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COMPUTER UTILIZATION AT THE HOUSTON AIR ROUTE TRAFFIC CONTROL CENTER (A3D2.10 SYSTEM)

Jacques Press

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JULY 1981

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16. Abstract

This report describes a computer performance analysis recently completed at the Federal Aviation Administration Technical Center for the HOUSTON Air Route Traffic Control Center. Based on scatter diagrams and linear regression, the analysis used field data to quantify the performance of the Central Computer Complex operating at that facility. The data was recorded once a minute for several days while the computer was supporting air traffic control operations. Graphs and tables summarize the results of the study.

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SUMMARY

Two documents entitled "Computer Utilization at Several Enroute Air Traffic Control Centers" (numbered ARD-140-1-81 and ARD-140-18-81) were published in December 1980 and June 1981. They provide estimates of processing utilization for the Central Computer Complexes at the twenty Air Route Traffic Control Centers in the National Airspace System. Based on field data, the analysis included in these reports contributes to the assessment of the ability of today's air traffic computers to handle forecasted traffic loads until a replacement system is available in the late 1980s. The present study used the same methodology described in ARD-140-1-81 and ARD-140-18-81 to assess computer utilization at the HOUSTON Center during the week ending July 12, 1981. HOUSTON Center, with its 9020A computer, represents one of the heavily loaded enroute facilities in the National Airspace System.

The HOUSTON analysis is based on data collected at the site while a software feature, known as Input-Output Control Element (IOCE) Offloading, was activated. This option, not yet operational at the time of the previous two studies, reduces computer utilization. The results obtained in this study have therefore been compared with those stated in the December report to identify the differences.

An additional storage element was installed as part of the program to increase storage at each Air Route Traffic Control Center. This added memory is expected to reduce computer storage access delays and should result in further reduction in computer utilization. However, the storage element was not yet operational at HOUSTON during the measurement period.

Computer programs based on the BMDP statistical package [1] * have been prepared and executed at the Federal Aviation Administration Technical Center in order to produce most of the quantitative results stated in this report. Documents providing an overview of the National Airspace System's enroute portion , a description of the Central Computer Complex operating at each enroute center as well as a discussion of the analysis conducted in the present study are listed in the reference section [see 2 through 9] .

* Note : terms in square brackets indicate reference numbers.

RESULTS

Scatter diagrams were prepared to describe the collected data and to derive regression equations for HOUSTON . Scatter diagrams are X-Y plots which contain coordinate pairs of various fields found in each data record. For example, the scatter diagrams in Figures 1 through 4 are plots of central processing utilization (shown as a percentage of the total available computer capacity along the y-axis) and the corresponding active flight plan count or track count (either one shown along the x-axis). Figures 1 and 2 represent utilization versus active flight plans based on data obtained at the A3d2.10 software version (with IOCE Offloading) and at the A3d2.9 version (which did not have IOCE Offloading), res pectively. Figures 3 and 4, similar to 1 and 2, apply to the case of utilization versus tracks. The A3d2.9 results have been extracted from the December study and incorporated in this report to illustrate the higher utilization occuring when IOCE Offloading is non-existent. Digits in the graphs denote single or repeated observations taken at different times. A "2", for instance, indicates two identical observations, a "3" denotes three observations, and so on. For counts greater than 9, the letter A denotes 10 observations, B denotes 11 observations, and so on. An asterisk signifies that 36 or more observations have identical coordinate pairs. The solid straight line drawn across the points corresponds to the calculated least squares first-order regression equation which fits best the data. The dashed line in Figures 1 and 3 pertains to the A3d2.9 case found

in Figures 2 and 4, respectively. According to Figures 1 and 3, the A3d2.10 line has a lower slope than the A3d2.9 case and the vertical difference between the two lines represents the average reduction in utilization created by IOCE Offloading. The results therefore show a utilization reduction from 82 percent down to 66 percent for a heavy load consisting of 300 active flight plans (see Figure 1) or 180 tracks (see Figure 3). The "N" near the bottom left of the scatter diagrams equals the sample size while the "COR" represents the coefficient of correlation between the vertical and horizontal variables. A "COR" close to 1.0 indicates a strong correlation. The utilization and active flight plan or track scatter in the four figures follows a linear trend which suggests that a straight-line regression equation is an appropriate way to describe the data.

HOUSTON 2.10 A-SITE SARC=1,TARS=OFF,REMON OFF,CE=3

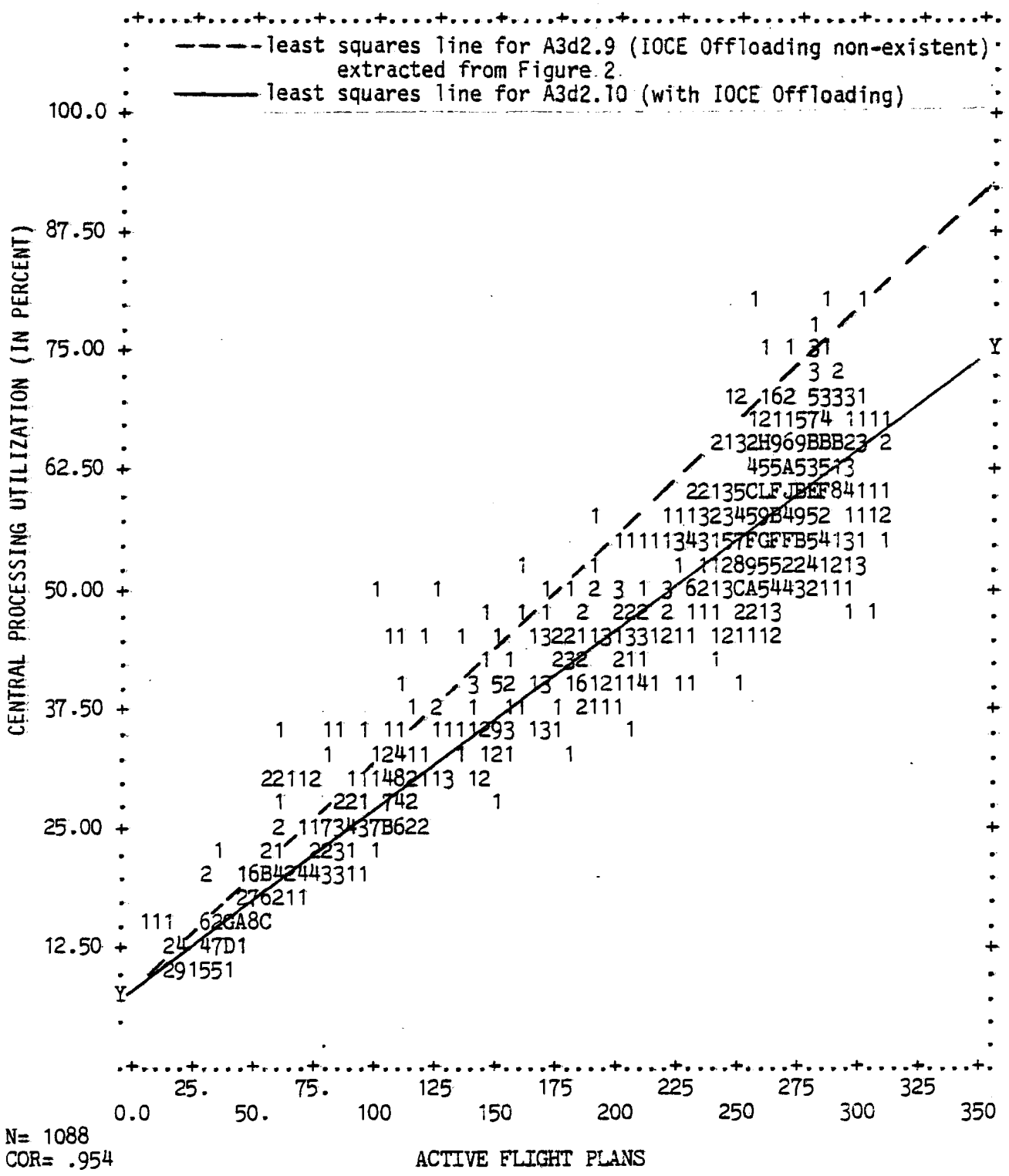
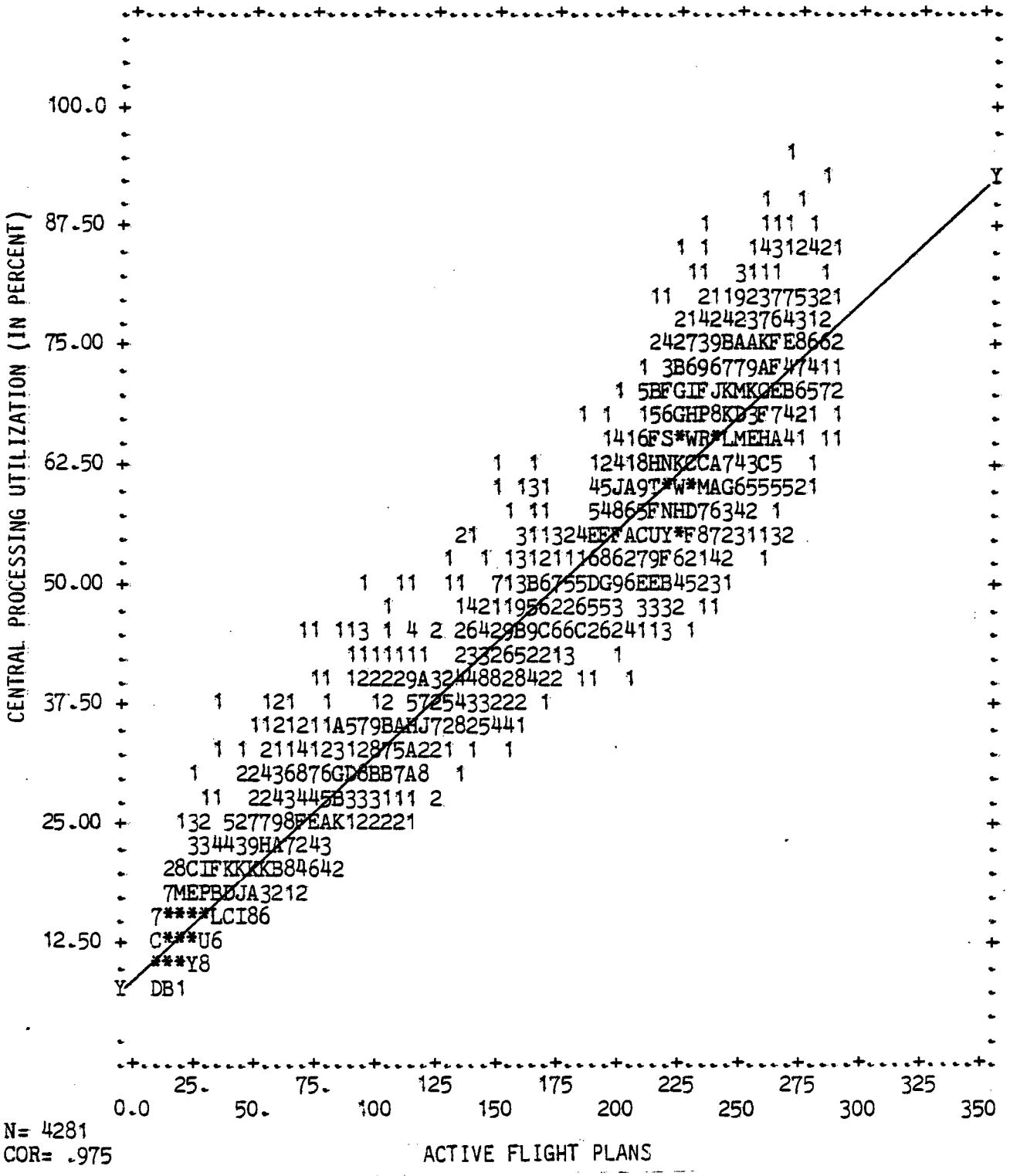


FIGURE 1: Scatter Diagram of Central Processing Utilization versus Active Flight Plans for the A3d2.10 System (with IOCE Offloading).

HOUSTON 2.9 A-SITE SARC=1,TARS=OFF,REMON OFF,CE=3



N= 4281
COR= .975

FIGURE 2: Scatter Diagram of Central Processing Utilization versus Active Flight Plans for the A3d2.9 System (without IOCE Offloading).

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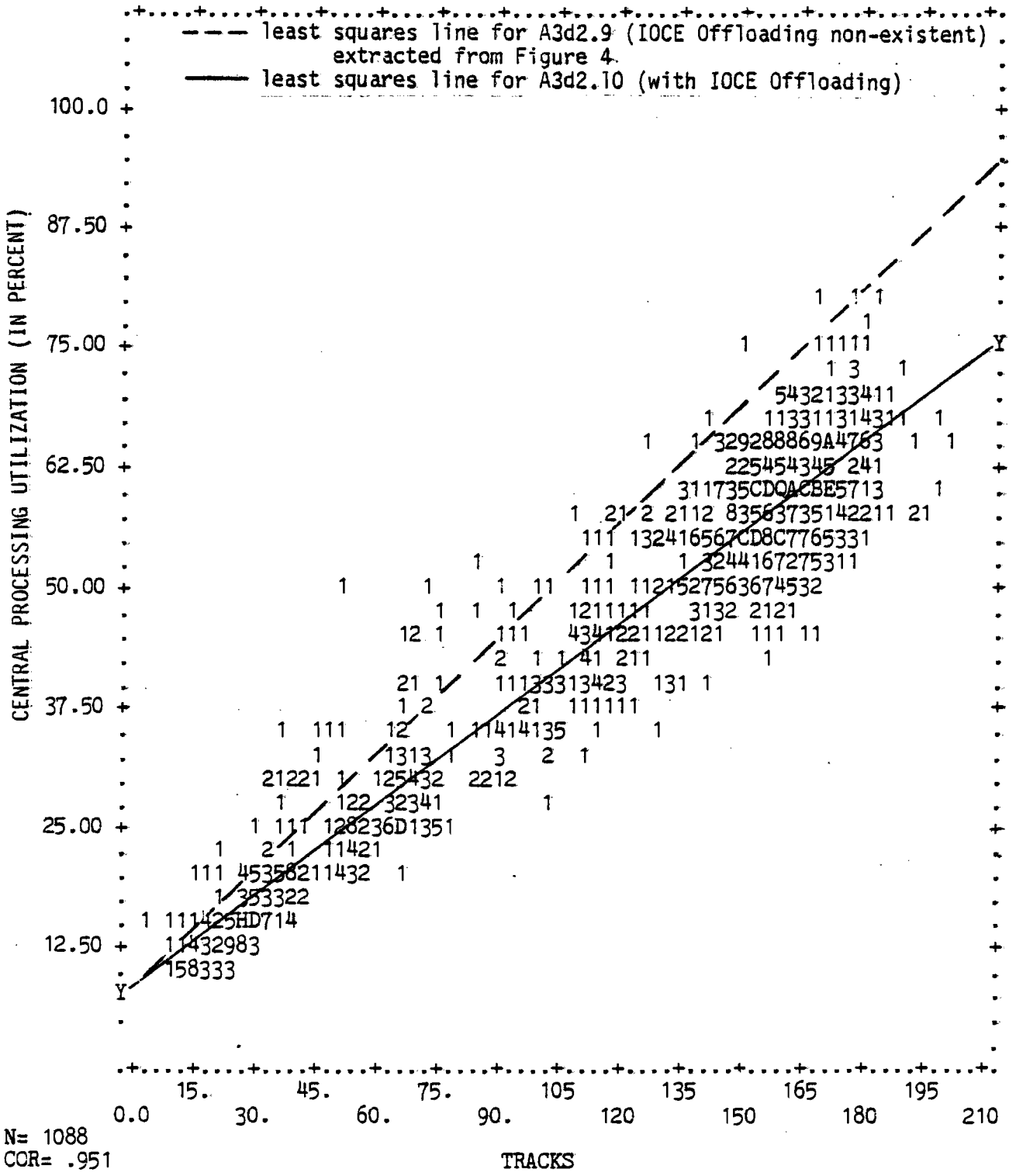

FIGURE 3: Scatter Diagram of Central Processing Utilization versus Tracks for the A3d2.10 System (with IOCE Offloading).

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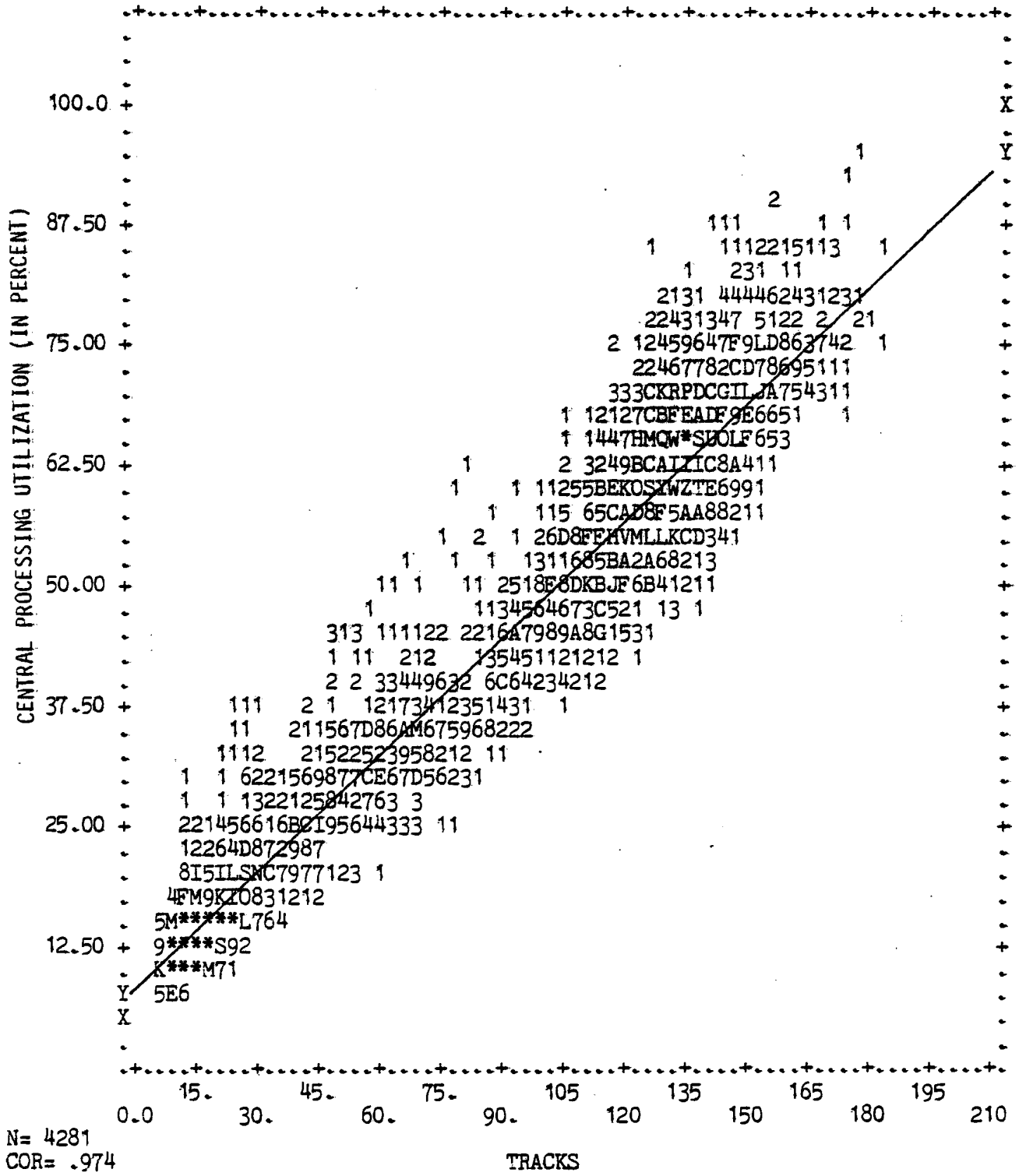
HOUSTON 2.9 A-SITE SARC=1,TARS=OFF,REMON OFF,CE=3



N= 4281
COR= .974

FIGURE 4: Scatter Diagram of Central Processing Utilization versus Tracks for the A3d2.9 System (without IOCE Offloading).

Figure 5 summarizes the relation between active flight plans and tracks. The high correlation in that graph implies that most active flight plans correspond to aircraft that are tracked by radar at HOUSTON. Furthermore, because these two workload parameters are highly correlated the contribution of each one cannot be separated from that of the other in the same model, according to statistical theory [10]. Therefore, it is assumed that either parameter reflects the effects of the other and is alone sufficient to represent the workload on the computer.

HOUSTON 2.10 A-SITE SARC=1,TARS=OFF,REMON OFF,CE=3

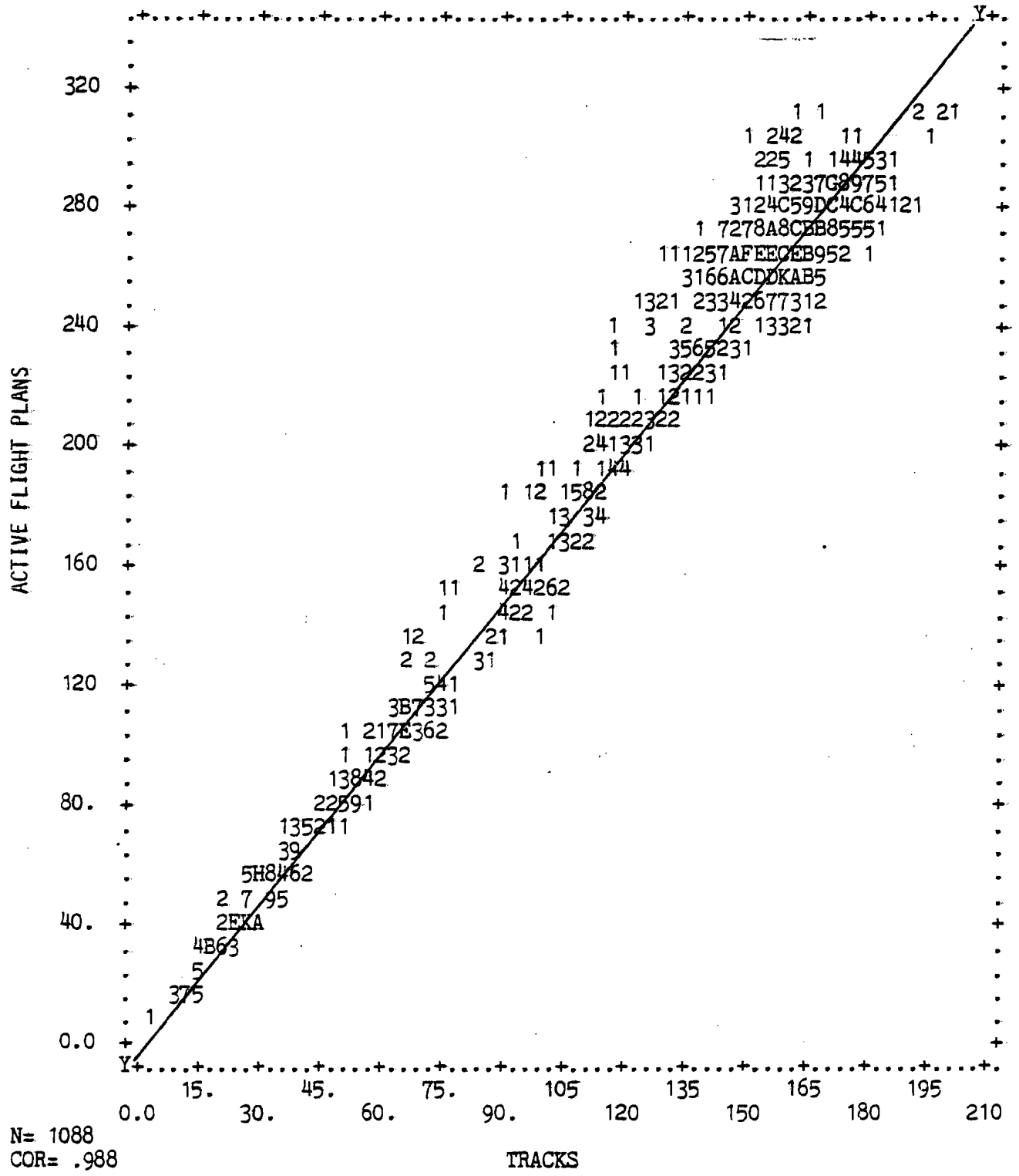


FIGURE 5: Scatter Diagram of Active Flight Plans versus Tracks.

The derived regression equations for the A3d2.10 system with IOCE Offloading consist of a first-order equation for central processing utilization as a function of active flight plans and a similar equation for utilization as a function of tracks. Each equation contains an intercept term followed by a "+" sign, and a slope term (immediately after the "+" sign) which multiplies the flight plans or tracks. The equations are:

1. Central Processing Utilization (in percent) =

$$8.44 + 0.188 \text{ active flight plans}$$

Subject to:

Standard error of estimate = 5.35 percent.

Coefficent of determination= 0.91 .

Sample size = 1088 observations.

2. Central Processing Utilization (in percent) =

$$8.10 + 0.316 \text{ tracks}$$

Subject to:

Standard error of estimate = 5.54 percent.

Coefficient of determination= 0.90 .

Sample size = 1088 observations.

The corresponding HOUSTON A3d2.9 equations extracted from the December report are:

1. Central Processing Utilization (in percent) =

$$8.46 + 0.236 \text{ active flight plans}$$

Subject to:

Standard error of estimate = 5.12 percent.

Coefficent of determination= 0.95 .

Sample size = 4281 observations.

2. Central Processing Utilization (in percent) =

$$7.50 + 0.415 \text{ tracks}$$

Subject to:

Standard error of estimate = 5.29 percent.

Coefficient of determination= 0.95 .

Sample size = 4281 observations.

The last two equations have approximately the same intercept values as those in the A3d2.10 case. Their slope terms however are different from A3d2.10 because of the IOCE Offloading condition. The intercept term, present even under no traffic load, accounts for

cyclic processing created by periodic programs. These programs, like the program element dispatcher and the beacon/primary radar data processor, are scheduled to work in continuous cycles or at specific intervals (ranging from one to a few seconds) regardless of traffic load.

The standard error of estimate listed after each equation is a statistical result which is usually reported during a regression analysis [11,12] . It is similar to the standard deviation of any data about an average value. This means that approximately 68.3% of the observations should fall within plus or minus one "standard error" vertically from the line, 95.4% should fall within plus or minus two "standard errors", and 99.7% should fall within plus or minus three "standard errors" assuming a normal distribution holds for the deviations.

The coefficient of determination, stated after the standard error, is a statistical indicator of the closeness of fit of the curve to the data and varies between 0 and 1. The closer this coefficient is to 1, the better is the overall fit of the curve.

Scatter diagrams of a different form, depicting performance and workload parameters as a function of time, have been produced to illustrate traffic build-up patterns, traffic intensity peaks and the corresponding computer utilization variations as the day progresses at HOUSTON. They are shown in Figures 6, 7 and 8 which represent the daily trend in active flight plan load, track load and computer utilization , respectively. All three variables are plotted as a function of local time in minutes from midnight. For example, the value "420" on the x-axis represents 7:00 AM when divided by 60 minutes. The three plots have the same trend shape and, therefore, indicate that utilization is closely related to either active flight plans or tracks.

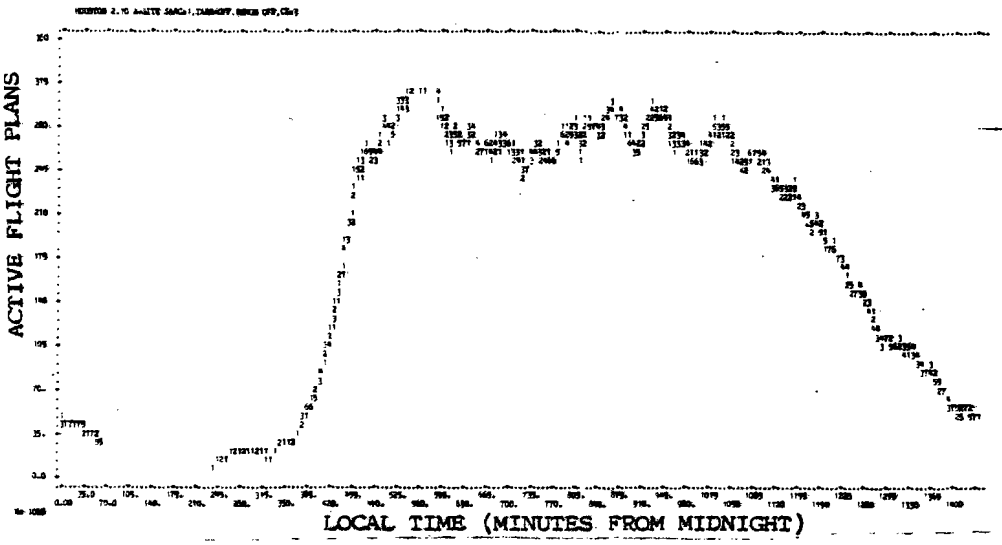


FIGURE 6

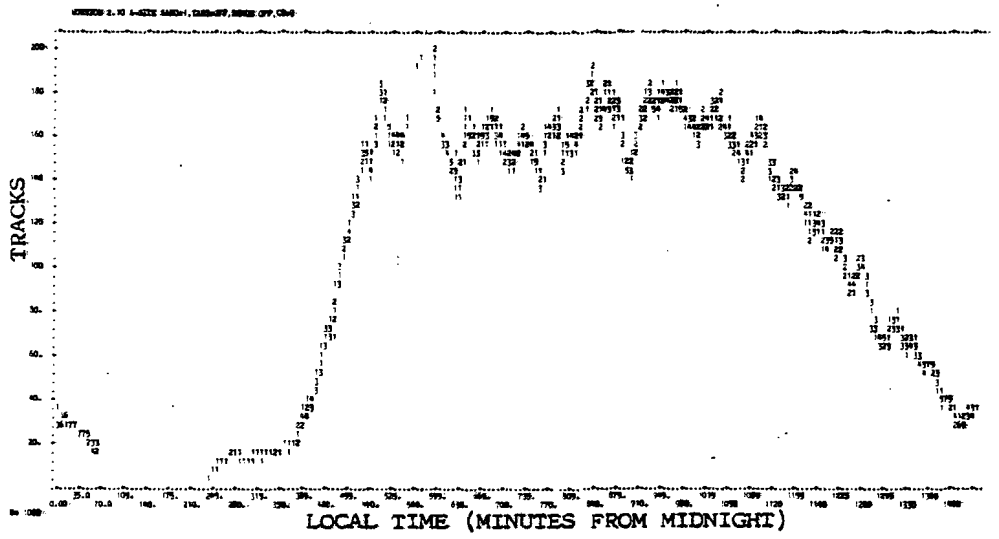


FIGURE 7

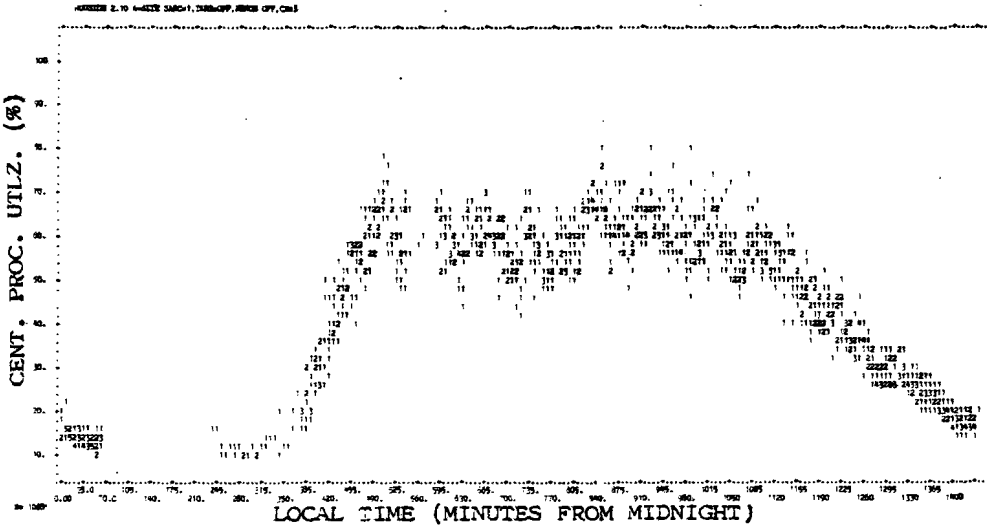


FIGURE 8

The results stated so far in this report are based on data collected while several computer processing and recording options (normally set at HOUSTON to control processing and to limit the amount of data being recorded for purposes beyond this study) were kept constant for a twenty-four hour period starting at midnight (Greenwich Mean Time) on July 9, 1981. This was done in order to insure an unbiased comparison with the December results. Furthermore, these options, known as System Analysis Recording (SAR), Timing Analysis Reports (TARS) , Resource Monitoring (REMON) and the number of configured computing elements, significantly affect computer utilization and, to negate their influence during the 7/9/81 measurement, they have been turned off or reduced to minimum levels as follows:

-SAR Category set to "2" (a "2" at HOUSTON corresponds to "1" in the Universal Data Set at the FAA Tech. Center)

-TARS set to "0000" (no TARS processing nor recording)

- 3 computing elements configured

and -REMON turned OFF.

These levels are identical to those established in the December Study.

On regular days, however, HOUSTON personnel set the options to recording levels higher than those stated in the preceding paragraph. They systematically reduce them when the computer reaches certain high utilization values during dense traffic periods,

and then reset them to their original value as computer utilization decreases over the day. These recording variations are illustrated in Figures 9, 10, and 11 which show data plotted as function of local time in minutes from midnight for July 8, 1981. On that day, HOUSTON variably reduced TARS processing and recording in order to lower utilization during dense traffic periods. The letter codes used in these figures correspond to measurements taken at various recording option levels set at HOUSTON as follows:

Condition A: SARC="4"
TARS="7FFC" (complete TARS recording)
3 Computing Elements Configured
and REMON=OFF

Condition B: SARC="4"
TARS recording="2010" (a reduction in TARS recording from "7FFC")
3 Computing Elements Configured
REMON=OFF

Condition C: SARC="4"
TARS="0000" (no TARS processing nor recording)
3 Computing Elements Configured
and REMON=OFF

Condition D: SARC="4"

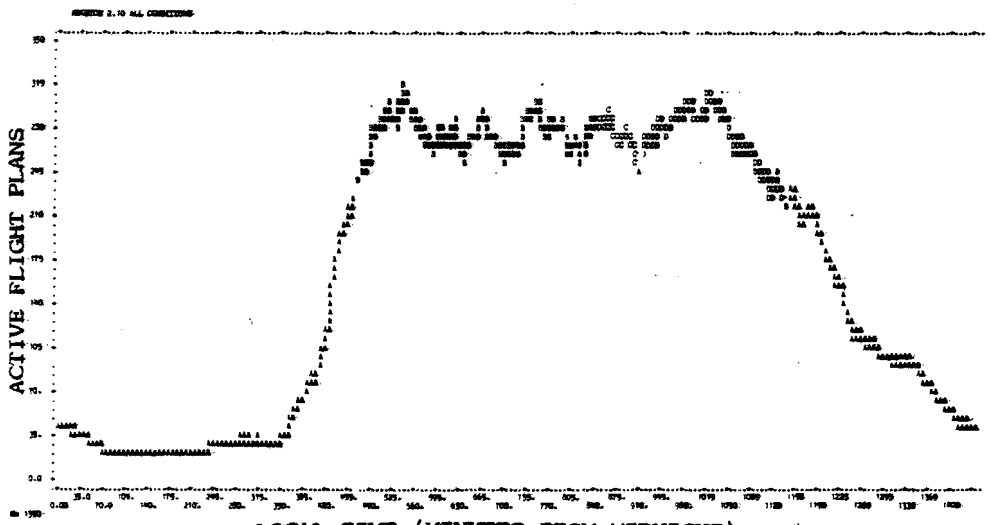
TARS="0F80" (a very limited TARS recording)

3 Computing Elements Configured

and REMON=OFF

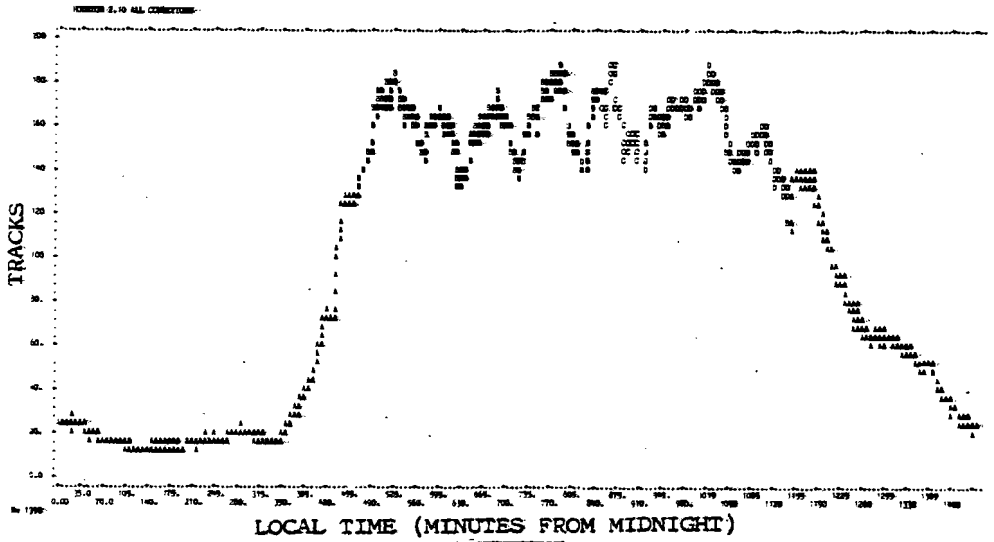
All four conditions above are identical except in terms of TARS setting. Figures 9 through 11 show the approximate times of day when the various TARS settings are switched back and forth as traffic loads and the corresponding computer utilization vary over a twenty-four hour period.

The same information has been plotted as a scatter diagram in Figure 12 which shows utilization as a function of workload (tracks in this case). An asterisk in that figure represents observations under different conditions but with identical x-y coordinates. Figure 12 indicates that, on the average, computer utilization is reduced by several percentage points when condition "C" or "D" replaces condition "A" or "B".



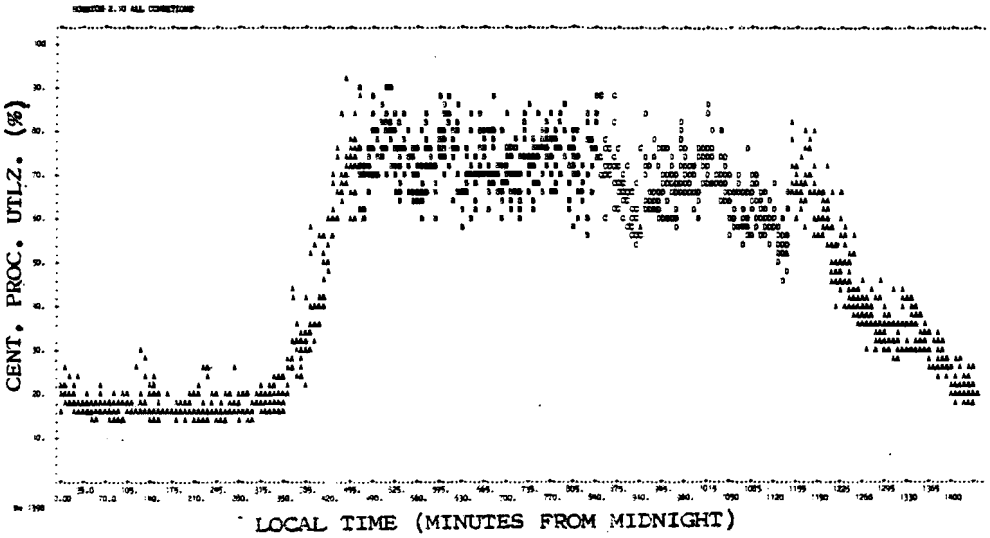
LOCAL TIME (MINUTES FROM MIDNIGHT)

FIGURE 9



LOCAL TIME (MINUTES FROM MIDNIGHT)

FIGURE 10



LOCAL TIME (MINUTES FROM MIDNIGHT)

FIGURE 11

HOUSTON 2.10 ALL CONDITIONS

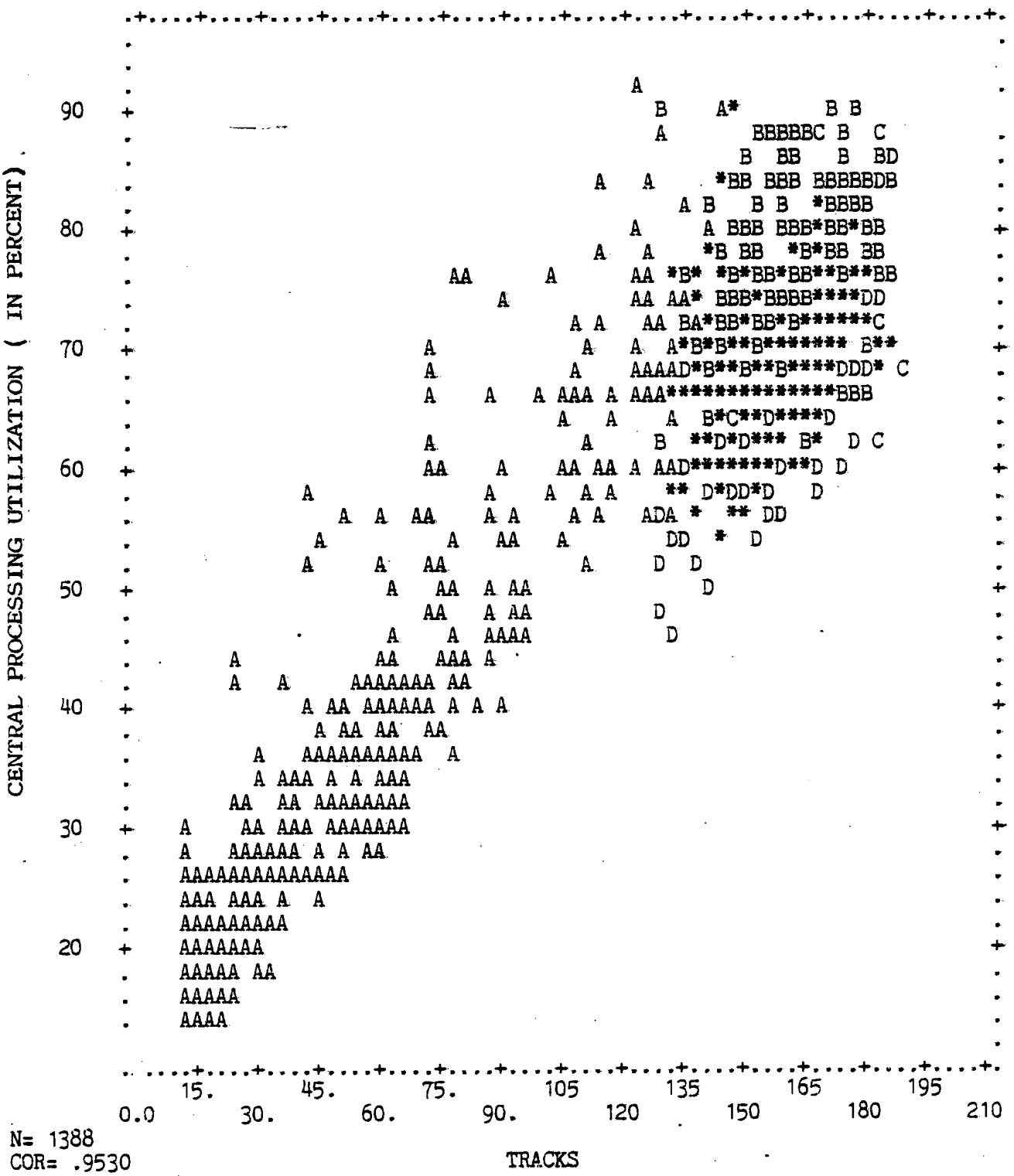


Figure 12 Scatter Diagram for Central Processing Utilization versus Tracks subject to following Conditions:

Condition A - complete TARS Recording
Condition B - TARS Recording set at "2010"
Condition C - No TARS Recording nor Processing
Condition D - Tars Recording set at "0F80"

CONCLUSIONS

The following conclusions can be drawn from the analysis of the HOUSTON data:

1. With the previous software version (A3d2.9), HOUSTON's 9020A computer was approximately 82 percent utilized for its heaviest observed track load (180 tracks) under constant minimum background recording conditions. The IOCE Offloading feature has reduced computer utilization to approximately 66 percent at this same track load.

2. A reduction in the recording of Timing Analysis Reports (TARS) to minimum levels lowers computer utilization by an order of magnitude comparable to IOCE Offloading.

3. Active flight plan count and track count correlate very well with computer processing utilization. This condition, observed in the previous two studies, remains applicable for HOUSTON with IOCE Offloading.

4. Active flight plans and tracks are highly correlated among themselves. Either one of these parameters reflects therefore the effect of the other.

5. The relationship between computer utilization and flight plans or tracks follows a straight-line equation unique to HOUSTON.

6. The selected methodology, based on scatter diagrams along with linear regression and shown to be effective in References 7, 8, and 9, remains applicable for this study as well, according to the statistical results obtained from the analysis.

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