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INTRA-CREW COMMUNICATION OF B-52 AND KC-135 STUDENT AND COMBAT CREWS DURING SELECTED MISSION SEGMENTS

MAURICE SISKEL, JR.
FRANCIS D. LANE
WILLIAM E. POWE
RALPH E. FLEXMAN

BELL AEROSYSTEMS COMPANY

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BEHAVIORAL SCIENCES LABORATORY
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FOREWORD

This research was accomplished by Bell Aerosystems Company of Buffalo, New York, as a portion of the work under Contract AF 33(616)-7681 with the Behavioral Sciences Laboratory, Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio. The work was accomplished during the period May 1963 to January 1964. The principal investigator for Bell Aerosystems Co. was Mr. Ralph E. Flexman. The contract was initiated and monitored by Theodore E. Cotterman, PhD in support of Project 1710, "Training, Personnel, and Psychological Stress Aspects of Bioastronautics," Task 171003, "Human Factors in the Design of Systems for Operator Training and Evaluation."

Grateful appreciation is expressed to the Staff and Crews of the 328th, 329th, and 330th Bombardment Squadrons (BS) and the 94th and 924th Air Refueling Squadrons (ARS), 93rd Bombardment Wing (H) (SAC), Castle Air Force Base, California. This work could not have been completed without their direct assistance and cooperation.

This technical report has been reviewed and is approved.

WALTER F. GRETHER, PhD
Technical Director
Behavioral Sciences Laboratory

ABSTRACT

An experiment was carried out to compare within-crew communications in B-52 and KC-135 aircraft during peacetime training flights as functions of crew experience and selected mission segments. Crew transmission and message rates were obtained from tape recordings of crew communications on the aircraft interphone system during takeoffs and bomb runs in the bomber and takeoffs and air refuelings in the tanker. In each case, samples were obtained from student crew solo missions and from the combat crew training missions. On the basis of earlier work, it was hypothesized that as a result of their lower level of coordination, the less experienced student crews would have a higher rate of communication than the more experienced combat crews. In two of the comparisons, this hypothesis was confirmed while in two others it was not. Because none of the differences were statistically significant, the results were discussed in terms of the trends which were indicated and several unavoidable compromises in experimental control.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
METHOD	4
Subjects	4
Equipment	4
Missions	5
Procedures	6
RESULTS	6
DISCUSSION	19
REFERENCES	22

LIST OF ILLUSTRATIONS

Figure		Page
1	Average Number of Transmissions and Message Units for Crews and Individual Crew Members During the B-52 Take-off	8
2	Average Number of Transmissions and Message Units for Crews and Individual Crew Members During the B-52 Bomb Run	10
3	Average Number of Transmissions and Message Units for Crews and Individual Crew Members During the KC-135 Take-off	11
4	Average Number of Transmissions and Message Units for Crews and Individual Crew Members During the KC-135 Air Refueling	13
5	Average Number of Transmissions for the In-flight and Integrated Simulator Crews and Individual Crew Members During the B-52 Bomb Runs	17
6	Average Number of Message Units for the In-flight and Integrated Simulator Crews and Individual Crew Members During the B-52 Bomb Runs	18

LIST OF TABLES

Table		Page
I	Summary of Range and Variability of Transmission and Message Rates for B-52 Combat and Student Crews on Two Mission Segments	15
II	Summary of Range and Variability of Transmission and Message Rates for KC-135 Combat and Student Crews on Two Mission Segments	16

INTRA-CREW COMMUNICATION OF B-52 AND KC-135 STUDENT AND COMBAT CREWS DURING SELECTED MISSION SEGMENTS

I. INTRODUCTION

The continuous improvement of the bomber crew capabilities has been a problem of increasing significance to military and scientific personnel since the early years of World War II. Experience gained during and since that conflict has demonstrated that in complex aircraft there can be little assurance that individual crew members will combine spontaneously into highly effective combat crews even though the individuals had attained a high level of proficiency in tasks associated with their respective crew stations. Other factors such as the ability to combine their individual skills, to anticipate each others needs, and to communicate effectively appeared crucial to the overall performance of whole crews. These factors, believed to influence the extent to which a crew could work together as an effective unit, led to the concept of crew coordination. As used here, this concept refers to the collective skills of crew members to interact efficiently and thereby combine their individual efforts into an effective crew effort.

Much of the earlier research aimed at improving the capabilities of bomber crews began during World War II and was directed toward the identification and evaluation of new procedures and criteria for crew member selection and crew composition. In addition to the development of selection and composition procedures, several other aspects of small group or crew behavior such as attitudes, personality variables, and leadership behavior were investigated to assess their influence upon the performance of combat crews. Although these efforts resulted in many useful insights into the functioning of task-oriented groups, most of the findings can not directly applied to the solution of current military problems. One major disadvantage arose from the fact that frequently changing manpower requirements often precluded the application of complex selection procedures.

Relatively recent research has been directed more toward the identification of performance variables which reflect the proficiency of combat crews, and toward determination of better training methods which can be used to improve crew coordination. A significant accomplishment of these efforts was the construction of a B-52 integrated simulator facility which provides not only a better means for carrying out crew research, but also a means for conducting whole-crew training in a simulator.

The most recent use of the integrated simulator was an evaluation of the facility as a means for improving the proficiency of experienced B-52 crews (Reference 1). The results of this work showed clearly that even experienced crews benefited from practicing EWO-type sorties in the integrated simulator. They further indicated the existence of an inverse relationship between the rate of within crew communications and crew proficiency as measured in terms of other performance measures. During the study, extensive recordings were made of the interphone communications of crews as they "flew" the EWO-type sorties in the simulator. The recordings were analysed in terms of the number of transmissions per minute and the number and kinds of messages transmitted per minute during bomb runs of about 30 minutes duration. At the same time, the execution of each bomb run by these crews was scored in terms of 16 objective performance measures. Bomb run performance by these experienced crews improved markedly over a sequence of four simulator sorties and concommitant decline was observed in the communication measures. Also, when the performance of these crews on their fourth sortie was compared with the performance of a control group of experienced crews flying the same sortie (but without prior integrated training), the crews with prior integrated training performed significantly better than the control crews and, again, an inverse relationship existed between communications and the other objective performance scores.

These results appeared to be accounted for best in terms of training or practice effects and suggested the possibility of using this inverse relationship between communications and performance as a measure of crew proficiency in both training and operational environments. The development of such a measure is of particular importance in that objective measures that are indicative of the true level of proficiency are not easily obtained at the present time. Consequently, group performance is usually rated on the basis of composite score of individual performance or instructor rating of the overall group. While such measures may have been useful for relatively simple systems, the complexity of modern weapon systems has created the need for an objective measure of crew performance which is easy to obtain and interpret and which at the same time has a high degree of validity and reliability.

The purpose of this study, therefore, is to further investigate the communication process of military aircrews and to determine if an inverse relationship exists between communication and performance of crews in different types of aircraft while performing different tasks. Specifically, it was intended to compare the communications rates of crews which have different levels of experiences in B-52 and KC-135 aircraft during segments of missions which are representative of normal peace time training flights and are a close approximation of the type of activities these crews would engage in during a period of hostility.

On the basis of the earlier work, it would be anticipated that the more experienced crews in both types of aircraft would have a lower communications rate, both in terms of transmissions and messages, than the less experienced crews.

II. METHOD

A. SUBJECT

A total of 21 crews from the 93rd Bomb Wing at Castle Air Force Base, California, were used as subjects in this study. The experienced crews were all a part of the SAC Alert Force and consisted of six B-52 combat crews from the 330th BS and five KC-135 combat crews from the 93rd ARS. The less experienced crews consisted of five B-52 student crews from the 328th and 329th BS and five KC-135 student crews from the 924th ARS. All student crews were undergoing B-52 or KC-135 transition training.

Participation by both the combat and student crews was on a purely voluntary basis. Potential crews were chosen on the basis of availability from the B-52 and KC-135 flying schedule published weekly by the 93rd BW at Castle. Following the selection of a potential crew, the aircraft commander was contacted and arrangements were made with him for the Experimenters to brief the entire crew. The crew briefing, usually held the day before the flight, consisted of an explanation of the background to the study and the purpose for which it was being conducted. The briefing was held in an informal manner and a strong effort was made to gain the crew's confidence and cooperation. It was pointed out to the crew that participation was voluntary and that refusal would in no way be held against them either individually or as a crew. They were further assured that if they did participate, the recordings would be used only as a source of data for the study and, in the subsequent use of the data, the crew identity would be kept anonymous. None of the crews so approached refused to participate.

B. EQUIPMENT

Two UHER (Model 4000 "Report") magnetic tape recorders were employed to obtain recordings of all crew interactions on the aircraft intercommunications system during each mission. The recorders were placed in a convenient but secure place aboard the aircraft and connected to the interphone system by a standard connection cable (USK-666) modified to fit the aircraft interphone system. Power for the recorder was supplied from the aircraft 115V AC, 400 cycle power system by use of a transformer-rectifier power supply unit (UHER Model 880). On some missions, a voice-operated switch (UHER Model 817) was used in order to actuate the recorder only during speech transmissions on the interphone system. Also, a UHER (Model 606) microphone was used by the Experimenters to record notes during the course of the missions.

C. MISSIONS

The mission flown by each of the crews was dependent upon the type of aircraft involved and the experience level of the crews. An attempt was made to choose missions which would assure a high degree of similarity in the tasks required of all crews within each group. For this purpose, a standard combat crew training mission was chosen for the B-52 and KC-135 combat crews and the crew solo mission for the B-52 and KC-135 student crews.

The B-52 combat crew mission was about 10 hours in duration and included a "buddy" takeoff from Castle Air Force Base, a "buddy" air refueling, one or two navigation legs, and several high and low altitude bomb runs on a radar bomb scoring site at Winslow, New Mexico. The KC-135 combat crew mission usually lasted 6 hours and included a "buddy" takeoff and air refueling, and one or two navigation legs. In both cases, the aircraft returned to Castle Air Force Base and completed airwork and jet penetrations in the local area for an hour or more before terminating their missions.

The student solo mission is the last or next to last mission flown as students and the first or second mission flown without instructors aboard the aircraft. The B-52 solo mission usually lasted 4 to 5 hours and included a takeoff from Castle Air Force Base, an air refueling, a navigation leg, and one or two bomb runs at various radar bomb scoring sites in California. The KC-135 student solo mission normally lasted 3 or 4 hours and included a takeoff from Castle Air Force Base, an air refueling, and a short navigation leg. All missions terminated at Castle Air Force Base.

The mission segments chosen for analysis in this study consisted of the Takeoff and Bomb Run for the B-52 combat and student crews and the Takeoff and Air Refueling for the KC-135 combat and student crews. These mission segments were chosen for four reasons: (1) the tasks required within each segment are relatively invariant from flight to flight, (2) each segment has the greatest potential for interaction between the crew members, (3) each segment requires the maximum coordination between crew members for its successful completion, and (4) they are representative of the types of activities which the crews would perform during a period of hostility.

The takeoff segment for both the B-52's and KC-135's began when the Start Engine checklist was begun by the pilots and terminated at the takeoff roll of the aircraft onto the runway. The air refueling commenced when the tanker crossed the Air Refueling Control Point and terminated at the End Air Refueling. The High Altitude Bomb Runs began at the Pre-Initial Point (or Initial Point if no PIP was used) to the bomb release time. The time required by the combat crews to complete each segment was recorded by the Experimenters aboard the aircraft and placed directly on the transmission tape through the use of a microphone. In the case of the student crews, the time required to complete each segment was calculated by timing the recording tape after the aircraft returned to its base.

It should be noted that the B-52 has a six-man crew consisting of a Pilot, Copilot, Navigator, Radar Navigator, EW Officer, and a Tail Gunner while the KC-135 crew is a four-man crew consisting of a Pilot, Copilot, Navigator, and Boom Operator. In addition to the regular crew members listed above, a member of the ground crew was also on the interphone during the first part of the Takeoff segment of each mission. This, in essence, adds an additional crew member during part of this segment which was not present during the second segment of each flight.

D. PROCEDURES

In the process of data collection, two procedures were used. For the combat crews, the Experimenters flew with the crews and operated the recorder throughout the flight. During these flights, a voice-operated relay was used which permitted the recorder to run only when a crew member made use of the interphone. The recorder was started shortly before the Start Engine checklist was read by the pilots and remained on throughout the flight. Time references were placed directly on the tape by the Experimenters through use of a manually operated microphone connected to the recorder. Due to the fact that the Experimenters were not permitted to fly with the student crews, one of the crew members was required to operate the recorder during each flight. The interphone and power connections were the same as used with the combat crews except the voice-operated relay was not used. The Experimenters accompanied the student crews to the aircraft for the purpose of setting up the recorders and to instruct the designated crew member with its operation. The recorder was started by the Experimenter prior to leaving the aircraft and was left running continuously throughout the flight except when the tape was being turned over. The time at which the recorder was started was noted and retained for later timing purposes.

III. RESULTS

The reduction of data provided two measures of within-crew communications on the interphone system: transmission rates and message rates. Transmission rate is the frequency per unit time that discrete usage is made of the system by a crew member, i.e., turn on his microphone, say something, and turn off his microphone. Message rate is the frequency per unit time that a complete thought or idea is expressed on the system. For the purpose of this study, the minute was used as the unit of time in computing all communications rates.

Figure 1 shows the transmission and message rates for the B-52 combat and student crews and individual crew members during the Takeoff segment of their respective missions. The average time to complete the takeoff was 32.4 minutes for the combat crews and 30.4 minutes for the student crews.

In the left panel of Figure 1, it can be observed that the student crews tended to exhibit a higher transmission rate than did the combat crews. In both cases, the pilots and copilots accounted for the majority of the transmission (68% for the combat and 78% for the student) while the other crew members accounted for relatively few. These findings are consistent with what would be expected on the basis of the experience level of the two groups of crews. The more experienced crews made less use of the interphone system than did the student crews during a similar mission segment. In the right panel, it is also apparent that the more experienced crews had a lower message rate than the less experienced student crews. Again, the pilots and copilots account for the greatest proportion of messages in both groups (69% and 82%). It should be noted in connection with Figure 1 that the communications rates of the ground crew are computed on the basis of the total takeoff time for each flight when in fact they were only on the interphone system approximately half this time. The ground crew disconnected from the aircraft just prior to taxiing. Consequently, it was not possible to obtain an accurate estimate of their total time on the interphone system. This time discrepancy, in effect, reduces the ground crews communication rate by approximately one half.

It will be noted in Figure 1 that, although the message rates are consistently higher than the transmission rates, the distribution of the two measures are quite similar for both the crews and individual crew members. While a single transmission can contain one or

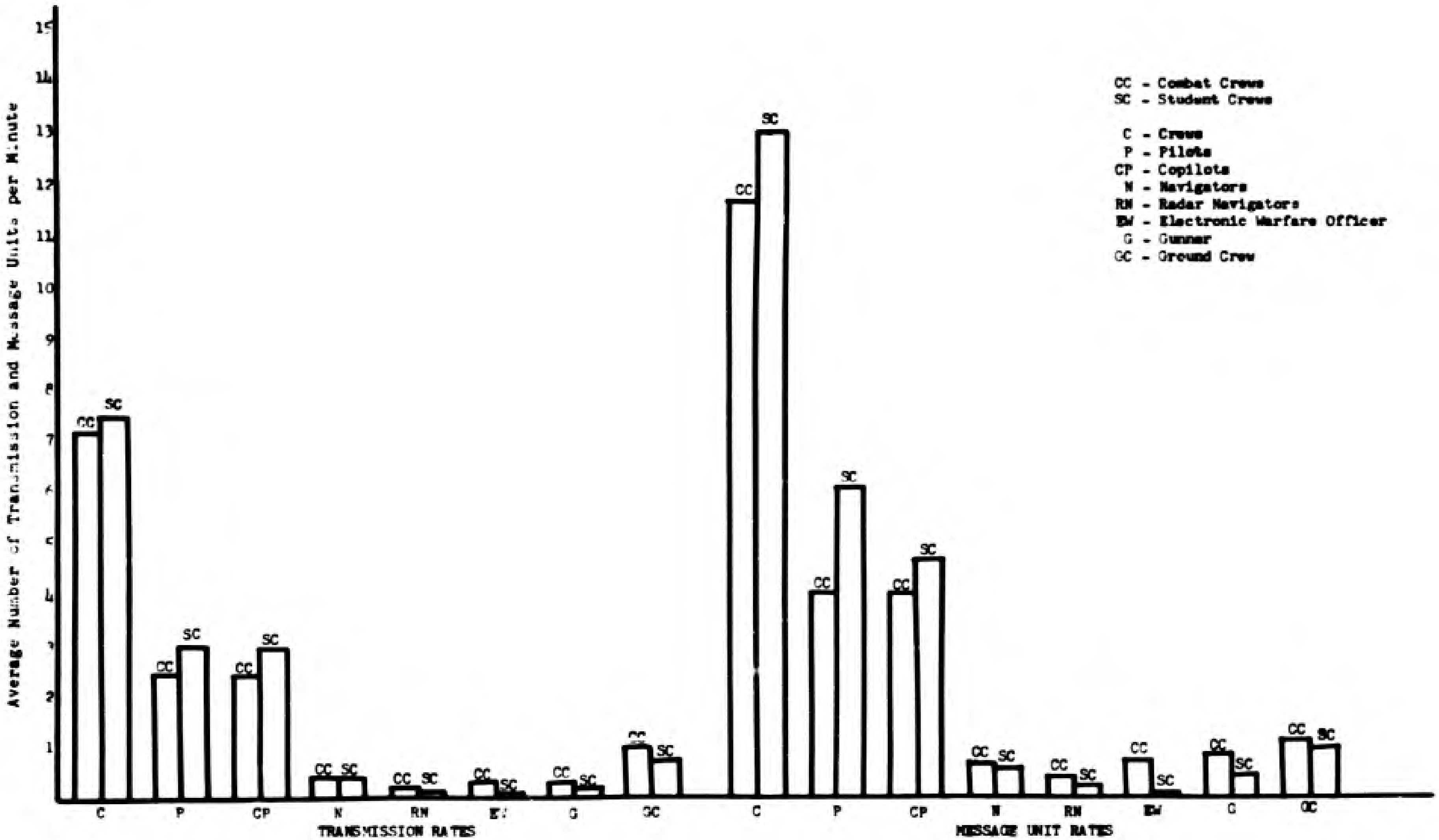

Figure 1. Average Numbers of Transmissions and Message Units Per Minute for Crews and Individual Crew Members during the B-52 Take-off.

more message units, the similarity of the two distributions indicates considerable stability in the number of thoughts or ideas which are expressed within a single transmission for both the crews and individual crew members.

The transmission and message rates in bomber combat and student crews during bomb runs are shown in Figure 2. The average time for the combat and student crews to complete their respective Bomb Runs was 11.5 and 12.8 minutes. It can be seen in the left panel of Figure 2 that the combat crews had a considerably higher transmission rate than did the student crews and that the navigators and radar navigators accounted for the greatest proportion of the transmissions (64% for the combat crews and 54% for the student) while the pilots accounted for 19% of the combat crew transmission and 30% of the student crew transmission. It may be noted also in Figure 2 that in all cases, except the pilots, the combat crew members showed higher transmission rates than the student crew members. These findings are not in accord with what would be expected on the basis of relative experience of the two groups of crews.

The right panel of Figure 2 shows the message rates for the two groups of crews during the same bomb run and again the combat crews showed a higher message rate than the student crews, but the individual crew members maintained the same distribution of message rates as they did transmission rates. As was the case with the transmission rates, the navigators and radar navigators accounted for the majority of the message units (65% for the combat crews and 58% for the student crews) while the pilots accounted for 18% of the combat crew messages and 29% of the student messages.

Figure 3 shows the transmission and message rates for the combat and student crews during the takeoff segment of the tanker missions. These rates are based on a takeoff time of 32.4 minutes for the combat crews and 30.4 minutes for the student crews. The results shown in Figure 3 indicate, as in the case of the B-52 Bomb Runs, that the inverse relationship between crew experience and communication was not realized. As was the case in bomber takeoffs, the pilots and copilots account for most of the transmissions (75% for the combat and 71% for the student crews) and in each case the combat crew pilots and copilots exhibited higher transmission rates than their student crew counterparts. Again, it may be seen that the message rates followed a pattern almost identical to that of transmission rates with the pilots accounting for 74% of the combat crew messages and 71% of the student crew messages.

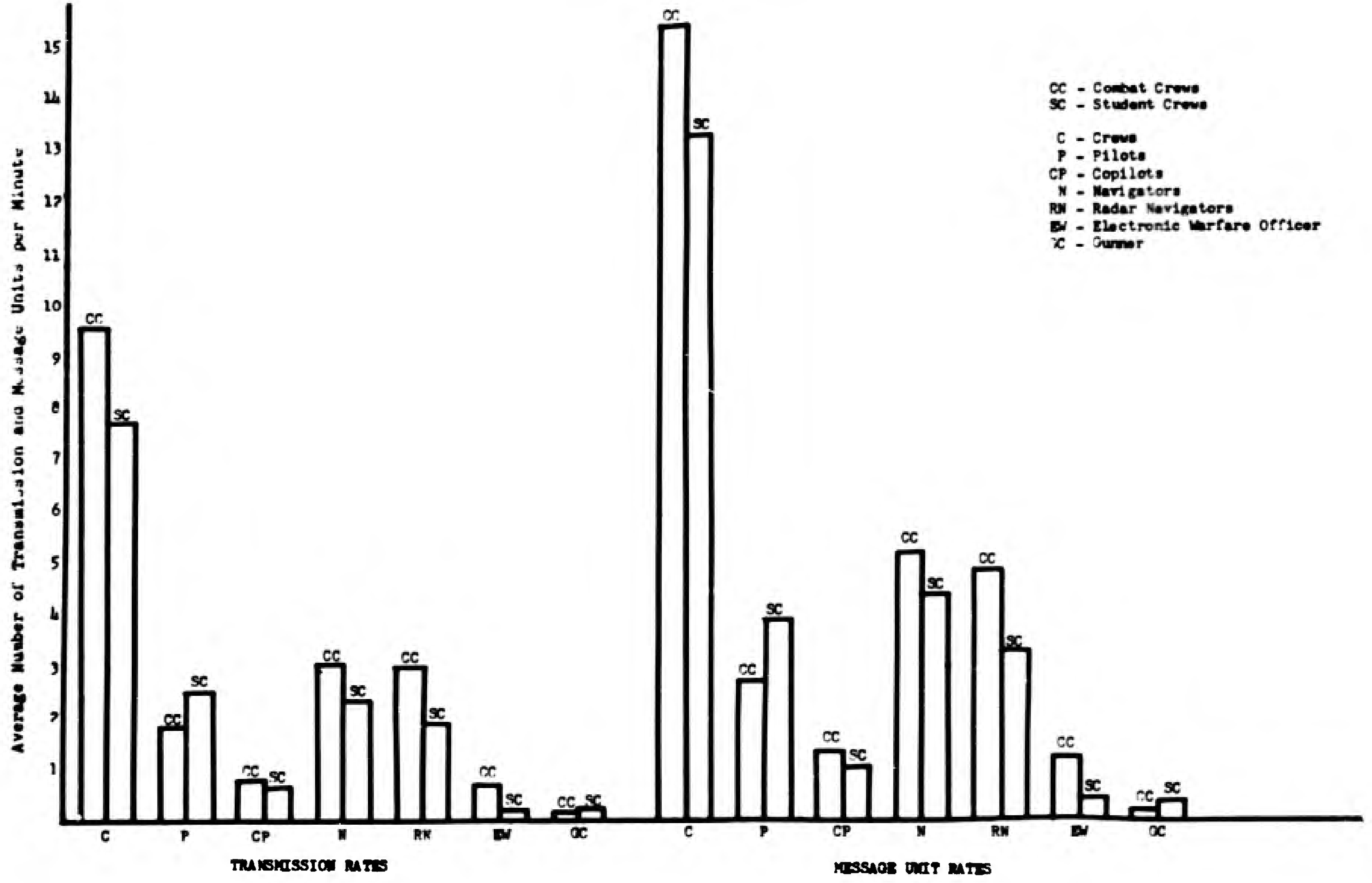

Figure 2. Average Numbers of Transmissions and Message Units Per Minute for Crews and Individual Crew Members during the B-52 Bomb Run.

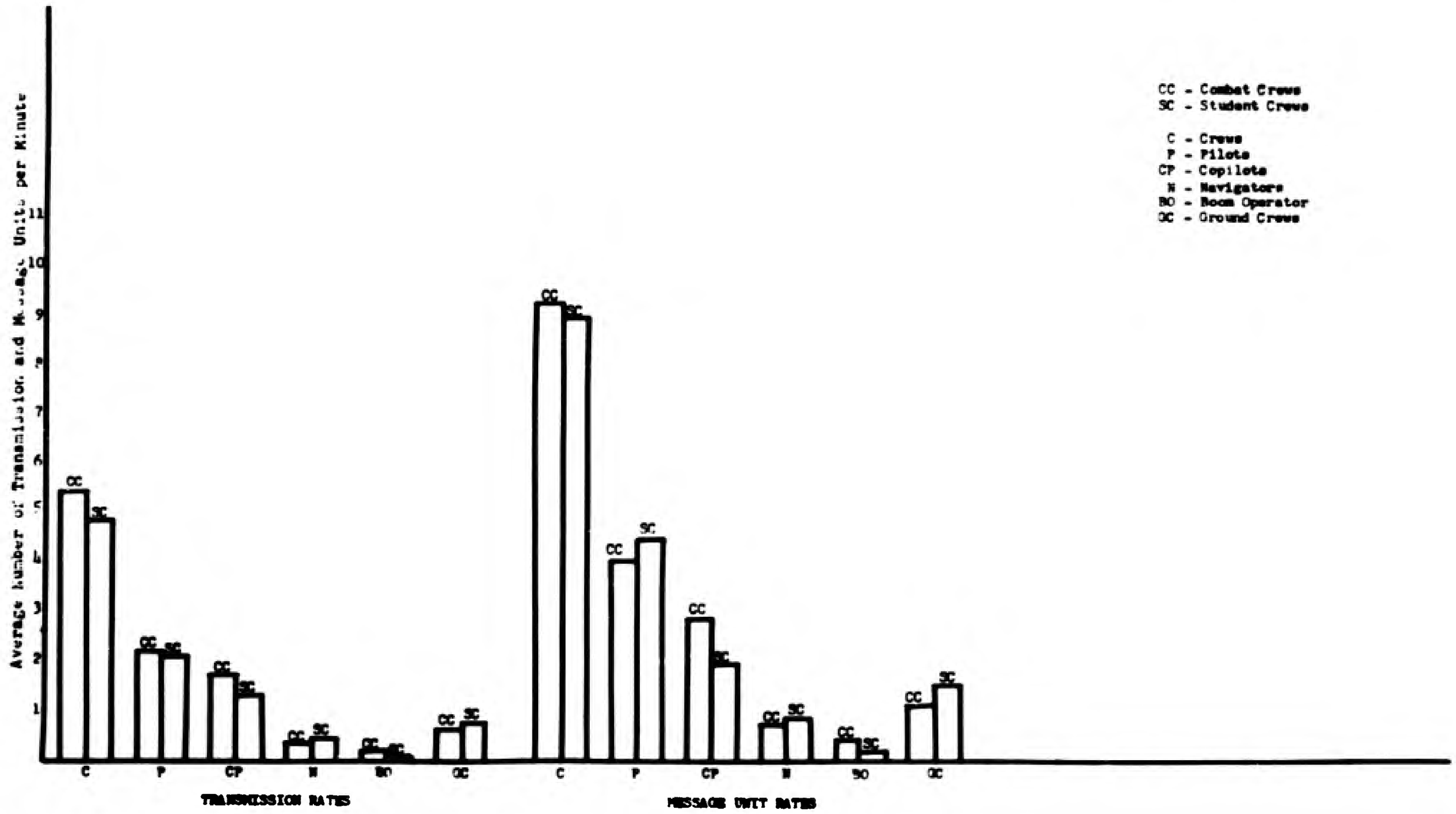

Figure 3. Average Numbers of Transmissions and Message Units Per Minute for Crews and Individual Crew Members during the KC-135 Take-off.

Figure 4 shows transmission and message rates for combat and student crews during the air refueling portion of the tanker missions. The average time required to complete this segment of the mission was 22.2 minutes and 62.6 minutes for the combat and student crews. Of the four segments used in this study, the time required to complete the air refueling portion of the tanker mission showed the greatest variability. The time for combat crews ranged from 11 to 48 minutes and the student crews ranged from 30 to 100 minutes. In Figure 4, it can be seen that the student crews had a higher transmission rate than the combat crews which is in accord with what would be expected on the basis of relative crew experience. Communications during this segment of the mission are confined mostly to estimates by the boom operator of the position of the bomber relative to the tanker or to requests by the pilots for this information. It is of interest to note in Figure 4 that the majority of the combat crew transmissions are accounted for by the boom operators (40%) and 29% are accounted for by the pilots, while this relationship is reversed in the case of the student crews (the boom operators account for only 23% of the transmissions while the pilots account for 40%). In the right panel of Figure 4, the student crews have a higher message rate than the combat crews, but the distribution among the crew members is essentially the same. As in the case with the transmission rates, an inverse relationship exists between the percentage of the messages accounted for by the pilots and boom operators. The pilots account for 20% of the combat crew messages and the boom operators account for 40%, while the student pilots account for 40% of the student message rates and the boom operators 23%.

One additional comparison that can be made on the basis of this data is between the B-52 and KC-135 takeoff for both the combat and student crews. Refering to Figures 1 and 3, it can be seen that both the combat and student B-52 crews made a substantially larger number of transmissions than did their KC-135 counterparts. This same relationship is seen to hold for the number of message units. In making these comparisons, it should be borne in mind that the two type crews differ in size and that the two aircraft differ in operating procedures. Crew size can be compensated for by dividing the crew transmissions and message rates by crew size which yields the average number of transmission per minute per crew member. A similar procedure was used with the message units, but neither resulted in any substantial change in the distributions of the communications measures. While the differences in operating procedures could not be adjusted for, it is reasonable to assume that, since

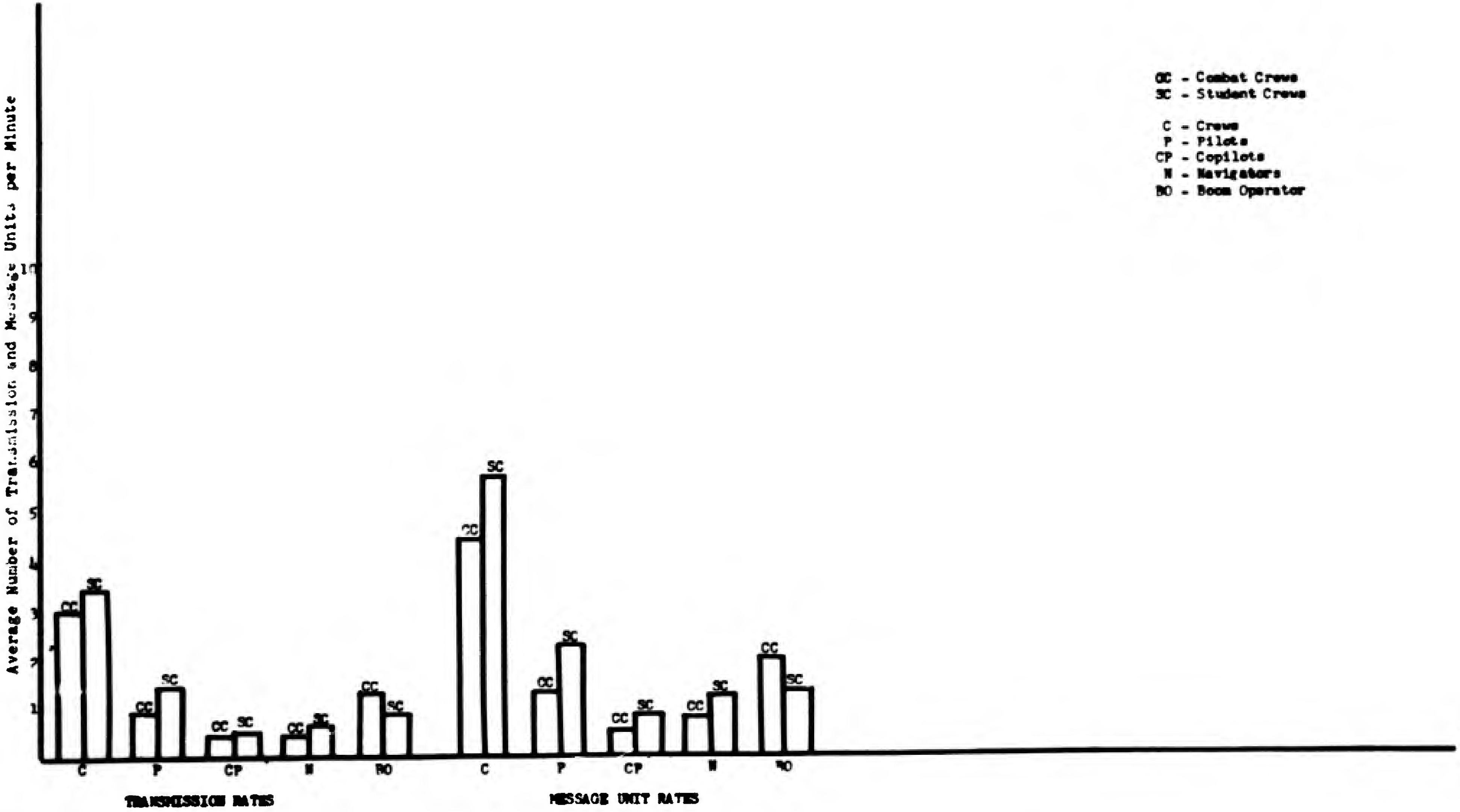

Figure 4. Average Numbers of Transmissions and Message Units Per Minute for Crews and Individual Crew Members during the KC-135 Air Refueling.

the B-52 is a more complex aircraft, the B-52 combat and student crews should require more coordination and consequently a higher communications rate than the KC-135 crews. This relationship can be seen in Figures 1 and 3.

The comparisons shown in Figures 1 through 4 were tested for statistical significance using both parametric (t - tests) and nonparametric (Mann-Whitney U test) methods. None of the results reported above, either for crews or individual crew members, reach significance at the 5% level.

Although some of the comparisons shown in Figures 1 through 4 differ substantially, there was considerable variability and overlap in the distribution of scores. Tables 1 and 2 show the standard deviations and ranges for the combat and student crews and the range for the individual crew members during each segment of the B-52 and KC-135 missions. The mean number of transmissions and message rates for each segment are repeated in Tables 1 and 2 for reference purposes.

It is apparent from an inspection of Tables 1 and 2 that a considerable amount of variability existed in both types of communications measures for the B-52 and KC-135 combat and student crews. In every case, however, the student crews had a higher standard deviation and a greater range than did the combat crews. For the individual crew members, two consistent patterns are apparent: in every case the student pilots had a greater range than did the combat crew pilots and the KC-135 student crew members all had greater ranges during the air refueling than did their combat crew counterparts with the exception of the boom operators' transmission rates.

Another interest of the present study concerns a comparison of the transmission and message rates obtained during the in-flight bomb runs by the combat and student crews and those rates for combat crews during bomb runs in the integrated simulator.

In Figures 5 and 6, the labels "Experimental" and "Control Crews" refer to the two conditions in the integrated simulator study. It will be recalled that an Experimental Group received three practice EWO-type sorties in the integrated simulator and then completed a similar criterion sortie. A Control Group received only conventional training and was then tested by the same criterion sortie in the integrated simulator. The results shown in Figures 5 and 6 are the transmission and message rates respectively for the two groups during the criterion sortie. Since the Electronics Warfare

TABLE I

B-52

TRANSMISSION RATE

		TAKE OFF		BOMB RUN	
		Combat	Student	Combat	Student
Crews	M	7.11	7.43	9.61	7.69
	SD	.61	1.77	3.12	6.60
	R	6.30-7.73	5.11-8.88	7.00-11.56	5.00-10.57
Pilots	M	2.42	2.95	1.84	2.51
	R	2.10-3.10	1.93-3.63	1.22-2.45	1.54-4.50
Copilots	M	2.42	2.91	.78	.56
	R	1.73-2.97	2.04-3.58	.14-1.50	.10-.93
Navigators	M	.43	.43	3.10	2.26
	R	.30- .60	.37- .50	1.42-4.83	1.38-4.00
Radar Nav.	M	.23	.12	3.02	1.90
	R	.07- .50	.03- .34	2.00-3.89	.88-3.43
EW	M	.34	.04	.71	.21
	R	.10- .66	0- .07	.25-1.00	.10- .46
Gunners	M	.31	.24	.6	.24
	R	.13- .73	.13- .39	0- .67	0- .53
Ground Crew	M	.95	.74		
	R	.67-1.87	.25-1.71		

MESSAGE RATE

		TAKE OFF		BOMB RUN	
		Combat	Student	Combat	Student
Crews	M	11.59	12.91	15.49	13.33
	SD	1.24	3.24	3.55	5.26
	R	9.87-12.90	7.89-16.24	10.83-18.67	7.62-20.14
Pilots	M	3.97	6.02	7.76	3.92
	R	2.83-5.27	3.64-7.77	1.89-4.56	2.64-7.30
Copilots	M	4.00	4.59	1.26	.94
	R	2.87-4.77	2.50-5.61	.21-2.58	.10-1.93
Navigators	M	.75	.61	5.16	4.43
	R	.53-1.00	.40- .77	2.42-9.17	1.85-9.57
Radar Nav.	M	.43	.24	4.91	3.30
	R	.23- .77	.07- .58	2.50-6.56	1.94-5.64
EW	M	.66	.06	1.18	.42
	R	.10-1.73	0- .13	.42-1.73	.30- .80
Gunners	M	.81	.42	.21	.35
	R	.30-2.07	.18- .75	0- .78	0- .82
Ground Crew	M	1.22	.99		
	R	.67-1.77	.32-2.87		

SUMMARY OF RANGE AND VARIABILITY OF TRANSMISSION AND MESSAGE RATES FOR B-52 COMBAT AND STUDENT CREWS ON TWO MISSION SEGMENTS

TABLE II

KC-135

TRANSMISSION RATE

		TAKE OFF		AIR REFUELING	
		Combat	Student	Combat	Student
Crews	M	5.49	4.89	3.01	3.36
	SD	1.10	2.40	1.35	1.87
	R	4.70-7.37	2.59-8.90	1.45-5.00	1.12-5.63
Pilots	M	2.29	2.20	.87	1.44
	R	1.93-3.23	1.03-4.20	.18-1.93	.36-2.32
Copilots	M	1.84	1.35	.38	.48
	R	.79-2.82	.19-2.87	.09- .73	.14-1.12
Naviga-tors	M	.40	.53	.44	.64
	R	.14- .60	.37- .63	.29- .60	.35- .83
Boom Oper.	M	.21	.05	1.32	.80
	R	.16- .33	0- .10	.50-2.00	.21-1.51
Ground Crew	M	.74	.82		
	R	.47-1.29	.60-1.23		

MESSAGE RATE

		TAKE OFF		AIR REFUELING	
		Combat	Student	Combat	Student
Crews	M	9.39	9.14	4.53	5.69
	SD	2.48	3.95	1.99	3.21
	R	7.33-13.43	5.53-15.47	2.18-7.40	1.39-9.00
Pilots	M	4.06	4.45	1.30	2.34
	R	3.45-6.00	1.97-5.40	.09-2.60	.41-4.60
Copilots	M	2.93	2.03	.50	.81
	R	1.14-4.73	.57-4.57	.09-1.13	.22-1.83
Naviga-tors	M	.69	.92	.77	1.23
	R	.26-1.27	.53-1.16	.50-1.07	.42-1.77
Boom Oper.	M	.48	.16	1.95	1.32
	R	.20- .70	.06- .30	1.36-3.20	.33-2.21
Ground Crew	M	1.22	1.61		
	R	.83-1.86	.87-2.47		

SUMMARY OF RANGE AND VARIABILITY OF TRANSMISSION AND MESSAGE RATES FOR KC-135 COMBAT AND STUDENT CREWS ON TWO MISSION SEGMENTS

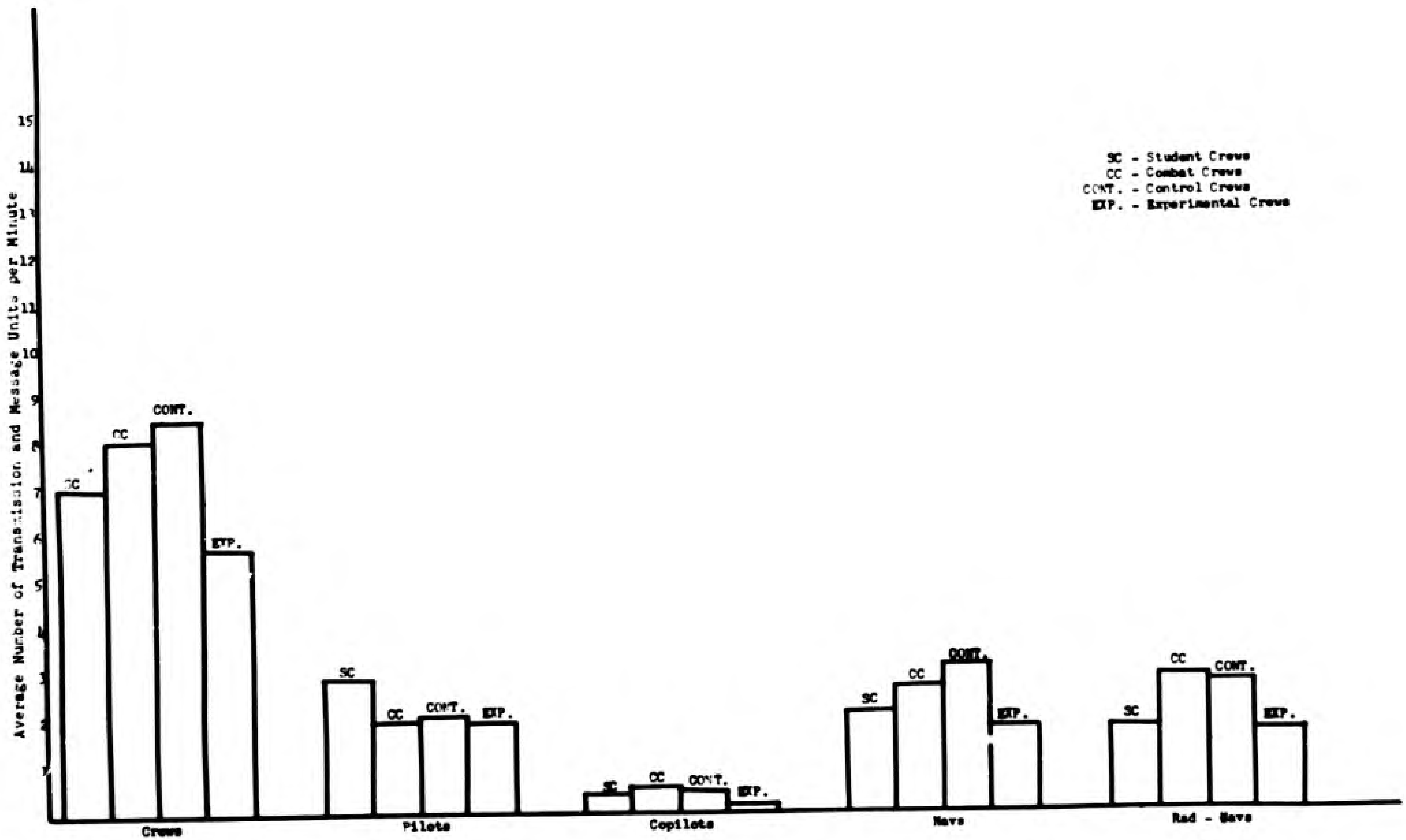

Figure 5. Average Number of Transmissions Per Minute for the In-flight and Integrated Simulator Crews during the B-52 Bomb Runs.

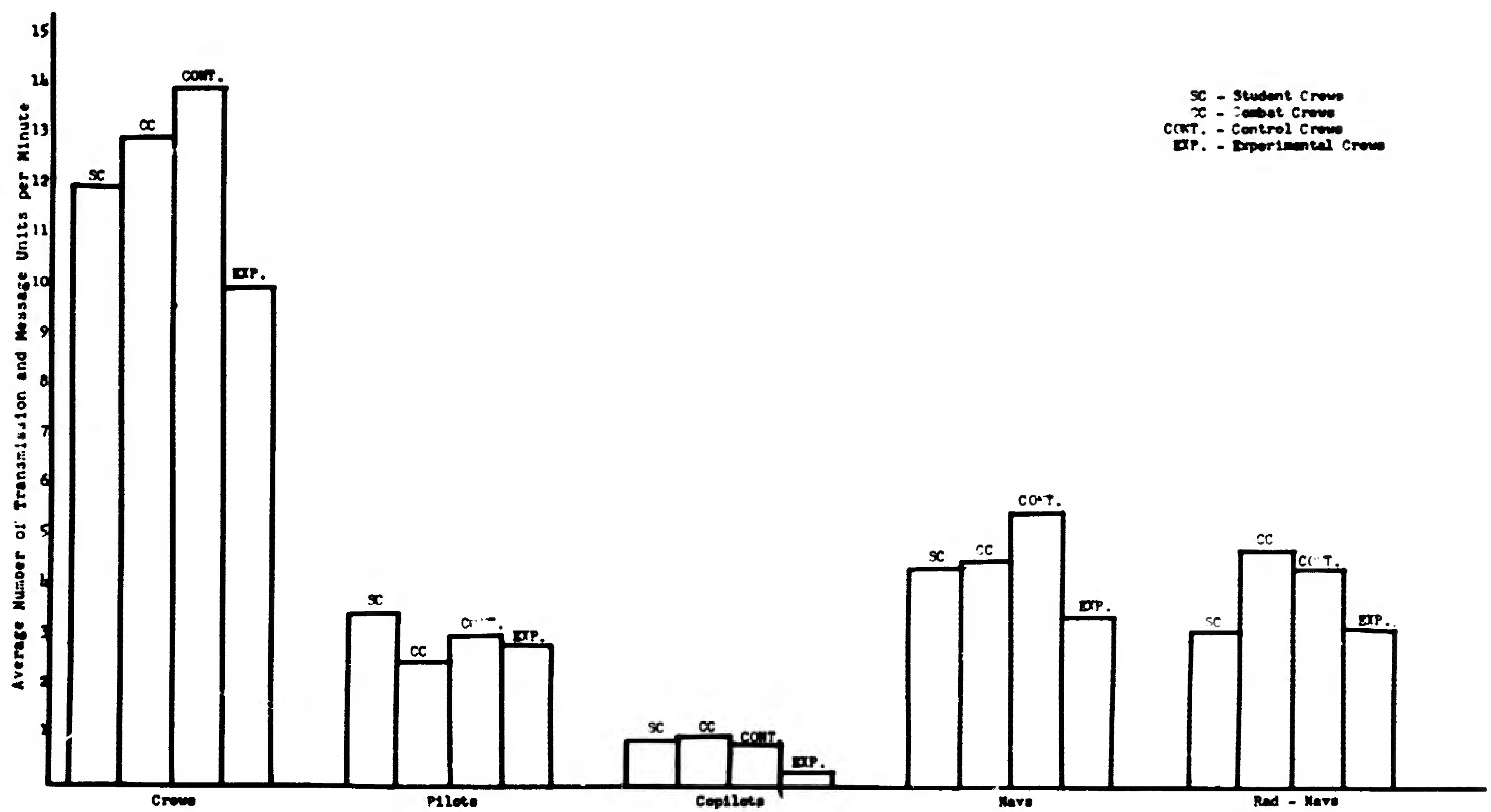

Figure 6. Average Number of Message Units Per Minute for the In-flight and Integrated Simulator Crews during the B-52 Bomb Runs.

officers and the gunners were not included in the integrated simulator study, the transmission and message rates for these two positions were removed from the data of the present study to permit an accurate comparison to be made between the four groups of crews. In Figure 5, it is apparent that considerable variability exists in the transmission rates of the four groups of crews with the Control Group showing the highest rate and the Experimental Group the lowest rate. It is of interest to note in Figure 5 that the shape of the distribution of transmission rates for the four groups of navigators and radar navigators very closely approximates that of the four groups of crews. However, the distribution for the pilots and copilots is substantially different from that of the navigators and radar navigators as well as that of the four groups of crews. These results indicate that, on the Bomb Runs, the crew transmission rates are determined almost completely by the navigators and radar navigators with very little variance accounted for by the pilots and copilots.

Figure 6 shows the message rates for the four groups during their respective bomb runs. As was the case in other comparisons, the crews show higher message rates than transmission rates, but the two measures maintain the same relative distribution among the groups of crews and among individual crew members. The comparisons shown in Figures 5 and 6 were tested for statistical significance. The only comparisons which reached significance at the 5% level of confidence were the transmission and message rates between the integrated simulator Experimental and Control Groups.

IV. DISCUSSION

Although none of the findings compared within this study were statistically significant (with the exception of the differences between the Control and Experimental Groups from the Integrated Simulator Study), the trends indicated by the data do merit further consideration. In all of the comparisons, it was expected that communication rates within student crews would exceed the communication rates within combat crews. The predicted trends actually occurred only during bomber takeoffs and tanker air refuelings: transmission rates of the combat crews exceeded those of the student crews during bomb runs and tanker takeoffs. In the comparisons of in-flight bomb run and integrated simulator bomb run, transmission and message rates were equally equivocal. The rates obtained from actual flights fall in between those obtained in the simulator with the Control Group highest and the Experimental Group the lowest.

A systematic interpretation of these results is hindered somewhat by the absence of a number of control procedures which could not be exercised over the collection of data. The circumstances were such that the data had to be obtained within approximately 60 days and this time period occurred near the end of a six month training period. These restrictions resulted in a number of undesired conditions such as a reduced sample size, inability to exercise adequate selection of missions and crews to assure greater comparable within some groups, and the use of missions during which substitute crew members from other crews were used or the crew member within an intact crew switched positions for upgrading purposes. While all the data was undoubtedly affected by the reduced sample size and some variables had a greater affect on different mission segments than others, it is felt that the results generally represent valid trends in crew communications.

The takeoff is a reasonably well structured situation so the comparisons during this segment should have been relatively unaffected by uncontrolled variables. The majority of the communications during this segment are accounted for by the pilots and copilots and consist to a large extent of reading checklist items between these positions and the ground crew. Of the four comparisons made, all but one, the comparison between the KC-135 combat and student crews, were in the anticipated direction. In the other cases, the B-52 student crews had a higher communications rate than the more experienced combat crews. The B-52 crews all had higher communication rates than their counterparts in the KC-135, which would be accounted for by the somewhat more complex procedure involved in the B-52 takeoff.

The air refueling segment of the KC-135 flight is the least variable of the in-flight mission segments and the least likely to be affected by uncontrolled variance. The communication rates during this segment were in the expected direction with student crews having a higher rate of communications than the combat crews. The majority of the communications during this segment are between the pilots and boom operators and consists of estimates by the boom operators of the distance that the bomber is behind the tanker or requests for this information by the pilots. The reversal in the proportion of the transmissions accounted for by the pilots and boom operators between the combat and student crews suggests that the student crew pilots tended to request information from the boom operator while the combat crew pilots tended to rely on the boom operators to volunteer information.

Of the four mission segments compared in this study, the bomb runs were the most affected by confounding variables listed above. In addition, the bomb runs were also affected by another source of variation which under the circumstances could not be controlled; namely, the difficulty level of the bomb runs. The Experimental and Control Groups in the integrated simulator study completed an EWO type bomb run which was, by far more, the most difficult. In turn, the bomb runs completed by the combat crews were more difficult than those completed by the student crews. It would appear reasonable to anticipate that the more difficult bomb runs would require a greater level of coordination between crew members and, consequently, a higher communication rate. Simultaneously, the more experienced crews would be expected to have a lower rate of communications than the less experienced crews. The results of this study tend to bear out this interpretation. The Experimental crews which had the most difficult bomb runs but which, in addition to being experienced crews, had received special training in the integrated simulator to improve their coordination had the lowest communications rate of the four groups of crews. On the other hand, the Control Group, who also had the most difficult bomb run but did not receive integrated simulator practices, had the highest transmission rate. The combat crews, whose experience level was approximately equal to the Control Group but which had a less difficult bomb run, had a lower transmission than the Control Group but a higher transmission rate than the student crews which were the least experienced group but which also had the easiest bomb run. Thus, to a limited extent, the results of the study tend to bear out the inverse relationship between skill and communications.

Certainly, the most consistent finding of this study is the almost absolute correspondence between transmission rates and message rates. This correspondence indicates that little or no modification occurs in crew member speech habits so far as the number of thoughts or ideas which tend to be expressed within a single transmission. The implication of this relationship is that message rates, as such, yield no information not available from transmission rates. Thus, because transmission rate data are substantially less costly to obtain, an economy in future research on crew communication is possible.

REFERENCES

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