Technology Service Corporation

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TSC-PD-B571-4

DESIGN OF AN IMPROVED AIR QUALITY TELEMETRY SYSTEM

FINAL REPORT

March 1979

by

John A. Eldon
Michael D. Teener
John D. Gins

Submitted to:

California Air Resources Board
Sacramento, California 95814

in fulfillment of Contract Number A6-207-30

Contract Officer:

Mr. Charles Bennett

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ABSTRACT

This is the final report for an engineering study of the feasibility of improving the air quality telemetry system maintained and operated by the California Air Resources Board. The three previous (interim) reports for this contract involved: 1) description of the existing system, identification of needed expansions and improvements, and design of four alternative systems incorporating these improvements, 2) engineering analysis of the four designs, to identify their relative advantages and drawbacks, and 3) detailed specification of the hardware and software for the improved system design most likely to meet the ARB's requirements.

The primary requirement for an air quality telemetry system is reliability, so that it will produce an acceptably complete and accurate record of observed air pollution concentrations. The new system must also be flexible, to permit the operator to modify or augment its data quality tests and data display routines to suit the ARB's changing needs. Finally, the new system must provide enhanced data collection capacity, to allow the direct connection of up to 60 additional air monitoring sites. (The current system comprises 20 sites and cannot be expanded without substantial modification of hardware and software.) The added sites will significantly reduce the number of future local air pollution episodes missed by the AQTS.

Part I of this document briefly describes the existing air quality telemetry system and lists the needed improvements. Part II sets forth detailed engineering specifications for an improved system designed to meet the ARB's objectives cost-effectively.

This report was submitted in fulfillment of Contract Number A6-207-30 by Technology Service Corporation, Santa Monica, California, under sponsorship of the California Resources Board. Work was completed in February, 1979.

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PART I

FEASIBILITY STUDY REPORT ON AN IMPROVED AIR QUALITY TELEMETRY SYSTEM

1.0 INTRODUCTION

The California Air Resources Board (ARB) currently maintains an Air Quality Telemetry System (AQTS), which monitors, in real time, the ambient concentrations of various air pollutants at approximately 20 sites spread throughout the state. Although this system has been operating reliably for several years and has met past requirements, it cannot be simply expanded to provide new capabilities required in the immediate or long-range future. Therefore, the ARB plans to modify and upgrade the AQTS to allow the necessary future changes to be made quickly and economically.

The present part (I) of this document reviews the existing system and the need for improvement and modification, lists four alternative improved systems capable of meeting the ARB's objectives to varying degrees, and identifies the most promising of these four objectives. Part II sets forth detailed engineering specifications for the hardware and software of the best option, incorporating changes suggested by the ARB.

Part I of this report, which summarizes two earlier interim reports, is divided into 6 chapters, including this Introduction. Chapter 2 describes the existing ARB AQTS, while Chapter 3 describes several local and regional AQTS in various parts of the state. Chapter 4 lists the criteria and objectives for an improved AQTS. Chapter 5 presents four alternative configurations for the improved AQTS, while Chapter 6 evaluates these and identifies the one most likely to meet the ARB's objectives.

2.0 EXISTING ARB AIR QUALITY TELEMETRY SYSTEM

2.1 HARDWARE CONFIGURATION

The existing ARB air quality telemetry system (AQTS) is a Monitor Labs (ML) system, number 10153. Currently, data from nineteen stations are being telemetered to the ARB headquarters in Sacramento. A complete configuration is given in Table 2.1, and a map depicting the locations of the remote sites is shown in Figure 2.1.

The central station uses a 32K Nova 1210 mini-computer with a pre-packaged software program (ADAM) as the foundation of the telemetry system. Included in the central station are an interface (ML 4100), power supply, time-of-year clock (ML 3100), and three leased-line modems (ML 4400L). Input devices consist of an ASR-33 teletype, REMEX 6500 paper-tape reader, and an Infoton CRT. Output devices are the ASR-33 teletype, Infoton CRT, Centronics 101A serial line printer, and a Pertec 6860 magnetic tape unit. Diagrammatic configurations are given in Figures 2.2 and 2.3.

TABLE 2.1 REMOTE SITE CONFIGURATION OF ARB AQTS

S.C.	I.D.	CITY	CHANNEL 0	1	2	3	4	5	6	7	8	9	10	11	12	13	
1	SAC 282	SACRAMENTO	O_3	NO_2	NO_x	CO	Hc	COH									
2	FAT 234	FRESNO	O_3	NO_2	NO_x	CO	Hc	COH					NE	SE	SW	NW	
3	BFL 203	BAKERSFIELD	O_3	NO_2	NO_x	CO	Hc	COH			SO_2		NE	SE	SW	NW	
4	TEM 580	TEMPLE CITY	O_3	NO_2	NO_x	CO	Hc	COH			VIS	NEP	•				
5	UPL 175	UPLAND	O_3	NO_2	NO_x	CO			RAD	O_3	SO_2		NE	SE	SW	NW	O_3 AT FONTANA
6	RAL 146	RIVERSIDE	O_3	NO_2	NO_x	CO			O_3				NE	SE	SW	NW	O_3 AT ESCONDIDO
7	LAH 177	LA HABRA	O_3	NO_2	NO_x	CO					SO_2						
8	CIC 621	CHICO	O_3	NO_2	NO_x	CO	Hc	COH			VIS	NEP					
9	RCH 433	RICHMOND	O_3			CO					SO_2						OUT OF SERVICE
10	SJC 382	SAN JOSE	O_3			CO				O_3							OUT OF SERVICE
11	SBA 355	SANTA BARBARA	O_3	NO_2	NO_x	CO	Hc	COH									
12	SIM 413	SIMI	O_3			CO	Hc	MPH	DEG								
13	PSP 137	PALM SPRINGS	O_3			CO											
14	LOS 001	LOS ANGELES	O_3	NO_2	NO_x	CO					SO_2	NEP					
15	LNX 076	LENNOX	O_3			CO					SO_2						
16	LGB 072	LONG BEACH	O_3			CO					SO_2						
17	MLE 581	MOUNT LEE	O_3					MPH	DEG		°C						
18	SMX 304	SANTA MARIA															OUT OF SERVICE
19	ESC 115	ESCONDIDO	O_3														RIVERSIDE CHANNEL 6
20	FON 170	FONTANA	O_3														UPLAND CHANNEL 7

Figure 2.1. Location of ARB AQTS Sites

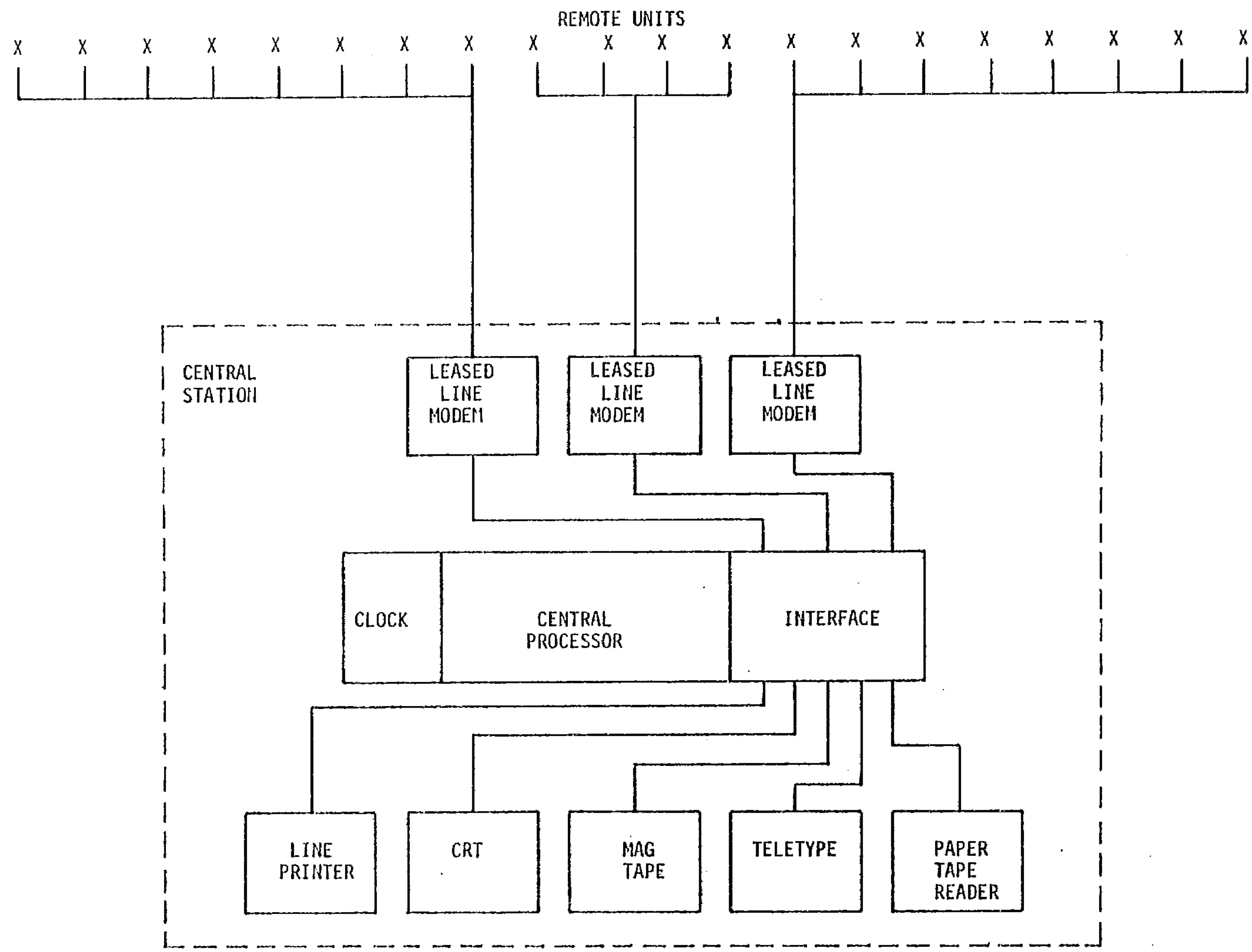


Figure 2.2. Hardware Configuration of ARB AQTS

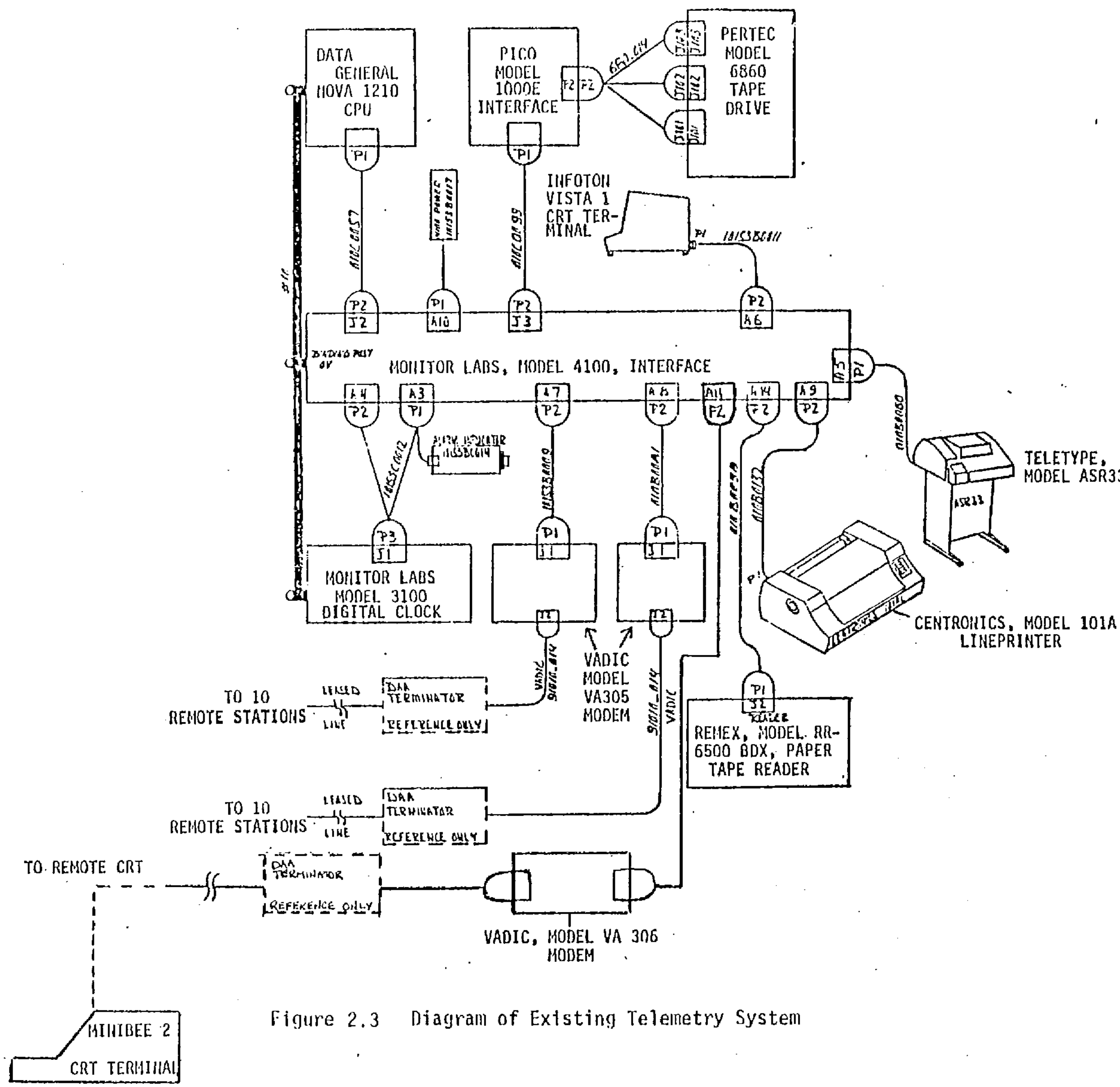


Figure 2.3 Diagram of Existing Telemetry System

2.2 SOFTWARE (ADAM III)

The existing ADAM III program by Monitor Labs is a user-oriented package which accesses air quality data, checks the data, and performs conversion, linearization, averaging, and reporting. Its flexibility allows operator controls of all aspects of the program in an easy-to-use method.

Some of the principal features of the system are as follows:

1. Provides two input alarm checks on each channel's instantaneous and hourly average data.
2. Detects instantaneous peak values for each channel.
3. Detects hourly average peak value for each channel.
4. Calculates true 15-minute, 30-minute, 1-hour and 24-hour averages.
5. Allows operator selection of linearization and conversion curves for each channel.
6. Allows operator to adjust easily the scale changes for each channel.
7. Monitors per channel rate-of-change.
8. Selects per channel automatic zero or span adjustment.
9. Includes automatic or manual entry of zero and span adjustment values for each channel.
10. Reports average wind direction and speed using vector arithmetic.
11. Supports coefficient of haze instruments.
12. Detects remote station and telephone equipment failures.
13. Continues operation in the event of output device malfunction.
14. Continues updating and reporting of hourly data in the event of input device, output device, or operator error.

The following subsections briefly describe some of the operational functions of the ADAM program. More details are available in the Monitor Labs Document 5000B ADAM III Users Manual.

Operational Features

Operator control is based on a 3-stage hierarchy of application: (1) system-controlled functions which pertain to the entire operation, (2) station functions which configure individual stations, and (3) channel functions which configure each individual channel within a station. The 15 operator intervention functions are as follows:

Channel (CHL)	Creates or changes one of a station's channel tables.
Check (CHK)	Forces a scan of a system station and reports the data in its input form regardless of errors or format.
Clear (CLR)	Cold, warm, or hot starts individual stations and channels.
Device (DVC)	Places the input and output devices in and out of service. This is used for changing paper, changing magnetic tape, performing off-line maintenance, etc.
Heading (HDG)	Creates or changes the alphanumeric heading of each channel used when outputting the results of a scan. Headings apply to all stations.
Linearity (LIN)	Creates or changes linearity tables used for converting a channel's data from voltage to engineering units.
Message (MSG)	Allows the operator to send a message to any system output device.
Playback (PBK)	This optional function allows magnetic tapes to be read and the previously recorded data to be printed.
Relay (RLY)	Reports status, manually enables, disables, opens and closes specified system relays.
Relay Operate (ROT)	Creates or changes relay operate tables used to define when a channel's relay is to be closed and opened.

Running Averages (RUN)	Changes the output frequency of running averages. For example, it may be desired to have 6-hour running averages output only every 6 hours instead of every hour.
Save (SAV)	Generates a tape of the current tables and parameters. If needed, this tape can be used to reload without having to re-enter operator data.
Scan (SCN)	Forces a scan of any of the system's stations.
Station (STN)	Creates or changes station tables.
System (SYS)	Changes the System Table which contains variables that apply to all stations and all channels in the system.

Synopsis of System Operation

Once all the particular tables have been specified, the program is allowed to run in an automatic mode. Every 5 minutes, ADAM begins an automatic scan and acquisition of data from each of the remote units. The polling sequence is specified according to the identification (select code) of the individual remotes. If any remote fails to respond or the data are in a garbled format, the re-polling of that station will take place at the end of the normal sequence.

Output for each of the scans is specified according to I/O devices. Data from all created channels are displayed, even though some channels may not even exist at a particular site. In that case, a flag is given (equivalent to an out-of-service channel) indicating that no such data are available. A complete list of possible flags is given below:

@ = The instantaneous or hourly average exceeded the warning limit specified for the channel.

* = The instantaneous or hourly average exceeded the limit specified for the channel.

> = The data varied more than the allowable change allowed for the channel.

N = Data was not taken; for example, it is being ignored during the zero or span settling time.

S = Span calibration value

Z = Zero calibration value

X = Channel is out of service

W = Warning, an hourly or daily average has less than the minimum number of readings specified by the operator or a running average was calculated with less than the necessary number of valid one-hour averages.

4-9 = Channel's status specified by a thumbwheel switch, analyzer status, or operator status.

Every hour, on the hour, tabulations of vital hourly data are performed and output, again according to specified I/O devices. Hourly summaries include both the instantaneous and hourly values, as well as any defined running averages.

Alarm conditions (when incoming data exceed specified alarm criteria) are denoted by flagged output and a change in scanning rate (if the alarm-scan rate has been selected to be different than the automatic scan rate). If the alarm is exceeded on an instantaneous scan, the alarm mode exists until the values drop below the alarm level. If the alarm is exceeded for an hourly average, the alarm mode will remain active until the next <u>hourly average</u> drops below the alarm level, even though the instantaneous values may have dropped below alarm criteria some time earlier.

At the end of the day (at midnight) a daily summary is output, containing peak values, maximum hourly averages, and their respective occurrence times. Daily averages are also available. If less than the specified number of scans were obtained during the 24-hour period, then the data are reported with a flag indicating an insufficient number of scans.

Errors occurring from non-accessibility of data or from I/O device failures are also reported automatically. Error messages are as follows:

"bbXXbb HAD EXCESSIVE DIAL ERRORS"

Station XX failed to respond after the number of times specified for the system. That station is excluded from processing and reporting for the current scan.

"bbXXbb HAD EXCESSIVE DATA ERRORS"

Station XX produced transmission or format errors after the number of times specified for the system. That station is excluded from processing and reporting for the current scan.

"TIME OUT ON XX"

Output device XX has failed while being used. The malfunctioning device is ignored for the remainder of the scan and retried during the next scan.

"NOT RDY ON XX"

Device XX has been specified for output and is in service but is not ready and on-line. Reporting continues on other devices specified and the unit will be tried again next scan.

"NO WRITE RING FOR XX"

Magnetic tape unit XX does not have a Write Enable Ring installed. Reporting continues for other devices specified and the unit will be tried again next scan.

"MT ERRORS ON XX"

Magnetic tape unit XX has given excessive errors. Reporting continues on other devices specified and that unit will be tried again next scan. This message does not occur until the operation has been tried the number of times specified in the System's Table "MT TRIES" entry.

In addition to the automatic features, the system allows for several intervention functions. Specific site scans can be generated at the input device using the SCN function. Data output is in the same format as a normal scan, except it is limited to the one particular site scanned. Using the CHK function, data are output in digital voltage format. This allows for convenient status checking between the remote unit and the central station. Specific instrument troubleshooting can be accomplished using this function.

Additionally, the operator can intervene to change any of the configuration tables at any time. This is convenient whenever field instruments are added, deleted, or changed. Constant updating of the total configuration is therefore possible without major revisions to the ADAM III software package.

3.0 EXISTING LOCAL DISTRICTS' AQT SYSTEMS

According to Larry Molek and Jerry Wendt of the ARB, the only California air pollution control districts that have telemetry systems are: Bay Area Air Pollution Control District, San Diego County Air Pollution Control District, Santa Barbara County Air Pollution Control District, Sacramento County Air Pollution Control District, South Coast Air Quality Management District, and Ventura County Air Pollution Control District. Although all of these districts use their telemetry systems for episode data, they still have historical data keypunched. Currently there is no direct link between the telemetry systems and the historical data bases. The majority of the counties sample only for particulates, using a HIVOL sampler. A few of the counties also sample for SO_2, but the data are reduced by hand from strip charts.

3.1 SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT'S TELEMETRY SYSTEMS

The SCAQMD currently has a separate telemetry system for each of its four counties. The SCAQMD plans to integrate the four networks into a single system, built around a new minicomputer, to be purchased in 1980.

The 14 stations in Los Angeles County are currently hooked to an Interdata 4 computer in downtown Los Angeles. The 6 stations in Riverside County are tied to a Nova 2 computer in El Monte, and the 7 stations in San Bernardino County are tied to a Nova 1220 computer, also in El Monte. Compatibility between this system and the existing ARB system was demonstrated in a 1975 test, whereby the use of a phone coupler and an additional output device at the ARB allowed for direct access of data from the San Bernardino Control Station. The 6 stations in Orange County are hooked to a DEC PDP11 in El Monte.

The reader can refer to Fig. 3.1 for a map showing the SCAQMD stations and their telemetry systems.

3.2 BAY AREA AIR POLLUTION CONTROL DISTRICT'S TELEMETRY SYSTEM

The BAAPCD telemetry system (see Fig. 3.2) currently handles twenty air monitoring stations. They are using a Physics International computer to give a printout of each set of parameters for each station at ten-minute intervals. All data reduction for episodes is done by hand.

3.3 TELEMETRY SYSTEMS FOR SANTA BARBARA, SACRAMENTO, SAN DIEGO, AND VENTURA COUNTIES

Table 3.1 lists the stations that are currently on telemetry systems in these four counties. Santa Barbara and Ventura Counties both have a Receptor's monitoring system with PDP 11 computers.* San Diego county utilizes a Nova 1220 as the computer for their telemetry system. They are in the process of having their software rewritten to handle more than ten stations. Sacramento county is using a Multisonics 8080 computer with a dual floppy disk system.

*At this writing, there are plans to replace the Ventura County PDP-11 computer in the near future.

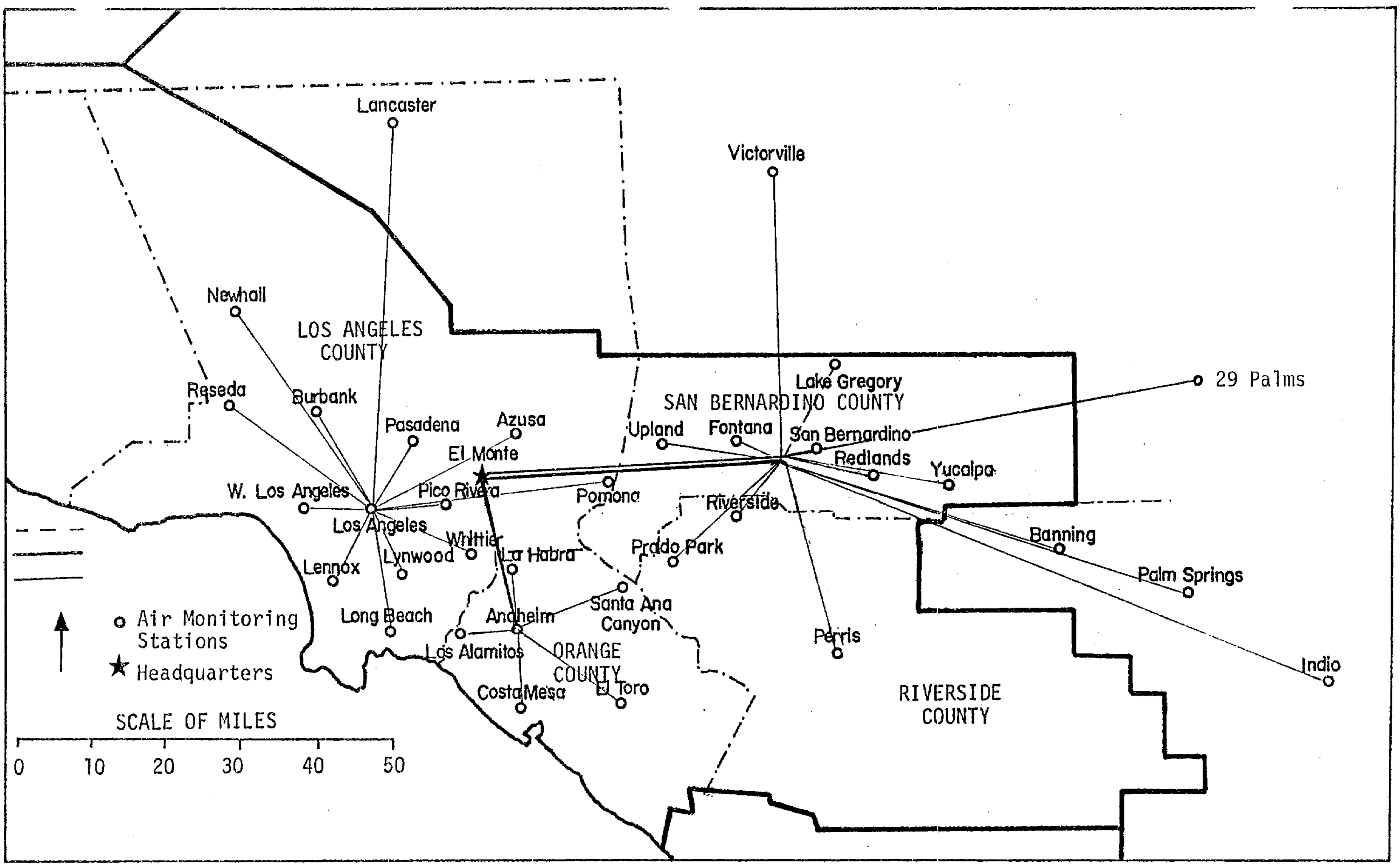


Figure 3.1 South Coast Air Quality Management District Telemetry System

main telephone lines
individual lines

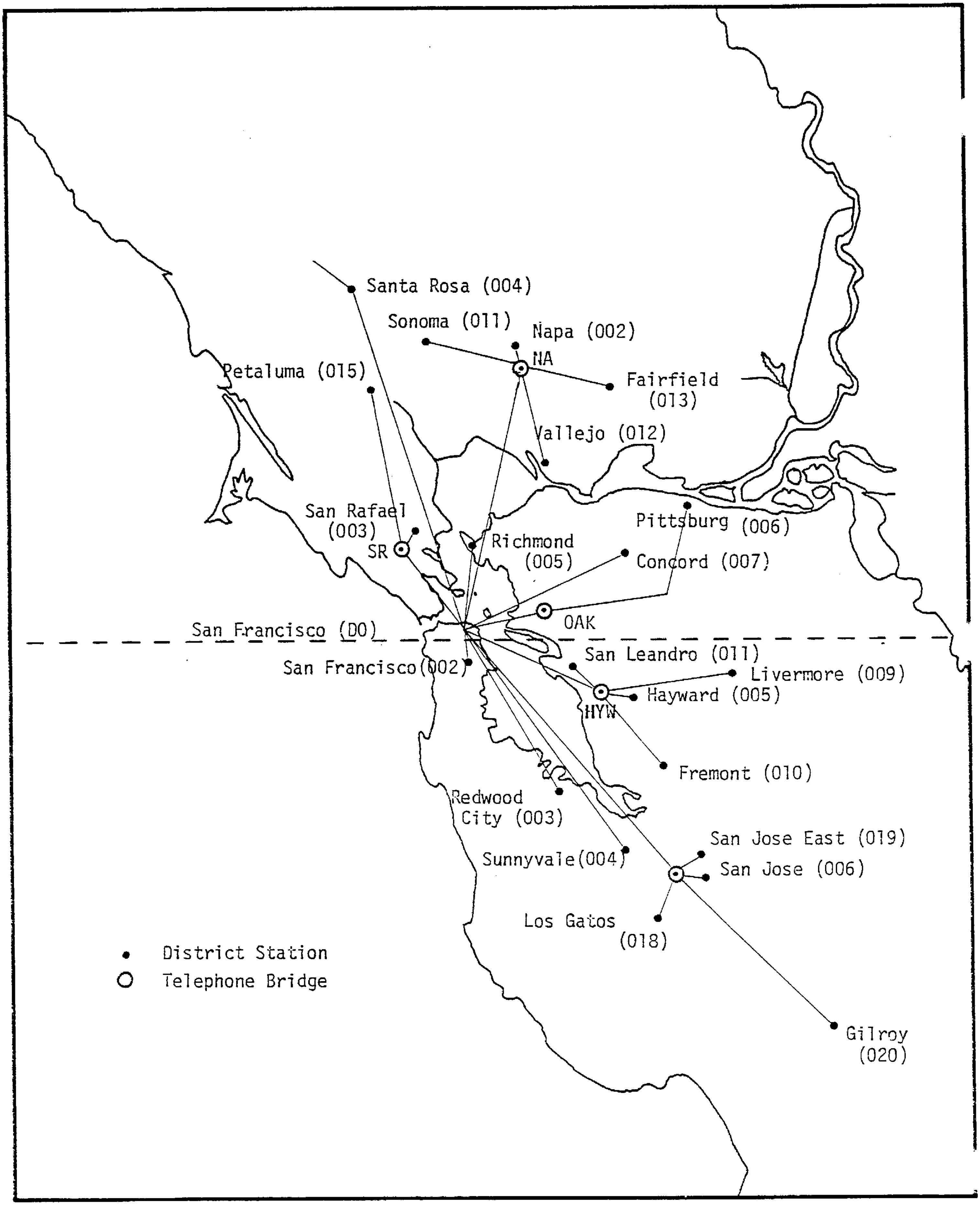


Figure 3.2 Bay Area Air Pollution Control District Telemetry System

TABLE 3.1 A LISTING OF STATIONS HOOKED TO THE VARIOUS TELEMETRY SYSTEMS OF VENTURA, SANTA BARBARA, SACRAMENTO, AND SAN DIEGO COUNTIES

Ventura County	ARB Station Designator
1. Ojai Valley	56-402
2. Piru	56-418
3. Port Hueneme	56-412
4. Simi Valley	56-413
5. Thousand Oaks	56-415
6. El Rio	56-419
Santa Barbara	
1. Goleta	42-363
Sacramento	
1. Creekside School (Sacramento)	34-278
San Diego	
1. Escondido (ARB)	80-115
2. Alpine	80-128
3. El Cajon	80-104
4. Chula Vista	80-114
5. San Diego	80-120
6. Oceanside	80-121
7. Kearny Mesa	80-123
10. Imperial Beach/Brownfield*	80-127

*Imperial Beach has been switched to Brownfield.

4.0 RECOMMENDED IMPROVEMENTS FOR ARB AQTS

This chapter summarizes telemetry system recommendations made by the authors and the ARB staff and lists features to be considered in the design of the improved AQTS. The objectives of these suggestions are enhancement of the system's reliability, flexibility, and simplicity of operation.

4.1 IMPROVED DATA GATHERING

The key word in this area is reliability of both the data and the hardware, to insure that the system accurately and consistently detects air pollution episodes. This is essential for real-time data input to the air quality information system, for confidence in calling episodes or health advisories, and for the establishment of optimal air pollution abatement policy.

The data system must be able to establish the objective reliability of air quality data for each station. The full set of data quality tests, which includes several comparisons of present to historical data, can be performed only on stations and pollutants with a sufficient amount of past data. Data verification at newer stations is limited to contaminant interaction and spatial distribution tests.

A data collection back-up feature should be built into the computer system, to allow data to be continuously gathered, even if one hardware component is down for routine maintenance or repair. This back-up feature can temporarily override the data reliability functions, as long as data gathered under it is reliability-tested when the system is restored.

The system should be able to automatically recover after a power outage, voltage drop or any other external cause for complete automatic shutdown. Automatic equipment recovery should be available at each station, as well as the central computer. An emergency power supply may be appropriate for the central computer. The system should be designed to eventually handle all air monitoring stations in the state.

One or two extra channels should be provided. These channels would be reserved for testing new equipment. In this way new equipment and/or repaired equipment could be completely checked with the computer before being put in the field. New types of equipment could be calibrated with equipment already in use. The statistics packages available with the new telemetry system could be used to derive a calibration or correction curve. It is anticipated that one of these channels could go to the ARB test facility in El Monte.

The capacity to interface with various automatic calibration systems should be built into the system. Software design should include the capability to check this calibration data for excessive drift and rate of change. Calibration data (zero or span) received by the telemetry system which has drifted in excess of a control value or has exceeded a predetermined rate of change should be flagged so action can be taken to correct the condition which caused the problem.

The system should also be expanded to permit the direct connection of up to 60 additional stations. With 20 stations, the present ARB ADAM III system is operating near capacity, with little or no room for additional stations or channels. Because this small system provides only spotty coverage of the state, it will frequently miss local air pollution episodes. Expansion of the system can significantly reduce the number of missed episodes. It would be particularly useful if the improved system could use data that is collected by the local districts or, at the very least, could use the same sensors. This additional station capacity would allow much more reliable and accurate reporting in the areas most likely to report incidents.

4.2 IMPROVED DATA VERIFICATION AND DISPLAY

The key word in this area is flexibility. Software and hardware should be designed to facilitate the decision-making process. The user must be provided with timely, succinct reports and also must be able to interact with the system to obtain more detailed information.

Along with a set of standard output formats, the system should allow a high degree of user control over output display and format. The user should be able to design, easily, new output formats which can be saved along with the standard set for use as a regular report.

The system should be ultra-responsive to control by the user in all aspects. This should include, but not be limited to, recall of prior scans, suppression of erroneous or meaningless forced outputs, interruption of output programs without loss of meaningful output data, and an ability to limit any alarm feature to a first-occurrence mode. Simple release of these suppression features should also be provided. The system shall include software to calculate and display any statistics which would indicate exceedance of episode levels or violation of state or federal standards. These statistics can include moving averages, set time averages, and functions of more than one contaminant statistic.

As an additional data verification tool, the system should include a statistics package to allow the user to perform multiple linear regression analysis and to compile multi-variate frequency distributions of any air quality, meteorology, AG-Burn, or calibration data collected by the system. An uncomplicated way of performing simple data transformations should also be included.

The system should provide for manipulation of data by time, space, and pollutant. The user should be able to group data by terrain, air basins, regions, or any other user-defined areas.

Specific software should be provided to do the following:

- Prepare and output wind flow trajectories both numerically and graphically.
- Store manually input meteorology and air quality data. This data will come from weather TTY'S SVC "A", SVC "C", LAX PONY, and AQ TTY from SCAQMD. Some data, such as vertical sounding data, may have to be pre-processed before storage.
- Plot user-specified parameters. These plots as a minimum would be:
  - Daily time continuity for each station on telemetry both separate and composite
  - Mean monthly diurnal plots for selected parameters and locations.
  - Area plots of a region or basin with isopleths for air contaminants, population exposure, and exposure-area products.

- Day-to-day continuity of selected meteorological parameters, such as LAX and EMT inversion data (base, DT, top and top temperature), VBG and MYF 500-mb heights, selected surface pressure differentials, and LAX and 850-mb temperature.

An appropriate Basic or Fortran compiler should be provided to allow the user to put existing air quality prediction programs on the computer. This should provide the user with the tools to put other helpful programs on the system. These would include dispersion programs and other analytical tools that might be developed in the years to come.

The system should include various "how-goes-it" features whereby statistics on episodes are computed, stored, and displayed and prediction verifications are calculated and displayed.

The system should be able to examine historical meteorological and air quality information and find an analogous day for today or tomorrow. Selected data from these days could then be made available to the user.

The system's software, as well as hardware, should come with a full range of documentation. This documentation should be readily understandable to the user. Examples of the many things that can be done on the system should also be provided.

All the software (source and object programs) necessary to make this system run should be made deliverable to the ARB. Thus, if, at some future time, data modifications are required, they can be easily made. This software should be structured where possible and well-documented. A necessary condition of software acceptability would be to specify that it works correctly on the computers that the ARB will use for the telemetry system.

4.3 SUMMARY OF REQUIREMENTS AND PERFORMANCE CRITERIA

The requirements for the improved AQTS can be summarized as follows:

1. The AQTS shall be operational at all times. Even if any major subsystem is not operational, the data from at least some of the stations will still be recorded.
2. The data recorded by the AQTS shall be the most reliable available. The currently existing checks on data reliability must be improved.
3. The display formats must be made more flexible. Simple graphical displays and geographic groupings of data will greatly ease data verification and interpretation.
4. Historical data must be available for display. Accurate prediction, policy, and data verification decisions require timely comparison of current to historical data.
5. It must be possible to modify the AQTS in the future, to enable it to prepare and edit data tapes for quarterly reports. Preparation of the written quarterly reports now requires extensive manpower. If the AQTS could regroup its data into the proper format and allow easy editing of the data, it could ease this strain on the ARB staff.
6. Other desired display and data reliability procedures must be easily added. The AQTS must provide enough reserve capacity for expansion that future demands will not require a complete new system.

7. It must be possible to increase the number of stations to whatever is necessary to meet future requirements. The maximum number of stations is estimated to be 60 in the long term, but reserve capacity beyond that is probably advisable, particularly if the regional telemetry systems are used.

The performance of the improved AQTS will be measured using the following criteria:

1. The percentage of time that the full system is operational (recording and displaying data from all working stations).
2. The percentage of time that the system is at least partially operational (recording data from at least the critical stations and displaying that data in a limited subset of formats).
3. Increased data reliability so that less data editing needs to be done for AQTS data than from other sources.
4. Presentation of useful data displays in a variety of formats.
5. Availability of AQTS data in standard formats so that it can be included in the State's air quality data banks.
6. An increased number of stations that can be easily added to the AQTS.
7. The capability to use regional and meteorological telemetry systems if the need arises.

4.4 CONSTRAINTS ON SYSTEM IMPROVEMENT

a. The Meteorological Section will have one person that can devote 25% of his or her time to programming and utilizing the software capabilities of the new AQTS.

b. The Air Quality Monitoring Section presently allocates one person for maintaining and trouble shooting the existing system. No additional resources will be available for this function.

c. There will be $175,000 of funds available from the FY 77-78 and 78-79 budgets. There should be no constraint imposed by the new system on later including more advanced capabilities than presented in this document. These more sophisticated capabilities will be specified in a future document after initial experience with the advanced AQTS.

4.5 CONSEQUENCES OF FAILURE TO ACT

The purpose of this project is to include more stations on the existing telemetry system and to provide the Meteorological Section with the capability to issue improved episode predictions and agricultural burning decisions. This requires more data reliability and much improved data display and interpretation capabilities. In addition, the improved system would permit more rapid response to request for analysis from the Executive Office and other staff agencies. Failure to act will not provide for the needed expansion and improved capabilities.

5.0 APPROACHES TO IMPROVING THE AQTS

5.1 IMPACT OF REQUIRED IMPROVEMENTS ON HARDWARE AND SOFTWARE

The improvements specified in the previous section require a number of changes in AQTS hardware and software. This section discusses the changes required in data collection, data verification and display, and data storage.

5.1.1 Data Collection

There are two main areas for improvement in the data collection portion of the ARB telemetry system. The first of these, reliability, is an absolute requirement.

Reliability can be increased in two ways: either the inherent reliability of individual subsystems can be improved, or the subsystem can be duplicated. Duplication tends to be expensive, but is the most fool-proof way to gain reliability, so it is the usual method used for the most critical components, such as the central processor and the recording devices. For the ARB telemetry system, this would mean duplicating the Nova CPU and the magnetic tape drive.

The second method, increasing inherent reliability, should be used no matter what the other system requirements are. This can be done by following a few simple rules:

- Always use standard, off-the-shelf equipment whenever possible.
- Try to obtain equipment and software from a single source.
- Make sure service is available from the vendor.

- In real-time computer-based systems, make sure that the on-line software (the data collection software) is well protected from any other software that might run on the system.

In the experience of the authors, failure to follow these rules has almost always led to unexpected difficulties and systems less reliable than they should be.

The other improvement in data collection is to provide the capacity to include more stations in the ARB air quality network. The easiest, and probably least costly method to do this it to duplicate the existing system. Another method would be to provide more memory for additional station tables in the processor, either by swapping tables in and out from a disk drive, or by a technique known as memory mapping (a very commonly used method to increase the effective memory size of minicomputers). The primary cost of the second method would be for changes to the existing ADAM III software.

It is technologically feasible to hook all air monitoring stations in the state to a central telemetry system. One method would be to install Data Loggers in parallel with existing modems at each station. This would ensure a maximum data compatibility within the telemetry system. An alternative method would be to hook to the central processor of each of the districts' telemetry systems in the ARB's system. This would entail hardware and software modifications to most of the districts' CPUs. Since the frequency of data acquisition varies among systems, data compatability problems will have to be solved.

5.1.2 Data Verification and Display

For effective data verification, using the ARB telemetry system, there must be some way to allow programs to run at the same time that data gathering is proceeding. This can be done either by providing a second processor dedicated to that task, or by utilizing the multi-tasking capabilities of a real-time operating system. Either method is effective, but most truly reliable multi-tasking operating systems require the use of fairly large and expensive computers.

In addition to the systems software changes, the proposed data analysis programs would require some sort of high-speed mass storage to hold programs and historical data. There would also have to be an interactive alpha-numeric terminal to provide operator control of data verification programs and to display results. For maximum effectiveness, this terminal should also be capable of plotting graphs and displaying maps and charts, since this is often the best way to present the results of data quality testing.

The key to successful data verification software is a simple, easy-to-use and efficient data base management system for the air quality data recorded on the disc and tapes. This would not have to be elaborate, but must guarantee that the verification software is not forced to continually do its own bookkeeping, which would be a tremendous hindrance to the development of new data verification algorithms.

5.1.3 Data Storage

If the improved system is used later to prepare data tapes for general use (e.g., to generate the quarterly reports at the Teal Center), then it will require a second tape drive, since it is always necessary to have one drive on-line, recording the raw data for verification.

Another useful peripheral device for report generation is a hard-copy plotter. Graphical representations of air quality data are particularly useful for data editing and verification.

Another desirable hardware item would be a status display of the entire ARB network, or perhaps a subset thereof. Although this could be a relay control system to light the indicators on the ARB status maps, a more flexible alternative would be a raster scan graphics display with a standard video output. This could easily be used to generate status maps of all or part of California. The information could be graphical or alphanumeric and could be displayed on any standard TV monitor, or even recorded on video tape.

5.2 ALTERNATIVE IMPROVED DATA COLLECTION SYSTEMS

This section presents what the authors consider to be four realistic alternative configurations for the data collection and verification systems. (See Figures 5.1 through 5.4.) Various types of equipment that can be used for data display are listed in the second part of this section.

5.2.1 System Descriptions

Alternative Zero is the status quo, as described in Chapter 2.

Alternative One would include a new, high-performance CPU, with disc and tape drive. This should be capable of using 256K words of memory, handling high-speed floating-point arithmetic and providing a powerful multi-task real-time operating system. The present system would be kept as a backup for the twenty most critical stations.

The advantages are:

1. A single CPU is very reliable.
2. Very powerful computations are possible.
3. Data analysis programs can be easily implemented on the system.

The disadvantages are:

1. The first hardware purchase would be costly.
2. Extensive changes would need to be made to the ADAM real-time data gathering system, which is the most expensive and critical part of the software.

Alternative Two would be to duplicate the present system with a virtually identical system.

The advantages are:

1. It would be easy to add additional stations.
2. No new software would be required.
3. Any one system could handle critical stations, so data collection reliability would be good for those stations.
4. The cost is relatively low.

The disadvantages are:

1. No data analysis would be available.
2. The probability of having a partial system failure is greater than for a single CPU.

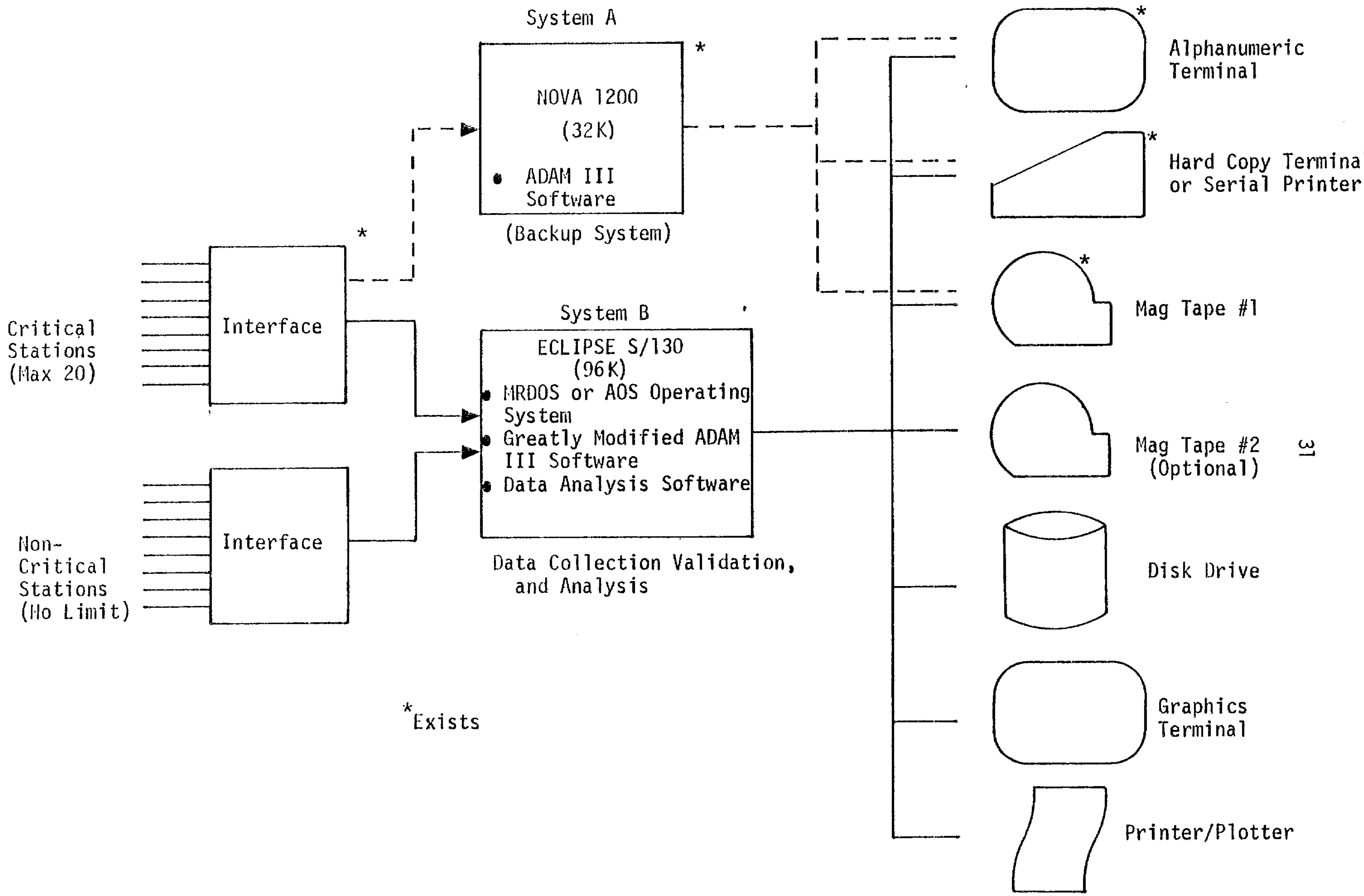


Figure 5.1 System 1--Replace Processor
Rewrite ADAM III Software to run under multi-tasking operating system. System A can record critical stations if System B is down.

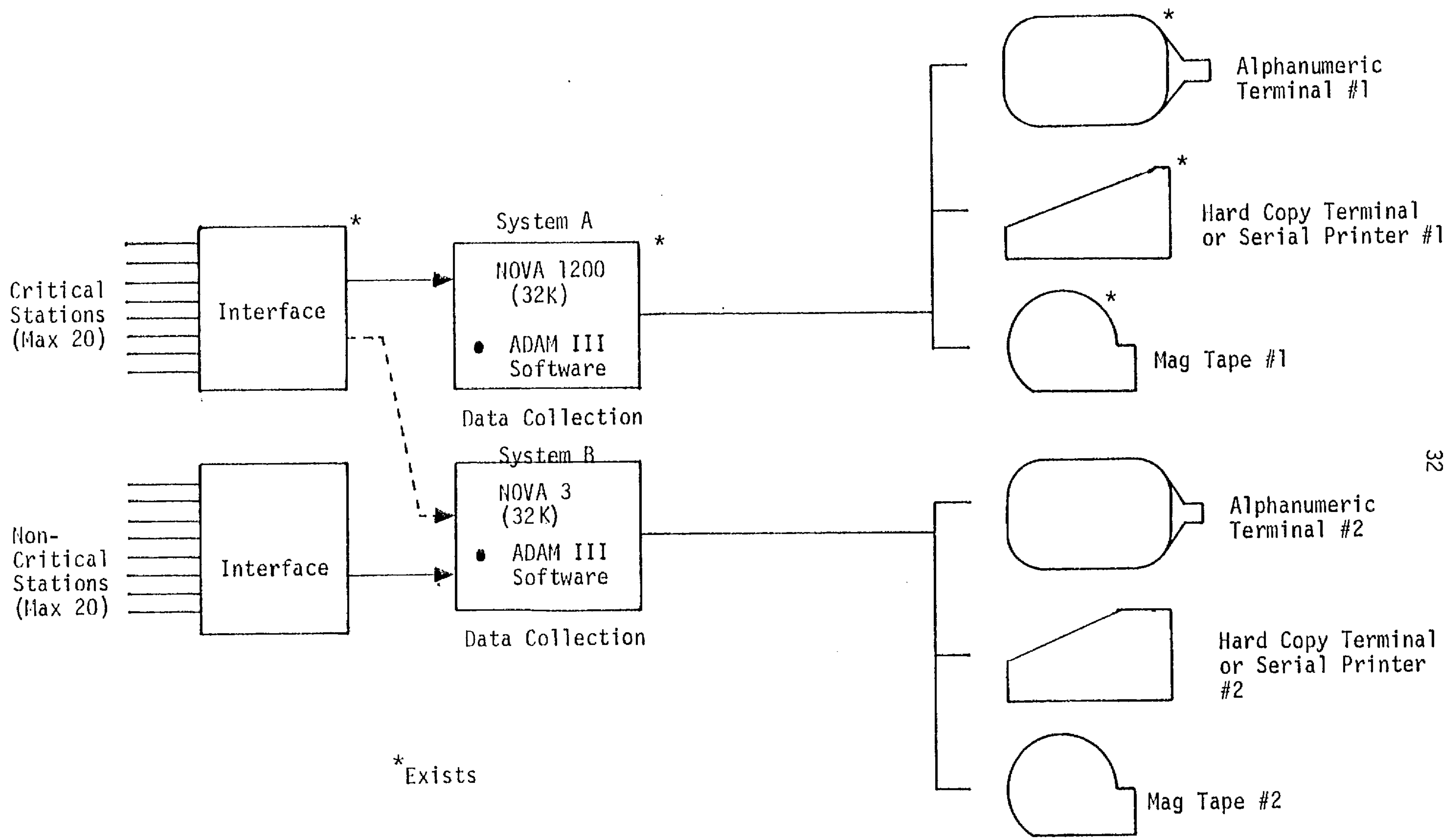


Figure 5.2 System 2--Duplicate System (System B can be connected to System A's stations if System A is inoperative)

Alternative Three would be to obtain a disk drive for the present system. The software would be rewritten to run as a task running under a simple real-time operating system. Station data tables would be kept on disk and swapped in when necessary. Data analysis programs could be run as background jobs simultaneously with data gathering. If the disk goes down, the critical stations could be handled using the present ADAM software.

The advantages are:

1. Low initial hardware costs.
2. The costs of converting the ADAM software to allow for more stations would be moderate.
3. Data analysis would be fairly easy.

The disadvantages are:

1. Some decrease in reliability would be realized.
2. It would be easy for an inexperienced user or for errors in the data analysis software to crash the data-gathering system.

Alternative Four could be described by the term "distributed processing." The system would comprise a NOVA 3D processor which would be used for all data collection tasks. This system could handle up to 128K words of memory using a memory-mapping scheme. The ADAM software would be modified to run in this mapped environment so that the number of stations could be more than quadrupled. The present processor would be put under control of a simple real-time operating system and used for data analysis and display. The present system could also serve as the backup system

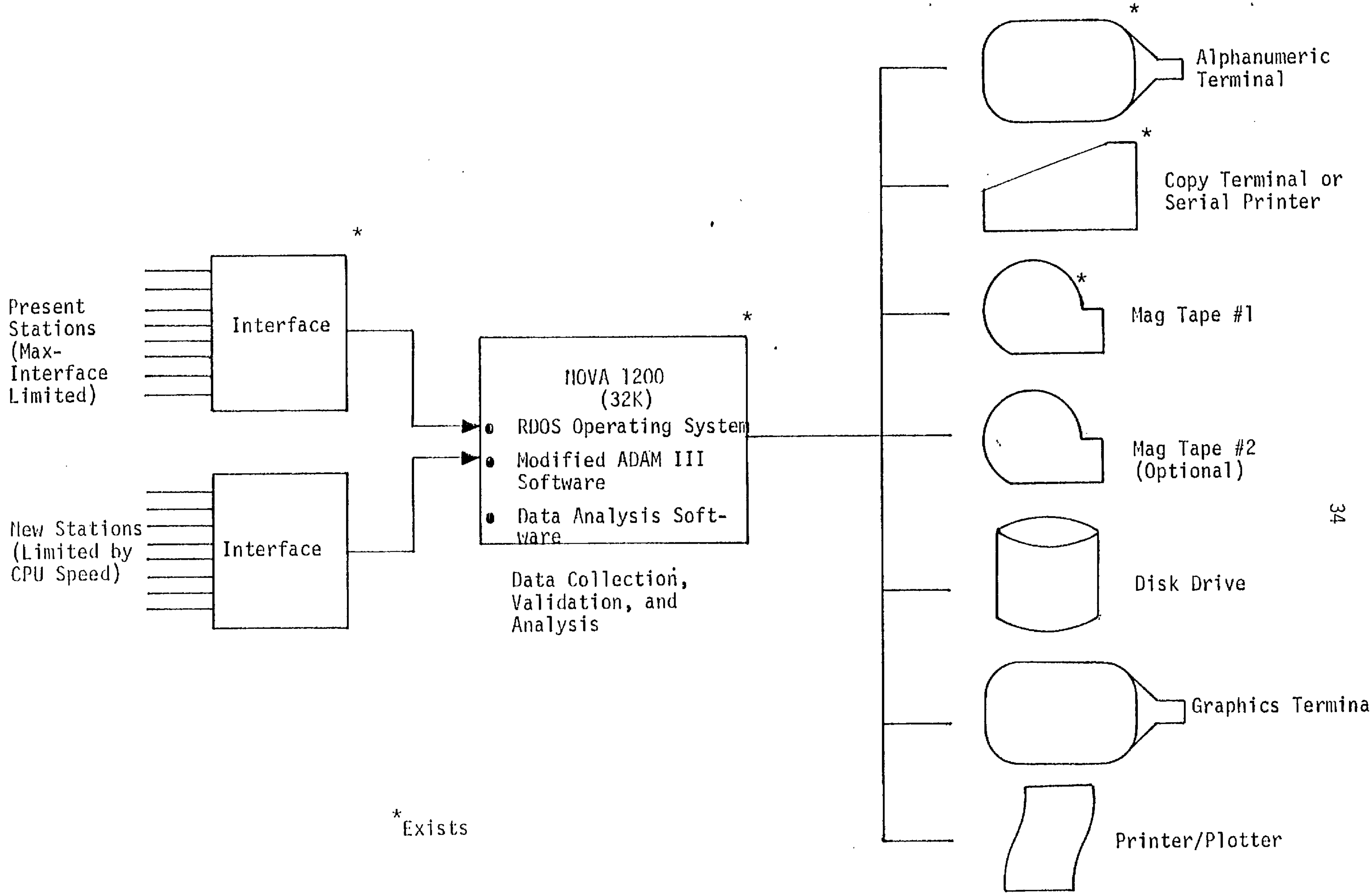


Figure 5.3 System 3--Add Disk to Present System, Modify ADAM III Software to Swap Station Tables to and from Disk

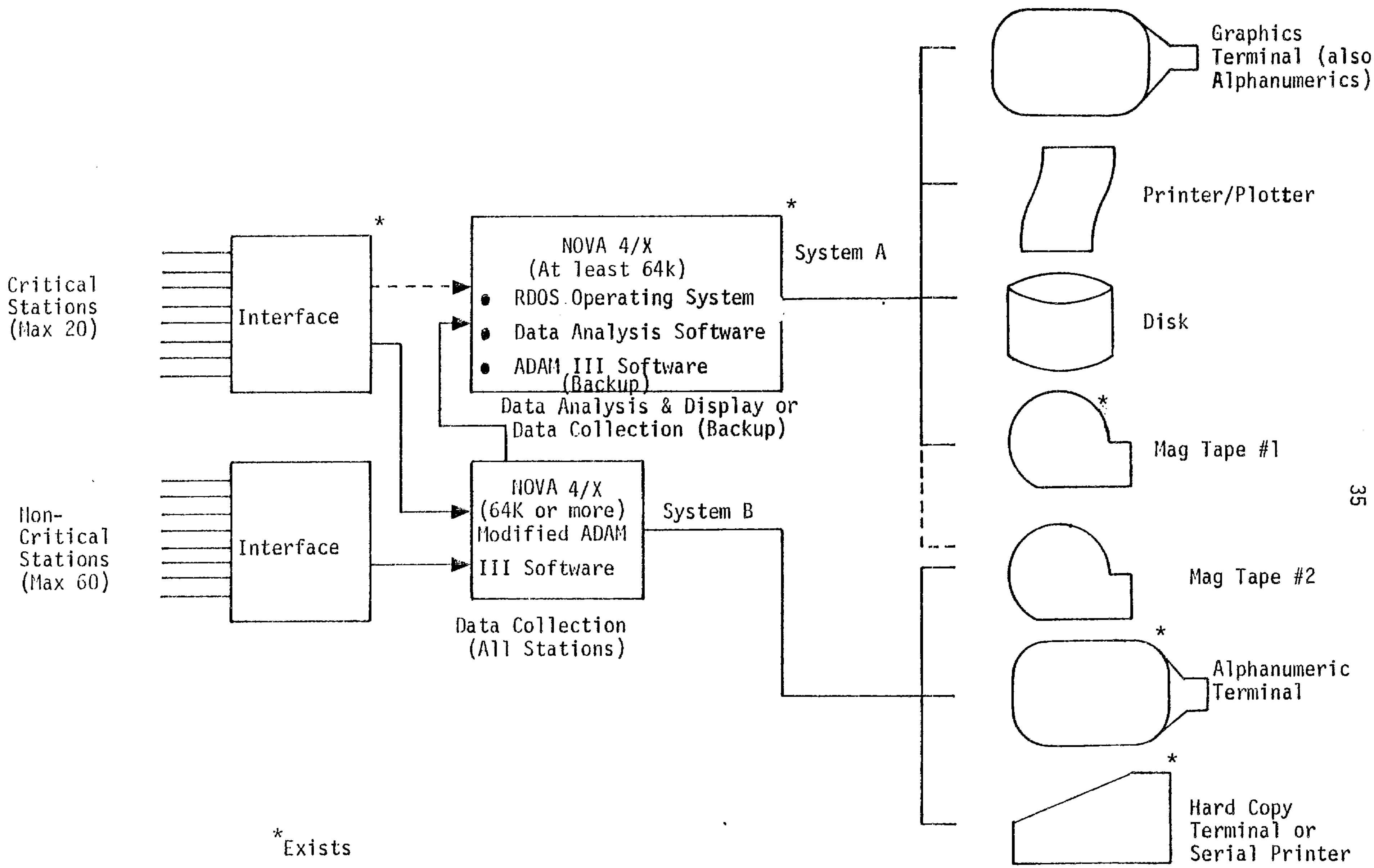


Figure 5.4 System 4--Distributed Processing. System A does data analysis and display, System B collects data and does preliminary validation. System A can do data collection for subset of stations.

for data collection at all twenty critical stations. A disk and tape drive would also be provided for the data analysis processor.

The advantages are:

1. A moderate overall cost.
2. The ADAM software should be fairly easily modified.
3. Since the data display software functions independently from the data collection software, it cannot crash the data gathering subsystem.
4. Either system could do data collection and backup onto magnetic tape. The display NOVA 4/X would back up the collection NOVA 4/X for all stations and thus ensure high reliability for data collection tasks.
5. The data collection process is done by the newer, more reliable NOVA 4/X...and it can record all stations, not just a critical subset.

The disadvantages are:

1. The ADAM software must be modified a small amount
2. Since there are two CPU's, the chance of partial system failure (loss of data analysis) is somewhat higher.

5.2.2 System Evaluations

Each system evaluation is in five main sections: the estimated reliability, the flexibility, the capacity, the technical risk (the likelihood of major overruns in cost or time), and the estimated dollar cost of the system. In addition a comments section may be included. The results of this evaluation are summarized in Table 5.1.

TABLE 5.1. SUMMARY OF SYSTEM EVALUATIONS

Alternative	Reliability (Physical/Data)	Flexibility	Capacity	Technical Risk	Total Cost
0. Current System	0/0	0	0	0	0
1. New Processor	++/+++	+++	++	--	$195,000
2. Duplicate System	++/0	0	+	0	$24,000
3. Add Disk Only	-/++	++	+	--	$175,000
4. Distributed System	+++/+++	+++	+++	-	$175,000

+++ Much better than current system.
++ Somewhat better " " " .
+ Slightly better " " " .
0 No better " " " .
- Slightly worse " " " .
-- Somewhat worse " " " .

0. CURRENT SYSTEM

Reliability -- The current system, an ADAM III from Monitor Labs, Inc. of San Diego, is the most reliable and useful air quality telemetry system in the state. Even so, if any one of its major subsystems (mag tape, modem interface, CPU) goes down, the whole system is dead. This only happens rarely, but it shouldn't happen at all.

Flexibility -- Although the simplicity of the ADAM III system improves its reliability, it unfortunately limits its flexibility. The data display and mag tape formats are fixed, there is no graphical output, and it is impossible to install advanced data reliability checks.

Capacity -- The ARB ADAM III is running at the absolute maximum number of stations possible. In addition, there is no room in the current system for added programs to improve flexibility, even if the ADAM III software would allow it.

Technical risk -- none.

Cost -- none.

1. REPLACE PROCESSOR

Reliability -- This would be somewhat more reliable than the current system, if only because there would be a backup. On the other hand, the massive changes necessary to the ADAM III software would entail considerable risk and would result in a primary system being unreliable for an extended (about 1 year) period of time. Once the software was debugged, however, the system should be quite reliable, and the backup system would ensure that partial operation is possible. Data reliability should be good since this system provides plenty of room and CPU capacity for advanced data checking techniques.

Flexibility -- The flexibility would be excellent since there is room for many display and data manipulation programs and the real-time operating system provides good program support.

Capacity -- The ultimate limit on the CPU memory is 124k words. After providing room for the ADAM III software, the data reliability and display software, and the operating system, there would be room for about 60 stations, probably enough for the reasonable future. The performance CPU should insure adquate computational capacity for the many functions that must be performed simultaneously.

Technical risk -- Fairly high.

Cost -- CPU and related hardware - $30,000. Modify ADAM III to run under operating system - $60,000. Data display and reliability software - $65,000. Total (with $40,000 peripherals) - $195,000.

Comments - The high cost of the ADAM III conversion reflects the difficulty of this task. The cost estimate does not allow for a contractor "learning curve," i.e., it assumes that Monitor Labs, who wrote the original ADAM III, would modify the system. If a different contractor is used, funds for familiarization with ADAM III would also have to be provided.

2. DUPLICATE SYSTEM

Reliability -- This would also be somewhat greater than the current single system, since either system could record the critical stations. The data reliability would be unchanged.

Flexibility -- Unchanged.

Capacity -- With a duplicate system, an additional 20 stations.

Technical risk -- none.

Cost -- Complete central system (not including any remote equipment) - $24,000.

Comments -- The only improvements would be in physical reliability and the number of stations.

3. ADD DISC TO CURRENT SYSTEM

Reliability -- The physical reliability of the system would actually be reduced slightly (more complex), but data reliability could be improved with fairly simple advanced checks.

Flexibility -- Many simple data display and reliability procedures could be used, the restriction being that the available computer memory would be severely restricted since both the operating system and the kernel of the ADAM III software would have to present. This would leave only about 10k words for all other software, a severe constraint.

Capacity -- The maximum number of stations would be limited by how fast the CPU could service all the stations and how much memory was available to the ADAM III software. The total number of stations could at least be doubled to 40, however. Unfortunately, no matter how the software was arranged, the computer would be strained to its maximum capacity, leaving no room for future enhancement.

Technical risk -- Fairly high.

Cost -- Modified ADAM III software - $60,000. Data display and reliability software - $75,000. Total (not including peripherals) - $135,000.

Comments -- There would not be any cost for non-peripheral hardware, but the cost of the ADAM III conversion would be high for the same reasons discussed in the first alternative. The other software would be more expensive simply because of the difficulty in making it small enough to fit in the available space. Even with this additional cost, it is likely that the resulting software would not be as flexible as desired.

4. DISTRIBUTED PROCESSING SYSTEM

Reliability -- This should be excellent, since a second CPU would be responsible for the data collection, and the changes to the ADAM III software would not be nearly as extensive. Bringing up the backup system could be done using the disc via already-developed techniques at Monitor Labs. Data reliability could be quite good since the entire user memory space (about 36k) of the display CPU is available for data manipulation programs. In addition, the physical separation of the data collection and manipulation tasks prevents one from interfering with the other.

Flexibility -- Will be quite good for the same reason that data reliability will be good: adequate memory space.

Capacity -- This alternative has virtually unlimited capacity. The new data collection CPU has an address space of 124k, which with only the ADAM III software resident allows up to 100 stations. And if this is not enough, an additional data collection CPU could be added for yet another 100 stations. Computation capacity should be adequate on the display CPU for all the currently envisioned data reliability and display functions. In addition, it would be possible to connect the display CPU to any State data center via phone lines if more extensive processing must be done.

Technical risk -- Low.

Cost -- Two CPUs and related hardware - $35,000. Conversion of ADAM III software - $30,000. Data manipulation software - $75,000. Total (less peripherals) - $140,000.

Comments -- The conversion of the ADAM III software would be fairly easy (hence the moderate cost), and could be much lower depending on a more detailed analysis of the task. One reason for replacing the present CPU is that it supports only older operating systems, which are harder to use than the newer versions. Thus, the use of two new CPUs (one for data collection, the other for display) will cost no more than the simple addition of one new CPU and modification of the old CPU's software.

5.3 OPTIONS FOR IMPROVED DATA DISPLAY AND STORAGE

This section discusses peripheral display devices and provides price estimates for them. All hardware items discussed in this section are readily available.

Interactive graphics display terminals are very useful tools. With the proper modem, they could be connected to one of the state's large computers, as well as to the telemetry system's data display and verification subsystem. There are two general types of graphics terminals that would be applicable: the storage scope and the raster-scan, refreshed display.

The storage scope (Tektronix 4010 is an example) costs as little as $4,000. It has moderate resolution, 1K x 1K bits, but not all bits are usable. (Higher resolution is available, up to 4K x 4K.) It is not flexible in that if the user wants to erase a title off the screen, the rest of the screen must be erased as well.

The raster-scan, refreshed display (Tektronix 4027) costs about $10,000. It also has a moderate resolution, 1K x 1K bits, and all bits are usable. It has a zoom feature which allows the user to zoom in on one part of the display and expand it up to sixteen times. The output is very flexible and can even drive a video display (a television set)...this might be a good replacement for the ARB status displays.

An impact line printer, pen-plotter or electrostatic printer/plotter would be used to provide hard copy results of data or data analysis.

An impact line printer operating at 300 lines per minute will cost $7,000 or more. Some line printers can do a limited amount of plotting with a low resolution of about 70 points per inch. They are fairly reliable but noisy.

A pen plotter costs $5,000 for an 11 x 17 inch model. Although they provide a high-quality output, they are not useful for printing tables.

An electrostatic printer/plotter has a higher cost of about $10,000 to $12,000. It can print very fast at 600 to 1000 lines per minute. The plotting is of high resolution, about 200 points per inch. It is very quiet, but the supplies are expensive, costing 5¢ per sheet of paper.

Mass storage is essential for handling the large amounts of data that must be kept for historical analysis and to store programs. Two types of random access mass storage are removable pack disks and fixed disks.

Removable pack disks are expensive. They cost $12,000 for a 10M Byte storage capacity. They are less reliable because they are delicate and susceptible to dust damage. However, they are very flexible in that one can change disk packs for back-up.

Fixed disks cost $12,000 for a 40M Byte storage capacity. Since they are self-contained in a sealed unit, they are more reliable and less dependent on a clean environment. The true cost would be higher since a magnetic tape drive would be needed to dump and load the disk.

6.0 RECOMMENDED NEW TELEMETRY SYSTEM

6.1 DESCRIPTION

The recommended system is the distributed processing system (option 4), comprising the following hardware items:

1. Two Nova 4/X or equivalent CPUs, ADAM III compatible, each with at least 64K words of memory, battery backup, I10 interface, line controller, and real-time clock.

   $24 K

2. A 9-track, 800/1600 BPI, 75 ips tape drive and transport controller.

   $10 K

3. A removable pack disc drive with at least 20 million bytes capacity, a controller, and six removable cartridges.

   $14 K

4. An impact printer/plotter with at least 300 lines/minute print speed, with all necessary hardware to interface directly with one CPU and the monochrome graphics terminal (item 5 below). (The Printronix P-300 with the $1 K Printronix/Tektronix graphics interface or equivalent).

   $7 K

5. Two raster-scan graphics CRT terminals with advanced alphanumeric and graphic capabilities, one with colder display, both with simple-command graphics software.

   $6 K (monochrome) + $11 k (color) = $17 K

6. Four-line asynchronous serial multiplexer and all hardware interfaces needed to connect the above system to the existing leased line modems of the existing telemetry system.

   $2 K

7. Additional modems and interfaces to support 60 new monitoring stations.

   $9 K

8. Two-bay equipment enclosure for the above hardware.

$1 K

9. An uninterruptible power supply to maintain operation of the system during power failures.

$7 K

10. Floating-point processor for one CPU.

$1 K

HARDWARE SUBTOTAL: $92 K

In addition to the above hardware, the following software must be acquired/developed:

1. Improved ADAM III software with 80 station capacity, verification of data transmission, able to run in a mapped environment on the new CPU.

$30 K

2. A basic real-time disc operating system compatible with new CPUs and with FORTRAN IV, multiuser basic, text editor, etc.

N/C

3. Data reliability and display software package, including initial data reliability program and simple data display procedures, to run on one of the new CPUs and to enable display-reliability CPU to monitor the other CPU through program control.

$45 K

SOFTWARE SUBTOTAL $75 K

Prime Contractor's Fee, including installation of system and training of ARB users	$14 K
Total Estimated Cost of System	$181 K

All software and hardware are to be provided with detailed documentation on their use and simple troubleshooting. All hardware is to be installed at the ARB offices in Sacramento, with minimal interference to the existing ADAM III telemetry system.

In addition, the optimal system would include programmable switchover of the interfaces from one CPU to the other in case of failure of the data collection CPU, thereby minimizing data loss.

6.2 RATIONALE FOR SELECTION

The distributed processing alternative is the lowest risk and cost system that still provides all the desired capabilities. It has the best combination of physical and data reliabilities, it is among the most flexible, and it has the greatest capacity for expansion.

The combination of a 20- megabyte removable pack disc drive and 9-track tape drive will provide the necessary mass storage for the real-time disc operating system and the AQTS programs and data. A removable pack drive was chosen because of the ease of unloading and loading new data or programs.

The high-resolution printer/plotter was selected as the most reliable and best quality method of generating hard-copy graphic reports and moderate volumes of printed data. If a higher volume of printed data is later desired, then it will be advisable to get an impact-type line printer.

A raster-scan graphics terminal is the best way to combine the necessary functions of the system command device and and a graphics display for data interpretation. A standard video output is desirable so that the resulting displays can be recorded or sent to video monitors in other locations.

The second modem interface is a reliability enhancement since it would ease the transfer of the recording functions back to the old CPU if the new CPU were to fail. This way each CPU would have its own interface and only the modem cables would have to be transferred.

The choice of the particular software listed above is dictated by the distributed processing system design. The operating system software will have no cost (or at the very most, a very low cost) since this is provided by the computer vendor when the appropriate hardware is purchased. As for the division of the data reliability and display software into two phases, this is prefered as a way to ensure that the programs actually acquired would be truly useful (experience using the first, simple system would allow analysts to determine what they really need).

6.3 IMPACT ON EXISTING OPERATIONS

The additional workload that will result in the Meteorology Section (25% of one person) will be offset by automation of routine reports and more efficient methods to perform air quality and meteorological analysis. If data for record can be captured by the improved system, the the expanded telemetry system could be maintained by the Air Monitoring Section without any increase in staff effort.

The improved capability to utilize large volumes of data in software routines will result in improved predictions and notices. This will also provide for faster response to request for analysis by the Executive Office and other staff agencies.

The expanded system will extend the present system into other areas of the state. It will also provide more spatial resolution in the data presently available for use in predictions and analyses.

6.4 IMPLEMENTATION PLAN

The bulk of the work necessary to implement the improved AQTS will be done by a single prime contractor under contract with the ARB. As a result, the main function of the ARB staff will be monitoring and directing the contract. The implementation itself will come in four main phases: the writing of a detailed specification that will provide the basis of an RFP, the bidding process for the improved AQTS, the monitoring of the winning firm(s) as the new system is developed, and a post-implementation evaluation of the usefulness of the system using the criteria previously mentioned.

Following approval of the telemetry system feasibility study (summarized in Chapters 4 and 5 of the present document) by the ARB Executive Officer, the ARB staff initiated Phase III of the contract with Technology Service Corporation of Santa Monica. The product of Phase III is the detailed specification of an improved AQTS, based on the feasibility report and included as Part II of the present document. The specification document will form the technical core of an RFP to be issued by the ARB. The specification document also sets forth schedules and instructions for monitoring of the development of the improved system and evaluation of its performance.

During the development of the final specifications (Phase III), it was discovered that:

1) The current telemetry system's Nova 1200 CPU would be inappropriate for the desired "foreground/background" operation, because its lack of memory protection could lead to data errors. The new Nova 4/X has the required protection.

2) The disc storage would have to be enlarged to 20 megabytes, to handle all desired "table-driven" data manipulation and verification procedures for the entire data base (up to 80 monitor sites). The use of "table-driven" software will permit simple future updates of the software, reducing the chance of the software becoming obsolete.

3) A color graphics terminal would be needed to permit more efficient human interaction with the system. In particular, the optimal use of color would permit the human operator to interpret the various data displays efficiently and to detect anomalous data quickly.

4) A second, monochromatic terminal would be required to permit a second operator to view the incoming data and to perform desired verification tests independent of the user of the color terminal.

5) The advanced reliability software package could be deleted from the specifications, but its necessity should be re-evaluated later, after the operating data reliability of the actual system has been established.

PART II

DETAILED SPECIFICATIONS FOR AN IMPROVED AIR QUALITY TELEMETRY SYSTEM

1.Ø INTRODUCTION

This document sets forth specifications for an improved air quality telemetry system (IAQTS), to be operated by the California Air Resources Board as an improvement and expansion of its existing telemetry system (AQTS--see Appendix A). The new system shall provide a larger Central Processing Unit (CPU) for enhanced data collection and verification capabilities, including the ability to accommodate up to eighty (8Ø) air monitoring stations. The system shall include a second Central Processing Unit (CPU), which will have two primary functions: 1) the ability to take over collection of raw data in the event of failure of the main data collection CPU; and 2) the provision of improved real-time graphic and data display and validation capabilities.

This document comprises three major sections -- Chapter 2, Hardware Specifications; Chapter 3, Software Specifications; and Chapter 4, Schedule and Implementation.

2.Ø HARDWARE

The Improved Air Quality Telemetry System (IAQTS) shall be built around two major subsystems: the Data Collection Subsystem and the Data Reliability and Display Subsystem. The hardware requirements for these two subsystems are specified in the following sections. Figure 2.1 is a block and data flow interface diagram of the existing and new hardware.

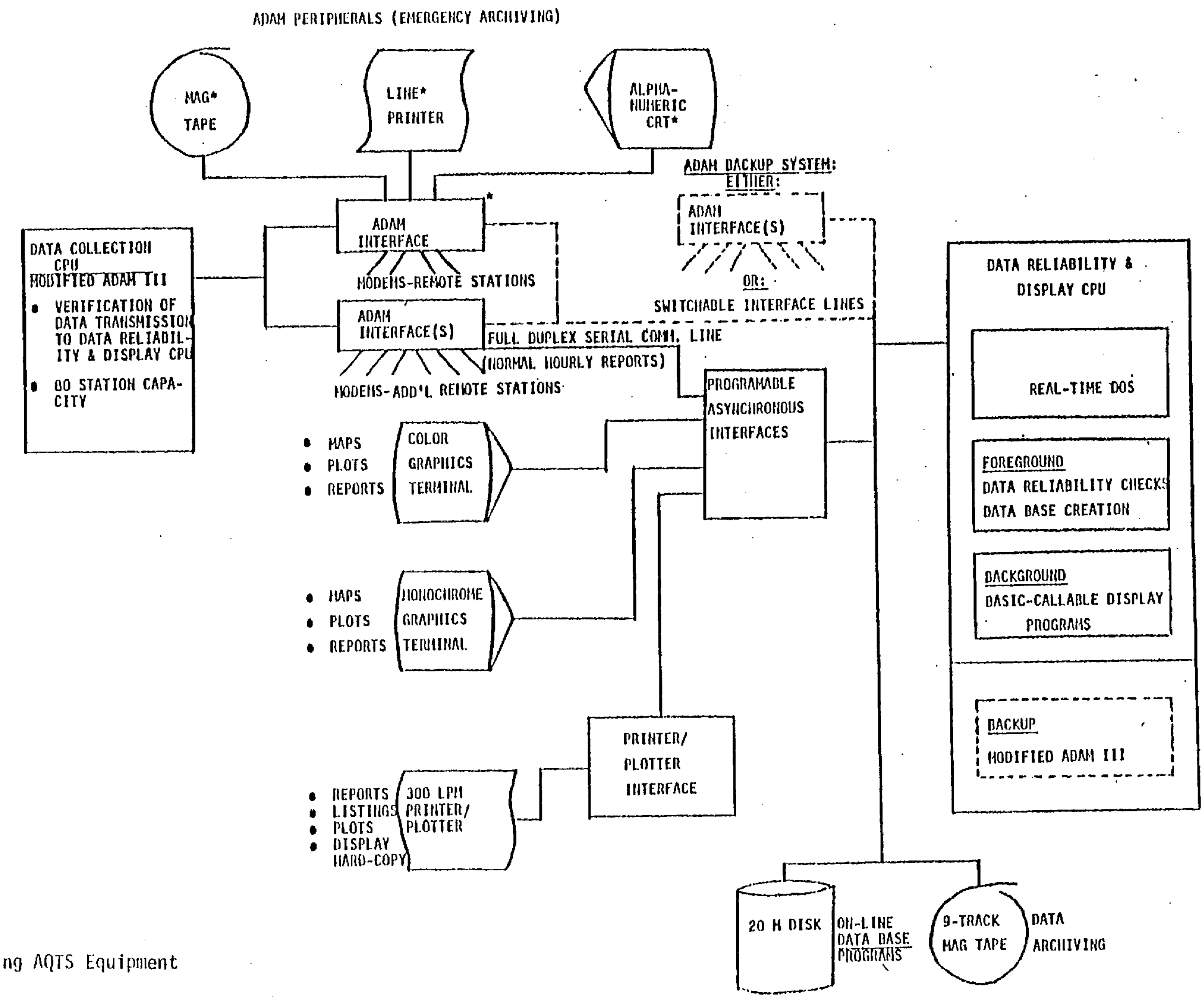
2.1 DATA COLLECTION SUBSYSTEM

The Data Collection Subsystem shall consist of a modification of the already existing Air Data Acquisition and Monitoring (ADAM) III system (Monitor Labs, Incorporated) that is installed at the ARB offices in Sacramento. The only two pieces of hardware necessary for this modification are a new NOVA-compatible processor with enough memory to support an 8Ø-station ADAM system and the additional interface(s) necessary to connect the CPU to the additional stations and to the Data Reliability and Display Subsystem. Specifically these hardware requirements include:

1. NOVA-compatible CPU with the following options: adequate memory to support 8Ø-station ADAM software or 64K words (whichever is greater), real-time clock, memory management and protection, hardware multiply and divide, auto program load, power fail/auto restart, virtual console, and 16-slot chassis. Any semiconductor memory must be of error-correcting MOS type and must have battery backup to retain the contents of memory for 1Ø minutes after a total power failure.

2. Additional ADAM-compatible interface(s) necessary to support both the increased number of modems needed for 8Ø stations, and a full duplex RS-232C serial communication line to the Data Reliability and Display Subsystem.

Thus, the contractor shall provide a processor to completely replace the present NOVA 1200 processor, using existing interfaces and software. In addition, all necessary interfaces (exclusive of data loggers) to support 60 additional monitor stations must be provided.



*Existing AQTS Equipment

Figure 2.1 Block Diagram of Improved Air Quality Telemetry System

2.2 DATA RELIABILITY AND DISPLAY SUBSYSTEM

The Data Reliability and Display Subsystem is an expansion of the display and verification capabilities of the existing AQTS, but since it must also serve as a backup system for the Data Collection Subsystem, it must also be built around a NOVA-compatible processor with all the requirements mentioned previously. The specific requirements for hardware include:

1. NOVA-compatible CPU with the following options: adequate memory to support 8Ø-station ADAM software or 64K words (whichever is greater), real-time clock, memory management and protection, hardware multiply and divide, auto program load, power fail/auto restart, virtual console, 16-slot chassis, any other options necessary to support a real-time disc operating system, and (optionally) hardware floating point arithmetic. Any semiconductor memory must be of error-correcting MOS type and must have battery backup to retain the contents of memory for 1Ø minutes after a total power failure. This CPU must be completely hardware and software-compatible with the CPU described in section 2.1.

2. 2Ø million bytes of disc storage, at least half of which must be on removable cartidges. The controller must be capable of handling at least another 2Ø million bytes of disc storage. At least 6 disc cartridges must be included.

3. A 9-track 8ØØ and 16ØØ BPI industry standard magnetic tape drive and controller. The controller must be capable of handling a second drive. The drive must read and write at a minimum of 75 inches per second. All tapes written on this drive must be compatible with and readable by the existing ARB Pertec Model 686Ø-9 tape drive.

4. A 3ØØ line per minute impact printer/plotter and interface. The printer/plotter must be capable of using standard 11"x14" and 11"x8.5" paper forms and producing 5 copies. In plot mode, the resolution must be 5Ø points per inch or better, while in print mode, the resolution must be 1Ø characters per inch horizontal and 6 characters per inch vertical. The printer must print the full 96-character printable ASCII subset. The interface must allow input to come from either the CPU or the graphics terminals described below. The interface shall perform any reformatting necessary to convert from the terminal graphs format to the printer plotting format, so that the printer is capable of generating a hardcopy image of the current image on the CRT terminal. Printer/plotter shall use an RS232 or GPIB connection.

5. An interactive color raster graphic terminal with RS232-C full duplex interface. Terminal must have a plotting resolution of at least 640h by 476v and character capacity of 80h by 34v. (h-horizontal, v-vertical) Higher resolution is desirable. Graphics memory must use a vertual bit mapping technique in order to conserve the amount of terminal memory required to store the graph. The alphanumeric and graphic displays must be independently alterable and simultaneously displayed. Terminal must have split screen display; the capability to monitor the graphics and alphanumerics memory simultaneously. Terminal must have at least 80 programmable keys. Terminal must be capable of displaying up to 8 colors and up to 120 user definable patterns simultaneously, these colors must be selectable from a table of at least 64 different colors which are representative of the full color/intensity spectrum. Plotting functions must include vector move, vector write, vector erase and polygon fill utilizing user-selectable colors or patterns. All plotting and user-definable functions must be initiated utilizing simple English-style commands either from the keyboard or host computer. Terminal must be capable of displaying the full 96 character printable ASCII subset and provide formatting controls for forms generation such as protected and numeric - only fields and choice of character and background colors. The terminal must be capable of interfacing with a printer to generate a hard-copy image of the terminal screen. The terminal must also provide an EIA-RS-330 closed circuit television standard output to drive additional high quality RGB color monitors. Terminal must have an independently selectable BAUD rate from 110 to 9600 BAUD. Terminal must have 32Kb of alphanumeric storage capacity and 96Kb of graphics storage capacity.

6. An interactive monochrome raster-graphic terminal with RS-232-C full duplex interface. Terminal must have a plotting resolution of at least 640 h and 476v and character capacity of 80h and 34v. (h-horizontal, v-vertical). Graphics memory must use a vertual bit mapping technique in order to conserve the amount of terminal memory required to store a graph. The alphanumeric and graphic displays must be independently alterable and simultaneously displayed. Terminal must have split screen display; the capability to monitor the graphic memory and alphanumerics memory simultaneously. Terminal must have at least 80 programmable keys. Plotting functions must include vector move, vector write and vector erase. All plotting and user-definable functions must be initiated utilizing simple English-style commands either from the keyboard or host computer. Terminal must be capable of displaying the full 96 character printable ASCII subset and provide formatting controls for forms generation such as protected and numeric only fields and choice of shaded background, inverted fields or underlined fields. The terminal must be capable of interfacing with a printer to generate a hard-copy image of the screen on the terminal. Terminal must have an independantly selectable BAUD rate from 110 to 9600 BAUD. Terminal must have at least 32 Kb alphanumeric storage capacity and 32 Kb graphics storage capacity.

7. A serial RS232 communication interface and cable to connect to the Data Collection (ADAM) Subsystem described in 2.1 above. This must be compatible with the ADAM remote serial communication interface provided by the existing ARB telemetry system and must allow simultaneous communication between the ADAM III interface and the two CPU's. The interface must provide programmable asynchronous connection to four ports (for terminals and printers), upgradeable to 8 ports.

8. Any additional hardware necessary to allow the Data Reliability and Display Subsystem to automatically serve as a backup Data Collection Subsystem if necessary. If there is a significant difference between the cost of a system with automatic switchover and one with manual switchover, then these two options must be bid separately. This hardware must include the full functionality of the ADAM interfaces currently in place at the ARB with the additions described in 2.1.2 above.

9. An uninterruptible power supply (UPS) to provide the necessary power to operate the Data Reliability and Display subsystem for at least 40 minutes in the event of a local power failure. This system shall augment an existing "Elgar" Model UPS 2501 - 2.5 KVA uninterruptible power supply connected to the present Data collection subsystem. The new UPS shall incorporate a battery charger, battery bank, solid state inverter and a bypass switch. The battery charger shall convert AC power to DC, the DC power being used to simultaneously float-charge the battery bank and power inverter. Batteries shall be sealed lead-calcium type, or equivalent, and shall be provided in sealed sheet metal enclosures which can be located in an office environment. The UPS shall meet or exceed the following performance and physical specifications.

<u>Performance Specifications</u>

A. Voltage Regulation: ± 2%
B. Instantaneous Transient: (30% load change) ± 10%
C. Frequency Stability ± 0.25%
D. Inverter Efficiency at full load: 75% minimum
E. Overload rating: 110% for 15 minutes
F. Operating Temperature: 0 to 50°C

<u>Physical Specifications</u>

A. The UPS equipment must be rack mounted in an enclosed cabinet.
B. All interconnecting cables shall be provided with the equipment.
C. The UPS equipment shall include a DC voltmeter, (indicating battery voltage) an AC voltmeter (indicating output voltage), and an AC ammeter (indicating output current) which are visible from the front panel.
D. Equipment status indicators shall flag:

   a. Input power ON
   b. Bypass switch position
   c. Overtemperature
   d. Overload
   e. Low DC voltage

10. All mounting racks, connecting cables, and cooling fans required by all of the above items.

As an additional requirement, each of the RS-232C interfaces described above (items 3, 5, 6, and 7) must have a programmable baud rate from 300 to 9600 BAUD.

3.0 SOFTWARE

All deliverable software shall be fully operational and documented, both internally (by extensive use of comment statements in the source code) and externally (in a separate "hard copy" users' manual) to permit rapid, efficient use and modification by the ARB staff. Simple instructions to enable nonprogrammers to use the data list, display, and verification options shall also be provided. The FORTRAN routines shall be documented to permit FORTRAN programmers to execute more sophisticated display routines. Documentation shall be provided to enable the user to re-initialize the system in the event of a malfunction.

All software for the Data Reliability and Display Subsystem shall be written in either ANS FORTRAN 77 or ANS FORTRAN 66 (commonly known as FORTRAN IV) whenever possible, to assure portability between the system on which it is developed and the new system to be installed at the ARB.

While the Data Reliability and Display Subsystem software will be in FORTRAN, it shall interface to a multi-user BASIC interpreter to permit the user to access the data and use simple display and verification routines by using BASIC language interpretation commands, without having to use detailed FORTRAN statements. The FORTRAN software shall be executable through the "CALL" command of a "BASIC" interpreter. The "CALL" command is of the form, "CALL FILE", where FILE is the label of the disc location on which the specified routine is located. FORTRAN, BASIC, and operating system hardware packages shall be demonstrated as compatible with the IAQTS.

Software for the Data Collection Subsystem may be written in assembly language.

All source code for the software is considered deliverable. The source code shall be provided in a form that is machine readable by the ARB's computer, as well as in computer listings.

All necessary software tools, such as preprocessors and editors, shall be delivered with the software itself.

All software shall be stored on removable discs in source form for rapid access and convenient adaptation or update.

3.1 OPERATING SYSTEM AND SOFTWARE SUPPORT

The Data Reliability and Display Subsystem shall be equipped with the development and operations software required to implement all specifications given in this document. All the software described in the following section, except for the ADAM III software, must run under the control of a standard real-time disc operating system and utilities. This system must include as a minimum:

1. A real-time disc operating system with named disc files (including random access capability), foreground/backgound programming, multi-tasking support, and full support (including drivers and diagnostics) for all the hardware previously listed.
2. An interactive source program editor.
3. A FORTRAN 77 or 66 compiler and support libraries.
4. A macro assembler.
5. A multi-user ANS BASIC interpreter or incremental compiler. This must support at least four simultaneous users.
6. A linking loader with overlay capability.
7. A file copy routine.
8. A sort/merge utility.
9. An operating system for the ADAM III software.

10. Simple-command graphics software for the CRT's.

3.2 IMPROVED DATA COLLECTION SOFTWARE

The IAQTS Data Collection Subsystem will use a modification of the existing ADAM III software which provides all the functionality of the existing software except when it conflicts with the following list of improvements:

1. The maximum number of typical ARB remote stations that can be handled must be increased from 20 to at least 80, providing that the remote stations are available.

2. The data collection software must be able to detect if the data sent to the Data Reliability and Display Subsystem has been received correctly. If a transmission error is detected, an audible alarm must be given and the suspect data must be flagged and printed on the Data Collection Subsystem printer. Error detection shall involve comparing each character sent to the other subsystem with its echo, and flagging all disparities encountered.

3. The modified ADAM software must be capable of being loaded and started from the real-time disk operating system (OS) described previously. It is permissible for the OS to be preempted by ADAM (i.e., the OS may have to be restarted by operator intervention). This will aid the data collection backup function that is to be performed by the Data Reliability and Display CPU. In addition, ADAM software must be able to make use of the magnetic tape, terminals, and printers that do not use the current ADAM interface.

3.3 DATA RELIABILITY AND DISPLAY SOFTWARE

3.3.1 DATA COLLECTION BETWEEN THE CPU'S

3.3.1.1 The Data Reliability and Display CPU shall automatically receive and echo (for verification) all hourly ADAM III format data from the telemetry system, via the data collection CPU. This enhancement will provide improved display of data to the user.

In the event of failure of the data collection unit, the

Verification and Display CPU shall be capable of receiving the "raw" signals from the field and converting these to hourly average data using the ADAM III software, as the Data Collection CPU normally does. Thus, the "second" CPU will serve as an emergency backup for the primary data collection CPU and as a controller for all display and data verification functions. In other words, the Display CPU must be capable of detecting that the Data Collection CPU is not operating and/or giving an audible alarm. At this time the Display CPU must load and start the modified ADAM software. A minor (brief) loss of data during the switchover can be tolerated.

3.3.1.2 The system shall reformat incoming hourly data (sent each hour by the Data Collection Subsystem) from ADAM III format to a working disk file, in a format given in Figure 3.1 or an alternate suggested by the contractor and approved by the ARB. Data shall be maintained on the disc for the 5 weeks preceding the current day. User-updateable cross-reference tables shall be provided, to relate data in one format to that in the other.

3.3.2 SIMPLE DATA VERIFICATION

The data reliability and display subsystem shall be capable of all data range and rate-of-change verification tests currently performed by the existing ADAM system.

The maximum permissible values and rates-of-change for each parameter at each station shall be encoded in a user-updateable table, to permit future changes, as might be warranted by changes in monitoring techniques or typical ambient levels of various pollutants.

The system shall be capable of both "difference" (new reading

Figure 3.1 ARCHIVE FILE RECORD FORMAT

Field Name	Record Column	Field Length	Field Type and Acceptable Codes or Range of Values
1) Action code	01	1	Numeric; value='2'
2) Form code	02	1	Numeric; value = '2'.
3) State code	03-04	2	Numeric; value = '05'.
4) Site number			AlphaNumeric; (from cross reference table)
a) County code	05-06	2	
b) Site code	07-11	5	
5) Agency	12	1	AlphaNumeric; identifies the type of agency submitting the data. (From cross reference table)
6) Project	13-14	2	Numeric; (From cross reference table)
7) Interval	15	1	Numeric; value = (From cross reference table)
8) Date			
a) Year	16-17	2	
b) Month	18-19	2	
c) Day	20-21	2	
9) Start Hour	22-23	2	Numeric; value = '00'.
10) Pollutant code (parameter code)	24-28	5	Numeric; identifies the pollutant (parameter) sampled. (From cross reference table)
11) Method code	29-30	2	Numeric; identifies the method of collection and/or method of analysis. (From cross reference table)
12) Units code	31-32	2	Numeric; identifies the units in which data values are expressed. (From cross reference table)

Figure 3.1, Continued

ARCHIVE FILE RECORD FORMAT

	Field Name	Record Column	Field Length	Field Type and Acceptable Code or Range of Values
13)	Decimal code	33	1	Numeric; indicates how many positions from the right the implied decimal point should be. (From cross reference table)
14)	Number of observation	34-35	2	Numeric; indicates the number of observation fields contained in the record. Value = '24'
15)	Observations *			
	a) Flag Reliability	36-155	1	AlphaNumeric; indicates data reliability flag
	b) Data field		4	Numeric; 0000-upper limit. '9999' indicates no data value.

* The five-character format is repeated to include 24 one-hour observations in the record.

minus previous) and "ratio" (new reading divided by previous) tests of data values. It shall automatically flag any new data value failing either of these tests.

The system shall be capable of sounding an appropriate audible or visible "alarm" whenever a new data value is flagged. The alarm shall also be sounded by any data value or average reading which exceeds the corresponding standard.

3.3.3 ENHANCED DATA VERIFICATION

The data reliability/display subsystem shall compare corresponding strings of readings at all sites, to detect the presence of identical strings of values at two or more sites, an indication of data logger malfunction.

Aerometric data gathered by the telemetry system shall be scanned for acceptability before being recorded, and individual values or groups of readings which appear unreasonable or inconsistent with other readings shall be flagged for manual examination. This requires that the system be able to perform several statistical tests, to classify the data into two groups: 1) "bad" or questionable data, to be flagged; and 2) "good" data, to be left unflagged. "Flagged data" are those which must be manually reviewed before acceptance or rejection.

Three classes of tests which shall be performed to flag erroneous or suspect data are: 1) single pollutant, single station, 2) single pollutant, multiple station (interstation), and 3) multiple pollutant, single station (intrastation).

Single pollutant, single station tests examine the values of each variable (e.g. the hourly average concentration of ozone) at each monitoring station separately. Every data value not lying within a "reasonable range" shall be flagged.

The lower bound of the "reasonable range" is either Ø ppm or the lower detectability limit of the particular measuring instrument, while the upper limits must be derived from the historical records for the given pollutant and station. The software shall compute and establish a table containing user- specified (e.g. 99th) percentiles of hourly readings contained on the disc file, for each pollutant, for each time of day, season of the year, and monitor site. Any new data value exceeding its corresponding historical percentile shall then be flagged.

The subsystem shall also note the time of day of the most recent diurnal peak of each pollutant at each station, flagging those readings which occur at extremely unusual times of day for the station, pollutant, and season in question. For each station, pollutant, and season, the software shall compile a frequency distribution of the hour of occurrence of each daily maximum. Using this information, the user shall be able to update a table of "acceptable" times of peak occurrences, covering a chosen percentage (e.g. 99%) of all recorded peaks. Daily peaks falling outside their respective "acceptable" ranges shall be flagged.

Outliers are single data values which do not appear to be consistent with surrounding data. To detect individual outliers, the subsystem shall: 1) Compute the differences between successive hourly values for each station and each pollutant, 2) Flag a difference if it is larger than 4 times the standard deviation of all successive differences for that station and variable.

The subsystem shall compute the quantity, $C_i = (Y_i - 2Y_{i-1} + Y_{i-2})$, where Y_i is the current value of a given variable, Y_{i-1} is the previous value, etc. The system shall compute the standard deviation (σ) of the C's for each station and pollutant. Any Y_i whose $C_i \geq 4\sigma$ shall be flagged as an outlier.

Upon encountering a data value exceeding a user-specified percentile of the historical record for a particular station and pollutant, the system shall compare this value to corresponding readings at user specified (up to five) sites. A high value not accompanied by comparable readings at other sites shall be flagged.

Finally, for each site, individual readings for various pollutants shall be flagged if they fail to meet the following criteria:

1) Nonmethane hydrocarbons shall never exceed total hydrocarbons by more than the precision of the hydrocarbon measurements.
2) Neither NO nor NO2 concentrations shall exceed measured NOx by more than the precision of these measurements.
3) Ozone or oxidant concentration times NO concentration shall not exceed 1ØØ pphm^2. Both the ozone and the NO shall be flagged if 1ØØ pphm^2 is exceeded.
4) Up to ten similar user-defined criteria.

Every data value failing one of the data quality tests shall be flagged with an alphabetical character immediately preceding it. The flag character shall uniquely specify which test has been failed. Simultaneous multiple test failures shall be indicated by a different alphabetic character.

3.3.4 DATA DISPLAY AND TABLE GENERATION

The system shall be capable of computing selected descriptive statistics (mean, standard deviation, maximum, minimum, and range) and a Pollution Standard Index (PSI) for any desired parameter and station, to facilitate data quality review. These values shall be presented depicting the station and parameter codes and names, the year, month, and day, and the statistics for a user-specified time period, set of stations, and set of pollutants (e.g., all ozone in the South Coast Air Basin for the last five days). The system shall prompt the user for the information required to produce the display. The display format for these summary descriptive statistics shall be designed by the contractor and is subject to ARB approval.

The Data Reliability and Display subsystem shall display on CRT and/or print out, upon simple instructions using "BASIC" computer language commands, any selected table of the format of Figures 3.2 and 3.3. The operator shall be prompted for the time range (dates), parameter(s), and station(s) to be displayed. Using a simple operator command, the operator shall be able to cause the display or printing of the entire hourly record for any specified range of days, pollutant(s), and station(s) on the disc file. When the current day is selected, the data for all hours up to the present one shall be displayed and/or printed. In addition, the daily maximum value and its time of occurrence shall be shown as indicated in the figures, along with special flagging of weekend days.

The user shall be able to generate displays of hourly meteorological and aerometric data for the present day, up to the current hour, and for the previous five weeks. Printed and CRT-displayed tables shall be accessible for a user- specified month and year, pollutant, station, or air basin, in the format of Figures 3.2 and 3.3.

The subsystem shall contain a user-updateable cross-reference

WHAT REGION? SOCAL

AIR RESOURCES BOARD
METEOROLOGY SECTION

HOURLY AVERAGE CONCENTRATION
OZONE (O3) PPHM
HOUR

Data DATE: MMM DD, YYYY

LOCATION	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	MAX/TIME TODAY	MAX/TIME YES'DAY
SIM	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX								XX/TTTT	XX/TTTT
LNX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX								XX/TTTT	XX/TTTT
LGB	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX								XX/TTTT	XX/TTTT
LAH	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX								XX/TTTT	XX/TTTT
LOS	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX								XX/TTTT	XX/TTTT
MLE	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX								XX/TTTT	XX/TTTT
TEM	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX								XX/TTTT	XX/TTTT
UPL	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX								XX/TTTT	XX/TTTT
FON	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX								XX/TTTT	XX/TTTT
RAL	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX								XX/TTTT	XX/TTTT
ESC	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX								XX/TTTT	XX/TTTT
PSP	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX								XX/TTTT	XX/TTTT

Figure 3.2 Display Format - Hourly Values*

Run Date: MMM DD YYY

*Present date up to present hour shown. Displays of past days will show all 24 hourly readings.

WHAT STATION? UPL
WHAT POLLUTANT? 03

AIR RESOURCES BOARD
METEOROLOGY SECTION

MONTHLY SUMMARY AT UPLAND
OZONE (03) PPHM

DATE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	MAX/TIME
1	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX/TTTT
2	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX/TTTT
3	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX/TTTT
4	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX/TTTT
5	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX/TTTT
6	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX/TTTT
7X	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX/TTTT
8X	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX/TTTT
9	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX/TTTT
10	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX/TTTT
11	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX/TTTT
12	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX/TTTT
13	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX/TTTT
14X	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX/TTTT
15X	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX/TTTT
16	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX					

Figure 3.3 Monthly Summary Table Format*

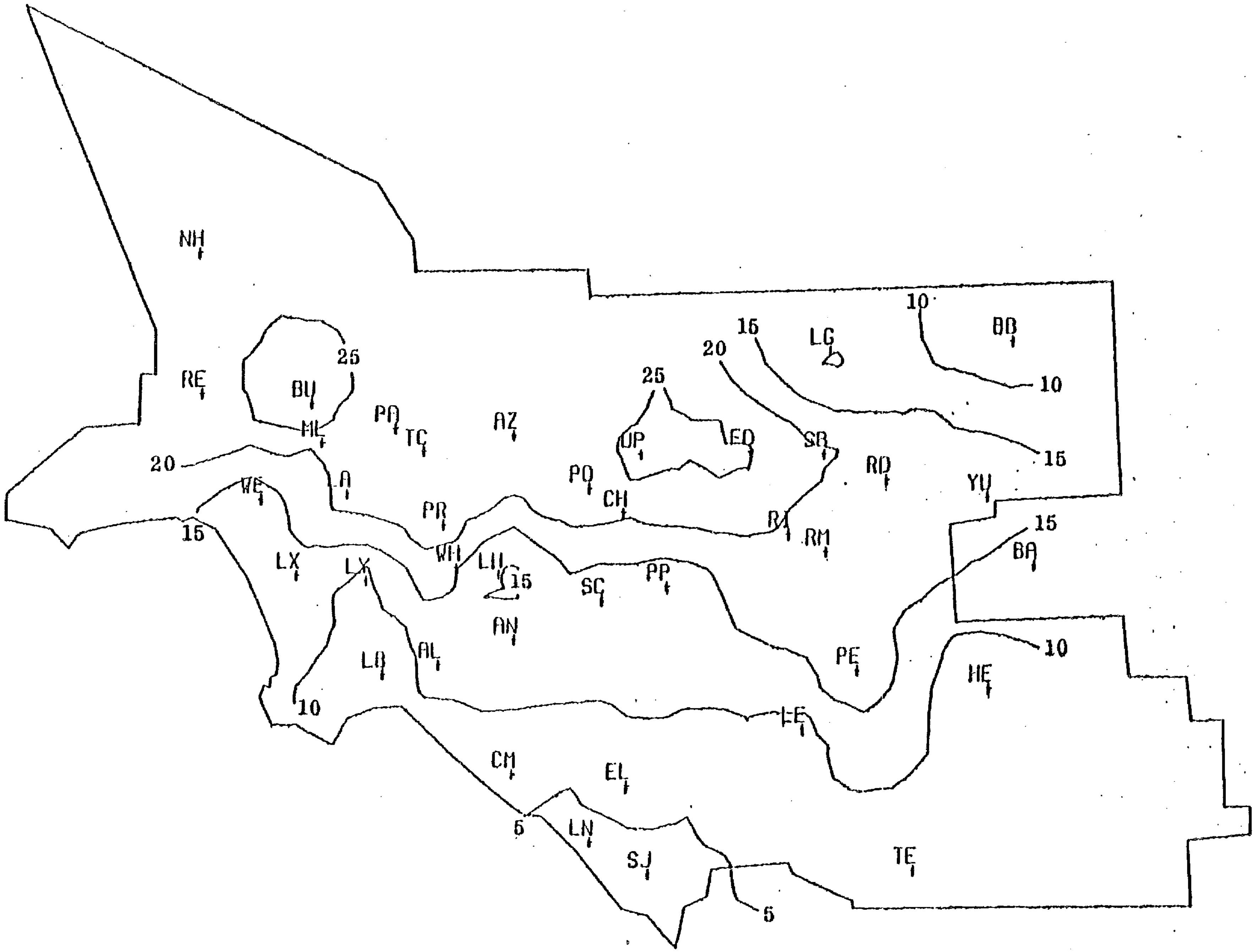
Run Date MMM DD YYYY

*Present month up to present date is shown. All days of past months will appear in this format.
7x, 8x, 14x, and 15x were weekends.

table of coordinates, names, and codes of the various monitoring sites, along with lists of names, codes, ADAM III channel numbers, and measurement units of pollutants monitored at each. Each site and pollutant shall be represented by user-specified three-letter mnemonic code, which can be used in normal data entry, display, and verification in conjunction with the other codes and names. The table shall permit the operator to display, for any desired station, the complete station name and list of pollutants monitored by name, code, and channel.

The software shall be capable of providing, for any of 14 selected air basins, isopleth diagrams of the type illustrated in Figure 3.4. This will be accomplished by interpolating between the measured values at the various monitoring sites located within user-specified coordinate boundaries and then fitting lines of constant concentration to a map of the monitor stations and appropriate basin or user-selected coordinate boundaries.

The software shall provide displays of isopleth maps similar to Figure 3.4. The software shall prompt the user and select for display values for either an individual hour, the average of each corresponding hour of a specified series of days, or a specific hour in each of a specified number of consecutive days. The software shall generate the appropriate isopleth display for the first hour, then upon command, the next hour, etc., for the period of interest. The isopleth plots and their background maps shall be available in different user-specified patterns, colors, or line types. Each isopleth drawing shall be superimposed on a map of a region bounded by user-selected coordinates. A user-updateable table of boundary coordinates for these maps shall be provided. (For example, a display enclosing a map of each of the 14



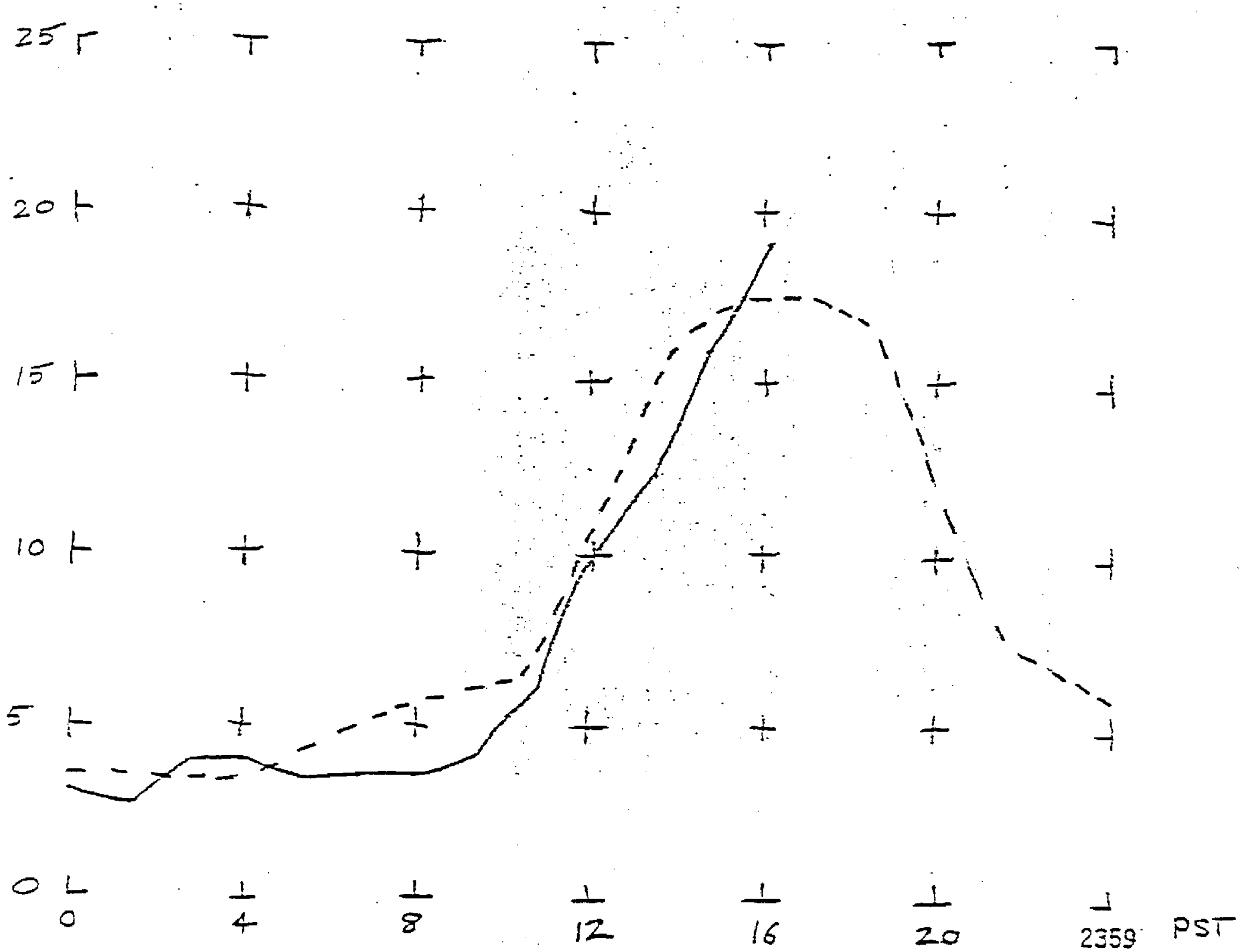
SCAB COMPUTERIZED OXIDANT ISOPLETH ANALYSIS: AUGUST 26, 1976 AT 1300 PST

Figure 3.4 Sample Isopleth and Monitor Site Map

Figure 3.5 Sample Time Series Graph

What Station? UPL
What Pollutant? OX
Scale Interval? 5

OXIDANT CONCENTRATION BY HOUR



As of 1600 PST January 12, 1978

---- Mean*
____ Today

* This is a "typical daily pattern" computed by averaging the corresponding hourly values over a user-specified series of days.

California air basins shall be available.) Maps shall include monitor sites (briefly labeled), county boundaries (with county names), and air basin boundaries (including the coastline).

The software shall be capable of generating time-series graphs of one or more parameters at a given site or from multiple sites (see Figure 3.5). The graph shall plot the hourly average parameter values against the hour of occurrence. The subsystem shall be capable of generating up to eight curves on one graph. The subsystem shall prompt the user for the monitoring site(s), parameter(s), and day to be represented by each specified curve on the plot. A series of consecutive days can be selected instead of a single day, in which case the values for each corresponding hour shall be averaged over all selected days, giving rise to a "typical" diurnal pattern. The subsystem, at the option of the user, shall prompt the user for values which represent historical values for each parameter at a monitoring site. These values are to be accessable in an updateable table and used, if so specified by the user, as data for isopleth or time series graphs. Time series shall be available for the preceding five weeks and for the present day up to the current hour. Each curve on the time series graph shall be in a different color, halftone pattern, or line type specified by the user.

The software shall be able to generate and display on the CRT and/or printer a daily mean of the hourly average values and daily maximum hourly values as well as the aggregated average and maximum over a specified range of days, for each pollutant at each station.

The user shall be able to call up either all data or all data bearing a specific flag (e.g., all values preceded by the flag "F") for display or printout. When displayed on a color CRT, flagged values and values exceeding air quality standards shall flash and/or appear in different colors than unflagged values within the standards. On a monochrome CRT, these values shall be distinguished by a flashing or inverted video field.

The software shall be able to change all patterns and colors displayed on a color CRT to user-specified monochromatic patterns and line types. The user shall be able to designate the respective colors, patterns, or line types to be used for the various isopleths and curves.

At the user's option, the subsystem shall prompt him/her for recent (within the last five weeks) historical values exceeding a given level for any selected parameter at any chosen monitoring site(s). These values shall be accessible for the generation of user- specified isopleth(s) or time series graph(s).

3.3.5 AUTOMATIC RECORDING OF CURRENT DATA

Incoming data in ADAM III format shall be recorded on a backup tape. In addition, at the end of each 24-hour period, the data collected during that period shall be archived from the disc file onto a tape in archive file format (see Figure 3.1). Thus, the system shall provide a daily-updated cumulative tape of the preceding 24 hours' flagged and edited data in archive file format, plus a continuously updated backup of the raw data in ADAM III format.

A disc file containing data in archive file format for the last five weeks shall be provided, to facilitate human and machine review of recent data, for verification of current readings.

The recording of data shall proceed automatically under normal operating conditions. After times of equipment malfunction, an operator with the required password shall be able to record ADAM III data manually, using software which will prompt the user for the required key information (station, data, pollutant, etc.) and allow entry of the data onto the disc. Data entered in this manner shall be flagged automatically with an "F" ("filled"). Software shall also be provided to allow the user to produce a backup tape copy of all archive file format data contained on the disc.

3.3.6 ALARM CAPABILITY

The system shall be capable of sounding an alarm (flashing light, audible tone, etc.) whenever a new reading is flagged for failure of a data quality test.

When data are displayed on the color terminal, all flagged data shall flash and/or appear in a different color than the unflagged, to permit rapid operator identification of suspect values. On a monochrome terminal, flagged values shall be distinguished by flashing or inverted video field.

The subsystem shall sound the alarm when an anticipated reading is not received on schedule (missing data flag). A user-updateable table shall be provided to permit the ARB to alter the time intervals at which readings of various pollutants are anticipated.

The subsystem shall sound the alarm whenever an hourly average data value exceeds the relevant ambient air quality standard. A user-updateable table shall be provided to enable ARB to alter the alarm threshold to reflect changes in standards.

The subsystem shall be capable of computing running averages of any parameter for any operator-selected period of time (e.g., 8-hour average CO concentration, computed as the arithmetic average of eight consecutive hourly CO readings). An ARB-approved averaging method shall be used.

The subsystem shall automatically compute multi-hour averages of parameters for which there exist ambient air quality standards (e.g. 8-hour CO), sounding the alarm immediately upon exceedance of one of these multihour standards. A user-updateable table shall be provided to enable ARB to alter the alarm threshold or averaging time to reflect changes in air quality standards.

The subsystem shall automatically compute all selected Pollution Standard Indices (PSI), where a PSI is a specific function of the readings of one or more pollutants (e.g. ozone plus sulfates), relative to the ambient air quality standards for the pollutants. Again, the alarm shall be activated for any PSI exceeding a select level.

3.3.7 ARCHIVAL OF DATA

Two parallel archival systems shall be provided:

1) continuous recording of hourly data, in ADAM III format, as received from the monitoring sites, onto a permanent magnetic tape.
2) edited one-hour average data, in archive file format (Figure 3.1), which have been run through the data quality tests during the preceding 24-hour period. This cumulative disc file and a cumulative tape copy shall be updated automatically at the end of every hour and at the end of every ARB-specified 24-hour period (e.g., calendar day) respectively.

The disc file of the flagged one-hour average data (archive format) shall be maintained for the latest five-week period, to permit rapid retrieval by the data reliability/display software. This will facilitate observation of trends and the implementation of more accurate, comprehensive data quality control procedures. The operator shall be able to alter or flag these data. The archive format tape shall be a cumulative, permanent record of the flagged and edited hourly data.

In the event of a malfunction in the data collection subsystem, the ADAM III data reformat and archival disc system shall stop, and then automatically restart following correction of the malfunction. A human operator with the proper commands shall be able to update the archive disc file manually, using backup data generated by the ADAM III software on the ADAM III format tape. Manually entered data shall appear on the disc and the archive format tape files, flagged "F" (filled"). The human operator shall also be able to halt the disc manually in case of malfunction. In the event of a loss of data on the archive disc or tape file, the system shall provide, under user control, the capability to recreate the disc file using the archival format data contained on magnetic tape. Conversely, the system shall also provide, under user control, the capability to transfer the last five weeks of archived disc data to the tape file.

The flagged zero and span values for each parameter at each station, where available, shall be maintained on the disc and archived on tape in archive file format (Figure 3.1). Recorded values shall be averages of the steady state readings obtained during the span and zero functions.

In the event of human error or an equipment malfunction, the user shall be able to recreate in archive file format any data missing from the disc, using data on the ADAM III format tape.

3.3.8 USER INTERFACE

3.3.8.1 Programming Language

Data shall be accessible for display and verification of reliability through the use of either BASIC language commands utilizing programs written in BASIC or FORTRAN subroutines which are in machine language.

All software for the system shall be fully documented to permit ARB "non-programmers" to access the data base through the BASIC language commands. Documentation shall include both extensive use of comments within the software and a separate written document telling how to use the software. All tables and programs shall be fully documented, to permit simple alteration of the data verification programs, functions, and tables.

All data verification programs, to the maximum extent possible, shall be table-driven, to permit the user to adapt or update the program functions without having to change the program source code itself. Documentation shall also be provided to allow the user to recreate the programs on the disc file from a machine- readable backup source, such as a tape.

3.3.8.2 Table-Driven Display Routines

The display routines shall be written to allow the user to cause the visual (CRT) display or printing of data through the use of BASIC language commands.

All display routines shall be table-driven to permit the user to request a specific period of time, subset of data, set of pollutants, and group of monitor sites or region of California. For example, all current data for each of 14 air basins shall be accessible through a command involving the abbreviated name of the chosen air basin (e.g., SC for South Coast). The user shall be able to select any specific air basin or county in the state of California, or any particular station of interest, through simple commands and station/basin name abbreviations.

The user shall be able to update these tables to define new coordinates and codes or names for the display function to use, e.g., to reflect added monitor sites or regions of interest.

3.3.8.3 User Update Of Archives And Flags

Appropriate FORTRAN subroutines shall be provided to enable the user to flag, alter, or add data to the archive format disc and tape files. These actions shall have no impact on the ADAM III format data tape and shall require intentional use of "protective" commands, to avoid accidental alteration of data.

Whenever a data value is filled in or altered, a flag shall be automatically generated with it. Flags shall appear as single alphabetic characters immediately preceding the left-most digit of each flagged data value. Each of the following conditions shall be defined by a unique alphabetic code:

FILLED - Previously missing data value has been entered manually.

CHANGED - Original data value has been replaced manually by user, because it was shown to be erroneous and the true value was determined.

DELETED - A data value has been removed and not replaced because the original value was erroneous and the true value is not obtainable.

SUSPECT - Data value does not pass one or more of data verification tests, but since there are no other grounds for deletion or alteration, it has been left in the data base. A separate code shall correspond to each verification test failed.

Again, the user shall be able to update the archive file format tape and disc from the ADAM III format tape in the event of equipment malfunction, to minimize data loss. The user shall be able to recreate the archive format disc file from the archive file tape, and vice-versa.

In the event of system malfunction or data loss due to transmission or operator error which results in loss of data for a period greater than 24 hours; the user shall be able to manually enter the data values and insert Archive File format records on the disk for that period. The user shall be prompted for all necessary information (ie. station code, parameter code, etc.) to develop these missing records. Data shall be appropriately flagged as being added onto this file.

4.Ø TRAINING

The contractor shall train five ARB personnel (engineers and technicians) to operate the system, diagnose simple equipment or software problems, maintain the hardware, and change the tables which drive the software. Training session shall cover the Data Collection and Data Reliability/Display subsystems.

5.Ø SCHEDULE AND IMPLEMENTATION

The following subsections include a description of contract deliveries, the required dates of delivery, and the warranty requirements.

5.1 DELIVERABLES

The contractor shall provide the ARB with the following hardware and software items, which were specified in more detail in Section 2:

1. Two CPUs, ADAM III software compatible, each with sufficient memory to support at least 8Ø stations, but no less than 64K words.
2. A 9-track, 75 ips, 8ØØ/16ØØ bpi tape drive and transport controller.
3. A removable pack disc drive with at least 2Ø million bytes capacity, a controller and six removable cartridges.
4. An impact printer/plotter with a printing speed of at least 3ØØ lines/minute. This must interface directly to one of the CPUs in (1) and the monochrome graphics terminal in (5).
5. Two raster-scan graphics CRT terminals with advanced alphanumeric and graphics capabilities. One terminal must have color capability and one must be capable of sending display data directly to the printer/plotter for hard copy. Terminals shall be provided with graphic interfaces and simple- command graphics software.
6. All required interfaces to connect the above system to the leased line modems currently installed at the ARB.
7. Additional hardware interfaces and modems necessary to support an additional 6Ø stations, utilizing ADAM III software.
8. All required mounting racks and cabinets for above equipment.
9. Improved ADAM III software with 8Ø station capacity, verification of data transmission over serial communication line, and full ADAM III functionality.
10. A basic real-time disc operating system compatible with the new CPU's and complete with FORTRAN, multi-user BASIC, libraries, and utilities.
11. An uninterruptible power supply to maintain operation of the data reliability and display subsystem during power failures.

12. (optional) Floating point processor for one of the CPUs in item 1.

13. Software and interfaces to enable the display/reliability CPU to monitor the data collection CPU through program control.

14. (optional) Programmable switchover of interfaces from one CPU to the other.

15. A basic data reliability and display software package to run on one of the new CPUs, including a simple data base system, an initial data reliability program, and some data display procedures that interface with the multi-user BASIC provided under item (1Ø).

16. Installation of the complete system at the ARB offices in Sacramento, with minimum interference with the existing ADAM III telemetry system. Installation shall include the replacement of the existing Nova 12ØØ CPU with the new data collection subsystem CPU and installation of the data reliability and display subsystem. Installation shall include complete programming and operation of the entire system and a demonstration of the completed system to the user.

17. Operation and maintenance manuals for all new hardware and software, complete with full schematics and wiring diagrams for the full system.

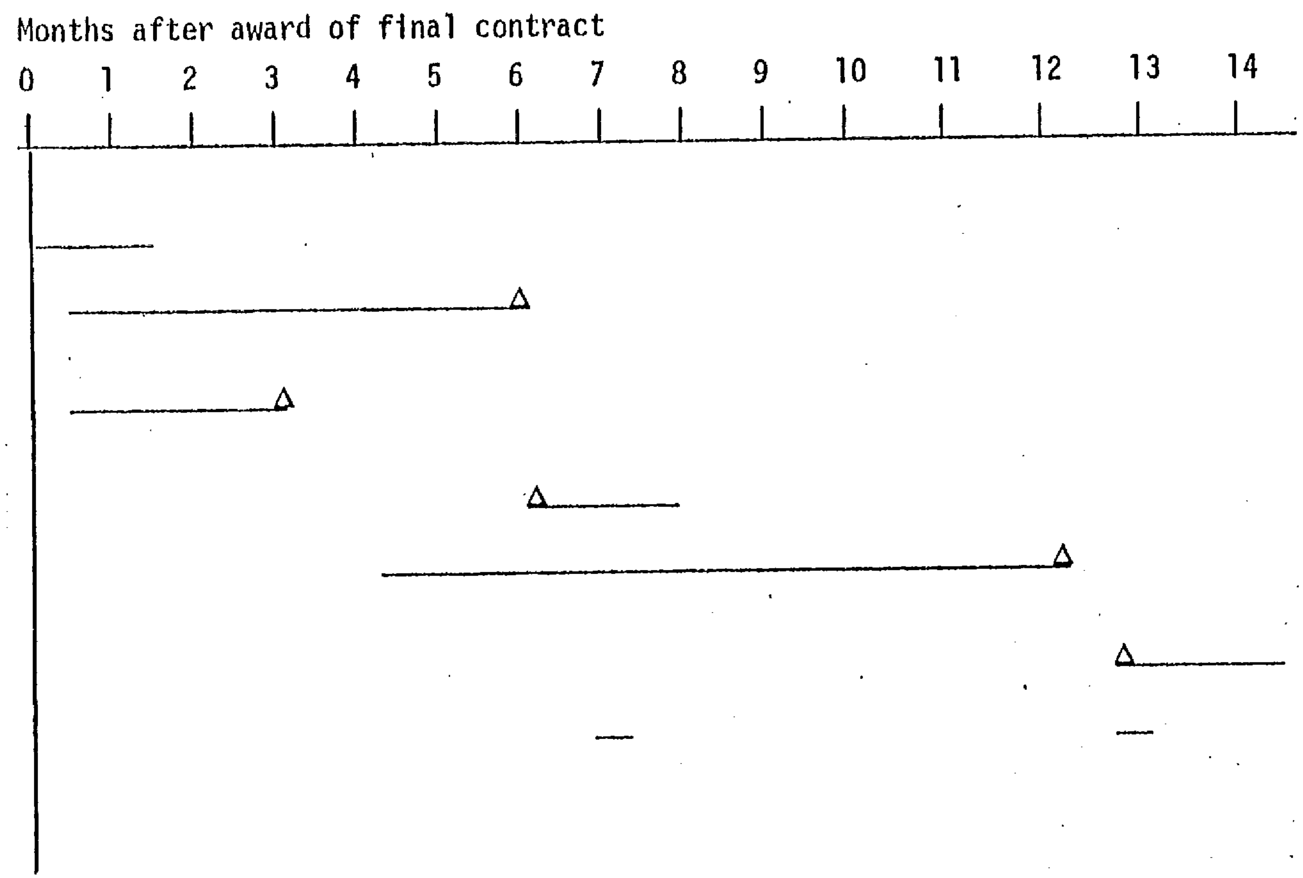
The purchaser reserves the right to waive any of these specifications if, in his opinion, a superior alternate is offered at an equivalent or lower cost.

5.2 SCHEDULE

The schedule for delivery of the above items is contained in Figure 5.1 for the 15-month period commencing with the start of the contract. A penalty of 1 percent of the total contract price shall be assessed for each week delivery falls behind the schedule.

After awarding the final IAQTS contract, the ARB will begin closely monitoring the performance of the chosen prime contractor. This shall be accomplished through frequent meetings between the prime contractor and the users of the IAQTS and through bimonthly progress reports written to the ARB. In addition, the prime contractor shall provide users' manuals of the system by the end of the third month of the contract, to enable ARB staff to determine compliance of the

1. preliminary meetings
2. modify ADAM III software, demo
3. compile and deliver user manuals
4. install D.C. CPU and test
5. develop R.D. software, demo
6. install R.D. CPU and test full system
7. train ARB users



*D.C. = data collection (subsystem of IAQTS)

R.D. = data reliability and display (subsystem of IAQTS)

Figure 5.1 Schedule of Delivery

evolving system with its specifications.

Sequential phases of the project are as follows:

1. Prime contractor meets with ARB staff to review final contract and plan compliance with it.

2. Modified ADAM III software is developed on the new data collection CPU at the prime contractor's facility and demonstrated to ARB representatives.

3. Prime contractor provides ARB with a full set of users' manuals for the proposed system.

4. New data collection CPU is delivered to ARB offices and operated in place of old data collection system for 30 consecutive days to demonstrate proper operation and reliability. Changeover from old to new, and, in case of failure of new system, from new to old data collection system shall require less than 24 hours.

5. Data reliability and display software is developed and implemented on second CPU at vendor's facility. Correct operation of this subsystem is demonstrated to ARB representatives.

6. Data display CPU and its peripherals are delivered to the ARB offices and integrated with the new data collection subsystem. Failure of the data collection subsystem shall be simulated, to test proper operation of the data display subsystem as a backup data collection system. The full system shall be placed into probationary operation until it has worked reliably for 30 consecutive days.

7. Prime contractor teaches ARB staff how to operate the new system, including how to exercise the available options.

8. ARB staff spend 3 months familiarizing selves with the new system, contacting the prime contractor when questions or problems arise. Prime contractor shall be expected to provide fast response to ARB's questions and complaints.

9. The ARB staff shall evaluate the final system for 6 months, measuring its performance against the specified criteria on data completeness, error rates, downtime, etc. The evaluation shall culminate in the writing of a summary report.

5.3 GUARANTEES

1. The prime contractor shall be designated as responsible for the installation of all hardware and software. This responsibility shall continue for one year after final installation of the system. If the prime contractor designates subcontractors to perform the warranty work, he shall still retain responsibility for all hardware and software guarantees throughout the warranty period.

2. Components which fail during the warranty period shall be replaced or repaired without cost to the California Air Resources Board.

3. All warranties pertaining to proprietary components used by the prime contractor in the system shall be extended by him to the California Air Resources Board. The prime contractor agrees to act in behalf of the California Air Resources Board should it become necessary to invoke the guarantee on a proprietary component. All warranty work shall be completed in a timely fashion, with a penalty of 1 percent of the total contract imposed for each cumulative week of unreasonable delay.

4. The prime contractor agrees to supply, upon receipt of a proper purchase order, spare or replacement parts of all components manufactured by him for a period of not less than ten years.

5. Proprietary components not manufactured by the prime contractor may, at the option of the California Air Resources Board, be purchased through the prime contractor or directly from the manufacturer.

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