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MULTIPLE CURVED DESCENDING APPROACHES AND THE AIR TRAFFIC CONTROL PROBLEM

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SUMMARY

Several modifications of the current terminal area traffic control procedures were investigated in the multicockpit facility at Ames Research Center. This simulation was based on the assumption that MLS and data-link would be available. The concepts which were investigated are: (1) multiple, curved, descending final approaches that merge on a common final path within 1 mile of the field; (2) parallel runways certified for simultaneous and independent operation under IFR conditions; (3) 1 min separation at the missed approach point (MAP); and (4) the use of TSD's in the cockpit coupled with a distributed air traffic management system between the air and ground. The objective was to develop solutions which singly, or in combination, would evolve a procedural system that could safely and expeditiously accommodate an increase in air traffic density. Three groups each consisting of three commercial airline pilots and two air traffic controllers flew a combined total of 350 approaches. Piloted simulators were supplied with computer generated traffic situation displays and flight instruments. The controllers were supplied with a terminal area map display and digital status information.

On the average, aircraft arrived at the Missed Approach Point at 64.5 sec intervals, however piloted aircraft tended to stay further behind any other aircraft than did the computer generated aircraft. The traffic management system strongly affected the standard deviation, but not the mean, of intercrossing times. Both pilots and controllers felt that the centralized, ground-based management condition was somewhat less safe and orderly than the distributed, pilot-spaced management condition. Pilots felt that the distributed management condition was more expeditious than the centralized management condition, but the controllers reported the reverse opinion.

Localizer and glide/slope rms deviation increased as the amount of turn required to intersect the outer marker increased. Pilots also rated the approaches as increasingly more difficult, and less safe, as the amount of turning required increased, however their comments were generally favorable about the feasability of multiple, curved, descending approaches. Pilots reported that they would prefer the alternative of multiple curved descending finals, with wider spacing between aircraft, to having closer spacing on single straight-in finals. Controllers, on the other hand, preferred the alternative of closer spacing on single straight-in finals. Both pilots and controllers felt that parallel runways as simulated in the present study, would also be an acceptable solution.

INTRODUCTION

The congestion around major airports may exceed the capacity of terminal area airspace and airport systems in the 1980's. One solution to this problem might be to upgrade smaller existing airports to provide a short-haul feeder system. Such a system might include increased use of vertical and short takeoff and landing (V/STOL) aircraft, upgraded guidance facilities, such as the microwave landing system (MLS), on-board computer-generated traffic situation displays (TSD's) joined by data-link with the ground, and modifications to current terminal area air traffic control (ATC) procedures.

The steep descent and slow speed capabilities of STOL aircraft allow the use of multiple descending approaches that merge on a common final approach path within 1 mile of the field (fig. 1). Multiple approach paths would allow aircraft to pass in time on different approach routes, thereby avoiding the current space- and time-wasting control procedure of generating large gaps behind slow aircraft. Guidance along these paths would be provided by MLS and would be electronically displayed on TSD's. Benner, Sawyer, and McLaughlin (ref. 1) investigated a similar concept at NASA Langley Research Center for single STOLcraft not under control by ATC. They found that descent rates of 368.5 m/min (1200 ft/min) on a 6° glide slope, with turn radii of no less than 914.4 m (3000 ft) and rollout altitude of 192.0 m (630 ft) were acceptable for airspeed of 75 knots and winds of 10 knots or less. Pilots felt that a minimum turn radius of 1828.8 m (6000 ft) was required for faster aircraft and higher winds. In the current study a turn radii ranging from 0 to 463.3 m (0-1520 ft) and a rollout altitude of 190 m (640 ft) were used to provide a range of nominal bank angles from 0° to 15° at 70 knots.

The concept of closely spaced parallel runways that are certified for simultaneous and independent operations under IFR conditions was also included in this study as an additional means of increasing terminal area capacity. Five curved, descending approaches were configured so as to merge into each of two 309.0-m (102-ft) wide runways which were spaced 230.8 m (750 ft) apart, centerline to centerline.

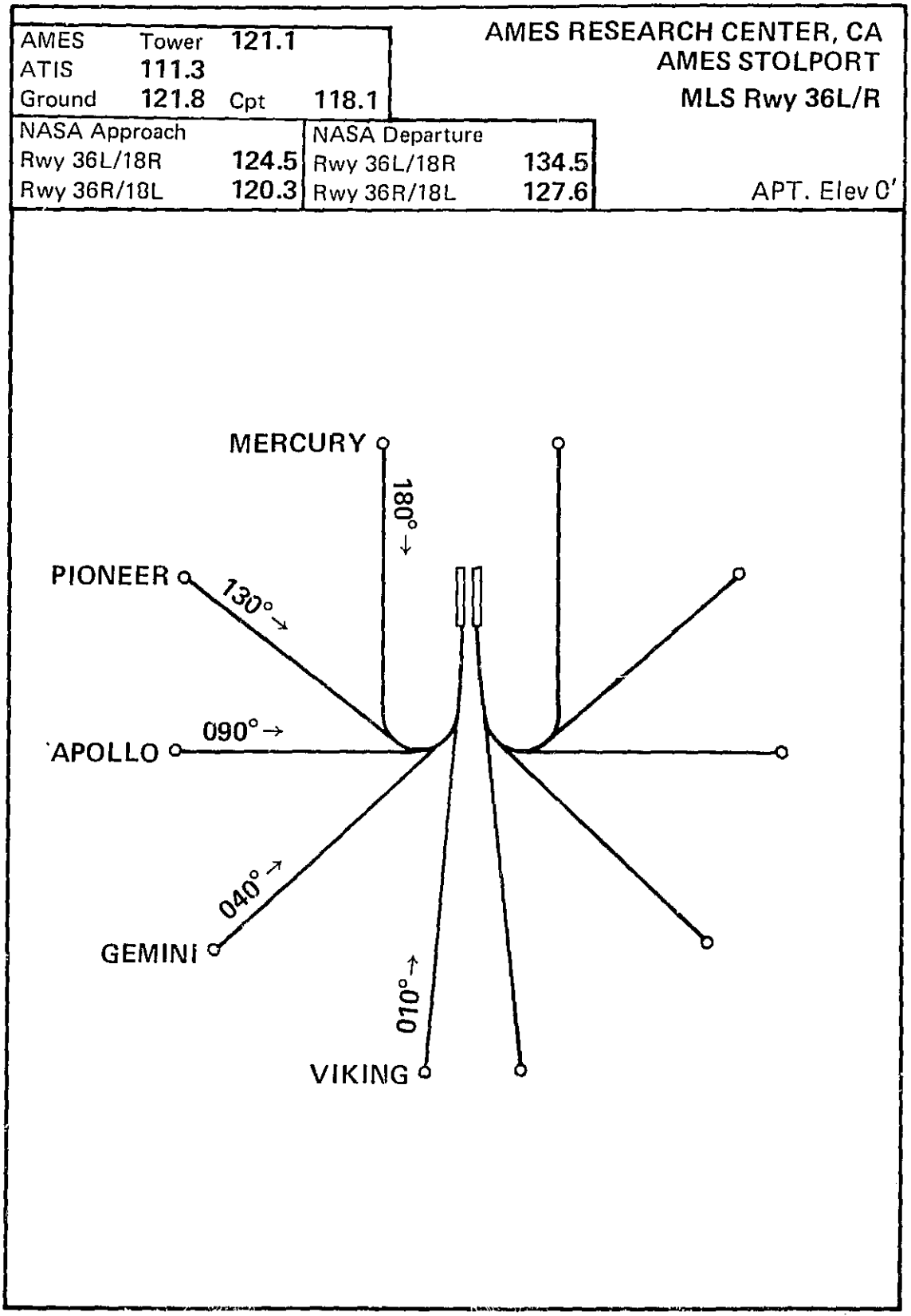

Figure 1.- Multiple approach routes with common final approach paths to two parallel runways.

Closer spacing (1.0 min at the MAP) between successive aircraft having different approach speeds was also included as another means of increasing terminal area density. Kreifeldt and Wempe (ref. 2) found that piloted STOL simulators having the same approach speeds could safely maintain separation as close as 30 sec, if pilots were provided with TSD's, flight path predictors, and were encouraged to manage their own local traffic situation with a moderate division of responsibility between ATC controllers and the airborne units.

Several modifications of the projected ground-based and computer-intensive ATC system (ref. 3) were also investigated. Kreifeldt and Wempe (ref. 2) have shown that the use of TSD, in the cockpit, coupled with a traffic management system in which the airborne units play a significant role in their own local management, provided an acceptable level of safety and expeditiousness for high traffic volume, with reasonable levels of pilot and controller workload. Two divisions of responsibility of control modes were compared in the present study: (1) a ground-centralized system in which controllers were responsible for maintaining separation as well as for issuing sequence commands and (2) a distributed management system in which controllers were only responsible for issuing landing order commands, and individual pilots were responsible for managing their local traffic situation by using their TSD's and by communicating directly with each other.

The primary purpose of this feasibility study was to obtain pilot and controller reactions to, and performance under, each of the different procedures included in the simulation. It was anticipated that the information gained would lead toward future experiments designed to study individual elements of the system.

METHOD

Subjects

Nine commercial airline pilots (first officers) and 6 terminal radar approach control air traffic controllers served as paid participants in the study. Pilots ranged in age from 30 to 45 yr and controllers ranged in age from 25 to 40 yr.

Simulators

Three fixed-base cockpits were used, each of which contained a movable seat, throttle, control stick, and a 25.6- by 25.6-cm (10- by 10-in.) CRT upon which the TSD and flight instruments were displayed. The upper portion of the CRT was used to display airspeed, bank angle, altitude, vertical speed, glide slope deviation, pitch, and roll (fig. 2). All simulators were provided with automatic throttle control and control-wheel steering. During each group's runs, one pilot flew a simplified STOLcraft simulation that represented the approach and landing speeds of a McDonald-Douglas YC-15

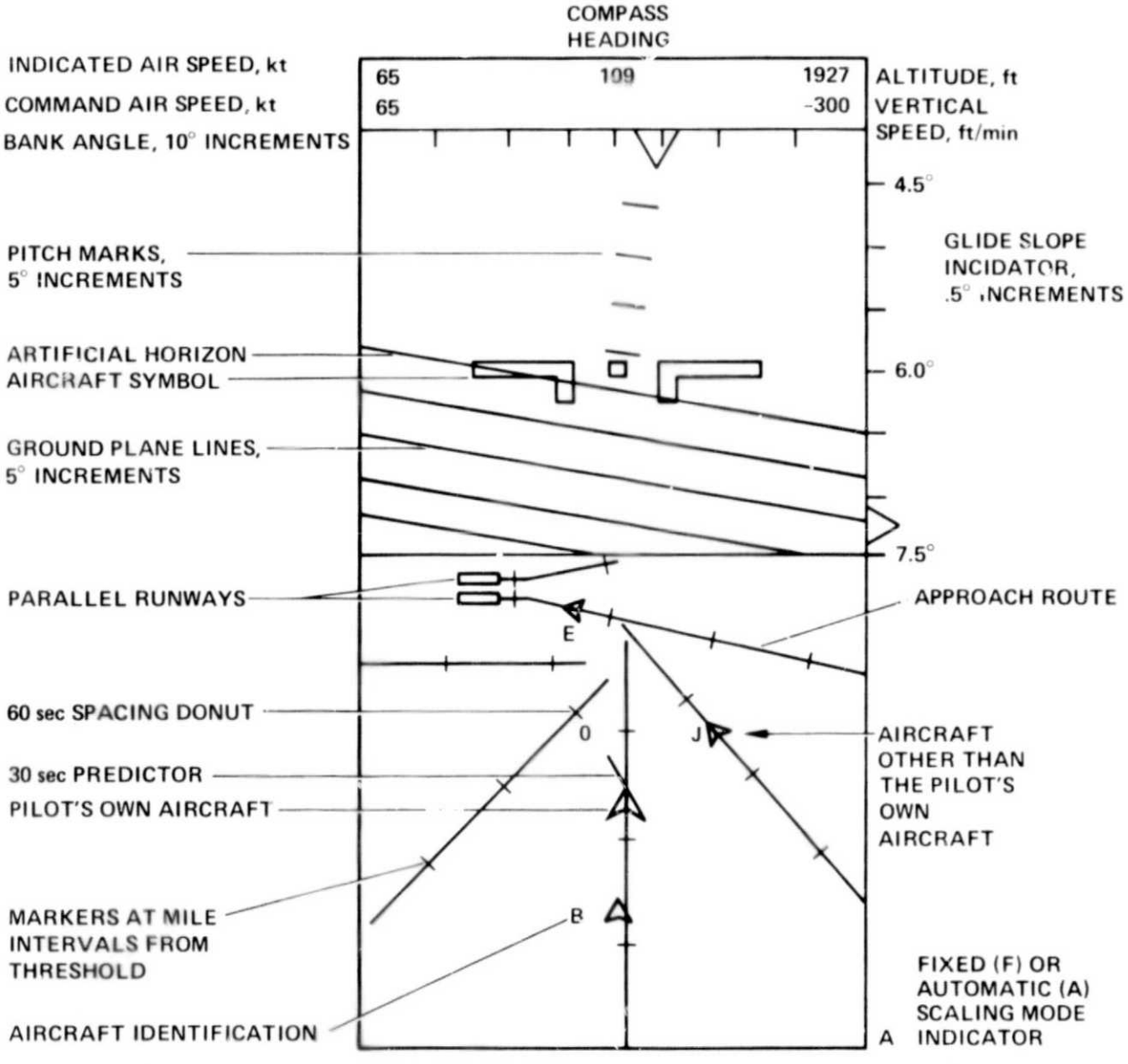

Figure 2.- Vertical situation display (upper) and traffic situation display (lower) serving as the pilots' flight instruments.

(100 and 85 knots, respectively). The other two pilots flew simplified simulations that represented the approach and landing speeds (80 and 65 knots, respectively) of a De Havilland DHC-7 STOLcraft.

The TSD was displayed in the lower portion of the CRT (fig. 2). An automatic scaling mode was available to pilots so that map scale would increase as altitude was decreased. For example, at the initial point, the scale was 1.16 km/cm (2 n. mi./in) and increased to 0.094 km/cm (0.13 n. mi./in) on the runway. A choice of map orientation was also available, allowing the pilots to select either a heading-up or north-up orientation. The pilot's own position was always centered on the display so that the map translated and rotated beneath the aircraft symbol when the aircraft turned. A 30-sec flight path predictor was always displayed projecting from the center of the pilot's own aircraft's symbol (i.e., current position), which graphically displayed a 30-sec projection of the aircraft's course if current ground speed and turn rate remained unchanged. A 60-sec spacing donut, whose position was determined by a 30-sec linear extrapolation from the end of the 30-sec predictor, was also always displayed to assist pilots in maintaining the required 60-sec spacing. All but the curved portion of the five approach routes for runway 36L, with 1-mile graduation marks, as well as the five approach routes for runway 36R, less the curved portion, were also always displayed. The part of the display that the pilot saw at a given moment was determined by his position and altitude, if he had selected the automatic scaling mode.

Under the ground-centralized traffic management conditions, only the pilot's own aircraft symbol was displayed. Under the distributed management conditions, the positions of other aircraft were also displayed as half-size aircraft symbols with alphanumeric call sign abbreviations.

Each pilot was provided with a headset and microphone with which he was able to communicate with the ground as well as with the pilots of other aircraft. All verbal communications were recorded on a four-channel tape recorder for later transcription and analysis. Pilots and controllers were also given a set of approach plates which provided them with all of the information needed to fly each of the approaches. Figure 3 is a representative example of an approach plate used.

Controller's Station

The ATC controllers were provided with a 20.7- by 20.7-cm (12- by 12-in.) CRT upon which all traffic within 5 n. mi. of the field and the five approach routes for each of the two runways was displayed. This display was fixed in a full-scale, north-up mode as shown in figure 1. A keyboard and CRT were also provided for data entry and alphanumeric readout of aircraft status (i.e., landing order, aircraft type and call sign, approach route, speed, heading, and altitude). Controllers were given headsets similar to those used by the pilots and hand-held microphones.

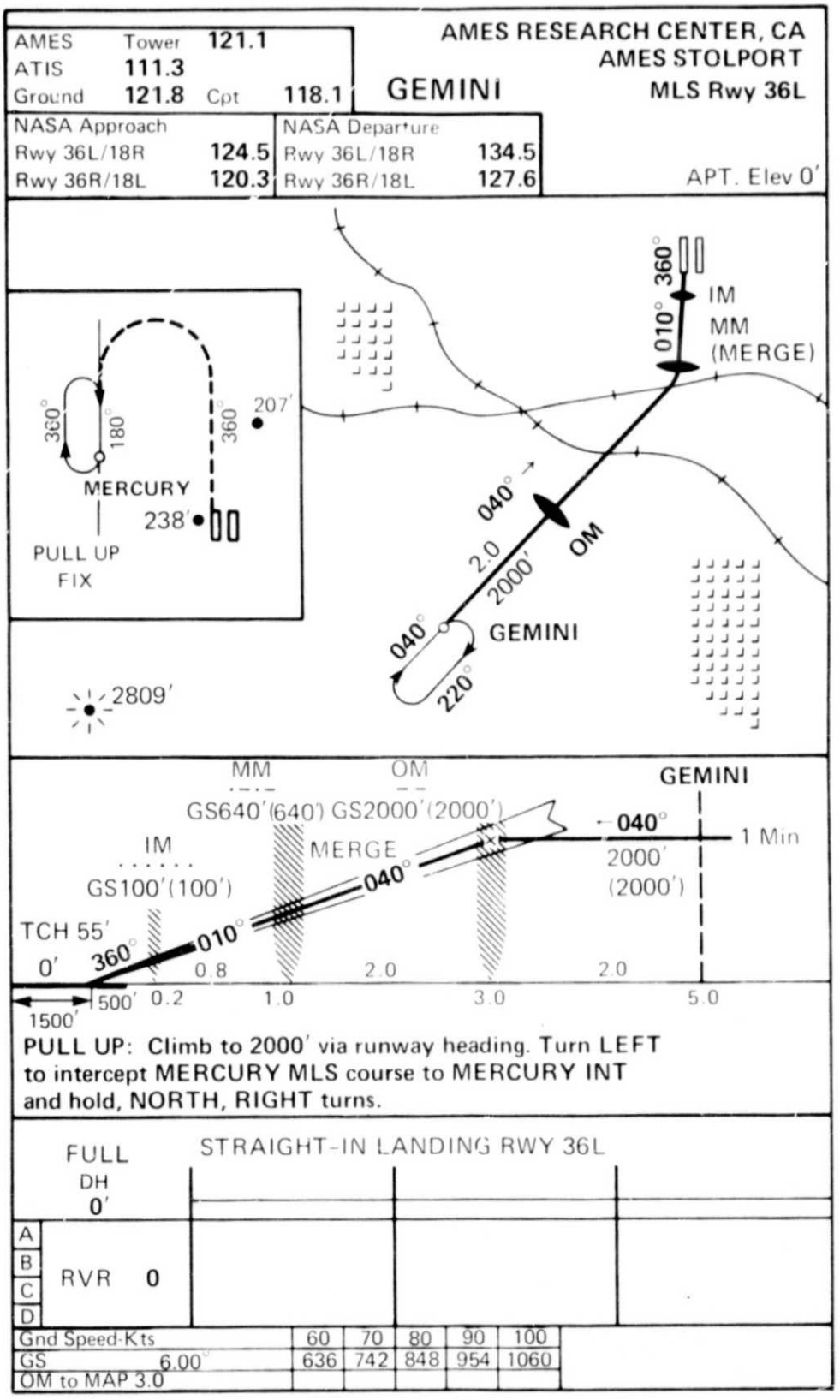

Figure 3.- Sample approach plate (Gemini approach route) from the five used during the simulation.

Computer-Generated Aircraft

The three piloted simulators always flew approaches to the left runway. Traffic density for that runway was increased through the use of as many as five additional computer-generated aircraft. Traffic to the right runway consisted of up to eight computer-generated aircraft at any one time. The right runway traffic situation was presented only to complete the appearance of parallel runway conditions and was not under the management of the air traffic controller participating in the study.

One of the two air traffic controllers in each group, the "Controller," had the task of providing ground-air communications appropriate to the two modes of control. The second controller was mainly responsible for data entry at the keyboard. He had keyboard control of the speed of computer-generated aircraft approaching the left runway and could enter those aircraft into preprogrammed holding patterns. The headings and altitudes of the computer-generated aircraft always conformed to preprogrammed profiles. It was also the duty of the second controller to simulate the verbal communications of the pilots of all computer-generated aircraft approaching the left runway. He accomplished this by initiating requests for approach and landing clearances and by responding to questions from the "Controller" and the simulator pilots regarding the status of the computer-generated aircraft.

Procedure

Three groups, each consisting of three commercial airline pilots and two air traffic controllers, participated in this experiment (fig. 4). Each group received 4 hr of instruction and practice in the simulators. Following a 2-hr break, they flew six experimental runs lasting 3-4 hr. Each run consisted of 3-4 approaches per aircraft, with each approach lasting between 4-6.5 min. Each aircraft was identified by a single letter followed by a number indicating the flight number within a given run (e.g., A2 would identify the simulator designated "A" for the second flight of that run).

At the beginning of each run, aircraft were automatically entered into the terminal area 5.5 n. mi. from the field, positioned just beyond one of the four primary approach route fixes (Viking, Gemini, Apollo, or Pioneer). The fifth approach (Mercury) was used for missed approaches only. Following approach and landing clearance, the pilot's task was to fly his aircraft to the MAP which was located 308.0 m (1000 ft) from threshold at an altitude of 30.8 m (100 ft). Upon reaching the MAP, the aircraft's heading, lateral, and glide slope error were automatically evaluated by the computer. If the aircraft position was within a predetermined "window," it proceeded into an automatic landing and rollout mode. The "window" tolerances were 6° ± 2° in glide slope, 360° ± 20° in heading, and a maximum lateral displacement from extended runway centerline of 110.9 m (364 ft). If the aircraft was off course, or if the controller issued a go-around command, pilots were required to follow the missed approach procedure which was outlined on the approach plates for each route. The missed approach procedure was to maintain runway heading until reaching 616 m (2000 ft), then proceed to the Mercury

		GROUPS:		
		3 COMMERCIAL AIRLINE PILOTS 2 AIR TRAFFIC CONTROLLERS 5 COMPUTER GENERATED AIRCRAFT		
		GROUP 1	GROUP 2	GROUP 3
TRAFFIC MANAGE-MENT SYSTEM	CENTRALIZED AUTHORITY	2 PRACTICE RUNS 3 EXP. RUNS 54 APPROACHES	2 PRACTICE RUNS 3 EXP. RUNS 71 APPROACHES	2 PRACTICE RUNS 3 EXP. RUNS 57 APPROACHES
	DISTRIBUTED AUTHORITY	2 PRACTICE RUNS 3 EXP. RUNS 53 APPROACHES	2 PRACTICE RUNS 3 EXP. RUNS 61 APPROACHES	2 PRACTICE RUNS 3 EXP. RUNS 54 APPROACHES

Figure 4.- Experimental design.

intersection and execute right-hand turns until cleared for the Mercury approach. Computer-generated aircraft flew each route precisely enough that the landing "window" always was entered successfully.

Following every successful landing, an aircraft was given a new flight number and, after a variable interval (approximately 0.5 to 2.5 min), was repositioned beyond one of the four normal approach route fixes. Entry into the terminal area was pre-calculated so that if the prescribed flight profile was actually maintained, the aircraft would accomplish the required 60-sec spacing at the MAP. However, the entry of successive aircraft into the system varied as a function of aircraft speed and relative winds. The wind was always from the north at 25 knots decreasing to 15 knots at field elevation. In other words, the predicted ground speed for each aircraft was used to determine when each aircraft would be "handed-off" to the controllers responsible for the simulated terminal area. This procedure was justified on the assumption that computers responsible for the enroute segments of flight would schedule aircraft in such a manner. Aircraft were continuously entered into the system for the first 20 min of each run. At the end of this 20-min period, piloted aircraft still in the process of flying an approach were allowed to land. The run was terminated when the last piloted aircraft was on the ground.

Time Estimation

Following each landing, pilots were asked to estimate how long they felt it had taken them to fly the final 3 n. mi. of the preceding approach. This verbal time estimation task was included as a measure of the workload involved in flying different routes under different experimental conditions. Time estimation has been used previously (refs. 4-6) as a measure of the attention demands of primary, flight-related tasks. The time estimation task was included in this experiment to determine *how* pilots make successive time estimates. To accomplish this, pilots were required to report the method they had used in making each estimate on the same response sheet that they placed their estimate. It was considered important to distinguish those estimates which were made actively during the interval to be estimated from those which were made retrospectively at the end of the interval. Previous research indicated that the length of actively made estimates should decrease with increased workload, because time may pass unnoticed when primary task demands draw attention away from active estimation. The length of retrospective estimates should increase as the amount of information presented and processed during an interval is increased, because "filled" intervals seem to have lasted longer than relatively "unfilled" intervals. It was further anticipated that the active mode of estimation would occur primarily in situations having less workload and that pilots would be more likely to defer estimation until they had landed when primary flying demands were heavy.

Ratings and Reports

Following each run, both pilots and controllers were asked to rate the run with respect to safety, orderliness, expeditiousness, and visual, verbal, manual, and total workload. All participants were also asked to fill out an extensive debrief survey at the conclusion of the simulation.

RESULTS AND DISCUSSION

Piloted simulators and computer-generated aircraft flew a total of 350 approaches to runway 36L during the six experimental runs for the three groups. On the average, aircraft passed the MAP at 64.5 sec intervals. Piloted simulators tended to stay farther behind any other aircraft (74.5 sec) than did the computer-generated aircraft (63.7 sec) as measured by the intercrossing times at the MAP. This may have been due to the limited control that the controllers could exercise over the computer-generated aircraft. As Kreifeldt reported (ref. 7), the traffic management system strongly influenced the standard deviation (21.9 sec for distributed vs 32.5 sec for centralized) but not the mean (75.8 sec for distributed vs 73.9 for centralized) of intercrossing times for piloted simulators following other piloted simulators. There was no significant difference in intercrossing time as a function of approach route flown. The variability that did exist prior to the merge point had been adjusted by the MAP.

As was expected, localizer and glide slope rms deviation of the simulators during the last 3 n. mi. of each approach increased as the degree of turn required to intersect the outer marker increased (fig. 5). Although the total number of missed appraoches was low (14 of 350 approaches) the relative frequency was quite high on the Mercury approach. The poorer flight performance on that route could have been due to the steep turn required or the difficulty of reentering the traffic pattern following a previous missed approach. Pilots rated the approaches as increasingly more difficult the greater the amount of required turn, although none of the ratings exceeded a neutral rating between easy and difficult. Pilot safety ratings for the five approaches were also inversely proportional to the amount of turning required. The relatively straight Viking and Gemini approaches were rated as very safe, whereas the Mercury approach was considered somewhat dangerous.

The results of the verbal time estimation task were primarily interesting for the insight that they provided into the estimation modes that pilots used in judging the duration of a flight segment. Following their simulator flights, pilots reported using the active mode of estimation less often (34% of the time) than the retrospective mode. When estimates were reported to have been made actively, they were consistently shorter than when they were reported to have been made retrospectively, as was predicted (fig. 6). The mean ratio between estimated and actual flight time was 1.13 for actively made estimates and 1.23 for retrospectively made estimates.

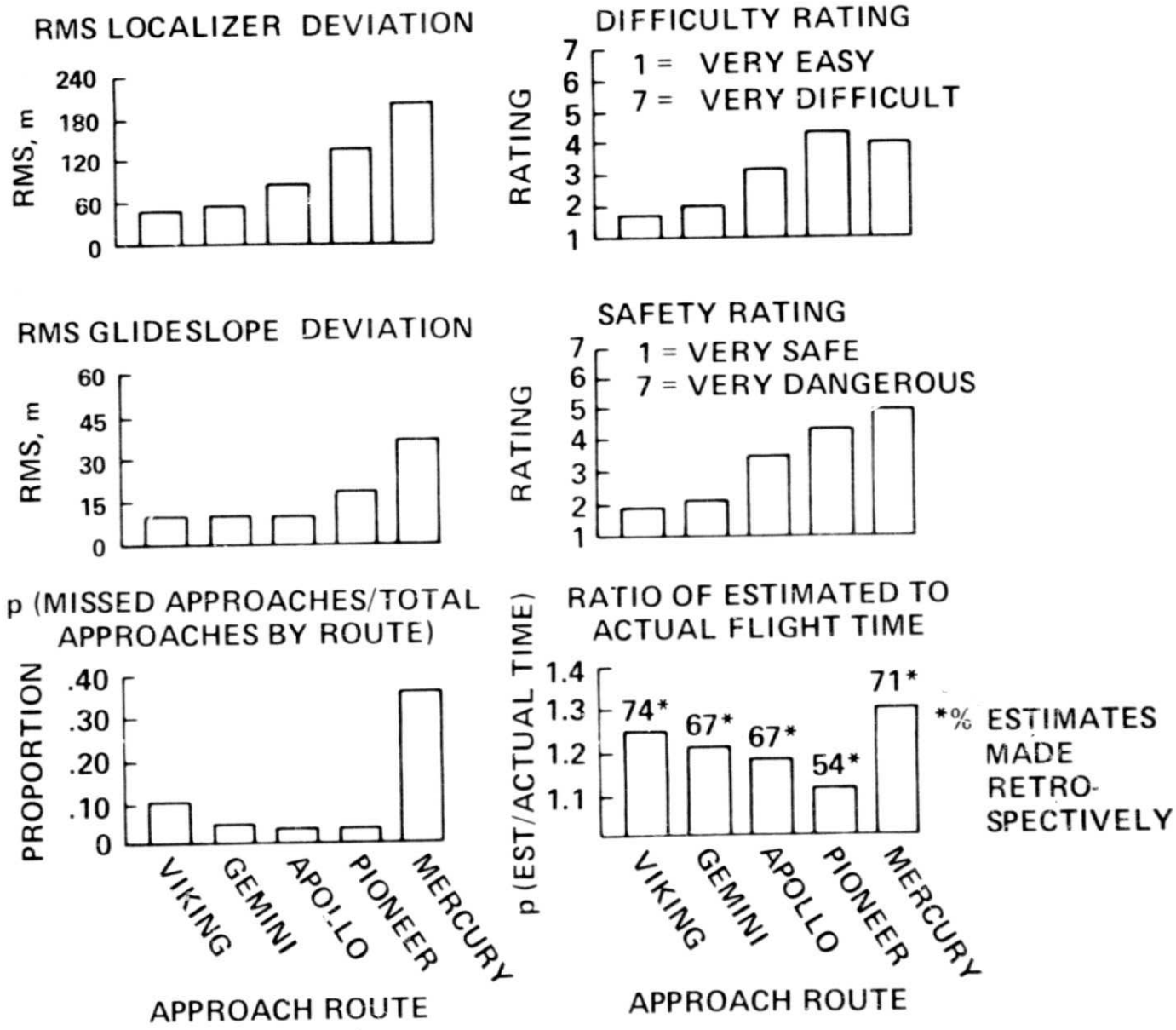

Figure 5.- Summary of results for final 3 miles of flight.

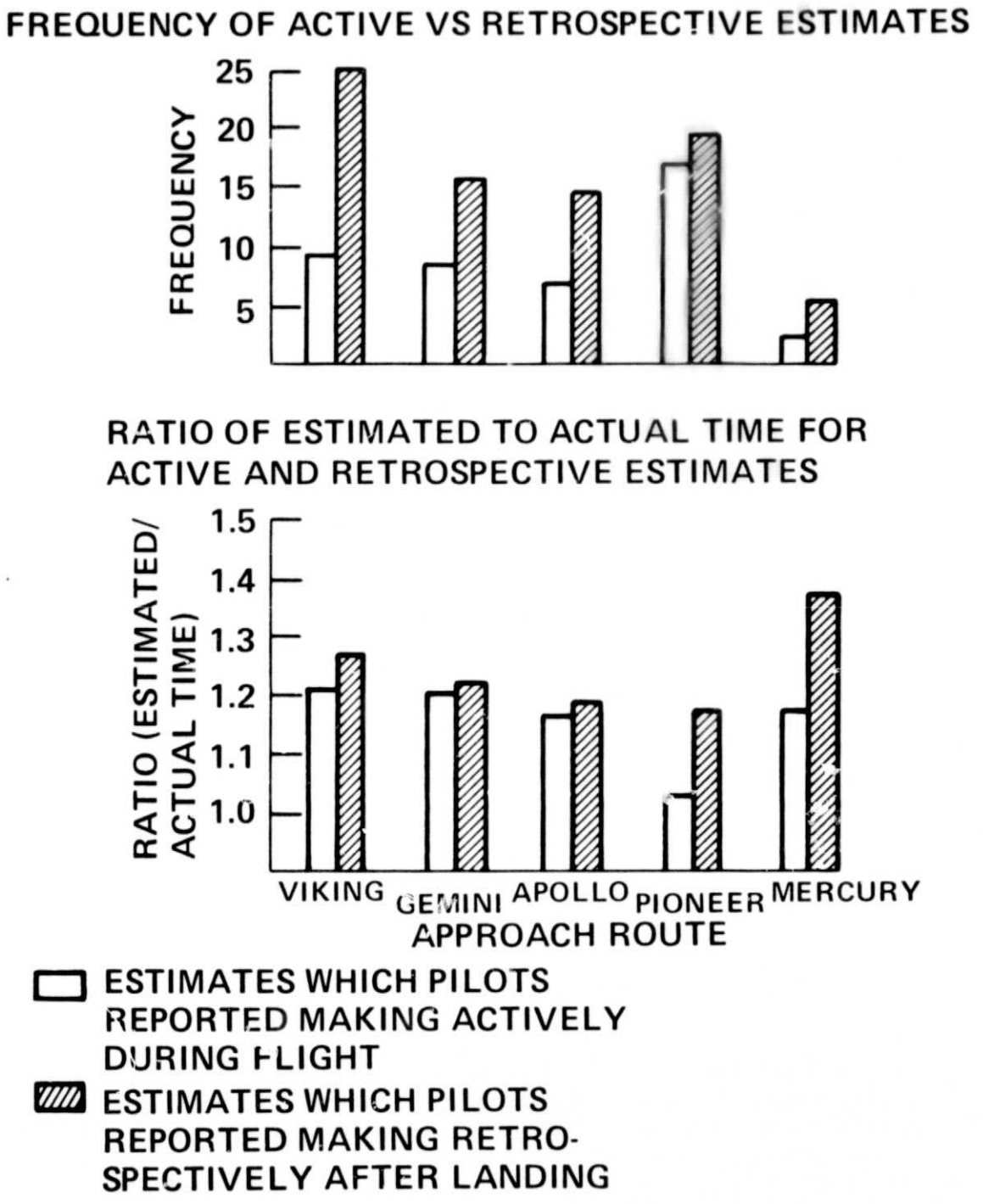

Figure 6.- Active vs retrospective verbal estimates of flight time for final 3 n. mi.

If both retrospective and active estimates are averaged together, as is presented in figure 5, a group of estimates that are primarily retrospective (e.g., estimates of flight time on the Mercury and Viking approaches) are relatively longer than a group of estimates that are primarily active (e.g., estimates of flight time on the Pioneer approach). This points out the importance of controlling or at least identifying, estimation mode when interpreting time estimation data.

Although there was no clear-cut relationship between approach route flown and mean time estimate duration, it was found that the shortest actively made estimate was obtained for the two most difficult routes (a ratio of estimated to actual flight time of 1.04 for the Mercury and Pioneer routes) whereas the longest retrospective estimates were obtained for the same two routes (a ratio of 1.21), as the model would predict. For the other, less difficult, routes, there was no effect due to route, and little difference between actively and retrospectively made estimates (fig. 6). It is possible that pilots consciously attempted to incorporate their estimate of the effect of wind on their ground speed when estimating flight time and thus confounded any purely subjective impression of duration.

A summary of pilot and controller run evaluations may be seen in figure 7. Pilots rated the safety and orderliness of the simulated traffic control problem higher than did the controllers. Both pilots and controllers felt that the centralized, ground-based management condition was somewhat less safe and orderly than the distributed, pilot-spaced management condition. Pilots felt that the distributed management condition was more expeditious than the centralized management condition, but the controllers reported the reverse opinion. Since the controllers were able to observe the overall flow of traffic on their display under both conditions, while the pilots were not able to do so, the controllers' judgments might be more relevant to system evaluation. Pilots rated the visual workload as less than the controllers did under both management conditions. It is interesting to note that pilots felt that their verbal workload was less in the distributed management condition, in which there was communication with other pilots as well as with the ground, whereas the controllers felt that their own verbal workload was higher, even though less communication should have been required of them under that same management condition. The frequency and content of verbal communications are being analyzed and will be reported in detail at a later date.

During the final debriefing, pilots expressed mixed reactions to the concept of closer spacing, particularly on single straight-in finals (fig. 8), while controllers' opinions were polarized. Pilots were much more positive about multiple, curved, descending approaches, particularly if spacing was increased, than controllers were. Managing aircraft merging from different directions was a difficult control problem and the controllers reported that they would need additional information, such as estimated time of arrival and indicated air speed, to safely control traffic in this situation. All pilots and all but one controller considered the use of parallel runways certified for simulataneous and independent operations under IFR conditions to be a feasible procedure for increasing the rate of aircraft arrivals.

AT THE END OF EACH RUN, PILOTS AND CONTROLLERS WERE ASKED TO RATE THE PRECEDING RUN WITH RESPECT TO ITS SAFETY, ORDERLINESS, ETC. THE FOLLOWING SUMMARIZES THEIR RESPONSES:

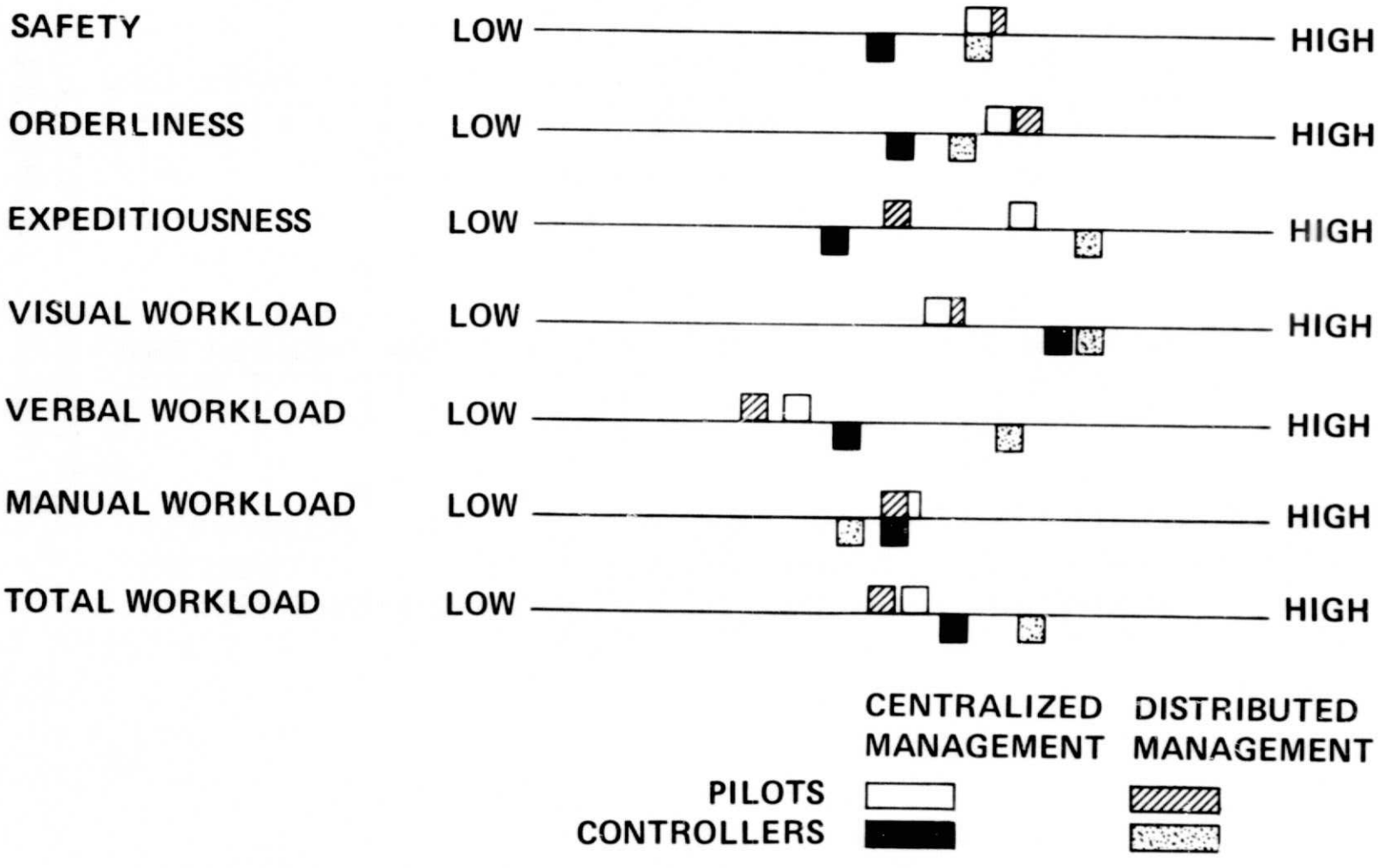

Figure 7.- Run evaluation summary.

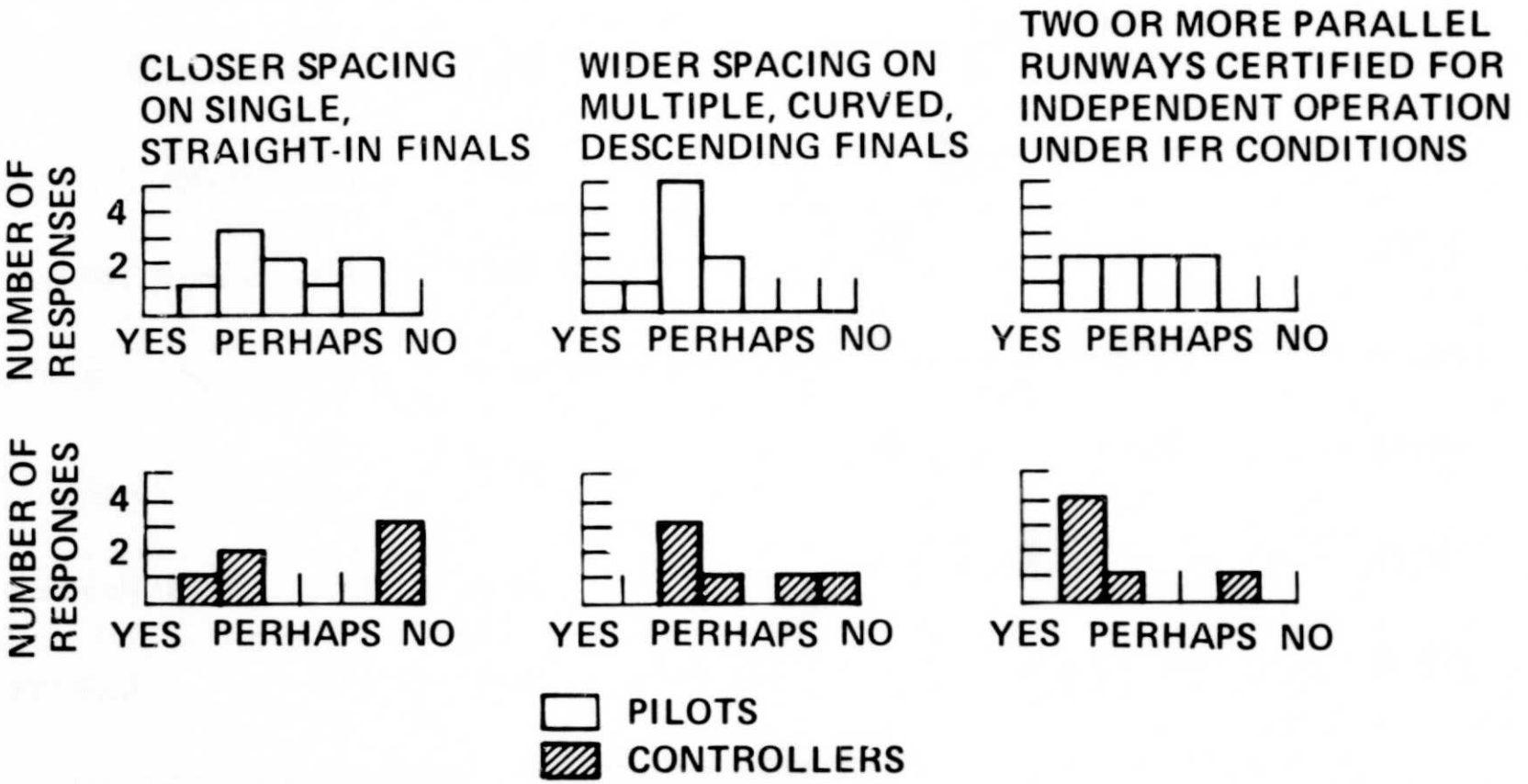

Figure 8.- Pilot and controller responses to the debrief question: "Do you consider the following to be viable solutions to the problem of increased air traffic density and limited airport facilities?"

It is anticipated that a follow up study will be undertaken in the near future which will include additional variables such as:

1. The length of the common final approach path.

2. The procedure for integrating departing aircraft into the system and the missed approach procedure.

3. The influence of deviations in the precision with which aircraft are entered into the terminal area.

4. The impact of emergency situations in the air and on the ground.

5. The distributed management system of air traffic control.

Several methods for increasing the arrival rate of aircraft in the terminal area have already received preliminary investigation and will receive additional examination, while others will be implimented. The introduction of departing aircraft to the control problem will complete the picture of a heavily trafficked airport and terminal area environment. The feasability of examining the complex air traffic control situation through flight simulation has been demonstrated. It is anticipated that data from subsequent simulations will suggest alternative procedural approaches for managing the higher volume of aircraft operations of the future.

REFERENCES

1. Benner, M. S.; Sawyer, R. H.; and McLaughlin, M. D.: A Fixed-Base Simulation Study of Two STOL Aircraft Flying Curved Descending Instrument Approach Paths. NASA TN D-7298, 1972.

2. Kreifeldt, J. G.; and Wempe, T. E.: Human Decision Making in Future ATC Systems: Comparative Studies in Distributed Traffic Management. Paper presented at the International Conference of IEEE Systems, Man and Cybernetics Society, Dallas, Texas, Oct. 1974.

3. Gilbert, G. A.: Historical Development of the Air Traffic Control System. IEEE Transcript Communications, COM-21 (5), May 1973.

4. Hart, S. G.: Time Estimation as a Secondary Task to Measure Workload. Proceedings of the 11th Annual Conference on Manual Control. NASA TM X-62,464, 1975.

5. Hart, S. G.: A Cognitive Model of Time Perception. In W. E. Wilsoncroft (Chair.), Symposium on Time Perception at the 56th Annual Meeting of the Western Psychological Association, Los Angeles, April 1976.

6. Hart, S. G.; and McPherson, D.: Airline Pilot Time Estimation During Concurrent Activity Including Simulated Flight. Paper presented at the 47th Annual Meeting of the Aerospace Medical Association, Bal Harbour, Fla., May 1976.

7. Kreifeldt, J. ; and Hart, S. G.: ATC by Distributed Management in an MLS Environment. Paper presented at the 13th Annual Conference on Manual Control, Massachusetts Institute of Technology, Cambridge, Mass., June 1977.

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16. Abstract

A terminal area air traffic control simulation was designed to study ways of accommodating increased air traffic density. The concepts that were investigated assumed the availability of the Microwave Landing System and data link and included: 1) multiple curved descending final approaches, 2) parallel runways certified for independent and simultaneous operation under IFR conditions, 3) closer spacing between successive aircraft, and 4) a distributed management system between the air and ground. Three groups each consisting of three pilots and two air traffic controllers flew a combined total of 350 approaches. Piloted simulators were supplied with computer generated traffic situation displays and flight instruments. The controllers were supplied with a terminal area map and digital status information. On the average, aircraft arrived at the Missed Approach Point at 64.5 sec intervals. Intercrossing time variability was greater under centralized, ground-based management, than under distributed, pilot-spaced management, however mean intercrossing times did not differ. Pilots and controllers also reported that the distributed management procedure was somewhat more safe and orderly than the centralized management procedure. Flying precision increased as the amount of turn required to intersect the outer marker decreased. Pilots rated the approaches as increasingly less difficult and more safe as the amount of turn required decreased. Pilots reported that they preferred the alternative of multiple curved descending approaches with wider spacing between aircraft to closer spacing on single, straight-in finals while controllers preferred the latter option. Both pilots and controllers felt that parallel runways would be an acceptable way to accommodate increased traffic density safely and expeditiously.

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