AN EVALUATION OF AUTOMATIC CONTROL SYSTEM CONCEPTS FOR GENERAL AVIATION AIRPLANES

by

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ABSTRACT

A piloted simulation study of automatic longitudinal control systems for general aviation airplanes has been conducted. These automatic control systems were designed to make the simulated airplane easy to fly for a beginning or infrequent pilot. Different control systems are presented and their characteristics are documented. In a conventional airplane control system each cockpit controller commands combinations of both the airspeed and the vertical speed. The best system in the present study decoupled the airspeed and vertical speed responses to cockpit controller inputs. That is, the cockpit throttle lever commanded only airspeed responses, and the longitudinal wheel position commanded only significantly reduced the pilot workload throughout an entire mission of the airplane from takeoff to landing. An important feature of the automatic system was that neither changing flap position nor maneuvering in steeply banked turns affected either the airspeed or the vertical speed. All the pilots who flew the control system simulation were favorably impressed with the very low workload and the excellent handling qualities of the simulated airplane.

The following pages are reproductions of the slides used in this presentation.
SIMULATION STUDY OF EASY-TO-FLY GENERAL AVIATION AIRPLANES

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OUTLINE

- Background
- Control description
- Display description
- Evaluation procedure
- Results (Video)
- Conclusions
- Follow-on activities
PURPOSE

Increase utility and productivity of general aviation airplanes by

- Making them easier to fly
  - Reduce initial training requirements
  - Reducing proficiency requirements
- Making them safer to fly
  - Reducing pilot blunders
  - Eliminating stalls
RESEARCH OBJECTIVES

- Simplify control--more "car-like"
- Improve display--more intuitive
STUDY METHOD

- Develop control system
- Develop display
- Evaluate combined system
CONVENTIONAL CONTROL
(Coupled)

Long. Wheel \[\rightarrow\] Vertical Speed

Throttle \[\rightarrow\] Airspeed

Lat. Wheel \[\rightarrow\] Heading Rate

(Cross-coupling)
ADVANCED CONTROL
(Decoupled)

- Long. Wheel → Vertical Speed
- Throttle → Airspeed
- Lat. Wheel → Heading Rate
PICTURE FROM A CAR
PICTURE FROM AN AIRPLANE
HIGHWAY IN THE SKY (HITS)
POSITION GUIDANCE

High, Left

High

High, Right

Left

On Path

Right

Low, Left

Low

Low, Right
HIGHWAY IN THE SKY (HITS) FORMAT
SIMULATOR SYSTEM

LANGLEY GENERAL AVIATION SIMULATION SYSTEM

- 3 DOF MotionBase
- Beech Baron fuselage
- Hydraulically-loaded controls
- Engine and airspeed noise
- Standard instruments
- Overall control
- Software options
- 16-channel strip charts
- 48" x 36" view
- 6 miles x 16 miles translation
- 9 feet to 6000 feet altitude

Cyber computer
Data recording
PICTURE OF C-402B
EVALUATION PROCEDURE

• Non-pilots/pilots as test subjects

• 30 minute briefing

• No practice runs

• 1st run: Display & Decoupled Control

• 2nd run: Display & Conventional Control
MANEUVER

Note: Not to Scale

(Cloud ceiling = 200 feet)
VIDEO

• Research recording

• Recorder over the pilot's shoulder
  - Pilot actions
  - Instruments

• Superimposed visual scene in upper right corner
CONTROL ACTIVITY

(With Pictorial HITS Display)

Non-Pilots

Pilots

Cockpit Control

Average RMS value, % full travel

THROTTLE LONG. WHEEL

DECOPLED
BASELINE

DECOPLED
BASELINE

Cockpit Control
IN-FLIGHT PERFORMANCE
(With Pictorial HITS Display)

Non-Pilots

Pilots

Average RMS error

Error type

LATERAL, 100 FT
AIRSPEED, KNOTS

LATERAL, 100 FT
AIRSPEED, KNOTS

DECOPLED
BASELINE

DECOPLED
BASELINE
RESEARCH RESULTS

- One-half of novices completed maneuver on first attempt
- Vertical degree-of-freedom is most troublesome
  - Pictorial visual cues are unfamiliar
    Horizon line
    Telephone poles
  - Longitudinal wheel force trim
  - Landing maneuver
    Narrow field of view on simulator
CONCLUSION

- Decoupled controls and pictorial display necessary for novice
FOLLOW-ON ACTIVITIES

- Command arrows
  - Rotation
  - Tracking
  - Flare
- Automatic pitch control force trim
- Additional pictorial altitude cues
- Flight Evaluation