NASA GRANT NAG 4-9

FINAL REPORT

SENSOR REDUNDANCY MANAGEMENT: THE DEVELOPMENT OF A DESIGN METHODOLOGY FOR DETERMINING THRESHOLD VALUES THROUGH A STATISTICAL ANALYSIS OF SENSOR OUTPUT DATA

(NASA-CR-173270) SENSORY REDUNDANCY MANAGEMENT: THE DEVELOPMENT OF A DESIGN METHODOLOGY FOR DETERMINING THRESHOLD VALUES THROUGH A STATISTICAL ANALYSIS OF SENSOR OUTPUT DATA Final (Queensborough Community G3/64 N84-16859 Unclas 10128

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THE PROBLEM

The National Aeronutics and Space Administration (NASA) has been conducting research in digital fly-by-wire (DFBW) flight control for aircraft and spacecraft. At the NASA Dryden Flight Research Center a DFBW flight control system has been tested in the F-8 aircraft. In the specific flight control area of sensor redundancy management (SRM) a method capable of verifying performance through statistical analysis of sensor data is desirable. It is hoped that this statistical analysis will define performance requirements concerned with detecting false alarms, missed alarms, and maximum vehicle transients caused by sensor failures. The results should be used to set tolerances (thresholds or trip levels) for each parameter measured.

This researcher developed a probability density function for the mid-value sensor select algorithm (NASA Grant NAG 4-6). The probability density function was used to obtain values for nomograph plots for the probability of false alarm, given the cummulative probability of being in the domain of failure and system reliability.

One of the objectives of this grant (NAG 4-9) is to apply the probability density function, developed in NASA grant NAG 4-6, to sensor output data from the AFTI F-16 aircraft. AFTI stands for Advanced Fighter Technology Integration and is a joint Air Force, NASA, and Navy program to apply futuristic aircraft technology using a highly modified F-16A aircraft. The AFTI F-16 program is expected to continue through the summer of 1984.

More specifically, this investigator will attempt to reach the following goals:

1. Rewrite the procedures, developed in NASA Grant NAG 4-6, for generating a probability density function to determine false alarm rates, using an algorithmic approach.

2. Develop microcomputer software which will print out table of values for the cummulative probability of being in the domain of failure; system reliability; and false alarm probability, given a signal is in the domain of failure.

3. Develop microcomputer software which will plot nomographs associated with the table of values in step 2.

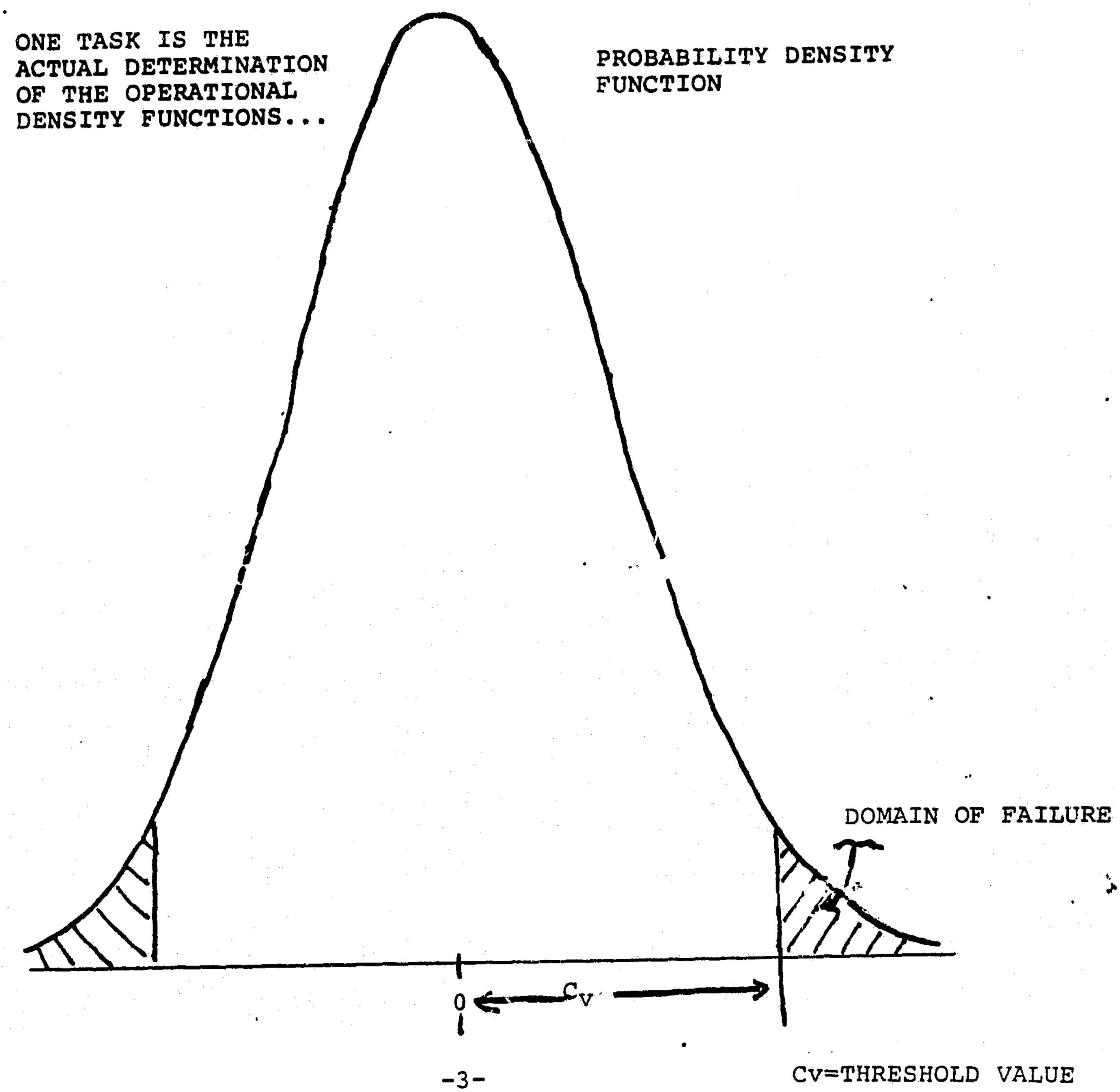
4. Apply the microcomputer software to sensor output data for various AFTI F-16 flights and sensor paramaters.

5. Survey various experimental SRM algorithms.

6. Make practical recommendations for further research.

Conditional probability and probability density functions will be used to find the probability of a false alarm, given the sensor select signal is in the domain of failure. Furthermore, the resulting probabilities may be used to select practical threshold values. This approach also includes system reliability in the determination of threshold values, and provides the probability of a false alarm, given an alarm occured. That is, if the fail light is on, the confidence level for resetting the system is available. The most difficult task will be to determine the probability density function for being in the domain of failure.

One important task is the determination of the operational probability density function.



REVIEW OF RELATED LITERATURE

Sensor redundancy management (SRM) requires a system which will detect failures and reconstruct avionics accordingly. In the F-8 DFBW aircraft SRM is extremely important to vehicle performance and the activity of output signals influenced by device errors, failures, and vehicle motion. Failures should not cause excessive vehicle transient motion, which might result in damage or loss of the vehicle.

Sensor redundancy management is required to detect a wide class of failures, detect and minimize false alarms, and detect whether or not the signals exceed a given trip level (threshold). To maximize the detection of failures, the trip level should be as small as possible. However, to minimize false alarms, the trip level should be large enough to include the expected errors in the parameter channels. Errors are divided into three classes: fixed errors (bias errors), noise errors (originating in sensor and AD converter), time varying errors (dynamic errors caused by scale factor deviations, transfer function errors, and sensor unalignment).

Gelderloos and Wilson (1976) designed a Monte Carlo Simulation (MCS) to verify flight control SRM in the NASA Space Shuttle project. This MCS gives probabilities of false alarms, failure transients, and failure dectability as dicated by performance requirements. They note that MCS was chosen because the non-linear nature of the problem does not lend itself to simple linear techniques, including elementary statistical analysis.

At the start of each run the MCS randomly chooses a number for each redundant parameter according to a given density function. Data is exercised through three sets of algorithms (Figures 1, 2, and 3) and, for each run, finds:

1. The maximum trip level which will give one false alarm.
2. The maximum failure transient.
3. The maximum trip level which will detect a given failure.

These maxima are collected for 500 runs and then normalized to achieve the desired probabilities. Two of Gelderloos and Wilson's findings are:

1. The probability of false alarms are a function of the size of errors between redundant sensors.
2. The probability of failure detections are a function of the size of errors on the "good" sensors as well as the signal differences between the "failed" and "good" sensors.

Sensor redundancy management for the F-8 DFBW aircraft at the NASA Dryden Flight Research Center is divided into two parts (RM1 and RM2) which are executed at different times in the computation cycle. Szalai, Felleman, Gera, and Glover (1976) illustrated F-8 DFBW hardware (figure 4), software sequence and timing during one minor cycle = 20 m/secs (figure 5), triplex SRM (figure 6), and triplex discrete rendundancy management algorithm (figure 7). A hard sensor fault is declared by RM2 when a sensor differs from a selected value by an amount greater than the allowable tolerance (trip level) for a given number of passes (for the F-8 DFBW n = given number of passes = 5=100m/sec). The given number of passes, n, is often referred to as a window width. Figure 8a illustrates a hardover sensor fault of sensor A, and figure 8b illustrates a transient fault of sensor A.

Szalai, Larson and Glover (1979) summarized the F-8 DFBW flights in and Advisory Group for Aerospace Research and Development (AGARD) lecture. Table 1 lists the sensor set and assigned tolerances (trip levels). Some of the findings for pitch rate gyro, roll rate gyro, yaw rate gyro, normal accelerometer, lateral accelerometer, and longitudinal accelerometer for sensors A and C are:

1. RMS value of the sensor pair difference was generally less than half the maximum difference recorded (i.e. (A-C) RMS value < ½ maximum (A-C)).
2. Maximum |A-C| < ½ fault threshold.

The counters in the program logged each miscompare of any sensor pair, triple, or duplex set and the number of times the counter reached three or four (one or two of n=5). Table 2 lists the cummulative sensor flight experience for the F-8 DFBW at NASA Dryden.

The results are not significant because of the following facts:

1. Angle of attack, pitch attitude, and altimeter tallies were caused by an actual hardware failure.
2. The one lateral accelerometer fault was a false alarm (acceleration threshold was increased to 0.2g).

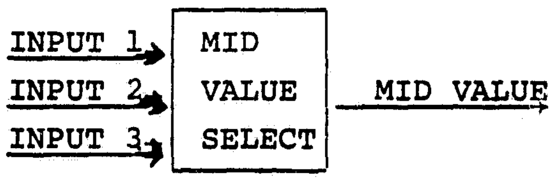
3. The other two lateral accelerometer and attitude where the count reached four were associated with a previous degrading of performance.

In a Boeing Company report (1978) on Signal Monitoring and Voting the following reasons are given for the importance of sensor select and failure detection: improve autoland performance, reduce nuisance disconnects, improve no failure performance, and add significant fault isolation capability. The Boeing sensor selection system is very similar to the Dryden F-8 DFBW system. They have also been trying to develop a statistical model to input sensor data, perform statistical analysis, identify the distributions, and predict exceedance rates. The Boeing Corporation has indicated that the identification of the distribution will help to predict low exceedance rates. However, they list the following as problem areas: Sensor data is not stationary; limited sample size (not true at Dryden since F-8 DFBW has had over 100 flights); no specific distributions for sensor data has been identified; and, sensor distributions are possible to model, but extremely difficult.

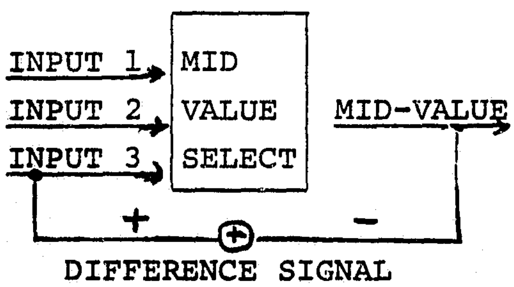
The determination of false alarm rates and practical threshold values would be beneficial to the AFTI F-16 research. Some of the futuristic capabilities of the AFTI F-16 would include a Voice Command System that allows the pilot and aircraft to converse verbally; A Digital Flight Control System computer and an Automated Manuvering Attack System computer that converse with each other to cut down pilot workload during combat type maneuvers;and direct force controls, such as "chin" canards that provide lift, sideforce, and axial translation capabilities. All of these and other features are designed to work together to attempt to make the AFTI F-16 aircraft the best fighter aircraft in the world.

METHODS AND PROCEDURES

Given three independent signals, each measuring the same parameter, one of the signals or a weighted average of the incoming signals would be used for input in a flight control system. For the F-8 DFBW project, the mid-value sensor select algorithm was chosen:



The monitoring of each of the three input signals, necessitates developing some criterion for determining when one of the input channels fails to function properly. The initial approach for chosing this criterion was to examine the difference between an input channel (say, input 3), and the mid value; then assume that this difference is approximately normally distributed and select a value C_v so that the probability of the "normally" distributed difference signal exceeding C_v is quite small.



As a practical matter, it was decided to determine C_v so that the probability of n consecutive values from the "difference signal" exceeding C_v is less than some specified value. The use of n values is commonly referred to as a window width of n. Determination of C_v is predicated on the assumption that samples from the difference signal are independent. The window width affects C_v directly (i.e., the greater n, the longer it takes to eliminate a bad sensor ; and smaller n, the more sensitive determination of C_v is to the kurtosis of the difference signal). Also, the longer the flight time, the more likely n consecutive values from the difference signal will exceed C_v. Thus to specify with at least 99% confidence, a maximum number of excursions (the event that n concecutive values exceed C_v):

i.e. $p(\min \{|yi|\}_{i=1}^{n} \geq C_v)$

C_v is selected so that

$$p(\min \{|yi|\}_{i=1}^{n} \geq C_v) \cdot \frac{SPS \cdot T}{n} \leq N$$

where T = total seconds

n = window width

N = number of excurisions per T seconds

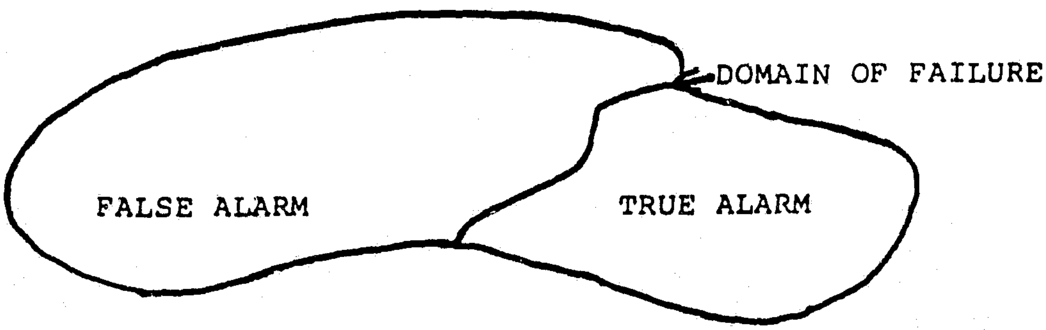
SPS = sampling rate of the system (samples per second)

Notice, once again, that n/SPS seconds is required to determine whether or not the input signal is faulty. This time may or may not be critical. Selection of C_v in this context simply establishes a level which the difference signal is not likely to exceed (without a hard failure of some kind). Figure 9 shows, for various window widths, what value C_V must take take for having the specified number (or fewer) of excursions in one million frames of data.

An alternative approach, to determining C_V would be to consider the conditional probability of a false alarm, given that the difference signal has exceeded the critical value (C_V). This approach is more desirable than the one outlined above; since it will include system reliability in the determination and provide the probability of a false alarm, given that an alarm has occured. In other words, if a fail light comes on, the conditional probability approach will provide a confidence level for resetting the system.

The following step-by-step procedure was developed by the investigator.

STEP 1: Find P(AF/DF), where AF=the event of a false alarm occuring, and DF=the event of the signal being in the domain of failure



Using Baye's law we obtain:

$$P(AF/DF) = \frac{P(DF/AF) \cdot P(AF)}{P(DF/AF) \cdot P(AF) + P(DF/\overline{AF}) \cdot P(\overline{AF})}$$

where $\overline{AF}$ = event of no false alarm (i.e., true alarm or no alarm)

but P(DF/AF)=1, therefore

i. $P(AF/DF) = \dfrac{P(AF)}{P(AF)+P(DF/\overline{AF})\cdot P(\overline{AF})}$

now let A = event an alarm occurs

AT = event a true alarm occurs

then $\overline{AF} = \bar{A} \cup AT$

and

$\bar{A} \cap AT = \phi$

therefore $P(DF/\overline{AF}) = P(DF/(\bar{A} \cup AT)$

$$= \frac{P(DF \cap (\bar{A} \cup AT))}{P(\bar{A} \cup AT)}$$

and since $\bar{A} \cap AT = \phi$

$$P(DF/\overline{AF}) = \frac{P(DF\ \bar{A}) \cup P(DF\ AF)}{P(\bar{A}) + P(AT)}$$

note $DF\ \bar{A} = \phi$ and $DF \cap AT = AT$

ii. $P(DF/\overline{AF}) = \dfrac{P(AT)}{P(\bar{A})+P(AT)}$

substituting ii. into i. we obtain

$$P(AF/DF) = \frac{P(AF)}{P(AF) + \dfrac{P(AT)}{P(\bar{A})+P(AT)} \cdot P(\overline{AF})}$$

or iii. $P(AF/DF) = \dfrac{P(AF)[P(\bar{A})+P(AT)]}{P(AF)[P(\bar{A})+P(AT)]+P(AT)\cdot P(\overline{AF})}$

Now we need formulas for P(AF) = P(false alarm,

$P(\bar{A})$= p(no alarm occurs) and P(AT)=p(a true alarm occurs)

so we can compute P(AF/DF).

Let $P(AF) = P(A\bar{F})$ = p(alarm $\cap$ not a hard fault)

where A = event an alarm occurs

F = event a hard fault occurs

$\bar{F}$ = event a hard fault does not occur.

iv. $P(AF) = P(A \cap \bar{F}) = P(A/\bar{F}) \cdot P(\bar{F}) = C(DF) \cdot R = [\int_{DF} P(y)dy] \cdot R$

where C(DF) = cummulative probability of being in the domain of failure

R = system reliability

i.e. $R = P(\bar{F})$

P(y) = operational density function

furthermore:

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$$\text{v.} \begin{cases} P(\overline{AF}) = 1 - P(AF) \\ P(A) = (1-R) + P(AF) \\ P(\bar{A}) = 1 - P(A) \\ P(AT) = 1 - R \end{cases}$$

Substituting v. into iii.we obtain:

$$P(AF/DF) = \frac{P(AF)[P(\bar{A}) + P(AT)]}{P(AF)[P(\bar{A}) + P(AT)] + P(AT) \cdot P(\overline{AF})}$$

$$= \frac{P(AF)[1-(1-R)-P(AF)+1-R]}{P(AF)[1-(1-R)-P(AF)+1-R]+(1-R)\cdot(1-P(AF))}$$

$$= \frac{P(AF)[1-P(AF)]}{P(AF)[1-P(AF)]+(1-R)\cdot(1-P(AF))}$$

$$= \frac{P(AF)}{P(AF) + (1-R)}$$

$$= \frac{P(AF)}{P(AF) + P(AT)}$$

STEP 2:

Determine the characteristics of the probability density function (pdf) = $\int_{DF} P(y)\,dy = C(DF)$

NORMAL PROBABILITY DISTRIBUTION FOR CONTINUOUS RANDOM VARIABLE X (RVX):

$$P(X) = \frac{1}{\sigma\sqrt{2\pi}} e^{[-1/2\ (X-\mu)^2/\sigma^2]}$$

where μ = mean RVX

σ^2 = variance RVX

σ = st. deviation RVX

STANDARD NORMAL PROBABILITY FUNCTION

$\mu = 0 \quad \sigma = 1$

$$f(X) = \frac{1}{\sqrt{2\pi}} e^{-X^2/2}$$

CUMMULATIVE PROBABILITY DENSITY FUNCTION

$$F(X) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{X} e^{-y^2/2}\, dy$$

ORDER STATISTICS

Now let X_1, X_2, X_3 (sensor triple)

be a random sample for RVX and

let y_1 = minimum (X_1, X_2, X_3)

y_2 = mid value (X_1, X_2, X_3)

y_3 = maximum (X_1, X_2, X_3)

The joint probability density function of X_1, X_2, X_3 is:

$$f(X_1)\cdot f(X_2)\cdot f(X_3)$$

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The following disjoint sets:

$A_1 = \{(X_1, X_2, X_3) | X_1 < X_2 < X_3\}$

$A_2 = \{(X_1, X_2, X_3) | X_1 < X_3 < X_2\}$

$A_3 = \{(X_1, X_2, X_3) | X_2 < X_1 < X_3\}$

$A_4 = \{(X_1, X_2, X_3) | X_2 < X_3 < X_1\}$

$A_5 = \{(X_1 \ X_2 \ X_3) | X_3 < X_1 < X_2\}$

$A_6 = \{(X_1, X_2, X_3) | X_3 < X_2 < X_1\}$

are one-to-one transformations which map each of $A_1, A_2, \ldots, A_6$ onto the same set $B = (Y_1, Y_2, Y_3) \quad y_1 < y_2 < y_3$. Furthermore, the inverse functions for points in:

A_1 are $X_1 = y_1, X_2 = y_2, X_3 = y_3$

A_2 are $X_1 = y_1, X_2 = y_3, X_3 = y_2$

A_3 are $X_1 = y_2, X_2 = y_1, X_3 = y_3$

A_4 are $X_1 = y_2, X_2 = y_3, X_3 = y_1$

A_5 are $X_1 = y_3, X_2 = y_1 \ X_3 = y_2$

A_6 are $X_1 = y_3, X_2 = y_2, X_3 = y_1$

The Jacobian for each of these transformations are:

$$J_1 = \begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix} = 1 \qquad J_2 = \begin{vmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{vmatrix} = -1$$

$$J_3 = \begin{vmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{vmatrix} = -1 \qquad J_4 = \begin{vmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{vmatrix} = 1$$

$$J_5 = \begin{vmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{vmatrix} = 1 \qquad J_6 = \begin{vmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{vmatrix} = -1$$

and $|J_i| = 1 \qquad i = 1, 2, 3, 4, 5, 6.$

Therefore the joint pdf of y_1, y_2, y_3 is:

$$g(y_1, y_2, y_3) = |J_1|f(y_1)f(y_2)f(y_3) + |J_2|\ f(y_1)f(y_2)f(y_3) + \ldots + |J_6|\ f(y_1)f(y_2)f(y_3)$$

or $g(y_1, y_2, y_3) = 6f(y_1)f(y_2)f(y_3)$

Now we will compute the probability density function (pdf) for the mid-value sensor select algorithm which is illustrated in figure 9.

The marginal pdf for y_2 (mid-value) is:

$$\begin{aligned} h(y_2) &= \int_{-\infty}^{y_2} \int_{y_2}^{\infty} g(y_1, y_2, y_3)dy_3dy_1 \\ &= \int_{-\infty}^{y_2} \int_{y_2}^{\infty} 6f(y_1)f(y_2)f(y_3)dy_3dy_1 \\ &= 6f(y_2)\int_{-\infty}^{y_2} f(y_1) \int_{y_2}^{\infty} f(y_3)dy_3dy_1 \\ &= 6f(y_2) \int_{-\infty}^{y_2} f(y_1)\ [1-F(y_2)]dy_1 \\ &= 6f(y_2)[1-F(y_2)]F(y_2) \end{aligned}$$

since $F(X) = \int_{-\infty}^{X} f(w)dw$

THE CUMMULATIVE PDF
and

$\int_{-\infty}^{\infty} f(w)dw = 1$

note that $h(y_2) = 6f(y_2)[1-F(y_2)]F(y_2)$

has edpected value, $\mu=0$

$p(y_2 \leq 0)=6\int_{-\infty}^{0}F(y_2)[1-F(y_2)]f(y_2)dy_2$

since $d(F(y_2)) = f(y_2)dy_2$

$p(y_2 \leq 0)= 6\int_{-\infty}^{0} F(Y_2)df(y_2)-[F(y_2)]^2df(y_2)$

$$= 6 \left. \frac{[F(y_2)]^2}{2} - \frac{[F(y_2)]^3}{3} \right|_{-\infty}^{0}$$

$$= 6 \frac{(0.5)^2}{2} - \frac{(0.5)^3}{3}$$

or $p(y_2 \leq 0) = 0.5$

Therefore our pdf has Median = 0 and is symmetric about μ(mean)=0.

Now $h(y_2) = 6f(y_2)F(y_2)[1-F(y_2)]$

$h(-y_2) = 6f(-y_2)F(-y_2)[1-F(-y_2)]$

$$f(x) = \frac{1}{\sqrt{2\pi}} e^{-x^2/2}$$

$f(-y_2) = f(y_2)$

$F(-y_2) = 1-F(y_2)$

$1-F(-y_2) = F(y_2)$

hence $h(-y_2) = 6f(y_2)[1-F(y_2)]F(y_2)$

has $\mu=0$, median = 0, and is symmetric about μ.

The variance $E(y_2{}^2)-E(y_2)^2=E(y_2)^2$

(since median = 0)

Therefore,

$\sigma^2(y_2)=\text{variance}(y_2)=6\int_{-\infty}^{\infty} y_2^2 \, f(y_2)F(y_2)[1-F(y_2)]$

Now we must integrate the mid-value variance.

The formula for variance (y_2) above is very difficult to integrate.

However, we can use the trapezoidal rule to integrate numerically and obtain variance (mid-value)$=\sigma^2(y_2) = 0.4487$.

The distribution $h(X)=6f(X)F(X)[1-F(X)]$

where: $f(X) = \frac{1}{\sqrt{2\pi}} e^{-X^2/2}$ and

$$F(X) = \frac{1}{\sqrt{2\pi}} \cdot \int_{-\infty}^{X} e^{-t^2/2} dt,$$

is not normal, but statistically indistinguishable from a normal distribution with $\mu=0$ and $\sigma^2 = 0.4487$ at the 0.05 level of significance. The distribution $h(X) = 6f(X)F(X)[1-F(X)]$ and $n(X) = \frac{1}{\sqrt{2\pi}(0.6699)} e^{-X^2/2(0.4487)}$ agree in the $\pm 3\sigma$ range to at least two decimal places.

We define a distribution to be "near-normal if a χ^2 (Chi-squared) test of goodness fit indicates the distribution is indistinguishable from some normal distribution at the 0.05 level of significance. Every normal distribution is "near-normal" as is $h(X) = 6f(X)F(X)(1-F(X))$.

The χ^2 goodness fit test indicates that at the 0.05 level of significance $h(X)$ is not significantly different from a normal distribution with $\mu=0$ and $\sigma^2 = 0.4887$. In fact, the 99 percent confidence interval for σ^2 is:

$0.4222 \le \sigma^2 \le 0.4970$.

Finally, our "near-normal" pdf for the mid-value selection is

$$n(X) = \frac{1}{\sqrt{2\pi}(1.2036)} e^{-X^2/2(1.4487)}$$

or $n(X) = 0.33145 e^{-X^2/2.8974}$

i.e. $\mu=0$

$$\sigma^2 = \text{Normal Part} + \text{Near-Normal Part} = 1+0.4487=1.4487$$

$$\sigma = \sqrt{1.4487} \approx 1.2036, \text{ and}$$

$$-3\sigma \leq 99 \text{ percent of signals} \leq 3\sigma$$

$$-3.099 \leq 99 \text{ percent of signals} \leq 3.099$$

STEP 3: The present investigator modified the NASA Dryden prepackaged programs FLIFRNT (for obtaining sensor channel data) and SPA (for obtaining a statistical analysis of sensor channel data) to obtain this information for differences (left-self, left-right, self-right) between sensor channels (see Appendix C).

STEP 4: Original microcomputer software (see Appendix D) was written to obtain tables of values and plots of corresponding nomographs for P(AF/DF), given the sensor channel difference was in the domain of failure and system reliability.

STEP 5: The revised SPA program and original microcomputer software was run using sensor data collected from various AFTI F-16 flights.

FINDINGS

The NASA Dryden computer center has a statistical package, entitled SPA (see Appendix E), which can cause linear trends to be removed from unfiltered data; filter data; perform descriptive statistical analysis; nonparametric statistics, root mean square analysis, spectrum analysis, histogram plots, and normal curve fitting to histogram plots. Figure 10 (roll rate gyro sensor data for channel C on flight 22) and figure 11 (longitudinal axis sensor data for channel C on flight 22) are indicative of F-8DFBW sensor data distributions. Most sensor data distributions for the F-8DFBW aircraft have the following properties: the data is subject to abrupt peaking; few or no extremity values exist; and observed chi-square values exceed critical values (see Table 3). These non-normal properties induced the investigator to formulate the near-normal probability density functions in the previous section of this paper.

Subsequently,for NASA Grant NAG 4-6 a BASIC computer program was constructed and executed using sensor data from roll rate gyros A and C for flight 23 of the F-8DFBW aircraft. This program accepted a sensor value; then computed the corresponding value of C(DF), using the probability density function; then let R = reliability of the system assume values from 0.9999 through 0.9950; and finally compute the corresponding values of P(AF/DF) probability of a false alarm, given the sensor select value was in the domain of failure.

The results of this BASIC program were used to construct the general nomograph, illustrated in figure 12. As an illustrative example, we see in figure 12 that for $C(DF) = 5.2 \times 10^{-5}$ and $R = 0.999$, $P(AF/DF) = 0.05$.

Now, introducing the selection of a desired window width (which was explained in the previous section of this paper); to the BASIC program and general nomograph which computes P(AF/DF), given C(DF) and R, a general nomograph for selecting C_V (critical threshold values) was constructed in Figure 13. For example, figure 13 illustrates that for a window width of $n = 5$, the threshold value $C_V \cong 1.48\sigma = 1.48(1.2036) \cong 1.78$ (for the mean-value sensor select algorithm).

Repeating the processes outlined above the investigator obtained a second output of values for the mid-value sensor-select pdf. The statistical comparison of the mid-value and mean-value sensor select distribution, as expected, was not significant at the 0.05 level. The general nomographs in figures 12 and 13 apply to both mid-value and mean-value sensor select probability density functions.

Modified versions of the FLIFRNT and SPA computer programs (Appendix C), and microcomputer software (Appendix D) were used to obtain complete statistical analyses, false alarm probabilities and corresponding nomographs for AFTI F-16 flight data collected by the investigator, during August, 1982 (Appendix F).

A COMPARISON OF VARIOUS SRM ALGORITHMS

After one sensor has failed in a triplex system, the SRM algorithm must perform selection, detection, and reconfiguration on the remaining two sensor inputs.

One basic idea in SRM, for a triplex system, is that when a particular sensor input differs from the other two; it is probably true that this particular sensor, and not the other two, has failed.

A miscompare between two inputs creates a problem for the computer, because it has no way of telling which input is correct. The computer must have a third source of information, before it can isolate the bad input and avoid declaring both inputs bad.

(A) <u>ASPECTS OF SRM</u>

1. Selection Process
2. Fault Detection Process
3. Failure Reconfiguration Process

(B) <u>SELECTION METHODS FOR SRM</u>

1. Mid-Value Select (MVL) - takes the three input signals and picks the value "inbetween" the other two (see figure 14).
2. Self-If-Good (SIG) - each processor uses its respective sensor input, providing it was not previously declared out of tolerance (see figure 15).
3. Averaging (AVE) - mathematical average of the three inputs (see figure 16). Notes: if one sensor

has failed, the remaining two are averaged; and only the MVL method allows selection to be run before detection.

(C) DETECTION METHODS FOR SRM

1. Result Minus Sensor (RES-X) - takes the result of the selection process and subtracts each sensor value for comparison to a tolerance (see figure 17). RES-X is performed every 20 m/secs and each miscompare represents one persistance count (PC). Given a frame rate and a set time, a fault must persist for a specified maximum PC before being declared permantently failed.

2. Differening (DIFF) - compares the difference of each sensor pair to a tolerance for determination of a miscompare. If two comparisons fail, the sensor common to those tested has its PC incremented.

NOTES:

a) Acceptable selection/detection processes: MVL/RES-X, MVL/DIFF, SIG/DIFF, AVE/DIFF.

b) RES-X requires selection first, and only MVL allows selection before detection.

(D) RECONFIGURATION METHODS FOR SRM

Reconfiguration indicates what must be done when only two good sensors remain and a miscompare between these two occurs. The needs for reconfiguration are to set system reliability requirements and indicate the importance of the sensor in question.

1. Resonability Check - determines if the input is within its physical range. For example, if an aircraft cannot reach an altitude greater than 40K, a value greater than 40K would be used as a resonability check for altitude.

2. Rate Change - tests the sensor input in question against a known physical limit, namely a given rate change. The rate of change and resonability methods are quite similar.

3. Analytic Redundancy Management (ARM)-makes use of unfailed sensors which are related to the sensor being monitored. The ARM relationship is modeled in the digital system and driven by dissimilar sensor inputs. The main function of the ARM algorithm is to output a third sensor value, in order to isolate the fault.

4. Failure Analysis - uses knowledge of the system hardware structure to isolate failures. If a number of analogue inputs fail at the same time; a failure of analogue to digital is declared, then all analogue inputs for the channel in question are put in a failed status. If a second miscompare occurs and this failure is analyzed as a failure of a higher order device (such as analogue to digital converter), then the corresponding input would be declared failed, allowing the remaining good sensor to be identified.

RECOMMENDATIONS

It seems that conditional probability and order statistics offer an elementary, interesting, and promising approach to the complex problem of analyzing sensor distributions, predicting false alarms, and selecting practical threshold values.

In conclusion, the investigator offers the following specific recommendations for further research:

1. Use the probability function and microcomputer software developed in this research paper to perform a statistical analysis for each of the sensor parameters on current AFTI F-16 flights.
2. Attempt to use the statistical analysis in step 1 to set practical threshold values for AFTI F-16 sensor parameters.
3. Develop microcomputer software to replace the NASA Dryden SPA statistical package.
4. Develop statistical procedures to study the various experimental SRM algorithms.
5. Develop statistical procedures to compare the results of various experimental SRM algorithms.
6. Determine the probability of a sensor miscompare based on noise frequency content and sampling delays in an asynchonous system. It is possible that an asynchonous system will reduce the input of electrical transients on system operations. One theory is that if an electrical transient occurs, it will appear on only one channel at a time and will be voted out in the selection process.

10a

BIBLIOGRAPHY

Bjurman, B.E., et. al. Airborne Advanced Reconfigurable Computer System (ARCS). Seattle, Washington: Boeing Company, 1976.

Brownlow, Jim. SPA Statistical Package. Edwards, California: NASA/Dryden, 1976.

Controls Department. Signal Monitoring and Voting. Los Angeles, California: Boeing Company, 1979.

Gelderloss, H.C. and Wilson, D.V. "Redundancy Management of Shuttle Flight Control Sensors," Proceedings IEEE Conference on Decision and Control, 76CH1150-2CS, Clearwater, Florida: December, 1976.

Jarvis, C.R., et. al. Experimental Shuttle Software Flight Test Report: F-8 Digital-Fly-By-Wire Program. Edwards, California: NASA/Dryden, 1977.

Kousourou, Gabriel, Sidney Sonsky, and Frank Scalzo. Introductory Technical Mathematics With Computing. Princeton, New Jersey: Petrocelli Books, 1979.

Scalzo, Frank and Rowland Hughes. Elementary Computer-Assisted Statistics (Revised Edition). New York: Van Nostrand Reinhold, 1978.

Swaroop, Ram, et. al. Bivariate Normal Conditional and Rectangular Probabilities: A Computer Program With Applications. Edwards, California: NASA/Dryden, 1980.

Szalai, Kenneth, et. al. Design and Test Experience With Triply Redundant Digital Fly-By-Wire Control System. Edwards, California: NASA/Dryden, 1976.

Szalai, Kenneth, et. al. Flight Experience With Flight Control Redundancy Management. Edwards, California: AGARD Lecture Series 109, 1980.

Wadsworth, George P.and Bryan, Joseph G. Probability and Random Variables. New York: McGraw Hill Book Co., 1960.

APPENDIX A

FIGURES

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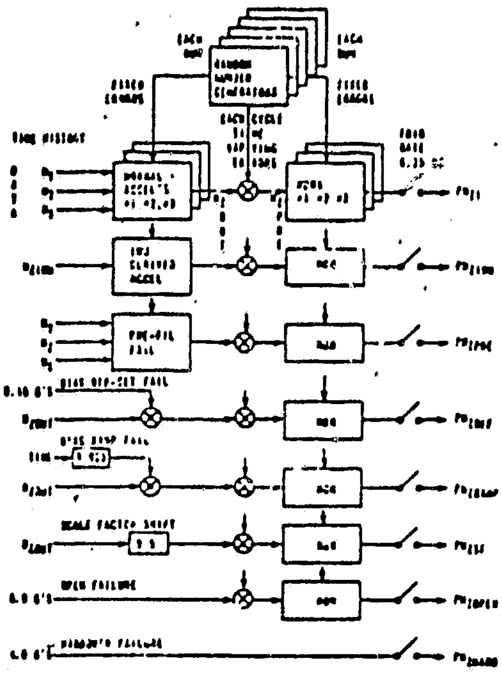

FIGURE 1. MONTE CARLO SIMULATION

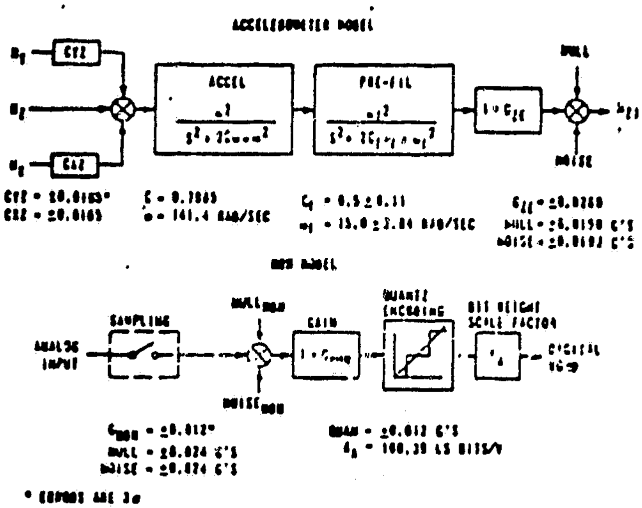

FIGURE 2. NORMAL ACCELEROMETER AND MDM MODELS

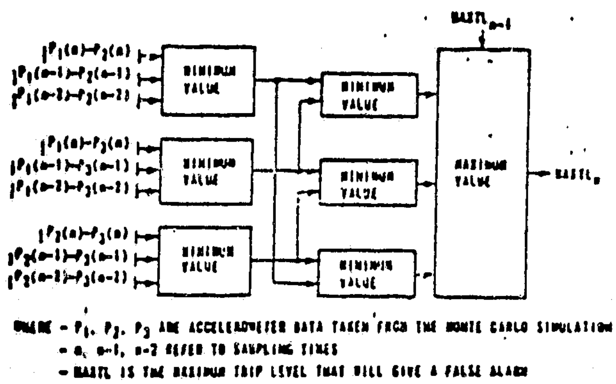

FIGURE 3. FALSE ALARM ALGORITHM

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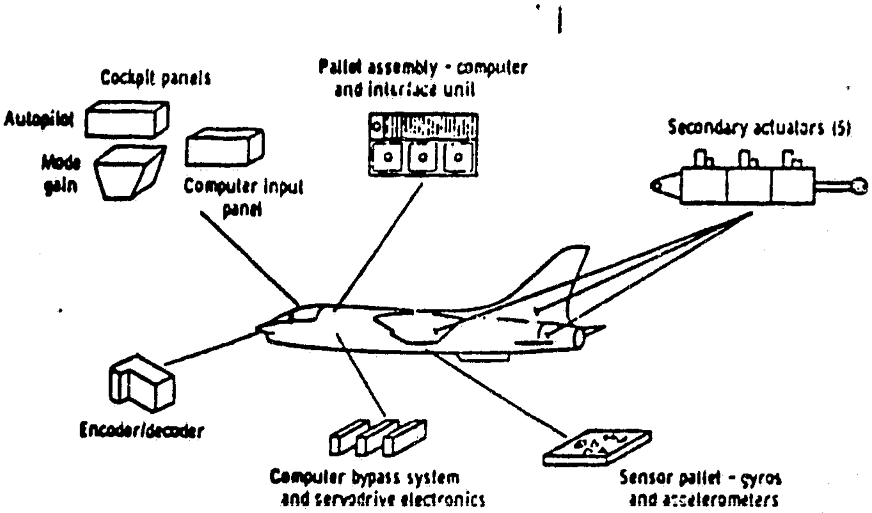
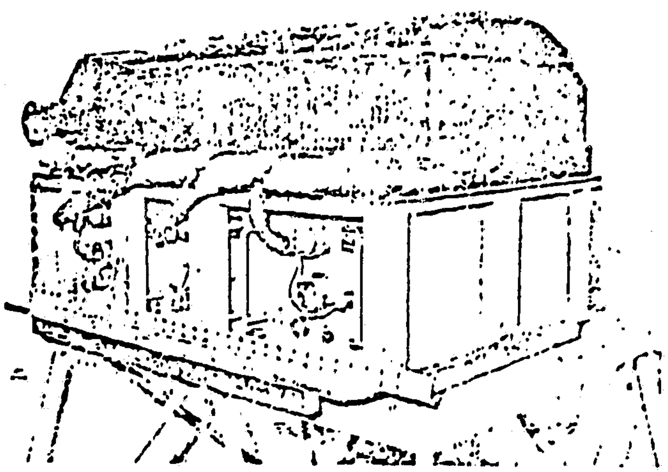


(a) Major hardware elements.



(b) Pallet assembly.

Figure 4. *F-8 DFBW hardware elements with detail of pallet assembly.*

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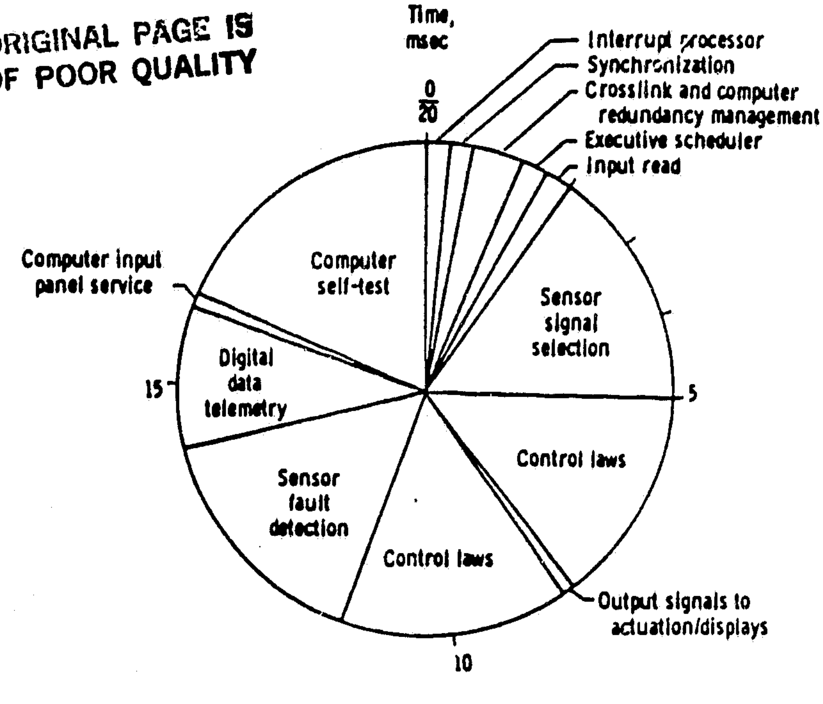
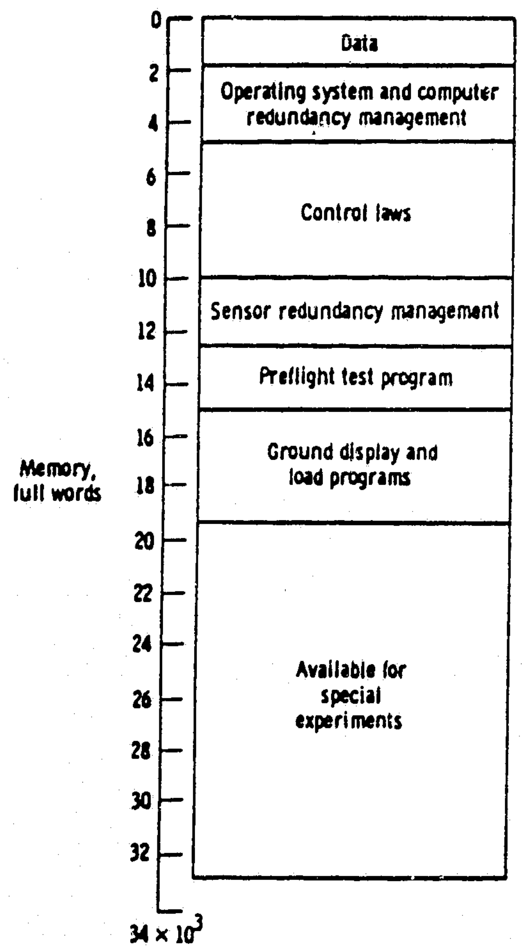


(a) Timing sequence with all control modes active. 20-msec minor cycle.



(b) Memory allocation.

Figure 5. F-8 DFBW software system.

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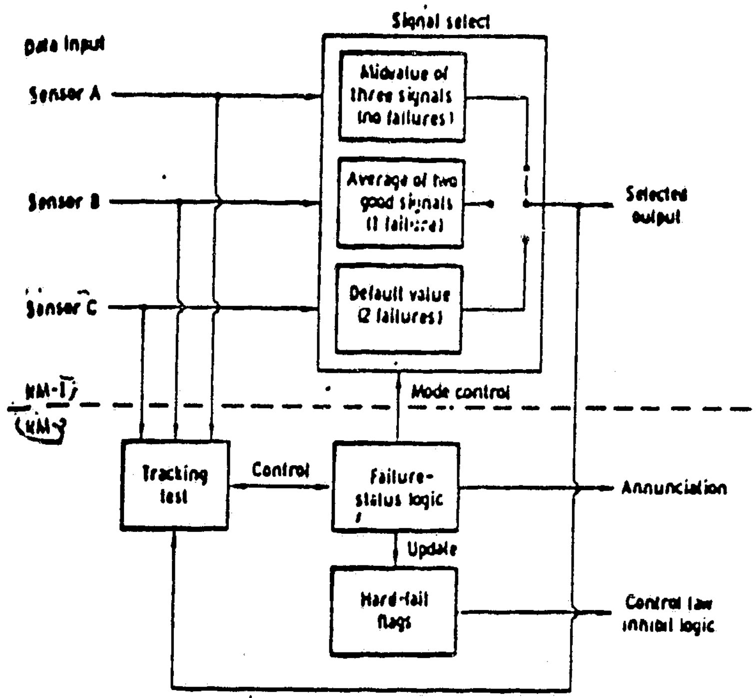

Figure 6. Triplex analog sensor redundancy management algorithm.

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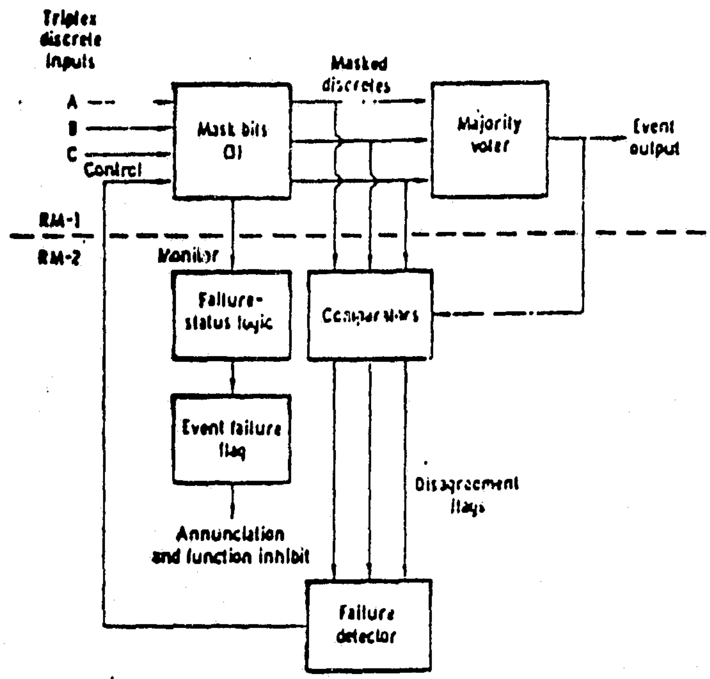


Figure 7. Triplex discrete RM algorithm.

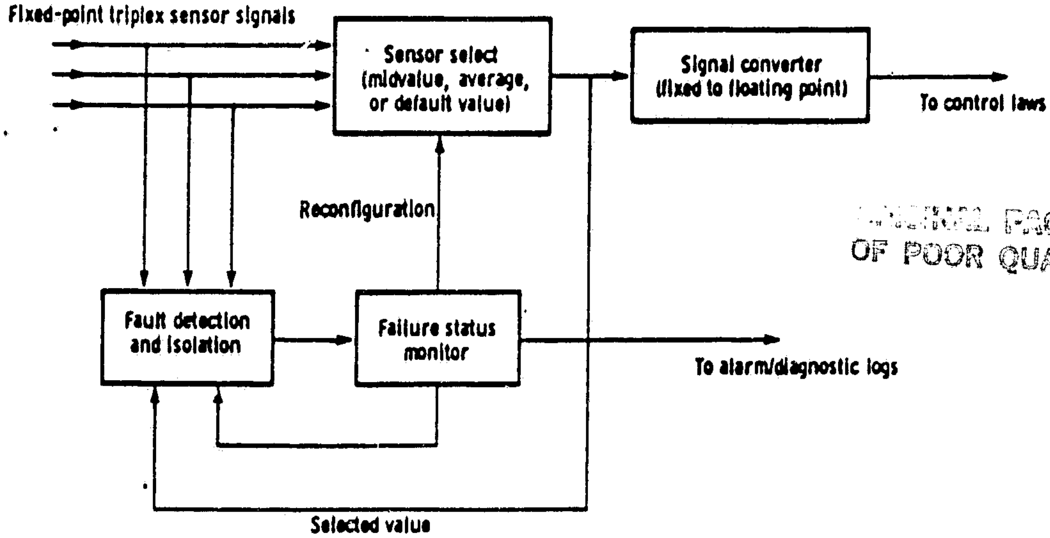
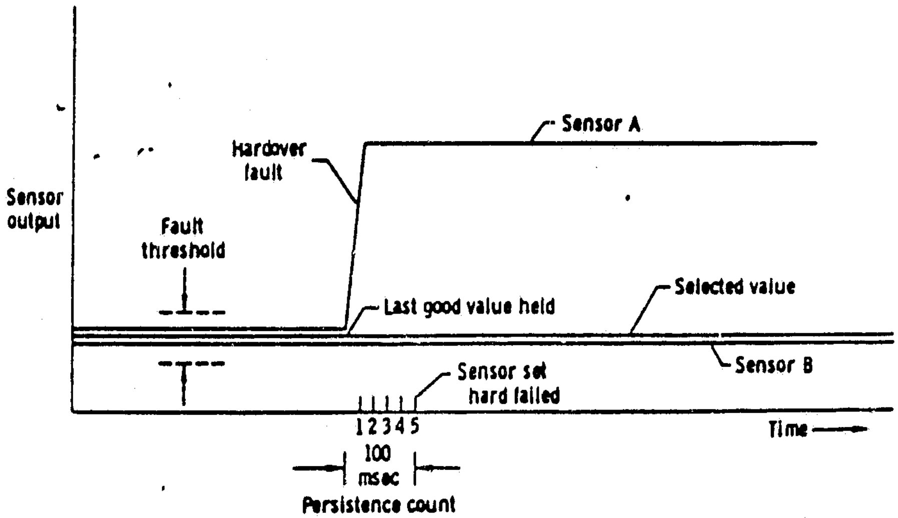
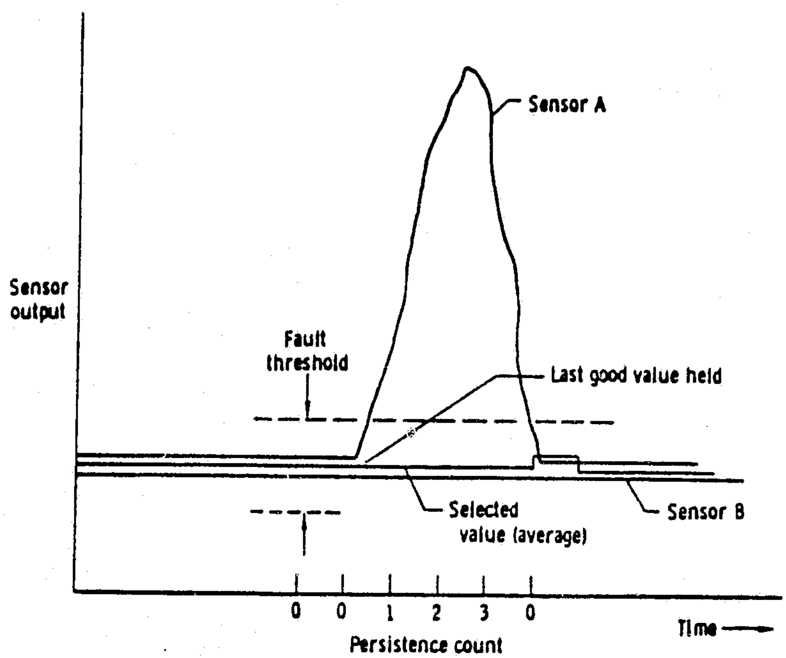


Figure 14. Analog sensor fault detection isolation and reconfiguration algorithm.

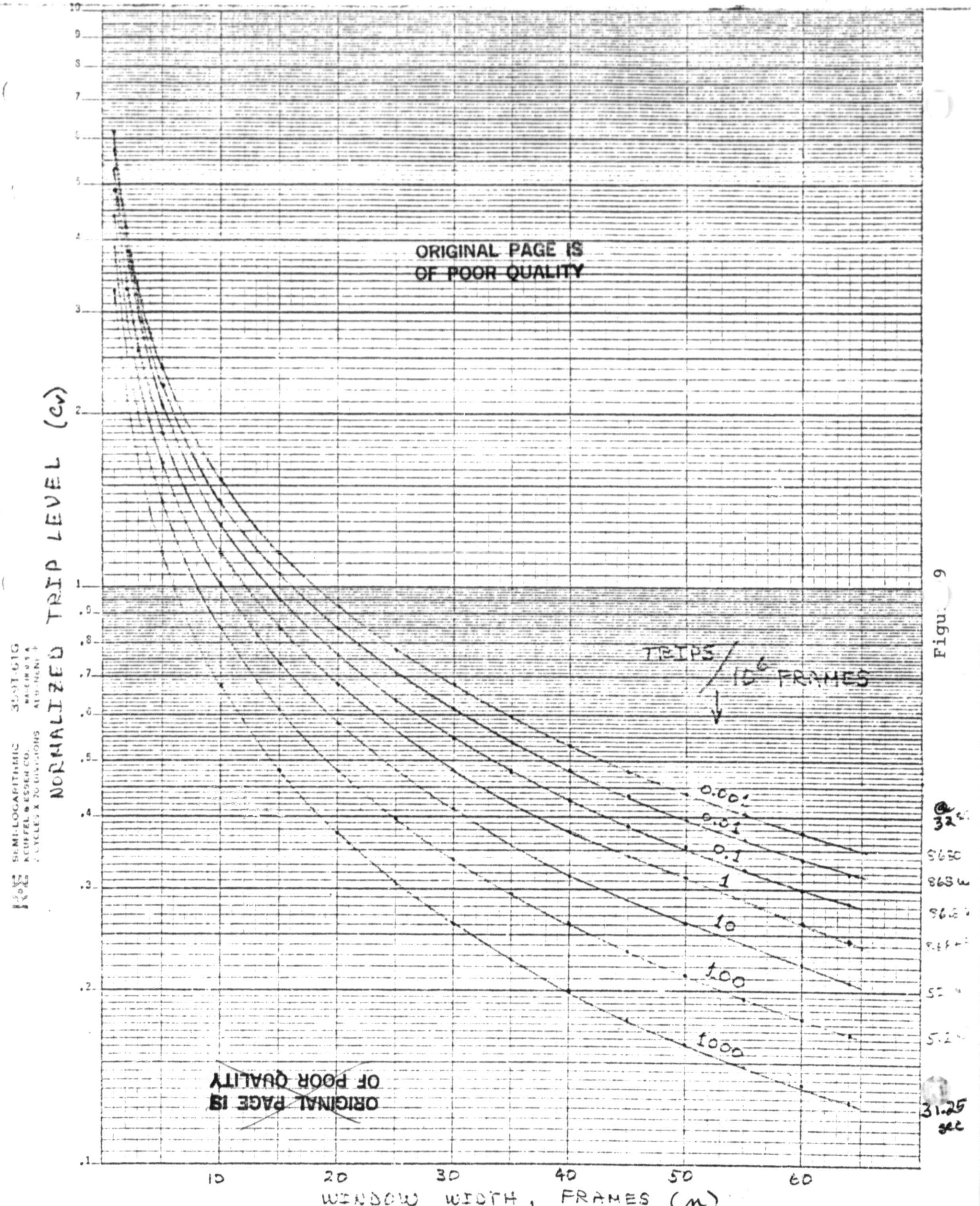


(a) Hardover failure of sensor A.



(b) Transient fault of sensor A.

Figure 8'. Concluded.



NORMALIZED TRIP LEVEL (σ)
WINDOW WIDTH, FRAMES (n)
10
20
30
40
50
60
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
2
3
TRIPS / 10^6 FRAMES
0.001
0.01
0.1
1
10
100
1000
31.25 sec
SEMI-LOGARITHMIC
KEUFFEL & ESSER CO.
359T-61G

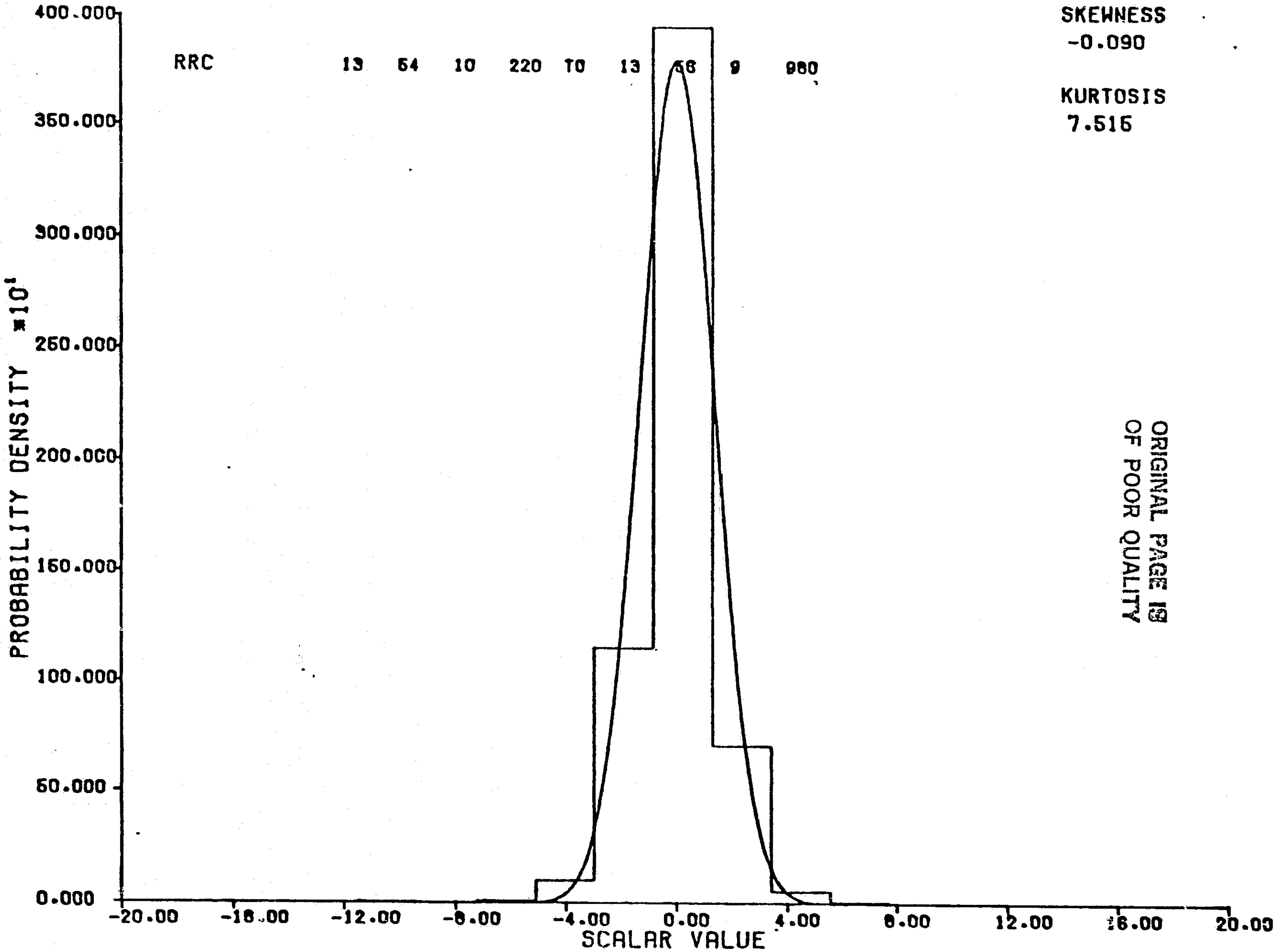
Figure 9

MEAN SQUARE	RMS	VARIANCE	CHI SQ	MEAN VALUE	STD DEV	MINIMUM	MAXIMUM	VALID OBS
1.810	1.345	1.810	999.00	-0.000	1.345	-11.515	9.832	5989 /5989

HIGH PASS FILTERED DATA, BREAK= 3.000 ORDER= 3

SKEWNESS
-0.090

KURTOSIS
7.516



F8DFBW FLIGHT 23

Fig. 10

F8DFBW FLIGHT 11 PILOT G KRIER 22 MARCH 1977 SENSOR STATS

MEAN SQUARE	RMS	VARIANCE	MEAN VALUE	STD DEV	MINIMUM	MAXIMUM	VALID OBS
0.027	0.165	0.017	0.102	0.130	-0.168	1.305	210530 /210530

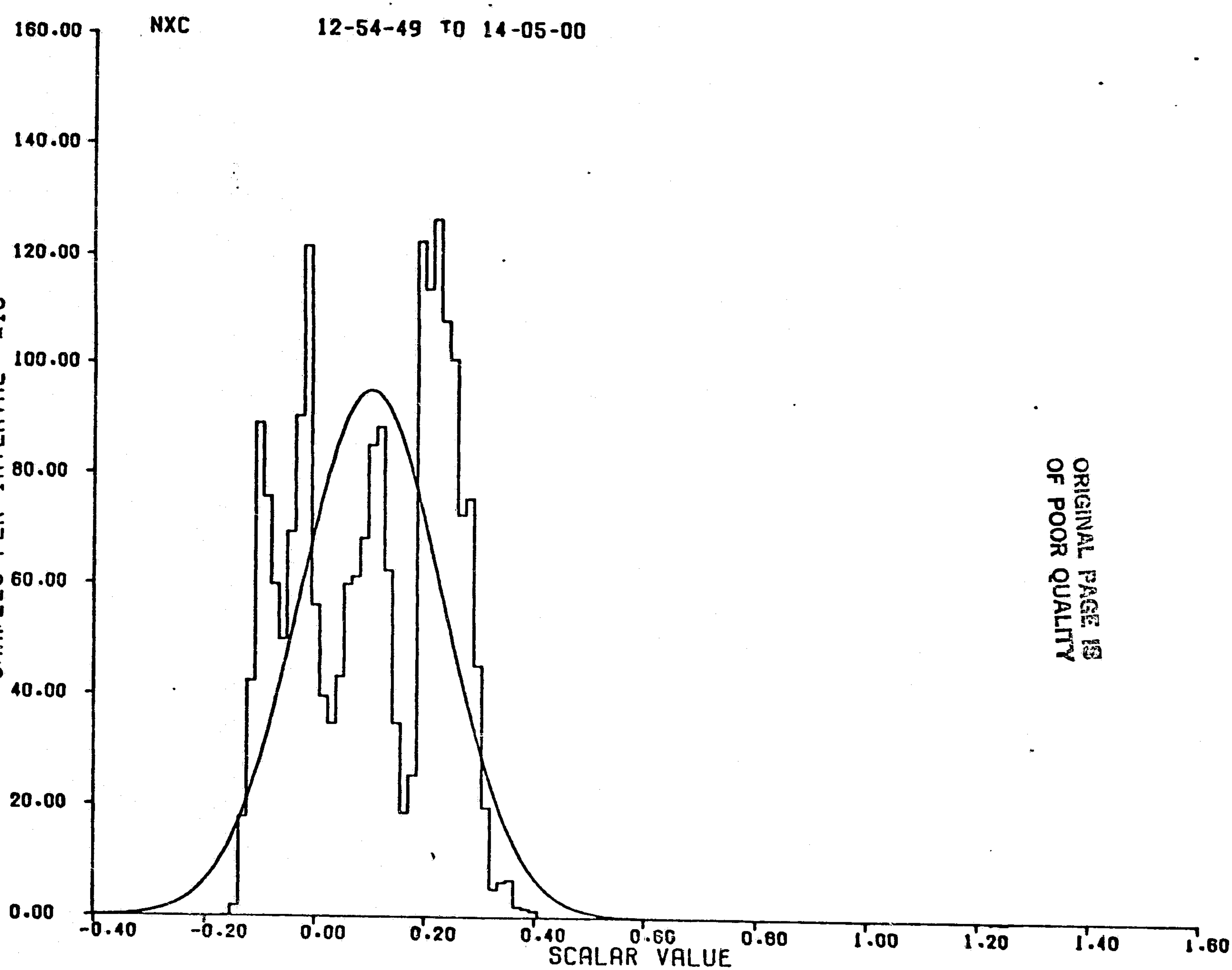


Figure 11

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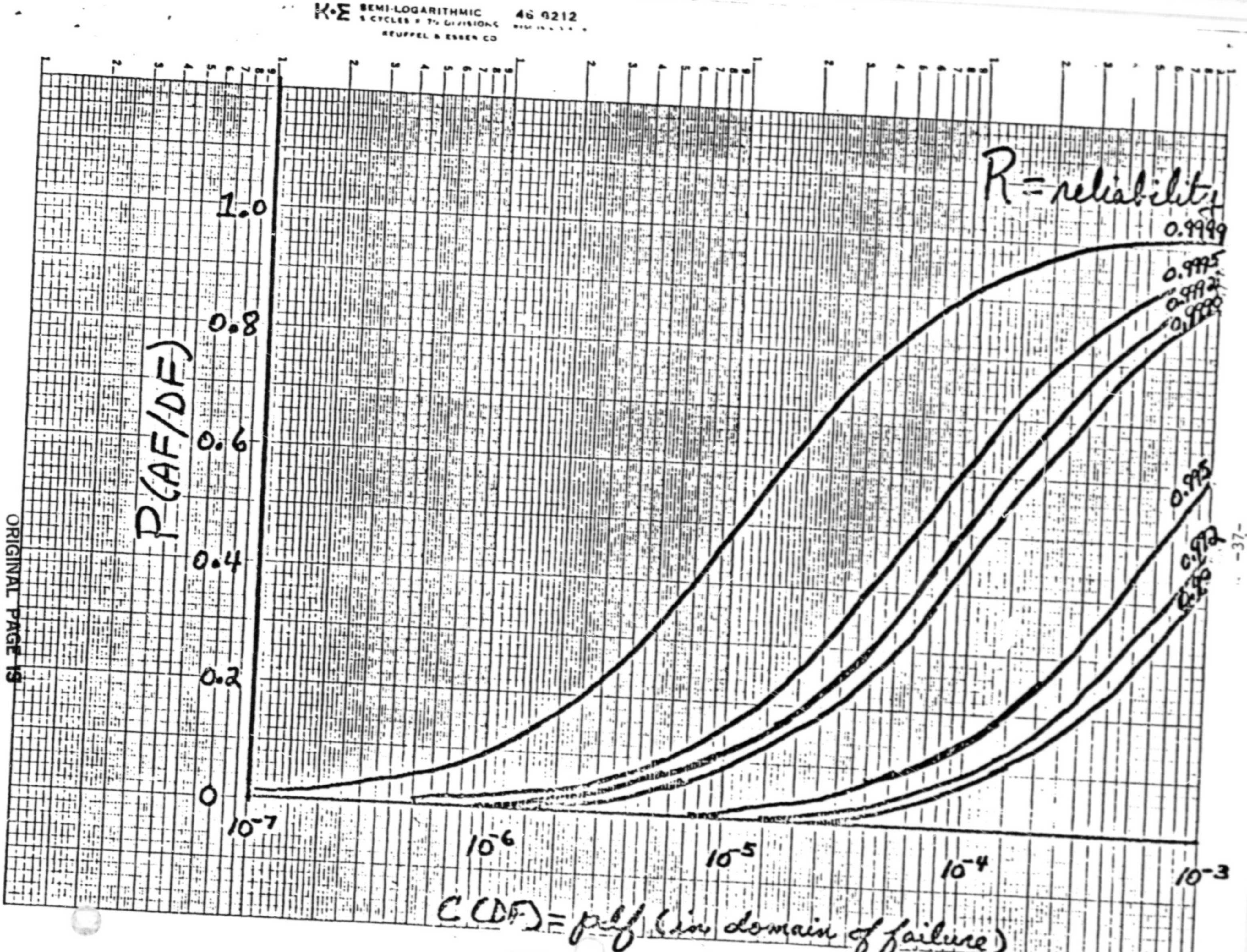
K+E SEMI-LOGARITHMIC 46 0212
KEUFFEL & ESSER CO
R = reliability
0.9999
0.9995
0.9992
0.9990
0.995
0.992
P(AF/DF)
1.0
0.8
0.6
0.4
0.2
0
10^{-7}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
C(DF) = p.f.f (in domain of failure)

FIGURE 2

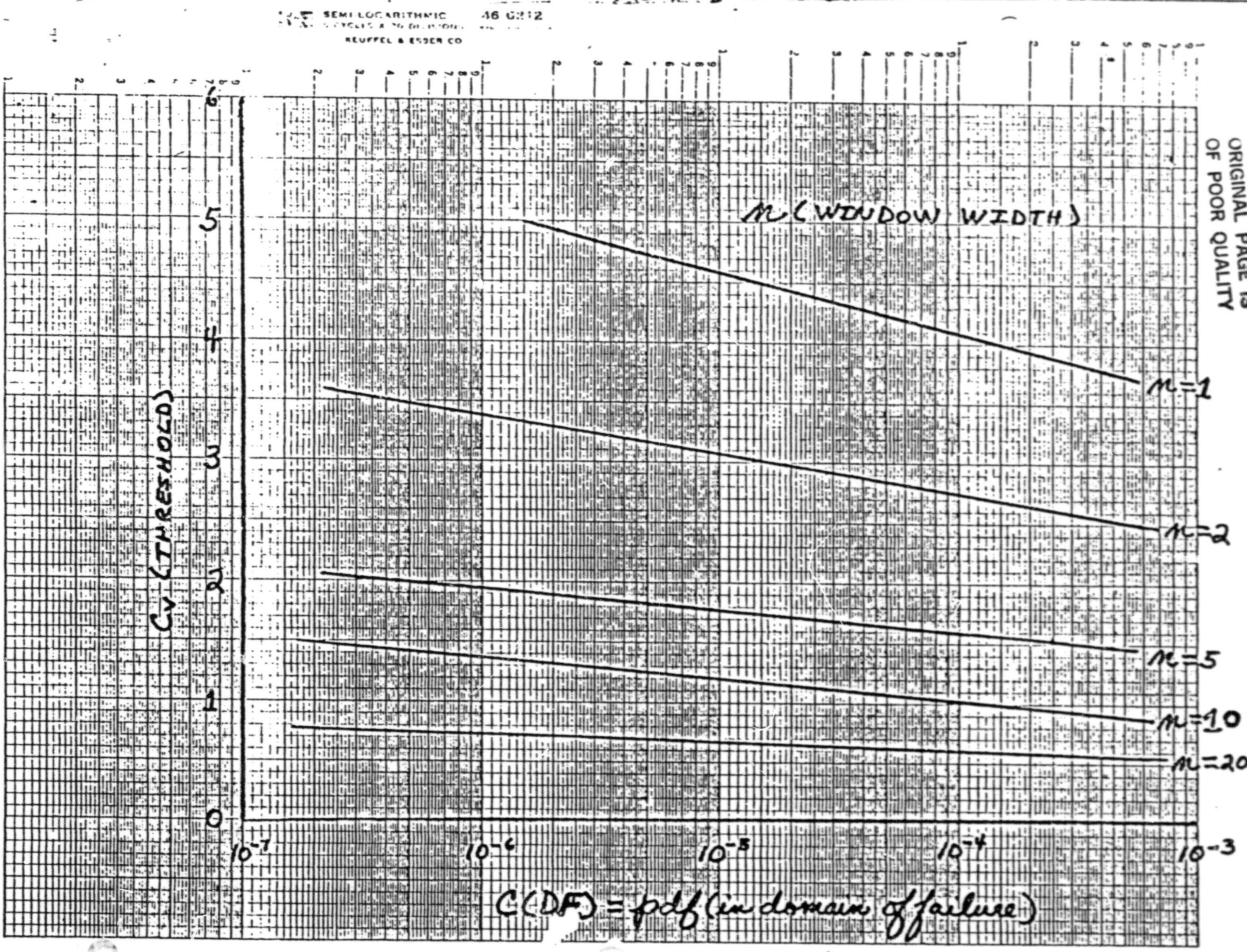
SEMI-LOGARITHMIC 46 6212
KEUFFEL & ESSER CO.
n (WINDOW WIDTH)
n=1
n=2
n=5
n=10
n=20
Cv (THRESHOLD)
0
1
2
3
4
5
6
10^{-7}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
C(DF) = pdf (in domain of failure)

FIGURE 13

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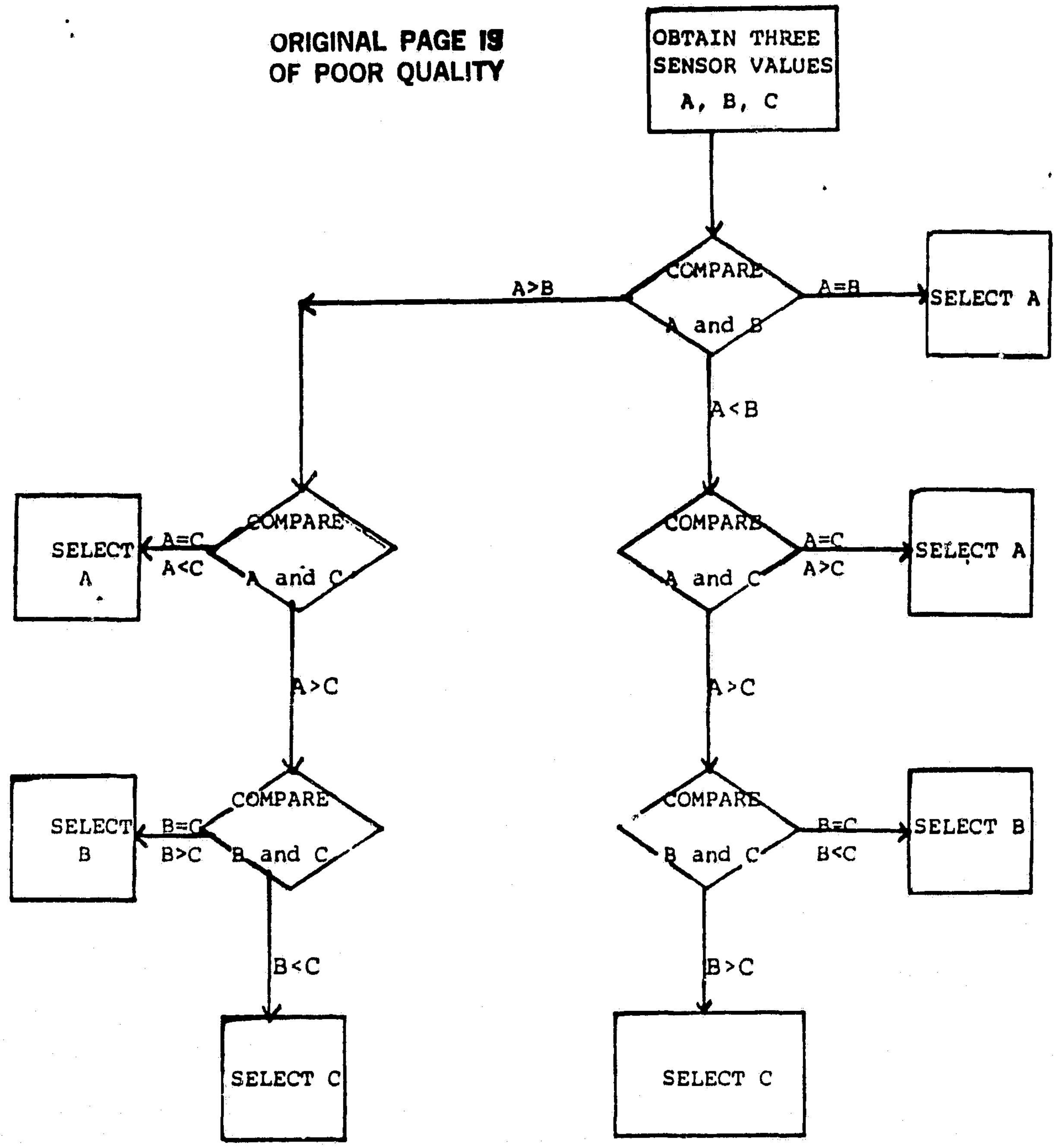

Figure 14. Mid-Value Sensor Select Algorithm

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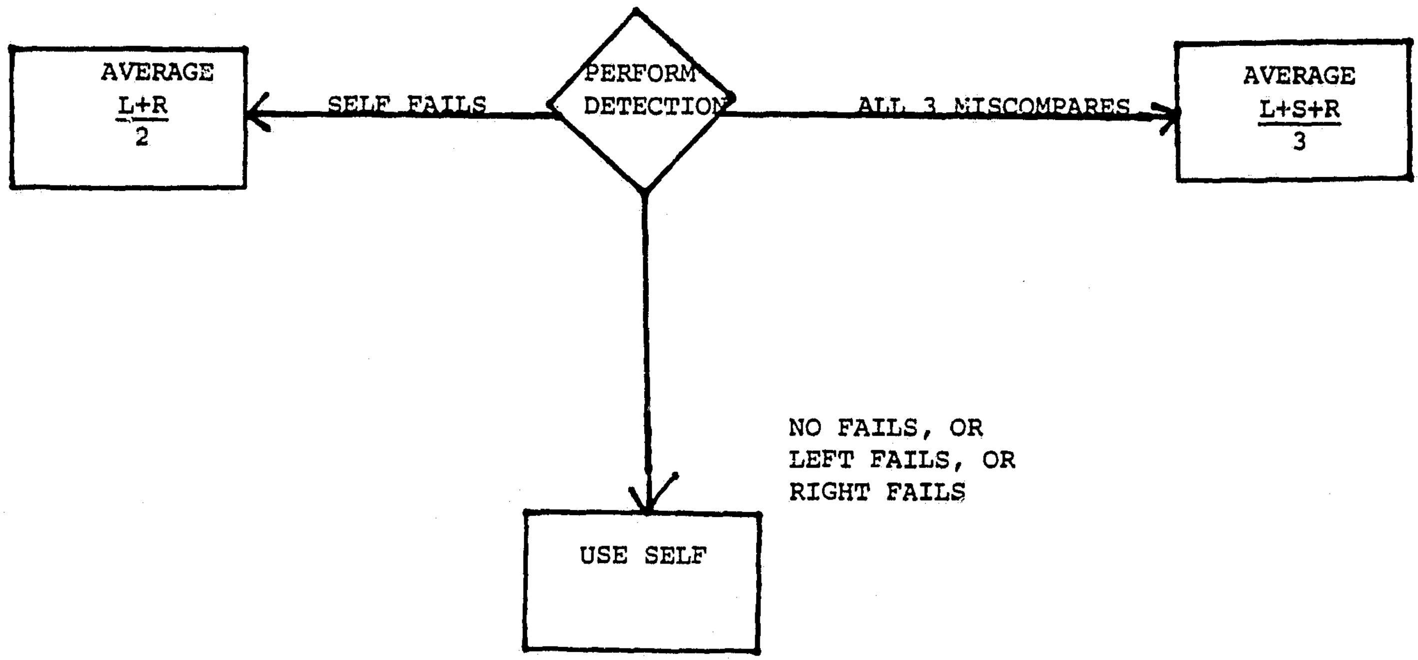


Figure 15. Self-If-Good Sensor Select Algorithm

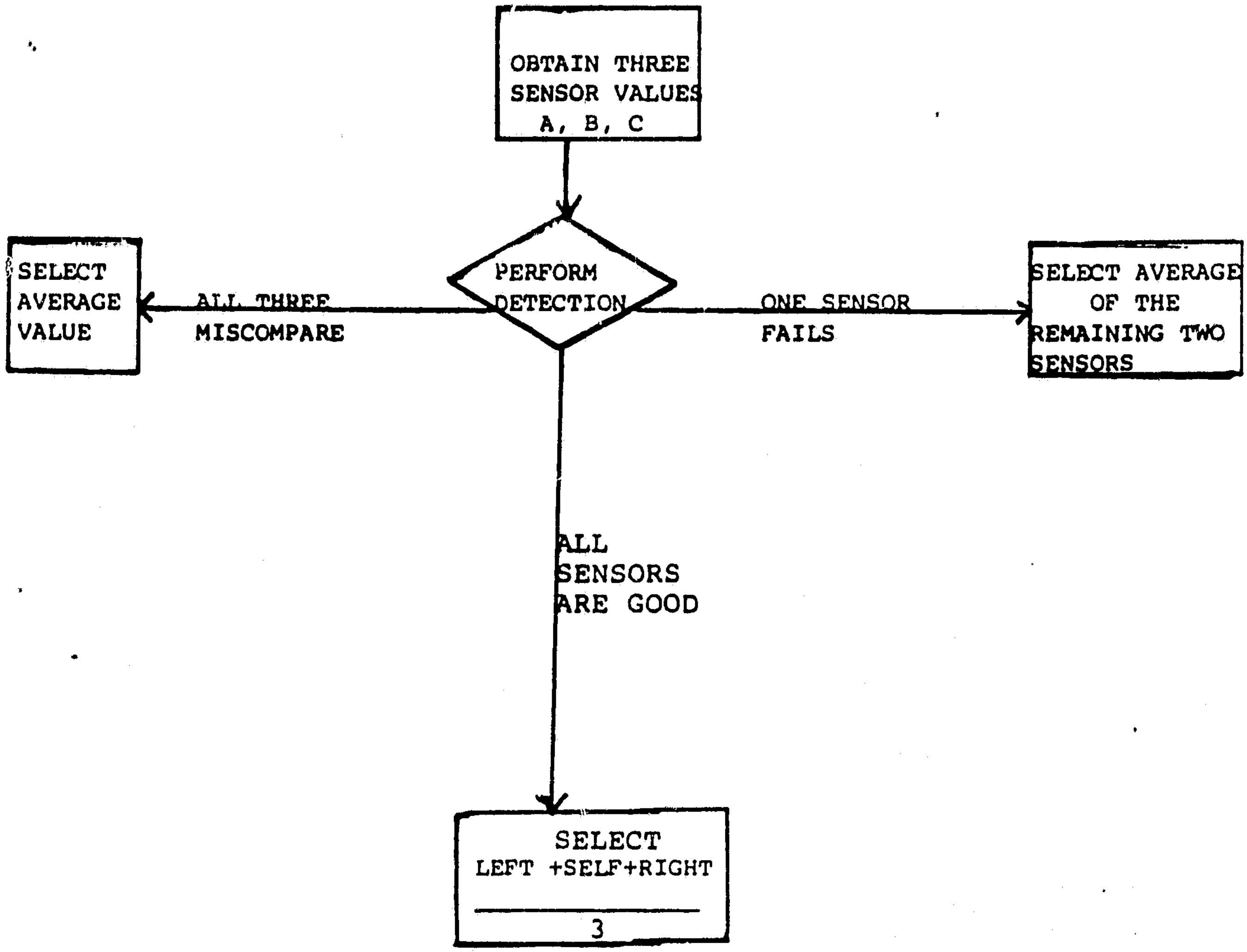


Figure 16. Mean-Value Sensor Select Algorithm

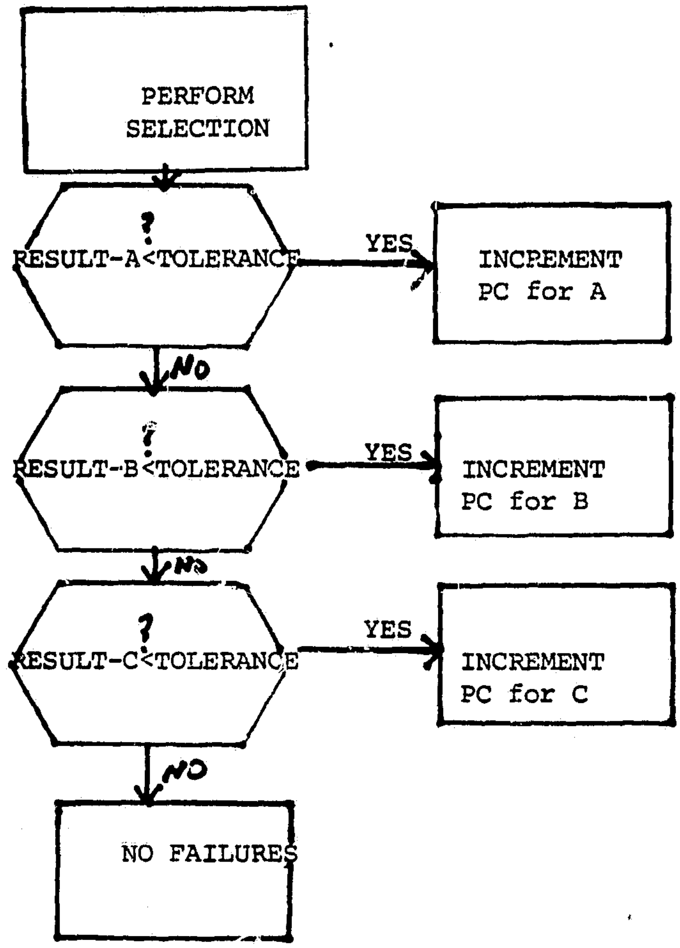


Figure 17. RES-X Detection Method for SRM

APPENDIX B

TABLES

SENSOR SET	TOLERANCE
Pitch rate (deg/s)	4 deg/sec
Roll rate (deg/s)	10 deg/sec
Yaw rate (deg/s)	4 deg/sec
Axial accelerometer (g)	0.1g
Lateral accelemoter (g)	0.2g
Normal accelerometer (g)	0.5g
Pitch C stick (cm)	1.0cm
Roll C stick (cm)	1.0cm
Rudder pedals (cm)	0.5cm
Angle of attack (deg)	2.0deg
Left secondary actuator (cm)	3.5cm
Right secondary actuator (cm)	3.5cm
Pitch attitude (deg)	15deg
Roll attitude (deg)	15deg
Heading (deg)	15deg
Mach number	0.05
Altitude (m)	150m

Table 1: Sensor Fault Thresholds

SENSOR	NUMBER OF ACTUAL HARDWARE FAULTS	NUMBER OF FALSE FAULT DECLARATIONS	NUMBER OF TIMES FAILCOUNT REACHED 4	MAXIMUM NUMBER OF MISCOMPARES ANY FLIGHT
YAW RATE GYRO	0	0	0	0
YAW RATE GYRO	0	0	0	0
YAW RATE	0	0	0	0
LONGITUDINAL ACCELEROMETER	0	0	0	0
LATERAL ACCELEROMETER	0	1	2	226
NORMAL ACCELEROMETER	0	0	0	6
ALTIMETER	1	0	5	267
MACH	0	0	0	0
PITCH ATTITUDE	1	0	2	10
ROLL ATTITUDE	0	0	0	72
HEADING	0	4	0	9
PITCH CENTER STICK	0	0	0	0
ROLL CENTER STICK	0	0	0	0
RUDDER PEDALS	0	0	0	0
PITCH SIDESTICK	0	0	0	0
ROLL SIDESTICK	0	0	0	0
ANGLE OF ATTACK	0	0	0	7

Table 2: F8 DFBW Sensor Flight Experience

χ^2 VALUES	χ^2	df	CRITICAL VALUE (0.995 level)
QBA-QBC	16475.	8	21.96
PBA-PBC	186386.	10	25.19
RBA-RBC	117647.	14	31.32
NXA-NXC	200559.	24	45.56
NYA-NYC	465560.	27	49.64
NZA-NZC	491741.	21	41.40

NOTE: χ^2 VALUES COMPUTED UP TO EXPECTED FREQUENCY LESS THAN 5.

IN EACH CASE COMPUTED VALUE EXCEEDS CRITICAL VALUE SO DISTRIBUTIONS MAY BE TAKEN TO BE DIFFERENT FROM NORMAL.

Table 3: Chi-Square Test for Sensor Select Values (Mid-Value Algorithm)

APPENDIX C

MODIFIED FLIFRNT PROGRAM

MODIFIED CARD SETUP FOR SPA PACKAGE

(II) CARD SETUP FOR SPA:

	Card #	Column 123
∠	1	white control card
CONTROL CARDS	2	F16SPA, T1ØØØ.
	3	USER(AF16, FDPS)
	4	CHARGE(45, Ø4, FTN)
	5	GETPF(PROCFIL / UN= CSDO)
??	5A (only if time periods overlap)	SWITCH, 3.
	6	BEGIN, TASK,, SPA, FLT=AF16ØØ1A, PLOT, FLIUN=AF16.
∠	7	7/8/9 Card (end of record)
FLIFRNT data cards *	8	F16SCALZO FLI/SPA FOR FLT (A). (A10 format)
	9	AF16ØØ1
	1Ø	$FLIN ST=--,--,--,---, ET=--,--,--,---, NCH=3, SPS=5Ø.Ø, PRINTIT=T$
	11	PARM1ID PARM2ID PARM3ID (A10 format)

notes: (a) ST = 2 secs to left of desired time ET = 2 secs to right of desired time
(b) repeat cards 8, 9, 1Ø, and 11 for each time period in the same flight (put them in numerical order EARLY to LATE)
(c) NCH ≤ 8

∠	12	7/8/9 card (end of record)
SPA data cards *	13	$CARDIN RMS=T, HGRAPH=T, STATIST=T$
	14	$STATIN ST=--,--,--,---, ET=--,--,--,---, ND=4, STOP=T$
	15	$RMSIN ST=--,--,--,---, ET=--,--,--,---, ND=4, STOP=T$

notes: (a) repeat cards 13, 14, and 15 for each time period in the same FLT.
(b) NCH = { 4 for unfiltered data; 5 for filtered data

∠16 Yellow Control card.

```
    1     D (1,101) TITLE
  101 FORMAT (8A10)
      IF(EOF(1).NE.0) GO TO 5
      WRITE (2) TITLE
      READ 102, UFLID
  102 FORMAT (A10)
      READ FLIN
      PRINT FLIN
      PRINT 103, UFLID
  10  FORMAT (1H0,"UFLID    = ",A10,/)
      IF(NCH.LT.1 .OR. NCH.GT.10) PRINT 201
  20. FORMAT (1X,"REQUESTED NCH IS OUTSIDE OF ALLOWABLE LIMITS. CORRECT
     -AND RESUBMIT.")
      IF(NCH.LT.1 .OR. NCH.GT.10) GO TO 999
      WRITE (2) NCH,SPS
      EAD 101, (PARMID(I),I=1,NCH)
       ITE (2) (PARMID(I),I=1,NCH)
        .NOT.PRINTIT) PRINT 104, (PARMID(I),I=1,NCH)
        PMAT(1X," PARMIDS REQUESTED ARE: ",10A10,/)
      ISHR = ST(1)
      ISMIN = ST(2)
      ISEC = ST(3)
      ISMIL = ST(4)
      IEHR = ET(1)
      IEMIN = ET(2)
      IESEC = ET(3)
      IEMIL = ET(4)
      CALL DABOP (IUCD,UFLID,NCH,PARMID,MEAS,IEU,CALID,ICV,PARMNAM)
      IF(ICCPRM.NE.0) PRINT 202
  202 FORMAT (1H0,"AT LEAST ONE REQUESTED PARAMETER IS MISSING FROM THE
     -FLIDAB. CORRECT AND RESUBMIT.")
      IF(ICCTME.NE.0) PRINT 203
  203 FORMAT (1H0,"AT LEAST PART OF THE REQUESTED TIME IS MISSING FROM T
     -HE FLIDAB. CORRECT AND RESUBMIT.")
       F(ICATS.NE.0) PRINT 204
  20   ORMAT (1H0,"CATASTROPHIC FLIDAB HEADER ERROR.")
      IF(ICCPRM.NE.0 .OR. ICCTME.NE.0 .OR. ICATS.NE.0) GO TO 999
      AST(1) = ISHR
      AST(2) = ISMIN
      AST(3) = ISEC
      AST(4) = ISMIL
      IF(PRINTIT) PRINT 105, TITLE,(PARMID(I),I=1,NCH)
  105 FORMAT(1H1,8A10,//T15,"UNFILTERED DATA FROM FLIDAB",//T17,
     - 9(A7,5X),A7)
    2 CALL DABIR (MEAS,DAT,ITYPE,ICV,NCH)
      IF(ICCDAT.GT.0) GO TO 3
      MILLI = IDTTL
      WRITE (2) ID1,ID2,MILLI,(DAT(I),I=1,NCH)
      IF(PRINTIT) PRINT 106, ID1,ID2,(DAT(I),I=1,NCH)
  106 FORMAT(1X,A10,A2,10G12.5)
      GO TO 2
    3 ENDFILE 2
      AET(1) = IDHR
      AET(2) = IDMIN
      AET(3) = IDSEC
      AET(4) = IDMIL
      PRINT 107, AST,AET
  107 FORMAT (1H0,"ACTUAL START TIME = ",I2,1X,I2,1X,I2,1X,I3,10X,
     - "ACTUAL END TIME = ",I2,1X,I2,1X,I2,1X,I3)
      WRITE (2) AST,AET
      GO TO 1
    5 ENDFILE 2
      REWIND 2
  999 STOP
      END
```

INSERT

DAT1 = DAT(1)
DAT2 = DAT(2)
DAT3 = DAT(3)
DAT(1) = DAT1 - DAT2
DAT(2) = DAT1 - DAT3
DAT(3) = DAT2 - DAT3

Then

PAR1 = PAR1 - PAR2
PAR2 = PAR1 - PAR3
PAR3 = PAR2 - PAR3

APPENDIX D

MICROCOMPUTER SOFTWARE FOR COMPUTING FALSE ALARM RATES AND PLOTTING CORRESPONDING NOMOGRAPHS

```
10 REM  ------------------------------------------------------------
20 REM  --   NASA PROGRAM  --  WRITTEN BY JERRY H. SITBON        -----
30 REM  --   PROGRAM WRITTEN ON NORTH*STAR COMPUTER (HP BASIC)    ---
40 REM  ------------------------------------------------------------
50 REM
60 REM   SELECTION PROGRAM
70 DIM S9$(255),F2$(8),F$(33),F1$(33),A$(15),T$(33),D(3,20),P$(25)
71 DIM V$(10000),P(2,300),Z9$(10)
80 GOSUB 10000 \ REM LEARN TERMINAL CODES
81 PRINT C1$
85 GOSUB 9500 \ REM CHRCK FOR DIR FILE AND DEFAULT DRIVE
90 PRINT C1$, B1$, H1$ \ REM CLEAR SCREEN, RING BELL, HIGH INTENSITY
100 PRINT TAB(20),"SENSOR REDUNDANCY MANAGEMENT"
110 PRINT TAB(20),FNS$(28,45)
145 Z=5
150 PRINT \ PRINT \ PRINT \ PRINT N1$
160 PRINT TAB(Z),"(",H1$,"1",N1$,")",TAB(15),"Enter data to file"
170 PRINT TAB(Z),"(",H1$,"2",N1$,")",TAB(15),"Display data from file"
180 PRINT TAB(Z),"(",H1$,"3",N1$,")",TAB(15),"Edit data in file"
190 PRINT TAB(Z),"(",H1$,"4",N1$,")",TAB(15),"Compute and graph probabilities"
220 PRINT TAB(Z),"(",H1$,"5",N1$,")",TAB(15),"Delete file"
225 PRINT TAB(Z),"(",H1$,"6",N1$,")",TAB(15),"Display file list"
230 PRINT TAB(Z),"(",H1$,"7",N1$,")",TAB(15),"Exit program"
325 PRINT \ PRINT
330 PRINT "Type in the number of your choice ...... ",
335 A$=INCHAR$(0) \ A=ASC(A$)
340 IF A<49 OR A>57 THEN GOTO 335
345 PRINT A$
350 ON A-48 GOTO 500,900,90,3000,90,6000,8990
355 GOTO 90
500 REM ENTER DATA TO FILE
501 PRINT C1$,H1$,B1$,CHR$(10),CHR$(10),CHR$(10)
502 PRINT TAB(25),"INPUT MODE" \FOR R=1 TO 1000 \ NEXT R
504 GOSUB 505 \ GOTO 575
505 PRINT C1$, B1$, H1$
510 Z=15
515 PRINT TAB(Z),"SENSOR REDUNDANCY MANAGEMENT"
520 PRINT TAB(Z),FNS$(28,45) \ Z=11
525 PRINT \ PRINT TAB(Z+5),"Probalility of false alarm"
530 PRINT \ PRINT TAB(Z+5),"Enter data program"
535 PRINT \ PRINT TAB(Z+5),"Written by J. Sitbon"
540 PRINT \ PRINT TAB(Z+5),"For F. Scalzo Ph.D"
545 PRINT N1$
550 PRINT \ PRINT TAB(8),"TYPE IN THE NASA PROJECT FILE NAME"
555 PRINT \ PRINT \ PRINT TAB(10),FNS$(25,45),U1$,U1$,H1$
560 PRINT TAB(10),
562 F$(1,33)=FNS$(33,32)
565 INPUT1"",F$(1,25)
566 A$=FNT$(F$)
567 IF L=0 THEN GOTO 565
568 PRINT \PRINT \ PRINT N1$\ PRINT TAB(10),"LOOKING UP DISK DIRECTORY",B1$
570 GOSUB 2000 \ REM SEARCH DIR
571 RETURN
575 IF M=1 THEN GOTO 650
580 PRINT \ PRINT C1$,FNT$(F$)," is a new project file name",B1$
585 PRINT \ PRINT
590 PRINT "Should this file be created ?  (Yes or No) ",
595 INPUT1 "",A$
600 IF LEN(A$) =0 THEN GOTO 595
605 IF A$(1,1)="N" THEN GOTO 90 \ REM GOTO MENU
610 IF A$(1,1)<>"Y" THEN GOTO 580
615 GOSUB 2500 \ REM WRITE DIR ENTRY
620 PRINT \ PRINT
621 IF M=0 THEN GOTO 625
622 FOR R=1 TO 500 \ NEXT R
623 GOTO 90
625 PRINT "Project file ",T$," will be stored in target file ",F2$(1,8)
630 PRINT
635 PRINT TAB(10) , "PRESS ANY KEY TO CONTINUE    ",B1$,
640 A$= INCHAR$(0) \ GOTO 700
650 PRINT
651 PRINT C1$,B1$,"Project name ",T$," exist, stored in target file ",F2$(1,8)
660 PRINT \ PRINT "SHOULD THIS FILE STORE NEW DATA ",
665 INPUT1 "",A$
670 IF LEN(A$)=0 THEN GOTO 665
675 IF A$(1,1)="N" THEN GOTO 90
680 IF A$(1,1)<>"Y" THEN GOTO 650
700 REM INPUT DATA
705 LINE#0,80,0
707 PRINT C1$,H1$,B1$,
708 X=LEN(T$)+16
709 A = INT(36-X/2)
710 PRINT FNP$(A,0),T$,"     (INPUT MODE)'
```

```
715 PRINT FNP$(A,1),FNS$(X,45)
720 PRINT TAB(13),"L-S",TAB(38),"L-R",TAB(63),"S-R"
725 PRINT FNS$(75,45),N1$
730 GOSUB 10100 \ REM DRAW GRID
731 PRINT H1$,
735 GOSUB 10500 \ REM INPUT DATA TO GRID
740 PRINT C1$,N1$,B1$
750 LINE#0,80
760 PRINT "SAVING FILE ",T$," ON DISK"
770 PRINT \ PRINT \ PRINT TAB(25),"PLEASE STAND BYE"
780 OPEN #1, F2$(1,8)+","+STR$(D)
790 FOR Y=1 TO Y6-3
800 FOR X=1 TO 3
810 WRITE #1, D(X,Y)
820 NEXT
830 NEXT
840 CLOSE #1
850 PRINT \ PRINT "DATA SAVED ",B1$
860 FOR R=1 TO 500 \ NEXT R
870 GOTO 90
900 REM READING DATA FROM FILE
901 PRINT C1$,H1$,B1$,CHR$(10),CHR$(10),CHR$(10)
903 PRINT TAB(15),"****** DISPLAY DATA FILE *******"
906 FOR R=1 TO 1000 \ NEXT R
910 GOSUB 505 \ REM GET FILE
920 IF M=1 THEN GOTO 985
930 PRINT \ PRINT TAB(20),"Can't find ",FNT$(F$(1,25)) \ PRINT
940 PRINT "Would you like to try again? ",
950 INPUT1 "",A$ \ IF LEN(A$)=0 THEN GOTO 950
960 IF A$(1,1)="N" THEN GOTO 90
970 IF A$(1,1)="Y" THEN GOTO 910
980 GOTO 950
985 GOSUB 990 \ GOTO 1080
990 PRINT \ PRINT "FOUND THE FILE ",T$,".  READING IN DATA"
1000 OPEN #1,F2$(1,8)+","+STR$(D)
1010 FOR Y=1 TO 20
1020 FOR X=1 TO 3
1030 READ#1, D(X,Y)
1040 NEXT
1050 IF TYP(1)=0 THEN EXIT 1075
1060 NEXT
1070 Y=Y-1
1075 CLOSE#1
1076 RETURN
1080 S=0 \ REM DISPLAY
1085 GOSUB 1300 \ REM DO DISPLAY
1090 PRINT FNP$(22,23),"H = HARDCOPY   E = EXIT ",
1100 A$=INCHAR$(0)
1110 IF A$="E" THEN GOTO 90
1120 IF A$<>"H" THEN GOTO 1100
1130 S=1 \ GOTO 1085
1300 REM DISPLAY DATA ONLY
1310 IF S=0 THEN GOTO 1350
1330 REM PRINTER
1331 FILL 65534,84 \ FILL 65532,88\S=1
1332 !#S CHR$(27),"[0w",CHR$(27),"[2z"
1350 A=INT(36-LEN(T$)/2)
1355 IF S=1 THEN PRINT#1 CHR$(10),CHR$(10),CHR$(10)
1360 IF S=1 THEN PRINT #1,TAB(A),T$
1370 IF S=0 THEN PRINT #0 H1$,B1$,C1$,FNP$(A,0),T$,N1$
1380 PRINT#S TAB(A),\A=LEN(T$) \ PRINT#S FNS$(A,45)
1385 IF S=1 THEN PRINT#1 CHR$(10),CHR$(10)
1390 PRINT#S TAB(13),"L-S",TAB(38),"L-R",TAB(63),"S-R"
1395 IF S=1 THEN PRINT#1 FNS$(75,45),CHR$(10)
1400 FOR X=1 TO Y
1410 PRINT #S X,TAB(7),D(1,X),TAB(32),D(2,X),TAB(57),D(3,X)
1411 IF S=1 THEN PRINT#1
1420 NEXT
1430 IF S=0 THEN RETURN
1440 A=CALL(65169)
1450 RETURN
2000 REM SEARCH PROGRAM OF DIR FILE
2005 OPEN #1%5,"DIR,"+STR$(D)
2010 M=0 \P=-25 \ REM NO MATCH
2015 IF TYP(1)=0 THEN GOTO 2035
2017 P=P+25
2020 READ #1,F1$(1,33)
2025 IF F1$(1,25)=F$(1,25) THEN M=1 ELSE GOTO 2015
2030 F2$(1,8)=F1$(26,33)
2035 CLOSE #1
2040 RETURN
2500 REM WRITE PROGRAM TO DIRECTORY
2503 M=0 \ REM DISK NOT FULL
2505 A=65
```

```
2508 F2$(1,8)=FNS$(8,32)
2510 F2$(1,8)="NASA#--"+CHR$(A)
2511 A$=F2$+","+STR$(D)
2515 IF FILE(A$)=-1 THEN GOTO 2530
2520 A=A+1
2525 GOTO 2510
2530 OPEN #1%5,"DIR,"+STR$(D)
2535 P=0 \ REM POINTER
2540 IF TYP(1) =0 THEN GOTO 2575
2545 READ #1%P,F1$(1,33)
2550 IF F1$(26,33)=FNS$(8,32) THEN 2565
2555 P=P+35
2556 IF P=875 THEN GOTO 2600
2560 GOTO 2540
2565 WRITE #1%P,F$(1,25)+F2$(1,8),NOENDMARK
2570 GOTO 2580
2575 WRITE #1, F$(1,25)+F2$(1,8)
2580 CLOSE #1
2585 CREATE A$,2
2590 RETURN
2600 PRINT "      DISK DIRECTORY FULL "\M=1\CLOSE#1\RETURN
3000 REM COMPUTE AND STORE PROBABILITIES
3010 PRINT C1$,H1$,B1$,CHR$(10),CHR$(10),CHR$(10)
3020 PRINT TAB(25),"COMPUTE PROBABILITIES" \ V=1
3030 FOR R=1 TO 1000 \ NEXT R
3040 GOSUB 505 \ REM GET FILE
3050 IF M=1 THEN GOTO 3120
3060 PRINT \ PRINT "      CAN'T FIND ",F$ \ PRINT
3070 PRINT "Would you like to try again? ",
3080 INPUT1 "" ,A$ \ IF LEN(A$)=0 THEN GOTO 3080
3090 IF A$(1,1)="N" THEN GOTO 90
3100 IF A$(1,1)="Y" THEN GOTO 3040
3110 GOTO 3080
3120 GOSUB 990 \ REM LOAD DATA
3130 PRINT C1$,N1$,B1$
3140 PRINT "Flight name and number is ",H1$,T$,N1$,CHR$(10)
3150 INPUT "Type in parameter name ",P$ \ PRINT
3160 PRINT "The number of sensor tripples are ",Y \ PRINT
3170 INPUT "Type in one of the three diffrences ",C7$
3171 INPUT "Type in two of the three diffrences ",D$
3172 INPUT "Type in thrree of the three diffrences ",E$
3181 PRINT \ PRINT "DO YOU WANT A HARDCOPY ? ",\A$=INCHAR$(0)
3182 S=0 \ IF A$="Y" THEN S=1
3183 PRINT C1$,B1$
3190 IF S<>1 THEN GOTO 3201
3191  FILL 65534,84 \ FILL 65532,88
3192 !#S CHR$(27),"[0w",CHR$(27),"[2z"
3200 REM PROBABILITIES
3201 GOSUB 3210 \ GOTO 3280
3210 !#S \!#S TAB(26),"Sensor Redundancy Management"
3220 !#S TAB(16),"Report of Probability Density Function, C(DF)"
3230 !#S TAB(12),"Reliability R, Probalility of false Alarm P(AF/DF)"
3240 !#S TAB(17),"For the Sensor Value in the Domain of Failure "
3250 !#S \!#S \!#S TAB((70-LEN(T$))/2),"FLIGHT = ",T$
3260 !#S "Parameter = ",P$,"   Sensor diffrences are ",C7$," ",D$," and ",E$
3270 !#S \ !#S
3275 RETURN
3280 FOR I=1 TO Y
3290 !#S "L-S = ",D(1,I),TAB(20),"L-R = ",D(2,I),TAB(40),"S-R = ",D(3,I)
3300 !#S \ !#S
3310 !#S TAB(15),"P(AF/DF) Table for Sensor Diffrence ",C$,"=",D(1,I)
3320 !#S
3330 P=1
3340 X1=D(1,I)
3350 REM COLUMN HEADING FOR TABLE
3360 !#S TAB(10),"          PDF",TAB(30),"RELIAB.",TAB(50),"P(AF/DF)"
3370 !#S TAB(10),FNS$(53,45)
3380 REM COMPUTE PROB.
3390 C=0.3314575*EXP(-(X1^2)/2.8974)
3400 FOR R= 9999 TO 9950 STEP -10
3410 R1 = R/1E4
3420 P1 = C*R1
3430 P2 = 1-P1
3440 P3 = 1-R1+P1
3450 P4 = 1-P3
3460 P5 = 1-R1
3470 A = P1*(P4+P5)/(P1*(P4+P5)+P5*P2)
3480 !#S TAB(10),C,TAB(30),R1,TAB(50),A
3482 P(1,V)=C \ P(2,V)=A
3483 V=V+1
3490 NEXT R
3500 !#S \ !#S \ P=P+1
3510 IF P=2 THEN GOTO 3540
3520 IF P=3 THEN GOTO 3570
```

```
3530 GOTO 3600
3540 X1= D(2,I)
3550 !#S TAB(15),"P(AF/DF) TABLE FOR SENSOR DIFFRENCE ",D$," =",D(2,I)
3560 GOTO 3360
3570 X1= D(3,I)
3580 !#S TAB(15),"P(AF/DF) TABLE FOR SENSOR DIFFRENCE ",E$," =",D(3,I)
3590 GOTO 3360
3600 NEXT I
3605 IF S=1 THEN A=CALL(65169)
3610 !B1$,C1$,TAB(20),"CALCULATION COMPLETED"\PRINT
3620 PRINT " DO YOU WANT A GRAPH ",
3630 INPUT1 "",A$ \ IF LEN(A$)=0 THEN GOTO 3630
3640 IF A$<>"Y" THEN GOTO 90
4000 REM CREATE GRAPH AND DRAW IT
4010 PRINT C1$,H1$,B1$,CHR$(10),CHR$(10),CHR$(10)
4020 PRINT TAB(25), "CREATE GRAPH",N1$ \!
4030  A=CALL(65169)
4035 !"SETTING UP PRINTER",B1$,CHR$(10)
4040 LINE#1,132 \FILL 65532,132 \ FILL 65534,(132-4) \REM SIZE,CURRENT PAGE
4050 !#1 CHR$(27),"[3z",CHR$(27),"[4w" \ REM SET PRINTER
4055 !"SORTING DATA ",B1$,CHR$(10)
4060 REM SORT POINTS IN TERM OF THE X VALUE
4080 FOR J=1 TO 5
4090 FOR T=J TO 15*Y-5+J STEP 5
4100 FOR V=T TO 15*Y-5+J STEP 5
4110 IF P(1,T)<P(1,V) THEN GOTO 4140
4120 T5=P(1,T) \ P(1,T)=P(1,V) \ P(1,V)=T5 \ REM XCHANG X
4130 T5=P(2,T) \ P(2,T)=P(2,V) \ P(2,V)=T5 \ REM XCHANG Y
4140 NEXT
4150 NEXT
4160 NEXT
4165 !"SETTING GRAPH LIMITS",B1$,CHR$(10)
4170 M1=P(1,1) \ M3=P(2,1) \ M2=M1 \ M4=M3
4180 FOR V=1 TO Y*15
4190 IF M1>P(1,V) THEN M1=P(1,V) \ REM MIN X
4200 IF M2<P(1,V) THEN M2=P(1,V) \ REM MAX X
4210 IF M3>P(2,V) THEN M3=P(2,V) \ REM MIN Y
4220 IF M4<P(2,V) THEN M4=P(2,V) \ REM MAX Y
4230 NEXT V
4235 !"CLEARING MEMORY",B1$,CHR$(10)
4240 REM PLOT IN MEMORY FUNCTION
4241 V$(1,10000)=FNS$(100,32)
4250 FOR X=1 TO 10000 STEP 100 \ V$(X,X+99)=S9$ \ NEXT
4260 DEF FNP(X,Y,C$)
4270 V$((X-1)*100+Y)=C$
4275 RETURN 1
4280 FNEND
4290 REM MAKE NUMBER NORAMAL
4295 !"SCALING DATA ",B1$,CHR$(10)
4300 M5=M2-M1 \ M6=M4-M3 \ REM TRUE SIZE
4310 FOR V=1 TO Y*15
4320 P(1,V)=INT(((P(1,V)-M1)/M5)*99+1.5)
4330 P(2,V)=INT(((P(2,V)-M3)/M6)*99+1.5)
4340 NEXT
4345 !"PLOTTING GRAPH IN MEMORY",CHR$(10)
4350 FOR J=1 TO 5
4355 C$=""\C$=CHR$(41+J)
4360 FOR V=J TO ((Y*15)-5)-5+J STEP 5
4365 IF P(2,V+5)-P(2,V)=0 THEN H=1 ELSE H=0
4367 IF H=1 THEN GOTO 4380
4370 M = (P(1,V+5)-P(1,V))/(P(2,V+5)-P(2,V)) \ REM SLOPE
4380 FOR X2= P( ,V) TO P(1,V+5)
4390 IF H=1 THEN GOTO 4420
4395 IF M=0 THEN GOTO 4450
4400 Y2=P(2,V)+(X2-P(1,V))/M
4410 GOTO 4430
4420 Y2=P(2,V)
4430 REM
4440 Z=FNP(X2,Y2,C$)
4450 NEXT
4460 NEXT
4470 NEXT
4480 REM PRINT OUT
4485 !"PRINTING GRAPH",B1$,CHR$(10)
4490 S=1 \ REM DEVICE
4500 GOSUB 3210 \ REM HEADING
4510 R=M6/10 \ !#S TAB(20),\ T=30
4520 FOR Y7 = M3 TO M4 STEP R
4530 !#S Y7,TAB(T),
4540  T=T+10
4550 NEXT
4555 !#S\!#S
4560 !#S FNS$(130,45)
4570 R= M5/10\L3=1 \T=M1
```

```
4580 FOR X =1 TO 10000 STEP 100
4590 IF L3<>1 THEN GOTO 4630
4600 !#S T,TAB(20),"|",
4610 T=T+R
4620 GOTO 4640
4630 !#S TAB(20),"|",
4640 !#S V$(X,X+99)
4650 L3=L3+1 \ IF L3=11 THEN L3=1
4660 NEXT
4665 !#S T+R \!#S\!#S
4670 !#S \!#S TAB(20),"CURVE KEY" \ R=9950
4675 !#S
4680 FOR X = 5 TO 1 STEP -1
4690 !#S TAB(25),R/1E4," = ",CHR$(41+X),"  ",\R=R+10
4700 NEXT
4701 !#S
4710 A=CALL(65169)
4720 FILL 65532,88 \ FILL 65534,(88-4)
4725 !#1 CHR$(27),"[2z",CHR$(27),"[0z"
4730 GOTO 90
6000 REM DISPLAY DIRECTORY
6010! B1$,H1$,C1$
6020 ! "DO YOU WANT A HARDCOPY ",
6030 A$=INCHAR$(0)
6040 IF A$="Y" THEN S=1 ELSE S=0 \ PRINT
6050 FILL 65532,88 \ FILL 65534 88-4
6060 OPEN #1%5,"DIR,"+STR$(D)
6070 !#S "      FLIGHT AND NUMBER                    TARGET FILE"\!#S
6080 IF TYP(1)=0 THEN GOTO 6120
6090 READ#1, F1$(1,33)
6100 PRINT TAB(10), F1$(1,33)
6110 GOTO 6080
6120 CLOSE#1
6125 A=CALL(65169) \ REM FF
6130 PRINT "PRESS ANY KEY TO GOTO MEMU ",
6140 A$=INCHAR$(0) \ GOTO 90
8990 PRINT C1$,TAB(15),"PROGRAM TERMINATED"
8995 PRINT \ PRINT \ PRINT
8999 END
9000 REM STRING$ FUNCTION
9010 DEF FNS$(L,C) \ REM L = LENGHT   C = ASC CODE  MAX LENGHT (255)
9020 S9$=""
9030 FOR X= 1 TO L
9040 S9$=S9$+CHR$(C)
9050 NEXT
9060 RETURN S9$
9070 FNEND
9100 REM FILE TEST FUNCTION
9105 REM 0 = NOT FOUND  1,2,3,4  IF FOUND   DRIVE LOCATED
9110 DEF FNF(Z9$)
9120 X=1
9130 ERRSET 9150,L,E
9135 X9$=","+STR$(X)
9140 IF FILE (Z9$+X9$) <> -1 THEN GOTO 9180
9150 X= X+1
9160 IF X<>5 THEN GOTO 9130
9170 X=0
9180 ERRSET
9190 RETURN X
9200 FNEND
9500 REM CHECK FOR DIR FILE SET DRIVE DEFAULT
9505 D=2 \ REM DEFAULT DRIVE
9510 A = FNF("DIR")
9515 IF A=0 THEN GOTO 9530
9520 D=A
9525 GOTO 9550
9530 CREATE "DIR,2",4,5
9535 OPEN #1 %5, "DIR,2"
9540 WRITE #1,&1,NOENDMARK
9545 CLOSE#1
9550 RETURN
10000 REM TERMINAL CODES
10010 B1$ = CHR$(7)              \ REM RING BELL
10015 N1$ = CHR$(126)+CHR$(25)  \ REM LOW INTENSITY
10020 C1$ = CHR$(126)+CHR$(28)  \ REM CLEAR SCREEN
10025 H1$ = CHR$(126)+CHR$(31)  \ REM HIGH INTENSITY
10030 U1$ = CHR$(126)+CHR$(12)  \ REM UP CURSOR
10050 RETURN
10100 REM DRAW GRID
10110 FOR X=1 TO 3
10120 FOR Y=1 TO 20
10130 PRINT FNP$((X-1)*25,Y+3),
10140 X$=STR$(X) \ Y$=STR$(Y)
10150 PRINT "(",X$(2),",",Y$(2),")",
```

```
10160 NEXT
10170 NEXT
10180 RETURN
10500 REM INPUT MODE PROGRAM
10510 X5=7 \ Y5=4 \ REM TRUE LOCATION
10520 Y6=0 \ Y6=0 \ REM END LOCATION
10530 A$=FNS$(11,32)
10540 PRINT FNP$(X5,Y5),
10550 IF Y6=57 AND Y6=23 THEN GOTO 10690
10560 GOSUB 11410
10570 IF Y=0 THEN GOTO 10690
10580 Q5$=INCHAR$(0) \ Q5=ASC(Q5$)
10600 IF Q5>47 AND Q5<58 OR Q5=46 OR Q5=69 OR Q5=45 THEN GOTO 10620
10610 GOTO 10720
10620  N5$=""
10630 GOSUB 11140 \ REM INPUT #
10640 X6=X5 \ Y6=Y5
10650 X5=X5+25
10660 IF X5<>82 THEN 10540
10670 X5=7 \ Y5=Y5+1
10675 IF Y5<> 24 THEN 10540
10678 X5=57 \Y5=23 \ GOTO 10540
10690 Q5$=INCHAR$(0) \ Q5=ASC(Q5$)
10700 IF Q5=67 OR Q5=68 OR Q5=83 OR Q5=76 OR Q5=82 OR Q5=85 THEN GOTO 10720
10710 GOTO 10690
10720 IF Q5$<>"S" THEN 10740
10730 IF X6=57 AND Y6>3 THEN RETURN
10740 IF Q5$<>"U" THEN GOTO 10760
10750 IF Y5<>4 THEN Y5=Y5-1 \ GOTO 10540
10760 IF Q5$<>"D" THEN 10820
10770 R=X5 \ C=Y5 \ REM TEMP
10780 Y5=Y5+1
10781 X=X6+25 \ Y=Y6 \ IF X<>82 THEN 10783
10782 X=7 \ Y=Y6+1
10783 IF Y<>24 THEN GOTO 10784 \ X=X6 \ Y=Y6
10784 IF X=X5 AND Y=Y5 THEN GOTO 10540
10790 GOSUB 11420
10800 IF Y=0 THEN GOTO 10540
10810 X5=R \ Y5=C
10815 GOTO 10540
10820 IF Q5$<>"L' THEN 10850
10830 IF X5<>7 THEN X5=X5-25
10840 GOTO 10540
10850 IF Q5$<>"R" THEN GOTO 10930
10860 IF X5=57 THEN GOTO 10540
10865 GOSUB 11420 \ IF Y=1 THEN GOTO 10540
10870 X5=X5+25
10880 IF Y5<>Y6 THEN GOTO 10910
10890 IF X5<=X6+25 THEN GOTO 10540
10900 X5=X5-25
10910 GOTO 10540
10930 IF Q5$<>"C" THEN GOTO 10540
10935 GOSUB 11420 \ IF Y=1 THEN GOTO 10540
10940 PRINT FNP$(X5,Y5),A$,
10950 PRINT FNP$(X5,Y5),
10960 GOSUB 11110
10970 GOTO  10540
11110 REM INPUT NUMBER
11120 N5$=""
11130 Q5$=INCHAR$(0) \Q5=ASC(Q5$)
11140 REM GET
11190 IF Q5=13 THEN GOTO 11280
11200 IF Q5=8 THEN GOTO 11220
11201 IF LEN(N5$)=10 THEN GOTO 11130
11205 N5$=N5$+Q5$
11206 PRINT Q5$,
11210 GOTO 11130
11220 IF N5$="" THEN GOTO 11130
11230 IF LEN (N5$)<>1 THEN GOTO 11250
11240 N5$="" \ GOTO 11260
11250 N5$=N5$(1,LEN(N5$)-1)
11260 PRINT Q5$,
11270 GOTO 11130
11280 ERRSET 11310,L,E
11290 D((X5-7)/25+1,Y5-3)=VAL(N5$)
11300 ERRSET \ RETURN
11310 PRINT FNP$(X5,Y5)," ERROR    ",B1$,
11320 FOR Z=1 TO 500 \ NEXT Z
11330 PRINT FNP$(X5,Y5),A$,FNP$(X5,Y5),
11340 ERRSET
11350 GOTO 11120
11410 REM POSITION LOCAT SIZE
11420 Y=1    \ REM Y=1 IF TRUE>END ELSE 0
11425 IF X5=X6 AND Y5=Y6 THEN Y=0
```

```
11430 IF X5>=X6 AND Y5<Y6 THEN Y=0
11440 IF X5<X6 AND Y5<=Y6 THEN Y=0
11450 RETURN
30000 REM FNT$ FUNCTION TO STRIP OFF TRAILING SPACES
30003 REM T$ CONTAINS STRIPPED WORD    L IS THE NEW LENGHT
30005 DEF FNT$(T$)
30007 X=LEN(T$)
30010 FOR L=X TO 1 STEP -1
30015 IF T$(L,L)<> " " THEN EXIT 30035
30020 NEXT
30025 T$="" \ L=0
30030 GOTO 30040
30035 T$=T$(1,L)
30040 RETURN T$
30045 FNEND
30100 REM PLOT TO SCREEN (TERMINAL)
30110 DEF FNP$(X,Y)
30120 RETURN CHR$(126)+CHR$(17)+CHR$(X)+CHR$(Y)
30130 FNEND
60000 REM  VARIABLE TABLE
60005 Z    TAB STOPS (TEMP)
60010 X    FOR NEXT LOOPS (TEMP)
60015 S9$ STRING$ FUNC. (SET)
60020 B1$,N1$,C1$,H1$  TERMINAL CODES (SET)
60025 Z9$ FILE TEST FNF (TEMP)
60030 X9$ TEMP VARIABLE (TEMP)
60035 A   TEMP VARIABLE (TEMP)
60040 A$  TEMP VARIABLE (TEMP)
60045 F$  INPUTED FILE NAME
60050 F1$ DISK FILE NAME
60055 F2$ TRUE FILE NAME
60060 T$  STRIPPED WORD
```

APPENDIX E

STATISTICAL

PROGRAMS

```
1   '*************************************************************************
2   '*                    = Sensor Redundancy Management =                   *
3   '*       This is a program to allow the input of sensor data to the data  *
4   '*            file for processing by the report generating program.      *
5   '*                         NASA Grant  NAG 4-6                           *
6   '*                              June 1981                                *
7   '*                        Frank Scalzo, Ph.D.                            *
8   '*************************************************************************
9   '
10 '     == DISPLAY HEADING ON THE SCREEN ==
11 '
12 CLS: CLEAR 1000                                   'set aside string space
13 PRINT @68,CHR$(23);"SENSOR REDUNDANCY MANAGEMENT"
14 PRINT STRING$(32,"=")
15 PRINT @324,"Probability of False Alarm"
16 PRINT TAB(6);"Data Entry Program"
17 PRINT @652,"By F. Scalzo, Ph.D."
20 '
21 ON ERROR GOTO 2000
22 OPEN "I",1,"SFILE1"
23 CLOSE 1
24 PRINT "There is already data on file"
25 INPUT "DO YOU WANT TO REPLACE IT";A$
26 IF LEFT$(A$,1) <> "Y" THEN RUN "MENU"
27 CLS
30 INPUT "Enter the number of Sensor Pairs ";N
35 DIM S(N,2)
40 FOR J=1 TO N
45       PRINT @195,CHR$(31)                       'Erase to the end of screen
50       PRINT @195,"Enter the Data for Pair #";J
55       PRINT @323,;
60       INPUT "READING #1 ";S(J,1)
65       PRINT @387,;
70       INPUT "READING #2 ";S(J,2)
80 NEXT J
90 PRINT
100 INPUT "Would you like to see the data ";A$
110 IF LEFT$(A$,1) <> "Y" THEN GOTO 160
115 CLS
120 FOR J=1 TO N
125      IF INT(J/12) = J/12 THEN GOSUB 1000
130      PRINT "Pair";J,"Reading #1";S(J,1),"Reading #2";S(J,1)
140  NEXT J
150  CLS
160  INPUT "Do You Have Any Corrections ";A$
170  IF LEFT$(A$,1) <>"Y" THEN GOTO 240
180  INPUT "Which Pair";J
190  INPUT "Reenter Reading #1 ";S(J,1)
200  INPUT "Reenter Reading #2 ";S(J,2)
210  INPUT "Any Other Corrections ";A$
220  IF LEFT$(A$,1) = "Y" THEN CLS: GOTO 180
230  CLS
240  INPUT "Do You Want a Hard Copy of the Data ";A$
250  IF LEFT$(A$,1) <> "Y" THEN GOTO 300
260  FOR J=1 TO N
270     LPRINT "Pair";J,"Reading #1";S(J,1),"Reading #2";S(J,1)
280  NEXT J
300  OPEN "O",1,"SFILE1"
310  PRINT #1, N;
320  FOR J=1 TO N
330     PRINT #1, S(J,1);S(J,2);
340  NEXT J
350 CLOSE 1
400 RUN "MENU"
900  END

1000 PRINT @900,"(press any key to continue)";
1010 IF INKEY$="" THEN GOTO 1010 ELSE CLS
1020 RETURN
2000 ' ****** FILE DOES NOT EXIST === OK TO CONTINUE ******
2010 RESUME 27
```

Sensor Redundancy Management
Report of Probability Density Function ,C(DF),
Reliability, R, and Probability of False Alarm, P(AF/DF)
For the Sensor Value in the Domain of Failure

Flight = FB-FBW823

Parameter =ROLL RATE GYRO Sensor Channels are A and C

Sensor1= 1.9441 Sensor2= 2.5997 Sensor1-Sensor2=-.6556

P(AF/DF) Table for Sensor Channel A = 0

PDF	RELIAB.	P(AF/DF)
.0899312	.9999	.998889
.0899312	.9998	.997781
.0899312	.9997	.996674
.0899312	.9996	.99557
.0899312	.9995	.994468
.0899312	.9994	.993369
.0899312	.9993	.992271
.0899312	.9992	.991176
.0899312	.9991	.990083
.0899312	.999	.988992
.0899312	.9989	.987903
.0899312	.9988	.986816
.0899312	.9987	.985733
.0899312	.9986	.98465
.0899312	.9985	.98357
.0899312	.9984	.982492
.0899312	.9983	.981417
.0899312	.9982	.980343
.0899312	.9981	.979271
.0899312	.998	.978202
.0899312	.9979	.977135
.0899312	.9978	.97607
.0899312	.9977	.975007
.0899312	.9976	.973946
.0899312	.9975	.972887
.0899312	.9974	.97183
.0899312	.9973	.970776
.0899312	.9972	.969723
.0899312	.9971	.968673
.0899312	.997	.967624
.0899312	.9969	.966578
.0899312	.9968	.965533
.0899312	.9967	.964491
.0899312	.9966	.963451
.0899312	.9965	.962413
.0899312	.9964	.961377
.0899312	.9963	.960342
.0899312	.9962	.959311
.0899312	.9961	.95828
.0899312	.996	.957252
.0899312	.9959	.956226
.0899312	.9958	.955202
.0899312	.9957	.95418
.0899312	.9956	.953159
.0899312	.9955	.952142
.0899312	.9954	.951125
.0899312	.9953	.950111
.0899312	.9952	.949098
.0899312	.9951	.948088
.0899312	.995	.94708

P(AF/DF) Table for Sensor Channel C = 2.5997

PDF	RELIAB.	P(AF/DF)
.0321661	.9999	.9969
.0321661	.9998	.99382
.0321661	.9997	.990757
.0321661	.9996	.987712
.0321661	.9995	.984685
.0321661	.9994	.981678
.0321661	.9993	.978687
.0321661	.9992	.975713
.0321661	.9991	.972759
.0321661	.999	.96982
.0321661	.9989	.966898
.0321661	.9988	.963993
.0321661	.9987	.961107
.0321661	.9986	.958236
.0321661	.9985	.955381
.0321661	.9984	.952542
.0321661	.9983	.949722
.0321661	.9982	.946916
.0321661	.9981	.944125
.0321661	.998	.941353
.0321661	.9979	.938594
.0321661	.9978	.935851
.0321661	.9977	.933123
.0321661	.9976	.930413
.0321661	.9975	.927716
.0321661	.9974	.925034
.0321661	.9973	.922368
.0321661	.9972	.919716
.0321661	.9971	.917078
.0321661	.997	.914455
.0321661	.9969	.911848
.0321661	.9968	.909254
.0321661	.9967	.906674
.0321661	.9966	.904108
.0321661	.9965	.901557
.0321661	.9964	.899019
.0321661	.9963	.896495
.0321661	.9962	.893985
.0321661	.9961	.891488
.0321661	.996	.889004
.0321661	.9959	.886533
.0321661	.9958	.884077
.0321661	.9957	.881633
.0321661	.9956	.879202
.0321661	.9955	.876785
.0321661	.9954	.874379
.0321661	.9953	.871986
.0321661	.9952	.869606
.0321661	.9951	.86724
.0321661	.995	.864884

```
      PROGRAM SENSTAT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
     +                TAPE1,TAPE2,TAPE3,TAPE4)
C
      COMMON/STATDAT/STATMIN,STATMAX,MEAN,VAR,DEV,MEANSQ,RMS,
     +               SKEW,KURT,XLOW,XHIGH,NSGOOD,NSTOTAL
      COMMON/HISTDAT/HISTMIN,HISTMAX,NSEGS,TALLY,NHGOOD,NHTOTAL
      COMMON/PLOTDAT/XSCALE(4),YSCALE(4),HSTART,HSTOP,TITLE(6),IOPLOT
      REAL MEAN,MEANSQ,KURT
      INTEGER TALLY(100)
      DIMENSION DATA(100),ITIME(6),MESSAGE(3)
C
      READ(5,10)TITLE
   10 FORMAT(8A10)
      IF(EOF(5).NE.0)STOP "NO TITLE CARD"
C
      READ(5,10)HSTART,HSTOP
      IF(EOF(5).NE.0)STOP "NO TIME CARD"
      BACKSPACE 5
C
      READ(5,20)ITIME
   20 FORMAT(2(3(I2,1X),1X))
      START=FLOAT(1000*(3600*ITIME(1)+60*ITIME(2)+ITIME(3)))
      STOP=FLOAT(1000*(3600*ITIME(4)+60*ITIME(5)+ITIME(6)))
C
      READ(5,30)IOPLOT,INDEXA,INDEXB,NPARAMS
   30 FORMAT(A10,3I10)
      IF(EOF(5).NE.0)STOP "NO JOB CARDS"
      CALL PLOTS(0,0,4)
      CALL FACTOR(.7871)
      CALL PLOT(0.,11.,-3)
      GO TO 50
C
   40 READ(5,30)IOPLOT,INDEXA,INDEXB,NPARAMS
      IF(EOF(5).NE.0)GO TO 990
C
   50 IF(INDEXA.GT.0.AND.INDEXA.LE.NPARAMS.AND.
     +   INDEXB.GE.0.AND.INDEXB.LE.NPARAMS)GO TO 55
      CALL REMARK("ILLEGAL JOB CARD")
      GO TO 40
   55 REWIND 1
      REWIND 2
      N=0
      MESSAGE(1)="WRITING 2"
      MESSAGE(2)=IOPLOT
      MESSAGE(3)=0
      CALL REMARK(MESSAGE)
C
   60 READ(1)T1,T2,TMILLI,(DATA(I),I=1,NPARAMS)
      IF(EOF(1).NE.0.OR.TMILLI.GT.STOP) GO TO 70
      IF(TMILLI.LT.START) GO TO 60
      A=DATA(INDEXA)
      B=0.
      IF(INDEXB.NE.0)B=DATA(INDEXB)
      C=A-B
      WRITE(2)C
      N=N+1
      GO TO 60
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
C
   70 ENDFILE 2
      IF(N.EQ.0)STOP "NO DATA WITHIN TIME SLICE"
      STATMIN=-1E99
      STATMAX=+1E99
      MESSAGE(1)="STATIST 2"
      CALL REMARK(MESSAGE)
      CALL STATIST(2)
      HISTMIN=XLOW
      HISTMAX=XHIGH
      NSEGS=100
      CALL HSTGRAM(2)
      IF(INDEXB.EQ.0)GO TO 40
C
      REWIND 2
      REWIND 3
      HISTMIN=HISTMAX=0.
      MESSAGE(1)="WRITING 3"
      CALL REMARK(MESSAGE)
C
   80 READ(2)C
      IF(EOF(2).NE.0)GO TO 90
      X=ABS(C-MEAN)
      HISTMAX=AMAX1(HISTMAX,X)
      WRITE(3)X
      GO TO 80
C
   90 ENDFILE 3
      NSEGS=100
      CALL HSTGRAM(3)
      GO TO 40
C
  990 CALL PLOT(20.,0.,999)
C
      STOP "END OF JOB"
C
      END
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
      SUBROUTINE STATIST(FILE)
      COMMON/STATDAT/XMIN,XMAX,MEAN,VAR,DEV,MEANSQ,RMS,SKEW,KURT,
     +               XLOW,XHIGH,NGOOD,NTOTAL
      COMMON/PLOTDAT/XSCALE(4),YSCALE(4),HSTART,HSTOP,TITLE(6),IDPLOT
      REAL MEAN,MEANSQ,KURT,N
      INTEGER FILE
C
      MEAN=VAR=DEV=MEANSQ=RMS=SKEW=KURT=SUMX=SUMX2=SUMX3=SUMX4=0.
      XLOW=+1E99
      XHIGH=-1E99
      NGOOD=NTOTAL=0
      REWIND FILE
C
   10 READ(FILE)X
      IF(EOF(FILE).NE.0)GO TO 20
      NTOTAL=NTOTAL+1
      IF(X.LT.XMIN.OR.X.GT.XMAX)GO TO 10
      NGOOD=NGOOD+1
      SUMX=SUMX+X
      X2=X*X
      SUMX2=SUMX2+X2
      X3=X*X2
      SUMX3=SUMX3+X3
      X4=X*X3
      SUMX4=SUMX4+X4
      XLOW=AMIN1(XLOW,X)
      XHIGH=AMAX1(XHIGH,X)
      GO TO 10
C
   20 IF(NGOOD.EQ.0)STOP "SUBROUTINE STATIST HAS NO DATA"
      N=FLOAT(NGOOD)
      MEAN=SUMX/N
      VAR=SUMX2/N-MEAN**2
      IF(VAR.LE.0.)STOP "SUBROUTINE STATIST SHOWS ZERO VARIANCE"
      DEV=SQRT(VAR)
      MEANSQ=SUMX2/N
      RMS=SQRT(MEANSQ)
      SKEW=(SUMX3/N-3.*MEAN*MEANSQ+2.*MEAN**3)/(DEV*VAR)
      KURT=(SUMX4/N-4.*MEAN*SUMX3/N+6.*MEAN**2*SUMX2/N-3.*MEAN**4) /
     +      (VAR*VAR)
      WRITE(6,30)TITLE,FILE,IDPLOT,NTOTAL,XMIN,XMAX,NGOOD,XLOW,XHIGH,
     +           MEAN,VAR,DEV,MEANSQ,RMS,SKEW,KURT,HSTART,HSTOP
   30 FORMAT(1H1////" RESULTS OF SUBROUTINE STATIST"////
     1       " TITLE",T28,6A10//" DATA FROM FILE NO.",T28,I2//
     2       " PLOT ID",T28,A10//" TOTAL NO. OF SAMPLES",T28,I6//
     3       " ALLOWABLE MINIMUM",T28,G12.6//
     4       " ALLOWABLE MAXIMUM",T28,G12.6//
     5       " SAMPLES ALLOWED",T28,I6//
     6       " OBSERVED MINIMUM",T28,G12.6//
     7       " OBSERVED MAXIMUM",T28,G12.6//
     8       " MEAN VALUE",T28,G12.6//" VARIANCE",T28,G12.6//
     9       " STANDARD DEVIATION",T28,G12.6//" MEAN SQUARED",T28,G12.6//
     A       " ROOT MEAN SQUARED",T28,G12.6//" SKEWNESS",T28,G12.6//
     B       " KURTOSIS",T28,G12.6//" START TIME",T28,A10//
     C       " STOP TIME",T28,A10)
      RETURN
      END
```

```
      SUBROUTINE HSTGRAM(FILE)
C
      COMMON/HISTDAT/XMIN,XMAX,NSEGS,TALLY,NGOOD,NTOTAL
      COMMON/PLOTDAT/XSCALE(4),YSCALE(4),HSTART,HSTOP,TITLE(6),IDPLOT
      COMMON/DAYTIME/DAY,HRMINSC
      INTEGER FILE,TALLY(100),TOTAL(100),REMAIN(100),PASSNO
      DIMENSION FROM(100),TO(100),MESSAGE(4)
C
      MESSAGE(4)=PASSNO=0
      PERCENT=0.95
      NCONSEC=3
C
    1 PASSNO=PASSNO+1
      ENCODE(27,5,MESSAGE)FILE,PASSNO,IDPLOT
    5 FORMAT("HSTGRAM ",I1," RUN ",I2,1X,A10)
      CALL REMARK(MESSAGE)
C
      DO 10  I=1,NSEGS
   10 TALLY(I)=0
C
      REWIND FILE
      NGOOD=NTOTAL=0
      DELTA=1.000001*(XMAX-XMIN)/FLOAT(NSEGS)
C
   20 READ(FILE)X
      IF(EOF(FILE).NE.0)GO TO 40
      NTOTAL=NTOTAL+1
      IF(X.LT.XMIN)GO TO 20
      TEST=XMIN
C
      DO 30  I=1,NSEGS
      TEST=TEST+DELTA
      IF(X.GT.TEST)GO TO 30
      TALLY(I)=TALLY(I)+1
      NGOOD=NGOOD+1
      GO TO 20
   30 CONTINUE
C
      GO TO 20
C
   40 CALL DATE(DAY)
      CALL TIME(HRMINSC)
      WRITE(6,50)TITLE,FILE,IDPLOT,NTOTAL,XMIN,XMAX,NGOOD,NSEGS,
     +            DAY,HRMINSC
   50 FORMAT(1H1//" RESULTS OF SUBROUTINE HSTGRAM"///
     1        " TITLE",T28,6A10//" DATA FROM FILE NO.",T28,I2//
     2        " PLOT ID",T28,A10//" TOTAL NO. OF SAMPLES",T28,I6//
     3        " ALLOWABLE MINIMUM",T28,G12.6//
     4        " ALLOWABLE MAXIMUM",T28,G12.6//
     5        " SAMPLES ALLOWED",T28,I6//
     6        " NO. OF SEGMENTS",T28,I3//
     7        " DATE/TIME",T28,A10,A9//)
C
      TOTAL(1)=TALLY(1)
      REMAIN(1)=NGOOD-TALLY(1)
      FROM(1)=X=XMIN
C
```

```
      DO 60 I=2,NSEGS
      TOTAL(I)=TOTAL(I-1)+TALLY(I)
      REMAIN(I)=NGOOD-TOTAL(I)
   60 FROM(I)=TO(I-1)=X=X+DELTA
C
      TO(NSEGS)=XMAX
C
      WRITE(6,70)(I,FROM(I),TO(I),TALLY(I),TOTAL(I),REMAIN(I),I=1,NSEGS)
   70 FORMAT(" SEG. NO      FROM",T29,"TO",T38,"SAMPLES    TOTAL",
     +        T57,"REMAINING"//100(2H  ,I3,4X,2(G12.6,2X),3(I6,4X)/))
C
      CALL PLHIST
      OLDMIN=XMIN
      OLDMAX=XMAX
      MINREQ=INT(PERCENT*FLOAT(NGOOD))
      IF(FILE.EQ.3)GO TO 110
      IF(PASSNO.EQ.1)CALL PLNORM
      IMIN=NCONSEC+1
      MINREQ=(NGOOD+MINREQ)/2
C
      DO 100 I=IMIN,NSEGS
      IF(REMAIN(I-1).LT.MINREQ)GO TO 110
C
      DO 90 J=1,NCONSEC
      K=I-J
      IF(TALLY(K).NE.0)GO TO 100
   90 CONTINUE
C
      XMIN=FROM(I)
  100 CONTINUE
C
  110 I=NSEGS-NCONSEC
C
  120 IF(TOTAL(I).LT.MINREQ)GO TO 150
C
      DO 130 J=1,NCONSEC
      K=I+J
      IF(TALLY(K).NE.0)GO TO 140
  130 CONTINUE
C
      XMAX=TO(I)
  140 I=I-1
      IF(I.GE.1)GO TO 120
C
  150 IF(XMIN.NE.OLDMIN.OR.XMAX.NE.OLDMAX)GO TO 1
C
      RETURN
C
      END
```

```
      SUBROUTINE PLHIST
C
      COMMON/HISTDAT/HISTMIN,HISTMAX,NSEGS,TALLY,NHGOOD,NHTOTAL
      COMMON/PLOTDAT/XSCALE(4),YSCALE(4),HSTART,HSTOP,TITLE(6),IOPLOT
      COMMON/DAYTIME/DAY,HRMINSC
      INTEGER TALLY(100)
      DIMENSION TOPLINE(4)
      DATA TOPLINE/"MINIMUM   "," MAXIMUM  ","  VALID OB","S"/
C
      CALL PLOT(11.43,0.,-3)
C
      XSCALE(1)=HISTMIN
      XSCALE(2)=HISTMAX
      CALL SCALE(XSCALE,10.,2,1)
      CALL AXIS(0.,0.,"SCALAR VALUE",-12,10.,270.,XSCALE(3),XSCALE(4))
C
      YMAX=0.
C
      DO 10  I=1,NSEGS
      TEST=FLOAT(TALLY(I))
   10 YMAX=AMAX1(YMAX,TEST)
C
      YSCALE(1)=0.
      YSCALE(2)=YMAX
      CALL SCALE(YSCALE,8.,2,1)
      CALL AX90(0.,0.,"SAMPLES PER INTERVAL",20,8.,0.,0.,YSCALE(4))
C
      X=(HISTMIN-XSCALE(3))/XSCALE(4)
      CALL PLOT(0.,-1.*X,3)
C
      DELTAX=ABS(HISTMAX-HISTMIN)/FLOAT(NSEGS)
C
      DO 20  I=1,NSEGS
      Y=FLOAT(TALLY(I))/YSCALE(4)
      CALL PLOT(Y,-1.*X,2)
      X=X+DELTAX/XSCALE(4)
   20 CALL PLOT(Y,-1.*X,2)
C
      CALL PLOT(0,-1.*X,2)
      CALL SYMBOL(0.,1.5,.15,TITLE,0.,60)
      CALL SYMBOL(9.,-5.87,.12,TOPLINE,270.,31)
      CALL NUMBER(8.75,-5.97,.12,HISTMIN,270.,3)
      CALL NUMBER(8.75,-7.35,.12,HISTMAX,270.,3)
      HGOOD=FLOAT(NHGOOD)
      CALL NUMBER(8.75,-8.50,.12,HGOOD  ,270.,-1)
      CALL SYMBOL(8.75,-9.35,.12,"/",270.,1)
      HTOTAL=FLOAT(NHTOTAL)
      CALL NUMBER(8.75,-9.50,.12,HTOTAL ,270.,-1)
      CALL SYMBOL(8.0,-.5,.12,IOPLOT,270.,10)
      CALL SYMBOL(8.0,-2.,.12,HSTART,270.,8)
      CALL SYMBOL(8.0,-3.12,.12,"TO",270.,2)
      CALL SYMBOL(8.0,-3.50,.12,HSTOP,270.,8)
      CALL SYMBOL(8.0,-7.75,.12,DAY,270.,10)
      CALL SYMBOL(8.0,-9.00,.12,HRMINSC,270.,9)
C
      RETURN
      END
```

```
      SUBROUTINE PLNORM
C
      COMMON/STATDAT/STATMIN,STATMAX,MEAN,VAR,DEV,MEANSQ,RMS,
     +                SKEW,KURT,XLOW,XHIGH,NSGOOD,NSTOTAL
      COMMON/HISTDAT/HISTMIN,HISTMAX,NSEGS,TALLY,NHGOOD,NHTOTAL
      COMMON/PLOTDAT/XSCALE(4),YSCALE(4),HSTART,HSTOP,TITLE(6),IDPLOT
      REAL MEAN,MEANSQ,KURT
      INTEGER TALLY(100)
      DIMENSION ABSCISS(302),ORDNATE(302),TOPLINE(6)
C
      DATA TOPLINE/"MEAN SQUAR","E     RMS  "," VARIANCE","   MEAN VA",
     +              "LUE    STD"," DEV"/
C
      X=XSCALE(3)
      XINC=ABS(XSCALE(4)/29.9)
      COEFF=FLOAT(NSGOOD)*(XHIGH-XLOW)/FLOAT(NSEGS)/(2.5066*DEV)
C
      DO 10 I=1,300
      ABSCISS(I)=X
      EXPON=-.5*(((X-MEAN)/DEV)**2)
      ORDNATE(I)=0.
      IF(EXPON.GE.-675..AND.EXPON.LE.741.)ORDNATE(I)=COEFF*EXP(EXPON)
   10 X=X+XINC
C
      ABSCISS(301)=XSCALE(3)
      ORDNATE(301)=YSCALE(3)
      ABSCISS(302)=-XSCALE(4)
      ORDNATE(302)=YSCALE(4)
C
      CALL LINE(ORDNATE,ABSCISS,300,1,0,0)
C
      CALL SYMBOL(9.,1.,.12,TOPLINE,270.,54)
      CALL NUMBER(8.75,+0.60,.12,MEANSQ ,270.,3)
      CALL NUMBER(8.75,-0.70,.12,RMS    ,270.,3)
      CALL NUMBER(8.75,-1.85,.12,VAR    ,270.,3)
      CALL NUMBER(8.75,-3.25,.12,MEAN   ,270.,3)
      CALL NUMBER(8.75,-4.75,.12,DEV    ,270.,3)
C
      RETURN
C
      END
```

```
      PROGRAM NORMFIT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
     +                TAPE1,TAPE2,TAPE3,TAPE4)
C
      COMMON/STATDAT/STATMIN,STATMAX,MEAN,VAR,DEV,MEANSQ,RMS,
     +               SKEW,KURT,XLOW,XHIGH,NSGOOD,NSTOTAL
      COMMON/HISTDAT/HISTMIN,HISTMAX,NSEGS,TALLY,NHGOOD,NHTOTAL
      COMMON/PLOTDAT/XSCALE(4),YSCALE(4),HSTART,HSTOP,TITLE(6),IDPLOT
      REAL MEAN,MEANSQ,KURT
      INTEGER TALLY(100)
      DIMENSION DATA(100),ITIME(6),MESSAGE(3)
C
      READ(5,10)TITLE
   10 FORMAT(8A10)
      IF(EOF(5).NE.0)STOP "NO TITLE CARD"
C
      READ(5,10)HSTART,HSTOP
      IF(EOF(5).NE.0)STOP "NO TIME CARD"
      BACKSPACE 5
C
      READ(5,20)ITIME
   20 FORMAT(2(3(I2,1X),1X))
      START=FLOAT(1000*(3600*ITIME(1)+60*ITIME(2)+ITIME(3)))
      STOP=FLOAT(1000*(3600*ITIME(4)+60*ITIME(5)+ITIME(6)))
C
      READ(5,30)IDPLOT,INDEXA,INDEXB,NPARAMS,TOL
   30 FORMAT(A10,3I10,F20.6)
      IF(EOF(5).NE.0)STOP "NO JOB CARDS"
      CALL PLOTS(0,0,4)
      CALL FACTOR(.7871)
      CALL PLOT(0.,11.,-3)
      GO TO 50
C
   40 READ(5,30)IDPLOT,INDEXA,INDEXB,NPARAMS,TOL
      IF(EOF(5).NE.0)GO TO 990
C
   50 IF(INDEXA.GT.0.AND.INDEXA.LE.NPARAMS.AND.
     +   INDEXB.GT.0.AND.INDEXB.LE.NPARAMS)GO TO 55
      CALL REMARK("ILLEGAL JOB CARD")
      GO TO 40
   55 REWIND 1
      REWIND 2
      N=0
      MESSAGE(1)="WRITING 2"
      MESSAGE(2)=IDPLOT
      MESSAGE(3)=0
      CALL REMARK(MESSAGE)
C
   60 READ(1)T1,T2,TMILLI,(DATA(I),I=1,NPARAMS)
      IF(EOF(1).NE.0.OR.TMILLI.GT.STOP) GO TO 70
      IF(TMILLI.LT.START) GO TO 60
      C=DATA(INDEXA)-DATA(INDEXB)
      WRITE(2)C
      N=N+1
      GO TO 60
C
   70 ENDFILE 2
      IF(N.EQ.0)STOP "NO DATA WITHIN TIME SLICE"
```

```
      STATMIN=-1E99
      STATMAX=+1E99
      MESSAGE(1)="STATIST 2"
      CALL REMARK(MESSAGE)
      CALL STATIST(2)
      XLOW=HISTMIN=-1.2*TOL
      XHIGH=HISTMAX=+1.2*TOL
      NSEGS=100
      CALL HSTGRAM(2)
      NSGOOD=NHGOOD
      CALL PLNORM
C
      REWIND 2
      XLOW=HISTMIN=MEAN-3.*DEV
      XHIGH=HISTMAX=MEAN+3.*DEV
      CALL HSTGRAM(2)
      NSGOOD=NHGOOD
      CALL PLNORM
      GO TO 40
C
  990 CALL PLOT(20.,0.,999)
C
      STOP "END OF JOB"
C
      END
```

```
      SUBROUTINE STATIST(FILE)
      COMMON/STATDAT/XMIN,XMAX,MEAN,VAR,DEV,MEANSQ,RMS,SKEW,KURT,
     +               XLOW,XHIGH,NGOOD,NTOTAL
      COMMON/PLOTDAT/XSCALE(4),YSCALE(4),HSTART,HSTOP,TITLE(6),IDPLOT
      REAL MEAN,MEANSQ,KURT,N
      INTEGER FILE
C
      MEAN=VAR=DEV=MEANSQ=RMS=SKEW=KURT=SUMX=SUMX2=SUMX3=SUMX4=0.
      XLOW=+1E99
      XHIGH=-1E99
      NGOOD=NTOTAL=0
      REWIND FILE
C
   10 READ(FILE)X
      IF(EOF(FILE).NE.0)GO TO 20
      NTOTAL=NTOTAL+1
      IF(X.LT.XMIN.OR.X.GT.XMAX)GO TO 10
      NGOOD=NGOOD+1
      SUMX=SUMX+X
      X2=X*X
      SUMX2=SUMX2+X2
      X3=X*X2
      SUMX3=SUMX3+X3
      X4=X*X3
      SUMX4=SUMX4+X4
      XLOW=AMIN1(XLOW,X)
      XHIGH=AMAX1(XHIGH,X)
      GO TO 10
C
   20 IF(NGOOD.EQ.0)STOP "SUBROUTINE STATIST HAS NO DATA"
      N=FLOAT(NGOOD)
      MEAN=SUMX/N
      VAR=SUMX2/N-MEAN**2
      IF(VAR.LE.0.)STOP "SUBROUTINE STATIST SHOWS ZERO VARIANCE"
      DEV=SQRT(VAR)
      MEANSQ=SUMX2/N
      RMS=SQRT(MEANSQ)
      SKEW=(SUMX3/N-3.*MEAN*MEANSQ+2.*MEAN**3)/(DEV*VAR)
      KURT=(SUMX4/N-4.*MEAN*SUMX3/N+6.*MEAN**2*SUMX2/N-3.*MEAN**4) /
     +     (VAR*VAR)
      WRITE(6,30)TITLE,FILE,IDPLOT,NTOTAL,XMIN,XMAX,NGOOD,XLOW,XHIGH,
     +           MEAN,VAR,DEV,MEANSQ,RMS,SKEW,KURT,HSTART,HSTOP
   30 FORMAT(1H1////" RESULTS OF SUBROUTINE STATIST"////
     1       " TITLE",T28,6A10//" DATA FROM FILE NO.",T28,I2//
     2       " PLOT ID",T28,A10//" TOTAL NO. OF SAMPLES",T28,I6//
     3       " ALLOWABLE MINIMUM",T28,G12.6//
     4       " ALLOWABLE MAXIMUM",T28,G12.6//
     5       " SAMPLES ALLOWED",T28,I5//
     6       " OBSERVED MINIMUM",T28,G12.6//
     7       " OBSERVED MAXIMUM",T28,G12.6//
     8       " MEAN VALUE",T28,G12.6//" VARIANCE",T28,G12.6//
     9       " STANDARD DEVIATION",T28,G12.6//" MEAN SQUARED",T28,G12.6//
     A       " ROOT MEAN SQUARED",T28,G12.6//" SKEWNESS",T28,G12.6//
     B       " KURTOSIS",T28,G12.6//" START TIME",T28,A10//
     C       " STOP TIME",T28,A10)
      RETURN
      END
```

```
      SUBROUTINE HSTGRAM(FILE)
C
      COMMON/HISTDAT/XMIN,XMAX,NSEGS,TALLY,NGOOD,NTOTAL
      COMMON/PLOTDAT/XSCALE(4),YSCALE(4),HSTART,HSTOP,TITLE(6),IDPLOT
      COMMON/DAYTIME/DAY,HRMINSC
      INTEGER FILE,TALLY(100),TOTAL(100),REMAIN(100),PASSNO
      DIMENSION FROM(100),TO(100),MESSAGE(4)
C
      MESSAGE(4)=PASSNO=0
      PERCENT=0.95
      NCONSEC=3
C
    1 PASSNO=PASSNO+1
      ENCODE(27,5,MESSAGE)FILE,PASSNO,IDPLOT
    5 FORMAT("HSTGRAM ",I1," RUN ",I2,1X,A10)
      CALL REMARK(MESSAGE)
C
      DO 10 I=1,NSEGS
   10 TALLY(I)=0
C
      REWIND FILE
      NGOOD=NTOTAL=0
      DELTA=1.000001*(XMAX-XMIN)/FLOAT(NSEGS)
C
   20 READ(FILE)X
      IF(EOF(FILE).NE.0)GO TO 40
      NTOTAL=NTOTAL+1
      IF(X.LT.XMIN)GO TO 20
      TEST=XMIN
C
      DO 30 I=1,NSEGS
      TEST=TEST+DELTA
      IF(X.GT.TEST)GO TO 30
      TALLY(I)=TALLY(I)+1
      NGOOD=NGOOD+1
      GO TO 20
   30 CONTINUE
C
      GO TO 20
C
   40 CALL DATE(DAY)
      CALL TIME(HRMINSC)
      WRITE(6,50)TITLE,FILE,IDPLOT,NTOTAL,XMIN,XMAX,NGOOD,NSEGS,
     +            DAY,HRMINSC
   50 FORMAT(1H1//" RESULTS OF SUBROUTINE HSTGRAM"///
     1       " TITLE",T28,6A10//" DATA FROM FILE NO.",T28,I2//
     2       " PLOT ID",T28,A10//" TOTAL NO. OF SAMPLES",T28,I6//
     3       " ALLOWABLE MINIMUM",T28,G12.6//
     4       " ALLOWABLE MAXIMUM",T28,G12.6//
     5       " SAMPLES ALLOWED",T28,I6//
     6       " NO. OF SEGMENTS",T28,I3//
     7       " DATE/TIME",T28,A10,A9//)
C
      TOTAL(1)=TALLY(1)
      REMAIN(1)=NGOOD-TALLY(1)
      FROM(1)=X=XMIN
C
```

```
      DO 60 I=2,NSEGS
      TOTAL(I)=TOTAL(I-1)+TALLY(I)
      REMAIN(I)=NGOOD-TOTAL(I)
   60 FROM(I)=TO(I-1)=X=X+DELTA
C
      TO(NSEGS)=XMAX
C
      WRITE(6,70)(I,FROM(I),TO(I),TALLY(I),TOTAL(I),REMAIN(I),I=1,NSEGS)
   70 FORMAT(" SEG. NO        FROM",T29,"TO",T38,"SAMPLES     TOTAL",
     +        T57,"REMAINING"//100(2H   ,I3,4X,2(G12.6,2X),3(I5,4X)/))
C
      CALL PLHIST
C
      RETURN
C
      END
```

```
      SUBROUTINE PLHIST
C
      COMMON/HISTDAT/HISTMIN,HISTMAX,NSEGS,TALLY,NHGOOD,NHTOTAL
      COMMON/PLOTDAT/XSCALE(4),YSCALE(4),HSTART,HSTOP,TITLE(6),IDPLOT
      COMMON/DAYTIME/DAY,HRMINSC
      INTEGER TALLY(100)
      DIMENSION TOPLINE(4)
      DATA TOPLINE/"MINIMUM   "," MAXIMUM  ","  VALID OR","S"/
C
      CALL PLOT(11.43,0.,-3)
C
      XSCALE(1)=HISTMIN
      XSCALE(2)=HISTMAX
      CALL SCALE(XSCALE,10.,2,1)
      CALL AXIS(0.,0.,"SCALAR VALUE",-12,10.,270.,XSCALE(3),XSCALE(4))
C
      YMAX=0.
C
      DO 10 I=1,NSEGS
      TEST=FLOAT(TALLY(I))
   10 YMAX=AMAX1(YMAX,TEST)
C
      YSCALE(1)=0.
      YSCALE(2)=YMAX
      CALL SCALE(YSCALE,8.,2,1)
      CALL AXIS(0.,0.,"SAMPLES PER INTERVAL",20,8.,0.,0.,YSCALE(4))
C
      X=(HISTMIN-XSCALE(3))/XSCALE(4)
      CALL PLOT(0.,-1.*X,3)
C
      DELTAX=ABS(HISTMAX-HISTMIN)/FLOAT(NSEGS)
C
      DO 20 I=1,NSEGS
      Y=FLOAT(TALLY(I))/YSCALE(4)
      CALL PLOT(Y,-1.*X,2)
      X=X+DELTAX/XSCALE(4)
   20 CALL PLOT(Y,-1.*X,2)
C
      CALL PLOT(0,-1.*X,2)
      CALL SYMBOL(0.,1.5,.15,TITLE,0.,60)
      CALL SYMBOL(9.,-5.87,.12,TOPLINE,270.,31)
      CALL NUMBER(8.75,-5.97,.12,HISTMIN,270.,3)
      CALL NUMBER(8.75,-7.35,.12,HISTMAX,270.,3)
      HGOOD=FLOAT(NHGOOD)
      CALL NUMBER(8.75,-8.50,.12,HGOOD  ,270.,-1)
      CALL SYMBOL(8.75,-9.35,.12,"/",270.,1)
      HTOTAL=FLOAT(NHTOTAL)
      CALL NUMBER(8.75,-9.50,.12,HTOTAL ,270.,-1)
      CALL SYMBOL(8.0,-.5,.12,IDPLOT,270.,10)
      CALL SYMBOL(8.0,-2.,.12,HSTART,270.,8)
      CALL SYMBOL(8.0,-3.12,.12,"TO",270.,2)
      CALL SYMBOL(8.0,-3.50,.12,HSTOP,270.,8)
      CALL SYMBOL(8.0,-7.75,.12,DAY,270.,10)
      CALL SYMBOL(8.0,-9.00,.12,HRMINSC,270.,9)
C
      RETURN
      END
```

```
      SUBROUTINE PLNORM
C
      COMMON/STATDAT/STATMIN,STATMAX,MEAN,VAR,DEV,MEANSQ,RMS,
     +               SKEW,KURT,XLOW,XHIGH,NSGOOD,NSTOTAL
      COMMON/HISTDAT/HISTMIN,HISTMAX,NSEGS,TALLY,NHGOOD,NHTOTAL
      COMMON/PLOTDAT/XSCALE(4),YSCALE(4),HSTART,HSTOP,TITLE(6),IDPLOT
      REAL MEAN,MEANSQ,KURT
      INTEGER TALLY(100)
      DIMENSION ABSCISS(302),ORDNATE(302),TOPLINE(6)
C
      DATA TOPLINE/"MEAN SQUAR","E     RMS   ","  VARIANCE","   MEAN VA",
     +             "LUE     STD"," DEV"/
C
      X=XSCALE(3)
      XINC=ABS(XSCALE(4)/29.9)
      COEFF=FLOAT(NSGOOD)*(XHIGH-XLOW)/FLOAT(NSEGS)/(2.5066*DEV)
C
      DO 10 I=1,300
      ABSCISS(I)=X
      EXPON=-.5*(((X-MEAN)/DEV)**2)
      ORDNATE(I)=0.
      IF(EXPON.GE.-675..AND.EXPON.LE.741.)ORDNATE(I)=COEFF*EXP(EXPON)
   10 X=X+XINC
C
      ABSCISS(301)=XSCALE(3)
      ORDNATE(301)=YSCALE(3)
      ABSCISS(302)=-XSCALE(4)
      ORDNATE(302)=YSCALE(4)
C
      CALL LINE(ORDNATE,ABSCISS,300,1,0,0)
C
      CALL SYMBOL(9.,1.,.12,TOPLINE,270.,54)
      CALL NUMBER(8.75,+0.60,.12,MEANSQ ,270.,3)
      CALL NUMBER(8.75,-0.70,.12,RMS    ,270.,3)
      CALL NUMBER(8.75,-1.85,.12,VAR    ,270.,3)
      CALL NUMBER(8.75,-3.25,.12,MEAN   ,270.,3)
      CALL NUMBER(8.75,-4.75,.12,DEV    ,270.,3)
C
      RETURN
C
      END
```

```
10 INPUT "ENTER THE NUMBER OF SCORES";N
20 LET S1=0
30 LET S2=0
40 PRINT "ENTER EACH SCORE (ONE AT A TIME)"
50 FOR I=1 TO N
60    INPUT X
70    LET S1=S1+X
80    LET S2=S2+X↑2
90 NEXT I
100 LET M=S1/N
110 LET V=(S2-(S1)↑2/N)/N
120 LET D=SQR(V)
130 PRINT "MEAN="M;"VARIANCE="V;"ST. DEV.="D
140 PRINT
150 INPUT "MORE DATA (TYPE YES OR NO)";A$
160 IF A$="YES" THEN 10
170 END
```

STAT1: Descriptive Statistics Ungrouped Data

```
10 DIM F(16),X(16),C(16)
20 INPUT "ENTER THE NUMBER OF CLASS INTERVALS";N
30 LET S1=0
40 LET S2=0
50 LET C(0)=0
60 PRINT "ENTER # FREQUNCIES,AND MIDPOINT FOR EACH CLASS"
70 PRINT "        ONE PAIR AT A TIME                    "
80 FOR I=1 TO N
90    INPUT F(I),X(I)
100    LET S1=S1+F(I)*X(I)
110    LET S2=S2 +F(I)*X(I)↑2
120    LET C(I)=C(I-1)+F(I)
130 NEXT I
140 LET M=S1/C(N)
150 LET V=(S2-(S1)↑2/C(N))/C(N)
160 LET D=SQR(V)
170 FOR I=1 TO N
180 IF C(I))C(N)/2 THEN 200
190 NEXT I
200 LET W=X(2)-X(1)
210 LET L=X(I)-W/2
220 LET M1=L-W*(C(I-1)-C(N)/2)/F(I)
230 PRINT "MEAN","MEDIAN","VARIANCE","ST. DEV."
240 PRINT M,M1,V,D
250 PRINT
260 INPUT "MORE DATA (TYPE YES OR NO)?";A$
270 IF A$="YES" THEN 20
280 END
```

STAT2: Descriptive Statistics Grouped Data

```
10 PRINT
20 INPUT "ENTER FIRST SAMPLE MEAN";M1
30 INPUT "ENTER SECOND SAMPLE MEAN";M2
40 INPUT "ENTER FIRST VARIANCE";V1
50 INPUT "ENTER SECOND VARIANCE";V2
60 INPUT "ENTER FIRST SAMPLE SIZE";N1
70 INPUT "ENTER SECOND SAMPLE SIZE";N2
80 IF N1)=30 THEN 130
90 LET D=SQR(((N1)*V1+(N2)*V2)/(N1+N2-2))*SQR(1/N1+1/N2)
100 LET T=(M1-M2)/D
110 PRINT "OBSERVED t="T
120 GOTO 170
130 IF N2)=30 THEN 150
140 GOTO 90
150 LET Z=(M1-M2)/SQR(V1/N1+V2/N2)
160 PRINT "OBSERVED Z="Z
170 INPUT "MORE DATA(TYPE YES OR NO)?";A$
180 IF A$="YES" THEN 10
190 END
```

STAT3: Testing For Significant Differences Between Two Sample Means

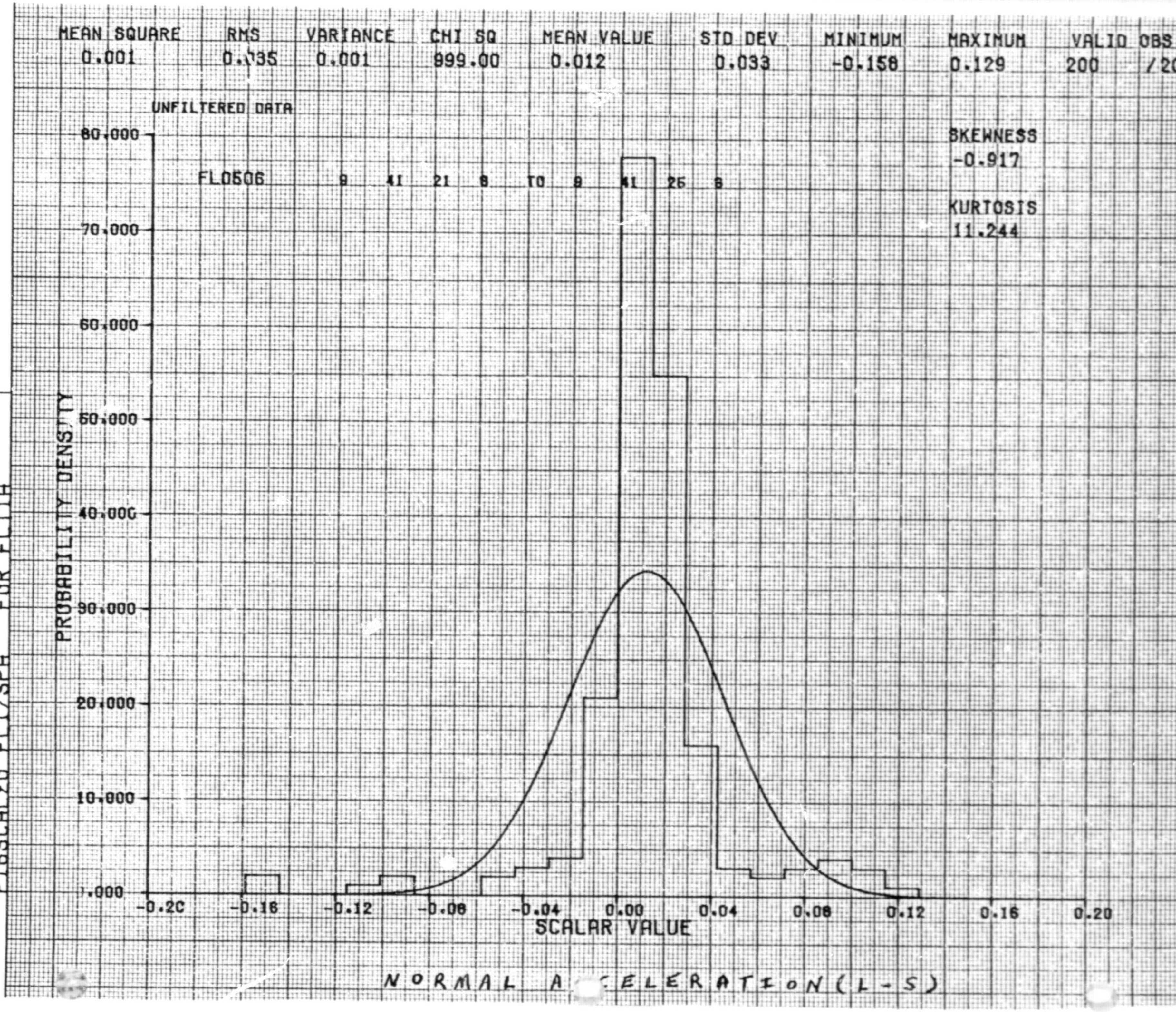
```
10 DIM M(30),F(30),E(30)
20 INPUT "ENTER THE NUMBER OF OBSERVATIONS";N
30 INPUT "ENTER PROB.SUCC.,OR A 0 IF PROB. IS UNKNOWN";P
40 PRINT "ENTER #OBSERVATIONS,#FREQUNCIES(ONE PAIR PER LINE)"
50 FOR I=1 TO N
60   INPUT M(I),F(I)
70 NEXT I
80 IF P=0 THEN 180
90 FOR I=1 TO N
100    LET E(I)=M(I)*P
110 NEXT I
120 LET S3=0
130 FOR I=1 TO N
140    LET S3=S3+(F(I)-E(I))↑2/E(I)
150 NEXT I
160 PRINT "OBSERVED CHI-SQUARE VALUE ="S3
170 GOTO 260
180 LET S1=0
190 LET S2=0
200 FOR I=1 TO N
210    LET S1=S1+F(I)
220    LET S2=S2+M(I)
230 NEXT I
240 LET P=S1/S2
250 GOTO 90
260 INPUT "MORE DATA (TYPE YES OR NO)?";A$
270 IF A$="YES" THEN 20
280 END
```

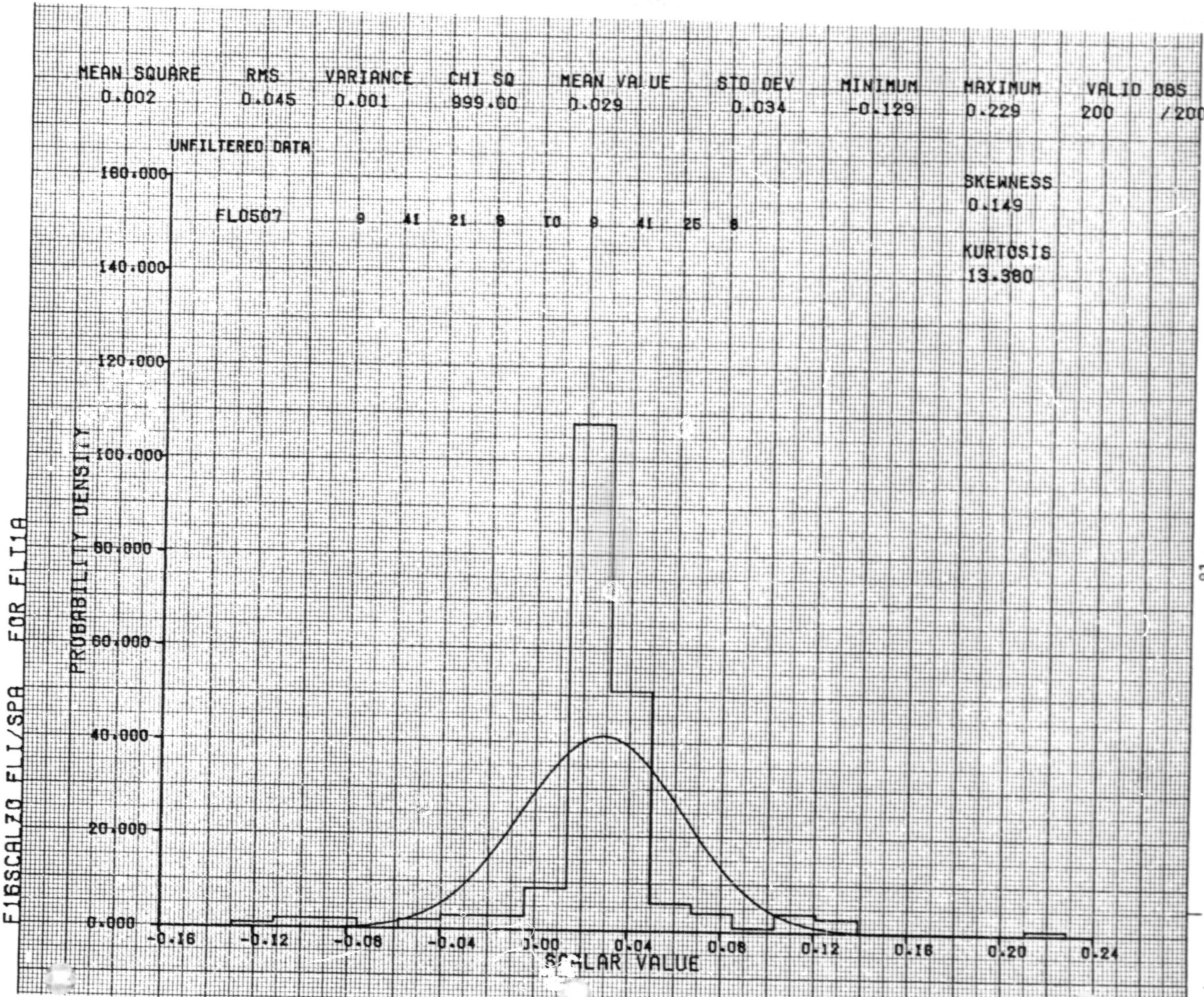
STAT4: Chi-Square Distribution

APPENDIX F

STATISTICAL ANALYSES AND CORRESPONDING FALSE ALARM PROBABILITY NOMOGRAPHS FOR AFTI F16 FLIGHT DATA

* Time 9-41-21-8 TO 9-41-25-8





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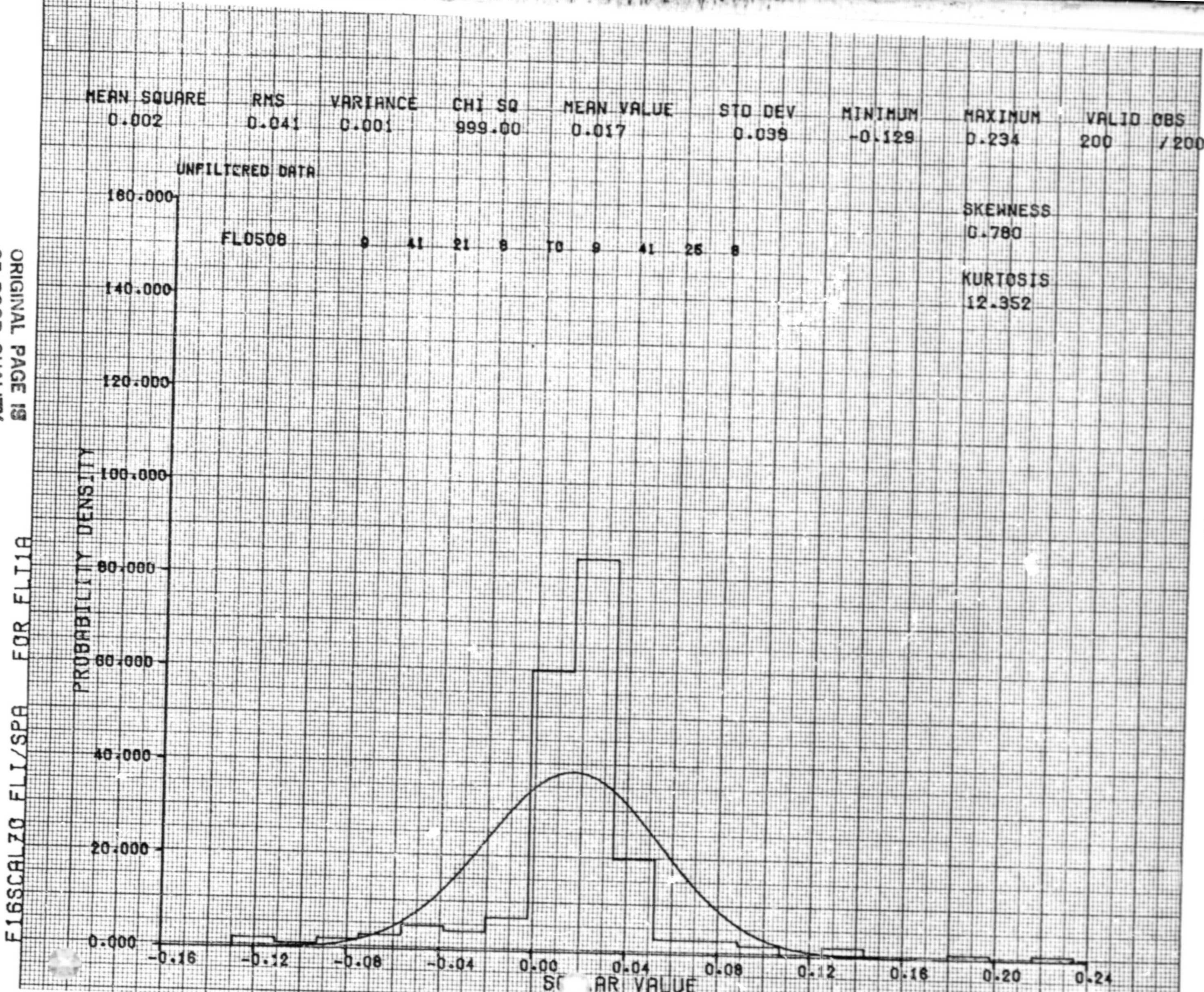
MEAN SQUARE 0.002
RMS 0.041
VARIANCE 0.001
CHI SQ 999.00
MEAN VALUE 0.017
STD DEV 0.039
MINIMUM -0.129
MAXIMUM 0.234
VALID OBS 200 / 200
UNFILTERED DATA
FL0508 9 41 21 8 TO 9 41 26 8
SKEWNESS 0.780
KURTOSIS 12.352
PROBABILITY DENSITY
180.000
140.000
120.000
100.000
80.000
60.000
40.000
20.000
0.000
-0.16
-0.12
-0.08
-0.04
0.00
0.04
0.08
0.12
0.16
0.20
0.24
AR VALUE
F16SCALZ0 FL1/SPA FOR FL11A

AFTIF16 FLT1A

Normal Acceleration (Sample Data)

	L-S	L-R	S-R
1	.023438	.035156	.011719
2	.023438	-.10547	-.12891
3	.0058594	.017578	.011719
4	-.017578	.0058994	.023438
5	.023438	.10547	.082031
6	.011719	.011719	0
7	.087891	.023438	-.064453
8	0	.029297	.029297
9	.099609	.13477	.0351156
10	.0058594	.041016	.035156
11	.082031	.029297	-.052734
12	.10547	.029297	-.076172
13	.12891	.035156	-.09375
14	.052734	.10547	.052734
15	-.0058594	.22852	.23438
16	.099609	.12305	.023438
17	.017578	.041016	.023438
18	-.087891	-.076172	.011719
19	.011719	.017578	.0058594
20	.029297	.035156	.0058594

Numerical output for plotting NOMOGRAPH

Sensor Redundancy Management
Report of Probability Density Function, C(DF)
Reliability R, Probalility of false Alarm P(AF/DF)
For the Sensor Value in the Domain of Failure

FLIGHT = AFTIF16 FLT1A
Parameter = NORMAL ACCELERATION   Sensor diffrences are L-S L-R and S-R

L-S = .023438   L-R = .035156   S-R = .011719

P(AF/DF) Table for Sensor Diffrence .= .023438

PDF	RELIAB.	P(AF/DF)
.33139466	.9999	.99969832
.33139466	.9989	.99668803
.33139466	.9979	.99368989
.33139466	.9969	.99070374
.33139466	.9959	.98772956

P(AF/DF) TABLE FOR SENSOR DIFFRENCE L-R = .035156

PDF	RELIAB.	P(AF/DF)
.33131613	.9999	.99969824
.33131613	.9989	.99668728
.33131613	.9979	.99368838
.33131613	.9969	.99070157
.33131613	.9959	.98772669

P(AF/DF) TABLE FOR SENSOR DIFFRENCE S-R = .011719

PDF	RELIAB.	P(AF/DF)
.33144179	.9999	.99969834
.33144179	.9989	.99668849
.33144179	.9979	.99369079
.33144179	.9969	.99070503
.33144179	.9959	.98773127

L-S = .023438   L-R = -.10547   S-R = -.12891

P(AF/DF) Table for Sensor Diffrence .= .023438

PDF	RELIAB.	P(AF/DF)
.33139466	.9999	.99969832
.33139466	.9989	.99668803
.33139466	.9979	.99368989
.33139466	.9969	.99070374
.33139466	.9959	.98772956

P(AF/DF) TABLE FOR SENSOR DIFFRENCE L-R = -.10547

PDF	RELIAB.	P(AF/DF)
.33018737	.9999	99969722
.33018737	.9985	.99667599
.33018737	.9979	.99366697
.33018737	.9969	.99067007
.33018737	.9959	.98768524

P(AF/DF) TABLE FOR SENSOR DIFFRENCE S-R = -.12891

PDF	RELIAB.	P(AF/DF)
.3295619	.9999	.99969662
.3295619	.9989	.99666965
.3295619	.9979	.99365503
.3295619	.9969	.9906525
.3295619	.9959	.98766213

L-S = .0058594   L-R = .017578   S-R = .011719

P(AF/DF) Table for Sensor Diffrence .= .0058594

PDF	RELIAB.	P(AF/DF)
.33145359	.9999	.99969835
.33145359	.9989	.99668864
.33145359	.9979	.99369099
.33145359	.9969	.99070537
.33145359	.9959	.98773171

P(AF/DF) TABLE FOR SENSOR DIFFRENCE L-R = .017578

PDF	RELIAB.	P(AF/DF)
.33142217	.9999	.99969834
.33142217	.9989	.9966883
.33142217	.9979	.99369038
.33142217	.9969	.99070448
.33142217	.9959	.98773055

P(AF/DF) TABLE FOR SENSOR DIFFRENCE S-R = .011719

PDF	RELIAB.	P(AF/DF)
.33144179	.9999	.99969834
.33144179	.9989	.99668849
.33144179	.9979	.99369079
.33144179	.9969	.99070503
.33144179	.9959	.98773127

L-S = -.017578 L-R = .0058994 S-R = .023438

P(AF/DF) Table for Sensor Diffrence .= -.017578

PDF	RELIAB.	P(AF/DF)
.33142217	.9999	.99969834
.33142217	.9989	.9966883
.33142217	.9979	.99369038
.33142217	.9969	.99070448
.33142217	.9959	.98773055

P(AF/DF) TABLE FOR SENSOR DIFFRENCE L-R = .0058994

PDF	RELIAB.	P(AF/DF)
.33145352	.9999	.99969835
.33145352	.9989	.99668864
.33145352	.9979	.99369099
.33145352	.9969	.99070537
.33145352	.9959	.98773171

P(AF/DF) TABLE FOR SENSOR DIFFRENCE S-R = .023438

PDF	RELIAB.	P(AF/DF)
.33139466	.9999	.99969832
.33139466	.9989	.99668803
.33139466	.9979	.99368989
.33139466	.9969	.99070374
.33139466	.9959	.98772956

L-S = .023438 L-R = .10547 S-R = .082031

P(AF/DF) Table for Sensor Diffrence .= .023438

PDF	RELIAB.	P(AF/DF)
.33139466	.9999	.99969832
.33139466	.9989	.99668803
.33139466	.9979	.99368989
.33139466	.9969	.99070374
.33139466	.9959	.98772956

P(AF/DF) TABLE FOR SENSOR DIFFRENCE L-R = .10547

PDF	RELIAB.	P(AF/DF)
.33018737	.9999	.99969722
.33018737	.9989	.99667599
.33018737	.9979	.99366697

.33018737	.9969	.99067007
.33018737	.9959	.98768524

P(AF/DF) TABLE FOR SENSOR DIFFRENCE S-R = .082031

PDF	RELIAB.	P(AF/DF)
.33068858	.9999	.99969768
.33068858	.9989	.99668101
.33068858	.9979	.9936765
.33068858	.9969	.99068409
.33068858	.9959	.98770365

L-S = .011719 L-R = .011719 S-R = 0

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P(AF/DF) Table for Sensor Diffrence .= .011719

PDF	RELIAB.	P(AF/DF)
.33144179	.9999	.99969834
.33144179	.9989	.99668849
.33144179	.9979	.99369079
.33144179	.9969	.99070503
.33144179	.9959	.98773127

P(AF/DF) TABLE FOR SENSOR DIFFRENCE L-R = .011719

PDF	RELIAB.	P(AF/DF)
.33144179	.9999	.99969834
.33144179	.9989	.99668849
.33144179	.9979	.99369079
.33144179	.9969	.99070503
.33144179	.9959	.98773127

P(AF/DF) TABLE FOR SENSOR DIFFRENCE S-R = 0

PDF	RELIAB.	P(AF/DF)
.3314575	.9999	.99969835
.3314575	.9989	.99668866
.3314575	.9979	.99369107
.3314575	.9969	.99070547
.3314575	.9959	.98773183

L-S = .087891 L-R = .023438 S-R = -.064453

P(AF/DF) Table for Sensor Diffrence .= .087891

PDF	RELIAB.	P(AF/DF)
.33057498	.9999	.99969754
.33057498	.9989	.99667985
.33057498	.9979	.99367433
.33057498	.9969	.99068092
.33057498	.9959	.98769949

P(AF/DF) TABLE FOR SENSOR DIFFRENCE L-R = .023438

PDF	RELIAB.	P(AF/DF)
.33139466	.9999	.99969832
.33139466	.9989	.99668803
.33139466	.9979	.99368989
.33139466	.9969	.99070374
.33139466	.9959	.98772956

P(AF/DF) TABLE FOR SENSOR DIFFRENCE S-R = -.064453

PDF	RELIAB.	P(AF/DF)
.33098259	.9999	.99969791
.33098259	.9989	.99668393
.33098259	.9979	.99368206
.33098259	.9969	.99069229
.33098259	.9959	.98771443

L-S = 0 L-R = .029297 S-R = .029297

P(AF/DF) Table for Sensor Diffrence .= 0

PDF	RELIAB.	P(AF/DF)
.3314575	.9999	.99969835
.3314575	.9989	.99668866
.3314575	.9979	.99369107
.3314575	.9969	.99070547
.3314575	.9959	.98773183

P(AF/DF) TABLE FOR SENSOR DIFFRENCE L-R = .029297

PDF	RELIAB.	P(AF/DF)
.33135934	.9999	.99969826
.33135934	.9989	.99668767
.33135934	.9979	.9936892
.33135934	.9969	.99070276
.33135934	.9959	.98772824

P(AF/DF) TABLE FOR SENSOR DIFFRENCE S-R = .029297

PDF	RELIAB.	P(AF/DF)
.33135934	.9999	.99969826
.33135934	.9989	.99668767
.33135934	.9979	.9936892
.33135934	.9969	.99070276
.33135934	.9959	.98772824

L-S = .099609 L-R = .13477 S-R = .0351156

P(AF/DF) Table for Sensor Diffrence .= .099609

PDF	RELIAB.	P(AF/DF)
.3303244	.9999	.99969733
.3303244	.9989	.99667736
.3303244	.9979	.99366954
.3303244	.9969	.99067389
.3303244	.9959	.98769029

P(AF/DF) TABLE FOR SENSOR DIFFRENCE L-R = .13477

PDF	RELIAB.	P(AF/DF)
.32938619	.9999	.99969649
.32938619	.9989	.99666793
.32938619	.9979	.99365165
.32938619	.9969	.99064757
.32938619	.9959	.98765566

P(AF/DF) TABLE FOR SENSOR DIFFRENCE S-R = .0351156

PDF	RELIAB.	P(AF/DF)
.33131646	.9999	.99969824
.33131646	.9989	.99668728
.33131646	.9979	.99368838
.33131646	.9969	.99070158
.33131646	.9959	.98772669

L-S = .0058594 L-R = .041016 S-R = .035156

P(AF/DF) Table for Sensor Diffrence .= .0058594

PDF	RELIAB.	P(AF/DF)
.33145359	.9999	.99969835
.33145359	.9989	.99668864
.33145359	.9979	.99369099
.33145359	.9969	.99070537
.33145359	.9959	.98773171

P(AF/DF) TABLE FOR SENSOR DIFFRENCE L-R = .041016

PDF	RELIAB.	P(AF/DF)
.33126511	.9999	.99969817

.33126511	.9989	.99668675
.33126511	.9979	.99368745
.33126511	.9969	.99070014
.33126511	.9959	.98772481

P(AF/DF) TABLE FOR SENSOR DIFFRENCE S-R = .035156

PDF	RELIAB.	P(AF/DF)
.33131613	.9999	.99969824
.33131613	.9989	.99668728
.33131613	.9979	.99368838
.33131613	.9969	.99070157
.33131613	.9959	.98772669

L-S = .082031 L-R = .029297 S-R = -.052734

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P(AF/DF) Table for Sensor Diffrence .= .082031

PDF	RELIAB.	P(AF/DF)
.33068858	.9999	.99969768
.33068858	.9989	.99668101
.33068858	.9979	.9936765
.33068858	.9969	.99068409
.33068858	.9959	.98770365

P(AF/DF) TABLE FOR SENSOR DIFFRENCE L-R = .029297

PDF	RELIAB.	P(AF/DF)
.33135934	.9999	.99969826
.33135934	.9989	.99668767
.33135934	.9979	.9936892
.33135934	.9969	.99070276
.33135934	.9959	.98772824

P(AF/DF) TABLE FOR SENSOR DIFFRENCE S-R = -.052734

PDF	RELIAB.	P(AF/DF)
.33113952	.9999	.99969807
.33113952	.9989	.99668549
.33113952	.9979	.99368504
.33113952	.9969	.99069664
.33113952	.9959	.98772023

L-S = .10547 L-R = .029297 S-R = -.076172

P(AF/DF) Table for Sensor Diffrence .= .10547

PDF	RELIAB.	P(AF/DF)
.33018737	.9999	.99969722
.33018737	.9989	.99667599
.33018737	.9979	.99366697
.33018737	.9969	.99067007
.33018737	.9959	.98768524

P(AF/DF) TABLE FOR SENSOR DIFFRENCE L-R = .029297

PDF	RELIAB.	P(AF/DF)
.33135934	.9999	.99969826
.33135934	.9989	.99668767
.33135934	.9979	.9936892
.33135934	.9969	.99070276
.33135934	.9959	.98772824

P(AF/DF) TABLE FOR SENSOR DIFFRENCE S-R = -.076172

PDF	RELIAB.	P(AF/DF)
.33079442	.9999	.99969778
.33079442	.9989	.99668204
.33079442	.9979	.9936785
.33079442	.9969	.99068701
.33079442	.9959	.98770757

L-S = .12891 L-R = .035156 S-R = -.09375

P(AF/DF) Table for Sensor Diffrence .= .12891

PDF	RELIAB.	P(AF/DF)
.3295619	.9999	.99969662
.3295619	.9989	.99666969
.3295619	.9979	.99365503
.3295619	.9969	.9906525
.3295619	.9959	.98766213

P(AF/DF) TABLE FOR SENSOR DIFFRENCE L-R = .035156

PDF	RELIAB.	P(AF/DF)
.33131613	.9999	.99969824
.33131613	.9989	.99668728
.33131613	.9979	.99368838
.33131613	.9969	.99070157
.33131613	.9959	.98772669

P(AF/DF) TABLE FOR SENSOR DIFFRENCE S-R = -.09375

PDF	RELIAB.	P(AF/DF)
.33045358	.9999	.99969744
.33045358	.9989	.99667865
.33045358	.9979	.99367205
.33045358	.9969	.99067751
.33045358	.9959	.98769501

L-S = .052734 L-R = .10547 S-R = .052734

P(AF/DF) Table for Sensor Diffrence .= .052734

PDF	RELIAB.	P(AF/DF)
.33113952	.9999	.99969807
.33113952	.9989	.99668549
.33113952	.9979	.99368504
.33113952	.9969	.99069664
.33113952	.9959	.98772023

P(AF/DF) TABLE FOR SENSOR DIFFRENCE L-R = .10547

PDF	RELIAB.	P(AF/DF)
.33018737	.9999	.99969722
.33018737	.9989	.99667599
.33018737	.9979	.99366697
.33018737	.9969	.99067007
.33018737	.9959	.98768524

P(AF/DF) TABLE FOR SENSOR DIFFRENCE S-R = .052734

PDF	RELIAB.	P(AF/DF)
.33113952	.9999	.99969807
.33113952	.9989	.99668549
.33113952	.9979	.99368504
.33113952	.9969	.99069664
.33113952	.9959	.98772023

L-S = -.0058594 L-R = .22852 S-R = .23438

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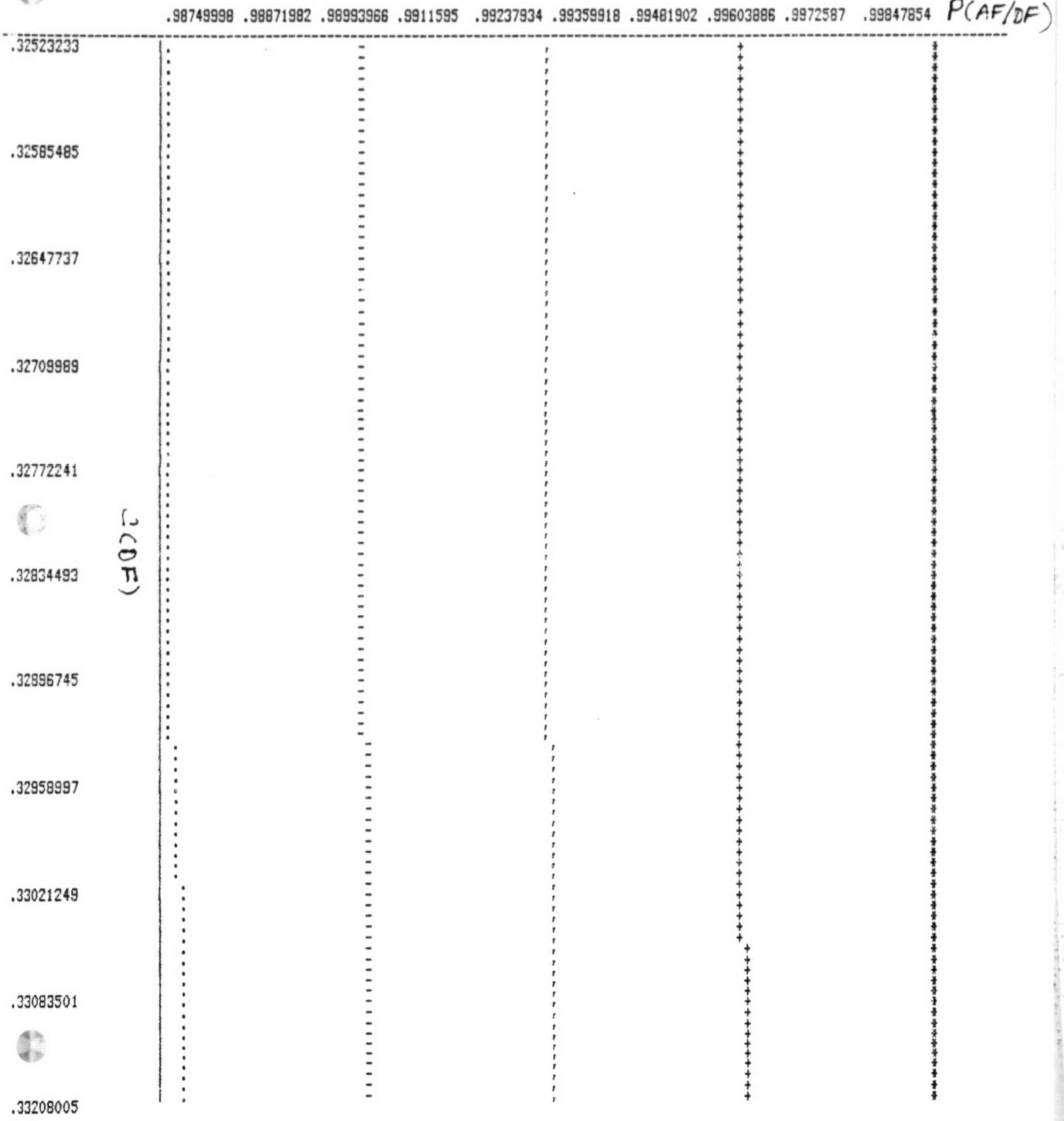
Sensor Redundancy Management
Report of Probability Density Function, C(DF)
Reliability(R), Probability of False Alarm, P(AF/DF)
For the Sensor Value in the Domain of Failure

FLIGHT = AFTIF16 FLT1A

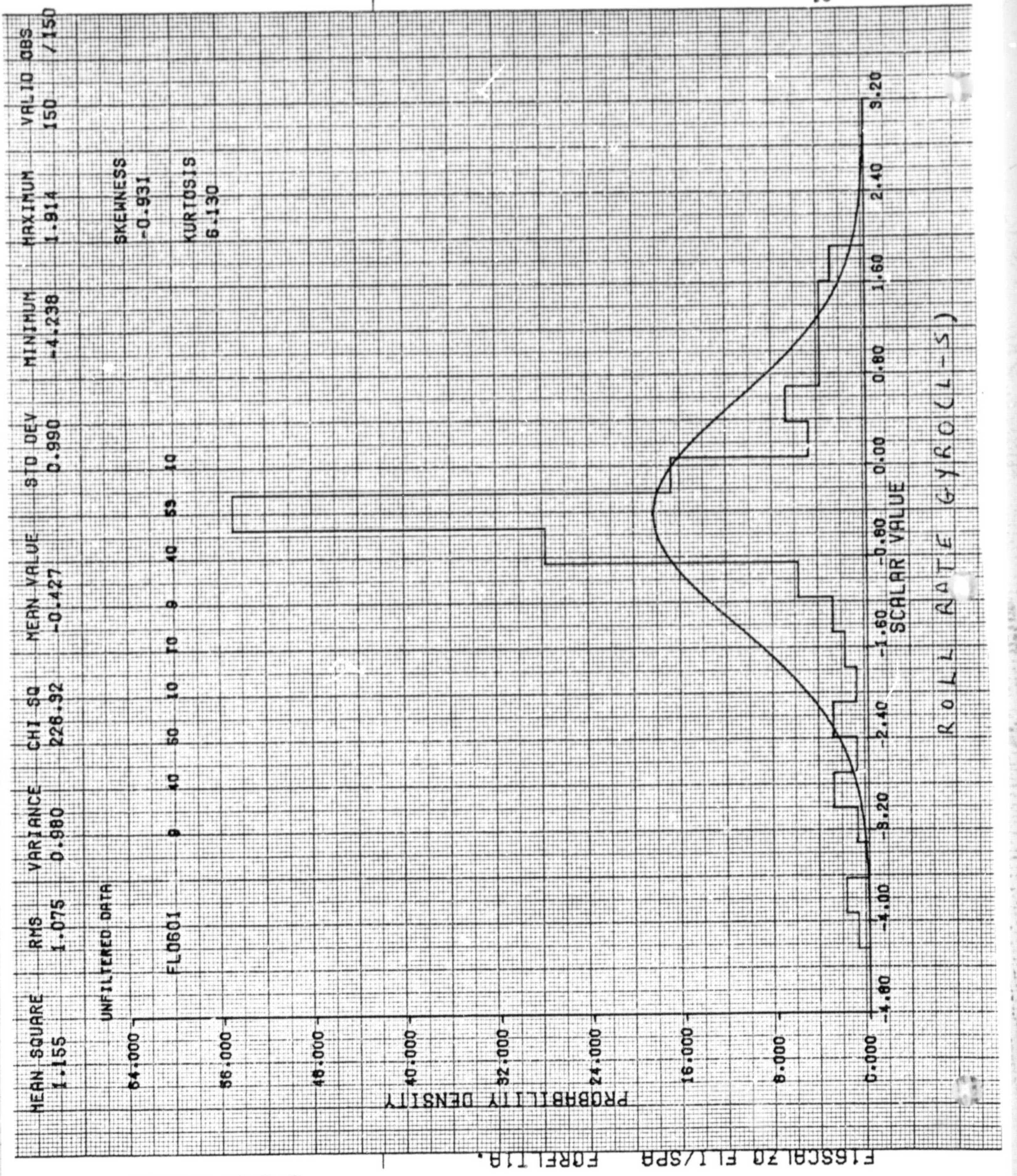
Pa[illegible]ter = NORMAL ACCELERATION Sensor diffrences are . L-S L-R and S-R

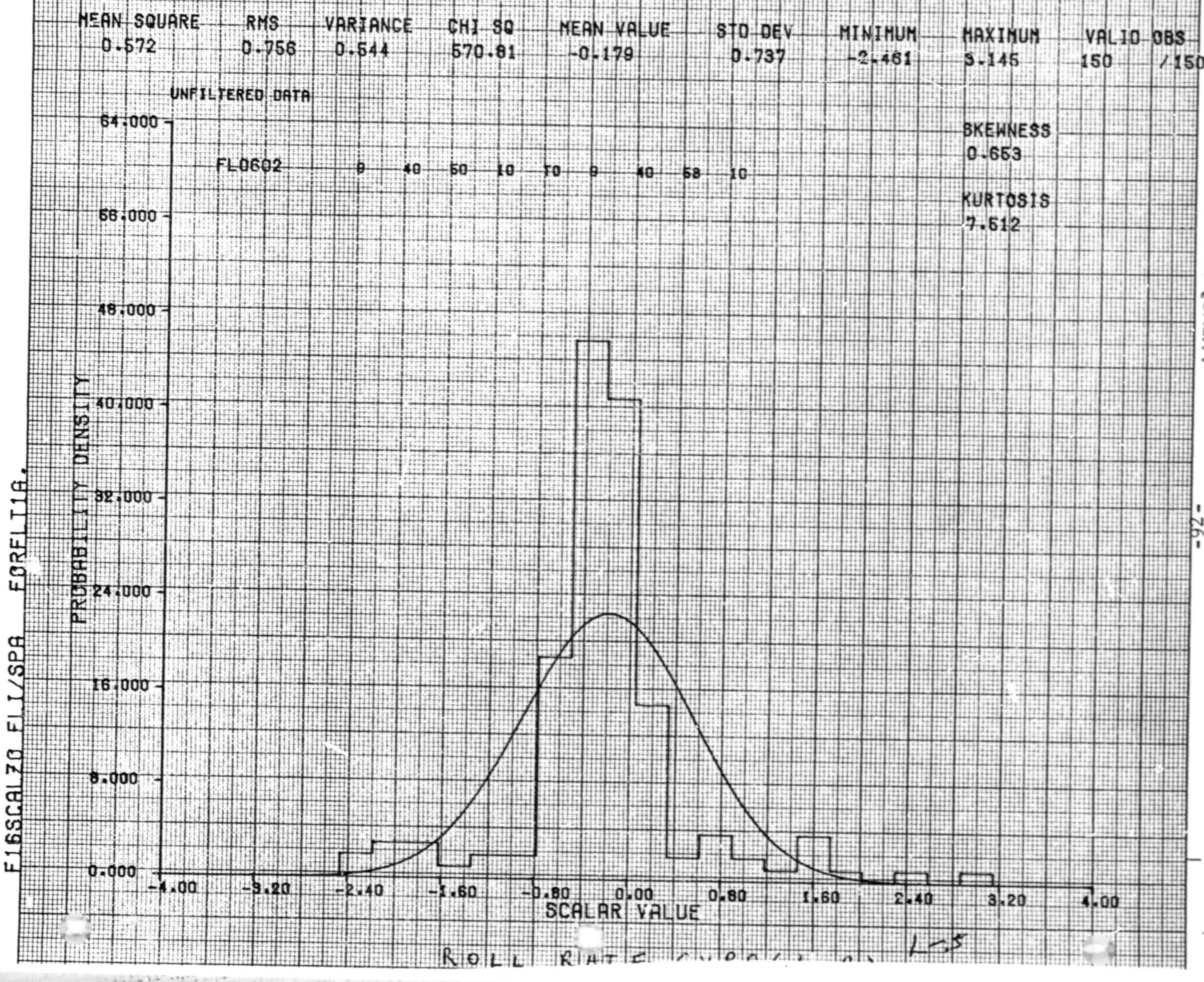


CURVE KEY
.995 = . .996 = - .997 = , .998 = + .999 = *

R

*Time 9-49-50-10 to 9-40-53-10




MEAN SQUARE 0.572
RMS 0.756
VARIANCE 0.544
CHI SQ 570.81
MEAN VALUE -0.179
STD DEV 0.737
MINIMUM -2.461
MAXIMUM 3.145
VALID OBS 150 /150
UNFILTERED DATA
FL0602 9 40 50 10 70 9 40 58 10
SKEWNESS 0.653
KURTOSIS 7.612
PROBABILITY DENSITY
64.000
56.000
48.000
40.000
32.000
24.000
16.000
8.000
0.000
-4.00 -3.20 -2.40 -1.60 -0.80 0.00 0.80 1.60 2.40 3.20 4.00
SCALAR VALUE
F16SCALZ0 FLI/SPA FØRFLT1A.

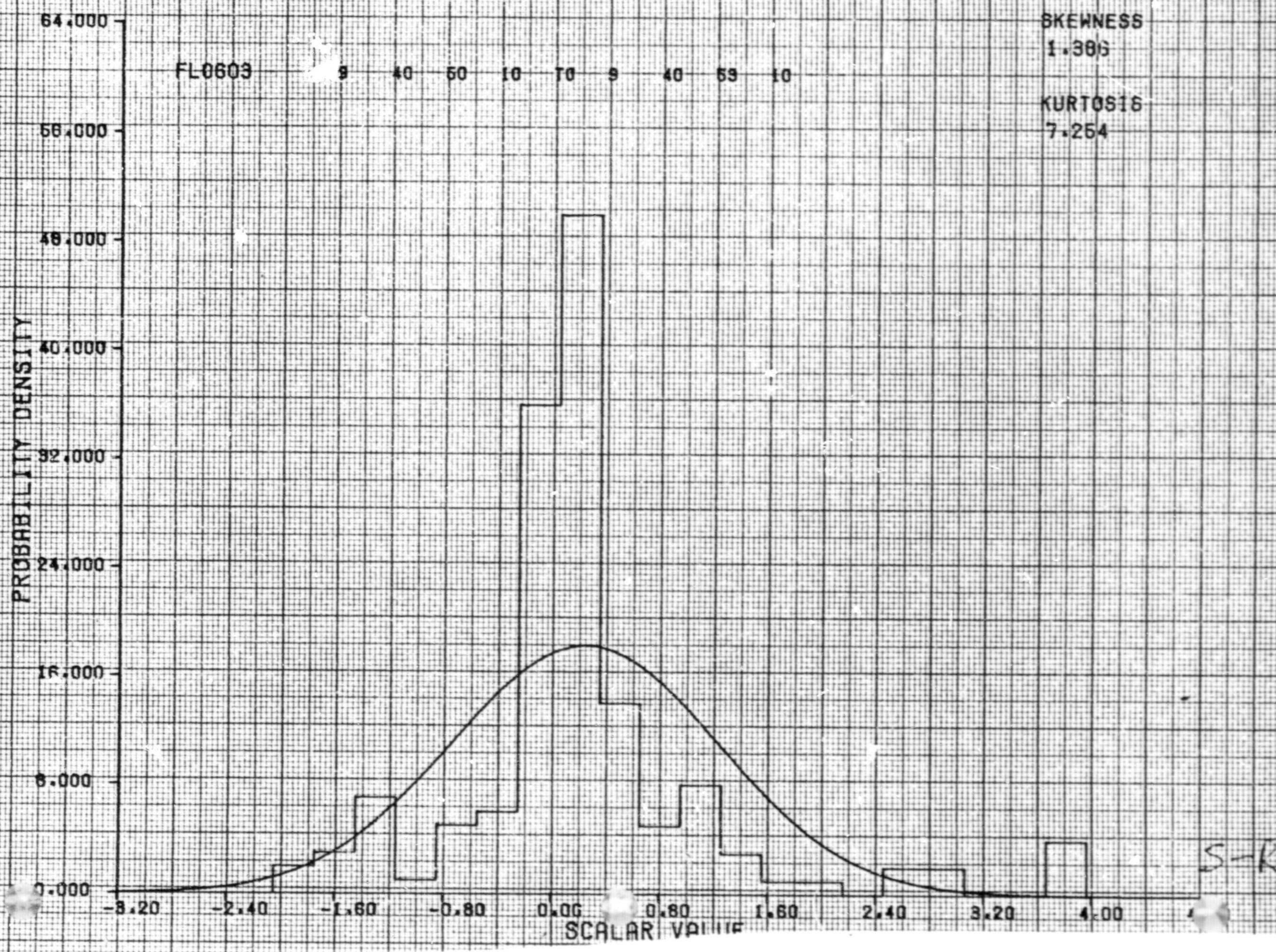
MEAN SQUARE	RMS	VARIANCE	CHI SQ	MEAN VALUE	STD DEV	MINIMUM	MAXIMUM	VALID OBS
1.022	1.011	0.967	704.80	0.248	0.983	-2.051	3.965	150 /150

UNFILTERED DATA

SKEWNESS
1.386

KURTOSIS
7.254

FL0603 9 40 50 10 T0 9 40 59 10



F16SCAL70 FLI/SPA FORFLT1A.

Roll Rate Gyro
... data..

AFTIF16 FLT1A

	L-S	L-R	S-R
1	.13672	.54688	.41016
2	0	0	0
3	-2.8711	-.13672	2.7344
4	-.54687	0	.54687
5	1.9141	1.6406	-.27344
6	-1.7773	.27344	2.0508
7	-.27344	-.41016	-.13672
8	.68359	-.41016	-1.0937
9	1.5039	1.7773	.27344
10	-.82031	-.54687	.27344
11	.82031	1.6406	.82031
12	1.0938	-1.9141	-3.0078
13	.13672	.41016	.27344
14	1.3672	1.5039	.13672
1[illegible]	.41016	-.13672	-.54687
16	-4.2383	-.27344	3.9648
17	.54687	-.13672	-.68359
18	-.68359	-.41016	.27344

Sensor Redundancy Management
Report of Probability Density Function, C(DF)
Reliability (R), Probability of False Alarm, P(AF/DF)
For the Sensor Value in the Domain of Failure

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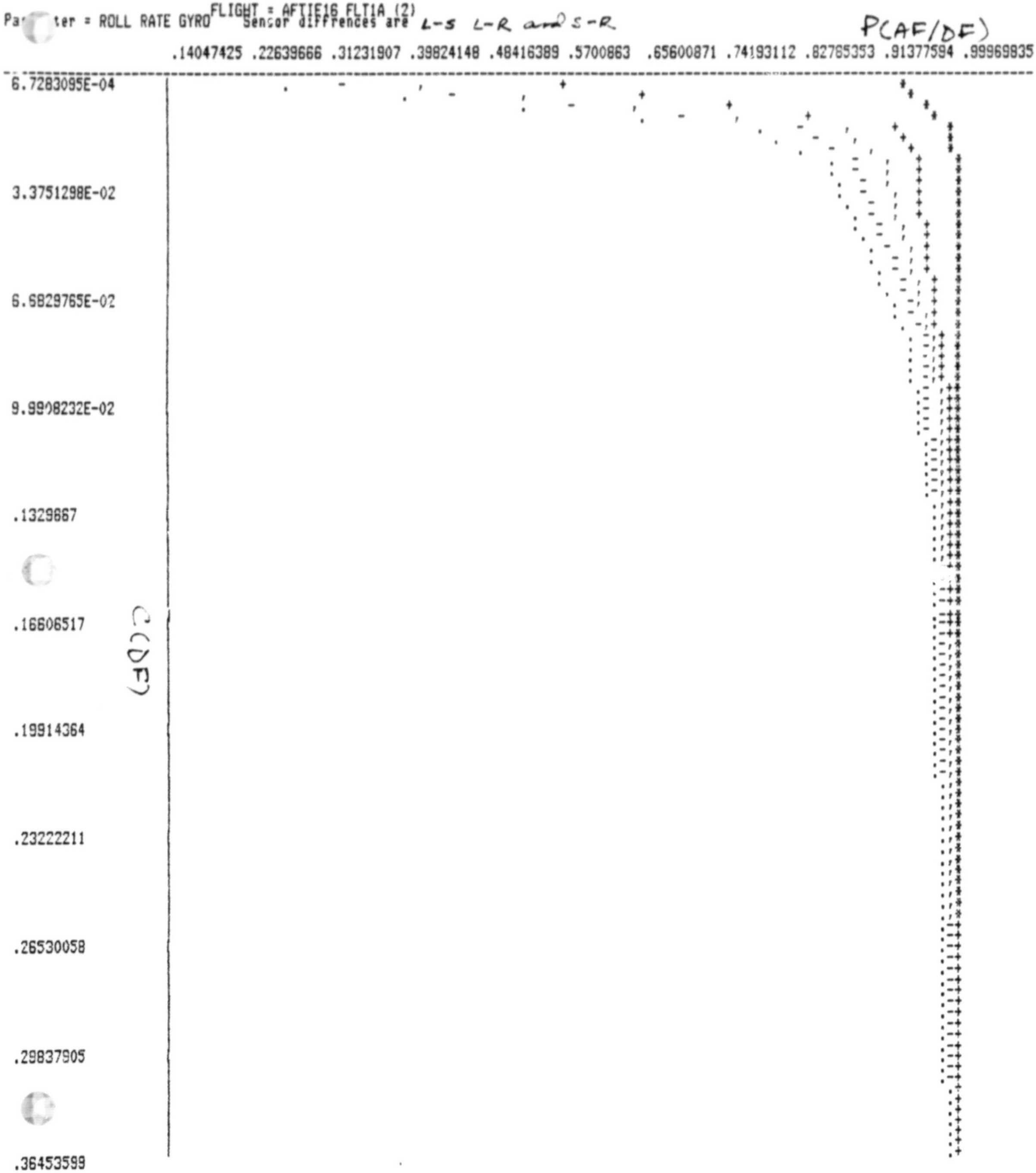
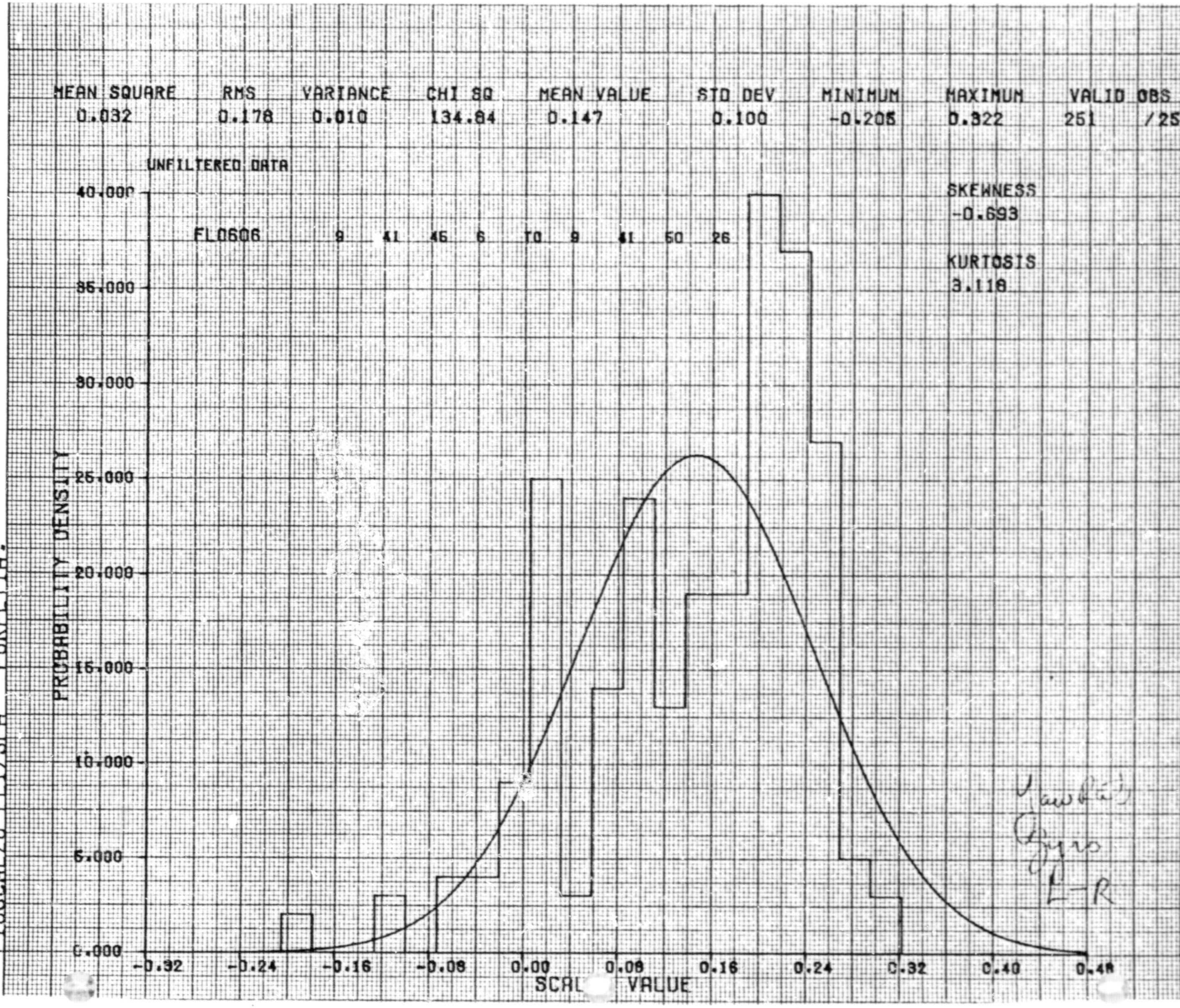
FLIGHT = AFTIF16 FLT1A (2)
Parameter = ROLL RATE GYRO Sensor diffrences are L-S L-R and S-R



CURVE KEY
.995 = . .996 = - .997 = , .998 = + .999 = *

R



+ Time 9-41-45-6 TO 9-41-50-26

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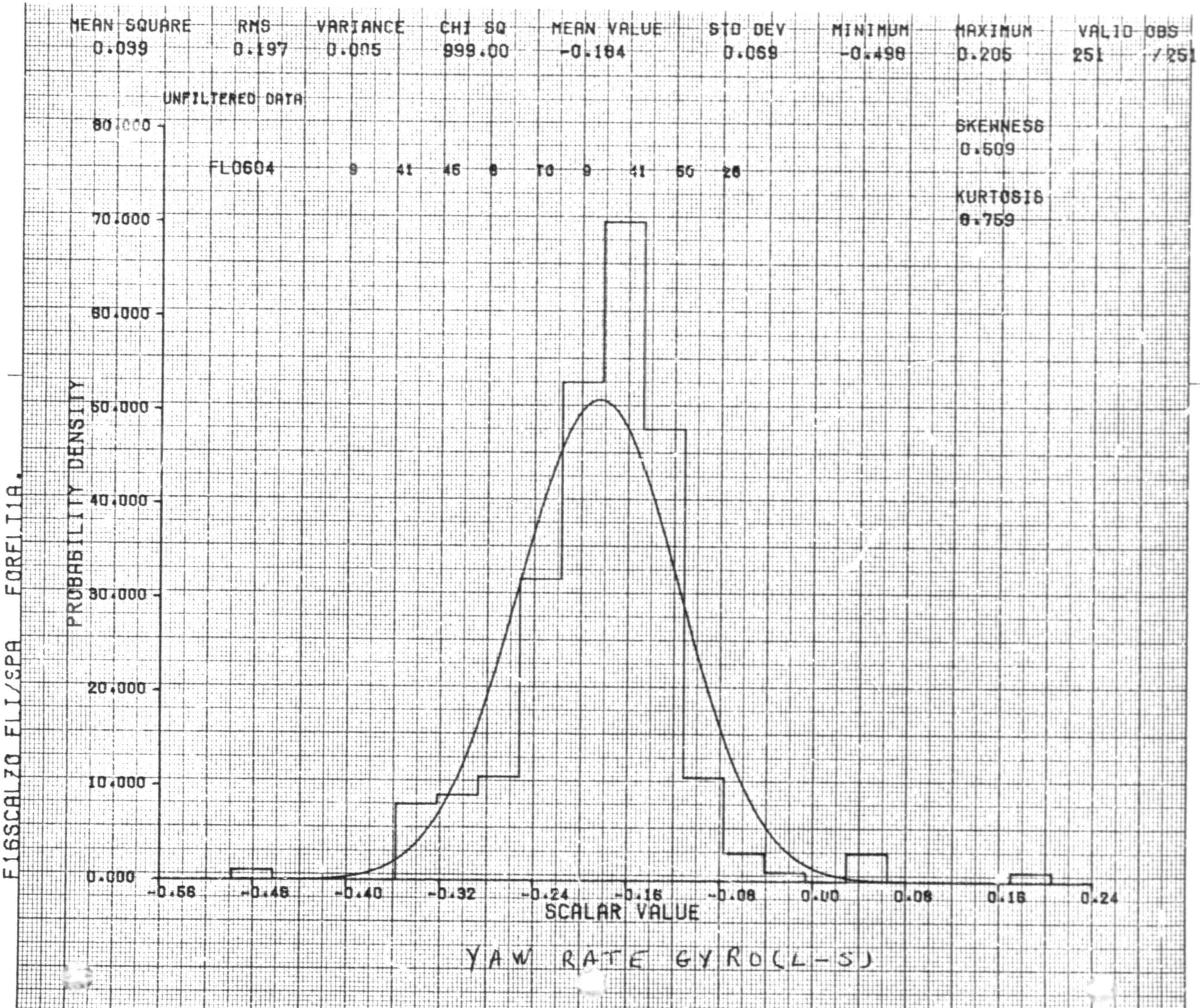
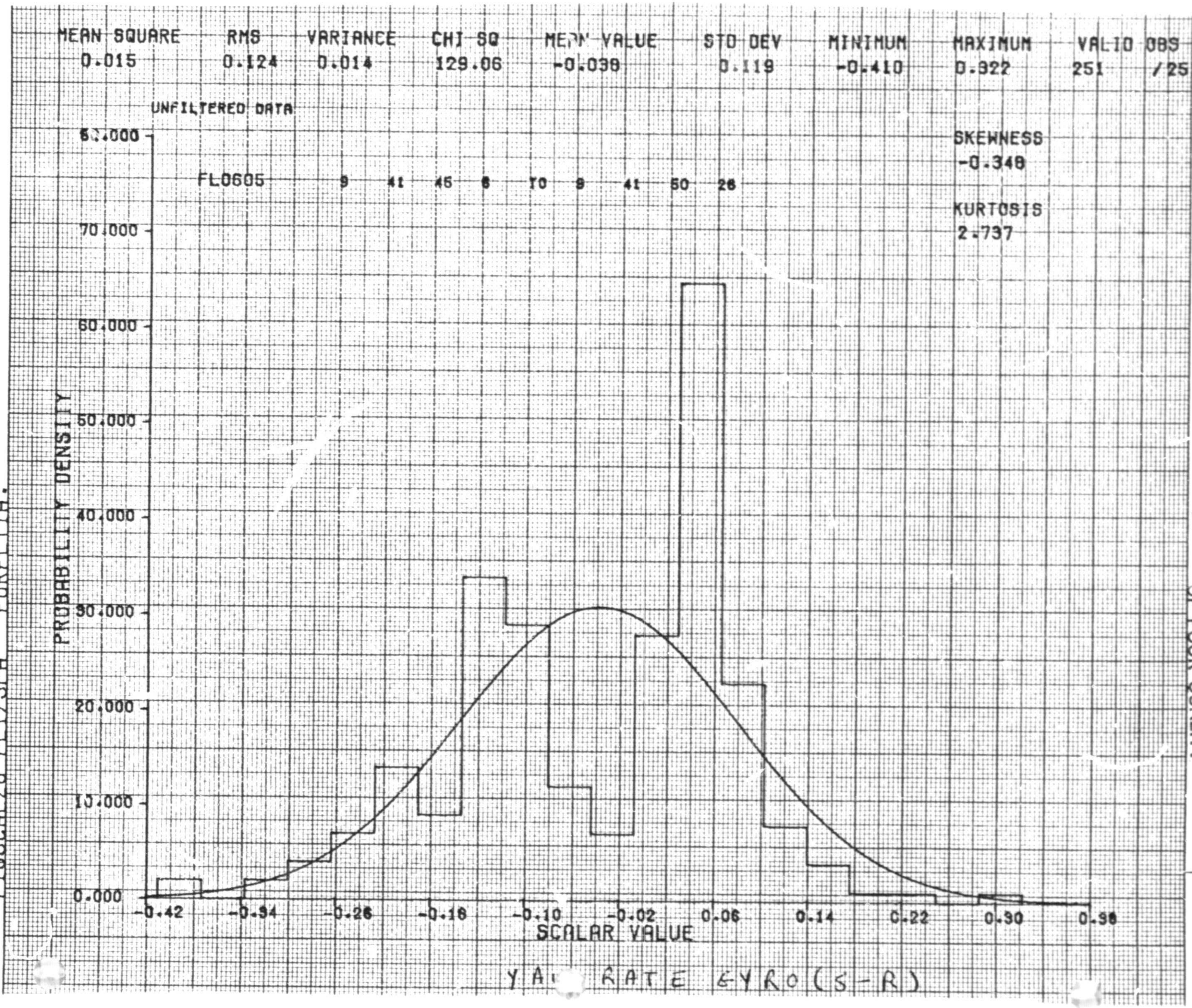

MEAN SQUARE 0.039
RMS 0.197
VARIANCE 0.005
CHI SQ 999.00
MEAN VALUE -0.184
STD DEV 0.069
MINIMUM -0.498
MAXIMUM 0.205
VALID OBS 251 / 251
UNFILTERED DATA
FL0604
9 41 46 8 70 9 41 50 28
SKEWNESS 0.509
KURTOSIS 0.759
PROBABILITY DENSITY
80.000
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0.000
-0.56 -0.48 -0.40 -0.32 -0.24 -0.16 -0.08 0.00 0.08 0.16 0.24
SCALAR VALUE
YAW RATE GYRO(L-S)
F16SCALZ0 FLT/SPA FOREL11A.
C-2


MEAN SQUARE 0.015
RMS 0.124
VARIANCE 0.014
CHI SQ 129.06
MEAN VALUE -0.038
STD DEV 0.119
MINIMUM -0.410
MAXIMUM 0.322
VALID OBS 251 /251
UNFILTERED DATA
FL0605
9 41 45 6 70 9 41 50 26
SKEWNESS -0.348
KURTOSIS 2.737
PROBABILITY DENSITY
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0.000
-0.42 -0.34 -0.26 -0.18 -0.10 -0.02 0.06 0.14 0.22 0.30 0.38
SCALAR VALUE
YAW RATE GYRO (S-R)
FIGSCAL70 FLI/SPA FOREL T1A.

Yaw Rate Gyro
sample data

AFTIF16 FLT1A

	L-S	L-R	S-R
1	-.11719	.058594	.17578
2	-.20508	.058593	.26367
3	-.17578	0	.17578
4	-.087891	.11719	.20508
5	-.14648	.058594	.0508
6	-.05894	.058593	.11719
7	-.26367	-.23437	.029297
8	-.23437	-.14648	.087891
9	-.49805	-.41016	.08789
	-.08789	-.08789	0
11	-.29297	-.14648	.14648
12	-.32226	-.08789	.23437
13	.029297	.23437	.20508
14	-.32226	-.11719	.20508

Sensor Redundancy Management
Report of Probability Density Function, C(DF)
Reliability & Probability of False Alarm P(AF/DF)
For the Sensor Value in the Domain of Failure

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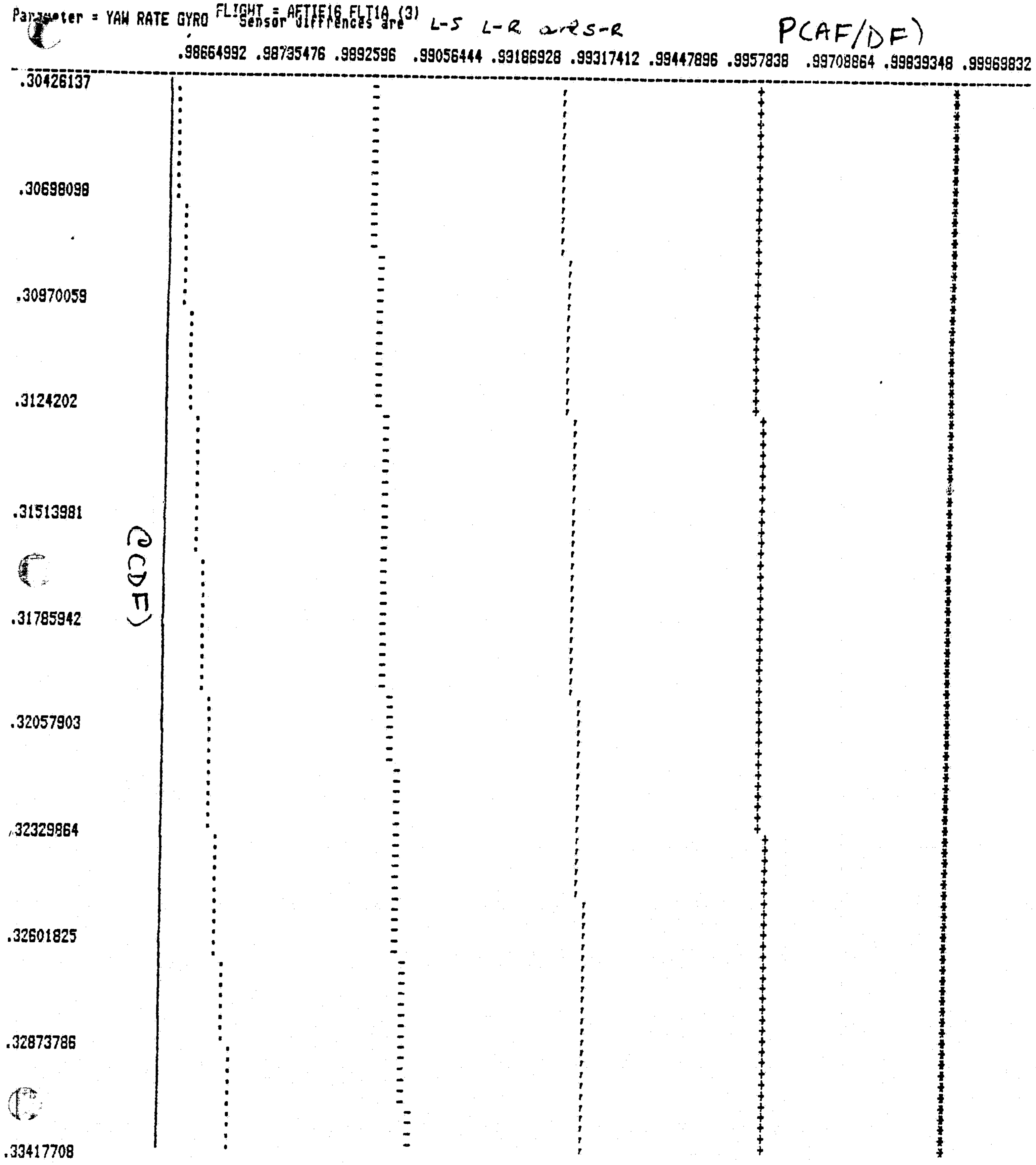
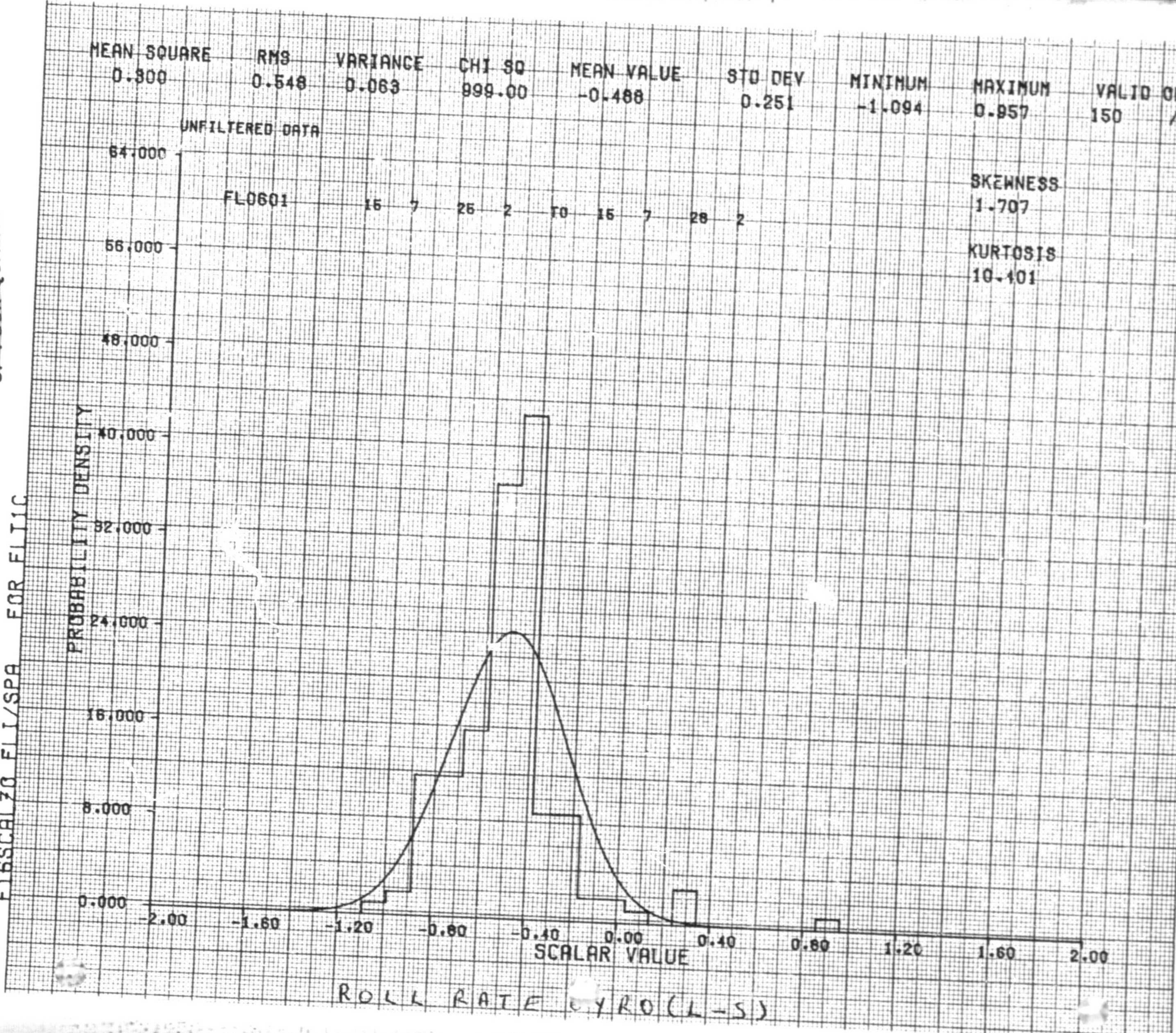
Parameter = YAW RATE GYRO FLIGHT = AFTIF16 FLT1A (3)
Sensor diffrences are L-S L-R and S-R



CURVE KEY
.995 = .   .996 = -   .997 = ,   .998 = +   .999 = *

R



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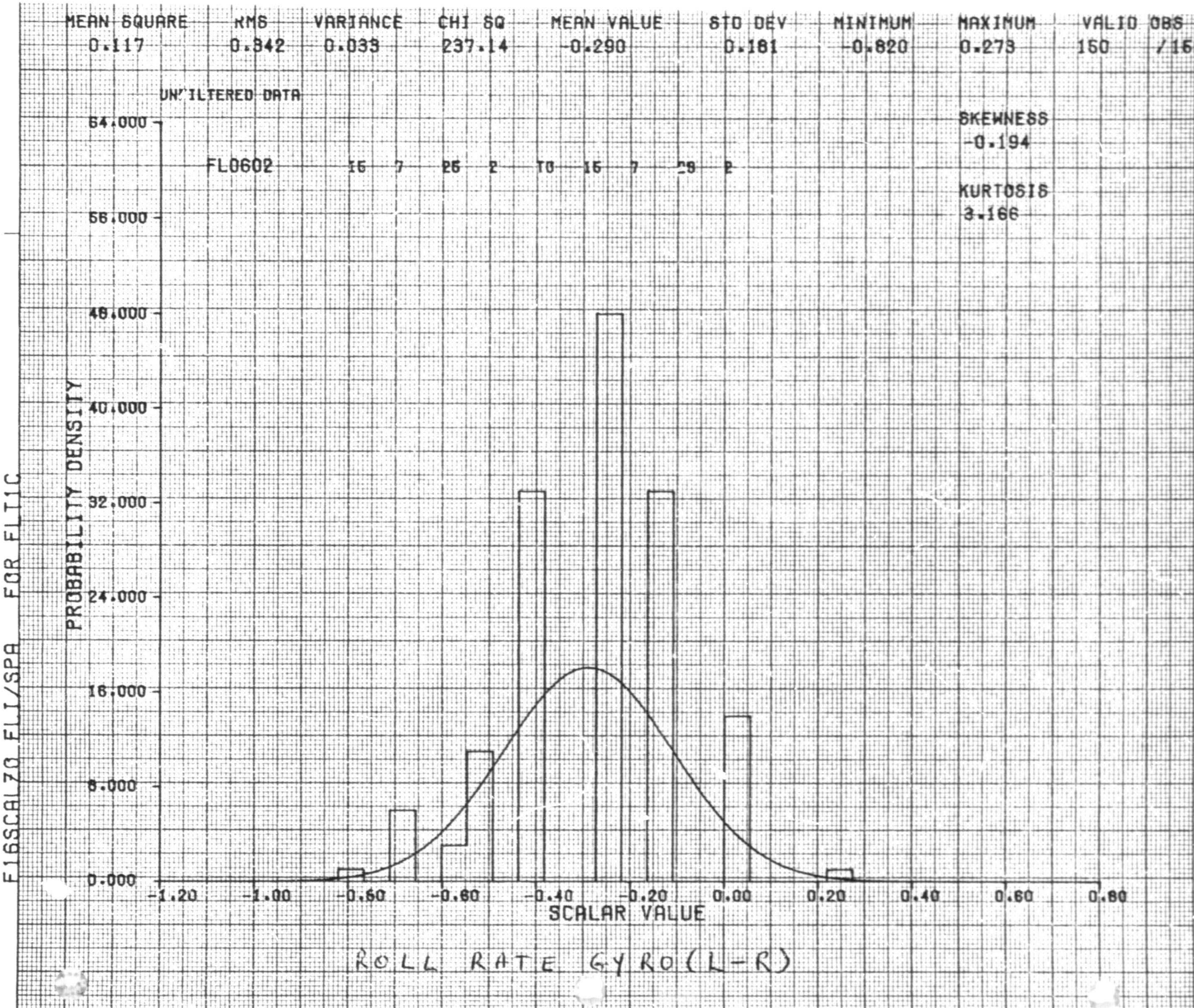
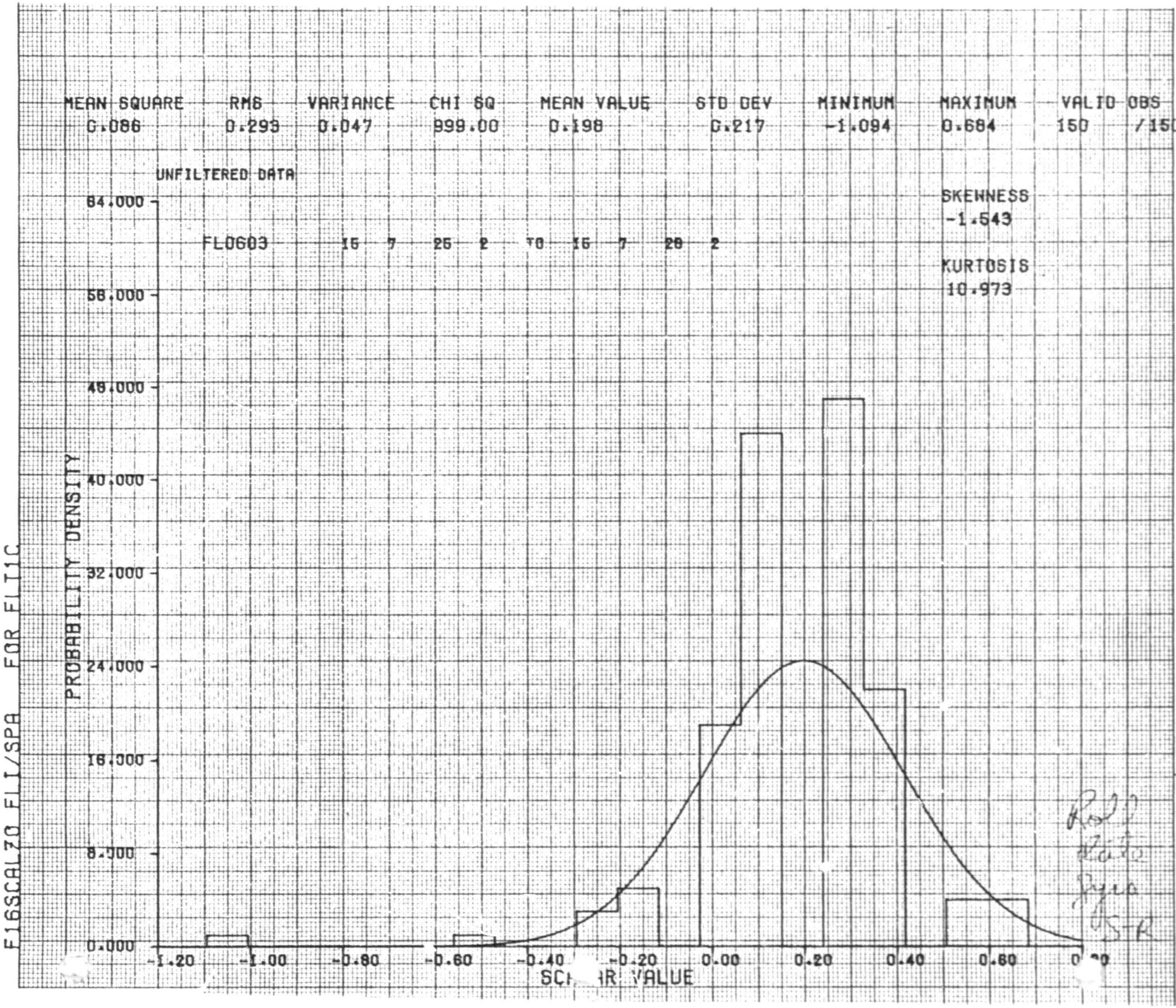
* Time 15-7-25-2 TO 15-7-28-2


MEAN SQUARE 0.117
RMS 0.342
VARIANCE 0.033
CHI SQ 237.14
MEAN VALUE -0.290
STD DEV 0.181
MINIMUM -0.820
MAXIMUM 0.273
VALID OBS 150 /150
UNFILTERED DATA
SKEWNESS -0.194
KURTOSIS 3.166
FL0602 15 7 25 2 10 15 7 29 2
PROBABILITY DENSITY
64.000
56.000
48.000
40.000
32.000
24.000
16.000
8.000
0.000
-1.20 -1.00 -0.80 -0.60 -0.40 -0.20 0.00 0.20 0.40 0.60 0.80
SCALAR VALUE
F16SCALZ0 FLI/SPA FOR FL11C
ROLL RATE GYRO (L-R)


MEAN SQUARE 0.086
RMS 0.293
VARIANCE 0.047
CHI SQ 999.00
MEAN VALUE 0.198
STD DEV 0.217
MINIMUM -1.094
MAXIMUM 0.684
VALID OBS 150 /150
UNFILTERED DATA
SKEWNESS -1.543
KURTOSIS 10.973
FL0603 15 7 25 2 70 15 7 28 2
PROBABILITY DENSITY
84.000
56.000
48.000
40.000
32.000
24.000
16.000
8.000
0.000
-1.20 -1.00 -0.80 -0.60 -0.40 -0.20 0.00 0.20 0.40 0.60
VALUE
F16SCAL70 FLI/SPA FOR FLI1C

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Roll Rate Gyro
Sample data.

AFTIFIG FLT1C

	L-S	L-R	S-R
1	-.54687	-.41016	.3672
2	-.82031	-.54687	.27433
3	-.41016	-.27344	.13672
4	.27344	0	-.27344
5	.95703	-.13672	-1.0937
6	-.68359	-.41016	.27344
7	-1.0937	-.41016	.68359
8	-.27344	-.13672	.13672
9	-.41016	-.41016	0
10	-.13672	-.13672	0
11	-.82031	-.27344	.54688
12	-.68359	-.13672	.54688
13	-1.2305	-.82031	.41016
14	0	0	0
15	-.13672	-.41016	-.27344

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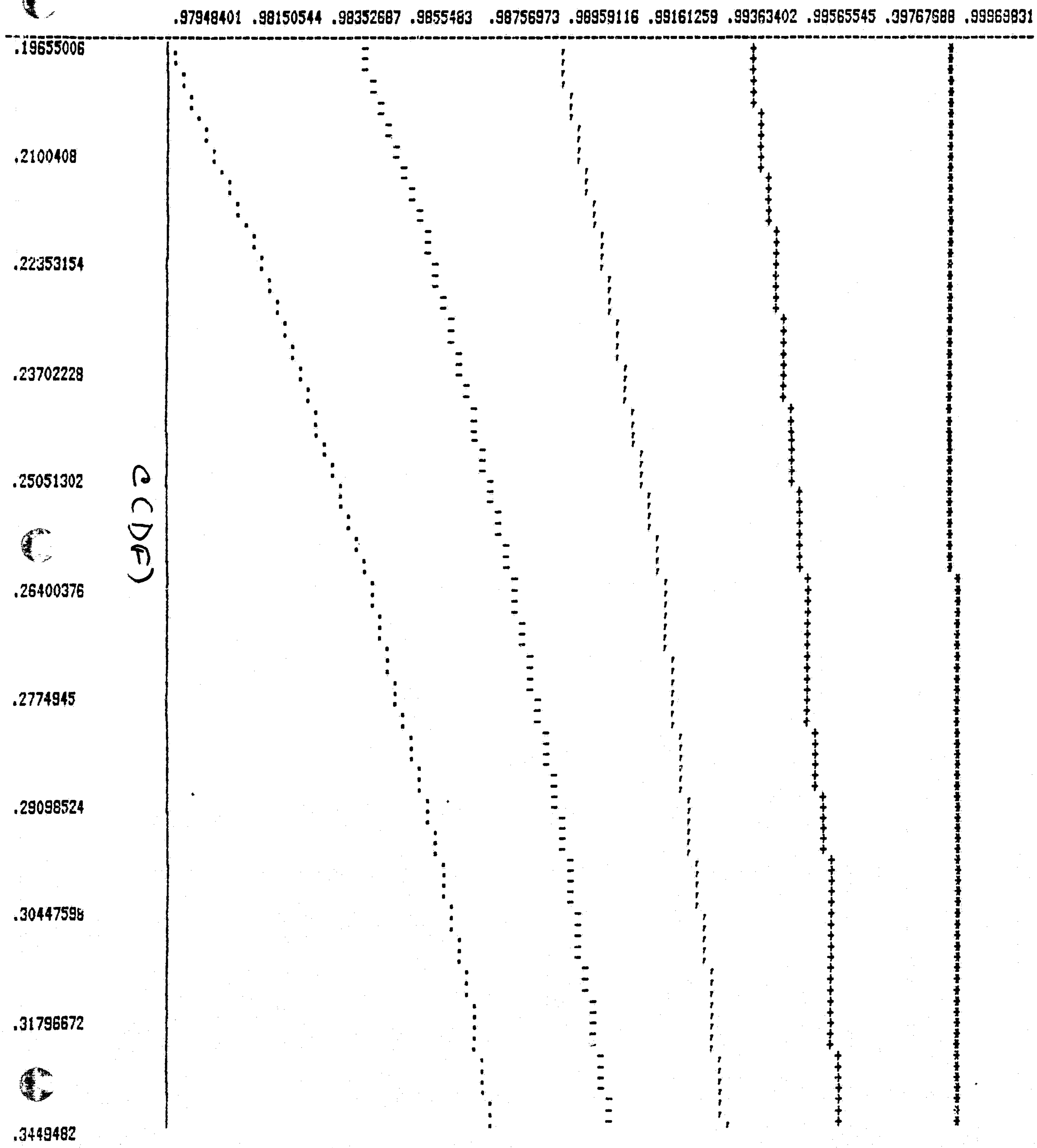
Sensor Redundancy Management
Report of Probability Density Function, C(DF)
Reliability(R) Probability of False Alarm P(AF/DF)
For the Sensor Value in the Domain of Failure

FLIGHT = AFTIFI6 FLTIC (2)
Parameter = ROLL RATE GYRO Sensor diffrences are L-S L-R and S-R

P(AF/DF)

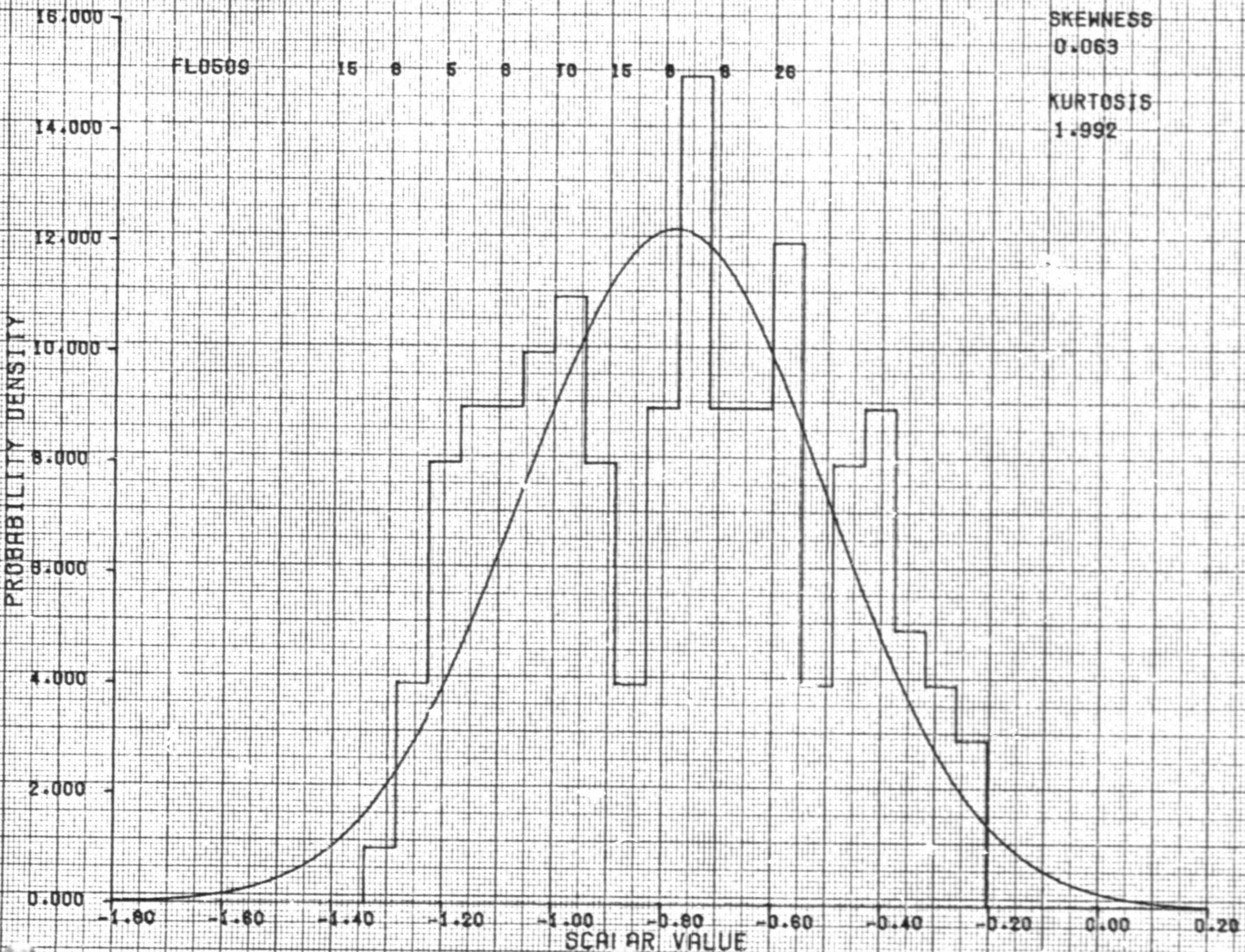


CURVE KEY
.995 = .   .996 = -   .997 = ,   .998 = +   .999 = *

R

MEAN SQUARE	RMS	VARIANCE	CHI SQ*	MEAN VALUE	STD DEV	MINIMUM	MAXIMUM	VALID OBS
0.686	0.828	0.078	25.84	-0.780	0.279	-1.340	-0.205	151 /151

UNFILTERED DATA



ANGLE OF ATTACK (L-5)

15-8-5-6 TO 15-8-8-26

* Time 15-8-5-6 TO 15-8-8-26

F16SCAL20 FLT/SPA FOR FLT1C

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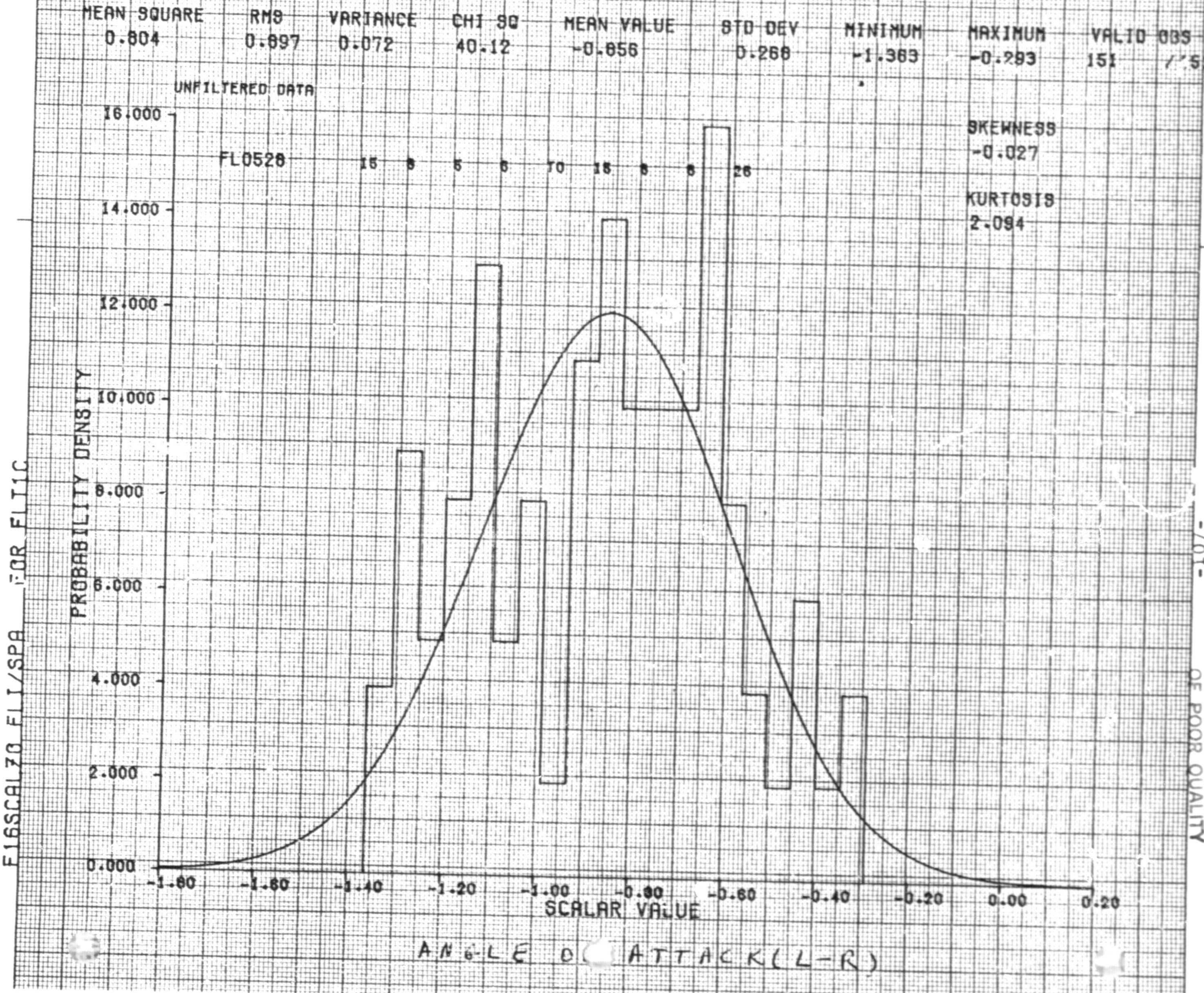
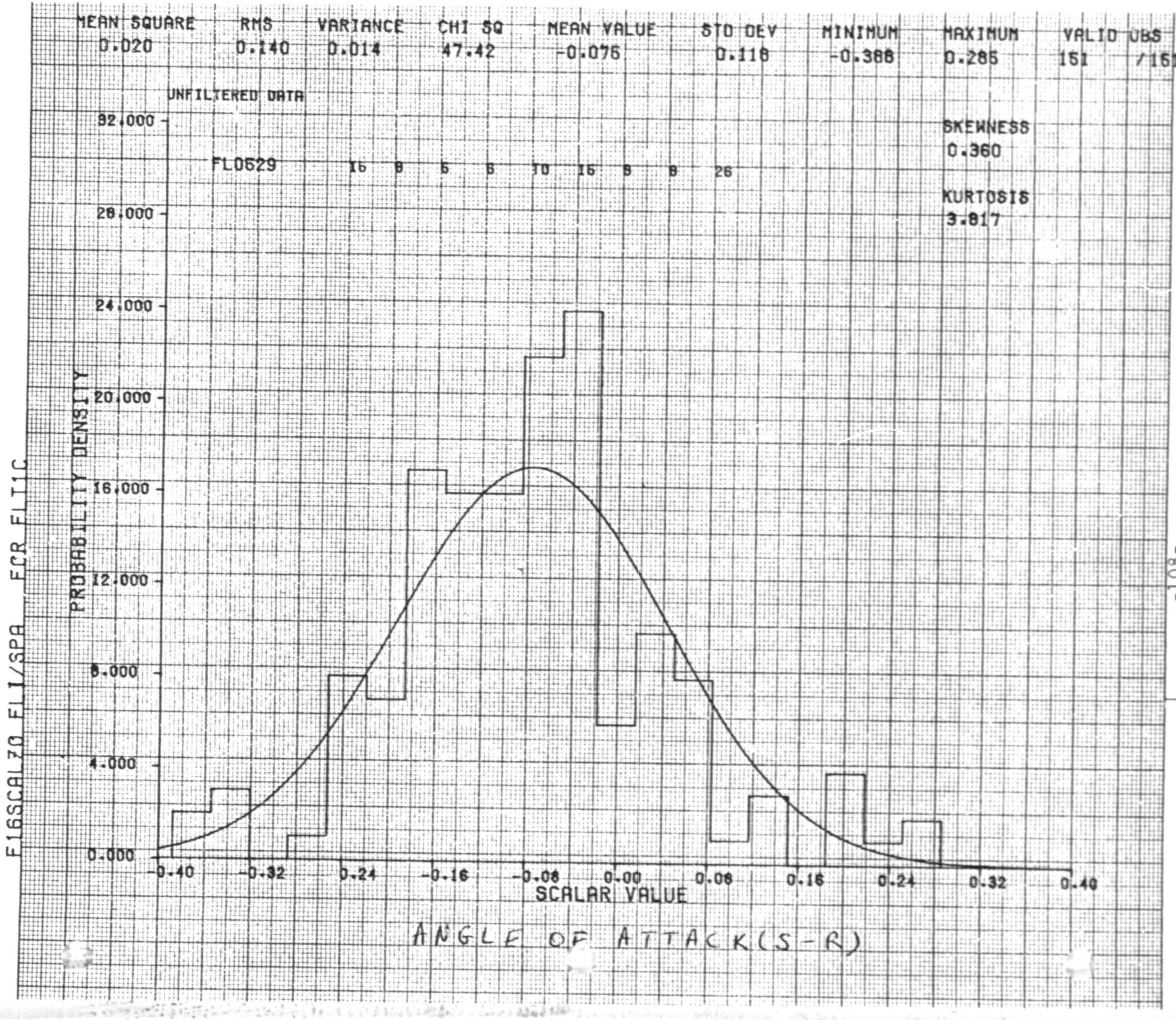


F16SCALZ0 FLI/SPA FOR FLT1C


MEAN SQUARE 0.020
RMS 0.140
VARIANCE 0.014
CHI SQ 47.42
MEAN VALUE -0.076
STD DEV 0.118
MINIMUM -0.388
MAXIMUM 0.285
VALID OBS 151 /151
UNFILTERED DATA
SKEWNESS 0.360
KURTOSIS 3.817
FL0529
16 8 5 8 10 16 8 8 26
PROBABILITY DENSITY
32.000
28.000
24.000
20.000
16.000
12.000
8.000
4.000
0.000
-0.40 -0.32 -0.24 -0.16 -0.08 0.00 0.08 0.16 0.24 0.32 0.40
SCALAR VALUE
ANGLE OF ATTACK(S-R)
F16SCAL70 FL1/SPA FCR FLT1C

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OF POOR QUALITY

Angle of attack
sample data.

AFTIF16 FLT1C

	L-S	L-R	S-R
1	-.5661	-.43686	.12824
2	-.62592	-.57892	.046997
3	-.92286	-.86731	.055542
4	-1.1183	-1.1183	-.11002
5	-.8877	-.77439	.037384
6	-.6131	-.66864	-.055542
7	-.90577	-.92392	-.018158
8	-1.0008	-1.0286	-.027771
9	-1.1076	-1.1354	-.027771
10	-.90256	-.61737	.28519
11	-1.1749	-1.2486	-.0737
12	-.49133	-.6398	-.14847
13	-.77652	-.93354	-.15701
14	-.34073	-.48813	-.1474
15	-1.1813	-1.255	-.0737
16	-.88654	-.61884	.2681

Sensor Redundancy Management
Report of Probability Density Function, C(DF)
Reliability(R), Probability of False Alarm P(AF/DF)
For the Sensor Value in the Domain of Failure

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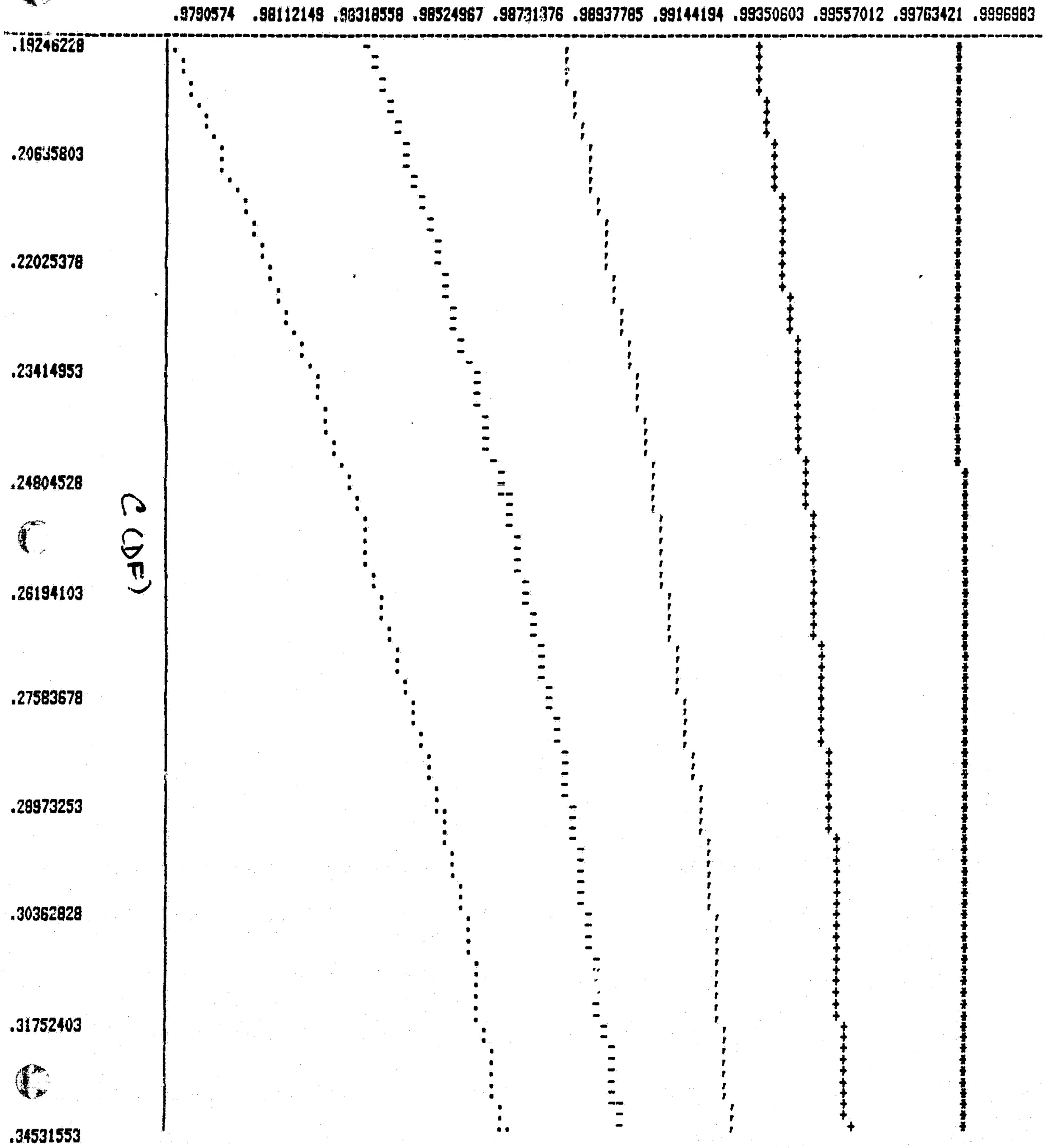
FLIGHT = AFTIF13 FLT1C (3)

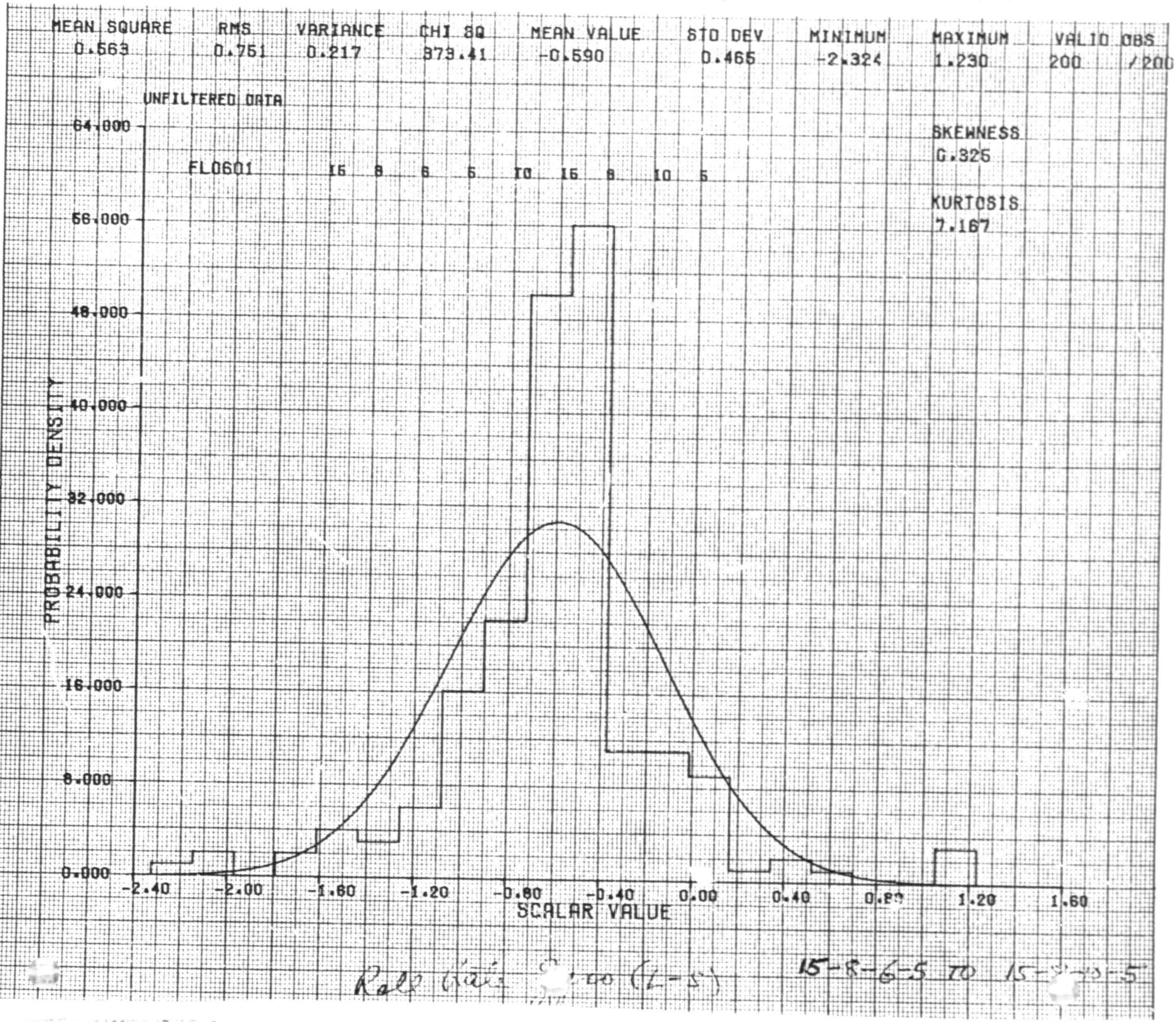
Pa[illegible]ter = ANGLE OF ATTACK Sensor diffrences are L-S L-R and S-R



CURVE KEY

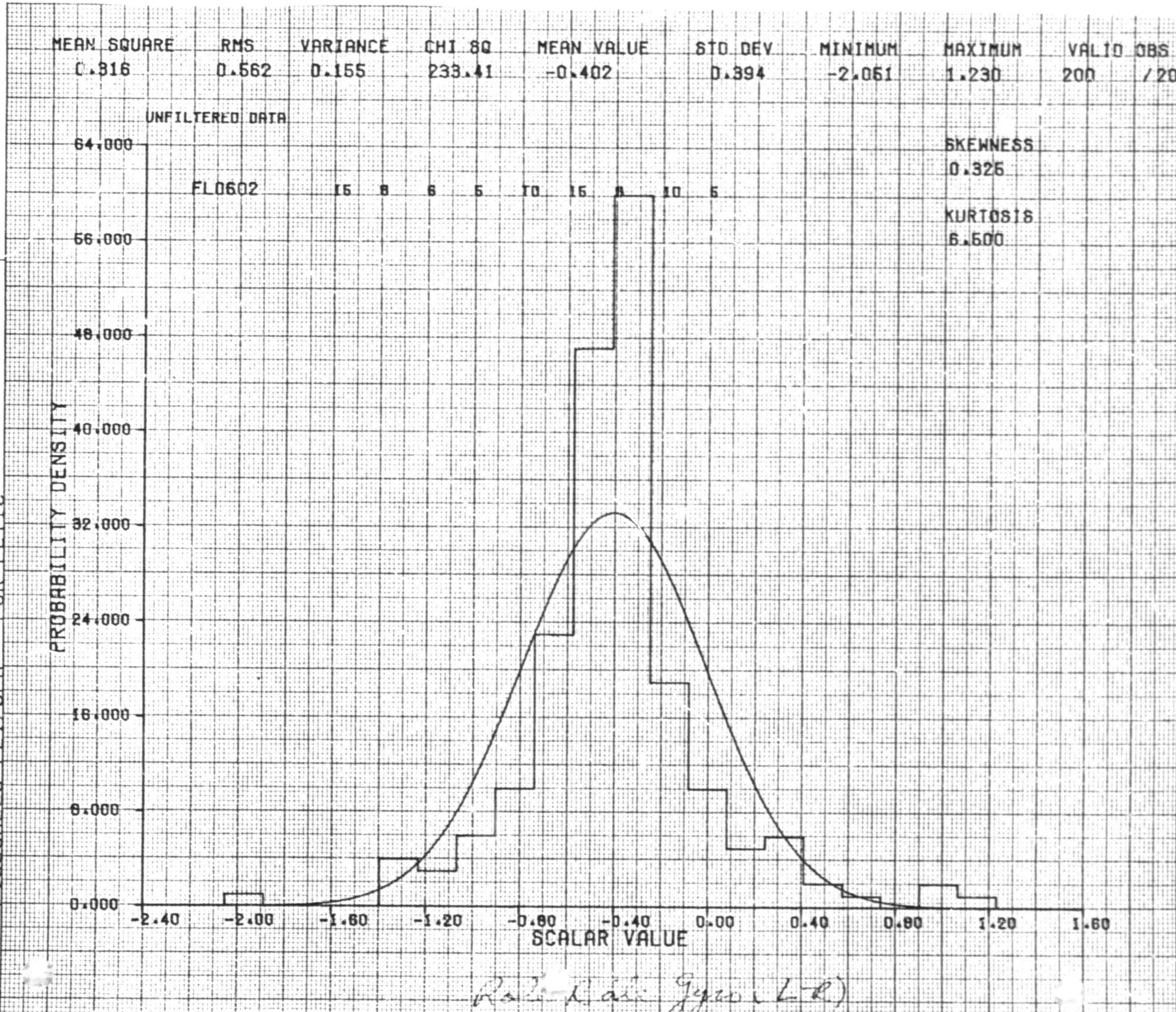
.995 = . .996 = - .997 = , .998 = + .999 = *

R

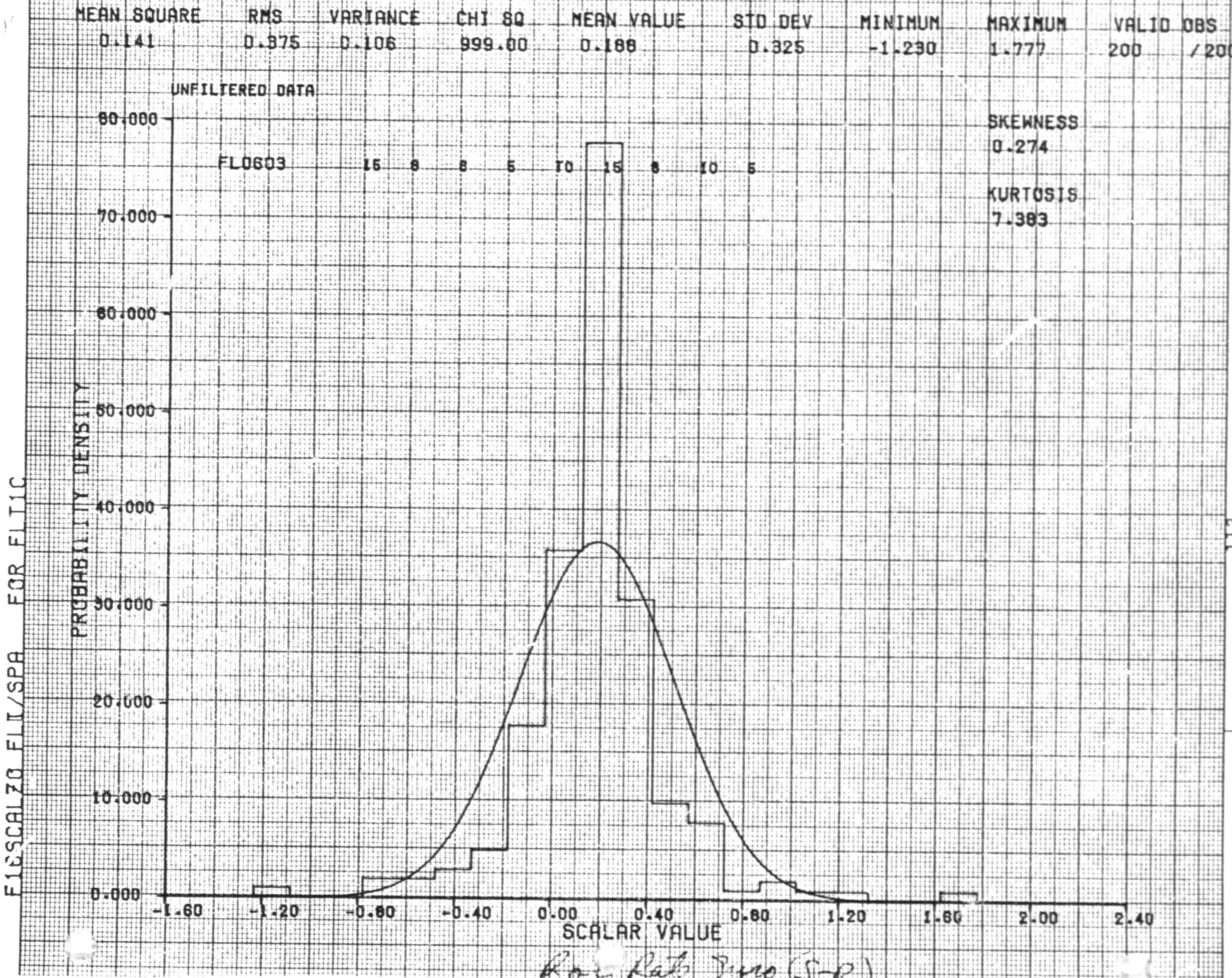


F16SCAL20 FL1/SPA FOR FL11C

* Time 15-8-6-5 TO 15-8-10-5



F16SCAL20 FL1/SPA FOR FL11C


MEAN SQUARE 0.141
RMS 0.375
VARIANCE 0.106
CHI SQ 999.00
MEAN VALUE 0.188
STD DEV 0.325
MINIMUM -1.230
MAXIMUM 1.777
VALID OBS 200 /200
UNFILTERED DATA
FL0603
15 8 8 5 10 15 8 10 5
SKEWNESS 0.274
KURTOSIS 7.383
PROBABILITY DENSITY
80.000
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0.000
-1.60 -1.20 -0.80 -0.40 0.00 0.40 0.80 1.20 1.60 2.00 2.40
SCALAR VALUE
F1ESCALZO FLI/SPA FOR FLI1C

Roll Rate gyro
sampled data.

AFTIF16 FLT1C

	L-S	L-R	S-R
1	1.2305	.95703	-.27344
2	-.13672	-.82031	-.68359
3	-.41016	-.27344	.13672
4	.54687	-.68359	-1.2305
5	-.68359	-.54687	.13672
6	-.13672	0	.13672
7	-.54687	-.41016	.13672
8	1.3672	1.2305	-.13672
9	-.82031	-.54687	.27344
10	1.5039	-1.2305	.27344
11	-.54687	-.41016	.13672
12	1.2305	1.2305	0
13	-.82031	-.95703	-.13672
14	-.95703	-.54687	.41016
15	1.2305	.95703	-.27344
16	-1.5039	-.82031	.68359
17	0	.27344	.27344
18	-.13672	.13672	.27344

Sensor Redundancy Management
Report of Probability Density Function, C(DF)
Reliability(R), Probability of False Alarm, P(AF/DF)
For the Sensor Value in the Domain of Failure

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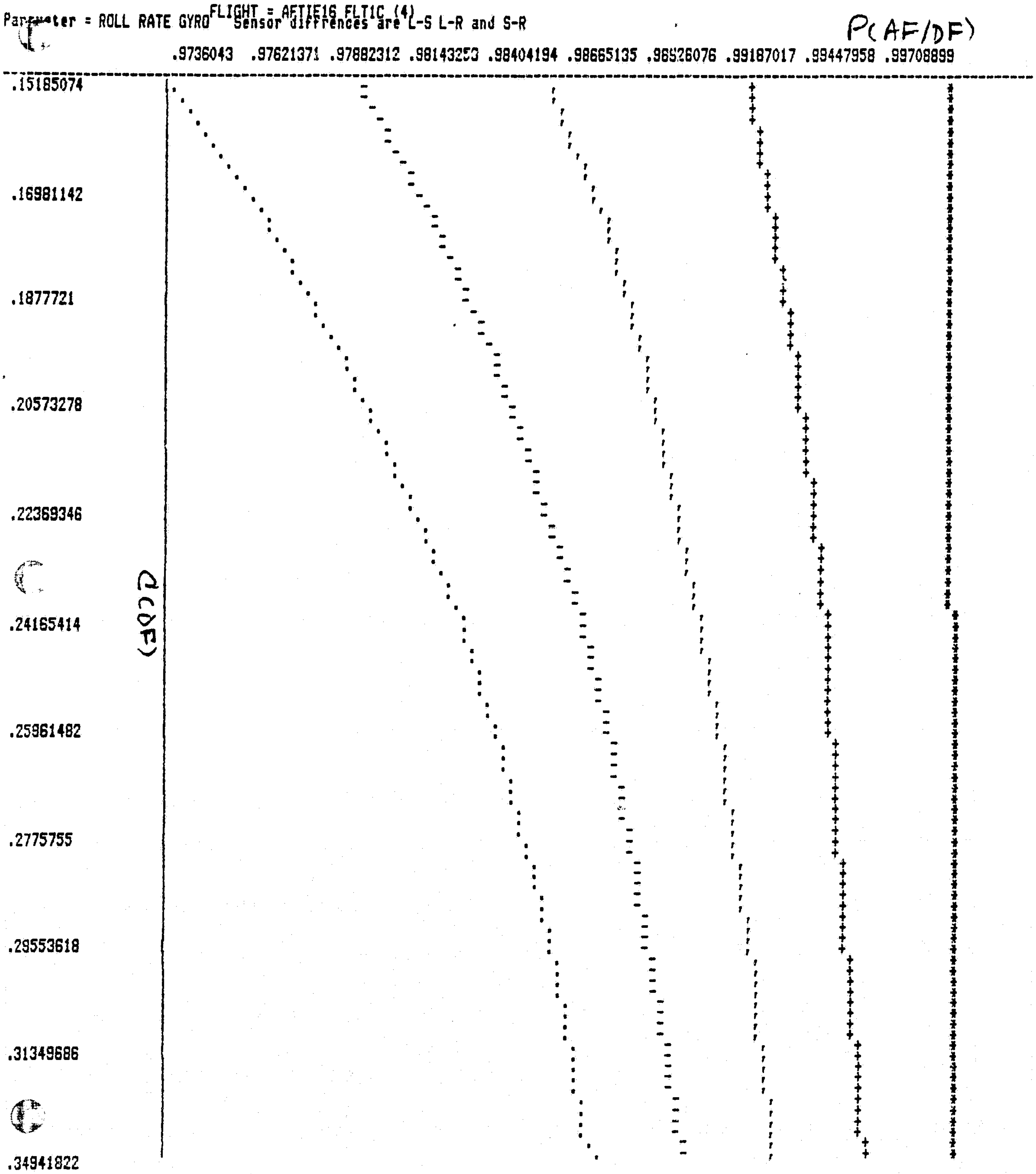
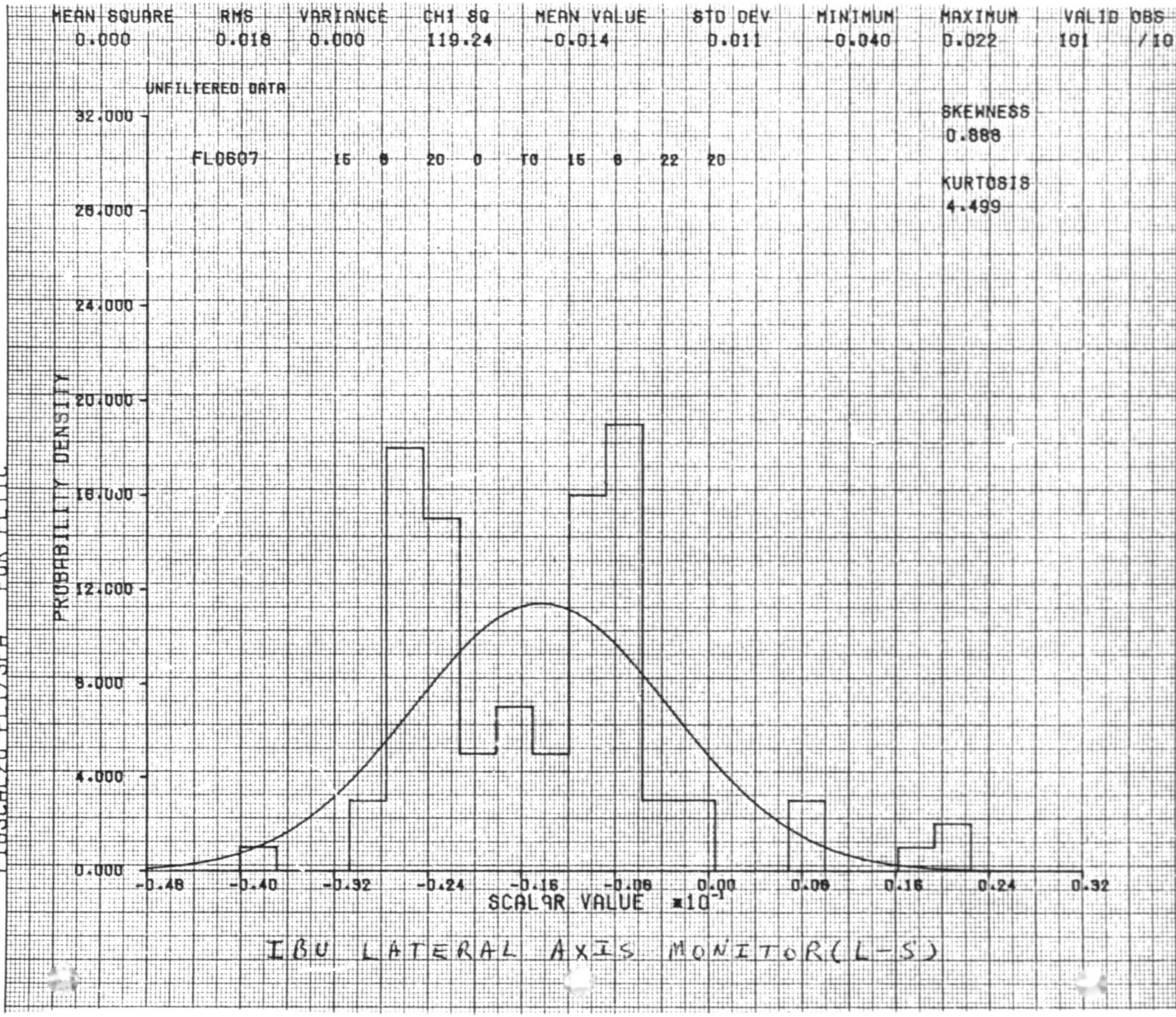
FLIGHT = AFTIF16 FLT1C (4)
Parameter = ROLL RATE GYRO Sensor diffrences are L-S L-R and S-R



CURVE KEY
.995 = .   .996 = -   .997 = ,   .998 = +   .999 = *

R



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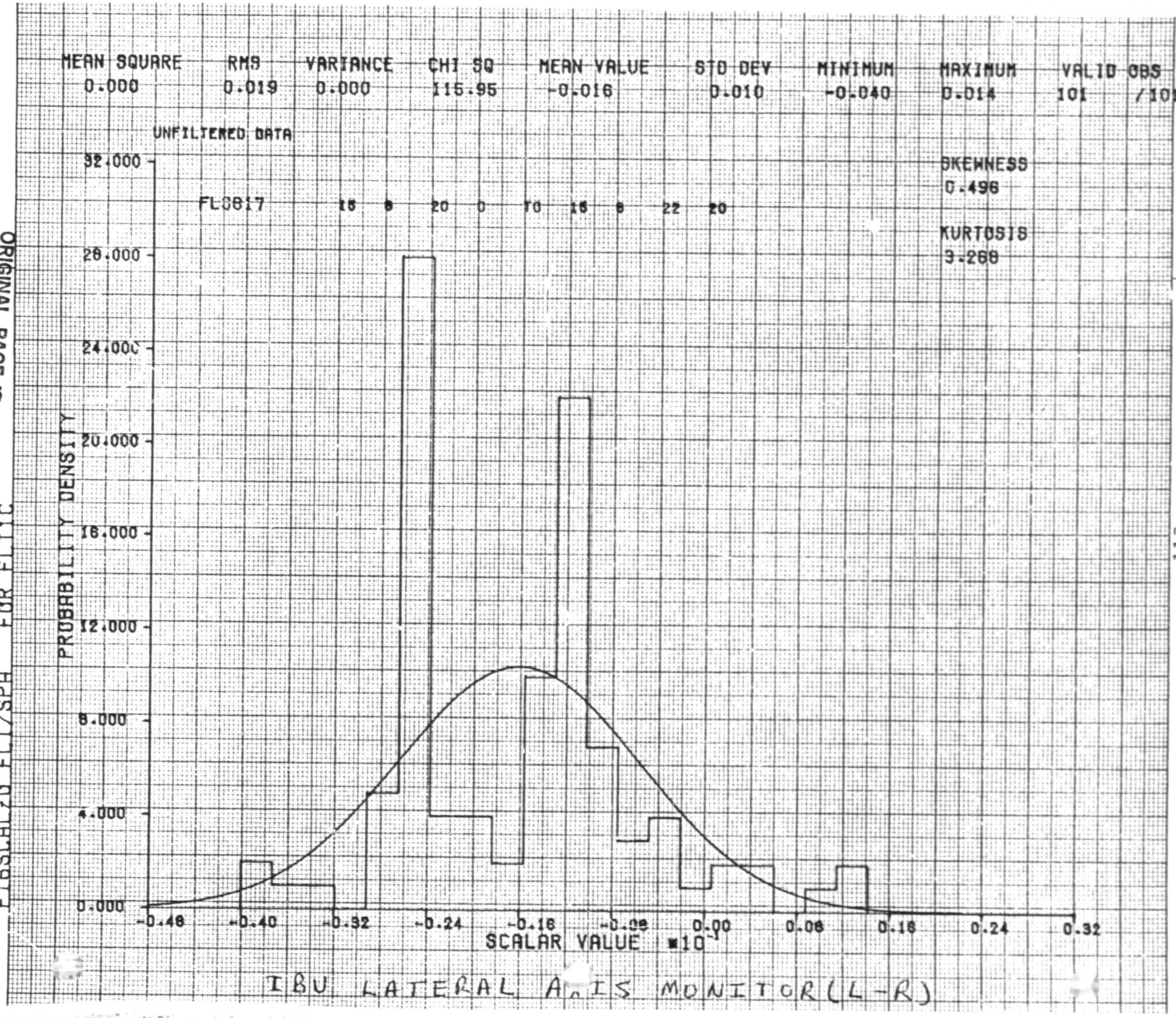
*Time 15-8-20-0 TO 15-8-23-20



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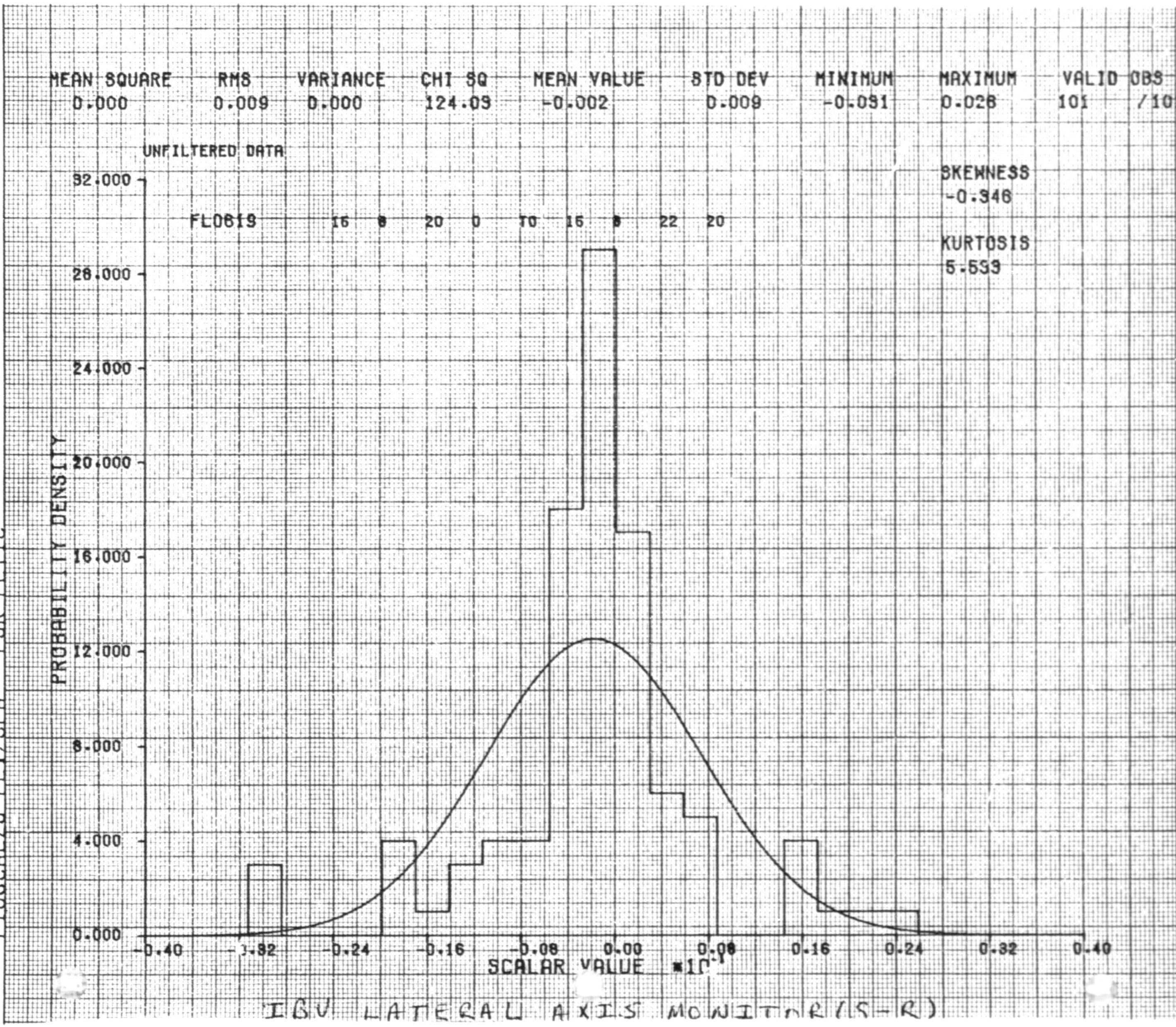

F16SCAL20 FL1/SPA FOR FL11C

I BU Lateral axis
Monitor sample data.

AFTIF16 FLT1C

	L-S	L-R	S-R
1	-.021973	-.020996	.00097656
2	-.02002	-.024414	-.0043945
3	-.04541	-.035645	.0097656
4	-.018555	-.023438	-.0048828
5	.012207	-.02002	-.032227
6	-.018066	-.018555	-.00048828
7	-.021484	-.018066	.003418
8	-.032227	-.021973	.010254
9	.0083008	.012207	.0039063
10	.0073242	-.010742	.018066
11	-.010742	-.012207	-.0014648
12	-.0097656	-.012207	-.0024414
13	-.0039063	-.011231	-.0073242
[illegible]	.0039063	-.0097657	-.013672
15	.00048828	-.01123	-.011719
16	-.0092773	-.010742	-.0014648

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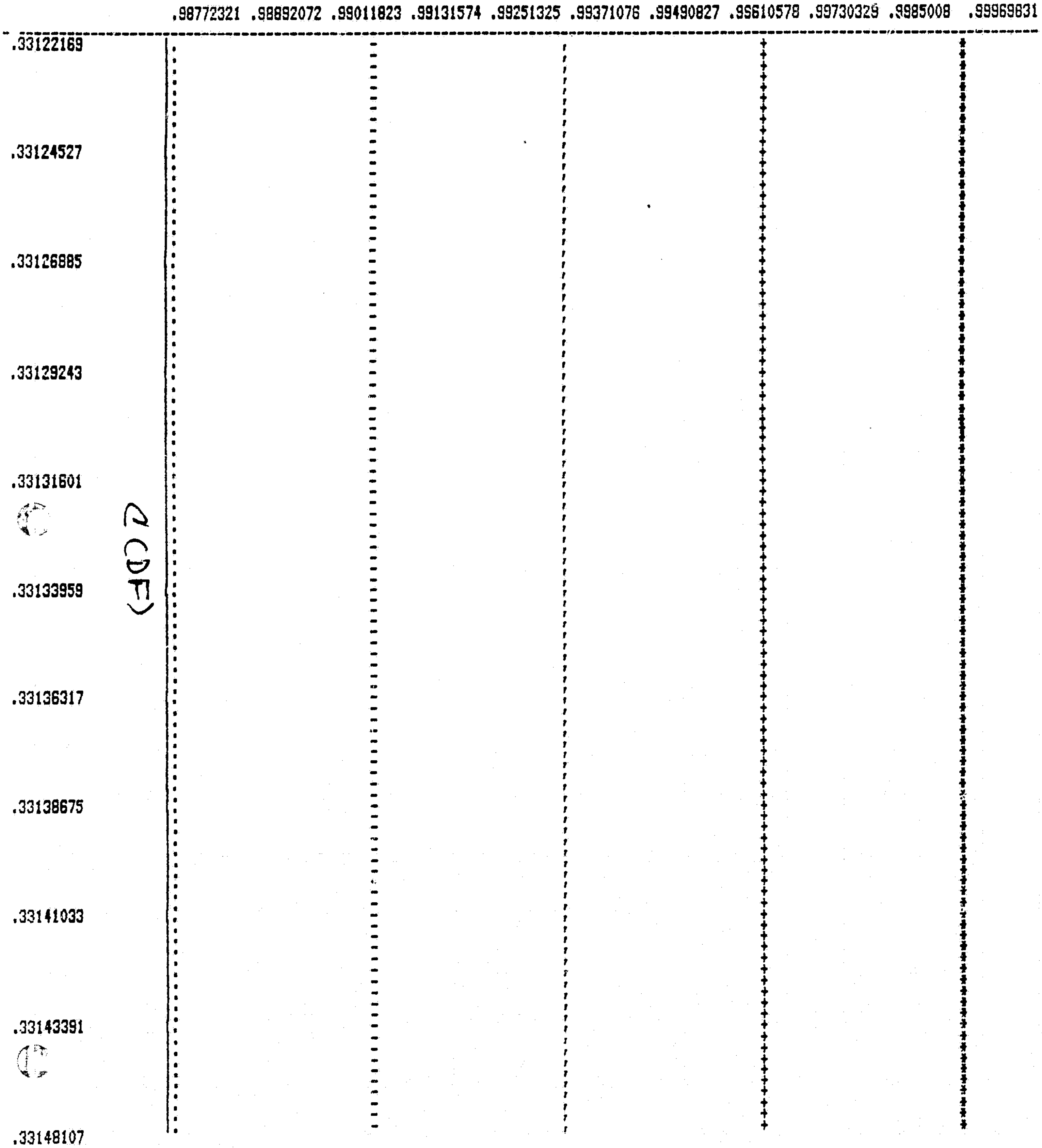
Sensor Redundancy Management
Report of Probability Density Function, C(DF)
Reliability vs Probability of False Alarm, P(AF/DF)
For the Sensor Value in the Domain of Failure

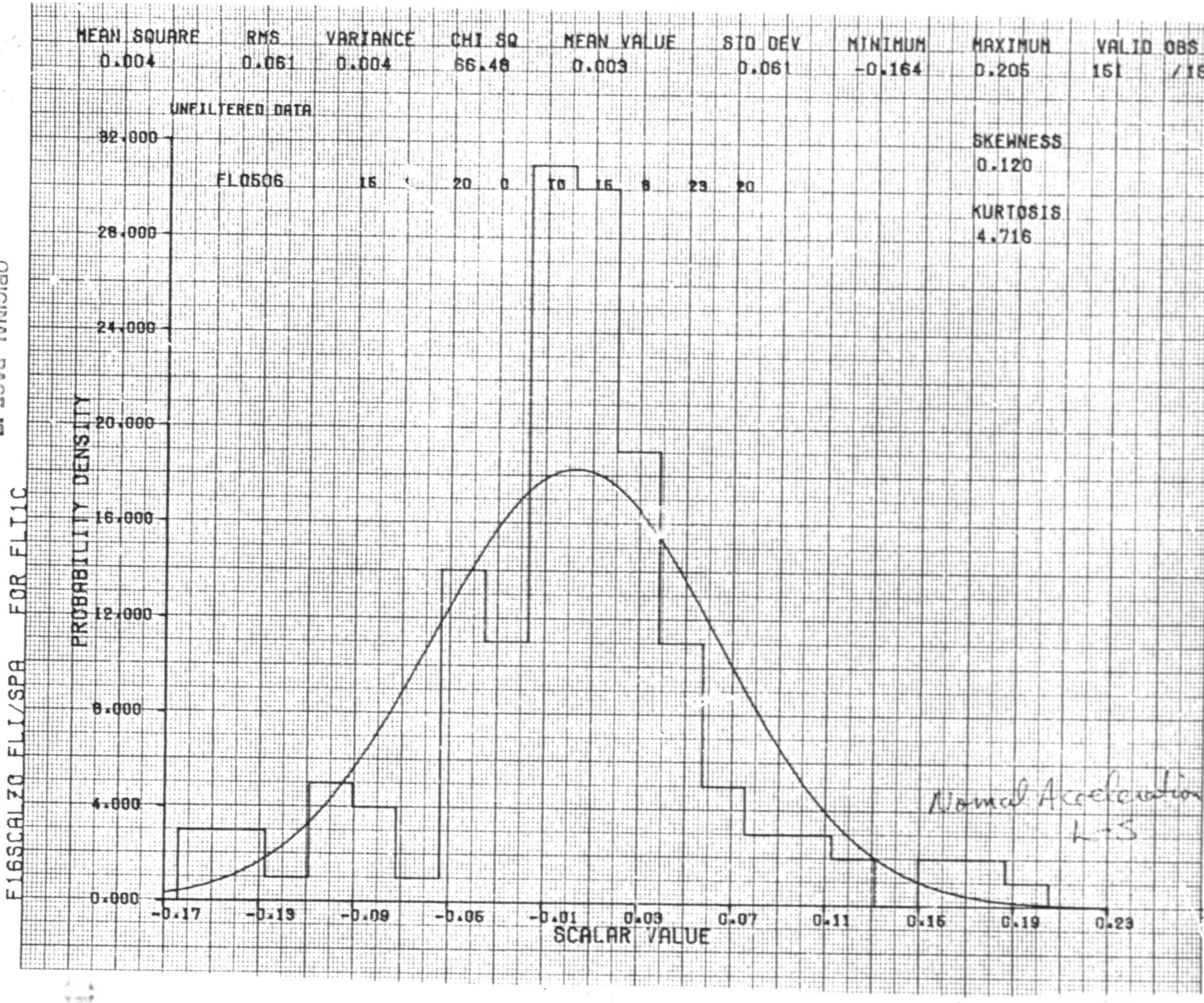
FLIGHT = AFTIE16 FLT1C (5)

Parameter = IBU LATERAL AXIS MONITOR   Sensor differences are L-S L-R and S-R

P(AF/DF)

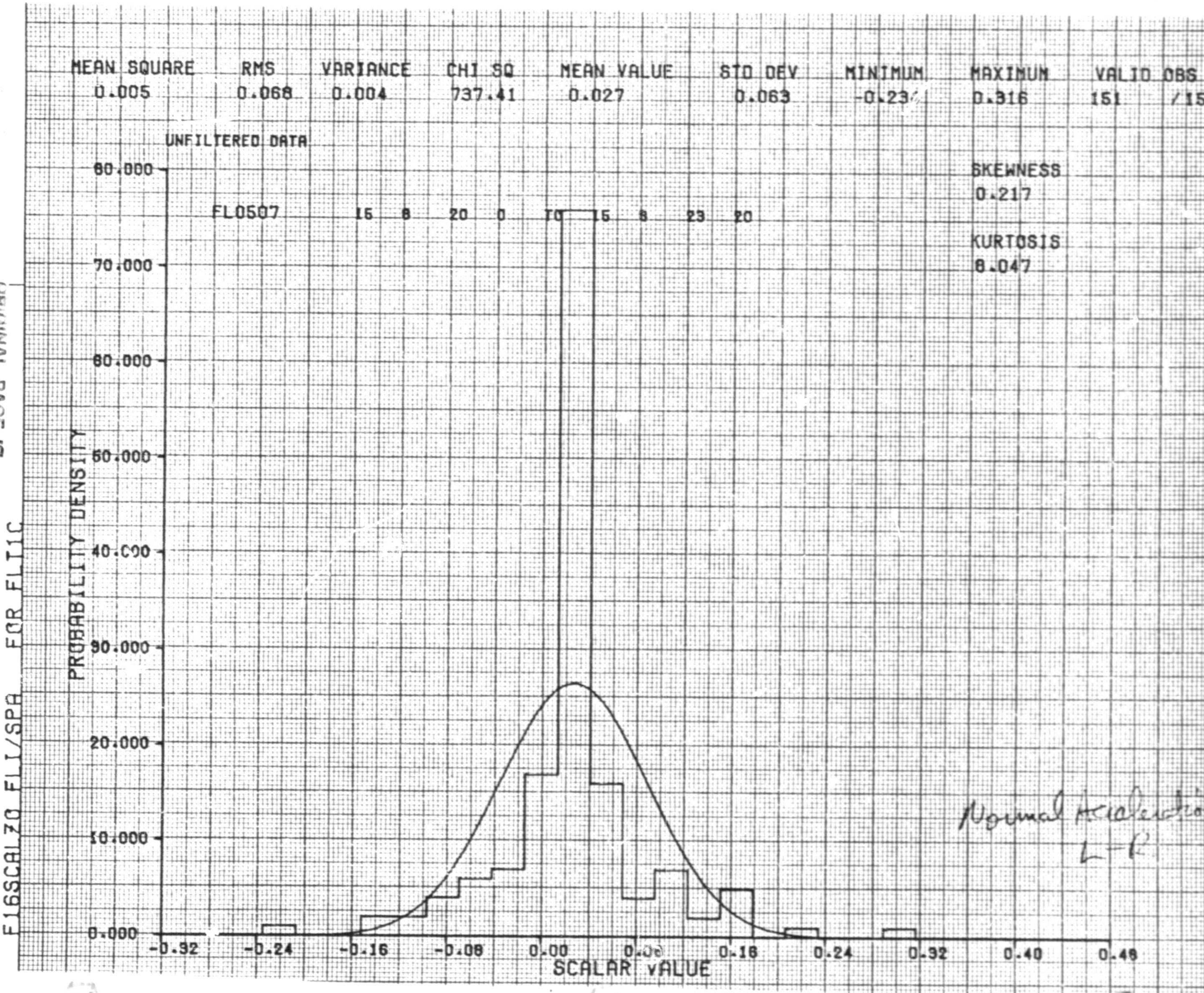


CURVE KEY
.995 = .   .996 = -   .997 = ,   .998 = +   .999 = *



* Time 15-8-20-0 TO 15-8-23-20

-121-



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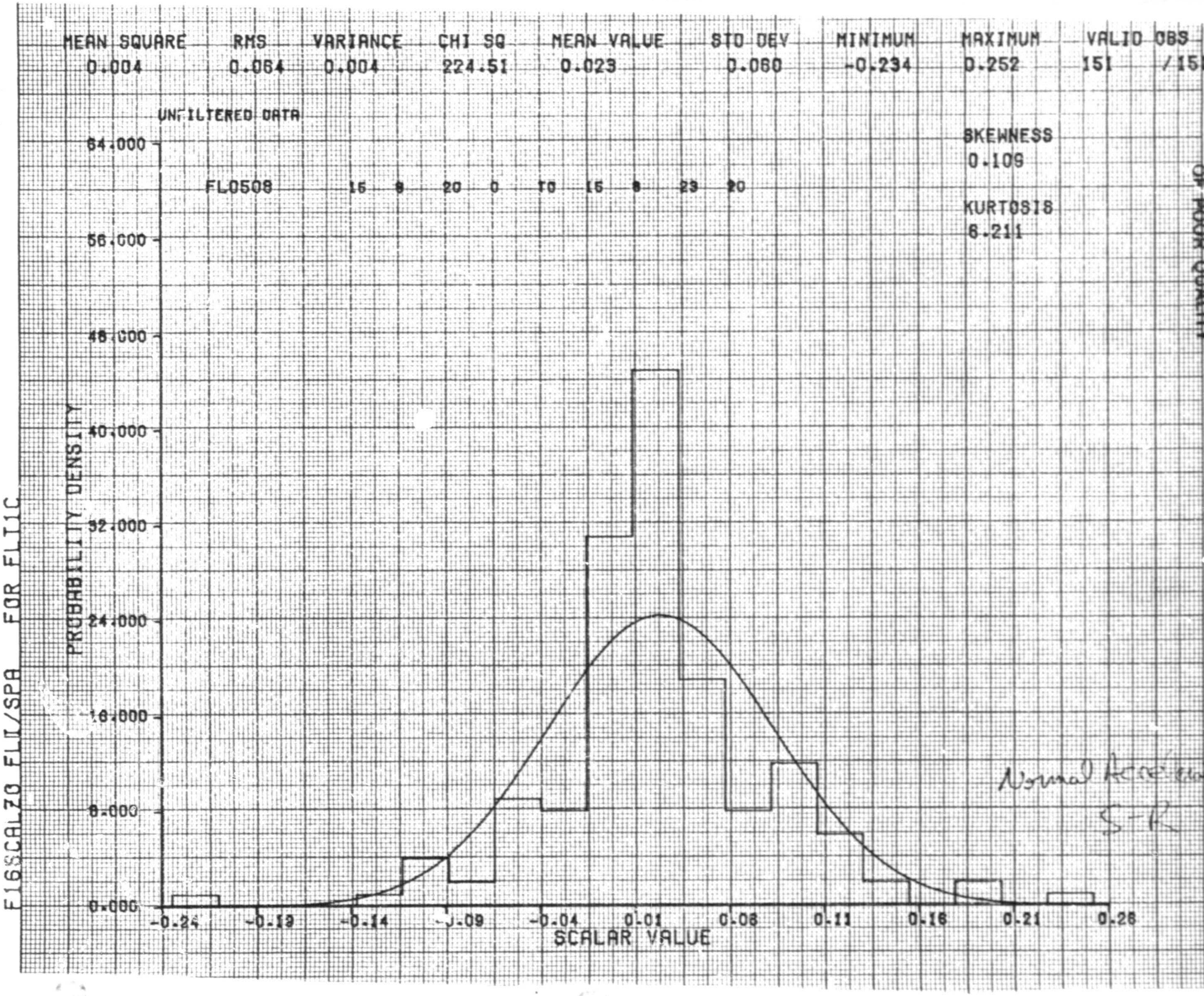
MEAN SQUARE 0.004
RMS 0.064
VARIANCE 0.004
CHI SQ 224.51
MEAN VALUE 0.023
STD DEV 0.060
MINIMUM -0.234
MAXIMUM 0.252
VALID OBS 151 /151
UNFILTERED DATA
SKEWNESS 0.109
KURTOSIS 6.211
FL0508 16 8 20 0 10 16 8 23 20
64.000
56.000
48.000
40.000
32.000
24.000
16.000
8.000
0.000
PROBABILITY DENSITY
-0.24 -0.19 -0.14 -0.09 -0.04 0.01 0.06 0.11 0.16 0.21 0.26
SCALAR VALUE
F16SCAL20 FLI/SPA FOR FLI1C

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Normal Acceleration
sample data

AFTIF16 FLTIC

	L-S	L-R	S-R
1	.058594	.04687	-.011719
2	.029297	.035156	.0058594
3	-.011719	.023438	.035156
4	0	.029297	.029297
5	-1.4648	-.13477	.011719
6	.20508	.2168	.011719
7	-.041016	-.046875	-.0058594
8	.0058594	-.011719	-.017578
9	.011719	.011719	0
10	.17578	.11719	-.058594
11	-.09375	-.087891	.0058594
12	.035156	.041016	.0058594
13	.017578	.15234	.13477
14	.10547	.029297	.076172
15	.052734	.052734	0

Sensor Redundancy Management
Report of Probability Density Function, C(DF)
Reliability/Ra Probability of False Alarm,P(AF/DF)
For the Sensor Value in the Domain of Failure

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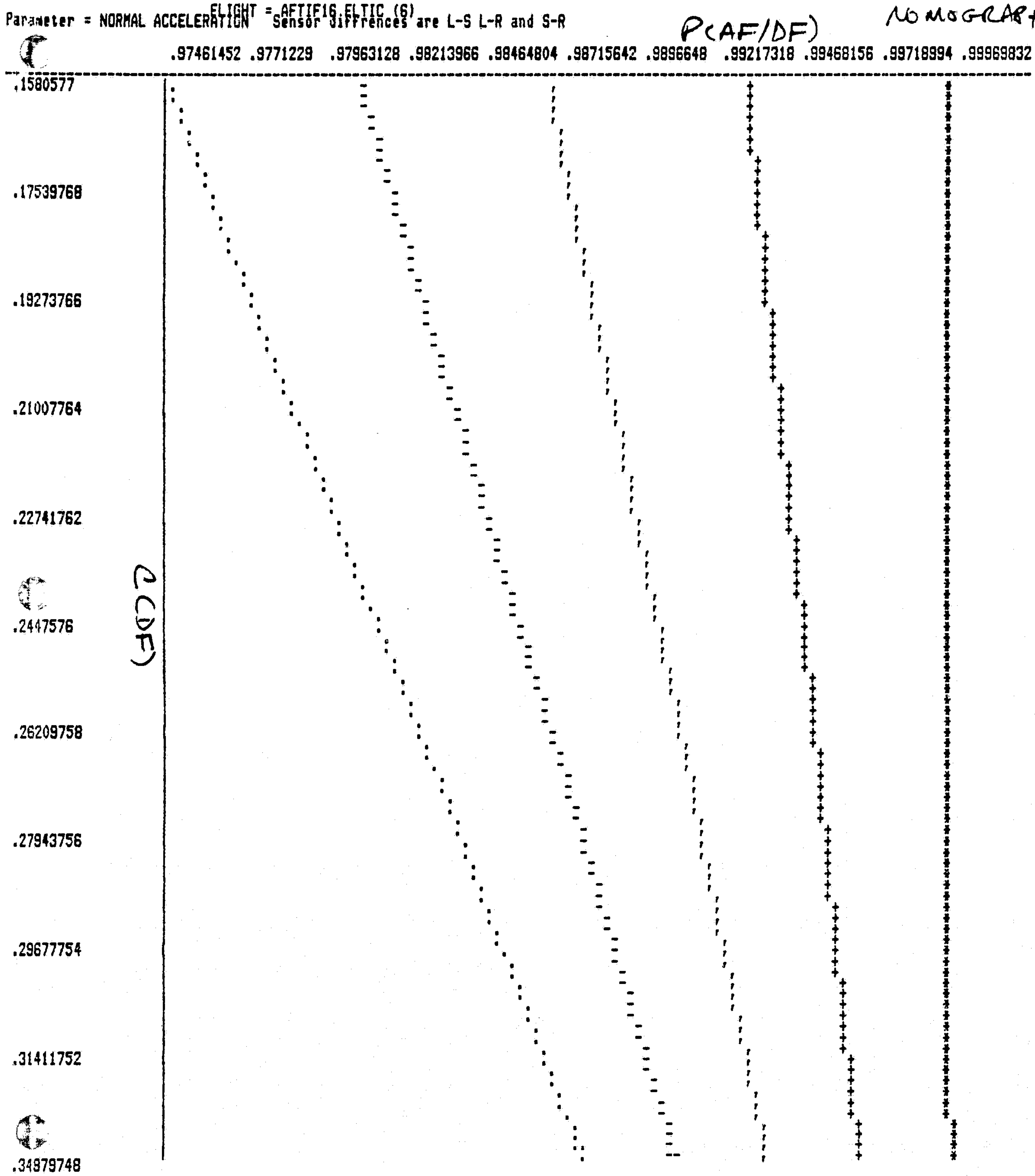
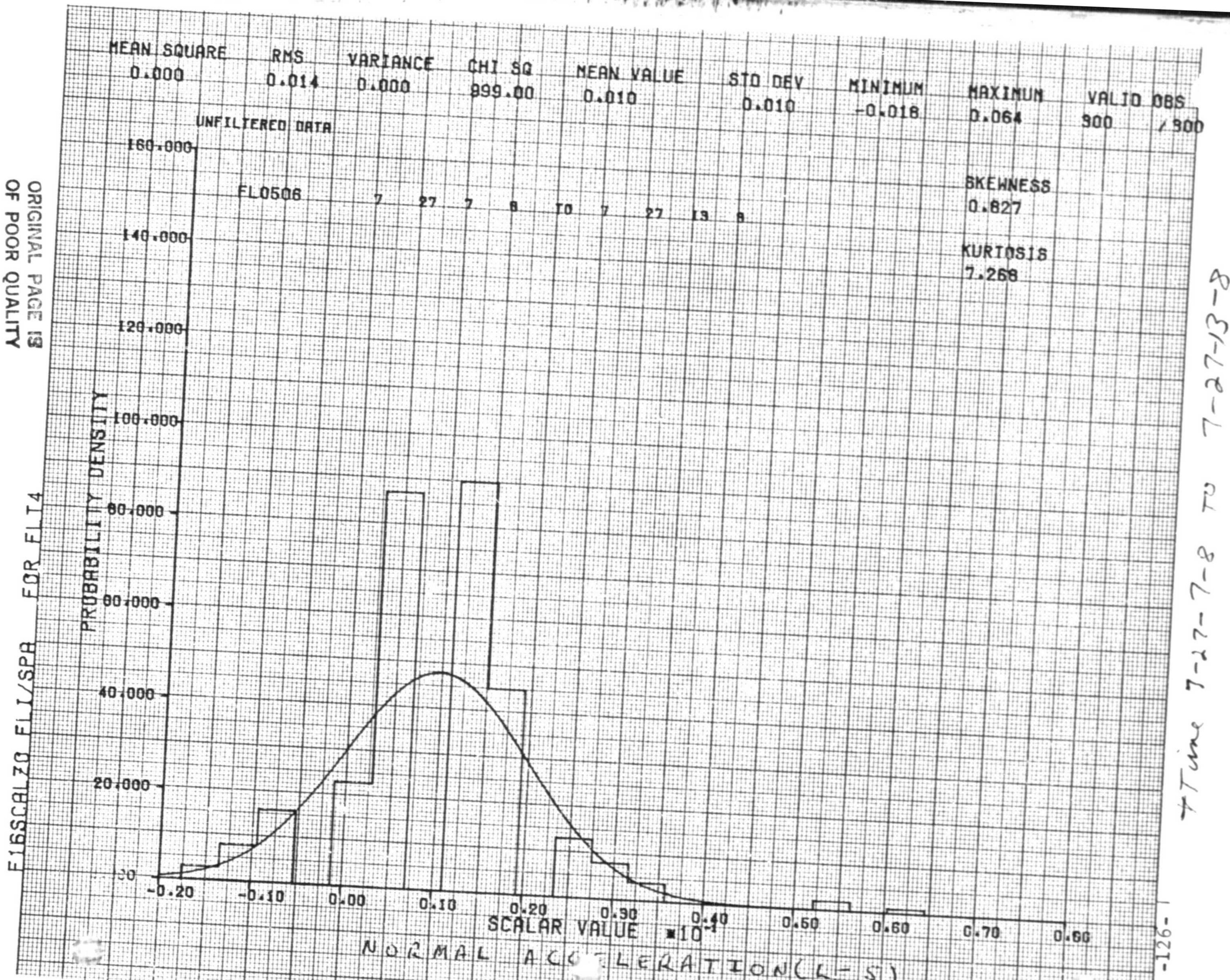
Normal Acceleration
Sample
NOMOGRAPH

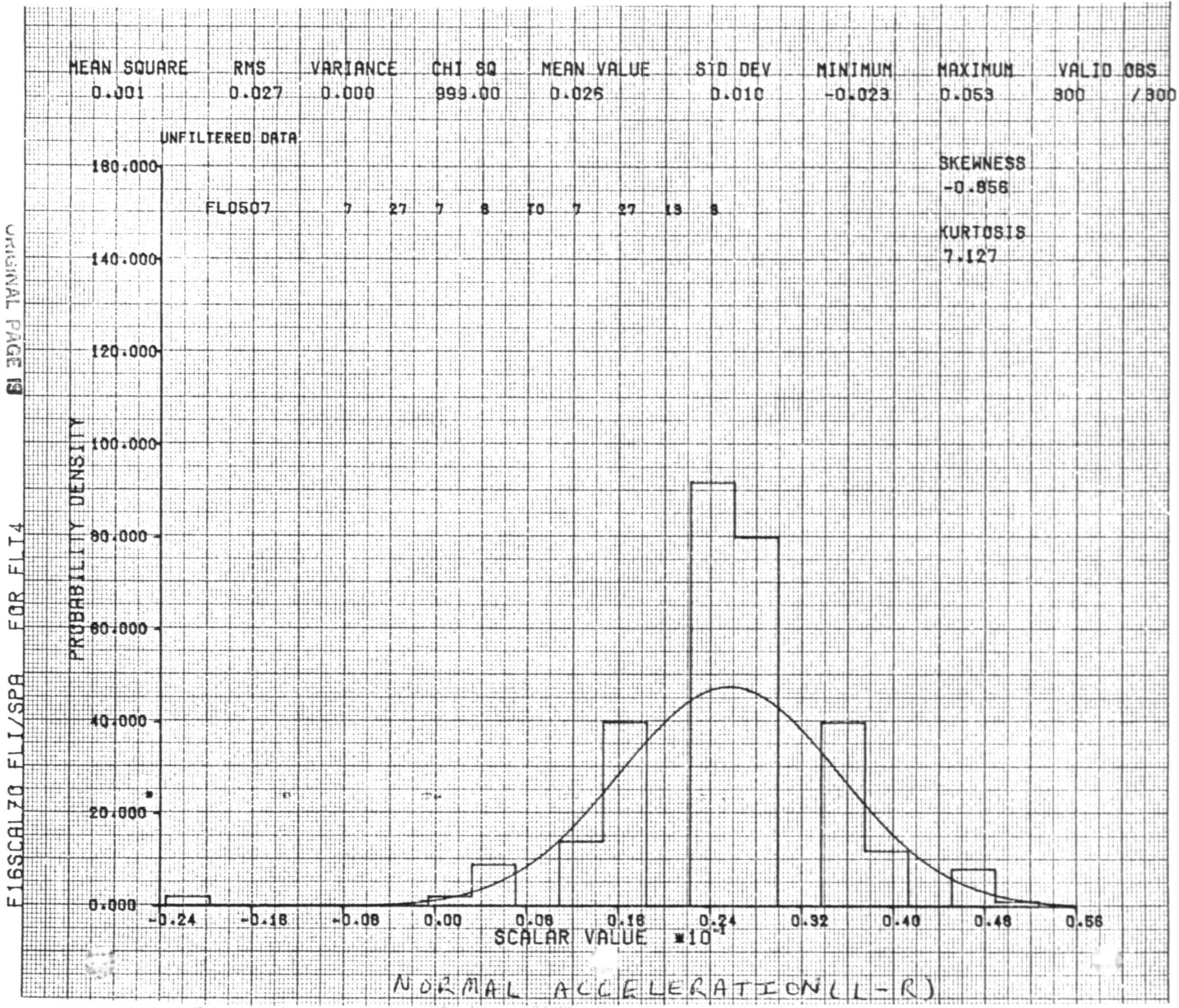
FLIGHT = AFTIF16 FLTIC (6)
Parameter = NORMAL ACCELERATION Sensor Diffrences are L-S L-R and S-R

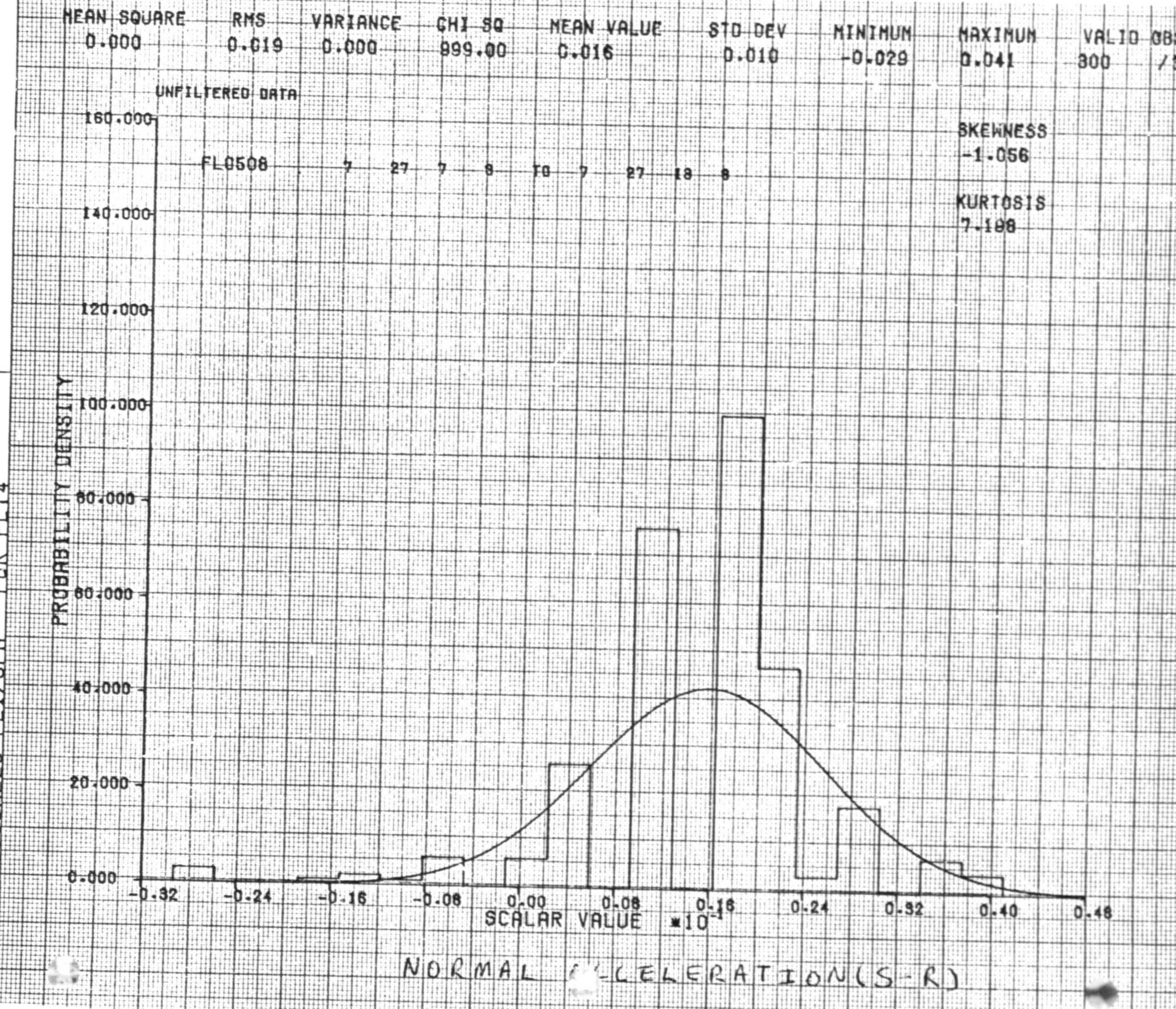


CURVE KEY
.995 = . .996 = - .997 = , .998 = + .999 = *

R


MEAN SQUARE 0.000
RMS 0.014
VARIANCE 0.000
CHI SQ 999.00
MEAN VALUE 0.010
STD DEV 0.010
MINIMUM -0.018
MAXIMUN 0.064
VALID OBS 900 / 900
UNFILTERED DATA
FL0506 7 27 7 8 TO 7 27 13 8
SKEWNESS 0.827
KURTOSIS 7.268
PROBABILITY DENSITY
160.000
140.000
120.000
100.000
80.000
60.000
40.000
20.000
-0.20
-0.10
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
SCALAR VALUE *10⁻¹
NORMAL ACCELERATION(L-S)
F16SCALZO FL1/SPA FOR FLT4
Time 7-27-7-8 TO 7-27-13-8


MEAN SQUARE 0.001
RMS 0.027
VARIANCE 0.000
CHI SQ 999.00
MEAN VALUE 0.025
STD DEV 0.010
MINIMUM -0.023
MAXIMUM 0.053
VALID OBS 300 /300
UNFILTERED DATA
SKEWNESS -0.856
KURTOSIS 7.127
FL0507 7 27 7 8 10 7 27 13 8
PROBABILITY DENSITY
SCALAR VALUE *10^-1
NORMAL ACCELERATION(L-R)
F16SCAL70 FLI/SPA FOR FLT4



F16SCALZ0 FLI/SPA FOR FLI4

Normal Acceleration sample data.

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AFTIF16 FLT4

	L-S	L-R	S-R
1	.0058594	.029297	.023438
2	.023438	.017578	-.0058574
3	.011719	.029297	.017578
4	0	.017578	.017578
5	.029297	.046875	.017538
6	-.058594	.017578	.023538
7	.023438	.035156	.011719
8	.058594	.023438	.017578
9	.011719	0	-.011719
10	-.011719	.0058594	.017578

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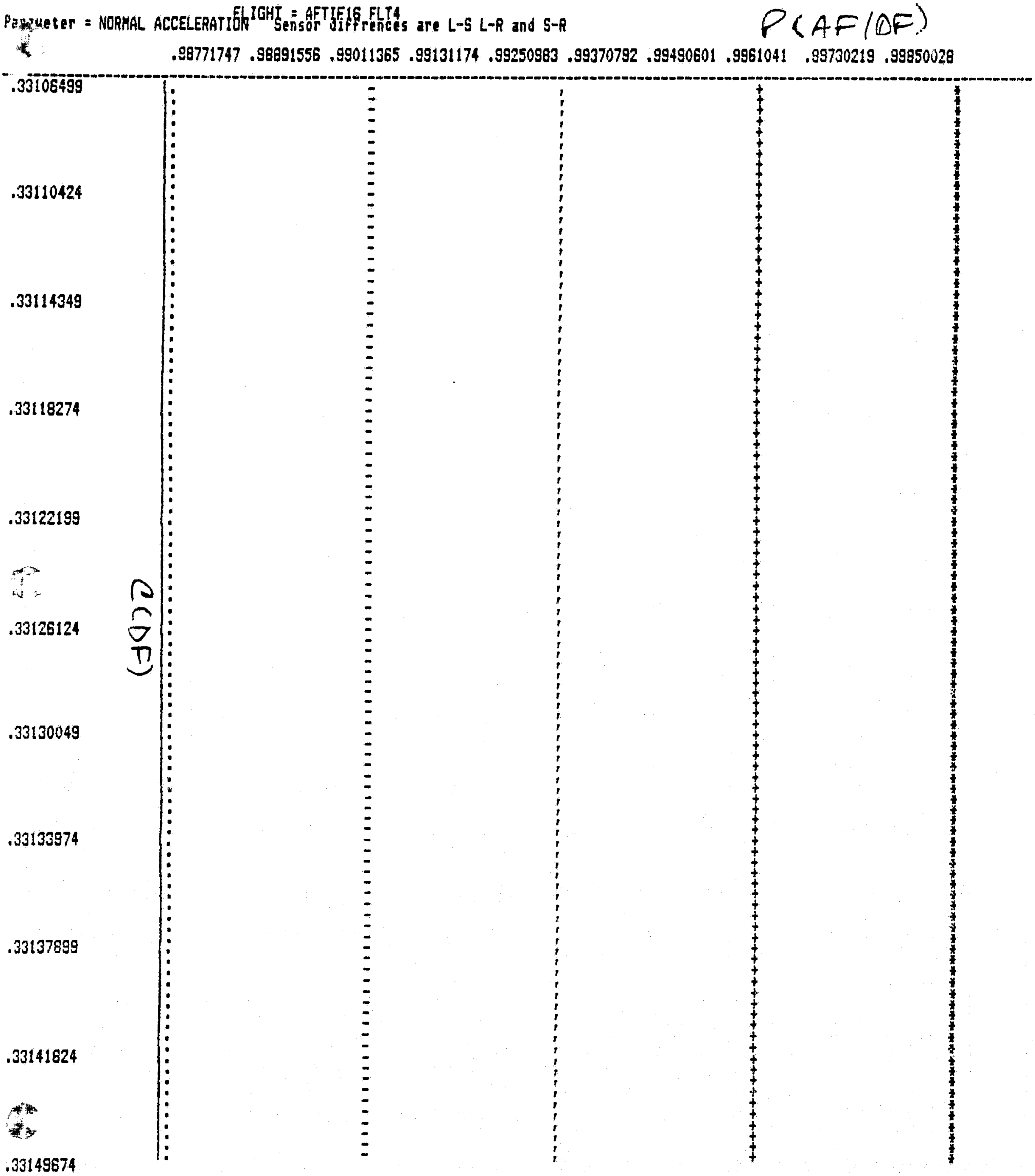
Sensor Redundancy Management
Report of Probability Density Function, C(DF)
Reliability (R) Probability of False Alarm P(AF/DF)
For the Sensor Value in the Domain of Failure

FLIGHT = AFTIF16 FLT4

Parameter = NORMAL ACCELERATION Sensor diffrences are L-S L-R and S-R



CURVE KEY

.995 = .   .996 = -   .997 = ,   .998 = +   .999 = *

R