Effects of Above Real Time Training (ARTT)
On Individual Skills and Contributions to Crew/Team Performance

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DEDICATION

Dedicated to

Jack L. Kolf

Father of Above Real Time Training (ARTT)

Who, as an engineer at

NASA Dryden Flight Research Center,

Invented ARTT and observed its effect in 1973

SUMMARY

Above Real time Training (ARTT) is the training acquired on a real time simulator when it is modified to present events at a faster pace than normal. The experiments on training of pilots performed by NASA engineers (Kolf, 1973 and Hoey, 1976) and others (see Crane and Guckenberger, 2000) have indicated that real time training (RTT) reinforced with ARTT would offer an effective training strategy for such tasks which require significant effort at time and workload management.

A study was conducted to find how ARTT and RTT complement each other for training of novice pilot-navigator teams to fly on a required route. In the experiment, each of the participating pilot-navigator teams was required to conduct simulator flights on a prescribed two-legged ground track while maintaining required air speed and altitude. At any instant in a flight, the distance between the actual spatial point location of the airplane and the required spatial point was used as a measure of deviation from the required route. A smaller deviation represented better performance. Over a segment of flight or over complete flight, an average value of the deviation represented consolidated performance. The deviations were computed from the information on latitude, longitude, and altitude.

In the combined ARTT and RTT program, ARTT at intermediate training intervals was beneficial in improving the real time performance of the trainees. It was observed that the team interaction between pilot and navigator resulted in maintaining high motivation and active participation throughout the training program.

Suggested improvements on the reported experiment are identified for conducting a more comprehensive study of reinforcement effects of ARTT on RTT. Further work is proposed on determining the effects of ARTT and other training strategies for basic and advanced flying maneuvers and variables influencing team training.

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INTRODUCTION

Training on Flight Simulator

With the advancements in computer technology, computer based simulators and trainers have progressively been adopted for imparting flying and combat skills at different stages of training of civilian and fighter pilots. The advantages of training on flight simulators include saving time and money. Computer based training invites researchers to explore and introduce innovative simulation techniques and training strategies to improve transfer value of simulation trials. Improvement in transfer value includes reduction in the required training time, enhanced retention of the acquired skill, and smoother transition from simulated environment to real environment (Adams, 1989). To obtain increasing benefits from the current advancements in simulation techniques, it is imperative to make speedy progress in determining the effects of new strategies for training of individual and team skills on flight simulators. The experiment reported here addresses the effects of Above Real Time Training for pilot-navigator teams required to conduct simulator flights following a prescribed two-legged ground track.

Above Real Time Training (ARTT)

ARTT is the training acquired on a real time simulator when it is modified to present events at a faster pace than normal. Crane and Guckenberger (2000) have provided a survey of the research work on ARTT, which covers its effects on training of novices and experienced individuals and the types of algorithms needed to implement it on a simulator.

Jack Kolf (1973) narrated his personal experience at NASA Dryden Flight Research Center that regardless of type or amount of pre-flight simulator training accomplished by the pilot, the actual flight appeared to take place in a much faster time frame than real time. He increased the simulator clock speed to have experimental flights conducted by the pilots who already had flying experience in the M2-F3 program. At an above real time factor of 1.5, they remarked that the simulator flight felt closest to their actual flying experience. Kolf's experiment was the genesis of ARTT on flight simulators. Kolf hypothesized that the appropriate above real time factor for ARTT would be a function of aircraft, individual, task and experience. For the lifting body program, he suggested that preliminary training be accomplished in real time, and then ARTT be used as top off training.

Hoey (1976) compared biomedical measurement data of test pilots flying remotely piloted vehicles, with the past data taken in flight. He inferred that the stress levels and physical and mental states of test pilots are primarily influenced by the strong sense of responsibility and resulting anxiety. He suggested that providing ARTT on a flight simulator could approximately simulate this mental state. According to his suggestion, ARTT compared with real time training, would lead to smoother transition from simulator to airplane.

Crane and Guckenberger (1997) found that Air Force F-16 pilots trained using ARTT performed emergency procedures more quickly then pilots trained in real time. Experienced pilots trained using ARTT on radar skill tasks performed similarly to those trained in real time, although training was accomplished in fewer clock hours for the ARTT group. Student F-16 pilots trained using ARTT, however, performed better than pilots trained using RTT on a real time test task that was more complex than any of the tasks experienced in training.

Ali, Guckenberger, Rossi and Williams (2000) trained University students for basic maneuvers on a flight simulator. One group was trained in real time and another one received initial training in real time and top off training in ARTT. Both groups were tested in real time. No significant difference was observed in the test performances of the two groups. They expressed the need of improving performance measures.

In the study reported here, Real Time Training (RTT) and ARTT are used for each participating team in a predetermined order at different intervals of the total training time. The details are given in the section on Method under the subheading: Experimental Design.

Self-Instruction Methods

Computer-based Instruction and Distance Education in the training of wide variety of tasks rely on using self-instruction. According to Proctor and Dutta (1995), extrinsic feedback has been found to be effective in training of motor skills under certain conditions (Proctor and Dutta, 1995). They have also cited a hypothesis of Schmidt, Young and Shapiro suggesting that if subjects are provided 100% knowledge of results they may come to rely too heavily on extrinsic feedback as opposed to intrinsic feedback inherent in the task situation.

From Ali et al's (2000) work, it is interesting to report here the comparison of two groups. In the first group, students were trained in real time with in-flight and post flight feedback for self-instruction. In the second group, the students were trained in real time without any feedback for self-instructions. For increasing amount of training to fly straight and level, the group with self-instruction had visible increase in performance until the end of the advanced stage of training, but the group without self-instruction had visible increase in performance in the initial stage only.

For self-instruction in the experiment, reported here, the participants received only post-flight feedback on their performances. After every flight, the participant-team looked at a graph of the ground projection of the actual flight path in comparison with the required route. Figure 1.2 shows a typical graph.

Team Training

Military and organizational personnel must often work as a team to operate effectively. For example, F-16 pilots work on "two ships" and four ships and thus must function as a team even though they are resident in separate cockpits (Ginnett, 1993). Such teamwork involves individuals in interdependent situations that require cooperation, coordination, and adaptability among team members whose roles are generally well-defined (Klaus and Glaser, 1968). Denson (1981) provides an overview of various definitions of team that have been postulated over the years. To organize research on Cockpit Resource Management, Spiker, Silverman, Tourville and Nullmeyer (1996) identified five functional areas, namely Function Allocation, Time Management, Tactics Employment, Situation

Awareness and Command-Control-Communications. Fowlkes, Lane and Salas (1994) have used team behavioral performance measures to assess different aspects of team activity.

The competency of the individual members of a team is an important component of team performance. Equally, and perhaps more important components of team performance, are the team process skills required to deal with the complexities of the operating environment. The tasks which are mostly cognitive and for which a number of alternative strategies are available, such as complex decision making, showed inconsistent to negative effects of ARTT (Lane, 1994). In the case of individual performance, it is observed that the tasks requiring procedural and motor skills or time and workload management are benefited by ARTT (Crane and Guckenberger, 2000). For team performance, it is anticipated that ARTT would give rise to improved team responses to critical or emergency situations, which require an ability to accurately and rapidly follow established procedures and perform motor tasks. To the extent that ARTT may reduce subsequent individual workload and individual stress during these established situations, it would reduce the likelihood of a breakdown in team processes.

In the experiment reported here the study of team training was limited to observation of qualitative aspects of the interaction between pilot and navigator. Video recording of their conversation was, however, obtained for further study.

METHOD

Participants

Twelve undergraduate University students volunteered to participate in the experiment. Volunteers received no financial compensation or extra course credit for their participation. There were eight males from the age of nineteen to twenty two and four females from the age of eighteen to nineteen. The piloting skills and/or level of experience on a flight simulator were not considered as factors in selecting participants. Some of the volunteers had flown the simulator, others had some experience flying a single engine airplane, and the remaining ones had no flying experience on airplane or simulator. The twelve participants were recruited individually, and were assigned to six pilot-navigator teams.

Equipment

The experiment was conducted in the Flight Vehicles Laboratory of the Aerospace Science Engineering Department at Tuskegee University. For the flight simulator, the computers and associated equipment have been configured, supplied and supported by the Advance Technology Division of SDS International, Inc. at Orlando, Florida. The system consists of two Heavy Metal Computers from Quantum 3D of Lake Forest, California. Each computer has two Pentium II, 400 MHz processors, 400 MB RAM, three extra display cards and a SoundBlaster audio card. The flight simulation software is Lite Flite version 3.3 from SDS International, Inc. Lite Flite offers flight simulation of several aircraft including a Predator Unmanned Air Vehicle (UAV) System. The simulation of a single Predator was used in the experiment. Williams (2000) had conducted certain fidelity checks on the simulator and noted that it had moderate fidelity. The computer monitors, joystick, throttle control and rudder pedals were arranged in a mock setup of a partial cockpit, which had been built by Tuskegee University students.

The pilot had a panoramic view on three monitors for the out-the-window display. The instrumentation panel was available on a fourth monitor directly below the three with the out-the-window display. A separate monitor showed top-down view of map terrain of Nellis Air Force Base in Nevada. This monitor was visible only to the navigator, as it was placed to the right of the cockpit monitors, and was separated from view by a partition between the pilot and navigator. The map screen included latitude-longitude information, a contour of the prescribed flight path, a moving icon of the airplane and a display box showing airspeed, heading and altitude. The pilot and navigator used voice-activated headsets to speak to one another. The audio from these headsets fed into a tape recorder to record the conversations between the navigator and the pilot.

A separate computer was used for the pilot to initiate emergency procedures. Its monitor, keyboard and mouse were placed to the left of the cockpit display so that they were conveniently accessible to the pilot during a flight.

An emergency situation was indicated by a sound coming from a separate audiotape created by the experimenters. This tape consisted of recordings of three different sounds indicating the need to initiate three different emergency procedures. These sounds were obtained from an inexpensive toy that emitted sounds of a car alarm, fire alarm, and horn.

Research Design

This project studied procedures for determining the effects of two different variables, training time and the presence or absence of emergency procedures in a team-training context. Thus, the levels of the first variable consisted of Above Real Time Training (ARTT) vs. Real Time Training (RTT) and the levels of the second variable consisted of flights requiring emergency procedures and flights not requiring emergency procedures. In particular, the study investigated how ARTT and RTT complement each other for training of a pilot-navigator team on a simulator. Every pilot-navigator team that participated in the experiment was exposed to the same variables in the same sequence. A team conducted a three-minute straight and level flight for familiarization, and then it received one session of training on one day, and a second session of training on another day. The net flying time of the two sessions together was 127 minutes. The first training session did not include emergency procedures (EPs), but the second session required EPs in every flight. Each of the two sessions was comprised of six flights in the following order: two flights in real time, three flights in above real time at 1.5 times real time, and one flight in real time. A flight required 12.7 minutes in real time simulation and 8.4 minutes in above real time simulation. The sixth flight in each training session was conducted in real time and served as a test of the effects of training.

Every participating pilot-navigator team conducted the following twelve flights in sequence: The rt1 and rt2 were the first two real time flights, without EPs; both flights were completed in the first 25.4 minutes of training. The art1, art2 and art3 were the three above real time flights, without EPs, conducted in the training time duration from 25.4 to 50.8 minutes. The rt3 was the third real time flight from 50.8 to 63.5 minutes. The rt1ep and rt2ep were the fourth and fifth real time flights respectively, with EPs, conducted from 63.5 to 88.9 minutes of training time. The art1ep, art2ep and art3ep were the fourth, fifth and sixth above real time flights respectively, with EPs, conducted from 88.9 to 114.3 minutes of the training time. The rt3ep was the sixth real time flight and the last flight of the training program, with EP, conducted in the duration from 114.3 minutes to 127 minutes of the training time.

Procedure

Data collection was completed over five days. The first two days were set aside for three participating teams. A professor and a research assistant remained available to meet the participants and to supervise the experiment. The first day the participants signed the informed consent forms and filled in the background survey forms. They received instructions on their mission, route, speed, heading, and altitude. If a participant was not knowledgeable about flying the simulator or the use of the correct terminology as navigator, he or she was given time to become acclimated to the flying and navigating respectively. The initial flight for every team was a familiarization flight of three-minute duration. The first day the participants completed the first session of training, which did not require EPs. The two required training sessions were completed in two days. Every session had two real time training flights, three above real time training flights, and one last real time training flight.

All the training flights required flying over the same prescribed two legged ground track, which included a 90-degree level turn. Figure 1.1 shows the desired ground track. The first leg started at 36.35 Latitude, -115 Longitude and ended at 36.50 Latitude, -115 Longitude. The second leg started from the end point of the first leg and it ended at 36.50 Latitude, -114.8 Longitude. The required air speed was 90 knots at an altitude of 5,000 ft. For feedback on performance after every flight, the trainees were shown a graph of the ground projection of the actually traversed flight path in comparison with the required route, as shown in Figure 1.2. Table 1.1 shows part of an output file indicating latitude and longitude values reached at every 20-second interval in a typical flight.

The second day the same three teams returned with the same instructions for mission, altitude, speed, and heading, but experimenters added an additional element of EPs. Before the flight, subjects had an opportunity to listen to the sounds for the EPs and see how an EP was to be performed on the computer by the pilot while he or she was still performing the task of flying. Experimenters explained to the subjects that it was permissible for the navigator to tell the pilot which emergency was in effect. After each flight in both sessions, the teams were given feedback on their performance. The feedback was a graph that displayed their latitude and longitude to show the teams how well they maintained their flight and it revealed any deviations from the required route. After the teams' last flight they were debriefed on their experiences as pilot or navigator. The next two days were spent with the other three teams and the fifth day was used finishing teams who had not completed their second day due to classes or some other engagement.

For the EPs, a fire alarm indicated engine failure, a horn indicated instrument malfunction, and a beep indicated hydraulic system interruption. For real time training flights, the emergencies came at the third, sixth, and ninth minute intervals, and for the above real time training flights they came at the second, fourth, and sixth minute intervals. These sounds were played and recognized by the participants before they were to begin their flights. During a flight, upon hearing an EP sound, the pilot was required to look at the EP screen, click the relevant tab, examine a condition corresponding to the numbers appearing on the screen, and key in a required alphanumeric word in a box on the screen. An experimenter made note of whether the pilot had identified the correct emergency and typed in the correct sequence to rectify the situation.

Performance Measures

"Private Pilot Practical Test Standards," a publication of the FAA (Federal Aviation Administration, 1995), identifies straight and level flight, climb, descent and level turn as the four basic flight maneuvers. For test of a trainee on a single engine airplane, the permitted tolerances are as follows: altitude ± 200ft, heading ± 20°, and airspeed ± 10 knots. Vogel (2000) suggests awarding of grade points 4, 3, 2, 1, and 0 on flying performances with maximum scores for flights within FAA standard tolerances and decreasing scores for flights with increasing deviations from the prescribed flight paths..

Ali et al (2000) also used grade points on flying performances. For example, an airspeed tolerance in knots was ± 3 for 4 points, ± 6 for 3 points, ± 9 for 2 points and ± 12 for 1 point. For automated scoring on computers, flight parameters were monitored at every

3 seconds. To validate the automated scoring, several flights flown on the simulator were simultaneously evaluated by the computer and by a certified flight instructor. The comparison of the two kinds of evaluations revealed acceptable correlations for straight and level flights but very low correlation for climb, descent and turning maneuvers. Comparison of automated computer scores with instructor's scores requires more elaborate considerations in computer scoring which may be pursued as a separate research program.

In the present work, instead of developing such computer grades which need to be correlated with a certified flight instructor's grades, the performance was measured by a single parameter that represented increase or decrease in performance at different stages of training. The pilot followed a prescribed ground track while maintaining required speed and altitude. At every prescribed instant of time, the performance was measured by a single parameter; the same parameter was averaged over a complete flight to obtain a consolidated performance measure. Thus the parameter offered a valid measure for the assessment of progress in training. This parameter also provided a continuous measure of performance ans avoided the discrete jumps in scores and arbitrary boundaries of the earlier category scales.

The representative single parameter was the magnitude of the displacement vector from the prescribed location at the given instant. The displacement vector at a given instant was the resultant of three component deviations, which were deviations in altitude, latitude and longitude respectively. Before determining the resultant vector, the latitude and longitude deviations in degrees were converted to the respective distances in feet. The Northern Arizona University website (see References) offered the method for conversion of latitude and longitude degrees to distances in feet. The method was verified by making some independent calculations.

Data Acquisition and Processing

A Visual Basic Program interacted with the Lite Flite simulator to operate the simulation at real time or above real time and to provide data on the desired parameters of a flight at the desired time intervals as small as one tenth of a second. For the reported experiment, the monitored flight parameters were Latitude, Longitude, heading, airspeed and altitude at every one-second interval. The output files of the flight data were obtained in the form of tables with the values of the desired parameters reached in a trainee's flight at every one-second interval. For every flight, the desired airspeed was 90 knots at 5,000 ft altitude. Table 1.2 shows the data of the first 20 seconds of a typical flight. Figure 1.1 shows the required ground track and Figure 1.2 shows the ground track actually traversed in a typical flight. At every second of a flight, the magnitude of the displacement vector or the deviation from the required location was calculated as described in the paragraph on Performance Measures.

For further data analysis and study, a flight was divided into three different segments. The first 240 seconds of a flight were treated as Segment I. The next 240 seconds were Segment II, and the rest of the 282 seconds were treated as Segment III. Thus, Segment I represented the initial straight and level portion on the first leg of the required two-legged track, Segment II essentially covered the 90-degree level turn and Segment III was comprised of the final straight and level portion on the second leg. Adding the deviations of every second and dividing it by the number of seconds obtained the average deviation for a segment in every flight. For the twelve flights of every one of the five participating teams, the segment-wise average deviations are shown in Tables 2.1, 2.2 and 2.3. A few boxes in the tables are left blank because the data were unanalyzable for reasons that could not be identified. One of the six participating teams, Team 400, did not complete all the desired flights; therefore, its data were not included in the analysis. As shown in Figures 2, 3 and 4, for every segment, one curve fit was obtained for all the six real time flights. Separate curve fits for the real time flights without EPs and with EPs were not attempted because an adequate number of flights was not available in the two different categories.

RESULTS AND DISCUSSION

Two different kinds of errors were noted and compensated in the data processing. The first kind was perhaps due to a software problem; the latitude values appearing on the navigator's screen and the ones recorded on the output files showed a constant difference of 0.045 degrees. To an appreciable degree, the error was automatically removed in data processing because the latitude value recorded at zero second (beginning of the flight) was used as reference value and it was subtracted from the recorded latitude values at every second. The second kind of error was natural in a two-legged mission. The flight performance of the second leg was influenced by performance at the end of the first leg. To take care of this influence to an appreciable extent, the deviations were normalized or made dimensionless. For a given segment and a given team, average of the deviations of all six real time flights was found. The segment deviation for every flight of the team was divided by this average deviation to obtain a value termed as normalized deviation for the given segment and the given team. The graphs in Figures 2, 3 and 4 show the normalized deviations of the five participating teams for the Flight Segments I, II and III respectively, plotted against cumulative training time. It is understood that a decrease in deviation with an increase in cumulative training time shows improvement in performance.

The curve fitting on the data points in Figures 2, 3 and 4 followed a method available on the Federal Aviation Authority website on the learning curve (see References). The website provides an equation for cost estimate based on unit theory. Similarly, the deviation against cumulative training time is expressed as:

Deviation = (T1) (t**b) where

T1 = theoretical deviation prior to any training, t = cumulative training time in minutes, and b = rate of decrease of deviation with increase in cumulative training time.

Every team received training under two different modes, Real Time Training (RTT) and Above Real Time Training (ARTT) with two different conditions, without emergency procedures (woEPs) and with emergency procedures (wEPs) in the following manner: RTT woEPs from 0 to 25.4 minutes (min) and 50.8 to 63.5 min, RTT wEPs from 63.5 to 88.9 min and 114.3 to 127 min, ARTT woEPs from 25.4 to 50.8 m, and ARTT wEPs from 88.9 to 114.3 min. For a flight with real time simulation, the required route was covered in 12.7 min on real clock as well as on simulation clock. The above real time simulation ran at 1.5 times faster pace than the real time simulation, so that a flight was completed in 12.7 min of simulation clock or 8.47 min of real clock.

To evaluate the performance, the flight duration of 12.7 min interval on simulation clock was divided in three different segments of 0 to 4 min, 4 to 8 min and 8 to 12.7 min called Segments I, II and III respectively. Every one of the Figures 2, 3 and 4 show twelve points corresponding with the twelve training flights and a curve fit for the six RTT flights. The curve is represented by the equation (described above):

Deviation = (T1) (t**b).

For Segments I, II and III, the T1 values are 2.5225, 2.17533 and 4.4694 respectively and the b values are –0.27346, -0.21059 and –0.39181 respectively. The correlation coefficient (R**2) values of the fit are 0.7357, 0.4904 and 0.8295 respectively.

The curves on normalized deviation versus cumulative training time for Segments I, II and III indicate that the improvement of pilot-navigator team performance follows the generally expected learning curve. The correlation coefficient has reasonable values for Segments I and III but it is rather low for Segment II, which essentially comprises of a 90-degree level turn. A consideration of the deviation points on the graph reveals that higher correlation coefficients would result if the curve fits were separately done for flights with EPs and those without EPs. Separate fits were not attempted because of small number of flights in different categories.

Previous investigations on ARTT, for example Rossi et al (1999), suggest that performing a challenging task is made more difficult in above real time simulation; therefore performance during ARTT is depressed compared with that during RTT. Accordingly, the deviations of ARTT flights are expected to be significantly larger than the deviations represented by the real time curve fits. In the graphs of Figures 2, 3 and 4, this feature is clearly visible for two of the three ARTT flights with EPs. Recognizing that the task of flying maneuvers with EPs require significant effort at time and workload management, the noted feature is in accordance with the suggestion of Crane and Guckenberger (2000) that ARTT is an effective strategy for such a task.

On the deviation of RTT flight with EP, which follows three ARTT flights with EPs, the beneficial effect of ARTT is evident for every one of the segments I, II and III. In the ARTT flights without EPs, the deviations for Segments I, II and III are about the same as represented by the real time deviation curve fit. Perhaps the required speed of 90 knots is a relatively low speed for simulator flying; therefore, the tasks of straight and level flying and level turn without EPs do not require significant effort in time and workload management. The RTT flight without EPs following three ARTT flights, however, is benefited by ARTT. On a closer look at the graphs for Segments I, II and III, one may suggest that the degree of benefit from ARTT is higher in the case of flights with EPs. For developing a better understanding of the comparative and complimentary features of ARTT and RTT, an expanded research program is suggested in a separate section in this report.

The pilot-navigator team flying offers an opportunity to study the team processes. A consideration of recent team training studies, for example Salas et al (1999), suggests an emphasis on both teamwork behaviors and task behaviors. The pilot-navigator conversations in the present experiment have been recorded to provide us initiating material for possible investigations on teamwork behaviors and task behaviors. It was observed that the pilot-navigator interaction resulted in maintaining high motivation and active participation throughout the training program. According to Schneider's (1982) guidelines, motivation and active participation are desired features for an effective training program.

EXPANDED PROGRAM FOR FUTURE ARTT RESEARCH

The reported experiment is especially valuable in motivating us to devise and explore different kinds of methods offering improvements over the existing evaluation studies of ARTT and RTT. The first improvement would be a rather detailed study designed to enhance our understanding of how the two different modes of training complement each other with respect to basic and advanced flying maneuvers. The second improvement would be to devise a program to evaluate ARTT and RTT, as well as various other factors that influence pilot-navigator training and performance.

For developing such an improved program of study, the following modifications on the present experiment would be worthwhile.

1) Predator is a relatively low speed remotely piloted airplane. ARTT is an acceptable training strategy for a single Predator airplane. But to observe significant effects of ARTT, simultaneous simulated flying of three or more Predator airplanes from a single ground station is recommended. Alternatively, a single airplane would be desirable if the mission complexity is increased by adding crosswinds and turbulence.

2) The complete training program in the reported experiment had only twelve flights with two switchovers from RTT to ARTT. The flying task with a level turn required 12.7 minutes of real time. It is suggested that shortening the straight and level flying legs before and after the turn appreciably reduce the time duration of a single flight. Then the training program would require a larger number of flights with more switchovers of training modes. That would offer a better opportunity to study the complimentary or detrimental effects of ARTT mode on RTT mode.

3) The reported experiment had RTT and ARTT sessions without EPs followed by RTT and ARTT sessions with EPs. It is suggested that the number of RTT sessions in the beginning of the program be increased to expose the participants to flying in both conditions: without and with EPs. This would bring more uniformity in the participants' skills before they are provided with both modes of training ARTT and RTT. This would also meet a condition prescribed by Crane and Guckenberger (2000) for effectiveness of ARTT. With reference to Fitts and Posner's (1967) model of skill acquisition and based on other investigations of ARTT, Crane and Guckenberger (2000) indicate that ARTT is effective for the trainees who have completed the cognitive portions of skill acquisition. Another suggested approach would be to have one group trained entirely with RTT up to asymptotic performance and then look at the effect of adding EPs on performance; how much additional training is required to restore criterion performance? Train two other groups to the same criterion using RTT and then overtrain by 30%. One group would overtrain using RTT and the other with ARTT and then look at the amount of RTT to restore criterion performance including EPs. Over-training the basic task using ARTT may be more efficient than either of the RTT conditions.

4) According to Crane and Guckenberger (2000), the research studies on ARTT suggest that it is an effective strategy for the tasks that require significant effort at time and workload management. In the reported experiment, the pilot's task included the emergency procedures and it required significant effort to be benefited by ARTT. The navigator was

comparatively lightly loaded. It is suggested that the navigator also be required to execute several emergency procedures.

For flying on Segments I, II, and III of the ground track, the Figures 2, 3 and 4 show the normalized deviation versus cumulative training time for all the twelve flights, and curve fits through the six RTT flights. The trainees received ARTT during two different intervals of the complete training program. The RTT performance after the ARTT intervals indicates that the ARTT has been beneficial in improving the real time performance of the trainees. The question whether ARTT has been more beneficial than RTT was not addressed by the present study. The existing investigations of two different training modes do not clearly show their comparative and complimentary features during the training intervals, they reveal only the comparative features through a brief test phase after the training. Such a question would be answered if data were obtained from a control group, which would conduct all the training flights in real time. Among the existing ARTT and RTT evaluation studies, typically one group is trained in RTT, another is trained under a proposed program, and both groups are tested in real time, for example see Rossi et al (1999). In the proposed method, the whole training program would reveal both comparative and complimentary features of two different modes of training. The suggested experimental program will open up new research opportunities on effects of ARTT and other training strategies for basic and advance flying maneuvers.

5) Further studies examining the effects of ARTT and variables such as frequency of feedback could be conducted to determine their effectiveness in training pilot-navigator teams.

6) The research efforts described above look at the effects of ARTT on overall mission performance. Within these efforts, it will also be possible to gather data on the effects of ARTT on teamwork and team processes.

CONCLUSION

University students received Above Real Time Training (ARTT) and Real Time Training (RTT) to perform a pilot–navigator team task on a flight simulator. In each training session, a team completed a two-legged mission consisting of heading N, taking a N-E level turn and then heading E. The pilot-navigator teams were observed to have maintained high motivation and active participation in both real time and above real time modes of training. In the combined ARTT and RTT program, ARTT at intermediate training intervals was beneficial in improving the real time performance of the trainees. Further studies on combined ARTT and RTT program for team training on a flight simulator are recommended to compare the benefits of ARTT and RTT, to determine how ARTT and RTT complement each other and to discern the effects of ARTT on team processes.

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FIGURES AND TABLES

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Table 2.2:	Average Deviation for Segment II
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Fig. 1.1: Desired Ground Path

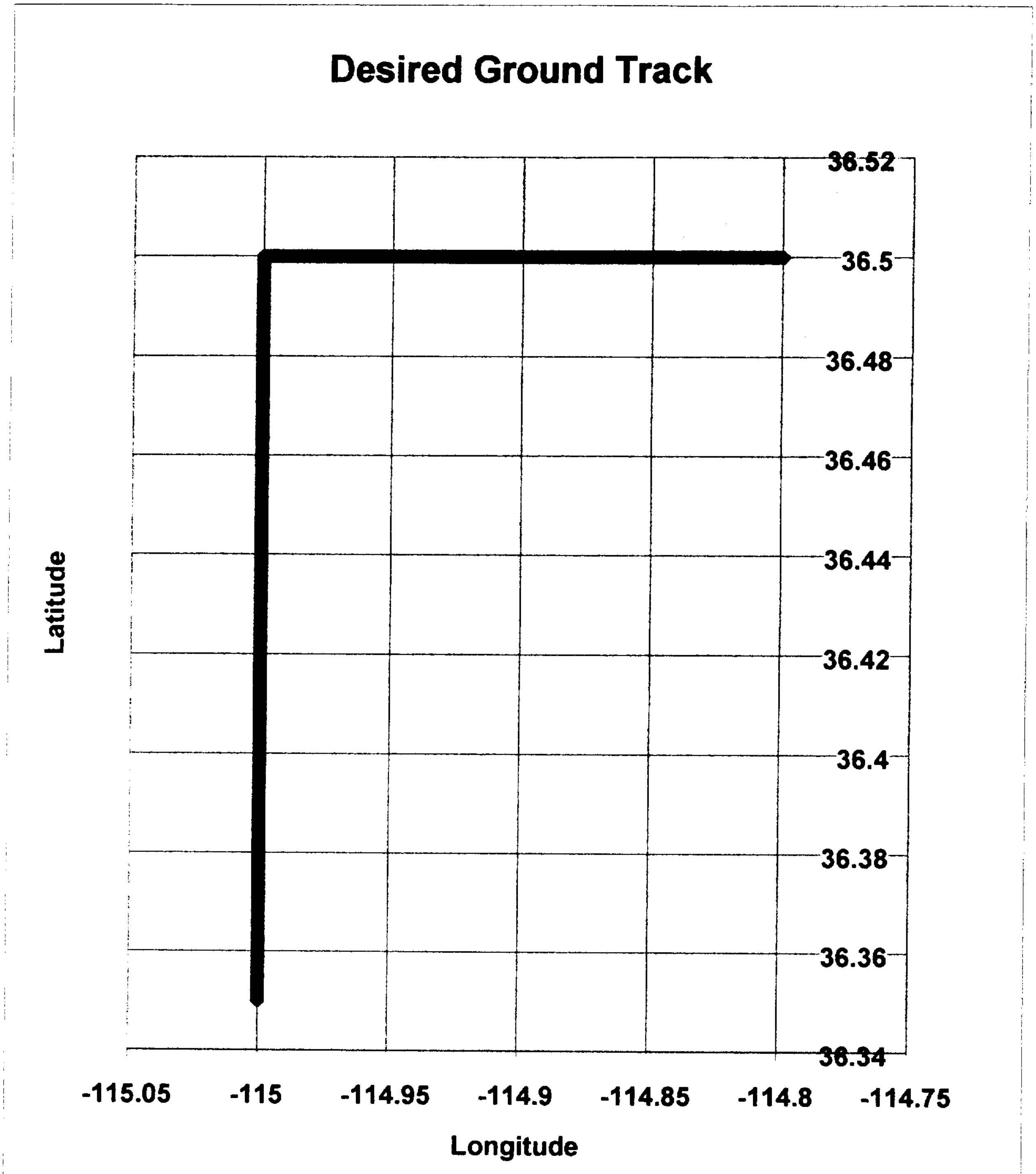
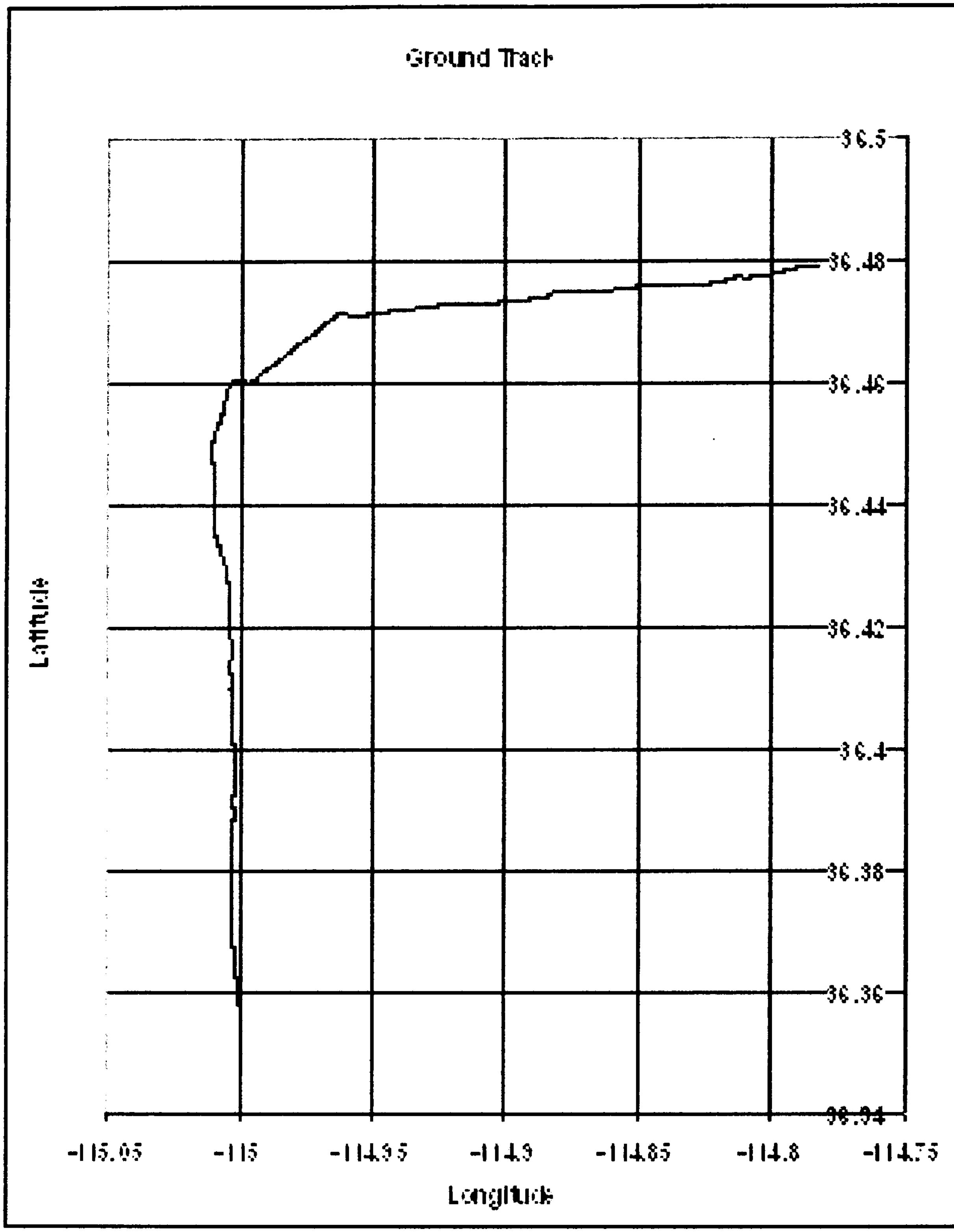


Fig. 1.2: Actual Ground Track (Team 100) (rt3+ep)



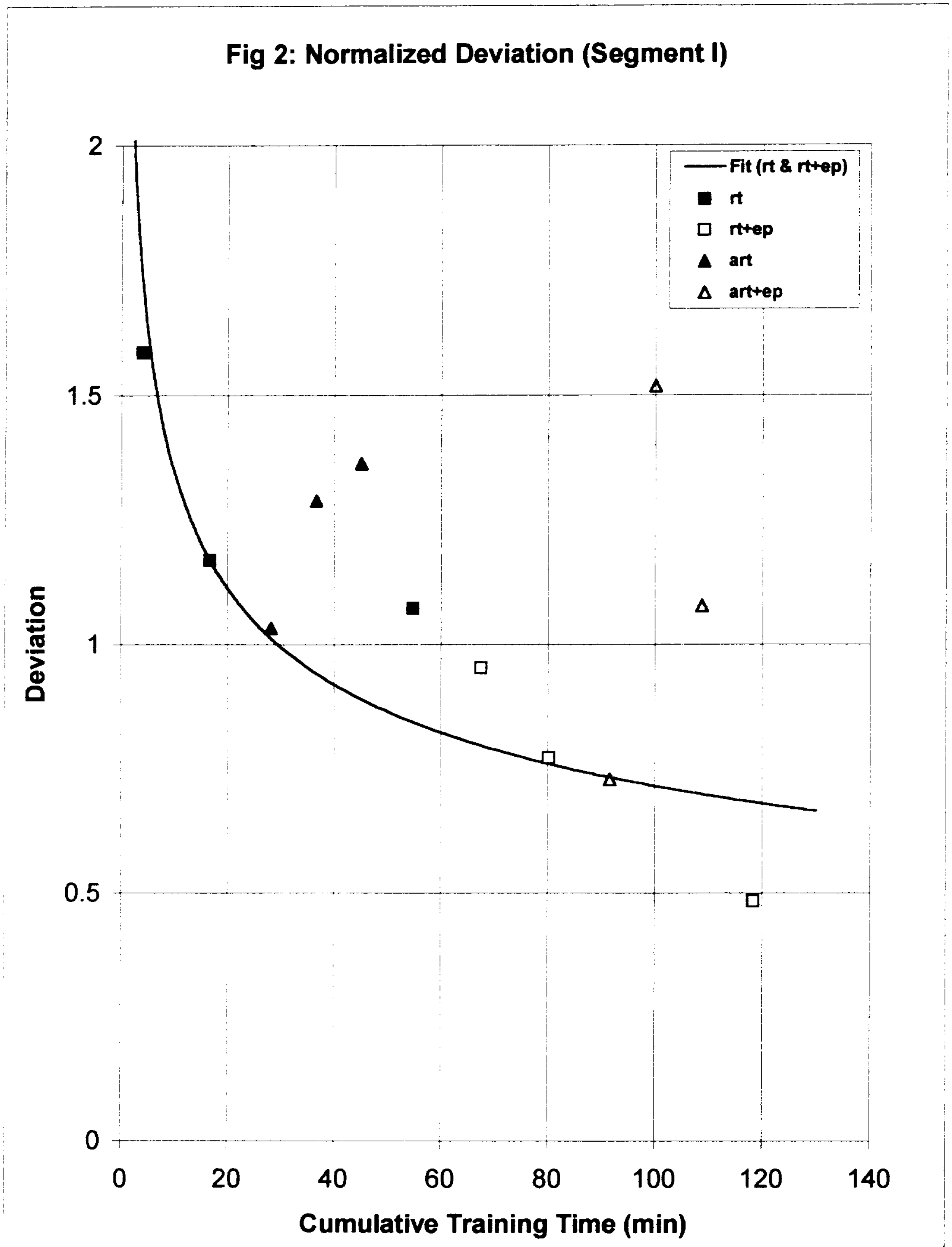


Fig 2: Normalized Deviation (Segment I)
Fit (rt & rt+ep)
rt
rt+ep
art
art+ep
Deviation
2
1.5
1
0.5
0
0
20
40
60
80
100
120
140
Cumulative Training Time (min)

Fig 3: Normalized Deviation (Segment II)

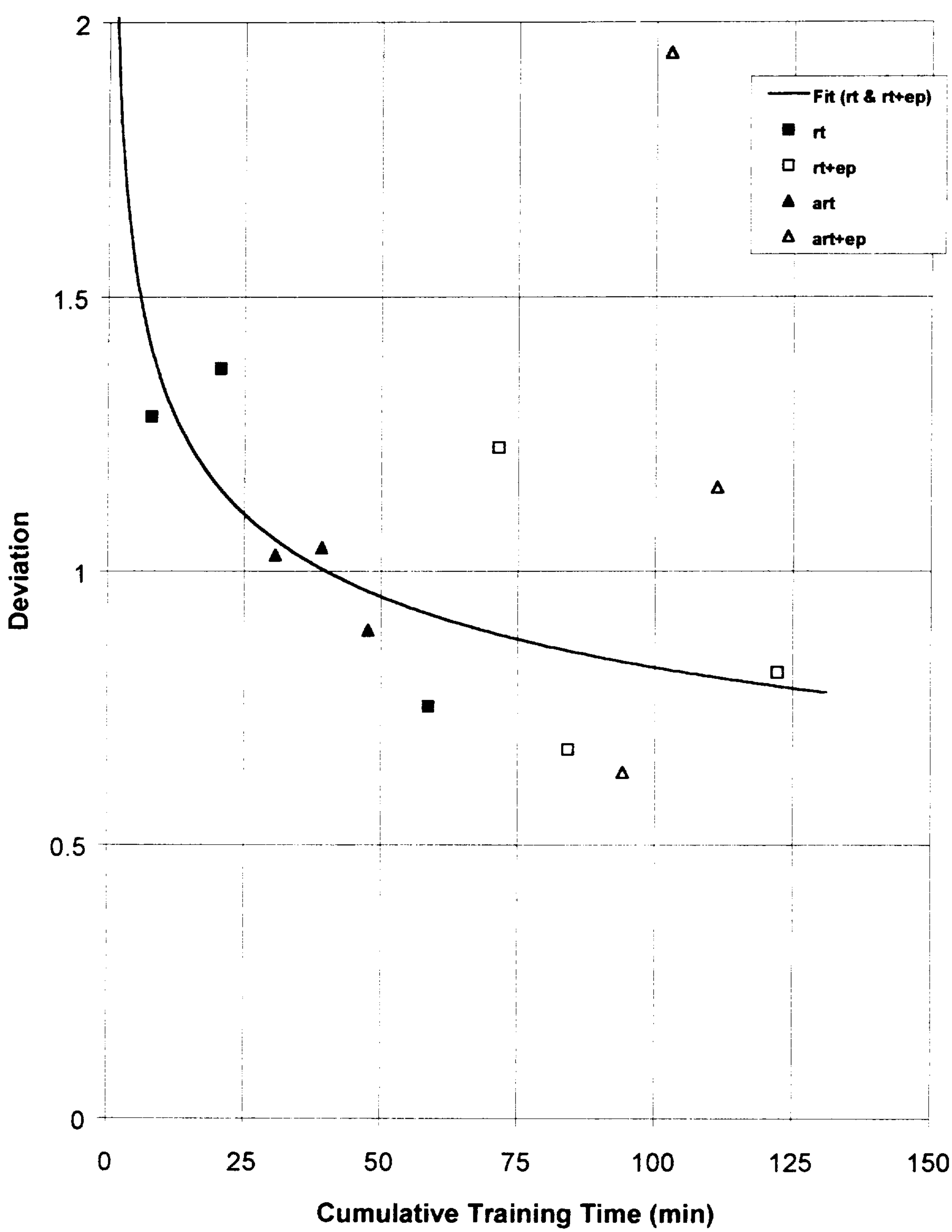


Fig 4: Normalized Deviation (Segment III)

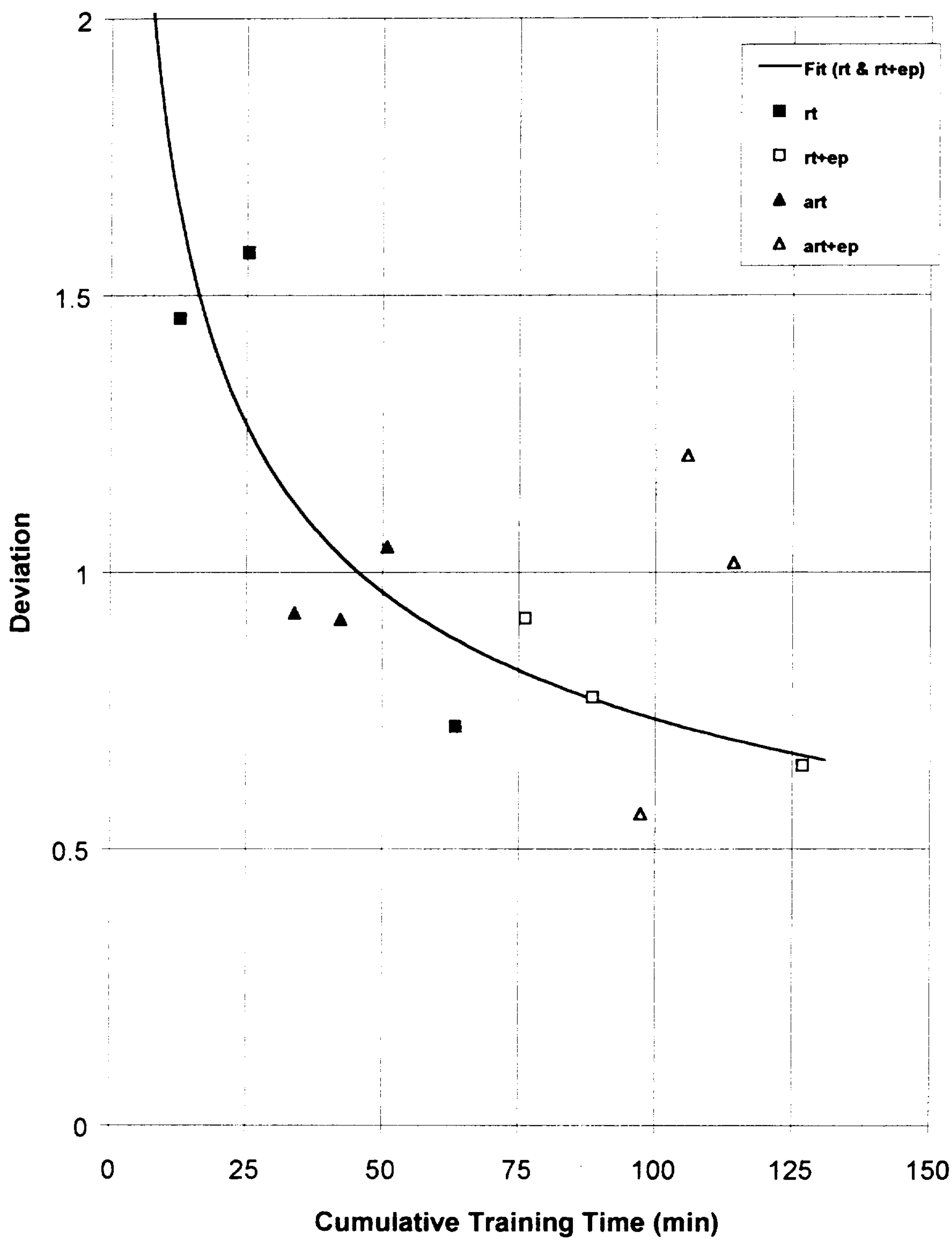


Table 1.1: Typical Ground Track

	rt1	
Time (sec)	lat	long
1	36.35739	-115
20	36.36768	-114.999
40	36.37819	-114.999
60	36.38708	-114.999
80	36.39558	-114.998
100	36.40423	-114.998
120	36.41266	-114.998
140	36.42127	-114.998
160	36.42939	-114.998
180	36.43782	-114.999
200	36.44872	-114.999
220	36.45987	-114.998
240	36.4688	-114.997
260	36.47343	-114.992
280	36.47392	-114.981
300	36.47372	-114.971
320	36.47354	-114.96
340	36.47329	-114.949
360	36.47299	-114.939
380	36.47256	-114.928
400	36.47221	-114.918
420	36.47202	-114.907
440	36.4718	-114.896
460	36.47169	-114.886
480	36.47171	-114.876
500	36.47159	-114.865
520	36.47149	-114.855
540	36.47134	-114.845
560	36.47107	-114.834
580	36.4706	-114.823
600	36.47016	-114.812
620	36.46995	-114.802
640	36.47008	-114.791
660	36.47045	-114.781
680	36.47451	-114.789
700	36.47484	-114.802
720	36.47743	-114.811
740	36.48141	-114.819
760	36.48584	-114.828

Table 1.2: Extract of Typical Output Data File

Time (sec)	speed (Kts)	speed (ft/s)	Altitude	Longitude	Latitude
0	79.54039	134.2465	4936.48936	-115	36.35728
1	78.20892	131.9993	4940.07778	-115	36.35765
2	77.2297	130.3466	4942.91095	-115	36.35801
3	76.25871	128.7077	4946.91436	-115	36.35837
4	75.21255	126.9421	4951.86698	-115	36.35873
5	74.12144	125.1005	4957.24427	-115	36.35908
6	73.03917	123.2739	4962.62911	-115	36.35942
7	72.85452	122.9622	4967.47484	-115	36.35977
8	74.41208	125.5911	4972.92897	-115	36.36011
9	76.63115	129.3364	4980.57978	-115	36.36047
10	79.16042	133.6052	4989.23637	-114.999	36.36083
11	81.13958	136.9456	4997.64276	-114.999	36.36121
12	81.03129	136.7628	5006.14745	-114.999	36.36159
13	80.40093	135.6989	5013.35181	-114.999	36.36197
14	80.1935	135.3488	5015.85315	-114.999	36.36234
15	80.5798	136.0008	5014.10339	-114.999	36.36271
16	81.8145	138.0847	5014.28629	-114.999	36.36309
17	83.28627	140.5687	5020.18298	-115	36.36348
18	85.24776	143.8793	5026.5269	-115	36.36388
19	87.7321	148.0723	5029.15853	-115	36.36429
20	89.46387	150.9951	5028.46125	-115	36.36471

Table 2.1: Average Deviation for Segment I (0-240 sec)

Flight name	Team 100	Team 200	Team 300	Team 500	Team 600
rt1	2277.415	7767.075	10337.18	1940.718	8642.352
rt2	704.3425	5964.535	7889.068		6640.617
art1	1100.835	3349.6.4	7623.74	3358.089	2251.113
art2	4029.808	1514.103		3754.901	2180.892
art3	395.3555	6073.092	11413.67	3622.604	4972.334
rt3	276.1533	3730.788	10228.17	3291.579	2896.179
rt1ep	2500.342	981.489	380.836	1800.414	11032.54
rt2ep	2892.705	1457.832	1305.102	1932.806	2781.67
art1ep	2499.495	1301.915	1376.574	2274.307	2013.264
art2ep	4508.531	3939.855	2896.611	2422.925	11417.19
art3ep	4363.369	5294.001	2135.137	1609.058	1075.452
rt3ep	1526.326	3496.132	1057.885	471.251	925.414

Table 2.2: Average Deviation for Segment II (240-480 sec)

Flight name	Team 100	Team 200	Team 300	Team 500	Team 600
rt1	9580.057	10769.6	22081.93	3722.559	16287.96
rt2	11906.73	10053.41	17572.05		18989.3
art1	1969.19	12614.36	17842.77	5179.307	7094.58
art2	2339.607	8602.868		8582.292	6240.89
art3	1688.115	7622.488	19297.25	4414.442	9218.213
rt3	5768.135	5030.261	14060.53	3432.455	5813.33
rt1ep	5451.589	5047.728		3614.222	38666.21
rt2ep	6389.937	6809.758	5498.21	3232.033	5280.607
art1ep	5460.577	5764.732	6097.89	3741.674	3453.97
art2ep	9923.755	13636.79	8182.122	16037.44	26053.81
art3ep	7311.17	11103.77	2763.467	7157.854	18051.82
rt3ep	7225.734	5477.904	8943.863	4958.416	6299.178

Table 2.3: Average Deviation for Segment III (480-760 sec)

Flight name	Team 100	Team 200	Team 300	Team 500	Team 600
rt1	10822.81	23238.4	32465.06	11391.23	25552.58
rt2	16254.48	13054.68	37266.07		40800.35
art1	5029.034	13043.84	19916.77	10595.73	14311.86
art2	5138.335	11718.24		7458.931	27649.2
art3	4880.578	14520.43	25429.51	9233.194	24541.76
rt3	9321.92	6881.636	13565.4	5701.519	14284.21
rt1ep	5044.635	4315.746		5954.791	48896.99
rt2ep	7504.903	17694.68	7454.758	6963.954	6341.313
art1ep	5038.086	8414.613	5759.43	7345.502	6932.383
art2ep	18993.63	10301.23	8350.967		37651.1
art3ep	12050.33	14586.38	4307.722	9609.336	
rt3ep	5762.935	6575.894	11625.81	6432.567	15695.15