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

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THE PROBLEM

The National Aeronautics 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 cumulative 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 cumulative 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 parameters.

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 occurred. 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.

\[
\text{DOMAIN OF FAILURE}
\]

\[
0 \leq \text{Cv} = \text{THRESHOLD VALUE}
\]
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 detectability as dictated 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/sec (figure 5), triplex SRM (figure 6), and triplex discrete redundancy 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 an 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 < \( \frac{1}{2} \) maximum (A-C)).

2. Maximum \( |A-C| < \frac{1}{2} \) 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 cumulative 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 air-
craft to converse verbally; A Digital Flight Control System
computer and an Automated Maneuvering 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:

\[
\begin{array}{c}
\text{INPUT 1} \\
\text{INPUT 2} \\
\text{INPUT 3}
\end{array}
\rightarrow
\begin{array}{c}
\text{MID} \\
\text{VALUE} \\
\text{SELECT}
\end{array}
\rightarrow
\begin{array}{c}
\text{MID VALUE}
\end{array}
\]

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 choosing 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 $n$ consecutive values exceed $C_v$):

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

$C_v$ is selected so that

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

where $T$ = total seconds

$n$ = window width

$N$ = number of excursions 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 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 occurred. 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 occurring, and $DF$=the event of the signal being in the domain of failure

![Diagram of domains of failure, false alarm, true alarm, and domain of failure](image)

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. \[ P(\text{AF/DF}) = \frac{P(\text{AF})}{P(\text{AF}) + P(\text{DF/AF}) \cdot P(\text{AF})} \]

now let \( A \) = event an alarm occurs
\( \text{AT} \) = event a true alarm occurs
then \( \overline{\text{AF}} = \overline{A} \cup \text{AT} \)
and
\( \overline{A} \cap \text{AT} = \emptyset \)
therefore \[ P(\text{DF/AF}) = P(\text{DF/(AUAT)}) \]
\[ = \frac{P(\text{DF} \cap \overline{\text{AUAT}})}{P(\overline{\text{AUAT}})} \]

and since \( \overline{\text{AUAT}} = \emptyset \)
\[ P(\text{DF/AF}) = \frac{P(\text{DF} \overline{A}) \cup P(\text{DF} \text{AF})}{P(\overline{A}) + P(\text{AT})} \]

note \( \text{DF} \overline{A} = \emptyset \) and \( \text{DF} \cap \text{AT} = \text{AT} \)
ii. \[ P(\text{DF/AF}) = \frac{P(\text{AT})}{P(\overline{A}) + P(\text{AT})} \]

substituting ii. into i. we obtain
\[ P(\text{AF/DF}) = \frac{P(\text{AF})}{P(\text{AF}) + \frac{P(\text{AT})}{P(\overline{A}) + P(\text{AT})} \cdot P(\overline{\text{AF}})} \]
or iii. \[ P(\text{AF/DF}) = \frac{P(\text{AF})[P(\overline{A}) + P(\text{AT})]}{P(\text{AF})[P(\overline{A}) + P(\text{AT})] + P(\text{AT}) \cdot P(\overline{\text{AF}})} \]

Now we need formulas for \( P(\text{AF}) = P(\text{false alarm}) \),
\( P(\overline{A}) = P(\text{no alarm occurs}) \) and \( P(\text{AT}) = P(\text{a true alarm occurs}) \)
so we can compute \( P(\text{AF/DF}) \).
Let \( P(AF) = P(A \cap \overline{F}) = p(\text{alarm} \cap \text{not a hard fault}) \)

where \( A = \text{event an alarm occurs} \)
\( F = \text{event a hard fault occurs} \)
\( \overline{F} = \text{event a hard fault does not occur} \).

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

where \( C(DF) = \text{cumulative probability of being in the domain of failure} \)
\( R = \text{system reliability} \)
i.e. \( R = P(\overline{F}) \)
\( P(y) = \text{operational density function} \)

furthermore:

\[
\begin{align*}
P(AF) &= 1 - P(AF) \\
P(A) &= (1 - R) + P(AF) \\
P(\overline{A}) &= 1 - P(A) \\
P(AT) &= 1 - R
\end{align*}
\]

Substituting v. into iii. we obtain:

\[
P(AF/DF) = \frac{P(AF)\left[P(\overline{A}) + P(AT)\right]}{P(AF)\left[P(\overline{A}) + P(AT)\right] + P(AT) \cdot P(\overline{AF})}
= \frac{P(AF)\left[1 - (1 - R) - P(AF) + 1 - R\right]}{P(AF)\left[1 - (1 - R) - P(AF) + 1 - R\right] + (1 - R) \cdot (1 - P(AF))}
= \frac{P(AF)}{P(AF) + (1 - R)}
\]
STEP 2: Determine the characteristics of the probability density function (pdf) \( f_{DF} P(y) dy = C(DF) \).

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

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

where \( \mu = \text{mean } RVX \)
\( \sigma^2 = \text{variance } RVX \)
\( \sigma = \text{st. deviation } RVX \)

STANDARD NORMAL PROBABILITY FUNCTION

\[
\mu = 0 \quad \sigma = 1
\]

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

CUMMULATIVE PROBABILITY DENSITY FUNCTION

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

ORDER STATISTICS

Now let \( X_1, X_2, X_3 \) (sensor triple) be a random sample for \( RVX \) and let
\( y_1 = \text{minimum } (X_1, X_2, X_3) \)
\( y_2 = \text{mid value } (X_1, X_2, X_3) \)
\( y_3 = \text{maximum } (X_1, X_2, X_3) \)

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

\[
f(X_1) \cdot f(X_2) \cdot f(X_3)
\]
The following disjoint sets:

\[ A_1 = \{ (x_1, x_2, x_3) | x_1 < x_2 < x_3 \} \]
\[ A_2 = \{ (x_1, x_2, x_3) | x_1 < x_3 < x_2 \} \]
\[ A_3 = \{ (x_1, x_2, x_3) | x_2 < x_1 < x_3 \} \]
\[ A_4 = \{ (x_1, x_2, x_3) | x_2 < x_3 < x_1 \} \]
\[ A_5 = \{ (x_1, x_2, x_3) | x_3 < x_1 < x_2 \} \]
\[ A_6 = \{ (x_1, x_2, x_3) | x < x < x \} \]

are one-to-one transformations which map each of 
\( A_1, A_2, \ldots, A_6 \) onto the same set \( B = (y_1, y_2, y_3) \) \( y_1 < y_2 < y_3 \).

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:

\[ J_1 = \begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix} = 1 \]
\[ J_2 = \begin{vmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{vmatrix} = -1 \]
\[ J_3 = \begin{vmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{vmatrix} = -1 \]
\[ J_4 = \begin{vmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{vmatrix} = 1 \]
\[ J_5 = \begin{vmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{vmatrix} = 1 \]
\[ J_6 = \begin{vmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{vmatrix} = -1 \]

and \( |J_i| = 1 \) \( i = 1, 2, 3, 4, 5, 6 \).
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:

$$h(y_2) = \int_{-\infty}^{\infty} \int_{-\infty}^{y_2} g(y_1, y_2, y_3) dy_3 dy_1$$

$$= \int_{-\infty}^{y_2} \int_{-\infty}^{\infty} 6f(y_1)f(y_2)f(y_3) dy_3 dy_1$$

$$= 6f(y_2) \int_{-\infty}^{y_2} f(y_1) \int_{-\infty}^{\infty} f(y_3) dy_3 dy_1$$

$$= 6f(y_2) \int_{-\infty}^{y_2} f(y_1) [1-F(y_2)] dy_1$$

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

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 expected 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 $d[F(y_2)] = f(y_2) dy_2$

$$p(y_2 \leq 0) = 6\int_{-\infty}^{0} F(y_2) df(y_2) - [F(y_2)]^2 df(y_2)$$
\[ h(y_2) = 6f(y_2)F(y_2)[1-F(y_2)] \]
\[ h(-y_2) = 6f(-y_2)F(-y_2)[1-F(-y_2)] \]

\[ f(x) = \frac{1}{\sqrt{2\pi}} e^{-x^2/2} \]
\[ f(-y_2) = f(y_2) \]
\[ F(-y_2) = 1-F(y_2) \]
\[ 1-F(-y_2) = F(y_2) \]

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

has \( \mu=0 \), median = 0, and is symmetric about \( \mu \).

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: \[ f(X) = \frac{1}{\sqrt{2\pi}} e^{-\frac{X^2}{2}} \]

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

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 \( n(X) = \frac{1}{\sqrt{2\pi}} e^{-\frac{X^2}{2}(0.4487)} \)

agree in the \( \pm 3\sigma \) range to at least two decimal places.

We define a distribution to be "near-normal if a \( \chi^2 \)
(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 \( \chi^2 \) 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 \( \sigma^2 \) is:

\[ 0.4222 < \sigma^2 < 0.4970. \]

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

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

or \[ n(X) = 0.33145 e^{-\frac{X^2}{2.8974}} \]
i.e. \( \mu = 0 \)

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

\[
\sigma = \sqrt{1.4487} = 1.2036, \text{ and}
\]

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

\[-3.099 \leq 99 \text{ percent of signals} \leq 3.099
\]

**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 $C_v = 1.48 \sigma = 1.48(1.2036) = 1.78$ (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) ASPECTS OF SRM
1. Selection Process
2. Fault Detection Process
3. Failure Reconfiguration Process

(B) SELECTION METHODS FOR SRM
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 persistence count (PC). Given a frame rate and a set time, a fault must persist for a specified maximum PC before being declared permanently failed.

2. Differencing (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 asynchronous system. It is possible that an asynchronous 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.
BIBLIOGRAPHY


FIGURE 1. MONTE CARLO SIMULATION

FIGURE 2. NORMAL ACCELEROMETER AND MDM MODELS

FIGURE 3. FALSE ALARM ALGORITHM
Figure 4. F-8 DFBB hardware elements with detail of pallet assembly.
(a) Timing sequence with all control modes active, 20-msec minor cycle.

(b) Memory allocation.

Figure 5. F-8 DFBW software system.
Figure 6. Triplex analog sensor redundancy management algorithm.
Figure 7. Triplex discrete RM algorithm.
Fixed-point triplex sensor signals

Sensor select
(mid-value, average, or default value)

Signal converter (fixed to floating point)

Reconfiguration

Fault detection and isolation

Failure status monitor

To control laws

To alarm/diagnostic logs

Selected value

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

Sensor output

Hardover fault

Fault threshold

Last good value held

Selected value

Sensor A

Sensor B

Persistence count

1 2 3 4 5

100 msec

(a) Hardover failure of sensor A.

Sensor output

Fault threshold

Last good value held

Selected value (average)

Sensor A

Sensor B

Persistence count

0 1 2 3 0

Time

(b) Transient fault of sensor A.

Figure 8. Concluded.
Original page is of poor quality.
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

Fig 10
Figure 14. Mid-Value Sensor Select Algorithm
Figure 15. Self-If-Good Sensor Select Algorithm
Figure 16. Mean-Value Sensor Select Algorithm
Figure 17. RES-X Detection Method for SRM
<table>
<thead>
<tr>
<th>SENSOR SET</th>
<th>TOLERANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pitch rate (deg/s)</td>
<td>4 deg/sec</td>
</tr>
<tr>
<td>Roll rate (deg/s)</td>
<td>10 deg/sec</td>
</tr>
<tr>
<td>Yaw rate (deg/s)</td>
<td>4 deg/sec</td>
</tr>
<tr>
<td>Axial accelerometer (g)</td>
<td>0.1g</td>
</tr>
<tr>
<td>Lateral accelerometer (g)</td>
<td>0.2g</td>
</tr>
<tr>
<td>Normal accelerometer (g)</td>
<td>0.5g</td>
</tr>
<tr>
<td>Pitch C stick (cm)</td>
<td>1.0cm</td>
</tr>
<tr>
<td>Roll C stick (cm)</td>
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</tr>
<tr>
<td>Rudder pedals (cm)</td>
<td>0.5cm</td>
</tr>
<tr>
<td>Angle of attack (deg)</td>
<td>2.0deg</td>
</tr>
<tr>
<td>Left secondary actuator (cm)</td>
<td>3.5cm</td>
</tr>
<tr>
<td>Right secondary actuator (cm)</td>
<td>3.5cm</td>
</tr>
<tr>
<td>Pitch attitude (deg)</td>
<td>15deg</td>
</tr>
<tr>
<td>Roll attitude (deg)</td>
<td>15deg</td>
</tr>
<tr>
<td>Heading (deg)</td>
<td>15deg</td>
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<tr>
<td>Mach number</td>
<td>0.05</td>
</tr>
<tr>
<td>Altitude (m)</td>
<td>150m</td>
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Table 1: Sensor Fault Thresholds
<table>
<thead>
<tr>
<th>SENSOR</th>
<th>NUMBER OF ACTUAL HARDWARE FAULTS</th>
<th>NUMBER OF FALSE FAULT DECLARATIONS</th>
<th>NUMBER OF TIMES FAILCOUNT REACHED 4</th>
<th>MAXIMUM NUMBER OF MISCOMPARSES ANY FLIGHT</th>
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<tbody>
<tr>
<td>YAW RATE GYRO</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
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<td>LONGTIDUAL ACCELEROMETER</td>
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<td>ALTIMETER</td>
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<td>2</td>
<td>10</td>
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<td>72</td>
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<tr>
<td>HEADING</td>
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<td>4</td>
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<td>9</td>
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<td>PITCH CENTER STICK</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ROLL CENTER STICK</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>RUDDER PEDALS</td>
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<td>0</td>
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<td>0</td>
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<tr>
<td>ROLL SIDESTICK</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ANGLE OF ATTACK</td>
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<td>7</td>
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Table 2: F8 DFEW Sensor Flight Experience
<table>
<thead>
<tr>
<th></th>
<th>$\chi^2$ VALUES</th>
<th>$\chi^2$</th>
<th>df</th>
<th>CRITICAL VALUE (0.995 level)</th>
</tr>
</thead>
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<tr>
<td>QBA-QBC</td>
<td>16475.</td>
<td>8</td>
<td>21.96</td>
<td></td>
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<tr>
<td>PBA-PBC</td>
<td>186386.</td>
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<td>25.19</td>
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<tr>
<td>RBA-RBC</td>
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<td>14</td>
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<td></td>
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<tr>
<td>NXA-NXC</td>
<td>200559.</td>
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<td></td>
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<tr>
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<td>49.64</td>
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<td>NBA-NBC</td>
<td>491741.</td>
<td>21</td>
<td>41.40</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: $\chi^2$ 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.
APPENDIX C

MODIFIED FLIPRNT PROGRAM

MODIFIED CARD SETUP FOR SPA PACKAGE
Card #

<table>
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<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5A(only 1 time)</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>9</td>
</tr>
</tbody>
</table>
| 10

Notes: 1) ST = space to left of desired time ET = 2000 T, right of desired time ET = 1000 T, repeat cards 8, 9, 10, and 11 for each time period in the same flight (put them in numerical order: EARLY TO LATE)
2) NCH = 8

7/8/9 Card (end of record)

Card #

<table>
<thead>
<tr>
<th>Card #</th>
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<tbody>
<tr>
<td>13</td>
</tr>
<tr>
<td>14</td>
</tr>
<tr>
<td>15</td>
</tr>
</tbody>
</table>

Notes: 1) repeat cards 13, 14, and 15 for each time period; same FLT
2) NCH = 3.5 for unfilled data

Yellow Control Card
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, UFLID
   FORMAT (1H0,"UFLID = ",A10,/)
   IF(NCH.LT.1 .OR. NCH.GT.10) PRINT 201
   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
   READ 101, (PARMID(I),I=1,NCH)
   WRITE (2) (PARMID(I),I=1,NCH)
   IF(.NOT.PRINTIT) PRINT 104, (PARMID(I),I=1,NCH)
   FORMAT(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)
   IEFIL = ET(4)
   CALL DABOP (IUCD,UFLID,NCH,PARMID,MEAS,IEU,CALID,IVC,PARMNAM)
   IF(I100,NE.0) PRINT 202
   202 FORMAT (1H0,"AT LEAST ONE REQUESTED PARAMETER IS MISSING FROM THE FLIDAB. CORRECT AND RESUBMIT.")
   IF(I100,NE.0) PRINT 203
   203 FORMAT (1H0,"AT LEAST PART OF THE REQUESTED TIME IS MISSING FROM THE FLIDAB. CORRECT AND RESUBMIT.")
   IF(I100,NE.0) PRINT 204
   204 FORMAT (1H0,"CATACSTROPHIC FLIDAB HEADER ERROR.")
   IF(I1CTME,NE.0 .OR. I1CTME,NE.0 .OR. ICEATS,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,IVC,NCH)
   IF(I1CDAT,GT,0) GO TO 3
   MILI = IDTL
   WRITE (2) ID1,DI2,MILI,(DAT(I),I=1,NCH)
   IF(PRINTIT) PRINT 106, ID1,DI2,(DAT(I),I=1,NCH)
   106 FORMAT(1X,A10,A2,16G12.5)
   GO TO 2
3  ENDFILE 2
   AET(1) = IDHR
   AET(2) = IDMIN
   AET(3) = IDSEC
   AET(4) = IDFIL
   PRINT 107, AST,AET
   107 FORMAT (1H0,"ACTUAL START TIME = ",12,1X,12,1X,12,1X,12,1X,13,10X,
   -" ACTUAL END TIME = ",12,1X,12,1X,12,1X,13)
   WRITE (2) AST,AET
   GO TO 1
5  ENDFILE 2
   REWIND 2
999 STOP
END
APPENDIX D

MICROCOMPUTER SOFTWARE FOR COMPUTING FALSE ALARM RATES AND PLOTTING CORRESPONDING NOMOGRAPHS
REM SELECTION PROGRAM
DIM S9$(255), F2$(33), F$(33), A$(15), T$(33), D(3,20), P$(25)
DIM V$(1000). P(2,300). Z9$(10)
REM LEARN TERMINAL CODES
PRINT 1$85 GOSUS 9500 
REM CHK FOR DIR FILE AND DEFAULT DRIVE
PRINT Cif, B1$, H1$ "REM CLEAR SCREEN, RING BELL, HIGH INTENSITY"
PRINT TAB(20), "SENSOR REDUNDANCY MANAGEMENT"
PRINT TAB(Z), "(.H1$,"1",N1$",")",TAB(15), "Enter data to File"
PRINT TAB(Z), "(",H1$,"2",N1$",")",TAB(15), "Display data From File"
PRINT TAB(Z), "(",H1$,"3",N1$",")",TAB(15), "Edit data in File"
PRINT TAB(Z), "(",H1$,"4",N1$",")",TAB(15), "Compute and graph probabilities"
PRINT TAB(Z), "(",H1$,"5",N1$",")",TAB(15), "Delete file"
PRINT TAB(Z), "(",H1$,"6",N1$",")",TAB(15), "Display file list"
PRINT TAB(Z), "(",H1$,"7",N1$",")",TAB(15), "Exit Program"
PRINT "Type in the number of your choice ......",
A$=INCHAR$(0) "A$=INCHAR$(1)$"
ON A-48 GOTO 500, 900, 90, 6000, 8990
REM ENTER DATA TO FILE
PRINT C1$, B1$, CHR$(10), CHR$(10), CHR$(10)
GOSUB 5G02 
GOTO 575
PRINT C1$, B1$, H1$"REM ENTER DATA TO FILE"
PRINT C1$, B1$, CHR$(10), CHR$(10), CHR$(10)
GOSUB 5G02 
GOTO 575
PRINT C1$, B1$, H1$"GOSUB 5G02 
GOTO 575"
PRINT C1$, B1$, H1$"GOSUB 5G02 
GOTO 575"
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
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PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
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PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
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PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
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PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
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PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
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PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
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PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
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PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
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PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
PRINT C1$, B1$, H1$"GET SET File",F2$(1,8)
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$(75,45),NIL$.
730 GOSUB 1010C \ REM DRAW GRID
731 PRINT H1$,
735 GOSUB 10500 \ REM INPUT DATA TO GRID
739 PRINT C1$,NIL$.
740 LINE#0,0
745 PRINT "SAVING FILE ",T$," ON DISK"
750 PRINT \ PRINT \ PRINT TAB(25),"PLEASE STAND BYE"
755 OPEN #1,F1$(1,8)+","+STR$(D)
760 FOR Y=1 TO 1000 \ NEXT R
760 FOR X=1 TO 3
765 CLOSE#1
770 REM DRAW GRID
775 FOR R=1 TO 400 \ NEXT R
780 OF' 01, F2$(1,8)+","+STR$(D)
790 FOR Y = 1 TO 1000 \ FOR ;, - 1 TO ~
800 READ# 1, D();, Y)
810 PRINT#1, D();, Y)
820 NE .`:T
830 IF TYP(1) =0 THEN EXIT 1075
840 A=INT(3G-LEN(T$)/2)
850 IF S=1 THEN PRINT#1 CH,1$(10),CHrt$(10),CHR$(10)
860 IF S=0 THEN PRINT#1 CH,1$(10),CHrt$(10),CHR$(10)
870 IF S-1 THEN PRINT#1 CH,1$(10),CHrt$(10),CHR$(10)
880 PRINT#S TAB(A),A=LEN(T$) \ PRINT#S FNS$(A,45)
890 IF S=1 THEN PRINT#1 FNS$(75,45),CHR$(10)
900 FOR X=1 TO Y
910 PRINT#S X,TAB(7),D(1,X),TAB(32),D(2,X),TAB(57),D(3,X)
920 IF S=1 THEN PRINT#1
930 NEXT
940 IF S=0 THEN RETURN
950 A=CALL(65160)
960 RETURN
970 REM SEARCH PROGRAM OF DIR FILE
980 OPEN #1"5, "DIR,"+STR$(D)
990 IF F1$(1,25)=F$(1,25) THEN M=1 ELSE GOTO 2015
1000 IF TYP(1) =0 THEN GOTO 2035
1010 READ #1,F1$(1,33)
1020 REM WRITE PROGRAM TO DIRECTORY
1030 M=0 \ REM DISK NOT FULL
1040 A=85
2508 F2$(1,8)=FNS$(8,32)
2510 F2$(1,8)="NASAM"+CHR$(A)
2511 A$=F2$",""+STR$(D)
2515 IF FILE(A$)=1 THEN GOTO 2730
2520 A=A+1
2525 GOTO 2510
30 OPEN #1%5,"DIR,"+STR$(D)
35 P=0 \ REM POINTER
35 P=0 \ REM POINTER
3540 IF TYP(1) =0 THEN GOTO 2575
3545 IF F$(26,33)=FNS$(8,32) THEN 2565
3550 P=P+35
3555 IF P=875 THEN GOTO 2600
3560 GOTO 2540
3565 WRITE #1%5,F$(1,25)+F2$(1,8),NOENDMARK
3570 GOTO 2550
3575 WRITE #1, F$(1,25)+F2$(1,8)
3580 CLOSE #1
3585 CREATE A$,21590 RETURN
3600 PRINT DISK DIRECTORY FULL "\M=1\CLOSE#1\RETURN
3600 REM COMPUTE AND STORE PROBABILITIES
3610 PRINT C1$,H1$,B1$,CHR$(10),CHR$(10),CHR$(10)
3620 FOR R=1 TO 1000 \ NEXT R
3630 GOSUS 505 \ REM GET FILE
3640 IF M=1 THEN GOTO 3120
3650 PRINT "CAN'T FIND ",F$ \ PRINT
3670 PRINT "Would you like to try again? ",A$=INCHAR$(0)
3680 IF A$="Y" THEN GOTO 3080
3690 CREATE A$,21590 RETURN
3700 PRINT "DO YOU WANT A HARDCOPY? ",A$=INCHAR$(0)
3710 IF A$="Y" THEN S=1
3720 GOSUB 980 \ REM LOAD DATA
3730 PRINT C1$,B1$,B1$
3740 PRINT "Flight name and number is ",H1$,T$,T$,N$,CHR$(10)
3750 INPUT "Type in Parameter name ",P$ \ PRINT
3760 INPUT "Type in one of the three differences ",Y \ PRINT
3770 INPUT "Type in two of the three differences ",D$ \ PRINT
3780 INPUT "Type in three of the three differences ",E$ \ PRINT
3790 PRINT "DO YOU WANT A HARD COPY? ",A$=INCHAR$(0)
3820 S=0 \ IF A$="Y" THEN S=1
3830 PRINT C1$,B1$
3840 IF S>1 THEN GOTO 3201
3845 FILL 65534,84 \ FILL 65532,88
3850 REM PROBABILITIES
3860 GOSUB 3210 \ GOTO 3280
3870 REM COLUMN HEADING FOR TABLE
3870 TAB(26),"Sensor Redundancy Management"
3880 TAB(19),"Report of Probability Density Function, C(DF)"
3890 TAB(17),"For the Sensor Value in the Domain of Failure"
3895 TAB(70-LEN(T$))/2,FLIGHT = ",T$
3900 TAB(15),"P(AF/DF) Table for Sensor Difference ",C$=",D$(1,I)
3910 TAB(10),FNS$(53,45)
3920 TAB(54),P(AF/DF)"
GOTO 3600
3540 \( X_1 - D(2, I) \)
3550 "P(\text{AF/DF}) \) TABLE FOR SENSOR DIFFERENCE \( D(2, I) \)
3560 GOTO 3260
3570 \( X_1 - D(3, I) \)
3580 "P(\text{AF/DF}) \) TABLE FOR SENSOR DIFFERENCE \( D(3, I) \)
3590 GOTO 33G0

3600 \( X_1 = D(2, I) \)
3610 IF \( S = 1 \) THEN \( A \) = \( \text{CALL(65169)} \)
3620 PRINT "CALCULATION COMPLETED" \PRINT
3630 INPUT \( A \) IF LEN(\( A \)) = 0 THEN GOTO 3630
3640 IF \( A <= Y \) THEN GOTO 90
3650 LINE \#1, 132 \ FILL 65532, 132 \ FILL 65534, (132-4) \ REM SIZE, CURRENT PAGE
3660 \#1 \ CHR\$(27), \"EA\" \ (4w) \ REM SET PRINTER
3670 \"SETTING UP PRINTER\", \( B_1 \) \ CHR\$(10)
3680 PRINT \"CREATE GRAPH\", \#1 \ CHR\$(10)
3690 A \ CALL (G5169)
3700 \"SETTING GRAPH LIMITS\", \( B_1 \) \ CHR\$(10)
3710 M_1 = P(1, V) \ REM MIN X
3720 IF M_2 = P(1, V) THEN M_2 = P(1, V) \ REM MAX X
3730 IF M_3 = P(2, V) THEN M_3 = P(2, V) \ REM MIN Y
3740 IF M_4 = P(2, V) THEN M_4 = P(2, V) \ REM MAX Y
3750 \"CLEARING MEMORY\", \( B_1 \) \ CHR\$(10)
3760 REM PLOT IN MEMORY FUNCTION
3770 V$(1, 10000) = FNS$(100, 32)
3780 FOR X = 1 TO 10000 STEP 100 \ V$(X, X+99) = S9 \ NEXT
3790 \#1 \ CHR\$(27), \"C0\" \ (4w) \ REM PLOT IN MEMORY FUNCTION
3800 \"SCALING DATA\", \( B_1 \) \ CHR\$(10)
3810 M_5 = P(1, V) \ REM SLOPE
3820 IF M_5 = C THEN GOTO 4350
3830 N = P(1, V) \ REM XCHANG X
3840 IF M_5 = C THEN GOTO 4370
3850 M = P(2, V) \ REM YCHANG Y
3860 FOR Y = 1 TO 15 \ REM SIZE
3870 IF M_1 = P(1, V) THEN M_1 = P(1, V) \ REM MIN X
3880 IF M_2 = P(1, V) THEN M_2 = P(1, V) \ REM MAX X
3890 IF M_3 = P(2, V) THEN M_3 = P(2, V) \ REM MIN Y
3900 IF M_4 = P(2, V) THEN M_4 = P(2, V) \ REM MAX Y
3910 \"PLOTTING GRAPH IN MEMORY\", \( B_1 \) \ CHR\$(10)
3920 FOR J = 1 TO S
3930 C$ = "\$" \ CHR\$(41 + J)
3940 FOR V = J TO Y*15 \ STEP 5
3950 IF P(2, V) = P(2, V) THEN H = 1 ELSE H = 0
3960 IF M = H THEN GOTO 4380
3970 Z = 10000 \ REM SLOPE
3980 IF M_5 = C THEN GOTO 4390
3990 M = (P(1, V)+P(1, V))/P(2, V) \ REM SLOPE
4000 FOR X = P(1, V) TO P(1, V)+99 \ NEXT
4010 IF M = 0 THEN GOTO 4450
4020 Y_2 = P(2, V) \ REM YCHANG Y
4030 GOTO 4430
4040 Y_2 = P(2, V)
4050 Z = 10000 \ REM SLOPE
4060 IF M = 0 THEN GOTO 4450
4070 Y_2 = P(2, V)
4080 REM
4090 Z = 10000 \ REM SLOPE
4100 FOR V = J TO Y*15 \ STEP 5
4110 IF P(2, V) = P(2, V) THEN H = 1 ELSE H = 0
4120 IF M = H THEN GOTO 4380
4130 M = (P(1, V)+P(1, V))/P(2, V) \ REM SLOPE
4140 FOR X = P(1, V) TO P(1, V)+99 \ NEXT
4150 IF M = 0 THEN GOTO 4450
4160 Y_2 = P(2, V) \ REM YCHANG Y
4170 GOTO 4430
4180 Y_2 = P(2, V)
4190 REM
4200 Z = 10000 \ REM SLOPE
4210 FOR V = J TO Y*15 \ STEP 5
4220 IF P(2, V) = P(2, V) THEN H = 1 ELSE H = 0
4230 IF M = H THEN GOTO 4380
4240 M = (P(1, V)+P(1, V))/P(2, V) \ REM SLOPE
4250 FOR X = P(1, V) TO P(1, V)+99 \ NEXT
4260 IF M = 0 THEN GOTO 4450
4270 Y_2 = P(2, V) \ REM YCHANG Y
4280 GOTO 4430
4290 Y_2 = P(2, V)
4300 REM
4310 Z = 10000 \ REM SLOPE
4320 FOR V = J TO Y*15 \ STEP 5
4330 IF P(2, V) = P(2, V) THEN H = 1 ELSE H = 0
4340 IF M = H THEN GOTO 4380
4350 M = (P(1, V)+P(1, V))/P(2, V) \ REM SLOPE
4360 FOR X = P(1, V) TO P(1, V)+99 \ NEXT
4370 IF M = 0 THEN GOTO 4450
4380 Y_2 = P(2, V) \ REM YCHANG Y
4390 GOTO 4430
4400 Y_2 = P(2, V)
4410 REM
4420 Z = 10000 \ REM SLOPE
4430 FOR V = J TO Y*15 \ STEP 5
4440 IF P(2, V) = P(2, V) THEN H = 1 ELSE H = 0
4450 IF M = H THEN GOTO 4380
4460 M = (P(1, V)+P(1, V))/P(2, V) \ REM SLOPE
4470 FOR X = P(1, V) TO P(1, V)+99 \ NEXT
4480 IF M = 0 THEN GOTO 4450
4490 Y_2 = P(2, V) \ REM YCHANG Y
4500 GOTO 4430
4510 Y_2 = P(2, V)
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REM INPUT MODE PROGRAM

A$=INCHARS(0) \ Q5=ASC(Q5$)
GOSUB 11410
GOTO 10690

GOSUB 11420
IF 135$<"U" THEN GOTO 10760
IF Y5C>4 THEN 10590
IF G5$="D" THEN 10820
R5=Y5 \ C5=Y5 \ REM TEMP
GOTO 10540

REM INPUT NUMBER

GOSUB 11420 \ IF Y=1 THEN GOTO 11120
IF Y=0 THEN GOTO 10540
IF Y>24 THEN GOTO 10540
IF X5=Y5 THEN GOTO 10540

GOSUB 11110
GOTO 10540

ERRSET 1131(),L,E
D((X5-7)/25+1,Y5-3)=VAL(N5$)
ERRSET \ RETURN
IF Q5$="" THEN GOTO 11120
GOTO 11130
IF NS$="" THEN GOTO 11130
IF LEN(NS$)<1 THEN GOTO 11250
NS$="" \ GOTO 11260
NS$=NS$(1,LEN(NS$)-1)
PRINT Q5$.
GOTO 11130
GOTO 11130

ERRSET 11310,L,E
PRINT FNP$(X5,Y5),", ERROR ",B1$.
FOR Z=1 TO 500 \ NEXT 2
PRINT FNP$(X5,Y5),A$,FNP$(X5,Y5),
ERRSET
GOTO 11120
GOTO 11120

REM POSITION LOCAT SIZE

IF X5=X6 AND Y5=Y6 THEN Y=0

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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 LENGTH
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$(Y)
30130 FNEND
60000 REM VARIABLE TABLE
60005 Z TAB STOPS (TEMP)
60010 X FOR NEXT LOOPS (TEMP)
60015 SS$ STRING$ FUNC. (SET)
60020 BI$,NI$,CI$,HI$ TERMINAL CODES (SET)
60025 ZS$ FILE TEST FNF (TEMP)
60030 XS$ TEMP VARIABLE (TEMP)
60035 A TEMP VARIABLE (TEMP)
60040 AS$ TEMP VARIABLE (TEMP)
60045 PS$ INPUTED FILE NAME
60050 F1$ DISK FILE NAME
60055 F2$ TRUE FILE NAME
60060 T$ STRIPPED WORD

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APPENDIX E

STATISTICAL PROGRAMS
This is a program to allow the input of sensor data to the data file for processing by the report generating program.

NASA Grant NAG 4-6

Frank Scalzo, Ph.D.

--- DISPLAY HEADING ON THE SCREEN ---

CLS: CLEAR 1000  'set aside string space
PRINT 058,CHR$(23);"SENSOR REDUNDANCY MANAGEMENT"
PRINT STRING$(32,"-"
PRINT 0323,"Probability of False Alarm"
PRINT TAB(6);"Data Entry Program"
PRINT 0652, "By F. Scalzo, Ph.D."

10 ON ERROR GOTO 2000
20 OPEN 1,1,"SFILE1"
CLOSE 1
24 PRINT "There is already data on file"
26 IF LEFTS(A$1) <> "Y" THEN RUN "MENU"

30 INPUT "Enter the number of Sensor Pairs ":N
35 DIM S(N,2)
40 FOR J=1 TO N
45 PRINT CHR$(27);"Erase to the end of screen"
50 PRINT 0195, "Enter the Data for Pair #":J
55 PRINT 0325,1
60 INPUT "READING #1 ":S(J,1)
65 PRINT 0387,1
70 INPUT "READING #2 ":S(J,2)
80 NEXT J
90 PRINT
100 PRINT "Would you like to see the data ":A$
110 IF LEFTS(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 LEFTS(A$1) <> "Y" THEN GOTO 240
180 PRINT "Which Pair":J
190 INPUT "Reenter Reading #1 ":S(J,1)
200 INPUT "Reenter Reading #2 ":S(J,2)
210 INPUT "Any other corrections ":A$
220 IF LEFTS(A$1) = "Y" THEN CLS: GOTO 180
230 CLS
240 PRINT "Do you want a hard copy of the data ":A$
250 IF LEFTS(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 0,1,"SFILE1"
310 PRINT 01, N
320 FOR J=1 TO N
330 PRINT 01, S(J,1):S(J,2)
340 NEXT J
350 CLOSE 1
400 RUN "MENU"
410 END

1000 PRINT 0900, "(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

#### Flight Mode: FS-PS4003

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#### PDF/DF Table for Sensor Channel A = 0

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PROGRAM SENSTAT (INPUT, OUTPUT, TAPE5=INPUT, TAPE6=OUTPUT, TAPE1, TAPE2, TAPE3, TAPE4)

COMMON/STATDAT/STATMIN, STATMAX, MEAN, VAR, DEV, MEANSQ, RMS,
+ SKEW, KURT, XLOW, XHIGH, NSGOOD, NSTOTAL
COMMON/HISTDAT/HISTMIN, HISTMAX, NSEGS, TALLY, NHGOOD, NHTOTAL
COMMON/PLODAT/XSCALE (4), YSCALE (4), HSTART, HSTOP, TITLE (6), IDPLOT
REAL MEAN, MEANSQ, KURT
INTEGER TALLY (100)
DIMENSION DATA (100), ITIME (6), MESSAGE (3)

READ (5, 10) TITLE
10 FORMAT (9(410))
   IF (EOF (5).NE.0) STOP "NO TITLE CARD"

READ (5, 10) HSTART, HSTOP
   IF (EOF (5).NE.0) STOP "NO TIME CARD"
   BACKSPACE 5

READ (5, 20) ITIME
20 FORMAT (2(3(12, 1X), 1X))
   START = FLOAT (1000 * (3600 * ITIME (1) + 60 * ITIME (2) + ITIME (3)))
   STOP = FLOAT (1000 * (3600 * ITIME (4) + 60 * ITIME (5) + ITIME (6)))

READ (5, 30) IDPLOT, INDEXA, INDEXB, NPARAMS
30 FORMAT (4(10, 3I10))
   IF (EOF (5).NE.0) STOP "NO JOB CARDS"
   CALL PLOTS (0, 0, 4)
   CALL FACTOR (1, 7871)
   CALL PLOT (0, 11, -3)
   GO TO 50

40 READ (5, 30) IDPLOT, INDEXA, INDEXB, NPARAMS
   IF (EOF (5).NE.0) GO TO 990

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) = IDPLOT
   MESSAGE (3) = 0
   CALL REMARK (MESSAGE)

60 READ (1) T1, T2, THILLI, (DATA (I), I=1, NPARAMS)
   IF (EOF (1).NE.0) OR. (THILLI.GT. STOP) GO TO 70
   IF (THILLI.LT. START) GO TO 60
   A = DATA (INDEXA)
   B = 0.
   IF (INDEXB.NE.0) B = DATA (INDEXB)
   C = A-3
   WRITE (2) C
   N = N+1
   GO TO 60

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PROGRAM SENSTAT 73/74  OPT=1

C

70 ENDIFIE 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

90 ENDFILE 3
   NSEGS=100
   CALL HSTGRAM(3)
   GO TO 40

C

990 CALL PLOT(20,0..999)

C

STOP "END OF JOB"

END
SUBROUTINE STATIST(FILE);
COMMON/STATDAT/XMIN,XMAX,MEAN,VAR,DEV,MEANSQ,RMS,SKEW,KURT,
+ XLOW,XHIGH,NGOOD,NTOTAL
COMMON/PLODAT/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(E3F(FILE).NE.0)GO TO 20
NTOTAL=NTOTAL+1
IF(X.LT.XMIN.OR.X.GT.XMAX)GO TO 10
NGOOD=NGOOD+1
SUM=SUM+X
X2=X*X
SUM2=SUMX2+X2
X3=X*X2
SUM3=SUMX3+X3
X4=X*X3
SUM4=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=FILE(NGOOD)
MEAN=SUMX/N
VAP=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"//
+1H2" TITLE",T28,6A10//" DATA FROM FILE NO.",T28,I2//
+1H3" PLOT ID",T28,6A10//" TOTAL NO. OF SAMPLES",T28,I6//
+1H4" ALLOWABLE MINIMUM",T28,G12.6//
+1H5" ALLOWABLE MAXIMUM",T28,G12.6//
+1H6" SAMPLES ALLOWED",T28,I6//
+1H7" OBSERVED MINIMUM",T28,G12.6//
+1H8" OBSERVED MAXIMUM",T28,G12.6//
+1H9" MEAN VALUE",T28,G12.6//" VARIANCE",T28,G12.6//
+1H10" STANDARD DEVIATION",T28,G12.6//" MEAN SQUARED",T28,G12.6//
+1H11" ROOT MEAN SQUARED",T28,G12.6//" SKEWNESS",T28,G12.6//
+1H12" KURTOSIS",T28,G12.6//" START TIME",T28,6A10//
RETURN
END
SUBROUTINE HSTGRAM(FILE)

COMMON/HISTORY/XMIN,XMAX,NSEGS,TALLY,NGOOD,NTOTAL
COMMON/PLTOAT/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)

MESSAGE(4)=PASSNO=0
PERCENT=0.95
NCONSEC=3

1 PASSNO=PASSNO+1
ENCODE(27.5,MESSAGE)FILE,PASSNO,IPLOT
5 FORMAT(***HSTGRAM***,I1,**RUN***,I2,1X,A10)
CALL REMARK(MESSAGE)

DO 10 I=1,NSEGS
10 TALLY(I)=0
REWIND FILE
NGOOD=NTOTAL=O
DELTA=(XMAX-XMIN)/FLOAT(NSEGS)

20 READ(FILE)*
IF(EQ(FIELD),NE.O)GO TO 40
NTOTAL=NTOTAL+1
IF(X,LT,XMIN)GO TO 20
TEST=XMIN

DO 30 I=1,NSEGS
TEST=TEST+DELTA
IF(Y.GT.TEST)GO TO 30
TALLY(I)=TALLY(I)+1
NGOOD=NGOOD+1
GO TO 20
30 CONTINUE

40 CALL DATE(DAY)
CALL TIME(HRMINSC)
WRITE(6,50)TITLE,FILE,IPLOT,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//)

TOTAL(1)=TALLY(1)
REMAIN(1)=NGOOD-TALLY(1)
FROM(1)=X=XMIN
UBRiOUTINE HSTGRAM  73/74  OPT=1

DO 60 I=2, NSEG$S
    TOTAL (I) = TOTAL (I-1) + TALLY (I)
    REMAIN (I) = NGOOD - TOTAL (I)
    .60 FROM (I) = TO (I-1) = X = X + DELTA
C
    TO (NSEG$S) = XMAX
C
    WRITE (6, 70) (I, FROM (I), TO (I), TALLY (I), TOTAL (I), REMAIN (I), I=1, NSEG$S)
 70 FORMAT ("** SEG, NO FROM", TO", TALLY", TOTAL", REMAIN", I=1, NSEG$S)

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, NSEG$S
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

XMIN = FROM (I)
100  CONTINUE

I = NSEG$S - NCONSEC

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

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

COMMON/HISTOAT/HISTMIN, HISTMAX, NSEGS, TALLY, NHGOOD, NHTOTAL
COMMON/PLOTOAT/XSCALE(4), YSCALE(4), HSTART, HSTOP, TITLE(6), IDPLOT
COMMON/OAYTIME/OAY, HRMINSC
INTEGER TALLY(110)
DIMENSION TOPLINE(4)
DATA TOPLINE/"MINIMUM", "MAXIMUM", "VALID OB", "S"

CALL PLOT(11, 0, 3)

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))

YMAX = 0.
DO 10 I = 1, NSEGS
TEST = FLOAT(TALLY(I))
10 YMAX = MAX(YMAX, TEST)

YSCALE(1) = 0.
YSCALE(2) = YMAX
CALL SCALE(YSCALE, 2, 1)
CALL Y90(0, 0, "SAMPLES PER INTERVAL", 20, 0, 0, 0, YSCALE(4))

X = (HISTMIN - XSCALE(3))/XSCALE(4)
CALL PLOT(0, 0, 1, X, 3)

DELTA = ABS(HISTMAX - HISTMIN)/FLOAT(NSEGS)
DO 20 I = 1, NSEGS
Y = FLOAT(TALLY(I))/YSCALE(4)
CALL PLOT(Y, 1, X, 2)
X = X + DELTA/XSCALE(4)
20 CALL PLOT(Y, 1, X, 2)

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)
HGGOOD = 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, OAY, 270, 10)
CALL SYMBOL(8.0, -9.00, 12, HRMINSC, 270, 9)

RETURN
END
SUBROUTINE PLNORM

COMMON/STATOAT/STATMIN,STATMAX,MEAN,VAR,DEV,MEANSQ,RMS,
SKEW,KURT,XLOW,XHIGH,NSGOOD,NSTOTAL
COMMON/HISTOAT/HISTMIN,HISTMAX,NSEGS,TALLY,NMG000,NHTOTAL
COMMON/PLOTOAT/XSCALE(4),YScale(4),HSTART,HSTOP,TITLE(6),IDPLOT
REAL MEAN,MEANSQ,KURT
INTEGER TALLY(100)
DIMENSION ABSCISS(302),ORDINATE(302),TOPLINE(6)

DATA TOPLINE/"MEAN","SQR","E RMS"," VARIANCE"," MEAN VA"," LUE STD"," DEV"/

X=XSCALE(3)
XINC=APS(XSCALE(4)/29.9)
COEFF=FLOAT(NSGOOD)*(XHIGH-XLOW)/FLOAT(NSEGS)/(2.5066*DEV)

DO 10 I=1,300
      ABSCISS(I)=X
      EXPON=-.5*(((X-MEAN)/DEV)**2)
      ORDINATE(I)=0.
      IF(EXPON.GE.-675..AND.EXPON.LE.741.)ORDINATE(I)=COEFF*EXP(EXPON)
10 X=X*XINC

      ABSCISS(301)=XSCALE(3)
      ORDINATE(301)=YSCALE(3)
      ABSCISS(302)=-XSCALE(4)
      ORDINATE(302)=YSCALE(4)

      CALL LINE(ORDINATE,ABSCISS,300,1,0,0)

      CALL SYMBOL(9,1,12,TOPLINE,270,54)
      CALL NUMBER(8.75,0.70,12,MEANSQ,270,3)
      CALL NUMBER(8.75,-0.70,12,RMS,270,3)
      CALL NUMBER(8.75,-1.75,12,VAR,270,3)
      CALL NUMBER(8.75,-3.25,12,MEAN,270,3)
      CALL NUMBER(8.75,-4.75,12,DEV,270,3)

RETURN

END
PROGRAM NORMFIT

COMMON/STATDAT/STATMIN, STATMAX, MEAN, VAR, DEV, MEANSQ, RMS,
    +     SKEW, KURT, XLOW, XHIGH, NSGOOD, NSTOTAL
COMMON/HISTDAT/HISTMIN, HISTMAX, NSEG, TALLY, NHG000, NHTOTAL
COMMON/PLMTDAT/XSCALE (4), YSCALE (4), HSTART, HSTOP, TITLE (6), IDPLOT
REAL MEAN, MEANSQ, KURT
INTEGER TALL (100)
DIMENSION DATA (100), ITIME (6), MESSAGE (3)

READ(5,10) TITLE
10 FORMAT (A110)
   IF (F) (5. NE. 6) STOP "NO TITLE CARD"

READ(5,10) HSTART, HSTOP
   IF (F) (5. NE. 6) STOP "NO TIME CARD"
   FBACKSPACE 5

READ(5,20) ITIME
20 FORMAT (2(3(I2,1X),1X))
   START = FLATAT (1000 * (3600 * ITIME (1) + 60 * ITIME (2) + ITIME (3)))
   STOP = FLATAT (1000 * (3600 * ITIME (4) + 60 * ITIME (5) + ITIME (6)))

READ(5,30) IDPLOT, INDEXA, INDEXB, NPARAMS, TOL
30 FORMAT (4(I10,3I10,F20.6))
   IF (F) (5. NE. 6) STOP "NO JOB CARDS"
   CALL PLOTS (4, 0, 4)
   CALL FLSTOP (.7871)
   CALL PLOT (0., 11., -3)
   GO TO 50

READ(5,30) IDPLOT, INDEXA, INDEXB, NPARAMS, TOL
40 IF (F) (5. NE. 6) GO TO 990

50 IF (INDEXA, GT. C. AND. INDEXA, LE. NPARAMS, AND.
   + INDEXB, GT. C. AND. INDEXB, LE. NPARAMS) GO TO 55
   CALL PERROR ("ILLEGAL JOB CARD")
   GO TO 40

55 REWIND 1

REWIND 2
   N = 0
   MESSAGE (1) = "FITTING 2"
   MESSAGE (2) = IDPLOT
   MESSAGE (3) = 0
   CALL PERROR (MESSAGE)

READ(1) T1, T2, THILLI, (DATA (I), I = 1, NPARAMS)
IF (EOC (1). NE. C. OR. THILLI, GT. STOP) GO TO 70
IF (THILLI, LT. HSTART) GO TO 60
C = DATA (INDEXA) - DATA (INDEXB)
WRITE (2) C
   N = N + 1
   GO TO F0

70 ENDFILE 2
   IF (N. NE. 0) STOP "NO DATA WITHIN TIME SLICE"
PROGRAM NORMFIT 73/74  OPT=1

STATHI=-1E99
STATHA=+1E99
MESSAGE(1)="STATIST 2"
CALL REMARK(MESSAGE)

CALL STATIST(2)
XLOW=HISTMIN=-1.2*TOL
XHIGH=HISTMAX=+1.2*TOL
NSEG=100
CALL HSTGRAM(2)
NSGO=NSGOO7
CALL PLNOFM

C
REWTO 2
XLOW=HISTMIN=MENG-3.*DEV
XHIGH=HISTMAX=MENG+3.*DEV
CALL HSTGRAM(2)
NSGO=NSGOO7
CALL PLNOFM
GO TO 40

C
990 CALL PLOT(20.,1.,999)
C
STOP "END OF JOB"
C
END

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SUBROUTINE STATIST

COMMON /STATOT/XMIN, XMAX, MEAN, VAR, MEANSD, RMS, SKEW, KURT,
+ XLOW, XHIGH, NGOOD, NTOTAL
COMMON /PLOT DAT/XSCALE(4), YSCALE(4), HSTART, HSTOP, TITLE(6), IPLOT
REAL MEAN, MEANSD, RMS, SKEW, KURT
INTEGER FILE

C

MEAN=0.0
VAR=0.0
MEANSD=0.0
RMS=0.0
SKEW=0.0
KURT=0.0
XLOW=-1.0E99
XHIGH=1.0E99
NGOOD=NTOTAL=0
C

C 10 REM FILE=FILE.X
IF (EOF(FILE), NE, 0) GO TO 20
NTOTAL=NTOTAL+1
IF (X, LT, XMIN, CR, X, GT, XMAX) GO TO 10
NGOOD=NGOOD+1
SUMX=SUMX+X
X2=X*X
SUMY2=SUMY2+X2
X3=X*X*X
SUMX3=SUMX3+X3
X4=X*X*X
SUMX4=SUMX4+X4
XLOW=A*MIN1(XLOW, X)
XHIGH=A*MAX1(XHIGH, X)
GO TO 10

C

C 20 IF (NGOOD.EQ, 0, ) STOP "SUBROUTINE STATIST HAS NO DATA"
N=FLOAT(NGOOD)
MEAN=SUMX/N
VAP=SUNX2/N*MEAN**2
IF (VAR.EQ, 0, ) STOP "SUBROUTINE STATIST SHOWS ZERO VARIANCE"
DEV=SOFT(VAR)
MEANSD=SUMX2/N
RMS=SOFT(MEANSD)
SKEW=(SUMX3/N-1./N)*MEAN*MEANSD+2./N*MEAN**3/(DEV*VAR)
KURT=(SUMX4/N-4.*MEAN*SUMX3/N+6./N*MEAN**2*SUMX2/N-3.*MEAN**4)/(VAR*VAR)
WRITE (1, 70) TITLE, FILE, IPLOT, NTOTAL, XMIN, XMAX, NGOOD, XLOW, XHIGH,
+ MEAN, VAR, MEANSD, RMS, SKEW, KURT, HSTART, HSTOP

FORMT (141) "RESULTS OF SUBROUTINE STATIST" //
1 "TITLE", T24, A10 // "DATA FROM FILE NO.", T24, I2 //
2 "PLOT NO.", T28, A10 // "TOTAL NO. OF SAMPLES", T24, I6 //
3 "ALLOWED MINIMUM", T28, G12, 6 //
4 "ALLOWED MAXIMUM", T28, G12, 6 //
5 "SAMPLES ALLOWED", T28, I5 //
6 "OBSERVED MINIMUM", T28, G12, 6 //
7 "OBSERVED MAXIMUM", T28, G12, 6 //
8 "MEAN VALUE", T24, G12, 6 // "VARIANCE", T24, G12, 6 //
9 "STANDARD DEVIATION", T24, G12, 6 // "MEAN SQUARED", T24, G12, 6 //
A "ROOT MEAN SQUARED", T24, G12, 6 // "SKEWNESS", T24, G12, 6 //
B "KURTOSIS", T24, G12, 6 // "START TIME", T28, A10 //
C "STOP TIME", T28, A10 //
RETURN
END
SUBROUTINE HSTGRAM

COMMON/HISTDAT/XMIN,XMAX,NSEGS,TALLY,NGOOD,NTOTAL
COMMON/PLTDAT/XSCALE(4),YSCALE(4),HSTART,HSTOP,TITLE(6),IDPLOT
COMMON/HRTIME/DAY,HRMINSC
INTERFACE FILE,TALLY(100),TOTAL(100),REMAIN(100),PASSNO

DIMENSION FROM(100),TO(100),MESSAGE(4)

MESSAGE(4)=PASSNO=0
PERCENT=0.95
NGCNSFC=3

1 PASSNO=PASSNO+1
END IF(27.5,MESSAGE) FILE,PASSNO,IDPLOT
5 FORMAT("HSTGRAM ",I1," PUN ",I2,1X,A10)
CALL REMARK(MESSAGE)

DO 11 I=1,NSEGS
10 TALLY(I)=0

READ FILE
NGOOD=NTOTAL=0
DELTA=1.00001*(XMAX-XMIN)/FLOAT(NSEGS)

20 READ(FILE)
IF(IF(30.0,ME,0)) GO TO 40
NTOTAL=NTOTAL+1
IF(X,LT,XMIN) GO TO 20
TEST=XMIN

DO 31 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

GO TO 20

40 CALL DATE(DAY)
CALL TIME(HRMINSC)
WRITE(F,5) 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 IC",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//)

TOTAL(1)=TALLY(1)
REMAIN(1)=NGOOD-TALLY(1)
FROM(1)=X=XMIN

-71-
SUBROUTINE HSTG

DO I=1,NSEGS
  TOTAL(I)=TOTAL(I-1)+TALLY(I)
  REMAIN(I)=NGOOD-TOTAL(I)
  FROM(I)=FROM(I-1)=X=X+DELTA
  TO(NSEGS)=XMAX

WRITE(F,70)(I,FROM(I),TO(I),TALLY(I),TOTAL(I),REMAIN(I),I=1,NSEGS)
70 FORMAT(1X,'SEG. NO FROM',1X,'TO',1X,'TALLY',1X,'TOTAL',1X,'REMAIN',1X,1X/)
      (13X,'REMAINING'/1002H,13X,4X,2G12.6,2X,3I5,4X/)

CALL PLHST

RETURN

END
SUBROUTINE PLIST 7.7/74  OPT=1  ORIGINAL PAGE 13  OF POOR QUALITY

COMMON/HISTDAT/HISTMIN,HISTMAX,NSEG, TALLY,NHG000,NHTOTAL 
COMMON/PLISTAT/XSCALE(4),YSCALE(4),HSTART,HSTOP,TITLE(5),IDPLT 
COMMON/DATAT/DATE/HMINSC 
INTEG TALLY(100) 
DIMENSION TOPLINE(4) 
DATA TOPLINE/"MINIMUM "," MAXIMUM "," VALID OR","S"/

CALL PLOT(0,0,0,0,0) 
XSCALE(1)=HISTMIN 
XSCALE(2)=HISTMAX 
CALL SCALE(XSCALE,10,2,1) 
CALL AXIG(6,,..,SCALAR VALUE",12, 10. 270.,XSCALE(3),YSCALE(4)) 
YMAX=0. 
DO 10 I=1,NSEG 
TEST=FLOAT(TALLY(I)) 
10 YMAX=AYAY1(YMAX,TEST) 

YSCALE(1)=C. 
YSCALE(2)=YMAX 
CALL SCALE(YSCALE,8,2,1) 
CALL AXIG(0,,0,,SAMPL ES PER INTERVAL",20,R,0..0..0.,YSCALE(4)) 
X=(HISTMIN-XSCALE(3))/XSCALE(4) 
CALL PLOT(0..-1.*X,3) 

DELTA=AY( HISTMAX-HISTMIN)/FLOAT(NSEG) 
DO 20 I=1,NSEG 
Y=FLOAT(TALLY(I))/YSCALE(4) 
CALL PLOT(Y,-1.*X,2) 
Y=Y+DELTA/XSCALE(4) 
20 CALL PLOT(Y,-1.*X,2) 

CALL PLOT(0,-1.*X,2) 
CALL SYMBOL(0.1.5.15,TITLE,0,.60) 
CALL SYMBOL(9.9.87,12,TOPLINE,270..31) 
CALL NUMBER(9.75,5.97,12,HISTMIN,270..3) 
CALL NUMBER(9.75,7.35,12,HISTMAX,270..3) 
HG000=FLOAT(NHG000) 
CALL NUMBER(9.75,8.50,12,NHG000,270..-1) 
CALL SYMBOL(9.75,9.35,12,"/",270..1) 
HTOTAL=FLOAT(NHTOTAL) 
CALL NUMBER(9.75,9.50,12,HTOTAL,270..1) 
CALL SYMBOL(8.0,-5,12,IDPLT,270..10) 
CALL SYMBOL(9.0,2,12,HSTART,270..8) 
CALL SYMBOL(9.0,3.12,12,"TO",270..2) 
CALL SYMBOL(9.0,3.50,12,HSTOP,270..8) 
CALL SYMBOL(9.0,-7.75,12,DAY,270..10) 
CALL SYMBOL(8.0,-9.00,12,HMINSC,270..9) 

RETURN 
END
SUBROUTINE PLOPNRM

COMMON/STATDAT/STATMIN, STATMAX, MEAN, VAR, DEV, MEANSD, RMS,
SKEW, KURT, XLOW, XHIGH, NSGOOD, NSTDAT
COMMON/HISTDAT/HISTMIN, HISTMAX, NSEG, TALLY, NHGOOD, NHTOTAL
COMMON/PLDAT/XSCALE(4), YSCALE(4), HSTART, HSTOP, TITLE(6), IDPLOT
REAL MEAN, MEANSD, KURT

DIMENSION ABSCISS(302), ORDNATE(302), TOPLINE(6)

DATA TOPLINE/"MEAN SQUARE", "RMS", "VARIANCE", "MEAN VAR",
"LUE STD", "DEV"/

X = YSCALE(3)
XINC = ABS(YSCALE(4) / 29.9)
COEFF = FLOAT(NSEG) * (XHIGH - XLOW) / FLOAT(NSEG) / (2.5066 * DEV)

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)
   X = X + XINC

10 ABSCISS(301) = XSCALE(3)
   ORDNATE(301) = YSCALE(3)
   ABSCISS(302) = -XSCALE(4)
   ORDNATE(302) = YSCALE(4)

CALL LINE(ORDNATE, ABSCISS, 300, 1, 0, 0)

CALL SYMBOL(9, 1, 12, TOPLINE, 270, 154)
CALL NUMBER(4, 75, 2, 60, 12, MEANSD, 270, 3)
CALL NUMBER(4, 75, 2, 70, 12, RMS, 270, 3)
CALL NUMBER(4, 75, 2, 85, 12, VAR, 270, 3)
CALL NUMBER(4, 75, 2, 25, 12, MEAN, 270, 3)
CALL NUMBER(4, 75, 2, 475, 12, DEV, 270, 3)

RETURN
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=SQRT(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 # FREQUENCIES 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(N)-X(1)
210 LET L=X(I)-W/2
220 LET M1=L-[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 = 0 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 = 0 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, #FREQUENCIES (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
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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

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

**FLIGHT = AFT14 FLT1A**

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

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

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

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

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

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

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

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

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### P(AF/DF) Table for Sensor Difference S-R = 0.087891

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

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### P(AF/DF) Table for Sensor Difference \( L-R \) = 0.029297

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### L-S = 0.099609

- \( L-R = 0.13477 \)
- \( S-R = 0.0351156 \)

### P(AF/DF) Table for Sensor Difference \( S-R \) = 0.0351156

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

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

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

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

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

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

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

P(AF/DF) Table for Sensor Difference = .076172

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Original page 13 of poor quality.
### P(AF/DF) Table for Sensor Difference $= .12891$

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### P(AF/DF) Table for Sensor Difference $L-R = .10547$

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### P(AF/DF) Table for Sensor Difference $S-R = .052734$

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

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

L-S = -.0058594  L-R = .22852    S-R = .23438
### Report of Sensor Redundancy Evaluation - C(NE)

**Reliability & Predictability of Alarm Response (P(AF/DF))**

For the sensor value in the domain of failure

**Pattern = Normal Acceleration**

Sensor differences are: L-S, L-R, and S-R

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**Curve Key**

- $995 = -$
- $996 = -$
- $997 = -$
- $998 = +$
- $999 = +$

---

**P(DF)**
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<th>VARIANCE</th>
<th>CHI SQ</th>
<th>MEAN VALUE</th>
<th>STD DEV</th>
<th>MINIMUM</th>
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**Unfiltered Data**

| FLO601 | 3 | 4 | 0 | 5 | 0 | 10 | 0 | 4 | 0 | 5 | 0 | 10 |

**Skewness**

-0.931

**Kurtosis**

6.130

---

The graph represents the probability density of roll rate gyro values. The histogram and the smooth curve show the distribution of the data points.
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<th>S-R</th>
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Parameter = ROLL RATE GYRO
Sensor differences are L-S L-R and S-R.

CURVE KEY

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

-95-
<table>
<thead>
<tr>
<th>L-S</th>
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<th>S-R</th>
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Sample No. = CRF/DF

Curves Key:
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T-S-R and S-R

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**UNFILTERED DATA**

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- KURTOSIS: 7.188

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- Normal Acceleration (S - R)
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