading excursions either by rudder and/or aileron displacement perceptible in terms of the external heading referent.

- Power changes, without trimming and in terms of the external horizontal referent should result in a nose down (pitch down) attitude with decreased power, and a nose up (pitch up) attitude with increased power.
- Constant control force feel.

Instrumentation. (For brevity, the requirements for pilot ground trainer instrumentation remain the same for all control or power inputs and will not be repeated hereafter.) Elevator, aileron, and rudder displacements must produce correct and corresponding changes in the altimeter, airspeed, and heading instrumentation. Power changes, with or without trimming, must produce correct and corresponding changes in the altimeter, airspeed, heading, and tachometer instrumentation.

Desirable Elements:

- Perceptible yaw (torque effect) with power/airspeed changes.
- Rudder trim tab to offset yaw.
- Slip/skid indicator, attitude gyro, directional gyro.
- Variable control force feel with power, airspeed, or attitude changes.
- Engine noise and engine noise pitch change with power/airspeed changes.
- Turbulence.
- Wind input (direction and force).
- Longitudinal and directional stability.
- Minimum lag between ground trainer control or power input and ground trainer response in terms of the visual referents.

Comment. The straight and level flight maneuver is a relatively easy maneuver for subjects to learn, requiring an average of 1.5 trials in the aircraft. General subject comments relate to the "tightness" of the aircraft controls and an apparent rapid response of the aircraft to control or power input. The test ground trainer was regarded as being more stable than the aircraft for establishing an attitude and in control movement response. Positive factors of the ground trainer which contributed to effective transfer of training appear to be a good or "tight" elevator control system and elevator trim response to establish a level attitude and a minimum of lag between pitch input and pitch response of the visual horizontal referent. On the negative side, only three of the ten subjects were able to demonstrate heading control in the aircraft while exercizing power changes during this maneuver. The most obvious differences between the trainer and the aircraft were the yaw accompanying power applications in the aircraft and the change of control force pressures with power changes. In all cases, left yaw in the aircraft was counteracted with right aileron (lowered wing) instead of right rudder. Observing the lowered wing or slight bank attitude of the aircraft, subjects would release right aileron pressure, and left yaw would recur with the ball of the slip/skid indicator indicating a slight skid. The effect of rudder application in the ground trainer was dissimilar (less sensitive with respect to slip/skid ball movement) to that in the aircraft. Further, rudder trim function was not a capability of the trainer. The lack of visible yaw as a product of torque effect with power changes appears to be the contributing factor for ineffective training transfer for maintaining heading while varying power during the straight and level flight maneuver. If heading hold is to be stressed during instruction for straight flight, the ground trainer must be capable of producing visible yaw which can be corrected with the application of rudder or rudder trim. The addition of a functional and sensitive slip/skid indicator to display yaw could serve to confirm this flight condition.

MANEUVER NO. 2 - MEDIUM BANK TURN (AIRCRAFT).

Synopsis: This level turn maneuver is initiated from a level flight attitude by banking the aircraft in the desired direction with the simultaneous application of aileron and appropriate rudder to maintain coordinated flight. The degree of bank, with relation to the visible horizon, is established and maintained with aileron control. Rate of turn increases as the bank angle increases. With no power change, back elevator pressure is required to increase the angle of attack in order to maintain altitude. The amount of back pressure needed is dependent on the angle of bank used in the turn and increases as the bank angle increases.

Visually, the level turn is maintained in terms of the nose position with reference to the horizon and bank information is derived from the angle the wing or wing tip makes with the horizon or ground plane which is visible throughout the turn. Broad turn rate information is provided by observing the velocity of the nose/wing referents as they move around the horizon or against the ground plane. In the medium bank turn (25° - 35°), stability of the aircraft tends to keep bank constant without the use of aileron control force.

Visual Aspects and Flight Characteristics.

- External horizon/ground plane is used for pitch and bank information.
- External heading or ground plain referent is used for indicating azimuth change in turns of varying degrees, i.e., 90°, 180°, 360°, etc.

- Aircraft referent, i.e., nose, cowling, wingtips.
- Loss of lift in the turn (nose drop) without the use of back elevator pressure or the addition of power.
- Relationship of bank angle and airspeed to rate of turn and radius of turn with respect to the ground plane.
- Recovery to a heading or direction requires a lead to offset the delayed response time required by the aircraft to return to straight flight.
- Increased bank angle results in increased turn rate under normal coordinated flight conditions.
- Increasing bank angle requires an increase in elevator back pressure and/or power to compensate for loss of lift and to maintain altitude.
- Uncoordinated use of aileron/rudder controls results in a slipping or skidding flight condition. (Note: The slip/skid indicator is the only visual reference cue the pilot has which indicates uncoordinated flight in the turn. Without this instrument the pilot relies on kinesthetic cues to determine broadly if a slipping or skidding flight condition exists.

GROUND TRAINER REQUIREMENTS.

Controls: Elevator, aileron, rudder, throttle.

Instruments: Altimeter, airspeed indicator, heading indicator, slip/skid indicator, tachometer.

Visual Aspects and Characteristics.

- External horizontal referent for pitch control (maintaining altitude) in the turn.
- External horizontal referent to depict a bank angle of 25° - 35°.
- External heading or ground plane referent to provide azimuth change information in the turn. The turn rate may be constant. (See change of heading or scenery requirements under Comment.)
- Internal frame of reference, i.e., cowling, nose, glareshield, for maintaining attitude with regard to the horizontal referent.
- Perceptible pitch change (nose drop) in terms of the horizontal referent without the use of back elevator pressure or power increase.
- Control force feel constant.

Desirable Elements.

- 360° of visual azimuth change in the horizontal turn.
- Variable turn rate.
- Turn needle, directional, and attitude gyros.
- Variable control force feel.
- Stability.
- Inertial effects requiring heading lead on the turn recovery.
- Minumum lag between control input and visual display response.
- Kinesthetic cues.
- Wide field of view including right/left visual cues (side window visibility).

Comment. All subjects completed this maneuver satisfactorily. The average number of trials was 1.8. All subjects had a slight tendency to overcontrol the aircraft in the roll axis when starting the bank. This tendency was attributed to the unobjectionable lag in the ground trainer between aileron control input and visual display response. Most subjects were inclined to start the turn recovery late because of the inertial effects upon turn recovery present in the aircraft but lacking in the ground trainer. Slipping and skidding which occurred in the aircraft during the turn maneuver, caused by inappropriate rudder application, was acceptable. The ball of the indicator was generally out of the reference mark frame by one-half. The ground trainer characteristic of pitch change, which required exercising elevator control during the turn entry and recovery, was reflected in the subjects' ability to maintain altitude in the aircraft during the turn and is regarded as a major factor contributing to positive training transfer. It is the investigator's opinion that azimuth motion may not be a requirement of the ground trainer if turn recovery to a general direction or heading is of no importance or, at least, is not stressed.

MANEUVER NO. 3 - SHALLOW BANK TURN (AIRCRAFT).

Synopsis: Similar to the medium bank turn, but more difficult to maintain the shallow bank of approximately 10°. The aircraft has a tendency to return to a wings level flight condition because of its' lateral stability. The maneuver is more difficult to perform if turbulent wind conditions exist.

Visual Aspects and Flight Characteristics. Similar to the medium bank turn maneuver. The pitch change in attitude is not as great and does not require the elevator back pressure used for the medium bank turn. Positive aileron pressures in the direction of the turn are needed to maintain the shallow angle of bank and to overcome the tendency for the aircraft to return to the wings level flight condition.

GROUND TRAINER REQUIREMENTS.

Controls: Elevator, aileron, rudder, throttle.

Instruments: Altimeter, airspeed indicator, heading indicator, tachometer.

Visual Aspects and Characteristics. Similar to the medium bank. There is no requirement for a perceptible change in attitude (nose drop) in terms of the horizontal referent. Bank angle capability - from the least perceptible to 25°.

Desirable Elements.

- Variable turn rate, i.e., a rate of turn less than that required for the medium bank turn.
- Lateral stability, requiring aileron pressure into the turn.
- Variable control force feel.
- Slip/skid indicator, attitude gyro, directional gyro, turn needle.

Comment. Subjects accomplished this maneuver in an average of 2.2 trials. Critical factors appear to be those of initial overcontrol in the aircraft and the trend to let the aircraft return to straight and level flight. In the ground trainer, little if any aileron pressure in the direction of the turn, is required to maintain the shallow bank angle. Subjects A and B had difficulty with this maneuver because of the moderate turbulence encountered during this maneuver. Subject F let the aircraft return to wings level flight throughout the three trials.

MANEUVER NO. 4 - STEEP BANK TURN (AIRCRAFT).

Synopsis: Similar to the medium bank turn maneuver with the bank angle established at a minimum of 45° and no greater than 60°. In addition, considerable back elevator pressure is required to maintain altitude. Positive rudder control in the direction of the turn is necessary to achieve coordinated flight. Unless some aileron pressure is maintained against the direction of the turn (opposite aileron) the aircraft has a tendency to overbank. Initial failure to maintain sufficient back elevator pressure as the bank steepens results in a nose low attitude. The use of back elevator pressure with this attitude established results in a tighter turn radius, loss of altitude, and excessive airspeed. Forces of 1.5g to 2.0g are experienced in the steep turn maneuver.

Visual Aspects and Flight Characteristics.

- Similar to the medium bank turn maneuver.
- Rapid turn rate.
- Overbanking tendency.
- g forces.
- Variable control force feel and pressures as the bank steepens.
- Considerable elevator back pressure and sufficient power are required to maintain altitude and flying speed.

GROUND TRAINER REQUIREMENTS.

Controls: Elevator, aileron, rudder, throttle.

Instruments: Altimeter, airspeed indicator, heading indicator, slip/skid indicator, tachometer.

Visual Aspects and Characteristics. Similar to the medium bank turn maneuver plus:

- Displayed bank angle of at least 45°.
- Variable control force feel. The elevator back pressure required to maintain altitude should be in excess of that required for the medium bank turn.
- Overbanking tendency beyond 35° of bank requiring holding opposite aileron in the turn.
- Greater pitch down attitude than that occurring in the medium bank turn as the bank angle increases without offsetting this attitude with corrective elevator back pressure.
- Minimum lag between flight control input and the response of the horizontal referent for depicting bank.
- Simulated inertial effect on turn recovery which requires leading the heading on turn recovery.

Desirable Elements.

- Variable turn rate or a turn rate in excess of that required for the medium bank turn maneuver.
- Attitude gyro, directional gyro.

- Turn needle.

- g force.

- Kinesthetic cues.

Comment. Training transfer for this maneuver was zero. Only Subject C came near to performing this maneuver satisfactorily. After an initial altitude loss of 250 feet on his third trial, the subject was able to maintain altitude and a bank angle of approximately 50° through 360° of turn.

All subjects had difficulty maintaining a constant bank angle, caused by either neglecting to correct for the overbanking tendency or by shallowing out the bank. Overcontrol in the roll axis was a common occurrence. What appears to be a critical factor in the steep turn maneuver is that the ground trainer experience did not prepare the subjects for the elevator control forces (i.e., back pressure) necessary to prevent the aircraft's nose position from dropping below the horizon as the bank angle was steepened. In this attitude, extreme steep bank angle, high-speed spirals, accompanied by excessive "g" forces resulted when subjects attempted to regain lost altitude with the use of elevator back pressure. Extreme altitude excursions occurred during the steep turn entry and recovery. In most cases the safety pilot had to take over control of the aircraft when the subject made no attempt to shallow the bank or to discontinue the turn. All subjects commented on the g forces experienced. The general opinion was expressed that the ground trainer was extremely stable in the steep turn maneuver and that control pressures of the ground trainer were not comparable to those experienced in the aircraft during the steep turn. In the course of the initial ground trainer assessment, it was noted that in any turn maneuver, once the nose attitude was established with elevator control, a hands-off-the-yoke turn could be made. The need for applying rudder forces for coordinated flight in the steep turn maneuver in the test ground trainer was not on a par with those forces required in the aircraft. Consequently, a slipping condition in the aircraft was a common occurrence during the steep turn trials. While subjects stated that the "g" forces experienced were unexpected and distracting, none acknowledged that they were aware of the physical sensations associated with uncoordinated flight (excessive slipping). The steep turn maneuver was described by five subjects as being comparable to a "wild ride in an amusement park vehicle." While g effect was not a capability of the test ground trainer, the investigator believes that the ground trainer requirements listed may contribute to some effective and positive training transfer for performing this maneuver. A study of a trainer having the listed characteristics should determine if g effect is a necessity for learning this maneuver.

MANEUVER NO. 5 - NORMAL CLIMB (AIRCRAFT).

Synopsis: This maneuver involves an attitude (pitch) change from the takeoff or normal cruise attitude to a nose-up attitude using back elevator pressure, climb power for the best rate of climb speed, and using elevator and rudder/rudder trim tab controls to establish and maintain, respectively, the climb attitude and directional control.

The external forward view of the horizon is diminished, if not lost entirely, during the climb because of the nose-high attitude established and requires the pilot to use external visual cues from the side windows of the aircraft. (In actual practice, it is common for pilots to monitor the airspeed indicator or attitude gyro for attitude information, and the heading indicator for directional control.) Torque effect, caused by the nose-high attitude and application of climb power, is minimized with appropriate rudder or rudder trim tab corrections. Climb rate is affected by varying pitch attitude and/or power. With a constant power setting, airspeed is controlled by changing the pitch attitude with the elevator control.

Visual Aspects and Flight Characteristics.

- External horizon/ground plane viewed from the front or side windows, provides for a horizontal pitch/roll displacement referent.
- External heading referent is used (for straight climb), such as a highway on the ground plane reference.
- Level flight is also maintained by observing the wing tip reference with the horizon (side visibility).
- Pitch changes during the climb maneuver and with respect to the visible horizon or ground plane occur with elevator, elevator trim tab displacements, and/or power changes.
- Excursions from the wings level climb attitude occur with aileron or rudder displacement and turbulence.
- Excursions from the straight climbing flight path are caused by rudder displacement, torque, and wind force/direction.
- Engine sound changes with the addition of climb power.

GROUND TRAINER REQUIREMENTS.

Controls: Elevator, aileron, rudder, elevator trim tab, rudder trim tab (see Comment), throttle.

Instruments: Altimeter, airspeed indicator, heading indicator, slip/skid indicator (see Comment), tachometer.

Visual Aspects and Characteristics.

- Visible external horizontal referent for maintaining a level wing position in the climb.
- External heading referent for maintaining direction in the climb.
- Internal frame of reference, i.e., cowling, glareshield, etc.
- Pitch changes, resulting from elevator, elevator trim tab or power changes should be perceptible in terms of the horizontal or ground plane referent.
- Excursions from the wings level position brought about by aileron or rudder displacements should be perceptible in terms of the horizontal or ground plane referent.
- Heading excursions caused by rudder/aileron displacement or torque should be perceptible in terms of the external heading referent.
- The application of climb power, without countering elevator control pressure with elevator or elevator trim tab corrections, should result in a nose-up attitude with respect to the horizontal referent.
- Torque effect resulting in perceptible yaw with the application of power and necessitating the use of rudder or rudder trim tab corrections (see Comment).
- Control force feel constant.

Desirable Elements.

- Side view cues or expanded ground plane reference for maintaining a wings level climb attitude.
- Variable control force feel with power, airspeed, or attitude changes requiring elevator or elevator trim tab corrections.
- Variable engine noise levels with power or airspeed changes.
- Variable speed range to include airspeeds in the stall range.
- Attitude gyro, directional gyro, vertical speed indicator.
- Directional stability.
- Turbulence.
- Wind direction/force input.
- Minimum lag betweeen aircraft control or power input and trainer response with respect to the visual referents.

Comment. The normal climb maneuver was a relatively easy maneuver for subjects to learn and was one which they accomplished in an average of 1.4 trials in the aircraft. The majority of subjects showed a slight but unobjectionable tendency to overcontrol in the pitch axis in the aircraft. This overcontrol resulted in minor variations of airspeed. In the ground trainer an effective elevator trim response contributed substantially to the establishment of acceptable climb attitudes when subjects performed in the aircraft. Normal climbs on a specific heading are another matter. Subjects were not successful in performing this phase of the climb maneuver. Heading in all cases varied as much as 20°. The zero transfer of training was attributed to the lack of torque effect in the test ground trainer. In training, subjects made minimum use of the rudder controls, because lacking torque effect, yaw or skidding information was not displayed on the slip/skid indicator or in the visual display; therefore, subjects never learned to correct for a nonexistent skid or yaw condition in the ground trainer. This nonlearning was carried over to the aircraft. Climbs were performed in a slight skid (ball one-half out of reference frame marks). The uncorrected yaw resulted in the heading variations mentioned above. In the aircraft, the majority of subjects attempted to correct for yaw by applying opposite aileron control, which in turn, resulted in a slight wing low flight attitude.

An acceptable training transfer for maintaining heading or at least staying within the heading tolerances specified, requires a simulation of torque effect in the ground trainer. Torque, with power application, should produce yaw that is perceptible in the visual display in terms of the heading referent, and should be displayed on a slip/skid indicator sensitive to this condition. The resultant yaw must be reduced or eliminated by applying appropriate rudder or rudder trim tab controls. If there is to be no emphasis on heading management during the climb maneuver, there is no requirement for a sensitive slip/skid indicator, rudder trim tab, or torque effect.

MANEUVER NO. 6 - NORMAL DESCENT (AIRCRAFT).

Synopsis: This maneuver involves an attitude change (pitch) generally from a normal cruise attitude to a slightly nose low or glide attitude. Ordinarily, power is reduced prior to starting the descent to avoid a buildup of airspeed and to establish a best descent airspeed.

With an established nose-low attitude, the horizon is clearly discernible. A wings level attitude is maintained with aileron control with respect to the external horizon, and directional control is maintained with rudder control with regard to external heading referents such as highways, buildings, or other landmarks. The elevator trim tab control is used to reduce elevator control forces. A slight yaw to the right occurs when the power is reduced which can be offset with the application of rudder or rudder trim tab control. Uncorrected yaw during the descent is of a lesser degree than that which occurs with the climb maneuver. Power and/or pitch changes regulate the vertical descent rate with corresponding changes in airspeed. With a constant power setting airspeed is controlled by varying pitch attitude with elevator control.

Visual Aspects and Flight Characteristics.

- External horizon/ground plane viewed from the front provides for a horizontal pitch/roll displacement referent.
- Aircraft referent i.e., cowling, nose, glareshield.
- External heading referent for (straight descent) such as a highway on the ground plane reference.
- Pitch changes during the descent maneuver and with respect to the visible horizon or ground plane occur with elevator, elevator trim tab, and/or power changes.
- Excursions from the wings level attitude during the descent occur with aileron or rudder displacements and turbulence.
- Excursions from the straight descending flight path occur with rudder displacement or turbulence. There appears to be minimal yaw with the reduction of power. Wind force and direction also effect the aircraft's flight path over the ground.
- The engine noise level decreases with power reduction.
- Control force feel changes with power reduction.

GROUND TRAINER REQUIREMENTS.

Controls: Elevator, aileron, rudder, elevator trim tab, throttle.

Instruments: Altimeter, airspeed indicator, heading indicator, slip/skid indicator, tachometer.

Visual Aspects and Characteristics.

- External horizontal referent for maintaining wings level flight during the descent.
- External directional referent for maintaining heading during the descent.
- Internal frame of reference, i.e., cowling, glareshield.
- Pitch change (nose drop) with power reduction.

- Pitch changes resulting from elevator, elevator trim tab or power changes should be perceptible in terms of the horizontal or ground plane referent.

- Heading excursions caused by rudder aileron displacement should be perceptible in terms of the external heading referent.

- Control force feel constant.

Desirable Elements.

- Variable control force feel with power changes.

- Rudder trim tab.

- Wind direction/force input.

- Turbulence.

- Stability.

- Engine noise level decrease with power reduction.

- Minimum lag between flight control/power input and trainer response with respect to the visual referents.

- Attitude gyro, directional gyro, vertical speed indicator.

Comment. A fairly easy maneuver for subjects to learn, requiring an average of 1.4 trials in the aircraft. There was a very slight tendency for some subjects to overcontrol the aircraft in the pitch axis when power was reduced which resulted in minor airspeed fluctuations. The overcontrol tendency displayed was less than that encountered with movement in the roll axis when subjects performed in the aircraft. An advantageous characteristic of the ground trainer for performing this maneuver appeared to be the perceptible pitch change (nose drop) with power reduction. Subjects did not experience problems with heading management during the descent as they did while performing the climb maneuver, although flight was slightly uncoordinated (less than one-half ball out of the reference frame of the slip/skid indicator during the descent).

MANEUVER NO. 7 - CLIMBING TURN (AIRCRAFT).

Synopsis: This maneuver is a combination of the aspects specified for Maneuvers 2 and 5, respectively, medium bank turn and normal climb.

GROUND TRAINER REQUIREMENTS.

Controls: Identical to those of the turn maneuver plus those of the climb maneuver.

Instruments: Identical to those of the turn maneuver plus those of the climb maneuver.

Visual Aspects and Characteristics. Identical to those of the turn maneuver plus those of the climb maneuver.

Comment. Subjects accomplished this maneuver in the aircraft in an average of 2.0 trials. Subject F did not meet the airspeed tolerances required for the climbing turn because of overcontrolling in both the pitch and roll axes. Flight for all subjects was uncoordinated to a slight extent, with the ball of the slip/skid indicator displaced by a half width.

Desirable Elements. Coincide with those elements specified for the medium bank turn and climb maneuvers.

MANEUVER NO. 8 - DESCENDING TURN (AIRCRAFT).

Synopsis: This maneuver is a combination of the aspects specified for Maneuvers 2 and 6, respectively, medium bank turn and normal descent.

GROUND TRAINER REQUIREMENTS.

Controls: Identical to those of the turn maneuver plus those of the descent maneuver.

Instruments: Identical to those of the turn maneuver plus those of the descent maneuver.

Visual Aspects and Characteristics. Identical to those of the turn maneuver plus those of the descent maneuver.

Comment. Subjects accomplished this maneuver in an average of 1.3 trials. Airspeed control was good with minimal overcontrol in the roll axis during the descent. Slipping/skidding tendencies were less than those encountered in the climbing turn maneuver.

Desirable Elements . Coincide with those elements specified for the medium bank turn and descent maneuvers.

MANEUVER NO. 9 - CROSSWIND TRACKING (AIRCRAFT).

Synopsis: Pilotage or visual point-to-point navigation by establishing a heading or heading correction which will counteract the effects of wind or drift and which in turn will result in a relatively straight track from one ground reference point to another. Crosswind tracking is generally performed in the normal cruise configuration and initially at an altitude low enough for the novice pilot to perceive drift. The procedure makes use of visual ground reference points, such as highways, buildings, and other like landmarks. Drift or heading corrections are made by perceiving excursions from the desired flight path in terms of the path or track made over the ground or by the apparent left or right movement of selected ground reference points on the horizon.

Visual Aspects and Flight Characteristics. Identical with those associated with the straight and level flight maneuver plus:

- A ground reference plane.
- Ground reference points or objects.
- Internal frame of reference.
- Perceptible drift.

GROUND TRAINER REQUIREMENTS.

Controls: Elevator, aileron, rudder, elevator trim tab, throttle.

Instruments: Altimeter, airspeed indicator, heading indicator, tachometer.

Visual Aspects and Characteristics. All visual cues and flight characteristics associated with the straight and level flight maneuver.

- Variable wind input (direction and force).
- Ground plane.
- Ground reference points.
- Perceptible forward and lateral movement.
- Perceptible drift in terms of visual heading and flight path or track information.

Desirable Elements. As in the straight and level flight maneuvers plus:

- Variable ground speed that is perceptible depending upon wind conditions.

Comment. A relatively easy procedure for subjects to learn requiring an average of 1.1 trials in the aircraft. The ground trainer equipment which contributed to good performance and effective training transfer consisted of the vertical ground reference plotting board with the aircraft position light and the wind force/direction capability. The fact that ground reference points and flight path or track are displayed on a vertical plane in the pilots' forward view rather than in a real-world horizontal reference ground plane did not affect the quality of pilots' performance in the aircraft.

MANEUVER NO. 10 - SLOW FLIGHT (AIRCRAFT).

Synopsis: This maneuver involves flying the aircraft at a minimum controllable airspeed in level flight, turns, and descents. The aircraft is flown in both the clean and landing configurations. Slow flight consists of reducing power and increasing the pitch attitude of the aircraft with back elevator pressure as the airspeed decreases to maintain altitude. Power is then added in order that the airspeed attained will be sufficient to maneuver the aircraft in level, turning, or descending flight without stalling. A nose-high attitude is apparent, and the flight controls lose considerable response effectiveness at the slow flight airspeed. Left yaw is experienced which requires a right rudder or rudder trim tab correction to maintain the desired heading.

Visual Aspects and Flight Characteristics. Similar to those associated with the straight and level flight maneuver plus:

- Less responsive flight controls.
- Greater control deflection required for maneuvering.
- Torque effect.
- Relatively higher nose attitude with respect to the horizon than that occurring in a normal cruise level flight condition.

GROUND TRAINER REQUIREMENTS.

Controls: Elevator, aileron, rudder, elevator trim tab, throttle.

Instruments: Altimeter, airspeed indicator, heading indicator, slip/skid indicator, tachometer, stall warning signal.

Visual Aspects and Characteristics. The same general visual requirements as for straight and level flight, plus:

- A higher nose attitude with regard to the horizontal referent.
- Variable control force feel.
- Torque effect perceptible as yaw requiring rudder or rudder trim tab correction.

- Stall capability with stall airspeed range.

Desirable Elements.

- Stall warning signal (aural).
- Spin and spin recovery capability.
- Rudder trim tab.
- Buffet.
- Attitude gyro, directional gyro.

Comment: Only three of the 10 subjects accomplished this maneuver in an average of 3.0 trials in the aircraft, and their performance was considered borderline. All subjects experienced difficulty controlling airspeed and heading. In all cases, flight was not coordinated ranging from a mild half-ball skid for those who finally met the performance criteria, to a full-ball deflection skid. The major comment offered by the subjects concerned the very noticeable difference between the ground trainer's constant and firm control force feel and the relative slackness of the aircraft controls. Overcontrol in the pitch and roll axis was a frequent occurrence. Since the chief characteristic differences between the test ground trainer and the aircraft are the lack of a variable control force feel and detectable yaw caused by torque in the ground trainer, it is likely that the addition of these characteristics could contribute to effective and positive training transfer for the slow flight maneuver.

MANEUVER NO. 11 - POWER-OFF STALL (AIRCRAFT).

Synopsis: The power-off stall maneuver is started from level flight at cruising airspeed. Power is reduced and a normal glide is established. The nose of the aircraft is raised with elevator control to stop the glide, and the attitude maintained requires continuous back pressure on the elevator control until the stall occurs. Buffet generally accompanies the approach to the stall and stall. Recovery is initiated with forward movement of the elevator control to decrease angle of attack and a simultaneous application of power. When flying speed is attained, the descent is halted with back elevator pressure to return the aircraft to the straight and level flight attitude. Directional control throughout the approach to the stall is maintained with rudder. A stall warning signal, either of visual or aural nature, or both, precedes the full power-off stall.

With respect to the visible horizon, the progression of aircraft attitude changes include level flight, nose-low glide, nose-high attitude during the approach to the stall, and nose-low attitude after the stall occurs. During the approach to the stall, the nose-high attitude obscures the forward view of the horizon, and the wing or wing tip position (lateral view) with relation to the horizon is used for wing level reference. In conjunction with visual attitude changes, control force feel and control response vary as attitude changes during the approach to the stall, at stall, and during stall recovery.

Visual Aspects and Flight Characteristics. The visual cues and flight characteristics necessary are those identical to the straight and level, normal descent, and slow flight maneuvers, respectively, Maneuver Nos. 1, 6, and 10. As the stall occurs the nose drops to or slightly below the horizon. Recovery is accomplished with forward elevator pressure and application of power. Attitude changes in pitch are perceptible in terms of the external horizon.

GROUND TRAINER REQUIREMENTS.

Controls: Elevator, aileron, rudder, throttle, carburetor heat control (for procedure).

Instruments: Altimeter, airspeed indicator, heading indicator, slip/skid indicator, tachometer, stall warning signal (aural).

Visual Aspects and Characteristics. Required are: all visual cues and flight characteristics associated with ground trainer requirements for straight and level flight (Maneuver No. 1); all visual cues and flight characteristics associated with the ground trainer requirements for the normal descent maneuver (Maneuver No. 6); all visual cues and flight characteristics associated with the ground trainer requirements for the slow flight maneuver (Maneuver No. 10).

- Stall airspeed range.
- Stall capability, with a pitch change as the stall occurs perceptible in terms of the horizontal referent.
- Recovery capability to be accomplished with forward elevator pressure and power application.

Desirable Elements.

- Torque effect.
- Buffet.
- Stall warning signal - aural and visual.
- Variable control force feel.

- Expanded visual scene to include side view capability.

- Instability in the roll axis, i.e., a visual capability of depicting wing drop.

- Kinesthetic cues - loss of lift sensation.

- Attitude gyro, directional gyro.

Comment. Subjects demonstrated positive training transfer for performing this maneuver which required an average of 1.8 trials in the aircraft. It appears that ground trainers can contribute substantially to the effective accomplishment of this maneuver if the loss of lift at stall is perceived as a definite pitch-down attitude. The aural/visual combination of the stall warning signal in the test ground trainer is an effective device for alerting subjects to the impending stall. In the aircraft, subjects were not familiar with the buffet accompanying the approach to the stall and at the stall point, since the test ground trainer did not have this capability. Three subjects started recovery before the full stall occurred on the basis of aircraft buffet and activation of the stall warning light. The test aircraft was not equipped with an aural stall warning signal. Since the prime objective of teaching stalls is to recognize the stall situation and to take appropriate action before it occurs, the subjects' performance was regarded as satisfactory. Full stall recoveries were accomplished on their second trials.

Subjects can maintain heading in the ground trainer while practicing this maneuver, since torque effect resulting in yaw is not present and therefore does not require corrective rudder action. Lacking this characteristic in the ground trainer, the transfer of training for heading maintenance in the aircraft during the stall maneuver was zero. It was interesting to note that the lack of variable control force feel in the ground trainer had no adverse effect on subjects' performance of stalls and stall recoveries in the aircraft. For the slow flight maneuver, the lack of this characteristic was considered to be a prime factor contributing to zero transfer of training. The difference may be attributed to the fact that the power-off stall maneuver was examined only in the straight ahead mode, whereas slow flight was conducted in level, turning, and descending attitudes.

Stalls, while in turning flight, were not taught in the ground trainer because the displayed visual cues at stall and the required stall recovery techniques were dissimilar with what actually occurs in the aircraft during the turning stall, especially if the turn is an exaggerated slipping or skidding turn.

MANEUVER NO. 12 - POWER-ON STALL (AIRCRAFT).

Synopsis: This maneuver is started from level flight. Pitch attitude is increased to the point where the aircraft no longer climbs. The nose high or climb attitude is maintained by a gradual increase of elevator back pressure, as the aircraft slows, until the stall occurs. Recovery is effected by decreasing the angle of attack and adding power (if additional power is available) simultaneously coordinating all flight controls to return to level flight. Control effectiveness is diminished similar to that occurring in the power-off stall, but elevator control may not be as responsive, since the stall breaks later than that of the power-off stall. Torque effect or yaw is more pronounced because of the higher nose attitude and power carried and consequently requires more rudder correction to maintain heading.

Visual cues are similar to those associated with the power-off stall, except the nose attitude achieved is higher or appears higher with regard to the horizon. The pitch down which occurs at stall, and before recovery, is also much greater than that which occurs with the power-off stall. The forward view of the horizon is obscured completely prior to the stall, and a wing level reference is maintained by lateral visual cues of wing position with respect to the ground plane and horizon.

Visual Aspects and Flight Characteristics.

- All visual cues and flight characteristics associated with the straight and level flight maneuver (Maneuver No. 1).
- All visual cues and flight characteristics associated with the normal climb maneuver (Maneuver No. 5).
- All visual cues and flight characteristics associated with the power-off stall maneuver (Maneuver No. 11).
- Laboring engine sound.
- Excessive torque effect.
- More pronounced pitch down at stall.

GROUND TRAINER REQUIREMENTS. The controls, instruments, and visual aspects and characteristics specified for the power-off stall maneuver apply to the power-on stall.

Comments. Comments made for the power-off stall maneuver apply equally as well to the power-on stall maneuver which subjects accomplished in an average of 1.4 trials. Subject D recognized the power-on stall, but consistently, i.e., for three trials, was slow to return to level flight which resulted in an excessive build up of airspeed.

MANEUVER NO. 13 - FLAP USAGE (AIRCRAFT).

Synopsis: Flap usage is not regarded as a true maneuver. However, it does require the subject to control the aircraft, since the use of flaps alters aircraft attitude, airspeed, and vertical rate, and effects a change in control force feel pressures. Flaps are normally used in the approach and landing phases of flight and also may be employed when runway or field conditions require a short or soft field takeoff. Lowering the flaps steepens the glide path and increases the rate of descent. Visually, the lowering of flaps causes a pitch-down attitude of the aircraft with regard to the horizon, the degree of pitch change being dependent upon the amount of flaps lowered. Control force feel changes with the change of pitch attitude. (In some aircraft, a pitch-up attitude may occur when flaps are lowered, however, this synopsis speaks of the characteristics encountered in the test aircraft when the flap control was activated.)

When flaps are lowered, the attitude change is accompanied by a "rising" sensation, caused by this initial lift provided by the lowered flaps. Conversely, when the flaps are retracted, the pitch-down attitude is decreased and is accompanied by a slight loss of lift which the pilot feels momentarily as a "sinking" sensation. The rising and sinking effects that occur respectively with flap deployment and retraction are normally offset by exercising appropriate elevator control.

Visual Aspects and Flight Characteristics.

- All visual cues and flight characteristics associated with the straight and level flight maneuver (Maneuver No. 1).
- Lowering of flaps results in a pitch change (nose-down attitude) with respect to the horizon.
- Lift sensation.
- Increased vertical descent rate.
- Steepened glide path.
- Decreased airspeed (without trimming).
- Flap retraction results in a pitch change (nose-up attitude) with respect to the horizon.
- Sinking sensation.
- Decreased vertical descent rate.

- Shallowed glide path.

- Elevator control force feel and pressure changes occur with the deployment or retraction of the flaps.

- The degree of pitch down or pitch up attitude change with flap activation varies with the amount of flap deployed or retracted.

GROUND TRAINER REQUIREMENTS.

Controls: Elevator, aileron, rudder, elevator trim tab, flap control, throttle.

Instruments: Altimeter, airspeed indicator, heading indicator, tachometer, flap position indicator.

Visual Aspects and Characteristics.

- All visual cues and flight characteristics associated with ground trainer requirements specified for straight and level flight (Maneuver No. 1).

- All visual cues and flight characteristics associated with ground trainer requirements specified for the normal descent maneuver (Maneuver No. 6).

- Perceptible pitch changes with respect to the horizontal referent when flaps are deployed or retracted.

- Elevator control force feel and pressure change to occur with flap activation. Elevator control forces or pressures should be minimized with elevator trim tab control.

Desirable Elements.

- Slip/skid indicator, attitude gyro, vertical speed indicator.

- Flap position indicator, if ground trainer has selectable flap positions other than full up or full down.

- Kinesthetic cues, e.g., heave.

Comment. All subjects learned flap control usage in the test ground trainer and demonstrated excellent airspeed control when the flaps were deployed or retracted. Depressing the flap control of the ground trainer simulated a full-flap deployment. This action resulted in a displayed decrease of airspeed on the airspeed indicator, and a slight pitch-down simulation in terms of the visual horizon display. Control force feel pressure remained unchanged. It is believed that the lack of a definite perceptible pitch-down attitude and changing control force feel or pressure simulation in the ground trainer contributed to an unacceptable performance of six subjects when this maneuver was attempted in the aircraft. There were two other factors which must be considered. The first is that all subjects were not familiar with the initial rising and sinking sensations accompanying deployment or retraction of the aircraft's flaps. Subject action on deployment of the flaps in the aircraft was observed to be one of excessive pushing forward on the control yoke as a response to the momentary lift effect. Retraction of flap and initial loss of lift and resultant sinking sensation triggered subjects to pull back on the yoke control, apparently to offset the sinking sensation. The subjects control response to the unexperienced "rise" and fall" sensation was not unexpected, even though throughout training in the use of flaps the subjects were taught to counteract flap effect with proper elevator control movement to maintain a desired and also safe airspeed. Excessive forward movement of the elevator control at flap deployment does not present a real problem, other than possible increased aitspeed and exaggerated pitch-down attitude. The latter response to flap retraction, that is, back elevator pressure to counteract the sinking sensation, is regarded as an unsafe, if not dangerous, procedure. It is known that an aircraft with full flaps deployed can fly at airspeeds below the no-flap minimum airspeed. Should flaps be suddenly retracted, without regard to airspeed, or worse, should back elevator pressure be used at this time, the likelihood of a stall is great.

The observed results show that learning airspeed control, while manipulating flaps and exercising proper elevator control in the test ground trainer, is negated by subject reaction to flap activation in the aircraft. It is the author's opinion that the four subjects who did meet the performance criteria for this maneuver learned to do so in the aircraft.

The second factor, a minor one, was the difference between the flap control location in the ground trainer and in the aircraft. The ground trainer had an up/down flap lever located on the instrument panel, whereas the aircraft's flap control is a three position stick-type located between the two front seats. Locking the flap control in any one of the desired positions is accomplished with a button press on top of the flap handle. Subjects learned its use in the aircraft. The extensive literature on transfer of training in simulators notes that positive transfer is benefited by duplicating, as closely as possible, the location and operation of simulator controls.

Realistic kinesthetic cues are difficult, if not costly, to simulate. Ground trainers may contribute to positive transfer of training in the flap usage maneuver if the constant control force feel and pressure is replaced with an elevator control which responds in both movement and direction (with corresponding elevator control pressure/force changes) when the flaps are deployed or retracted. A greater perceptible change in pitch with flap activation should enhance the pilot response to the flap usage maneuvers.

MANEUVER NO. 14 - SLIPS/SKIDS (AIRCRAFT).

Synopsis: Slips and skids are not true maneuvers but are flight conditions which result from the uncoordinated use of the aileron and rudder controls. Slipping, as observed in this study, is not to be confused with the intentional slip maneuver used to lose altitude, or as a cross-wind landing technique. The slip is caused by the bank being too steep for the rate of turn. Conversely, the skid condition occurs when the bank angle is too shallow for the established rate of turn.

Visually, there are no cues to indicate the slip or skid condition other than those which are displayed by the slip/skid indicator. A video tape presentation of the outside world through the aircraft's windscreen while in a deliberate slipping or skidding condition is meaningless to the viewer. (See General Comments.)

Visual Aspects and Flight Characteristics.

- Visual cues - none.
- Kinesthetic cues: The skidding force tends to slide the pilot to the outside of the turn and is caused by either excessive rudder application for the angle of bank established or the use of aileron opposite to the turn.
- The slipping conditon is a force that causes the pilot to fall to the inside of the turn and is caused by use of aileron controls only, in the turn or the application of rudder opposite to the direction of the turn.

GROUND TRAINER REQUIREMENTS.

Controls: Elevator, aileron, rudder, elevator trim tab, rudder trim tab, throttle.

Instruments: Altimeter, airspeed indicator, heading indicator, sensitive slip/skid indicator, tachometer.

Visual Aspects and Characteristics.

- Visual - none.
- Slip/skid indicator sensitive to uncoordinated use of the aileron and rudder controls. In the ground trainer the slip/skid indicator is the only source of information the pilot has that shows uncoordinated flight.
- Torque effect.

Desirable Elements.

- Kinesthetic cues.
- Directional gyro, attitude gyro, turn needle.

Comment. The lack of kinesthetic cues in the test ground trainer associated with a slipping,skidding condition precluded an effective transfer of training for teaching procedures to correct uncoordinated flight conditions. The ball of the slip/skid indicator in the test ground trainer did not respond effectively to uncoordinated flight conditions unless the forces applied to the rudder and aileron controls were overemphasized. It was observed that subjects had a tendency to overcontrol with rudder action in the aircraft when uncoordinated flight conditions, as displayed on the slip/skid indicator, were noted.

Perhaps, a more sensitive slip/skid indicator would contribute to effective training transfer. Lacking kinesthetic cues, the use of a more sensitive slip/skid indicator may induce trainees to spend more time in the cockpit monitoring this instrument to correct uncoordinated flight conditions, which in turn, would result in a reduced time for external scan under VFR conditions.

The results of the slip/skid "maneuver" indicate that the effects of uncoordinated flight, with regard to ground trainers which do not simulate kinesthetic cues, or do not have effective slip/skid indicators, can be learned only in the aircraft.

The slip/skid indicator is not required (under minimum instrumentation requirements) in an aircraft for VFR flight.

MANEUVER NOS. 15 and 16 - RECTANGULAR AND AIRPORT TRAFFIC PATTERNS (AIRCRAFT).

Synopsis: These pattern maneuvers are practiced so subjects may learn to fly the aircraft in a controlled manner relative to its path over the ground. The patterns are of prime importance for preparing the subject for maneuvers that are required immediately after departure and preparatory to landing an aircraft. The procedure requires flying four straight and level course legs with turns of 90° at the end of each leg. Flight at a relatively low altitude (600 - 1,000 feet) is conducive to detecting drift with regard to the aircraft's flight path and the roads or boundaries selected for the ground reference rectangular pattern.

Visually, the aspects are identical to those associated with straight level flight and the turn maneuvers. The flight path is maintained with reference to roads, buildings or boundaries that are viewed through the windshield, or more commonly, through the side windows.

Visual Aspects and Flight Characteristics.

- Identical to straight level flight and turn maneuvers.
- Ground reference points to define the pattern.
- Flight path over the ground is affected by wind direction and force unless appropriate drift corrections are made.
- Perceptible change in ground speed, dependent upon the direction and force of the wind.

GROUND TRAINER REQUIREMENTS.

Controls: Elevator, aileron, rudder, elevator trim tab, throttle.

Instruments: Altimeter, airspeed indicator, heading indicator, slip/skid indicator, tachometer.

Visual Aspects and Characteristics.

- Identical to the ground trainer requirements for straight, level flight and turns. Observable flight path or track through 360° of rectangular pattern flight. This includes visible closure or closure rate information with respect to the rectangular ground reference pattern.
- Aircraft position information with regard to the ground reference pattern.
- Wind input having variable force and direction.
- Perceptible drift under an uncorrected heading situation in relation to wind direction and force.
- Perceptible difference between heading and flight path as affected by wind conditions.

Desirable Elements.

- Expanded forward view of ground plane.
- Perceptible ground speed differences dependent upon wind conditions.
- Course legs visible from side windows.
- Directional gyro, attitude gyro.
- Rudder trim tab.

Comment. Subjects demonstrated positive transfer of training for performing rectangular and airport traffic patterns requiring respectively an average of 1.8 and 1.7 trials. This acceptable performance is attributed to the test ground trainer's ground reference display screen with an aircraft position light. As with the crosswind tracking maneuver, the fact that ground reference cues are displayed to the pilot on a vertical plane as opposed to the real-world horizontal reference plane had no adverse effect on pilot performance. One general, but unobjectionable, comment made by four subjects was that, in a short time span, drift is observed sooner in the aircraft than in the test ground trainer.

MANEUVER NO. 17 - S TURNS (AIRCRAFT).

Synopsis: The S turn is a ground reference maneuver and like other ground reference maneuvers is practiced so subjects may learn to fly the aircraft in a controlled manner relative to its path over the ground. Subjects learn to counteract the effects of wind (drift) by varying bank angle throughout the turn in order to fly a pattern of two half circles of equal dimension across a road. Further, a crab angle must be established to offset drift when the aircraft is flown through the crosswind segments of each turn. Flight at relatively low altitudes (600 - 1,000 feet) enhances drift detection. The visual aspects of the maneuver are similar to those encountered in the turn maneuvers, and the correct flight path over the ground is maintained with reference to ground landmarks.

Visual Aspects and Flight Characteristics.

- Similar to those of the turn maneuvers.
- Ground reference landmarks.
- Flight path over the ground effected by wind velocity and direction.
- Angle of bank and heading are varied to counteract wind effects to make the desired flight path over the ground.

GROUND TRAINER REQUIREMENTS.

Controls: Elevator, aileron, rudder, throttle.

Instruments: Altimeter, airspeed indicator, heading indicator, slip/skid indicator, tachometer.

Visual Aspects and Characteristics.

- All visual cues and flight characteristics associated with ground trainer requirements for the turn maneuvers.

- Observable flight path or track through the two 180° turns of S turn. This includes visible closure or closure rate information with respect to the ground referenced flight path (see Comment). Observable aircraft position with regard to the ground reference pattern.

- Observable relationship between bank angle and ground path track.

- Variable wind velocity and direction input.

- Perceptible drift in relation to wind velocity and direction with respect to the ground reference pattern.

Desirable Elements .

- Side view and downward view of ground reference pattern or landmarks.

- Directional gyro, attitude gyro.

Comment. This was not only a difficult maneuver to perform but difficult to assess in terms of what visual display capability is required of ground trainers to provide for positive transfer of training. The three subjects who managed to perform this maneuver did so on an extremely calm day with winds of less than 5 miles per hour (mi/h). There are three probable causes or problem areas which contributed to the subjects low performance.

First, the subjects inability (through lack of experience) to associate the bank angle variations necessary throughout the turns to counteract wind effect on the ground track. In the crosswind tracking or rectangular pattern maneuver, subjects recognized drift, and their chief concern was to establish a drift correction (crab angle) sufficient to maintain a straight track. Other than unusual wind conditions, once this correction was established, the crab angle was not expected to change unless a deliberate change in heading was made. Thus, the subject learned to cope with wind effect on a one axis (longitudinal) basis, derived from their experience of viewing heading, track and ground reference information from the simulated aircraft movement on the ground trainer's two-dimensional vertical screen. Their aircraft performance confirms this transfer.

Subjects performed S turns in the ground trainer, using the appropriate controls so that the track of the aircraft position light was congruous with the S-turn pattern inscribed on the ground reference chart. It is the observers' opinion that subjects did not realize they were altering bank to make good the S-turn track since bank angle information is not displayed on the screen of the ground reference chart. As a result, subjects performance in the aircraft indicated that learning S turns on a two-dimensional vertical screen does not carry over to the horizontal plane of the real-world, where to offset wind effect, bank angle is varied by looking down at ground reference points to ensure a proper S-turn track over the ground. If subjects are not exposed to moderate wind conditions, which require bank angle variations, the maneuver can be accomplished as confirmed by the performance of three subjects.

Secondly, when subjects were flying straight course legs in the ground trainer, with a wind velocity and direction input, drift was not as readily detectable as it was when flying the aircraft. This minor problem was compounded when the subjects tended to establish a turn coincident with the displayed S-turn pattern, and observed the track of the aircraft position light on the screen. If the track of the aircraft position light appeared to be inside of the inscribed pattern, subjects would shallow out the bank or even stop the turn to get back on track. There appeared to be an interval before the subjects were able to identify drift before appropriate corrective action was taken. When attempting the S-turn maneuver in the aircraft, subjects were presented with readily detectable drift which was not commensurate with what they had learned from the ground trainer experience.

In the third circumstance, the subjects had to cope with the aircraft's response to aileron control movement which produced a roll rate sooner than that which the subjects learned in the ground trainer. The subsequent result was a tendency to overcontrol in the roll axis when performing in the aircraft. Further, subjects were faced with the slip/skid problems encountered in the three earlier turn maneuvers. The ground reference display of the test trainer is considered to be effective for teaching the procedural aspects of the S-turn pattern. It is the observer's opinion that a display which can depict bank angle directly in relation to a ground reference pattern under simulated wind conditions would contribute to a more effective training transfer of required flight control movement to fly the S-turn pattern.

GENERAL COMMENTS

The video taping of flight maneuvers, in most cases, proved to be beneficial for analyzing the external visual aspects associated with each maneuver. However, there were shortcomings using the video recording system. One major limitation was the restricted angular field of view capability of the camera lens. This limitation precluded a recorded visual presentation of the normal expanse of horizon or peripheral cues as seen by the human eye.

Forward view video recordings of the normal climb, climbing turn, slow flight and the approach to the power-off and power-on stall maneuvers did not provide the horizontal reference the pilot needs, because the nose-high attitude of the aircraft obscured the horizon as a visual cue. External video recordings of slipping and skidding as products of uncoordinated flight, and of crosswind tracking were meaningless to the viewer because the visual aspects of these maneuvers could not be distinguished from the visual aspects of other maneuvers such as the shallow turn or straight and level flight.

The integrated method of flight instruction was used throughout ground training instruction with emphasis on the external visual presentation. Thus when subjects were instructed to perform a medium 30° bank turn, the approximate bank angle was established with respect to the ground trainer's visual horizon and substantiated by the degree of bank displayed on the attitude gyro.

Project results confirmed that subjects can learn the basics of VFR flight using the minimum of flight instrumentation defined in FAR-91.33b. This regulation specifies that for VFR flight an aircraft must have flight instruments consisting of an airspeed indicator, altimeter, magnetic direction indicator and a tachometer. Using integrated ground training instruction techniques, subjects first were taught all maneuvers with the aid of the visual presentation complemented by a full instrument panel, which consisted of the required minimum flight instruments plus a turn/slip indicator, a directional gyro and an attitude gyro. In later stages of instruction, when subjects had achieved an acceptable level of flight proficiency, these last mentioned gyroscopic instruments were masked. Subjects learned to perform all maneuvers using only the visual presentation and minimum flight instruments.

Subjects learned to perform standard rate turns although this maneuver and the instrument used, the turn/slip indicator, are not required for VFR flight. The standard rate turn maneuver is excellent for teaching the relationship that exists between angle and airspeed, where to maintain the standard rate of turn, bank angle is increased or decreased as airspeed is increased or decreased. The intent of emphasis is that for VFR flight a corresponding and exact relationship between bank angle and airspeed is not required as a capability of ground trainers for instruction in the turn maneuver. This capability, like engine sound, vibration, buffet, and other like factors is considered as a desirable element, one which would enhance the simulation, and one which could be used effectively in later stages of training proficiency instruction.

A visual acceleration/deceleration characteristic is not considered to be a pilot ground trainer requirement for instruction in air-to-air maneuvers as examined in this project. From an instrument viewpoint it is desirable to have some lag in the instrument indications of airspeed, heading, altitude, and vertical rate changes to acquaint subjects with displayed effects of acceleration/deceleration. It is most likely that a visual acceleration/deceleration capability would be not only desirable but would be a necessity for the air-to-ground reference maneuvers of taxi, takeoff, approach, landing, and roll-out phases of flight. On the subject of these maneuvers, while they were dropped from the original maneuver syllabus primarily because of a lack of a visual cue or visual cues, this does not imply that the test ground trainer did not contribute to learning the <u>procedural</u> aspects and <u>instrument</u> indications linked to these maneuvers, since all ground trainer flight sessions began with a takeoff and ended with a landing. Subjects learned to control heading during the takeoff and landing by observing the ground trainer's aircraft position light on the ground reference chart of an airport runway. The lack of visual longitudinal or vertical closure rate information of necessity forced subjects to obtain this information from the airspeed indicator, altimeter, and vertical speed indicator. Thus, the approach and landing were accomplished more by instrument indications than by visual cues.

Because of the small sample of 10 subjects, the data were not subjected to any statistical treatment other than the documented averages for ground training time and aircraft performance trials. The three trial system was selected with the opinion that a greater number of trials would constitute a learning of the maneuver in the aircraft and detract from an understanding of the utility of pilot ground trainers as effective training devices.

Two factors which contributed significantly to the project results were the availability of highly motivated subjects on a daily basis throughout the experiment and a lack of "down time" for maintenance or repair of the test ground trainer. These two items provided for an exceptional continuity of ground training sessions which is not always attainable in the real world training situation.

SUMMARY OF RESULTS

Subjects having no previous flight experience were instructed to perform 17 presolo VFR type maneuvers using a commercially available pilot ground trainer. The objective of the project was to establish guidelines for the development of standards prescribing the acceptability of pilot ground trainers used as primary pilot training devices in lieu of flight instruction in an aircraft.

The flight simulation test environment consisted of a fixed-base pilot ground trainer representative of a single-engine general aviation aircraft with conventional flight controls and instruments. A visual display interconnected to the pilot ground trainer responded to trainer flight control and power inputs and simulated aircraft motion in the pitch, roll, and yaw axes.

All subjects successfully completed the 17 presolo VFR maneuvers in the pilot ground trainer. The average ground instruction time for all subjects was 8.4 hours. Instruction time ranged from a high of 10.3 hours to a low of 6.1 hours.

Subjects demonstrated an acceptable level of proficiency and positive transfer of training by performing, within an allotted three trials during their performance validation check flight in the aircraft the following maneuvers:

- Straight and level flight.
- Shallow bank turn.
- Medium bank turn.
- Climb.
- Descent.
- Climbing turn.
- Descending turn.
- Power-off stall.
- Power-on stall.
- Crosswind tracking.
- Rectangular pattern.
- Airport traffic pattern.

An acceptable level of pilot performance within three trials in the aircraft was not achieved on the following maneuvers:

- Flap usage.
- S turns.
- Slow flight.
- Steep bank turns.
- Slip/skid.

The zero transfer of training encountered in the performance of the above maneuvers is suggestive of a deficiency in the test ground trainer in terms of capability, characteristic, or equipment.

Subjects trained in a ground trainer lacking the kinesthetic cues of true motion use movement of the flight instrument indicators as cues for forward and vertical motion while performing VFR maneuvers in the ground trainer.

CONCLUSIONS

1. A positive and effective transfer of training for performing a majority of VFR presolo flight maneuvers can be achieved in a ground trainer with a visual presentation which provides the pilot pitch, roll, and yaw information with respect to external horizontal and directional referents.

2. To achieve positive transfer of training in performing the VFR presolo maneuvers listed, a ground trainer requires: functional rudder, aileron, elevator, and elevator trim controls, throttle, and the minimum instrumentation of airspeed, altimeter, heading information, and a tachometer.

3. The flight controls must change the attitude of the visual presentation in the correct direction. There must be minimum lag between control or power input and response of the ground trainer or visual presentation. A characteristic lag or decreased response of flight control input is acceptable for the slow flight and stall maneuvers. Response rates of the ground trainer or visual presentation which are not within the boundaries of those normally encountered in primary training aircraft result in overcontrolling of the aircraft by the subjects.

4. Coordination of aileron and rudder controls while performing maneuvers is important, but exact amounts of control pressure are not required in most cases. A constant pressure control system is acceptable provided it affects attitude correctly. Most critical is elevator control with a good system interconnect of elevator trim control, preferably a system movement which is detectable by changing pressures in the elevator control, the movement of which is portrayed in the visual presentation.

5. Pilot ground trainers require a functional and sensitive slip/skid indicator to display the effects of uncoordinated use of aileron and rudder controls. There are no visual or kinesthetic cues in ground trainers, especially of the fixed-base type, which can alert a subject to this flight condition.

6. Torque effect with power or attitude changes is a necessary ground trainer characteristic for training subjects to maintain an accurate heading when performing slow flight, climbs, descents, stalls, and also with power changes while maintaining straight and level flight.

7. A positive transfer of training was not achieved in the performance of the steep turn and slow flight maneuvers.

8. A vertical visual display system is equally as effective as the real world horizontal ground plane for training subjects in ground reference maneuvers such as crosswind tracking, rectangular and airport traffic patterns. The vertical visual display system, while not effective for performing the S-turn maneuver, does contribute to learning the procedural aspects of that maneuver.

9. A successful and positive training transfer for accomplishing the VFR taxi, takeoff, approach, landing, and rollout phases of flight requires a complex visual system (i.e., one with a capability of at least two axes of variable closure rate, changing perspective of ground plane geometry, crosswind effect, etc.) which was not a capability of the ground trainer employed for experimentation. At the present time such a visual system does not appear to be economically feasible in a general aviation pilot ground trainer.

APPENDIX

AIRCRAFT FLIGHT CHARACTERISTIC CHECKOUT

The project pilot will perform all the required maneuvers. The observer in the rear seat will use the video camera and recorder to record all maneuvers. Because of the limited field of view of the video camera each maneuver will be recorded twice. The first video recording will focus on the external world (horizon, ground plane, etc.) while the pilot performs the maneuver, and the second video recording will focus on the primary flight instruments while the maneuver is repeated. When recording external views the camera must be positioned so that the recorded scene will approximate the view as seen by the pilot looking directly forward through the aircraft's windshield.

The project pilot will perform the following maneuvers and flight procedures:

1. Trim the aircraft for normal cruise (75 percent power) straight and level flight ___mi/h at ___ altitude. Observer record external view and instrument panel. Have pilot leave controls free and record external view and instrument panel.

2. Ease the elevator control forward to lower the nose of the aircraft 10°, hold for 5 seconds, then release. (If the globe of the attitude gyro does not have reference marks in degrees, use the attitude gyro horizon bar width as a reference). Observer record the external view and instrument panel.

3. Ease the elevator control backward to raise the nose of the aircraft 10° as in Maneuver 2, hold for 5 seconds, then release. Observer record the external view and instrument panel.

4. With the aircraft trimmed for a hands-off normal cruise straight and level flight attitude, decrease aircraft power by 200 r/min. Observer record the external view and instrument panel.

5. After procedure number 4 add or return power 200 r/min or to original power setting. Observer record the external view and instrument panel.

6. With the aircraft trimmed as in number 4, increase aircraft power by 200 r/min. Observer record the external view and instrument panel.

7. After number 6, reduce or return power 200 r/min or to original power setting. Observer record the external view and instrument panel.

8. Establish a trimmed approach speed of 85 mi/h. Lower flaps 10°. Observer record the external view and instrument panel. Retract flaps. Record the external view and instrument panel. Repeat number 8 using (a) 25° flap setting and (b) 40° flap setting. Observer record the external views and instrument panel.

9. The pilot will maintain altitude and vary power from a slow flight speed condition to fast cruise then return to a slow flight airspeed. Observer record airspeed indicator acceleration/deceleration with cockpit clock in view.

10. The pilot will trim the aircraft (with power off) for 1.5 VS_1 (VS_0), bleed off 1 knot/sec to stall or maximum elevator deflection, whichever comes first. The power-off stall will be accomplished in both the clean and landing configurations. Observer record the external views and instrument panel.

11. For the power-on stall the pilot will trim for 90 percent cruise power then use procedure as in number 12. Observer record the external view and instrument panel.

12. For stalls in the turn the pilot will establish a 30° maximum bank with the aircraft trimmed for power off/on as indicated in numbers 10 and 11. Observer record the external view and the instrument panel.

13. Observer record bank angle for standard rate turns with airspeed increments of 10 mi/h from minimum control airspeed to maximum cruise airspeed.

14. While maintaining altitude, the pilot will perform coordinated turns using bank angles of 10°, 20°, 30°, 45°, and 60°. The observer will record the external view and the instrument panel.

15. The project pilot will perform shallow, medium, and steep banked turns at 75 percent power. When the appropriate degree of bank is obtained the pilot will release all controls. Observer will record the external view and the instrument panel.

16. Observer record a normal takeoff.

17. Observer record all aspects of the landing approach from base leg to final turn on, through the landing and roll out.

18. Observer take video recordings of the external view and of the instrument panel of all presolo maneuvers listed in Table 1.

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