The CADAE computer program guides non-statisticians through experimental design, data entry/management and statistical analysis of a multi-objective searching scheme based upon Response Surface Methodology (RSM). The program consists of 29 screens written using the SAS/AF system on a MicroVAX II.

The searching strategy is to fit a response surface model for each of several performance attributes (dependent variables) over a single factor space and to utilize contour plots and grid searches to identify the factor level combinations which meet objectives on multiple performance attributes simultaneously.

Central composite and $2^k$ designs are offered with options to block orthogonally and to choose sample size according to the size of the factor effects to be detected. Randomization is applied.

Data entry employs SAS/FSP to retrieve the design factor level combinations in the randomized order so that the experimenter enters only the observed performance attribute responses.

Statistical analysis includes model diagnostics, contour plots of any pair of factors at fixed levels of all other factors and multivariate grid searching to identify factor level combinations that produce performance attribute levels which simultaneously meet corresponding project objectives.

GUIDING PRINCIPLES
Like Consulting a Statistical Expert - CADAE guides users through aspects of experimental design and analysis likely to be overlooked by experimenters who have little specialized statistical knowledge. These aspects include sample size selection, blocking, randomization and avoiding extrapolation beyond the experimental region.

Flexibility and Sophistication are Sacrificed for Simplicity - Some examples are: a) Design options include only orthogonally blockable central composite designs (CCD's) and the $2^k$ factorial designs embedded in them. b) Alpha and Beta errors for sample size evaluations are fixed at 5% and 20%, respectively. c) Only full models are fit to the data. Models cannot be customized by adding or removing terms.

The resulting simplicity allows users to carry-out the multi-objective response surface searching scheme with only a little expert assistance.

Some Expert Assistance is Required - Model diagnostics are produced with the recommendation that they be examined by a knowledgeable data analyst.

GETTING STARTED
The instructions for using CADAE are to fill in all information requested by each screen, moving among fields within a screen by pressing "key pad 4" and "key pad 5", and then press "PF3".

The initial screen is a menu with the following offerings:
Up to 8 performance attributes (dependent variables) can be accommodated. None, some or all can be defined during the session in which the project is initiated or they can be defined in subsequent sessions.

For each performance attribute, the following information is requested:

a) a name,
b) the standard deviation of replicate values,
c) either 1) the difference to be detected - CADAE computes sample size or -
   2) the desired sample size - CADAE computes detectable difference -
   all with alpha=5% and beta=20%. For CCD's, the detectable difference is across the factorial portion of the design. Different values of sample size and/or detectable difference may be tried repeatedly until a satisfactory sample size is found. 
d) the desired block size for blocked studies.

After the above information is entered, it is summarized and the user is given the opportunity to review and revise it. If the user does not revise, then a randomization/data recording sheet is produced.

Note that each performance attribute has its own individualized sample size, blocking scheme and randomization. This is appropriate when the performance attributes are measured in separate experiments but it is cumbersome when several performance attributes comprise a multivariate/vector response in a single experiment. Future versions of this program should correct this shortcoming.

DATA ENTRY AND MANAGEMENT
Data entry or editing is initiated by selecting "Data Entry" in the initial screen. The subsequent screen provides instructions for entering or altering the data for a given performance variable using SAS/FSP.

The SAS/FSP screens recall the observations in the same order as the randomization/data recording sheet and display all factor levels so that the user need only key-enter his observed responses in the order in which they were collected. The data set is printed at the user's option.

STATISTICAL ANALYSIS
Selecting "Analyze Performance Attribute Data" leads to the Analysis menu:

Model diagnostics are produced for a given performance attribute by selecting the first menu item. The diagnostics include a histogram of the data, the ANOVA produced by PROC RSREG, a plot of residuals vs predicted values, and a PROC UNIVARIATE for the residuals. The ANOVA, which accounts for any blocking, provides a lack-of-fit test, tests for the significance of all terms of the second order model and, for 2^k studies, a test for curvilinearity (Since RSREG fits a full second order model, all curvilinearity in a 2^k study is attributed to the squared term of the first factor). The UNIVARIATE procedure provides a stem and leaf plot of the residuals, a test of their normality and other information.

Contour plot for any two factors at fixed levels of all other factors are produced by selecting the second item in the Analysis Menu and providing the information requested in the following screen:
The example of user input shown above produced the contour plots shown below. Note that the plotted circular areas change in size to avoid extrapolating beyond the experimental region, which is hyperspherical for CCD's. For 2^k designs, the experimental region is a hypercube, therefore, contour plots are square and equal in size at different levels of the non-axis factors.

```
CONTOUR PLOT FOR PROJECT: FACT3
PERFORMANCE ATTRIBUTE: CLEAN
10/22 WEDNESDAY, FEBRUARY 3, 1988
PP1=1.5

CONTOUR PLOT OF X1*X2
```

The third item in the analysis menu initiates multi-objective grid searching. The first search screen requests the names of all performance attributes to be simultaneously searched in the session and the approximate number of points to be searched, either 1000 or 5000. Completion of this screen creates a data set containing the factor levels evenly distributed in the experimental region (without extrapolating beyond it, as described for contour plotting). In addition to the factor levels, each data set record contains values for all selected performance attributes predicted by their regression models at that point. This data set constitutes a "digitized" representation of the response surface system.

```
CONTOUR PLOT FOR PROJECT: FACT3
PERFORMANCE ATTRIBUTE: CLEAN
10/22 WEDNESDAY, FEBRUARY 3, 1988
PP1=3

CONTOUR PLOT OF X1*X2
```

```
CONTOUR PLOT FOR PROJECT: FACT3
PERFORMANCE ATTRIBUTE: CLEAN
10/22 WEDNESDAY, FEBRUARY 3, 1988
PP1=3

CONTOUR PLOT OF X1*X2
```
The desired performance level for each selected performance attribute is provided in the next screen:

<table>
<thead>
<tr>
<th>PERFORMANCE ATTRIBUTE</th>
<th>PERFORMANCE OBJECTIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUMBER</td>
<td>NAME</td>
</tr>
<tr>
<td>1</td>
<td>CLEAN</td>
</tr>
<tr>
<td>2</td>
<td>DISN</td>
</tr>
</tbody>
</table>

Objectives of the form "4.5 < CLEAN < 5.5" can be applied to an attribute by listing it twice in the table, "CLEAN < 5.5" and "CLEAN > 4.5". Completing this screen initiates the search of the digitized response surface system for points which simultaneously satisfy all performance objectives.

The outcome of the search is summarized in the Search Review screen:

The key benefit of this "digitized" representation of the response surface system is that it provides an effective way to thoroughly search multiple response surfaces when the number of factors becomes too high for effective use of multiple contour plots.

Using grid searching of the digitized response surface system, CADAE can accommodate from 1 to 8 factors with from 1 to 8 performance attributes, thus greatly extending the complexity and thoroughness of the empirical searches which are typically used by most researchers.

The digitized response surface system may be searched repeatedly. If the first pass finds no points which meet all objectives, the user may revise the performance objectives to identify available trade-offs. If the first pass finds a very large number of points which meet all objectives, the user may wish to search again using more ambitious objectives.