A SIMULATOR EVALUATION OF AN AUTOMATIC TERMINAL APPROACH SYSTEM

David A. Hinton
NASA Langley Research Center

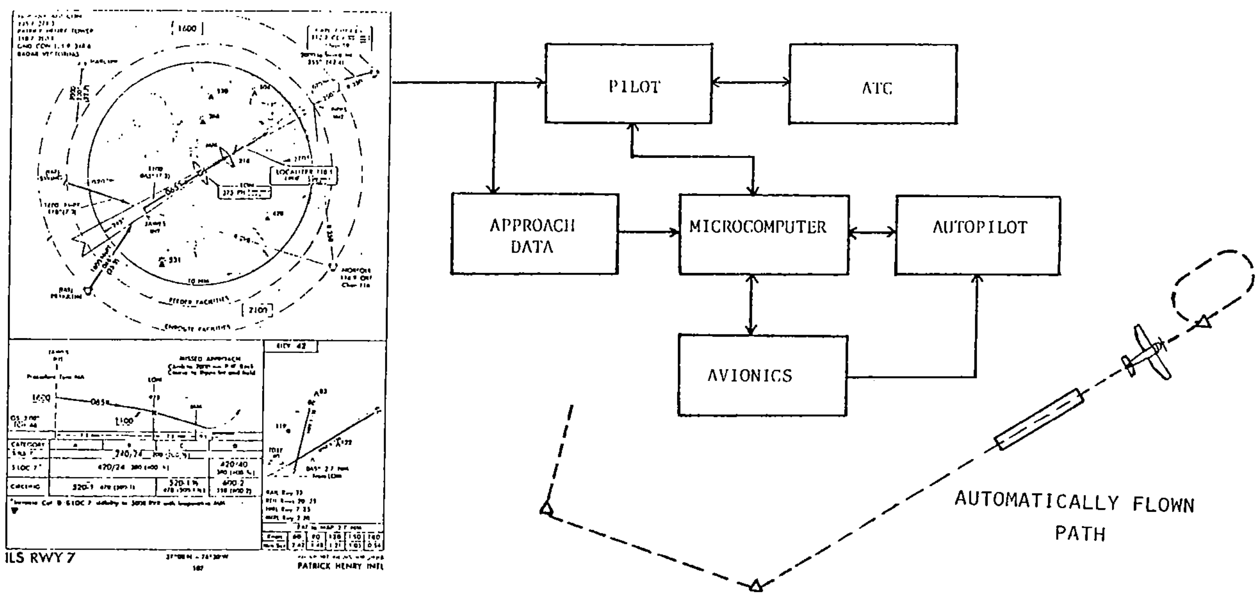
ABSTRACT

The automatic terminal approach system (ATAS) is a concept for improving the pilot/machine interface with cockpit automation. The ATAS can automatically fly a published instrument approach by using stored instrument approach data to automatically tune airplane avionics, control the airplane's autopilot, and display status information to the pilot.

A piloted simulation study was conducted to determine the feasibility of an ATAS, determine pilot acceptance, and examine pilot/ATAS interaction. Seven instrument-rated pilots each flew four instrument approaches with a baseline heading select autopilot mode. The ATAS runs resulted in lower flight technical error, lower pilot workload, and fewer blunders than with the baseline autopilot. The ATAS status display enabled the pilots to maintain situational awareness during the automatic approaches. The system was well accepted by the pilots.

ATAS CONCEPT

This figure depicts the ATAS concept in block diagram form. A flight system would store approach data in memory and use a microcomputer to control aircraft radios and autopilot and to accept inputs from the pilot. The pilot will use an approach chart for backup. Air traffic control (ATC) vectors and altitude assignments could be entered directly on the ATAS control panel. When the aircraft is cleared for the approach by ATC, the pilot would press a button to enable ATAS to automatically complete the approach. At the conclusion of the approach the ATAS would automatically execute the missed approach procedure unless the pilot disengages the system to land.

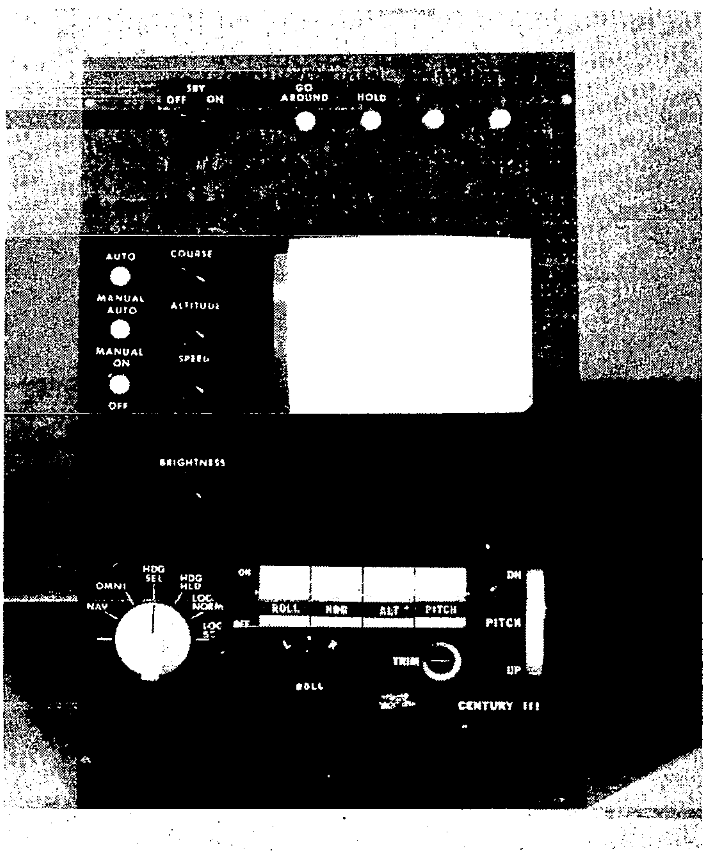


- MICROPROCESSOR-BASED SYSTEM
- STORAGE OF APPROACH DATA
- COMPUTER CONTROL OF AVIONICS AND AUTOPILOT
- AUTOMATIC EXECUTION OF HOLDING PATTERNS, PROCEDURE TURNS, AND MISSED APPROACH
- EASY PILOT OVERRIDE FOR ATC RADAR VECTORS/ ALTERNATE PROCEDURES
- EXPANDABLE TO ENROUTE AND DEPARTURE PHASES OF FLIGHT
- FREES PILOT FROM FLYING AND NAVIGATION RADIO TUNING TASKS
- WILL EXECUTE ALL TYPES OF APPROACHES

ATAS CONTROL PANEL

The ATAS control panel constructed for a simulation study is shown below. At the bottom of the panel is a conventional autopilot control head. The ATAS controls on the top half of the panel consist of a few rotary knobs and push-buttons around the CRT display. The three knobs to the left of the CRT are used to manually input heading, altitude, and speed to fly. The three push-buttons to the left of the CRT determine whether the course and altitude parameters are automatically or manually controlled and whether the autothrottle is on or off. Switches and buttons along the top turn ATAS on and off and select the go-around and holding pattern functions. The CRT provides a continuous display of approach status including reference course, altitude, and speed; distance and direction to the airport; position in approach (OUTBOUND TO PROCEDURE TURN, FINAL APPROACH, ENTERING HOLDING PATTERN, etc); and the actual autopilot mode.

The ATAS panel was installed in the Langley General Aviation Simulator immediately to the right of the flight instruments.



EXPERIMENT DESIGN

Seven instrument rated pilots were used in the simulation study. Each pilot flew 8 instrument approaches. In one half of each pilot's approaches the ATAS system was used. In the other half a baseline heading select autopilot configuration was used. Each pilot flew four ILS approaches with radar vectoring and four NDB approaches with no radar vectoring. An outside-the-windshield visual scene with variable ceiling and visibility was used for breakout and landing. The ceiling and visibility were set above landing minima for four of each pilot's runs and below minima for the other half of the runs.

Realistic ATC communications with the pilot were provided. The communications included radar vectors, altitude assignments, controlled handoffs, and clearance for the approach and for landing. A self-paced side task was used to estimate pilot workload. The pilot was given a circular slide rule type flight computer. On pilot request, a time-speed-distance problem was given verbally. The pilot solved the problem and announced the answer.

The airplane math model used was of a typical general aviation single engine airplane.

EXPERIMENT DESIGN

- ½ ILS (VECTORING, PRECISION)
- ½ NDB (NO VECTORING, NONPRECISION)
- ½ ATAS ON, ½ ATAS OFF (HEADING SELECT)
- ½ WEATHER ABOVE MINIMA, ½ WEATHER BELOW MINIMA
- 8 APPROACHES, 7 PILOTS (ALL IFR, 300 TO 7000 HRS)
- SELF-PACED SIDE TASK (TIME-SPEED-DIST)
- REALISTIC ATC COMMUNICATIONS
- DATA
  - -PILOT COMMENTS
  - -X,Y,Z PLOTS WITH PRINTS
  - -RESEARCHER OBSERVATIONS
  - -SIDETASK RESULTS

RESULTS

Fewer pilot blunders were made with the ATAS than with the baseline autopilot. A blunder is defined as any pilot error that results in a flight path deviation. Eleven blunders were made with the ATAS. Three factors were predominant in these errors. Problems with ATAS mode interaction were involved in 9 of the 11 blunders, a lack of situational awareness in 4 of the 11 blunders, and a data entry error in one of the occurrences. An example of a mode error would be trying to select automatic ATAS modes when the autopilot is off. An example of a situational awareness blunder is forgetting that a landing flap setting is selected while the ATAS is executing an automatic missed approach. The data entry error occurred when the pilot was assigned a heading of 160 by ATC and dialed in 060 instead.

Nineteen blunders were made with the baseline autopilot. Situational awareness was involved 11 times, instrument interpretation 7 times, input errors 3 times, and chart interpretation and basic airplane familiarization once each. Examples of situational awareness errors include descending below decision height in clouds, flying through the localizer instead of intercepting it, and not having the navigation radios tuned properly prior to reaching the localizer. Instrument interpretation errors were made on the NDB approaches and with the HSI on the localizer back course during ILS missed approaches.

BLUNDERS 11 ATAS ON

TYPES (ATAS)

- MODE ERRORS (9)
  - SETTING AUTO ALT IN DESCENT
  - TRYING TO SELECT AUTO WITH A.P. OFF
  - FORGETTING TO SELECT AUTO ALT OR CRS
- SITUATION AWARENESS (4)
  - CLIMBOUT WITH FLAPS
  - DIALED 060 FOR 160 VECTOR AND DID NOT REALIZE ERROR
- DATA ENTRY (1)
  - VECTOR INPUT ERROR

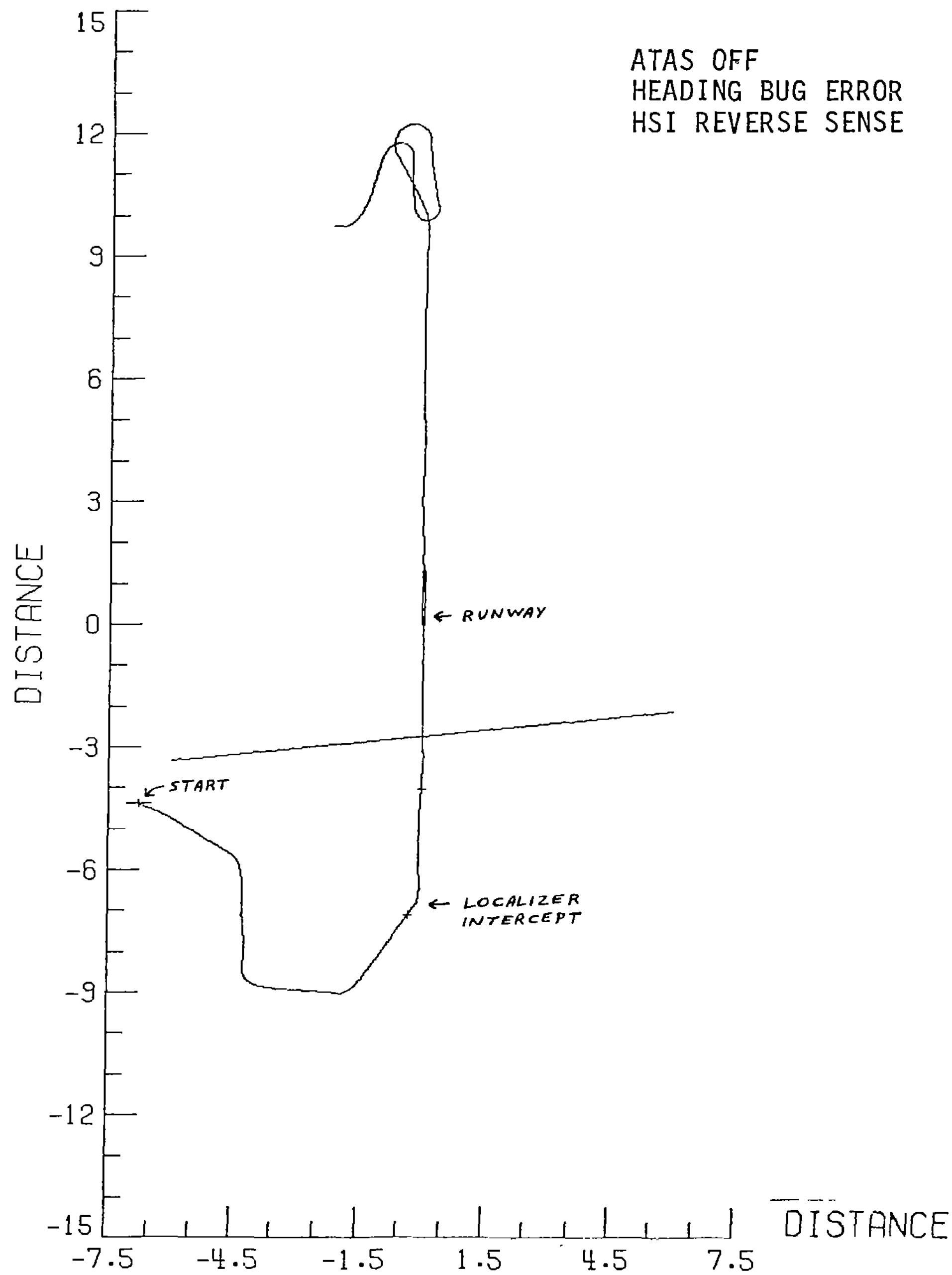
19 ATAS OFF

TYPES (NON-ATAS)

- SITUATION AWARENESS (11)
  - NOT REALIZING A WRONG DIRECTION TURN WAS COMMANDED
  - MADE MISSED APPROACH WITH RUNWAY IN SIGHT
  - LOCALIZER OVERSHOOTS
  - DESCENT BELOW DH/LANDED BELOW MINIMA
  - RADIOS NOT TUNED AT LOCALIZER
  - 2 MILE DEVIATION ON MISSED APPROACH
  - AT 1700 FEET (MDA+860) AT M.A.P.
- INSTRUMENT INTERPRETATION (7)
  - HSI REVERSE SENSING
  - NDB TRACKING
- INPUT ERROR (3)
  - COMMAND WRONG DIRECTION TURN
  - RADIOS NOT TUNED
- CHART INTERPRETATION (1)
- AIRPLANE FAMILIARIZATION (1)

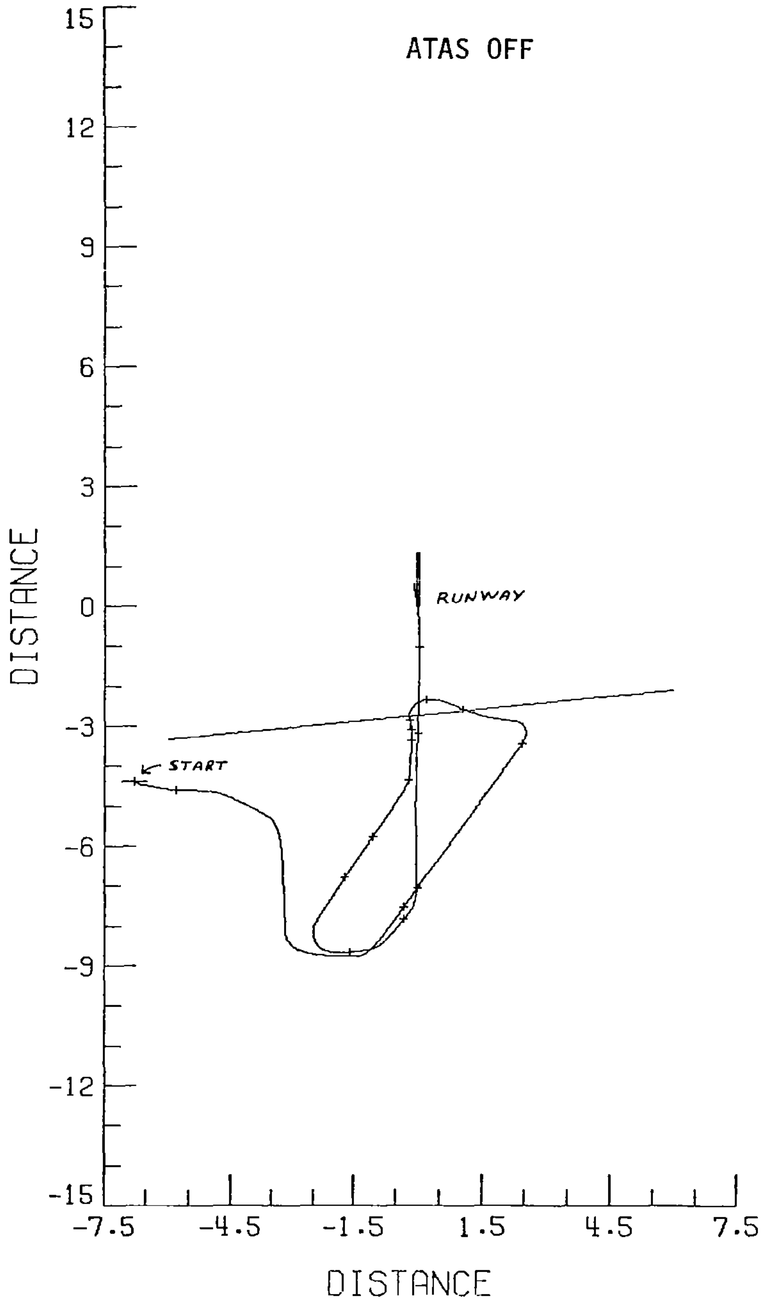
EXAMPLE OF BLUNDER WITH AUTOPILOT

A plan view pilot of an ILS approach, including a missed approach, is shown below. The ordinate and abscissa indicate distance in nautical miles along the runway axis and perpendicular to the runway axis, respectively. The run begins near the left edge of the plot. The airplane is vectored to the ILS and the approach and missed approach are flown normally. After making a normal holding pattern entry, however, the pilot rotated the HSI heading bug more than 180 degrees to the right. This caused an inadvertent left turn out of the holding pattern. The pilot then misinterpreted the HSI course error indicator and turned away from the localizer in an effort to intercept it.



ANOTHER EXAMPLE OF BLUNDER WITH AUTOPILOT

The plot below has the same format as the previous example plot. The run starts at the left edge and the airplane is vectored to the ILS localizer. The pilot was distracted by tuning to the tower frequency and communicating with ATC and did not intercept the localizer. The ATC controller had to call this to the attention of the pilot and radar vectored the airplane out for another try.

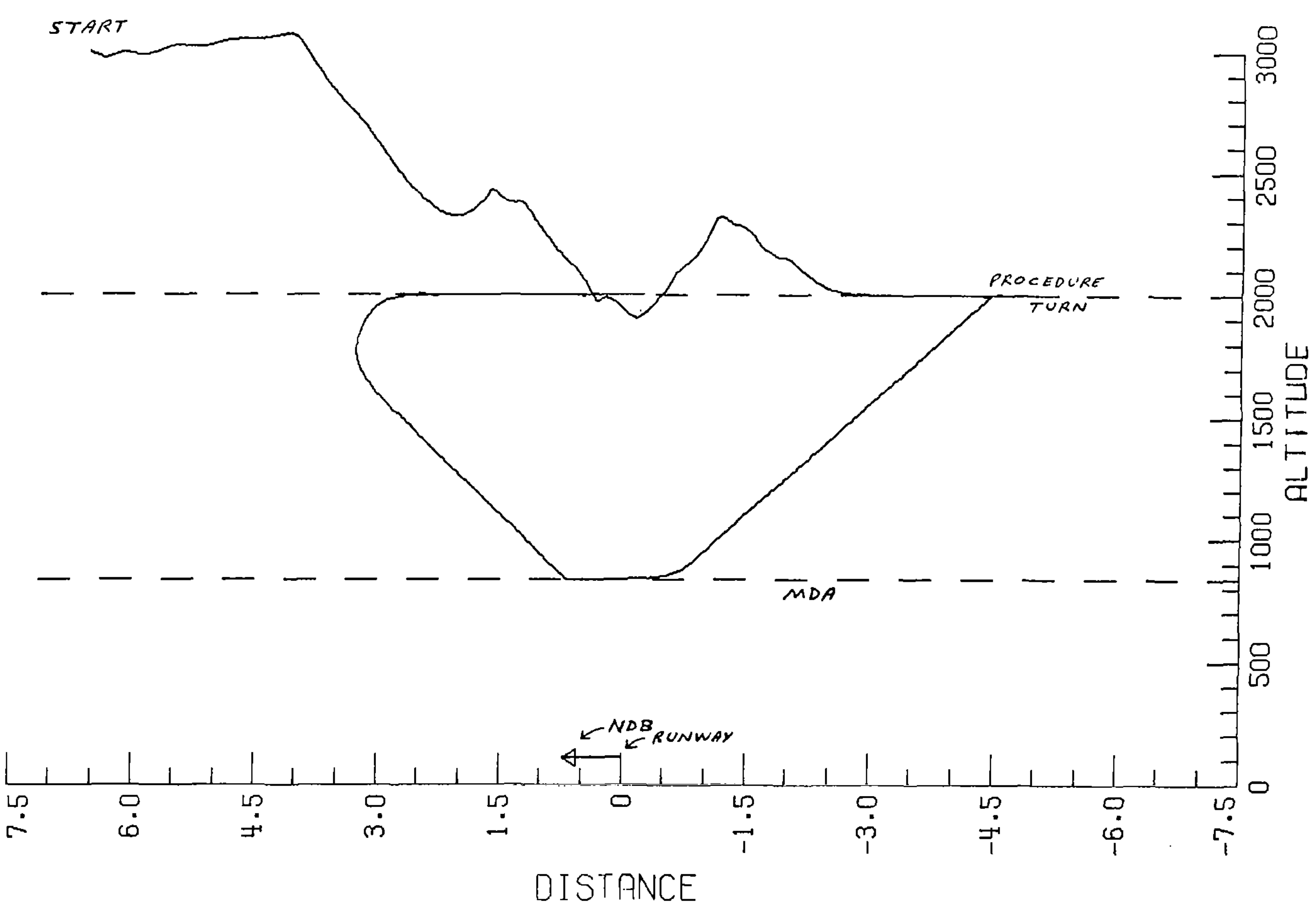


EXAMPLE OF BLUNDERS WITH ATAS

The plot below is a side view of an NDB approach. The ordinate depicts airplane altitude in feet and the abscissa shows distance along the runway axis in nautical miles. The NDB used in this approach is located on the airport.

The run began at the left of the plot. The pilot turned the autopilot on but did not turn the pitch channel on to engage the pitch "servo". This made it impossible to switch the ATAS altitude mode to automatic. The pilot tried to put the altitude mode into automatic, however, and allowed large altitude excursions while trying. The pilot finally turned the autopilot pitch channel on and had no further difficulty during the approach or missed approach.

ATTEMPT TO ENGAGE AUTO ALTITUDE WITH AUTOPILOT OFF



PILOT COMMENTS

Pilot comments were grouped into control, display, and mode interaction comments. Control comments tend to indicate that the autopilot and ATAS controls should be consolidated to reduce confusion. As the system was implemented, the pilot did not always use the same control for control of the same parameter. For example, the HSI heading bug was used to select heading when the ATAS was off and the heading knob on the ATAS panel selected heading when ATAS was on. The display comments indicate that situational awareness could be maintained with the information shown. The pilots desired additional data, however, such as time-to-airport and a positive indication that valid navigational signals are being received. The mode interaction comments indicate that much improvement is needed in this area. The system should provide for more prompting and should generate an appropriate advisory if the pilot attempts to select a mode when conditions required for that mode are not met. The AUTO and MANUAL labeling was confusing. Does MANUAL mean that they should hand-fly, manually make entries to the basic autopilot, or manually set parameters onto the ATAS display? Some pilots consistently made the error of dialing in a new ATC vector then selecting AUTO to "automatically" fly the heading. The pilots had confidence in ATAS once everything was running automatically but sometimes had difficulty reaching that mode.

PILOT COMMENTS

CONTROLS

- KNOB SCALINGS NEED IMPROVEMENT
- PUT ATAS POSITION ON AUTOPILOT MODE CONTROL
- SERVO DRIVE THE HSI HEADING BUG
- CONSOLIDATE ATAS AND AUTOPILOT CONTROLS

DISPLAY

- DISTANCE AND DIRECTION TO AIRPORT IS USEFUL
- WOULD LIKE TIME-TO-AIRPORT
- WOULD LIKE INTERSECTION PASSAGE ANNUNCIATION
- ALL NEEDED INFORMATION IS THERE, WELL THOUGHT OUT
- WOULD LIKE A SIMPLE MAP
- WOULD LIKE POSITIVE INDICATION OF RECEIVING VALID NAV SIGNALS
- WOULD LIKE INDICATION THAT FINAL VECTOR WILL INTERCEPT THE ILS

MODE/INTERACTION

- AUTO/MANUAL LABELING CONFUSING
- TRANSITION TO AUTO SHOULD BE SAME FOR COURSE AND ALTITUDE
- NEEDS PROMPTING
- WANT ABILITY TO CYCLE BETWEEN AUTO AND MANUAL WITHOUT RESTARTING APPROACH
- AUTOTHROTTLE SHOULD DISENGAGE WITH AUTOPILOT

SUMMARY

A piloted simulation study was performed to evaluate the concept of using stored instrument approach data to automatically fly an instrument approach through automatic control of airplane radios and autopilot. The pilots were able to maintain situational awareness with this high level of automation by using the ATAS alphanumeric display of flight status. Fewer blunders were made with the ATAS than with a baseline heading select autopilot mode. Many of the blunders committed with ATAS involved pilot confusion over the various ATAS modes. Pilot comments and blunders indicate that it will be necessary to consolidate the ATAS and autopilot into one device instead of using ATAS as an add-on to existing autopilots.

SUMMARY

- PILOTS HAD CONFIDENCE IN ATAS ONCE IT WAS ENGAGED BUT HAD SOME DIFFICULTY WITH MODE SELECTION
- PILOTS MAINTAINED BETTER SITUATIONAL AWARENESS WITH SIMPLE ALPHANUMERIC DISPLAY THAN WITH CONVENTIONAL INSTRUMENTS/AUTOPILOT AND PILOT IN THE LOOP
- FEWER BLUNDERS WERE MADE WITH ATAS THAN WITH BASELINE HEADING SELECT AUTOPILOT
- PILOT HAS FEWER BLUNDER OPPORTUNITIES WITH ATAS
  ATAS CAN MONITOR PILOT INPUTS
- 9 OF 11 ATAS BLUNDERS WERE MODE INTERACTION ERRORS