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IMPACT OF AUTOMATION UPON AIR TRAFFIC CONTROL SYSTEM PRODUCTIVITY/CAPACITY (ARTS-III)

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DEPARTMENT OF TRANSPORTATION • UNITED STATES OF AMERICA

Final Report

November 1976

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16. Abstract

This report documents the results of a study to assess the impact of the Automated Radar Terminal System (ARTS III) upon air traffic control system capacity. It is based upon on-site measurements of air traffic activity, controller work pace, controller workload indicators, and staffing at the San Antonio, Texas and San Francisco/Oakland, California TRACONS. Measurements were taken of both the pre-ARTS III and post-ARTS III environments and comparisons made to determine the direction and degree of change attributable to ARTS III. The results indicate that the ARTS III system has reduced controller workload and increased system capacity by 10.5%. A reasonable estimate of the productivity increase is 8.5%.

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METRIC CONVERSION FACTORS

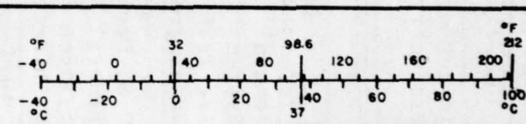
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



EXECUTIVE SUMMARY

This report documents the results of a study conducted to assess the impact of the Automated Radar Terminal System (ARTS III) upon air traffic control system productivity and capacity.

In December of 1972, the FAA Executive Committee directed the Associate Administrator for Engineering and Development, in coordination with the Associate Administrator for Operations, to develop a method for assessing the impact of the agency's automation programs and to validate FAA and/or contractor projections on productivity/capacity increases. A preliminary report, issued in February of 1974, documented the results of a study designed to achieve the stated purpose. The results of that first effort were inconclusive, and it was decided to proceed with a follow-on effort that could provide a more realistic appraisal of the impact of the ARTS III system.

Two sets of data were established to provide a base from which conclusions could be drawn as to the type and degree of impact of automation. The first set contained workload data measured at two TRACONS; San Antonio, Texas (SAT), and San Francisco/Oakland, California (BAY) prior to the implementation of the ARTS III system. The second set of data contained the same type of workload data measured at the same facilities after the ARTS III system had been operational for a reasonable period of time.

The methodology utilized in establishing the data bases included measuring the workload at the various operating/control positions. This was accomplished by identifying workload indicators that could be readily distinguishable and recordable. In addition to the workload indicators, other relevant information was also recorded and utilized in the analysis. This information included traffic volume and distribution, staffing, weather conditions, airport and equipment operational status, and an assessment of the controller's degree of busyness, expressed as a qualitative "pace rating". These "pace ratings" considered workload, stress, complexity, and ranged from very light to very heavy.

Analysis of the data included the comparison of measured workload and traffic activity at specific "pace" levels. These comparisons were made on a position by position basis, comparing the "before" and "after" data sets, to determine the relationships and changes induced by the introduction of the ARTS III system into the air traffic control operation.

The results of the analysis indicate that the ARTS III system has reduced workload in the system and improved productivity and capacity. Equivalent comparisons of the ARTS III and non-ARTS III systems reveal that these two TRACON facilities experienced a 10.5% increase in capacity (i.e., numbers of aircraft handled under an average work pace). A reasonable estimate of the productivity increase is 8.5%. This reflects the degree of influence attributable to ARTS III, by itself, since the only environmental difference between the two sets of data is the introduction of the

ARTS III system into the air traffic control operation. All other pertinent areas remained the same (airspace configuration, operational procedures, letters of agreement, etc.). Some operating position designations were changed, but this was a name change only and had no influence on the operation of the air traffic control system within that particular airspace.

Analysis of individual controller workload indicators compared at the "average" pace level reveals the following:

- In general, the volume of air/ground/air transmissions increased slightly at both locations after the ARTS III system became operational. While verifications of altitude, altitude control instructions, verifications of speed, speed control instructions, etc., had decreased at both locations, traffic advisories and other control instructions (weather and vectors to expedite traffic movement) had increased.
- Interphone activity increased slightly (+2.1%) at SAT after the ARTS III system became operational, but decreased (-12.6%) at BAY. Actions requiring coordination, except for hand-off of aircraft, were responsible for the slight increase of interphone activity at SAT.
- At BAY, coordination activity via interphone increased slightly. However, interphone activity affecting aircraft hand-offs and general information decreased significantly.
- At SAT, flight strip activity and oral communications had increased in volume. This is due to the fact that the SAT data revealed a significant increase in total number of "aircraft minutes"

(duration of aircraft time under actual control) and a significant increase in "peak aircraft" handled (highest number of aircraft under control at any instant).

- At BAY, however, the data reflected a decrease in the flight strip and oral communication activity. This is due to the fact that the total number of "aircraft minutes" and "peak aircraft" had decreased.
- Keypack activity (to initiate/accept aircraft hand-offs; start/drop tracks on aircraft; quick-look, etc.) was a new workload indicator imposed by the ARTS III system. The reflected impact on controller workload is an additional 2.25 activities per 5 minute period.

In general, it is the opinion of the study team that:

1. It is necessary to analyze the impact of the ARTS III system on each specific workload indicator. This methodology identifies those areas that are affected, and to what degree. This approach also provides guidance in the planning of future systems and enhancement packages, identifying areas of concern and areas requiring some measure of improvement.
2. After careful analysis, it is clear that the ARTS III system has increased the productivity and capacity of the terminal operation portion of the air traffic control system. Primary supporting evidence is the fact that, in the ARTS III environment, the air traffic controllers handled a greater number of aircraft at the same work pace than had been previously recorded.

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1. Introduction

1.1 Foreword

This report documents the results of an in-house study conducted from August 1973 through April 1976. The study was directed by the Federal Aviation Administration Executive Committee (EXCOM) and conducted jointly by the FAA's Systems Research and Development Service (SRDS) and the Air Traffic Service (AAT). Air Traffic Service facility personnel, along with National Aviation Facilities Experimental Center (NAFEC) personnel assisted in the data collection and data preparation phases of the project.

The purpose of the study, as identified in the EXCOM directive dated December 1, 1972, was to develop alternative methods to assess the impact of the agency's automation program upon air traffic controller productivity and to validate FAA and/or contractor projections wherever possible. A report was to be prepared and submitted for EXCOM review by January 15, 1973.

1.2 Study Team Organization

The responsibility for organizing and conducting the study was originally assigned to the SRDS Analysis Division, ARD-600, and later to ATC Systems Division, ARD-100. Responsibility for operational support was assigned to the Air Traffic Service's Operations Research Branch (AAT-12), which enlisted additional support from their ATC Systems Program Division (AAT-100). The study team was augmented by air traffic controllers and administrative personnel from the air traffic control facilities visited during the data collection phase of the effort, and by controllers and data reduction personnel from NAFEC.

1.3 Background

The study team presented a Prospectus for determining the impact of automation on air traffic control productivity. The Prospectus was presented to the Director, SRDS, on September 6, 1973. The Prospectus contained various plans (including a contingency plan) for conducting the study. A plan was approved by the Director, SRDS, in coordination with the Director, Air Traffic Service, and the study was implemented immediately.

The study team established a data base by measuring workload at four different air traffic control TRACON facilities. Two of these facilities were operational with ARTS III (Phoenix, Arizona, and Miami, Florida). Two were not ARTS III facilities (San Antonio, Texas, and San Francisco/Oakland, California). This first effort consisted of an operational comparison of the "without ARTS III" data and the "with ARTS III" data. The results of the impact of the automated ARTS III on productivity were influenced by the many variables that existed in the operational differences at the four subject TRACONS. This influence distorted the percentage of change in productivity sufficiently to render the results of the first effort inconclusive. A study report was submitted in February of 1974 and a decision made to limit distribution and consider a follow-on effort. A determination was made in October of 1974 to proceed with the contingency plan contained in the original Prospectus.

2. STUDY APPROACH

2.1 Modification of Workload Indicator Codes

The data base established from pre-ARTS III workload measurements recorded at San Antonio, Texas (SAT), and San Francisco/Oakland, California (BAY), TRACONS was reviewed to ensure completeness and validity. The codes and definitions of the workload indicators were revised, and the number of indicators was reduced to 25 from 33. It was determined that several indicators were either indiscernible, or not utilized, and the codes and definitions were adjusted accordingly. (See Appendix A)

2.2 Workload Data

To completely understand the air traffic control functions and the responsibilities of each operating position, the organization and layout of both subject facilities were studied. To obtain a representative sample of the total facility operation and workload, a determination had to be made as to what and how many operation positions needed to be measured.

San Antonio TRACON has 17 control positions, of which 12 are actual radar control positions. Workload data was recorded at 7 radar control positions that provided the most representative and busiest level of activity.

A total of 128 hours and 55 minutes of workload activity was recorded at these positions. All of the data was recorded in increments of 5 minute samples for analysis. There were a total of 1,547 workload samples recorded at SAT, compared with 1,189 workload samples from the pre-ARTS III data base.

San Francisco/Oakland (BAY) TRACON has 28 control positions, of which 18 are actual radar control positions. Workload data was recorded at 10 radar control positions that were most representative of the facility operation. A total of 175 hours of workload activity was recorded at these positions (or 2,100 workload samples). This compared to 1,369 workload samples from the Pre-ARTS III data base.

3. DATA COLLECTION

An attempt was made to record workload data during the busiest periods for the operating position being measured. Facility logs, sector hourly traffic profiles, air carrier schedules, stored flight plan, etc., were examined to identify periods of peak activity. Additionally, data collection periods were scheduled to utilize any advantage provided by seasonal trends, weather conditions, etc. Operating positions were eliminated for measurement only when the historical data indicated a level of busyness that would not provide meaningful data.

Data was recorded at the operating position by a two-man observation team of air traffic controllers. A "full performance level" controller from the facility, certified to operate the control position being measured, recorded data related to sector workload volume and pace, giving full consideration to complexity and stress. Pace was divided into seven gradients of busyness (See APPENDIX B). The controllers were tested for validity and uniformity of pace rating assignments. In addition to the pace rating assignments, the facility controller recorded data related to facility status, airport runway configuration, traffic flow and distribution, weather, and any other information that may have influenced the pace ratings (See APPENDIX C). The pace ratings were assigned in increments of five minute periods. This time frame was established because of the often short durations that aircraft were in the sector and under the jurisdiction of the controller. Additionally, it was a reasonable retention time span for the pace rater.

The second observation team member was a controller from the FAA's National Aviation Facilities Experimental Center (NAFEC). This observer recorded sector controller activity on a kymograph recorder utilizing the workload indicator codes described in Attachment A. This provided information relative to length of activity in time, each division on the graph representing one second. (See APPENDIX D.)

4. <u>DATA REDUCTION</u>

Workload data from both sets of measurements (before and after ARTS III at San Antonio and San Francisco/Oakland) were coded and keypunched. The data was merged into files and sorted by facility, operating position, and staffing. The primary mathematical techniques involved in the analysis of the numerical data were regression analysis and computation of means and standard deviations. The regression analysis approach was utilized in determining which of the various independent variables of workload and aircraft activity have a significant impact on the work pace of the air traffic controller. Means and standard deviation computations were made in order that comparisons could be made of the effect of automation upon the various workload indicators.

5. DATA ANALYSIS

5.1 Operating Position Designator Changes

Since there were changes in operating position (sector) designations at both TRACONs (See Appendix E) in the ARTS III configuration, it was necessary to assure equivalence of the two sets of data for comparison purposes. The Standard Operating Procudures (SOP's), letters of agreements, and other pertinent information relative to the way the TRACONS conducted business were reviewed to determine that the duties and responsibilities of positions of operation and allocated airspace and functions had not changed. It was determined that the only differences were in name designator only.

5.2 Definitions

Peak Aircraft is the highest instantaneous aircraft count observed during a five minute workload sample.

Aircraft Minutes is the total number of minutes that all aircraft were under juridictional control of the operating position for a workload sample period.

Position (Sector) Flight Time is the average number of minutes that each aircraft was under the jurisdictional control of the operating position.

Aircraft Handled is a measure of aircraft flow rate and is computed by dividing aircraft minutes by Position Flight Time.

5.3 Validation of Pace Ratings

The pace ratings for both "Before" data sets were examined to determine which rating could best serve as an indicator of productivity and capacity. The workload samples were tabulated, and it was determined that the "average" work pace would be suitable. The pace ratings were normalized by setting each operating position's "A" (average) pace rating to one. The peak aircraft handled for all other paces was then expressed as a percentage of the peak aircraft handled at the "A" pace. These values were computed for each position, summarized by facility, and are shown in the following table (TABLE 5-2).

TABLE 5-2
PACE RATING EVALUATIONS (Based on Peak Aircraft)

	Pace Ratings						
Facility	VL	L	A-	A	A+	H	VH
San Antonio	.39	.53	.78	1	1.16	1.53	1.75
Oakland	.36	.54	.76	1	1.18	1.52	-

The above figures support the validity and accuracy of the pace rating techniques utilized at each of the facilities.

5.4 Regression Analysis

Multiple linear regression analysis was used to investigate the degree of significance that each of the workload indicators and aircraft activity variables had upon determining the work pace of the air traffic controller. The initial computer runs utilized all measured values as independent variables, and pace as the dependent variable. Partial correlation coefficients were then examined to determine the closeness of relationship between pace and all other variables. Additional regression runs were then made using only those variables that had some relationship to pace, i.e., a correlation coefficient in excess of 0.50. A summary of the numerical results is contained in Appendix F.

Columns 3 and 5 of Appendix F indicate the percentage of the variation in the dependent variable (pace) that can be attributed to the linear variation of the independent variables. For the "Before" regression runs, sector flight time was input as a constant for each position. Since equivalent aircraft is calculated by dividing aircraft minutes by sector flight time, the equivalent aircraft variable is not linearly independent and could not be included in any regression run that included aircraft minutes. Correlation coefficients for equivalent aircraft would be the same as those for aircraft minutes. A review of the significant variable column in Appendix F indicates that only the traffic variables of equivalent aircraft, aircraft minutes, and peak aircraft are consistently significant for all positions at both locations. In fact, just using these indicators and the regression equations derived, it is possible to predict the controller work pace, within one pace rating, over 80% of the time.

The lack of appreciable correlation between pace and many of the workload indicators is probably due to the nature of the air traffic control process and related environmental factors. That is, during low traffic periods, the controller may occupy himself by giving advisories, checking of speeds and altitudes, or otherwise engaging in "small talk" that does not actually increase his work pace. During high traffic periods, the controller is occupied with the mental processes of traffic planning and sequencing, and many activities, if not absolutely required for conflict resolution or safety, can be omitted or, at least, deferred for some period of time. This changing nature of the controller's activity tends to distort some of the linear relationships that one might normally expect to be revealed by the use of multiple linear regression analysis.

5.5 Comparison of "Average" (A) Pace Data

The "average" (A) pace aircraft activity for each facility was computed for the before ARTS III data and the after ARTS III data. The following table (TABLE 5-3) reflects the hourly aircraft handled at the A pace, by position of operation, at the same staffing, before and after ARTS III.

It is evident from the comparison of the two sets of measurements that there is a definite increase in the controller's ability to handle more aircraft at the same work pace in the ARTS III environment than in the non-ARTS III operation.

TABLE 5-3

SAN FRANCISCO/OAKLAND (BAY) TRACON

OPERATING* POSITION	STAFFING	MEASURED A/C HANDLED PER HOUR AT THE AVERAGE WORK PACE		
		BEFORE ARTS III	AFTER ARTS III	% CHANGE
AR3	1	14.5	16.1	+11
AR4	1	18.0	21.0	+17
AR9	1	26.4	25.9	-2
AR10	1	24.0	28.0	+17
AR1	1	25.6	29.0	+13
AR2	1	24.5	26.0	+7
DR6	1	28.1	23.8	-15
DR2	1.5	31.6	36.5	+16
DR1	1.5	30.8	30.5	-1
DR5	1	27.2	22.3	-18

AVERAGE INCREASE PER OPERATING POSITION = +4.5%

SAN ANTONIO, TEXAS (SAT) TRACON

OPERATING* POSITION	STAFFING	MEASURED A/C HANDLED PER HOUR AT THE AVERAGE WORK PACE		
		BEFORE ARTS III	AFTER ARTS III	% CHANGE
AR-2	1	14.5	16.6	+14
AR-2	1.5	14.3	20.6	+44
AR-3	1	15.5	19.0	+23
AR-3	1.5	18.8	21.0	+12
AR-5	1	12.0	17.3	+44
AR-5	2	15.0	19.7	+31
AR-6	1	27.4	31.9	+16
AR-6	1.5	29.6	34.7	+17
AR-7	1	23.9	18.6	-22
AR-7	1.5	28.9	26.4	-9
DR-1	1	18.4	24.6	+34
DR-1	2	21.8	24.1	+11
DR-3	1	22.4	22.2	-1

AVERAGE INCREASE PER OPERATING POSITION = +16.5%

*"After" position designation

This analysis indicates an average increase in capacity for the two subject TRACONS of 10.5%. There is no doubt that this increase in capacity is attributable to ARTS III alone, since the only difference in the two data sets was the introduction of the ARTS III system itself.

The workload indicators were compared individually in order to determine what impact the ARTS III system may have had on each particular function performed by the air traffic controller. Appendix G clearly depicts the areas or "work functions" performed by the controllers that are affected and to what degree. Additionally, the two sets of data were compared in an attempt to determine what impact the ARTS III system may have had on the manner in which the controller does business or if it altered the manner in which the system now functions. Since, in many instances, the frequency of occurrence of a particular workload indicator is extremely low, it was necessary to group certain indicators into broad categories to be used for comparison purposes. The following paragraphs present the findings for each workload category.

<u>Average Sector Flight Time</u> was reduced at both TRACONS. BAY TRACON data reflects a decrease of 12.8% while SAT TRACON decreased 0.9%. This reduction in average sector flight time was the result of traffic being expedited through the sector because of the readily available altitude and speed information displayed continually in the data block on the radar display, thus requiring less vectoring and other control instructions on the part of the controller. Earlier hand-offs of the

flight information contained in the data block also caused a reduction in the flight time through the sector.

Control Type Messages, transmitted via the air/ground/air facilities increased in frequency at both TRACONS. It is significant to note however, that air/ground/air activities related to speed and altitude control and verification were reduced sharply at both locations. For example, at San Antonio the altitude verification workload indicator was reduced from a five minute average of 9.96 (total of all positions) before ARTS III to 4.87 after ARTS III. At San Francisco/Oakland the corresponding figures are 17.58 and 7.07.(See Appendix F). Speed control instructions were reduced by similar appreciable percentages at both locations. At the same time, other air/ground/air activity, such as vectors to shorten flight paths, weather and traffic advisories, etc., increased at both TRACONS. The indication is that the automated system has reduced the "decision making" workload functions for the controller, thereby increasing his ability to provide additional and better service, resulting in a safer system.

Coordination and Flight Data type workload activity conducted via the interphone system decreased 12.6% at San Francisco/Oakland and increased by 2.1% at San Antonio. Interphone activity related to coordinating and affecting hand-offs of aircraft control from one operating position to another decreased significantly as a result of the automated hand-off feature of the ARTS III system. Transmitting flight data information from position to position was also reduced at both TRACONS since this flight data information is displayed on the radar screen continually (See Appendix G).

Other Communications, such as direct oral and visual coordination requirements were reduced at both TRACONS. This reduction is attributable also to the data block feature presented on the controller's radar display, negating the need to communicate via other means.

Flight Strip activity increased in frequency of occurrence at San Antonio. This activity increased by 17.4%, from 42.49 before ARTS III to 49.91 after ARTS III (total of all positions). This increase was in proportion with the increase in aircraft handled and is, therefore, self explanatory. At San Francisco/Oakland the flight strip workload activity decreased by 5.9% while the equivalent aircraft handled increased by 3.3% (Appendix G). The rate of change at San Francisco/Oakland is not considered significant and any conclusions derived from this information would be speculative.

Equipment Adjustment type activity (changing brilliance, focus or contrast on radar displays, adjusting ambient lighting, background lights, etc.) was reduced from 40% to 50% at both TRACONS. This was quite noticable at both locations, and particularly in view of the normal tendency to experiment or play with new gadgets. Queries regarding this subject at both TRACONS resulted in replies typical of "the equipment is working beautifully, installed and adjusted well, no need to touch it!"

Keypack workload activity is the only indicator where the ARTS III system inflicted a penalty, at both TRACONS. Since this type of controller workload activity was non-existent in the "before ARTS III" operation, it was expected that some increase in workload would be evident. At San Antonio, the workload imposed by this activity represents an average of 2.08 additional controller actions per five minute period. At San Antonio, the figure is 2.43 controller keypack actions per five minute observation period.

6. CAPACITY/PRODUCTIVITY RELATIONSHIPS

As shown earlier, the average increase in capacity for the two subject TRACONS is 10.5%. If one wishes to consider that this represents an additional 10.5% of output (aircraft handled) for the same level of input (staffing), 10.5% can also be thought of as the potential productivity increase. However, in actual practice, this productivity increase cannot be realized since fluctuating demand levels will prevent a control position from continuously operating at capacity.

Realized productivity gains, then, will be somewhat less than 10.5%. This gain could be estimated by referring to the terminal staffing standards contained in Order 1380.33A, raising the staffing break-point values by 10.5%, and re-computing staffing requirements. Staffing decreases occur when a shift in the break point causes position staffing to be reduced from 1.5 to 1.0, or from 2.0 to 1.5.

In consideration of the fact that an ARTS III Staffing Standard Study was conducted by Air Traffic Service and the Office of Management Systems in 1975, this approach was not followed. The staffing standard study modified the rules for determining position staffing in that average position flight time is now a part of the criteria (Notice N1380.67). The effect of this change, along with other study findings, was to reduce ARTS III staffing by approximately 8.5%. This figure is considered to be quite compatible with the capacity figure of 10.5%, and is a most reasonable estimate of the ARTS III productivity increase.

7. CONCLUSIONS

It is the opinion of the study team that all workload and performance data used in this effort and obtained through actual measurements at the operating positions in the two subject TRACONS is accurate and representative of the air traffic control terminal operation.

After careful analysis, and ensuring that proper consideration was given to all pertinent facts, it is clear that the ARTS III system has definitely increased the productivity and capacity of the terminal operation. The most prominent piece of evidence that substantiates this statement is the fact that the air traffic controllers did, indeed, handle a greater number of aircraft at the same work pace than had been previously recorded.

The methodology employed in this endeavor identifies in every detail those areas affected by the introduction of the ARTS III system and to what degree. This is especially useful in planning and developing improved systems or enhancement packages.

The results of this effort should also clarify the issue and question of inducing an intolerable "button-pushing" workload (via the keypacks) onto the air traffic controller. It is evident in this data that that is not the case.

APPENDIX A

CODES AND DEFINITIONS OF CONTROLLER WORK ACTIVITIES

FOR PRODUCTIVITY/CAPACITY STUDY

(BEFORE ARTS III)

CODE	WORKLOAD INDICATOR	ACTIVITY
130	altitude control instruction	air/ground/air
131	altitude verification	
140	speed control instruction	
141	speed verification	
100	other control instruction	
400	advisory	
GHF	handoff - to another facility	interphone
RHF	handoff - from another facility	
GHS	handoff - to complex within the facility	
RHS	handoff - from a complex within the facility	
CCI	coordination between controller & coordinator	interphone
CF	coordination with another facility	
CS	coordination within the same facility	
INT	other transactions	
GHM	give a verbal handoff	oral
RHM	receive verbal handoff	
CC	coordinate w/coordinator position	
CSM	coordinate w/complex outside the facility position	
CR	coordinate w/radar controller	
CH	coordinate w/handoff controller	
CFD	coordinate w/flight data position	
QL	quick look	keypack
KGH	initiate handoff	
KRH	accept handoff	
KU	update/change/cancel	
KI	request information	
KG	unknown keyboard action	
CV	coordination	visual
FS	all flight strip activity	manual
M	monitoring	
S	stand-by	
AE	adjusts radar, radios, etc.	
LC	refers to charts, maps, handbooks, etc.	

APPENDIX A (continued)

CODES AND DEFINITIONS OF CONTROLLER WORK ACTIVITIES FOR PRODUCTIVITY/CAPACITY STUDY

(AFTER ARTS III)

CODE	WORKLOAD INDICATOR	ACTIVITY
130	altitude control instruction	air/ground/air
131	altitude verification	
140	speed control instruction	
141	speed verification	
100	other control instruction	
400	advisory	
GHF	handoff - to another facility	interphone
RHF	handoff - from another facility	
GHS	handoff - to complex within the facility	
RHS	handoff - from a complex within the facility	
CCI	coordination between controller and coordinator	interphone
CF	coordination with another facility	
CS	coordination within the same facility	
INT	other transactions	
GHM	give a verbal handoff	oral
RHM	receive verbal handoff	
QL	quick look	keypack
KGH	initiate handoff	
KRH	accept handoff	
KU	update/change/cancel	
KG	unknown keyboard action	
CV	coordination	visual
FS	all flight strip activity	manual
AE	adjusts radar, radios, etc.	
LC	refers to charts, maps, handbooks, etc.	

APPENDIX B

WORK PACE DEFINITIONS

1. Very Light Workload - "VL". A "VL" rating should be assigned when the work pace level is so low that relatively little attention has to be paid to the position of operation. Minimal exertion is required.

2. Light Workload - "L". An "L" rating should be assigned when the work pace is such that more than minimal exertion is required, but the complexity of situations is such to only engage the controller's complete attention periodically. There are no complex control situations.

3. Average Workload - "A". An "A" should be assigned when the situation complexity requires almost full time attention of the controller. The workload is evenly distributed and places no unusual demand upon the controller. This pace could be maintained up to an eight-hour period with normal relief.

   a. - Gradient. A - should be assigned when significantly less than full attentiveness is required at the position; the demands placed upon the controller are slightly less than one could expect at average. Infrequent periods of inactivity occur.

   b. + Gradient. A + should be assigned when the demands are slightly greater than "A". Rare periods of inactivity, full attentiveness to the position is required. A controller could be expected to work at this pace up to six hours with normal relief.

4. Heavy Workload - "H". An "H" rating should be assigned when the complexity, and exertion required to cope with the situation necessitate rapid decisions; there is constant operational activity. Demands placed upon the controller exceed those of a normal pace. A controller could be expected to securely deal with this level of work for up to three hours.

5. Very Heavy - "VH". A "VH" should be assigned when there is continuous laborious activity, superior exertion is required and the rapidity of response and thinking processes are critical. There are delays in acknowledging demands placed upon the position. A controller would be "pushed" to maintain this pace for one hour.

APPENDIX C **BEST AVAILABLE COPY**

-WORKLOAD MEASUREMENTS-

FACILITY OAKLAND BAY TRACON COMPLEX/POSITIONS DR1 DATE 11/8/73

OBSERVER/S DH OBSERVATION PERIOD: FROM: 1630Z TO: 1730Z

CONTROLLER/S 1½

OBSERVED IN CONJUNCTION WITH COMPLEX/ES CI5, HO7, DR2

A/C IDENT	IN	OUT	A/C IDENT	IN	OUT	A/C IDENT	IN	OUT
UA414	—	1632	N79246	1654	1704	UA890	1723	1727
#1 N87R	—	1641	UA22	1655	1659	VVNE611	1724	[illegible]
WA750	1635	1638	N20331	1656	1707	VM ME301	1728	—
N175P	1637	1642	N1622Q	1657	1707	#4 STOL41	1729	—
VLAF651	1637	1642	AA822	1658	1700			
[illegible]	1639	1643	N6601L	1703	1710			
NA1052	1641	1646	N4312T	1705	1715			
UA813	1643	1646	UA50	1706	1711			
WRP31	1643	1648	N70003	1708	1716			
UA460	1644	1648	UA306	1709	1712			
AA220	1646	1649	VVNE611	1711	1714	(34)		
#2 C7229	1646	1650	AA14	1710	1714			
UA60	1647	1651	FOGGY 22	1713	1714			
WA522	1651	1655	#3 STOL 101	1717	1721			
AA92	1652	1657	N3898Q	1719	1728			

PACE RATINGS-POSITIONS	5 MINUTE TIME INTERVALS											
POSITION: DR1	A-	A+	A+	A	A	A+	A	A+	H	A-	A	H
POSITION:												
POSITION:												
SECTOR PACE RATINGS	A-	A	A	A	A	A	A-	A	A+	A	A	A+

WEATHER M32⊕10 / 1700? M32⊕250⊕10

CONTROL/COMM/NAV-AID STATUS:

RUNWAYS IN USE:
PRIMARY AIRPORT: SFO D01 L28
SECONDARY AIRPORT: OAK 29 27
SATELLITE/S AIRPORT: NGZ 31

COMMENTS:
HO7 NOT MANNED 1630Z

C-1 CSY

NOTES:
#1 ORIGINALLY AS VFR TCA REQUESTED IFR OTP CLIMB
#2 SFO TCA DEPARTURE #3&4 POP UP TCA SFO ARRIVALS

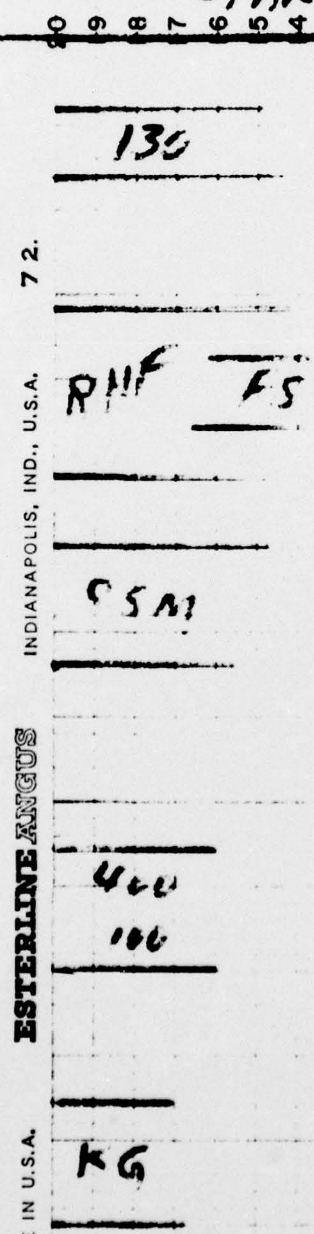
MACHINE # 48 CURLEY

MIA POSN AR-2

12/4/73

WX- 25Ø5ØØ7

START Ø413.3ØZ



ON RADIO ISSUING MESSAGE(S) RELATED TO ALTITUDE CONTROL

RECEIVED RADAR HANDOFF FROM ANOTHER FACILITY via INTERPHONE AND MARKED FLIGHT STRIP(S) DURING HANDOFF PERIOD

COORDINATED MANUALLY WITH ANOTHER POSITION WITHIN FACILITY BUT OUTSIDE OF COMPLEX UNDER OBSERVATION

ON RADIO ISSUING ADVISORY AND AIR TRAFFIC CONTROL MESSAGES

A/N KEYPACK ENTRY (Action unknown)

APPENDIX E

OPERATING POSITION (SECTOR) DESIGNATIONS

SAN ANTONIO TRACON

BEFORE ARTS III	AFTER ARTS III
DR-1	DR-1
DR-2	DR-3
AR-1	AR-2
AR-2	AR-3
AR-3	AR-5
AR-4	AR-6
AR-5	AR-7
AR-6	R-1
AR-7	R-2

SAN FRANCISCO/OAKLAND TRACON

BEFORE ARTS III	AFTER ARTS III
DR-1	DR-2
DR-2	DR-1
DR-3	DR-5
AR-1	AR-3
AR-2	AR-4
AR-3	AR-9
AR-4	AR-10
AR-5	AR-1
AR-6	AR-2
AR-8	DR-6

APPENDIX F

OAKLAND (BEFORE)
REGRESSION ANALYSIS SUMMARY

POSITION*	STAFFING	R^2 (All Variables)	SIGNIFICANT VARIABLES	R^2 (Selected Variables)
AR1	1.0	.771	MIN,PK,A/C,O/C,ADV,FS	.691
AR2	1.0	.774	MIN,PK,A/C,O/C	.714
AR3	1.0	.586	MIN,O/C	.532
AR4	1.0	.767	MIN,PK,A/C,O/C,FS	.684
AR9	1.0	.676	MIN,PK,A/C,O/C,FS	.704
AR10	1.0	.742	MIN,PK,A/C,O/C,ADV,VC,FS	.625
DR1	1.5	.529	MIN,PK,A/C,A/V,O/C,FS	.493
DR2	1.5	.565	MIN,PK,O/C	.506
DR5	1.0	.667	MIN,PK,A/C,O/C	.587
DR6	1.0	.688	MIN,PK,A/C,O/C	.612

*"After" position designator

INDEX OF VARIABLES

MIN - Aircraft Minutes
PK - Peak Aircraft
A/C - Altitude Control Message
A/V - Altitude Verification Message
O/C - Other Control Message
ADV - Advisory Message
VC - Visual Coordination
FS - Flight Strip Activity

APPENDIX F

OAKLAND (AFTER)
REGRESSION ANALYSIS SUMMARY

POSITION*	STAFFING	R^2 (All Variables)	SIGNIFICANT VARIABLES	R^2 (Selected Variables)
AR1	1.0	.695	EQ,MIN,PK,A/C,O/C,ADV	.614
AR2	1.0	.622	EQ,MIN,PK,O/C,ADV	.577
AR3	1.0	.725	EQ,MIN,PK,A/C,O/C	.589
AR4	1.0	.708	EQ,MIN,PK,A/C,O/C	.541
AR9	1.0	.486	EQ,MIN,PK,A/C,O/C	.618
AR10	1.0	.599	EQ,MIN,PK,O/C	.563
DR1	1.5	.499	EQ,MIN,PK,O/C	.442
DR2	1.5	.500	EQ,MIN,PK,O/C,FS	.413
DR5	1.0	.631	EQ,MIN,PK,O/C	.481
DR6	1.0	.672	EQ,MIN,PK,O/C	.644

*"After" position designator

EQ - Equivalent Aircraft Handled
MIN - Aircraft Minutes
PK - Peak Aircraft
A/C - Altitude Control Message
O/C - Other Control Message
ADV - Advisory Message
FS - Flight Strip Activity

APPENDIX F

SAN ANTONIO (BEFORE)
REGRESSION ANALYSIS SUMMARY

POSITION*	STAFFING	R^2 (All Variables)	SIGNIFICANT VARIABLES	R^2 (Selected Variables)
AR2	1.0	.807	MIN,PK,A/C,A/V,O/C,ADV	.708
AR2	1.5	.779	MIN,PK,A/C,A/V,O/C	.771
AR3	1.0	.502	MIN,PK,O/C	.448
AR3	1.5	.729	MIN,PK,O/C	.701
AR5	1.0	.799	MIN,PK,A/C,O/C	.729
AR5	2.0	.777	MIN,PK,A/C,O/C	.771
AR6	1.0	.570	MIN,PK,O/C	.410
AR6	1.5	.740	MIN,PK,A/C,O/C	.615
AR7	1.0	.562	MIN,PK,O/C	.532
AR7	1.5	.596	MIN,PK,A/C,O/C,ADV,GF	.619
DR1	1.0	.751	MIN,PK,A/C,O/C	.705
DR1	2.0	.805	MIN,PK,O/C	.783
DR3	1.0	.738	MIN,PK,O/C	.735

*"After" position designator

INDEX OF VARIABLES

MIN - Aircraft Minutes
PK - Peak Aircraft
A/C - Altitude Control Message
A/V - Altitude Verification Message
O/C - Other Control Message
ADV - Advisory Message
GF - Give Handoff to Another Facility

APPENDIX F

SAN ANTONIO (AFTER)

REGRESSION ANALYSIS SUMMARY

POSITION*	STAFFING	R^2 (All Variables)	SIGNIFICANT VARIABLES	R^2 (Selected Variables)
AR2	1.0	.626	EQ,MIN,PK,O/C	.548
AR2	1.5	.708	EQ,MIN,PK,A/C,O/C	.681
AR3	1.0	.751	EQ,MIN,PK,O/C	.701
AR3	1.5	.795	EQ,MIN,PK,O/C,ADV,FS	.786
AR5	1.0	.781	EQ,MIN,PK,O/C	.759
AR5	2.0	.205	EQ,MIN,PK,O/C	.300
AR6	1.0	.818	EQ,MIN,PK,O/C,FS	.773
AR6	1.5	.763	EQ,MIN,PK,O/C,FS	.752
AR7	1.0	.780	EQ,MIN,PK,A/C,O/C,ADV	.645
AR7	1.5	.878	EQ,MIN,PK,A/C,O/C,ADV,FS	.775
DR1	1.0	.760	EQ,MIN,PK,A/C,O/C,CF	.639
DR1	2.0	.570	EQ,MIN,PK,O/C	.537
DR3	1.0	.668	EQ,MIN,PK	.636

*"After" position designator

INDEX OF VARIABLES

EQ -- Equivalent Aircraft Handled

MIN - Aircraft Minutes

PK - Peak Aircraft

A/C - Altitude Control Message

O/C - Other Control Message

ADV - Advisory Message

FS - Flight Strip Activity

CF - Co-ordination with Another Facility

APPENDIX G
OAKLAND, CALIFORNIA (OAK) TRACON
"A" PACE AVERAGES PER 5 MINUTE SAMPLE
(BEFORE ARTS III)

	AR1 1.0	AR2 1.0	AR3 1.0	AR4 1.0	AR5 1.0	AR6 1.0	AR8 1.0	DR1 1.5	DR2 1.5	DR3 1.0	Total	AVG
1. Flight Time	6.80	7.30	5.80	6.10	4.80	5.50	4.60	4.80	4.30	4.50	54.50	5.45
2. Aircraft Minutes	8.20	10.94	12.77	12.19	10.22	11.20	10.76	12.63	11.05	10.20	110.16	11.02
3. Peak Aircraft	2.40	3.00	3.95	3.56	2.89	3.30	3.31	4.00	3.75	3.25	33.41	3.34
4. Altitude Control	2.00	2.78	3.00	3.25	3.67	3.85	2.07	1.34	1.30	1.85	25.11	2.51
5. Altitude Verify	.40	1.39	1.05	1.69	2.00	.65	1.34	4.16	3.70	1.20	17.58	1.76
6. Speed Control	.80	.50	.77	.50	2.11	1.30	.14	.08	.20	.50	6.90	.69
7. Speed Verify	.20	.50	.32	.06	.11	.65	.14	.05	.10	.10	2.23	.22
8. Other Control	5.60	6.11	7.27	7.75	8.22	6.35	6.14	5.76	6.55	4.65	64.40	6.44
9. Advisory	1.40	3.50	1.86	2.88	1.89	2.35	2.72	2.66	3.10	4.85	27.21	2.72
10. Give Facility	1.00	.67	.14	-	-	-	.38	.11	.40	.15	2.85	.29
11. Receive Facility	.20	.56	.95	1.00	-	-	.55	-	-	.10	3.36	.34
12. Give Sector	.20	.28	.36	.25	-	-	.03	.03	.10	.10	1.35	.14
13. Receive Sector	.60	.22	.14	.06	.33	-	-	-	.05	.15	1.55	.16
14. Co-ord/Co-ord	-	-	-	-	-	-	-	.05	-	-	.05	.01
15. Co-ord/Facility	2.00	1.17	.55	.38	-	.10	2.76	.16	.15	1.60	8.87	.89
16. Co-ord/Within	1.00	.44	.41	.06	-	.05	.28	.08	.10	.65	3.07	.31
17. Other Transmissions	-	.17	.09	-	-	-	.03	.03	.05	.40	.77	.08
18. Oral Communication	1.80	.67	.64	.75	1.33	.35	.59	.71	1.30	.80	8.94	.89
19. Data Look-up	-	-	.14	.19	-	-	-	.03	-	-	.36	.04
20. Visual Co-ord	1.20	.11	.27	.38	.11	.15	.24	.05	-	-	2.51	.25
21. Flight Strip	3.20	2.67	4.86	4.63	4.56	4.10	3.97	2.79	2.50	2.45	35.73	3.57
22. Equip. Adjustment	-	.67	.32	.44	-	-	.17	.03	.05	.50	2.18	.22
EQ. A/C Per 5 Min.	1.21	1.50	2.20	2.00	2.13	2.04	2.34	2.63	2.57	2.27	20.89	2.09
EQ. A/C Per Hour	14.52	18.00	26.40	24.00	25.56	24.48	28.08	31.56	30.84	27.24	250.68	25.07

APPENDIX G
OAKLAND, CALIFORNIA (OAK) TRACON
"A" PACE AVERAGES PER 5 MINUTE SAMPLE
(AFTER ARTS III)

	AR3 1.0	AR4 1.0	AR9 1.0	AR0 1.0	AR1 1.0	AR2 1.0	DR6 1.0	DR2 1.5	DR1 1.5	DR5 1.0	TOTAL	AVG
1. Flight Time	6.25	6.38	4.52	3.68	4.18	4.42	6.40	3.63	4.19	3.83	47.48	4.75
2. Aircraft Minutes	8.38	11.26	9.70	8.42	9.97	9.48	12.67	10.97	10.57	7.21	98.63	9.86
3. Peak Aircraft	2.41	3.17	3.00	2.73	3.16	2.77	3.45	3.61	3.05	2.57	29.92	2.99
4. Altitude Control	1.94	1.64	3.27	3.00	2.63	2.19	2.21	.78	1.32	1.71	20.69	2.07
5. Altitude Verify	.41	.58	.80	.68	.11	.27	.62	1.89	1.14	.57	7.07	.71
6. Speed Control	.35	.25	1.27	.35	.63	.54	.52	.06	-	-	3.97	.40
7. Speed Verify	.24	.06	-	.08	.16	-	.07	-	-	.14	.75	.80
8. Other Control	9.53	10.83	7.53	8.89	11.00	10.88	13.28	11.98	9.95	9.86	103.64	10.36
9. Advisory	2.76	3.56	1.13	1.70	5.47	7.04	2.69	3.39	2.00	1.14	30.88	3.09
10. Give Facility	.53	.36	.13	-	.11	.19	.28	-	.05	-	1.65	.17
11. Receive Facility	.06	.08	.07	.11	-	-	.17	-	.05	-	.54	.05
12. Give Sector	.12	-	-	-	-	.04	-	.06	.05	-	.27	.03
13. Receive Sector	.06	.06	-	-	-	.12	.03	-	.05	-	.32	.03
14. Co-ord/Co-ord	-	.03	-	-	-	-	-	-	-	-	.03	.00
15. Co-ord/Facility	1.94	1.00	.73	.73	.26	.19	1.38	.06	.09	3.14	9.52	.95
16. Co-ord/Within	1.12	1.17	.60	.89	.79	.35	.52	.17	.05	1.14	6.80	.68
17. Other Transmissions	.06	.03	-	.05	.05	-	.03	-	.05	-	.27	.03
18. Oral Communication	.94	.86	.47	.14	.53	.31	.62	1.28	.41	1.00	6.56	.66
19. Data Look-up	-	.03	-	.19	-	-	-	-	-	-	.22	.02
20. Visual Coord	-	-	.07	.03	-	-	.07	.17	-	-	.34	.03
21. Flight Strip	3.00	3.44	4.27	4.54	.89	1.50	5.45	5.89	2.36	2.29	33.63	3.36
22. Equip Adjustment	.31	.06	.07	.03	.11	-	.07	-	.09	.57	1.41	.14
Quick Look	-	.08	.27	.43	.21	.31	.10	.06	.09	-	1.55	.16
Handoff Initiate	-	-	.07	.05	-	.04	-	-	-	-	.16	.02
Handoff Accept	-	-	-	-	-	-	-	-	-	-	-	-
Keyboard Unknown	2.35	2.19	3.53	2.76	2.05	2.58	2.28	1.61	1.27	1.86	22.48	2.25
Cap Change %	10.7	16.7	-1.8	16.5	13.6	6.4	-15.4	15.6	-1.2	-18.1	+43.0	+4.30%
EQ. A/C Per 5 Minute	1.34	1.75	2.16	2.33	2.42	2.17	1.98	3.04	2.54	1.86	21.59	2.16
EQ. A/C Per Hour	16.08	21.00	25.92	27.96	29.04	26.04	23.76	36.48	30.48	22.32	259.08	25.91

APPENDIX G
SAN ANTONIO, TEXAS (SAT) TRACON
"A" PACE AVERAGES PER 5 MINUTE SAMPLE
(BEFORE ARTS III)

	AR1 1.0	AR1 1.5	AR2 1.0	AR2 1.5	AR3 1.0	AR3 2.0	AR4 1.0	AR4 1.5	AR5 1.0	AR5 1.5	DR1 1.0	DR1 2.0	DR2 1.0	TOTAL	AVG
1. Flight Time	10.40	10.40	8.90	8.90	8.60	8.60	4.60	4.60	4.90	4.90	6.60	6.60	9.20	97.2	7.48
2. Aircraft Minutes	12.60	12.40	11.50	13.94	8.63	10.77	10.48	11.38	9.75	11.80	10.09	12.00	17.18	152.52	11.73
3. Peak Aircraft	3.40	3.40	3.25	3.76	2.50	2.91	3.14	3.85	2.25	3.80	3.00	3.40	4.36	43.02	3.31
4. Altitude Control	1.73	1.55	1.88	2.33	1.38	1.64	.62	1.77	1.25	2.40	1.87	1.73	.64	20.79	1.60
5. Altitude Verify	1.47	.90	.25	1.24	.63	.27	.19	.38	-	.40	1.83	2.13	.27	9.96	.77
6. Speed Control	.13	.15	.25	.36	-	.23	.24	.08	1.00	.20	-	-	.36	3.00	.23
7. Speed Verify	-	.15	-	.24	-	.32	.24	.08	.25	.20	-	.20	-	1.68	.13
8. Other Control	8.47	7.55	8.38	11.27	8.50	10.09	6.81	10.15	7.00	10.20	6.09	6.87	4.18	105.56	8.12
9. Advisory	4.33	3.85	2.25	2.27	1.13	1.86	2.10	1.77	4.25	6.60	1.57	1.67	2.18	35.83	2.76
10. Give Facility	-	.05	-	.09	.38	.09	1.00	.23	1.00	1.60	.91	-	-	5.35	.41
11. Receive Facility	-	.15	1.13	.15	.25	-	.19	.08	-	-	.04	-	-	1.99	.15
12. Give Sector	.20	.05	.25	.09	.13	.05	.29	.15	-	-	-	-	.55	1.76	.14
13. Receive Sector	-	.05	.25	-	-	-	.29	.23	.25	-	.17	-	.27	1.51	.12
14. Co-ord/Co-ord	-	.10	.25	.30	.13	-	-	-	-	-	-	.33	-	1.11	.09
15. Co-ord/Facility	-	.10	-	.09	1.50	.41	1.05	.31	.75	.20	1.48	.13	.09	6.11	.47
16. Co-ord/Within	.73	.45	.88	.01	1.13	.09	.29	.31	3.25	.40	1.43	.73	.45	10.23	.79
17. Other Transmission	.07	.05	.25	.24	-	.14	.10	.15	.25	-	.65	.13	-	2.03	.16
18. Oral Communication	.20	.35	-	.36	-	.27	.19	.31	.25	-	.26	.33	-	2.52	.19
19. Data Look-up	-	.15	.13	-	-	-	-	-	-	-	.04	.07	-	.39	.03
20. Visual Co-ord	.20	.15	.50	.30	.13	.14	.05	.08	-	-	.35	.07	.36	2.33	.18
21. Flight Strip	2.07	3.15	4.75	2.49	3.38	2.95	3.38	4.77	3.75	4.00	3.13	2.40	2.27	42.49	3.27
22. Equipment Adjustment	-	-	-	-	.75	.32	.29	.15	.75	.20	-	.13	.09	2.68	.21
EQ. A/C Per 5 Minute	1.21	1.19	1.29	1.57	1.00	1.25	2.28	2.47	1.99	2.41	1.53	1.82	1.87	21.88	1.68
EQ. A/C Per Hour	14.52	14.28	15.48	18.84	12.00	15.00	27.36	29.64	23.88	28.92	18.36	21.84	22.44	262.56	20.20

APPENDIX G

SAN ANTONIO, TEXAS (SAT) TRACON

"A" PACE AVERAGES PER 5 MINUTE SAMPLE

(AFTER ARTS III)

	AR2 1.0	AR2 1.5	AR3 1.0	AR3 1.5	AR5 1.0	AR5 2.0	AR6 1.0	AR6 1.5	AR7 1.0	AR7 1.5	DR1 1.0	DR1 2.0	DR3 1.0	TOTAL	AVG
1. Flight Time	10.61	9.68	10.21	9.44	8.44	9.04	4.20	4.38	5.90	4.50	5.68	5.66	8.57	96.31	7.41
2. Aircraft Minutes	13.97	16.38	15.97	16.58	11.86	14.67	11.20	12.50	9.38	10.00	11.72	11.31	15.36	170.90	13.15
3. Peak Aircraft	3.69	4.12	4.06	4.17	3.14	3.78	3.10	3.79	2.50	4.00	3.69	3.25	3.82	47.11	3.62
4. Altitude Control	1.13	1.97	1.44	1.60	1.64	2.44	1.00	1.38	2.25	2.50	2.38	3.00	.82	23.55	1.81
5. Altitude Verify	.38	.67	.69	.50	.14	.33	.20	.14	-	-	1.19	.63	-	4.87	.37
6. Speed Control	-	.36	.13	.03	.29	.44	-	.10	-	-	-	-	.27	1.62	.12
7. Speed Verify	-	.06	.13	.17	-	.22	-	-	-	-	-	-	.09	.67	.05
8. Other Control	8.50	7.76	9.50	11.43	13.14	11.44	10.20	12.24	7.75	5.00	9.63	9.25	7.73	123.57	9.50
9. Advisory	2.94	6.06	3.19	4.03	2.29	2.67	3.40	3.90	4.00	5.50	1.06	1.13	1.64	41.81	3.22
10. Give Facility	.06	.06	.06	.07	1.00	.22	.70	.24	1.00	-	.06	.44	-	3.91	.30
11. Receive Facility	-	.03	-	-	-	-	.15	.03	-	-	.06	-	.18	.45	.03
12. Give Sector	.19	-	.38	.03	.07	-	-	-	-	-	-	-	.09	.76	.06
13. Receive Sector	-	-	.06	-	-	-	-	-	-	-	.06	-	-	.12	.01
14. Co-ord/Co-ord	.19	-	-	.03	-	-	-	-	-	-	.06	.19	-	.47	.04
15. Cor-ord Facility	.38	.30	.19	.17	2.36	.67	2.15	.14	1.75	.50	2.94	.81	.18	12.54	.96
16. Co-ord/Within	1.44	.39	.88	.17	.86	1.22	.15	.34	1.75	-	3.13	1.44	.27	12.04	.93
17. Other Transmission	-	-	.13	.07	.07	-	.10	.03	-	-	.13	.06	-	.59	.05
18. Oral Communication	.50	.45	1.06	.80	.71	1.22	.25	.34	.75	-	.38	1.56	.09	8.11	.62
19. Data Look-up	-	.06	-	.03	.14	-	-	.76	-	-	.13	.06	-	1.18	.09
20. Visual Co-ord	-	.06	.38	-	-	.33	-	-	-	-	-	-	.27	1.04	.08
21. Flight Strip	3.13	3.27	3.38	3.73	5.50	3.00	6.45	6.10	2.00	4.50	2.50	3.44	2.91	49.91	3.84
22. Equipment Adjustment	.31	.09	.15	.03	.36	.22	-	.14	-	-	.06	-	.09	1.43	.11
Quick Look	.19	.03	1.50	.17	.07	-	.40	.28	-	.50	.38	.06	.64	4.22	.32
Handoff Initiate	.06	.09	-	-	-	-	-	-	-	.50	-	-	-	.65	.05
Handoff Accept	.31	.06	-	.03	-	.22	.15	-	-	-	-	-	-	.77	.06
Keyboard Unknown	1.88	1.85	2.50	1.77	1.71	.67	1.90	2.10	.50	.50	1.50	1.69	2.82	21.39	1.65
Cap Change %	14.1	44.5	22.5	11.5	44.0	31.2	16.7	17.0	-22.0	-8.7	34.0	10.4	-1.1	+214.1	16.47
EQ. A/C Per 5 Minute	1.38	1.72	1.58	1.75	1.44	1.64	2.66	2.89	1.55	2.20	2.05	2.01	1.85	24.72	1.90
EQ. A/C Per Hour	16.56	20.64	18.96	21.00	17.28	19.68	31.92	34.68	18.60	26.40	24.60	24.12	22.20	296.64	22.82