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Visual Approach Data Collection at San Francisco International Airport (SFO)

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January 1992

Final Report

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16. Abstract Data on aircraft executing simultaneous visual approaches to parallel runways 28R and 29L were collected at San Francisco International Airport (SFO) between November 9, 1989 and March 12, 1990. The purpose of data collection was to analyze the navigational characteristics of aircraft flying the "fly visual" segment of the approach. Aircraft position data were collected using the in-place Bay Terminal Radar Approach Control Facility (TRACON) Airport surveillance primary and secondary radars. Data Reduction and limited analysis were done at the Federal Aviation Administration (FAA) Technical Center by ATC Technology Branch (ACD-340) personnel. The discussion in this concerns the accuracy of the collected position data and possible sources of error in the data collection. The reduced data will be sent to the Standards Development Branch (AVN-540) for further analysis. AVN-540 will conduct the final analysis of the data and report on their findings and recommendations.					
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EXECUTIVE SUMMARY

Current FAA regulations allow all nonprecision and precision Category I and Category II approach and landing operations to include a transition from instrument flight to visual flight, followed by a "fly visual" segment to complete the landing. As a means for increasing airport capacity, numerous "fly visual" concepts have been envisioned - simultaneous charted visual approaches to closely spaced parallel runways, simultaneous instrument approaches to closely spaced runways, simultaneous visual approaches to intersecting runways, and simultaneous converging instrument approaches to intersecting runways. To date, very little qualitative and quantitative data are available for use in evaluating the safety of these concepts.

The Standards Development Branch (AVN-540) at the Mike Monroney Aeronautical Center, Oklahoma City, requested that data be collected to be used to formulate criteria for conducting simultaneous visual operations to parallel runways having spacing less than established standards and to converging runways. The Dual Sensor Receiver and Processor (DUALSRAP) Data Collection System data collection system previously used to collect data at the Chicago O'Hare International Airport (ORD) was modified to collect the necessary data. The system used position reports generated by the Airport Surveillance Radar (ASR)-7 along with its associated secondary radar, the Air Traffic Control Beacon Interrogator (ATCBI)-4. Data was collected on arriving targets-of-opportunity aircraft to San Francisco International Airport (SFO). These arriving aircraft had to be equipped with Mode C/S transponders while conducting the Quiet Bridge and Tipp Toe visual approaches to runways 28R and 28L, respectively. The data collection began November 1989 and continued until March 1990 when the required number of approximately 3000 tracks had been recorded. Voice recordings of all communications between observed aircraft and air traffic control were also obtained, along with accurate and timely weather data.

Data processing and reduction was done at the FAA Technical Center, resulting in smooth track files and various plots of the data. The reduced track data files and their plots were sent to AVN-540. A Master data base was constructed and provided all pertinent data and certain aspects important to analysis. Limited data analysis was performed at the FAA Technical Center in order to determine the overall accuracy of the collected data. AVN-540 will conduct the final analysis of the reduced data and report on their findings and recommendations.

1. INTRODUCTION.

The Visuals Approach Final Report describes the data collection and reduction methodology that was employed to provide the Standards Development Branch, AVN-540, with the data they requested. These data were part of an operational test and evaluation of the visual segment of approaches to runways 28L and 28R at the San Francisco International Airport (SFO). The final report is intended to accomplish the following:

- a. Describe the data collection and data reduction hardware and software.
- b. Specify the data collection and data reduction procedures.
- c. Describe the deliverables for which the Engineering, Research, and Development Service, Air Traffic Control (ATC) Technology Branch, ACD-340 was responsible.
- d. Discuss general conclusions derived from preliminary ACD-340 data analysis.
- e. Provide the milestone project schedule.

1.1 OBJECTIVES.

The objective of this effort was to provide an accurate data base of the navigational accuracy of aircraft flying the visual approaches to the closely spaced parallel runways at SFO under different environmental conditions. It sought to describe the current use and practices during day in, day out operations. This data base will be used by AVN-540 to determine operating minimums, operational criteria, and operational procedures associated with certain "fly visual" approach and landing operations.

1.2 BACKGROUND.

Airport capacity remains a critical issue for the Federal Aviation Administration (FAA). The ability of a highly active airport to operate at its optimal capacity is crucial to daily operations. One method to maintain airport capacity is to permit standard Instrument Flight Rules (IFR) separation. Operations based on IFR separation, however, have not accommodated the capacity requirements at specific airports. The increases in traffic, plus the limited number of runways where standard IFR separation can be applied, have led to the increased use of the fly visual concept in operations. The fly visual concept provides standard IFR separation until the aircraft arrive at a point where visual separation must be established by either the pilots or the controller. In simultaneous fly visual operations, this usually occurs just prior to arriving at the point where the two flightpaths converge to the required minimum IFR lateral separation distance. Flight standards are needed to establish criteria and operational requirements necessary to safely conduct simultaneous fly visual operations for simultaneous visual approaches to closely spaced parallel runways which have a fly visual segment (based on visual separation), as well as to converging runways.

2. RELATED PROJECTS AND DOCUMENTATION.

A recent work effort conducted by the ATC Technology Branch, ACD-340, under the Capacity Studies project, F20-06A, resulted in the development and employment of the Dual Sensor Receiver and Processor (DUALSRAP) Data Collection System. The DUALSRAP system collected data from a Sensor Receiver and Processor (SRAP) which was connected to the source of radar data. The source consisted of an Airport Surveillance Radar (ASR)-7 and an ATC Beacon Interrogator (ATCBI)-4. This system was used to characterize the Instrument Landing System (ILS) navigational performance of a typical mix of today's aircraft, and to determine the degree of containment within several hypothetical Normal Operating Zones (NOZ) smaller than presently allowed. The system was set up at Chicago O'Hare International Airport from January 1989 through March 1989 to collect a data base of over 3000 simultaneous ILS approaches. The DUALSRAP Data Collection System was employed by this project with some system modifications. System modifications included termination of data collection at a preset time and modification of system defaults for SFO data collection. Additional software was used to facilitate automatic start up of data collection and provide for remote monitoring and control of data collection. Additionally, a local area network was installed to provide the ability for on-site plotting of data and better utilization of disk space and computers. A more detailed description of the DUALSRAP Data Collection System was supplied by Thomas and Timoteo, April 1990.

3. PROJECT IMPLEMENTATION.

The primary data for this study were radar tracks of aircraft flying visual approaches to the closely spaced parallel runways 28L and 28R at SFO. Airport diagrams are shown in figures 1, 2, and 3. In order to extract the maximum information from this data, secondary data collected included the precise weather conditions during the approach, the type of aircraft, the aircraft's beacon code and identification, and the approach fix for each aircraft. Approximately 3000 aircraft tracks were collected in order to provide AVN-540 with a large enough data base for analysis.

The project phases were divided into data collection, data extraction and reduction with limited analysis, and data output to Flight Standards. In addition, system support software was modified as needed to accomplish the project goals.

4. DATA COLLECTION.

4.1 DATA COLLECTION HARDWARE.

4.1.1 Data Collection System Hardware Description. The data collection system was installed partly at the Bay Terminal Radar Approach Control (TRACON) and partly at the Bay radar site (shown in figure 4). It consisted of the following hardware:

- a. SRAP (radar site).
- b. Interface Card Cage containing: (radar site)

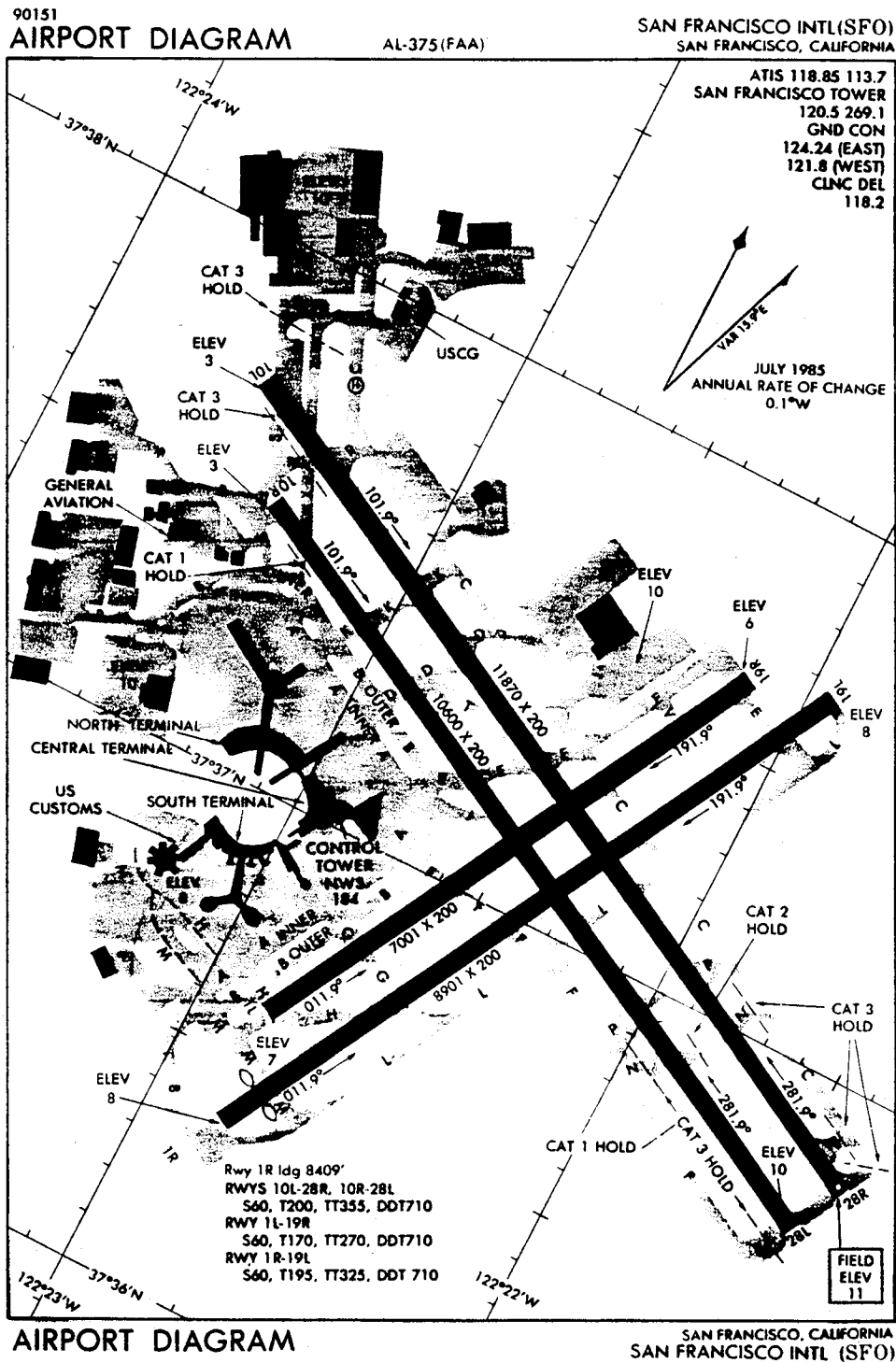


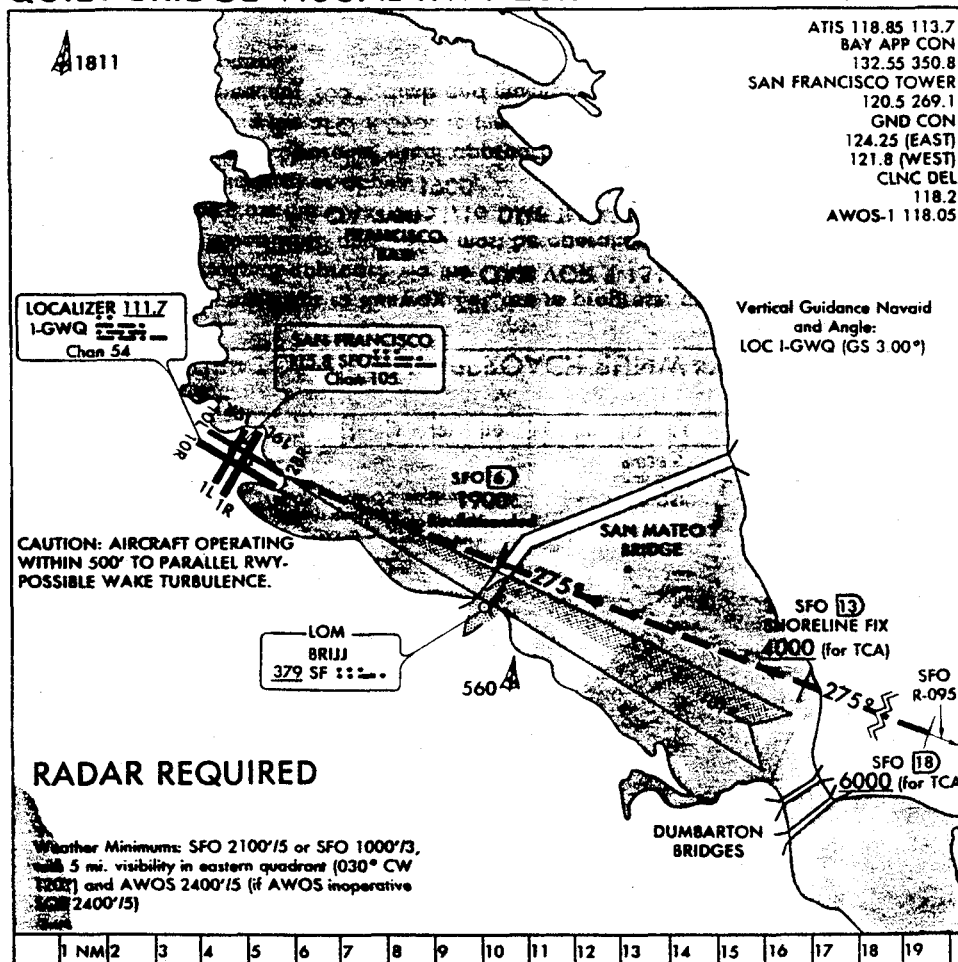
FIGURE 1. SAN FRANCISCO INTERNATIONAL AIRPORT (SFO) DIAGRAM

Amdt 5 90179

AL-375 (FAA)

QUIET BRIDGE VISUAL RWY 28R

SAN FRANCISCO INTL (SFO)
SAN FRANCISCO, CALIFORNIA



QUIET BRIDGE VISUAL APPROACH RUNWAY 28R

When visual approaches to Runway 28R are in progress, arriving aircraft may be vectored into a position for a straight-in visual approach to Runway 28R via the SFO VOR R-095.

SFO VOR and DME must be operating.

Aircraft should remain on the SFO R-095 until passing the San Mateo Bridge.

NOTE: Closely spaced parallel visual approaches may be in progress to Runway 28L utilizing I-SFO. In the event of a go-around on Runway 28R, turn right heading 310°, climb and maintain 3000, or as directed by Air Traffic Control.

QUIET BRIDGE VISUAL RWY 28R

SAN FRANCISCO, CALIFORNIA
SAN FRANCISCO INTL (SFO)

37°37'N. 122°22'W
391

FIGURE 2. SFO CHARTED VISUAL 28R APPROACH PLATE

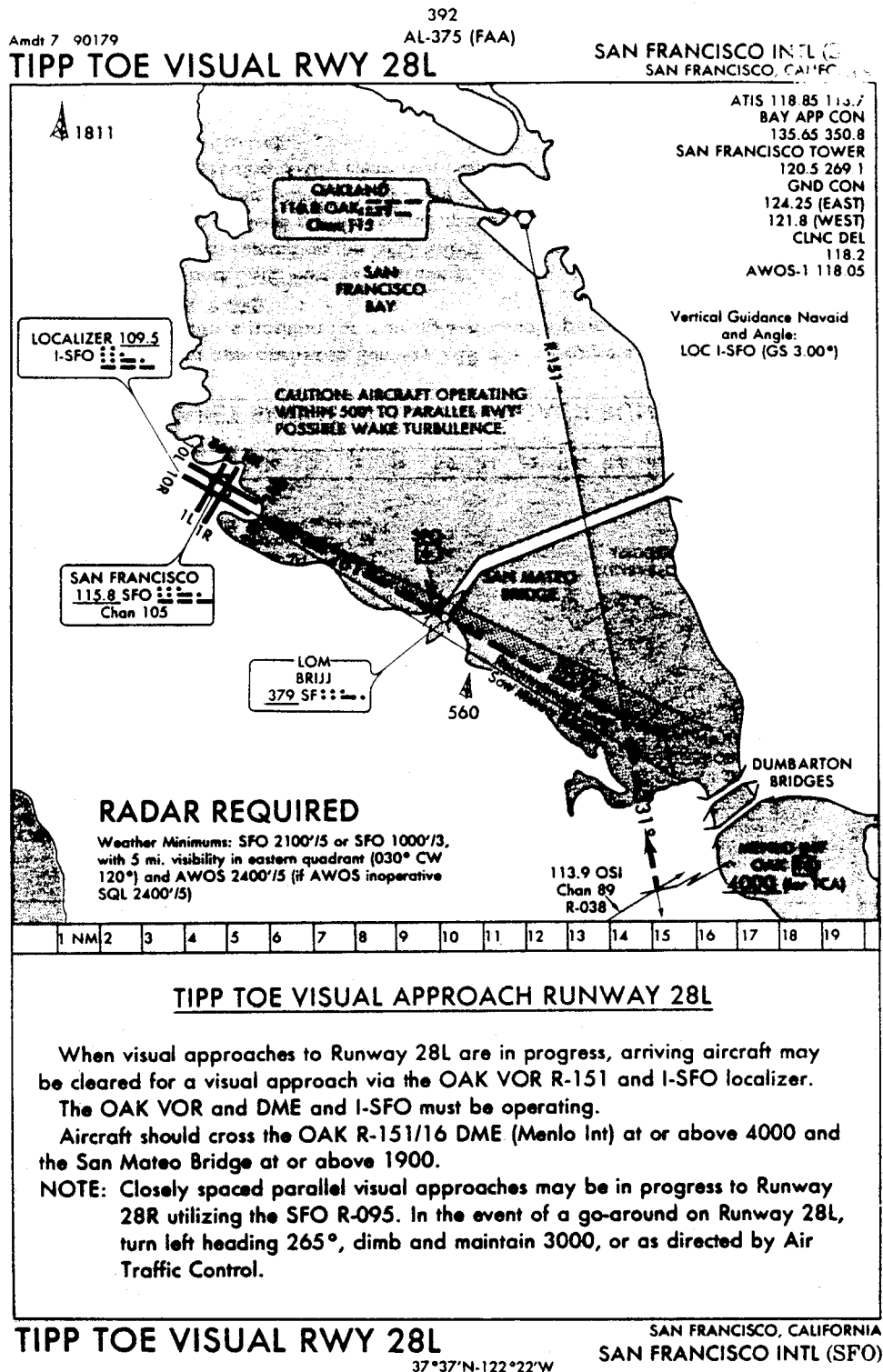
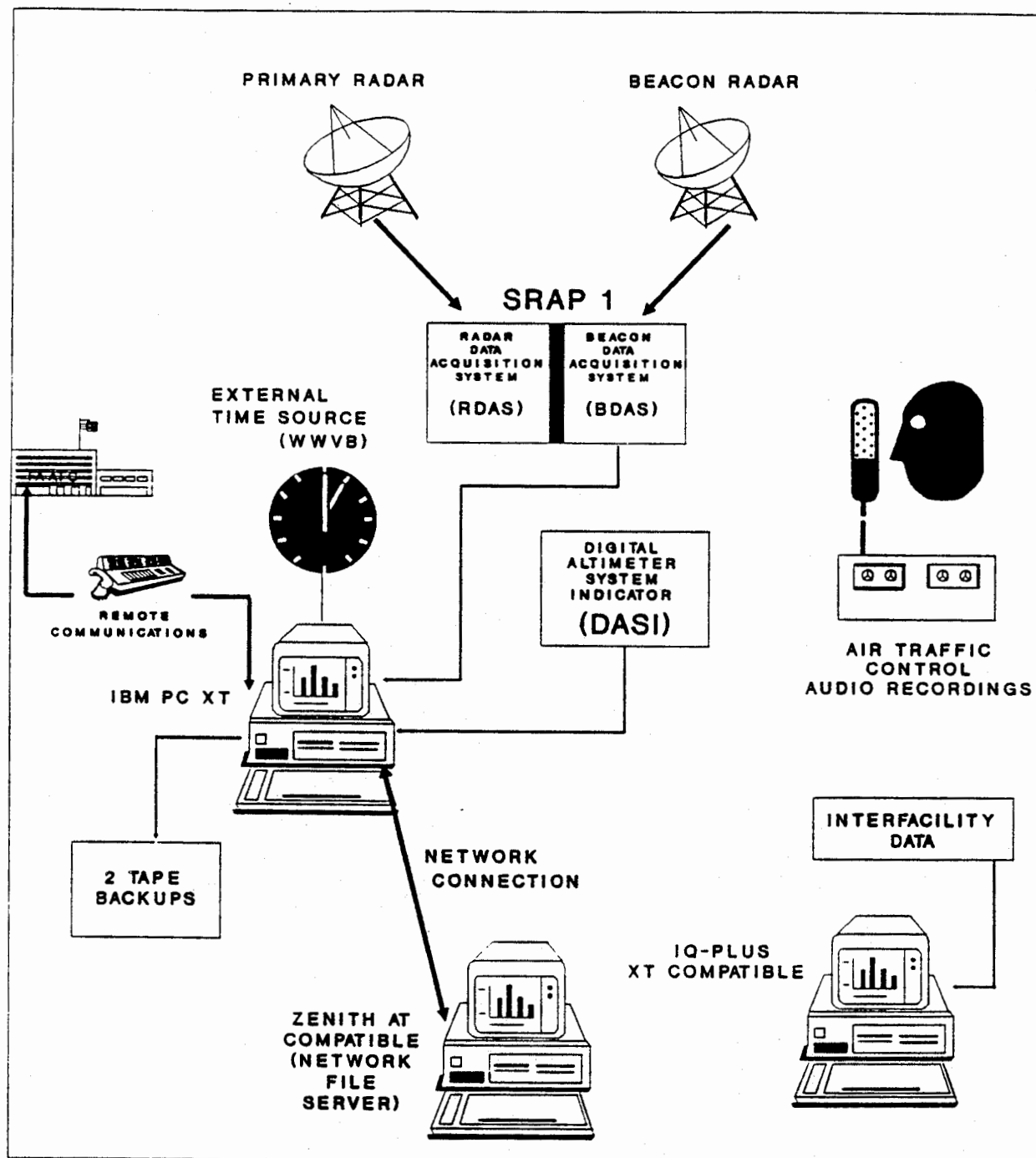


FIGURE 3. SFO CHARTED VISUAL 28L APPROACH PLATE



DUALSRAP DATA COLLECTION SYSTEM (as used at San Francisco)

FIGURE 4. DUALSRAP DATA COLLECTION SYSTEM

1. Two SRAP to Personal Computer (PC) interface cards.
 2. Sensor Interface to PC interface card.
 3. Digital Altimeter Setting Indicator (DASI) interface card.
- c. Interfacility Data System Microprocessor (IDSM) Interface Unit and cables (TRACON).
- d. WWVB Time Code Receiver and Antenna (radar site).
- e. IBM PC XT Computer System with Expansion Chassis (radar site).
- f. Zenith Z-248 Computer System (radar site).
- g. IQ-Plus XT Compatible Computer (TRACON).
- h. Two Mountain Filesafe Series 7300 150 MB Tape Backups (radar site).
- i. VLR-466 Voice Logging Recorder (TRACON).
- j. American Power Conversion 1200VX Uninterruptible Power Supply (radar site).

4.1.1.1 SRAP. The project SRAP accepted analog signals from the ASR-7 and ATCBI-4 and converted the data into digital target reports used by the ARTS IIIA processor. The SRAP consisted of a Radar Data Acquisition Subsystem (RDAS) and a Beacon Data Acquisition Subsystem (BDAS). The RDAS provided detection of range and azimuth of aircraft targets and weather. The BDAS provided for the detection and reporting of the range, azimuth, altitude, and identity of transponder equipped aircraft. The BDAS also received data from the RDAS in order to perform radar/beacon target correlation. Data were output from the SRAP via the Peripheral Interface Module (PIM) in the form of either a one, two, or three 32-bit word message. SRAP output consisted of the following message types:

<u>Report Type</u>	<u>Description</u>
--------------------	--------------------

- | | |
|---|---|
| 1 | Radar only reports (2 words)
Used ASR radar video |
| 2 | Beacon only/radar reinforced beacon reports (3 words)
Used ATCBI or ATCBI/ASR radar videos |
| 3 | Alarms (1 word)
Reported SRAP processing errors |
| 4 | Sector mark (1 word)
Message output every 11.25° of radar scan |

4.1.1.2 SRAP/XT Interface. FAA Technical Center personnel designed and fabricated a SRAP Interface and Control card set that served as an interface between a PC and the SRAP. SRAP data were obtained from the PIM using two 50-conductor flat cables. The interface card converted 32-bit SRAP message words into the IBM PC 8-bit word format. The card read each complete SRAP message as

quickly as the SRAP could send it (one, two, three words). Each message was broken down in two, four, six, or twelve 8-bit bytes. An interrupt was then sent by the card to notify the PC of data ready to send. The interface card supported the four previously defined SRAP message types. The interface permitted simultaneous collection of data from two separate RDAS/BDAS subsystems (SRAP0 and SRAP1). These subsystems can be connected to the same or different radar sources. It provided the following preprocessing functions for each channel:

- a. Automatic synchronization with the SRAP data by sector marks.
- b. Identification of each SRAP data report type.
- c. Filtering by sector for report types 1 and 2 above.
- d. Input, reformatting, and storage of a complete SRAP report.
- e. Hardware interrupt to XT to request report transfer.
- f. Transmission of report to XT via input/output (I/O) channel on a byte basis.

The interface incorporated azimuth filtering of the radar and beacon only/radar reinforced messages based on sector mark. Board-mounted DIP switches were used to select both a start and stop sector. These switches were set prior to each test to restrict collected sectors to those actually used by the aircraft during approach and landing. In this way the amount of unwanted data were minimized, thereby reducing the XT workload and the amount of collected data. The sector switches could be changed during a test without stopping collection. In this way changing approach configurations were accommodated while minimizing the amount of missed data.

4.1.1.3 DASI/XT Interface. DASI data were collected by the DASI interface card. The IBM PC polled the DASI interface card every 4.7 seconds to see if data were present.

4.1.1.4 IDSM Interface. SFO Interfacility data were collected via the Landrum and Brown Automated Radar Terminal System (ARTS) Identification Data Acquisition System (ID-DAS). The ID-DAS interface consisted of a Persyst multiport serial coprocessor board, a distributed communications processor capable of running independently of the Host PC, and the ID-DAS Fortran software.

4.1.1.5 Computer Equipment. The computers used for data collection were standard IBM XT or AT Compatible systems with a number of add-on cards. The IBM XT and the Zenith Z-248 were located at the radar site. The IQ-PLUS was located at the TRACON. A dedicated phone line at each site was required for remote monitoring and control of data collection.

The IBM XT ran the DUALSRAP program that collected, time-tagged, and stored SRAP and DASI data. Add-on cards included a 80286/80287 Turbo card with onboard memory cache for added processing power, a 2 MB expanded memory board, a LAN card, and a 2400 baud modem.

The Zenith Z-248 AT compatible functioned as a network server for the XT. The Zenith had a 600 megabyte drive that SRAP and DASI data were saved to after the day's data collection finished. The Zenith also included software to allow on-site plotting of collected data while the XT continued to collect data. Add-on cards included 2.5 MB of extended memory, a 2400 baud modem, and a LAN card.

The IQ-PLUS XT Compatible was set up to collect interfacility data. Add-on cards were the IDSM interface and a 2400 baud modem.

A personal computer located at the FAA Technical Center was used to collect the weather data for SFO.

4.1.2 Data Collection Interfaces. Two types of data were collected. Aircraft track data was collected via the DUALSRAP system. Weather and pilot/ controller communications were collected by separate systems. More detailed descriptions of the individual data files are contained in appendix A.

4.1.2.1 DUALSRAP Hardware Interface. The DUALSRAP data collection system, shown in figure 4 and described in section 4.1.2, interfaced with the following hardware:

- a. ASR-7 and ATCBI-4 search and beacon radar, via a SRAP.
- b. Interfacility Data System Microprocessor (IDSM).
- c. Digital Altimeter System Indicator (DASI).
- d. WWVB Reference Time.

Aircraft position was determined from target replies provided by the Bay TRACON ASR-7 and ATCBI-4. Radar videos and triggers were received by a project-supplied SRAP from a feed on the TRACON radar distribution amplifiers; the project used the same raw radar data used by the operational system. The SRAP converted the radar analog data into digital processed information for the Automated Radar Terminal System (ARTS) IIIA processor. To minimize impact to the San Francisco ARTS, the project obtained a surplus SRAP from the FAA Depot in Oklahoma City for standalone use. This SRAP's analog front end and digital parameter settings were brought up to certification standards by SFO Airways Facilities personnel.

The SFO interfacility data was collected from the IDSM. The IDSM provided information on flights in the National Airspace System (NAS). This information consisted of each flight's beacon code, aircraft ID, aircraft type, approach fix, and altitude at the fix. The information was transmitted between the Bay TRACON and the en route centers. For this data collection, only SFO arrival information was extracted and stored to disk, departures and over flight data were ignored.

DASI data was collected at SFO. The DASI provided local digitized barometric pressure and was received at the radar site from the TRACON via a Radar Microwave Link (RML)-6.

The National Bureau of Standards (NBS) WWVB broadcast station located in Fort Collins, Colorado, was used as the data collection's reference time source. WWVB

time was received and processed by a commercially available unit with an accurate internal clock. This provided a stable reference at the site when radio reception was poor. This time was used at the start of each data collection session to synchronize the PC internal real-time clock (Disk Operating System (DOS) time). The DOS time was then used to time-stamp each of the SRAP Sector reports recorded to disk.

4.1.2.2 Additional Interfaces. Data obtained from these sources were not used by DUALSRAP during the data collection process. These data were used in the data extraction and reduction processes.

The SFO National Weather Service (NWS) meteorological reports were collected once a day via modem from the Kavouras, Inc. Meteorological Data Base computer located at the Minneapolis International Airport (shown in figure 5). Surface Observation Reports (SA) were normally available on an hourly basis, with Special Reports (SP) given more frequently when warranted by rapidly changing weather conditions. A full report consisted of cloud heights and coverage, visibility, weather, temperature, dewpoint, wind direction and speed, altimeter, and remarks. Remarks were conditions considered significant to aviation such as runway visibility, cloud types, icing conditions, etc.

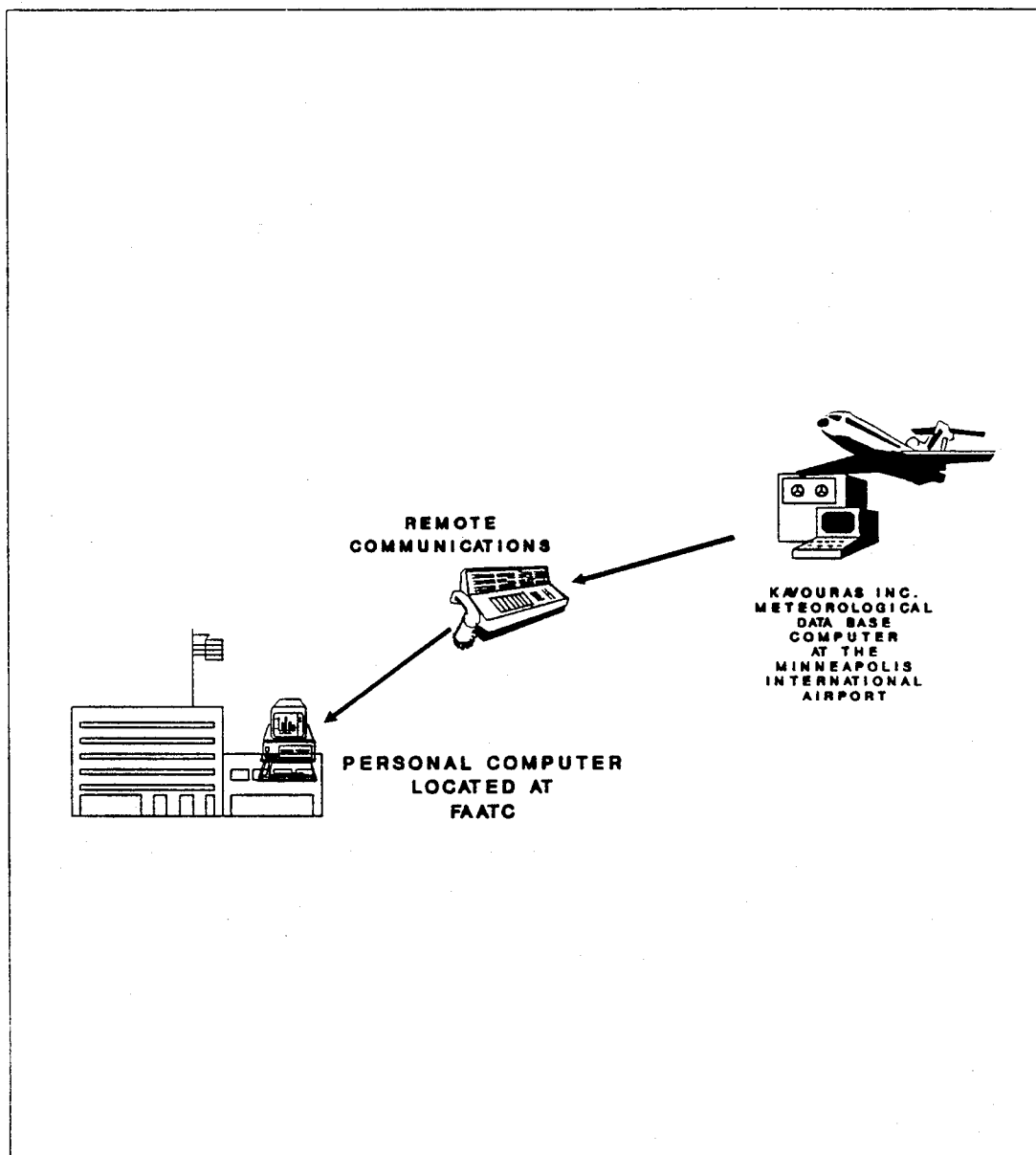
Voice recordings of pilot/controller communications for approach control, all local control, and the Air Traffic Information Service (ATIS) channel were made on a 4-channel audio recorder interfaced with the Granger Link Microwave system. An accurate date and time-of-day stamp was integrated with each recorded channel. This allowed searches for specific portions of the recordings on a time basis.

4.2 DATA COLLECTION SYSTEM SOFTWARE.

4.2.1 SRAP Data Collection Software. An ACD-340 written 8088 assembly language program, collected, time-stamped, and stored SRAP and DASI data to disk. Assembly language was used for maximum speed and hardware control. The program consisted of foreground and background processes. Since DASI data collection had a relatively low data rate, the background process polled the DASI to PC interface card every 4 seconds. SRAP data collection had a much higher data rate and was handled by the foreground routine using hardware interrupts. Collected SRAP and DASI data were saved into buffers; after these buffers filled up, the data were written to disk.

The DUALSRAP system software was modified to allow greater flexibility for remote operation. The options that defined the system configuration for a given session included:

- a. Synchronization of DOS time with WWVB time at start of data collection (synchronized for SFO).
- b. Range filtering (4, 8, 16, 32, or 64 miles) of collected targets with respect to radar collection (16 miles for SFO).
- c. Collection of DASI sensor data (collected for SFO).



WEATHER DATA COLLECTION SYSTEM (as used at FAA Technical Center)

FIGURE 5. WEATHER DATA COLLECTION SYSTEM

- d. SRAP(s) to be used (SRAP 0 for SFO).
- e. Collection of radar-only messages for each SRAP, however, these messages had limited use and require considerable storage space and, therefore, were not collected for SFO.
- f. Termination of data collection at a preset time each day (2200 hours for SFO).
- g. Specification of Start and Stop Sector Marks using board-mounted switches.

4.2.2 Interfacility Data Collection Software. An executable Fortran program collected and stored interfacility data. The program's configuration had to be set up each time data collection was started. The ID-DAS provided the ability to execute the collection software via a batch command. The batch command specified a redirected input file with the necessary responses needed to initialize and configure the software. These options were set as:

- a. Processing mode - Arrivals only for SFO (Options were all Operations, Arrivals, Departures, Not Overflights).
- b. Included all aircraft ID's for SFO.
- c. All ARTS Interfacility messages, pertinent to ID-DAS, were copied to a buffer file.
- d. Start and Stop times were specified for SFO (data collection began immediately upon program execution and stopped at 2200 hours).
- e. Default output filename set for SFO (Imddhhmm.AOL - m - month, dd - day, hh - hour, and mm - minute).

4.2.3 Weather Data Collection Software. PC Weather was a telecommunications program which accessed the Kavouras Inc. Meteorological data base. The software was set up to call up and log onto the Kavouras data base, request the 30 previous SA Reports, save the reports to disk, and log off the system. Since PC Weather was intended primarily to be used as an interactive program, it was necessary to use Extended Batch Language (EBL) to execute the program unattended. EBL was used to execute the following actions in the weather data collection program:

- a. Dial the weather data base.
- b. Enter the User Name and Password to gain access to the system.
- c. Send the command "SA/SFO RPTS=30," which requested the last 30 SA reports for SFO.
- d. Request that the weather data be saved to disk.
- e. Log off the data base and then exit the data collection program.

4.2.4 Data Collection Support Software. Various off-the-shelf software packages were used to support the SFO data collection effort. The support software were supplied by Mountain Computer, Inc., Fox Software, Inc., Seaware Corporation, Novell Incorporated, and Dynamic Microprocessor Associates, Inc.

4.2.4.1 Autorun. Autorun is a program supplied with the Mountain Filesafe Tape Backup software. The program executed appointments based on the DOS time and date of a computer. Autorun was used to start the SRAP and Interfacility data collection each day.

4.2.4.2 Foxbase. Foxbase +2.10 is a data base management program. When daily data collection was started, a Foxbase language program was executed. This program created DOS batch files that were used to rename data collection files, to set the attributes of those files, and to delete the files at various stages of the data collection. For a more detailed description of these batch files, refer to appendix D of this report.

4.2.4.3 EBL. Extended Batch Language is a command programming language. The "Keyboard Stack" feature of EBL was used for weather data collection and allowed for answering questions within programs without operator intervention. Data placed in the "stack" was seen by the weather data collection program during execution as operator input.

4.2.4.4 Novell NetWare. NetWare was used to set up the local area network for the IBM XT and the Zenith Z-248 computers at SFO with the Z-248 being used as the network server.

4.2.4.5 pcAnywhere. pcAnywhere is a remote access software package that provided for remote monitoring and operation of the project computers via modem from the FAA Technical Center.

4.3 DATA COLLECTION PROCEDURES.

After the data collection procedures were established, it was not necessary to have ACD-340 personnel on-site. Data collection was monitored and operated by ACD-340 personnel at the FAA Technical Center.

4.3.1 SRAP Data Collection Procedures. The SRAP and DASI data collection process consisted of various programs invoked by a batch file. The batch file was started on the IBM XT each day at 0600 hours (Pacific time) by an appointment scheduling program, Autorun. The batch file initiated the following procedures:

- a. Created DOS batch files that were later executed during data collection to rename, set attributes of, and delete data files.

- b. Started the DUALSRAP data collection program. This program ran from the time it was started until 2200 hours (Pacific time).

- c. After the data collection program terminated, the names of the SRAP, DASI, and message data files were changed to reflect the month, day, and hour of that day's data collection. The day's data were then saved to the network drive.

d. Primary and secondary tape backups of the day's data files were performed.

e. If the day's data were successfully copied to the network drive, then the day's data files were deleted from the XT's hard drive.

If any problems occurred during data collection and the XT had to be rebooted, the data collection batch file could be restarted manually by on-site personnel or remotely by FAA Technical Center personnel. For more details on the SRAP data collection procedures, refer to appendix D of this report.

4.3.2 Interfacility Data Collection Procedures. The Landrum and Brown ARTS ID-DAS was invoked by a batch file. The batch file was started on the IQ-PLUS XT PC compatible each day at 0500 hours (Pacific time) by Autorun. Interfacility data collection started 1 hour before SRAP data collection. The earlier start time accounted for the up to 1 hour time difference between the receipt of interfacility data for an aircraft and the aircraft's arrival time at the airport. The batch file initiated the following procedures:

a. Checked for the existence of old data files in the interfacility data subdirectory on the IQ-PLUS hard drive. If any files were present, they were deleted.

b. Set up configuration and started execution of the interfacility data collection program. This program ran from when it was started until 2200 hours (Pacific time).

c. Backed up the day's data to hard disk and onto floppy disk.

If any problems occurred during data collection necessitating a reboot of the IQ-PLUS, interfacility data collection may be restarted manually either remotely or by on-site personnel. For more detail on interfacility data collection procedures, refer to appendix D.

4.3.3 Weather Data Collection Procedures. The weather data collection process was invoked by a batch file. The batch file was started on an IBM compatible computer, located at the FAA Technical Center, each day at 0100 hours (Eastern time) by Autorun. The batch file initiated the following procedures:

a. Checked for the existence of old data files in the weather data subdirectory on the computer's hard drive. If any files were present, they were deleted.

b. Set up configuration and started execution of the weather data collection program.

c. Backed up the weather data to the network drive, the PC's hard drive and onto floppy disk.

5. DATA PROCESSING.

The raw SFO data were processed at the FAA Technical Center to reduce it to a form suitable for analysis by ACD-340 and AVN-540. Data files generated in the collection and reduction processes are described in detail in appendix A. The data extraction and reduction processes are outlined in figure 6.

5.1 DATA EXTRACTION AND REDUCTION.

5.1.1 Data Unpacking. Subsequent to data collection but prior to data analysis, track data were extracted from the raw SRAP and Interfacility files and merged into a data base consisting of parallel approaches. The extraction procedure, unpacking, was the process whereby radar data, recorded in a foreign format for purposes of space and efficiency, was converted to a format compatible with the analysis environment. The unpacking process consisted of the following:

- a. Raw SRAP and Interfacility data were converted to engineering units.
- b. Data were sorted according to beacon code, aircraft tracks with a sufficient number of scans were identified, and the runway being approached was determined for each track.
- c. SRAP and Interfacility data were cross referenced to obtain the aircraft ID and the aircraft type for each track.
- d. One record for each track was appended to the Master data base.

The raw track files were placed into a session subdirectory, where the session was the day of the collection period. For a description of the software used during unpacking, see appendix B.

5.1.2 Parrot Statistics. The Parrot Statistics test was executed on the raw SRAP data to assist in the calculation of the radar range and azimuth biases for a session. This test was a series of programs that collected, unpacked, analyzed, and produced a statistical report on the quantity and quality of transponder data. The transponder data, collected continuously during each session, was received from the Oakland radar Parrot transponder located approximately 8 miles from the radar antenna. The report had values, based on the total number of Parrot returns, for the mean and standard deviation of both range and azimuth, and the Azimuth Change Pulse (ACP) skewness and kurtosis of the azimuth. The report (figure 7) was compared with previous reports to determine if there had been any change in the radar range and azimuth biases. These biases were computed and removed from the raw track data during the translation to runway origin.

5.1.3 Data Reduction. The reduction process took the raw track files created by the unpacking process and performed the following operations on them:

- a. Individual Track file data were checked for reasonableness; multiple scans were deleted, altitudes were added or corrected as needed, time gaps in

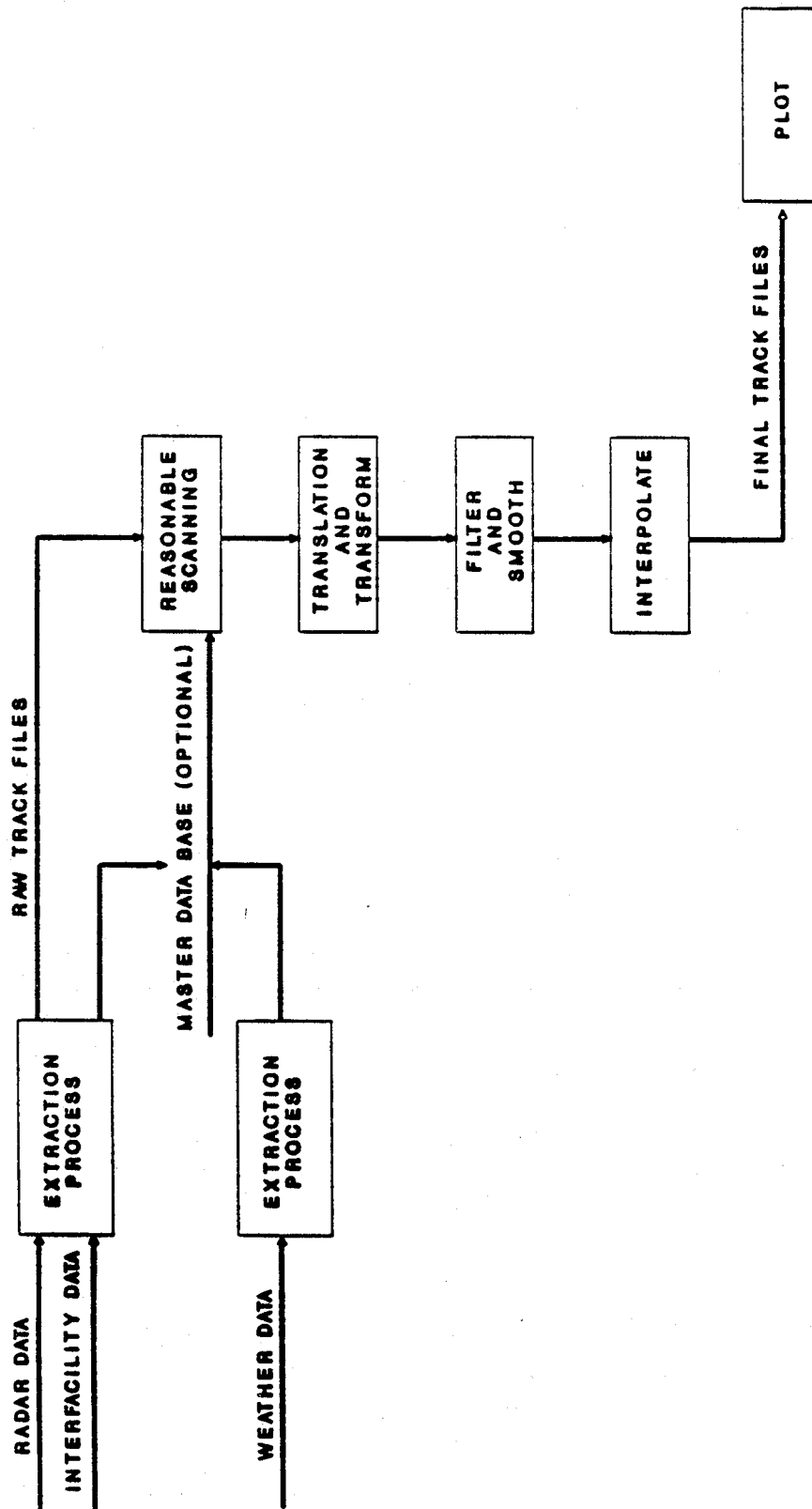


FIGURE 6. DATA EXTRACTION AND REDUCTION PROCESS

16:29:50

10/31/90

Radar Statistics using K:\SFO\UNPACK\SC030930.DBF

>>> PARROT STATISTICS FOR DECEMBER 3, 1989 <<<

Total number of samples is 9487
Mean value of RANGE is 7.201 nmi (43708 ft)
Mean value of ACP count is 4072.45 (357.93 deg)
Standard Deviation of RANGE is 0.006 nmi (33.6 ft)
Standard Deviation of ACP is 0.985 (0.087 deg/1.51 mr)
or 66.0 ft @ 7.201 nmi
The Skewness of ACP is 1.386
The Kurtosis of ACP is 22.230
Range of ACP's is from 4064 to 4087
or 357.19 to 359.21 deg

ACP	CNT
4064	2
4065	1
4066	3
4067	1
4068	5
4069	20
4070 **	98
4071 *****	987
4072 *****	*****
4073 *****	***
4074 *****	775
4075 *	45
4076	17
4077	5
4078	3
4079	2
4080	4
4081	2
4082	0
4083	1
4084	2
4085	1
4086	1
4087	1

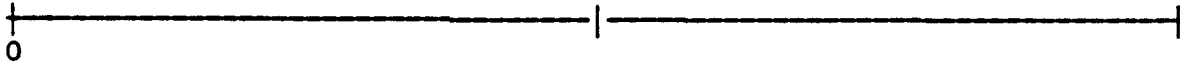


FIGURE 7. RADAR STATISTICS FOR PARROT TRANSPONDER

in data were identified, and pre- and post-gap data were checked to see if they were from the same track.

b. Data were converted from (range, azimuth, altitude) to cartesian (x, y, z) coordinates. Range and Azimuth biases were removed from the track data.

c. Data were filtered and smoothed using Lincoln Laboratory developed algorithms.

d. Interpolated data points were calculated at 0.15 nautical mile (nmi) increments along the extended runway centerline.

The final reduced track file consisted of reports at 0.15 nmi increments along the extended runway centerline. Each track file record contained, Time - the time of day in hours, minutes, and seconds, X - distance from runway threshold along the extended runway centerline, Y - deviation from extended runway centerline, and Z - altitude above sea level. All fields were in nautical miles, except time. The conversion factor was 6076 feet/nmi. The file was in reverse time order. This meant that the first record in the file represented the touchdown point or the distance closest to touchdown. Each successive record was an additional 0.15 nmi from touchdown in the X direction. These track files were, in turn, individually plotted and then sent to AVN-540 for further analysis. For a description of the software used during reduction, see appendix B.

All track files for each session were plotted as a group on a two-dimensional (x,y) scale where x represents distance to runway touchdown and y represents deviation about extended runway centerline. An example of this type of plot is shown in figure 8. The plots were identified by the session (test) number, runway designation, and the number of track files plotted. A grid in both axes was superimposed on the plot so that distances could be more easily judged. The scale in x was from touchdown to 15 nmi out. The scale in y was from -1 to 1 nmi.

5.1.4 Master Data Base. A Master data base, consisting of information about each track and the weather at the time of data collection, was produced through the unpacking process. The Master data base did not contain any radar data. This data base was used to identify tracks for conditions that need to be analyzed. For a more detailed description of the Master data base fields, see appendix C.

5.2 DELIVERABLES.

The requested track data and their plots were delivered to AVN-540. The format for sending the data was floppy disks. The floppy disks included the final track files for each session and the Master data base. Documentation explaining the data were also sent along with the plots created for each session.

SFO\TRACKSA\SC011230.28L\133 TRACKS

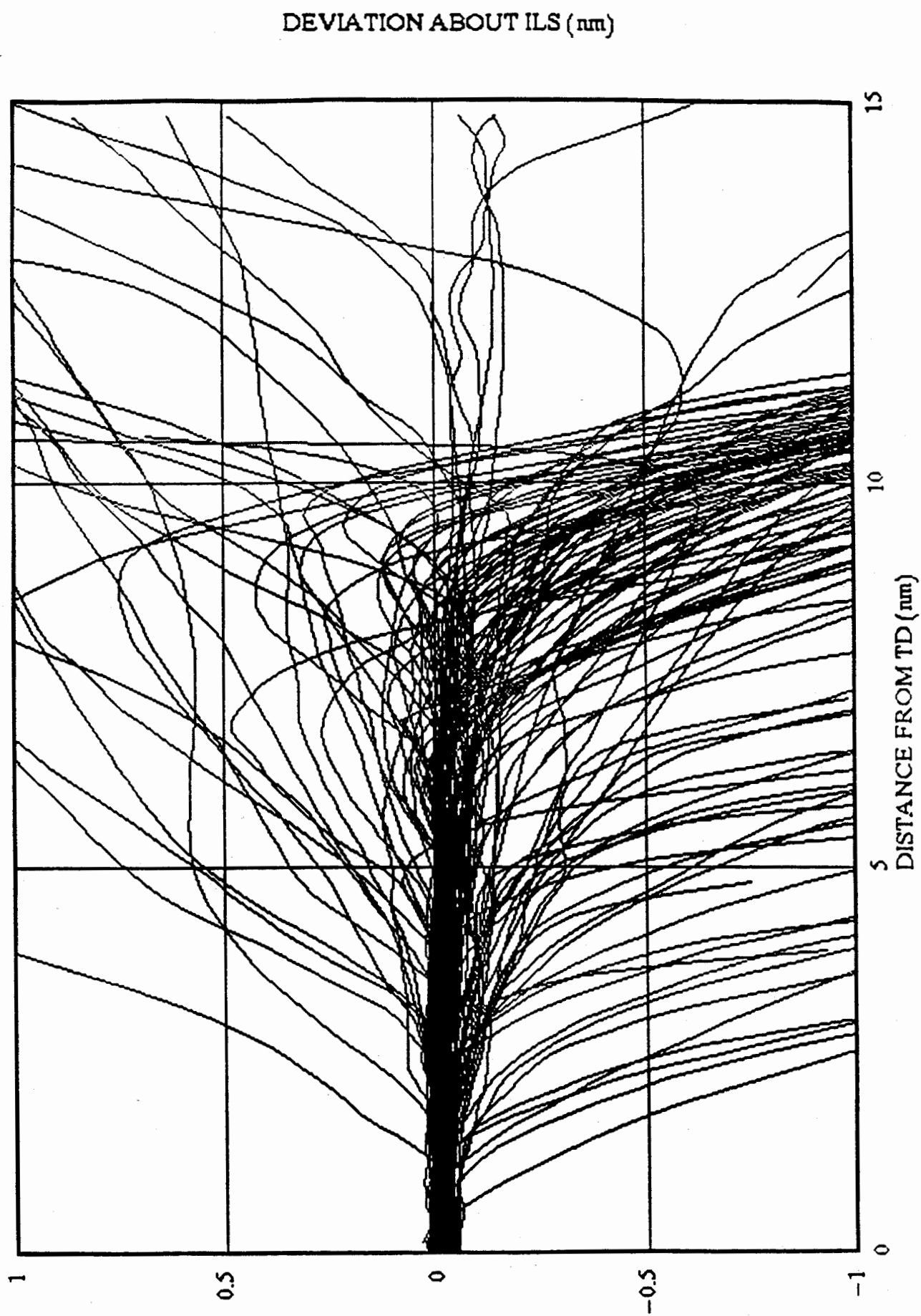


FIGURE 8. EXAMPLE SESSION TRACKS PLOT

6. DISCUSSION.

6.1 DATA REDUCTION RESPONSIBILITIES.

The Engineering, Research, and Development Service, ATC Technology Branch (ACD-340), was tasked to collect and reduce track data for aircraft conducting visual approaches to San Francisco International (SFO) Airport's runways 28L and 28R. These data will be used by the AVN-540 to justify existing procedures and/or specify new procedures for these approach operations. Since AVN-540 had expressed the need to conduct their own analysis of this data, ACD-340 did not conduct any analysis for the purposes of characterizing the approaches in any way or validating the ability of the sample tracks to navigate the approach routes. That level of analysis was considered the domain of AVN-540. The type of analysis provided by ACD-340 dealt with the data on a more universal level; specifically, what could be said about the validity of a data sample, how well did it represent what really happened, and its overall accuracy. Also considered were the most likely causes of error in the sample data.

6.2 DATA FIDELITY.

The data reduction process, as described in section 5 of this report, produced a file of position information (time, x, y, z) for each recorded track where time was time of day, x was the distance from touchdown along the extended runway centerline, y was the perpendicular distance from the extended runway centerline, and z was the altitude above mean sea level (m.s.l.). These data had been filtered, smoothed (appendix A and reference 2) and interpolated to give a point at each 0.15 nmi increment along the extended runway centerline. In addition, since the data were collected via an air traffic control airport (ATC) ASR-7, range and azimuth biases were removed as much as possible, and the data were translated from range, azimuth, and altitude with respect to the radar antenna to x, y, and z with the origin at the runway threshold.

The final result was a collection of sessions. A session consisted of the reduced data files for all the tracks collected in a day. All tracks for a session were plotted on a single graph and were also subjected to a simple statistical analysis producing average and standard deviations about the extended runway centerline at increments of 0.15 nmi away from runway threshold. Examples of these plots and statistics can be found in the Data Reduction section. Details of the procedures used to remove radar data biases can also be found in that section.

In the absence of any independent devices with which to observe each track, such as a second radar, the only way to judge the validity of the positional information was to consider the data at aircraft touchdown. It was known that every aircraft that landed, did so on the runway surface. However, the plots and statistics show that the data had a significant variance about the runway centerline just prior to runway touchdown. On average, the standard deviation at 0.45 nmi from touchdown was approximately 140 feet. This meant that many of our aircraft appeared to be touching down off the runway surface, on one side or the other. Two concerns needed to be addressed at this point. The first one was why there was such a large variance near touchdown. The second involved what this variance meant for the data that were not near touchdown.

6.2.1 Radar Coverage Near Touchdown. It was unfortunate that touchdown was the only place where track positional validity could be determined. This was because the radar was not effective at seeing targets that were at low altitudes or close to the ground. Reflections caused by the ground produced erroneous radar replies and lowered the occurrence of primary/beacon radar reinforcement. In addition, the lower the target, the more it was missed by the radar.¹ When coupled with the relatively low ASR-7 scan rate of 4.7 seconds this meant that a single bad point close to touchdown could skew the smooth estimate of the track at touchdown. The end of the track, which occurred at touchdown, was a particularly difficult area to smooth with high fidelity (Thomas and Timoteo, April 1990). All these factors gave rise to poor positional accuracy in the touchdown zone. It was, therefore, a bad point at which to check track positional validity; nevertheless, as stated previously, it was the only usable point.

Radar reflections and missed scans only partly addressed the large variance about the runway centerline at touchdown however. There was another factor that must be taken into consideration which not only compounded the situation at touchdown but was not limited to the touchdown zone. The target position determined via the beacon radar report was a combination of range, azimuth, and altitude. Each of these measurements had the potential to contribute error (Thomas and Timoteo, April 1990). Azimuth error was mainly dependent on the radar antenna alignment and wind loading, the Azimuth Change Pulse (ACP) resolution, and the signal strength. These were factors associated with the radar and atmospheric conditions. Altitude error was chiefly dependent upon the aircraft's measuring system, since an aircraft's altitude was determined by its transponder. Range error, on the other hand, was caused by a combination of the radar and the aircraft. This was because the beacon range of the target was determined by computing elapsed time between the start of interrogation by the radar and the receipt of the target reply at the radar. At the target the interrogation was received via a transponder and, after a definite time delay introduced by the transponder ($3.0 \pm 0.5 \mu s$), the reply was transmitted from aircraft back to radar. The allowable error limit in the transponder turnaround delay could build as much as a ± 245 -foot range bias into the beacon range report. This was larger than the standard deviation of the runway lateral deviation error observed in the SFO sample near touchdown. For information on tests conducted on transponder delay error, the reader is directed to Thomas and Timoteo, April 1990.

The range error became significant near touchdown at SFO. This was because of the orientation of radar with respect to runways 28R and 28L (figure 9). The terminal radar used for SFO was located at Oakland Airport, approximately 8 miles directly across the bay from SFO. This means that error in the measurement of aircraft lateral deviation from runway centerline was almost totally dependent on the radar range error and not on the azimuth error. Any azimuth error would affect only the measurement of distance from touchdown.

Taking the amount of transponder delay error into consideration along with the radar-runway orientation at SFO, the magnitude of the random error in the data

¹In tests conducted at SFO, the radar could not get replies from a test transponder with its antenna mounted approximately 20 feet above the end of runway 28R.

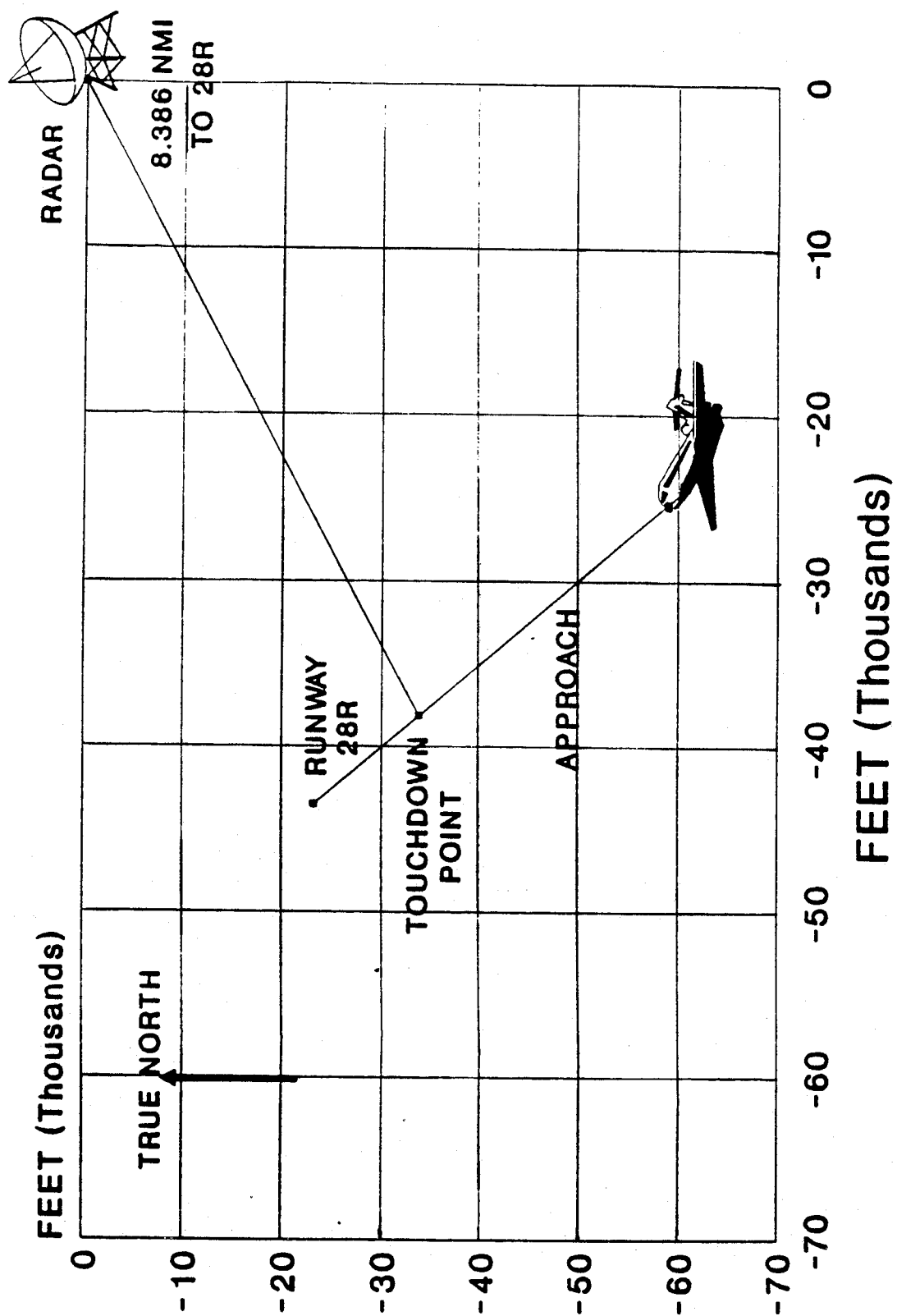


FIGURE 9. RELATIONSHIP OF RUNWAY AND RADAR SITE

for SFO near touchdown could be considered reasonable. It must be remembered that the error in the range measurement, caused by the transponder delay error, resulted in random error for the data sample because of the large number of transponders in the sample, one for each aircraft.

6.2.2 Data Fidelity Moving Away From Touchdown. The situation of SFO radar coverage at touchdown was unique due to target altitude and radar/runway orientation. SFO radar measurement accuracy during the approach to touchdown was different situation. The radar measurements on the approach were not subject to the problems associated with low altitude; i.e., missed and reflected reports, since the target was always high enough. However, the measurements were still subject to range and azimuth errors. Once again the radar/runway orientation was the main factor because of the requirement to determine how well an aircraft flew its assigned approach course centerline. This course was composed of a turn onto the final approach, followed by a straight line path to touchdown along the extended runway centerline as defined by the ILS localizer navigation beam. Referring to figure 9, it can be seen that the farther the aircraft was from touchdown on the final approach course, the deviation from course centerline became more dependent on azimuth measurement and less dependent on range measurement. At touchdown this deviation was nearly all due to range, at 5 miles from touchdown the azimuth accounted for 25 percent of this measurement, and at 10 miles from touchdown azimuth accounted for 49 percent. Since measurement of azimuth was not related to the transponder delay, little random azimuth error was expected. In tests performed using parrot transponders (Thomas and Timoteo, April 1990), the azimuth had a standard deviation of 0.13 degrees. This translated to a standard deviation of 69 feet at 5 nmi and 138 feet at 10 nmi from the radar. Within limits the azimuth error would decrease the closer the target was to the radar. Since azimuth error was dependent chiefly on the radar, the azimuth bias was a constant value and could be removed from the track data during the reduction process.

6.3 SUMMARY.

In conclusion, when considering an aircraft that had turned onto and was flying the final approach at SFO, the collected radar data exhibited some error. The error was composed of both a random (range) component and a constant (azimuth) component. The constant component was removed via the parrot transponder procedure discussed in section 5, but the random component could not be reliably identified and removed. For the measurement of aircraft deviation from extended runway centerline (final approach centerline), there was less random error the farther the aircraft was from touchdown. Therefore, the reduced track data would exhibit more random error about the extended runway centerline at touchdown than at any other final approach point. A summary of the percentages of deviation random error versus fixed error, at 2.5 nmi increments, is shown in table 1.

TABLE 1. RUNWAY CENTERLINE DEVIATION ERROR

<u>Distance from Threshold (along runway centerline)</u>	<u>Random Error (Range component)</u>	<u>Fixed Error (Azimuth component)</u>
0.0	77%	23%
2.5	98%	2%
5.0	75%	25%
7.5	62%	38%
10.0	51%	49%
12.5	45%	55%
15.0	39%	61%

7. PROJECT SCHEDULE AND MILESTONES.

SFO data collection was originally planned to be completed by December 1989; however, AVN-540 requested additional data collection up through March 1990. In October 1990, AVN-540 perceived a need for additional data and requested that all remaining data be processed and sent out to them. These additional and unforeseen requests necessitated that the planned completion dates for data delivery to AVN-540 and the Final Report Technical Note be pushed back.

<u>MILESTONE</u>	<u>COMPLETION DATE</u>
a. Complete Software Modifications to the DUALSRAP Data Collection System.	10/89
b. Complete System Integration Testing of New Modifications.	10/89
c. Perform Optimization Tests at San Francisco.	10/89
d. Start Data Collection for San Francisco.	11/89
e. End Data Collection for San Francisco.	03/90
f. Final delivery of Data Base and Plots to AVN-540 (SFO).	03/91
g. Publish Technical Note on SFO results.	01/92

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ID-DAS Users Manual, Landrum & Brown, 1989.

PC Weather 2.22 User's Guide, Kavouras, Inc., 1989.

Thomas, J. and Timoteo, D., Chicago O'Hare Simultaneous ILS Approach Data Collection and Analysis, DOT/FAA/CT-TN90/11, April 1990.

LIST OF ACRONYMS

ACP	Azimuth Change Pulse
ARTS	Automated Radar Terminal System
ASR	Airport Surveillance Radar
ATC	Air Traffic Control
ATCBI	Air Traffic Control Beacon Interrogator
ATIS	Automatic Terminal Information Service
BDAS	Beacon Data Acquisition System
DASI	Digital Altimeter System Indicator
DOS	Disk Operating System
EBL	Extended Batch Language
FAA	Federal Aviation Administration
ID-DAS	Identification Data Acquisition System
IDSM	Interfacility Data System Microprocessor
IFR	Instrument Flight Rules
ILS	Instrument Landing System
I/O	Input/Output
IRIG	Inter Range Instrumentation Group
m.s.l.	Mean Sea Level
NAS	National Airspace System
NBS	National Bureau of Standards
nmi	Nautical Miles
NOZ	Normal Operating Zone
NWS	National Weather Service
PC	Personal Computer
PIM	Peripheral Interface Module
RDAS	Radar Data Acquisition System
RML-6	Radar Microwave Link
SA	Surface Weather Observation
SFO	San Francisco International Airport
SP	Special Report
SPI	Special Position Indicator
SRAP	Sensor Receiver and Processor
TRACON	Terminal Radar Approach Control Facility

APPENDIX A

DATA FILES

Two types of data files are described in this appendix. Raw data files consist of data collected in the field, both at San Francisco International Airport (SFO) and at the FAA Technical Center. Reduced data files consist of data that has been converted to a format compatible with the analysis environment.

A.1 RAW DATA FILES.

Raw Sensor Receiver and Processor (SRAP), Interfacility, and Digital Altimeter Setting Indicator (DASI) data were collected on-site at SFO. Raw weather data were collected at the FAA Technical Center. The following is a description of the raw data files created at the time of field collection.

A.1.1 SRAP.

The raw SRAP data were recorded onto disk using the filename format Smdhmm.DAT:

where: S - the letter "S"
m - the month (1 thru 9, A for October, B for November, and
C for December)
dd - day of month-2 digits (01 to 31)
hh - hour of start of test (00 to 23)
mm - minute of start of test (00 to 59)

From the raw SRAP file the following data were extracted:

- a. Time in hours, minutes, seconds referenced to SFO (Pacific time zone)
- b. Radar sector number
- c. SRAP channel number (0)
- d. Slant range in nmi from radar
- e. Azimuth Change Pulse (ACP) (0 thru 4096)
- f. Azimuth in degrees
- g. Quality (0 thru 7)
- h. Special Position Indicator (SPI) (not used)
- i. Beacon code (0000 thru 7777)
- j. Beacon code validity (0 thru 3)
- k. Altitude in hundreds of feet (uncorrected)

- l. Altitude validity (0 thru 3)
- m. Beacon hit count
- n. Message type (BO for beacon only, RB for radar reinforced beacon)

A.1.2 INTERFACILITY.

The interfacility data was recorded onto disk using the filename format Imddhhmm.AOL (for more information on "mddhhmm", see A.1.1). The interfacility data file contained the following data:

- a. ARR (arrival)
- b. Time in hours and minutes with respect to SFO
- c. Beacon code (0000 thru 7777)
- d. ACID (e.g., UAL923)
- e. ACTYPE (e.g., B737)
- f. Approach fix (e.g., JOT)
- g. Altitude at fix in hundreds of feet (e.g., 100 for 10,000 feet)

A.1.3 DASI.

DASI data were recorded onto disk using the filename format Smddhhmm.RCM (for more information on Smddhhmm, see A.1.1).

A.1.4 WEATHER.

The raw weather data were collected on an FAA Technical Center computer by logging on the Kavouris Inc. weather data base and requesting the day's weather reports for SFO. The data were recorded onto a disk file whose name had the format WXmmddyy.TXT:

where: WX - the letters "WX"
 mm - the month - 2 digits (01 thru 12)
 dd - day of month - 2 digits (01 to 31)
 yy - year - 2 digits (00 to 99)
 . - "."
 TXT - the letters "TXT"

The weather file consisted of weather reports, each report containing the following data:

- a. Date in month/day/year
- b. Time in hours and minutes (Zulu)
- c. Location (SFO)

- d. Report type (SA or SP or RS)
- e. Lowest ceiling type (E or M or W)
- f. Lowest ceiling height in hundreds of feet
- g. Lowest sky descriptor (OVC or CLR or BKN or ...)
- h. Next lowest ceiling type (E or M or W)
- i. Next lowest ceiling height in hundreds of feet
- j. Next lowest sky descriptor (OVC or CLR or BKN or ...)
- k. Visibility in nmi
- l. Weather (rain or fog or snow or ...)
- m. Sea level pressure in millibars
- n. Temperature in degrees fahrenheit
- o. Dewpoint in degrees fahrenheit
- p. Wind direction in tens of degrees referenced to true north
- q. Wind speed in knots
- r. Wind gust in knots
- s. Altimeter setting in inches of mercury
- t. Remarks

Note: for more information on this data refer to the Aviation Weather Services Manual, AC 00-45B published, jointly by FAA and National Oceanic and Atmospheric Administration (NOAA).

A.2 DATA REDUCTION FILES.

Raw SRAP, Interfacility, DASI, and weather data files were unpacked and reduced at the FAA Technical Center. The following is a description of the Data Reduction files created from the raw data files.

A.2.1 DATA REDUCTION TRACK FILES.

The track files created during the reduction process consisted of all the position reports for a single aircraft's approach. The type and format of the information contained in each track file type is listed below.

FILENAME --> MEANING

_acid.rwy --> raw track file (SRAP 0) (output of TRACKS)
 DATA: HR,MN,SEC,CH,RANGE,AZMTH,BC,ALT,TYPE

 @acid.rwy --> corrected track file (SRAP 0) (output of GAP)
 DATA: HR,MN,SEC,CH,RANGE,AZMTH,BC,ALT,TYPE

 \$acid.rwy --> GAP documentation file (SRAP 0)
 DATA: list of missing scans and altitudes, and multiple scans

 &acid.rwy --> translated to runway, corrected track file (SRAP 0) (output
 of PTTRANS)
 DATA: HR,MN,SEC,X,Y,Z

 'acid.rwy --> smoothed, translated, corrected track file (SRAP 0) (output
 of SM)
 DATA: HR,MN,SEC,X,Y,Z

 (acid.rwy --> interpolated, smoothed, translated, corrected track file
 (SRAP 0) (output of INTERP)
 DATA: HR,MN,SEC,X,Y,Z

 where: acid --> aircraft ID (AAL1115, UAL100, ...)
 rwy --> runway designator (28L, 28R, ...)

A.2.2 DATA REDUCTION INTERFACILITY FILES.

The interfacility data files created during the reduction process consisted of the data present in the raw interfacility data file, however, these file data were converted to a Foxbase data base format.

Imddhhmm.DBF --> Interfacility data in a Foxbase data base format
 DATA: (see Appendix A.1.2)

A.2.3 DATA REDUCTION DASI FILES.

The DASI data files created during the reduction process consisted of DASI data extracted from the raw DASI data files. The reduced data files were converted to Foxbase data base format.

Rmddhhmm.DBF --> DASI data in a Foxbase data base format
 DATA: Digital Altimeter Setting Indicator (DASI)

A.2.4 DATA REDUCTION WEATHER FILES.

The weather data files created during the reduction process consisted of the data present in the raw weather data files. The reduced data files were converted to a Foxbase data base format and merged with the MASTER data base (see Appendix C).

WXmmddyy.FIX --> preprocessed and corrected weather data file
 DATA: (see Appendix A.1.4)

WXmmddyy.DAT --> weather data for 1 day in Foxbase data base compatible
format
DATA: (see Appendix A.1.4)

SFOmmm.DAT --> weather data for 1 month (mmm = Jan, Feb, etc.)

APPENDIX B

DATA REDUCTION

The data collected at the site was brought back to the FAA Technical Center where it was reduced to a form to be used in the final analysis. Unpacking was the process whereby data, recorded in a foreign format for purposes of space and efficiency, was converted to a format compatible with the analysis environment. Reduction was the process of coordinate conversion, filtering, smoothing, and interpolation of the unpacked radar data. Each of the raw data files identified in Appendix A had to be unpacked. The unpacking and reduction procedures are described here.

B.1 SRAP AND INTERFACILITY DATA.

The radar data collected via the Sensor Receiver and Processor (SRAP) required considerably more processing than any other type of data collected to prepare it for analysis. Unpacking and reduction of the radar data involved:

- a. Conversion to engineering units and sorted according to beacon code.
- b. Deletion from further processing if any of the following were detected; large gap(s) in the track, track was of short duration or no Mode C altitude and altitude can't be had from other sources.
- c. Conversion to (time, x,y,z), then translation and rotation to the runway threshold being approached.
- d. Filtering and smoothing of radar data to eliminate radar outliers and to obtain a more accurate estimate of aircraft position.
- e. Interpolation to attain estimates of cross-track deviation at specific points along the Instrument Landing System (ILS) approach.

The following software programs performed these processes on the raw SRAP data with the following results.

B.1.1 TRACKS.FOX.

- > language: Foxbase + 2.10 programming language
- > input:
 - a. Smddhhmm.DAT (raw SRAP data file)
 - b. Imddhhmm.AOL (raw Interfacility data file)
- > process:
 - a. Invoked SRAPUNPK.PAS to unpack raw SRAP data and produced SRAP foxbase database file Smddhhmm.DBF
 - b. Indexed Smddhhmm.DBF by session and beacon code
 - c. Identified tracks with sufficient number of scans
 - d. Determined runway being approached for each track
 - e. Cross referenced SRAP data with interfacility data file Imddhhmm.AOL to obtain aircraft ID (ACID) and aircraft type (ACTYPE) for each beacon code

- f. Appended a record to the master data base (MASTER.DBF) for each identified track (see Appendix C)
- > output:
 - a. Created directory "Smddhhmm" and placed ASCII aircraft track files _acid.RWY for SRAPO into this directory (see Appendix A.2)
 - b. Appended one record for each identified track to the MASTER database (see Appendix C)

B.1.2 SRAPUNPK.PAS.

- > language: Turbo PASCAL 5.0
- > input: Smddhhmm.DAT (raw SRAP data file)
- > process: Unpacked beacon and radar reinforced beacon messages only
- > output: Smddhhmm.DBF (Foxbase database format)

B.1.3 GAP.C.

- > language: Turbo C 2.0
- > inputs:
 - a. All _acid.rwy files (raw track files)
 - b. MASTER.DBF master data base (optional, depended on version of GAP.C)
- > process:
 - a. Deleted illegal multiple scans
 - b. Added missed altitudes
 - c. Altitude correction based on airport altimeter setting
 - d. Identified large time gaps and determined if the pre-gap and post-gap data is from the same track
 - e. Produced documentation explaining results
- > outputs:
 - @acid.rwy (SRAPO) corrected track files (Appendix A.2.1)
 - \$acid.rwy (SRAPO) documentation files (Appendix A.2.1)

B.1.4 PTTRANS.C.

- > language: Turbo C 2.0
- > inputs: All @acid.rwy files (corrected track files)
- > process:
 - a. Converted data from (rng,az,alt) to (x,y,z)
 - b. Translated data to runway threshold identified in filename
- > outputs: &acid.rwy (SRAPO) translated and corrected track files (Appendix A.2.1)

B.1.5 SM.C.

--> language: Turbo C 2.0

--> inputs: All &acid.rwy files (translated and corrected track files)

--> process: Filtered and smoothed using Lincoln Lab's radar smoothing algorithms

--> outputs: 'acid.rwy (SRAP0) filtered, smoothed, translated, and corrected track files (Appendix A.2.1)

B.1.6 SPLINE.C.

--> language: Turbo C 2.0

--> inputs: All 'acid.rwy files (filtered, smoothed, translated, and corrected track files)

--> process: Inserted an interpolated data point (time,x,y,z) at each 0.15 mile X increment

--> outputs: (acid.rwy (SRAP0) interpolated, filtered, smoothed, translated, and corrected track files (Appendix A.2.1)

B.2 DASI DATA.

The raw DASI data was processed by the following program with the described results.

B.2.1 RCMSUPK.PAS.

--> language: Turbo Pascal 5.0

--> inputs: Smddhhmm.RCM (raw RCMS data file)

--> process: Unpacked DASI data and put it into a Foxbase data base format

--> outputs: Rmddhhmm.DBF (unpacked DASI data in Foxbase format)

B.3 WEATHER DATA.

The weather data for San Francisco International Airport (SFO) required some preprocessing before it could be unpacked by the weather data unpacking program, SFOWX.BAS. The weather data preprocessing and unpacking procedures are described here.

Preprocessing a weather data file consisted of:

- a. Removed correction weather reports and blank lines between weather reports.
- b. Added, if necessary, a ")" to the end of the weather data file as an End of File marker (EOF).
- c. Checked that the first line of each weather report had at least one "/" in it. SFOWX.BAS needed at least one "/" in the first line of a weather report to process that report properly.

Unpacking the preprocessed weather data files created one Foxbase database compatible file for each day and one Foxbase database compatible file for each month of weather data files.

B.3.1 CORRECT.BAS.

--> language: Turbo BASIC 1.0

--> input: WXmmdyy.TXT (raw weather data file)

--> process:

- a. Kept last correction weather report in data file, all previous correction reports and the original report were removed from the weather data file
- b. Removed blank lines between weather reports in a file
- c. Added, if needed, a ")" to the weather data file as an EOF marker

--> output: WXmmdyy.FIX (corrected weather data files)

B.3.2 SLASH.BAS.

--> language: Turbo BASIC 1.0

--> input: WXmmdyy.FIX (corrected weather data file)

--> process: Counted number of "/" in first line of each weather report

--> output: WXmmyy.BAD (listing by time for each ".FIX" file of weather reports with less than five "/" in their first line)

B.3.3 SFOWX.BAS.

--> language: Turbo BASIC 1.0

--> input: WXmmdyy.FIX (corrected weather data file)

--> process: Unpacked a weather data file to produce a Foxbase database compatible record for each weather report and reordered records by time and date in ascending order in the output files

--> outputs: WXmmddy.DAT (unpacked weather data file)
SFOmmm.TOT (combined WXmmddy.DAT files for 1 month, where
mmm = JAN, FEB, MAR, etc.)

B.3.4 STRU.DBF.

--> language: Foxbase + 2.10 programming language

--> input: SFOmmm.TOT (combined WXmmddy.DAT files)

--> process: STRU.DBF was a database structure with fields for the data contained in a weather report, it was copied to WX_mmm.DBF. The data in the SFOmmm.TOT file was then added to WX_mmm.DBF using the Foxbase APPEND command.

--> output: WX_mmm.DBF (weather data for one month in Foxbase database format)

Certain weather database fields were next merged with the Master Database (see Appendix C).

B.4 PARROT TRANSPONDER DATA.

Parrot data statistics were extracted from the raw SRAP data, to assist in the calculation of the radar range and azimuth biases, using the program described below.

B.4.1 TC PAROT.FOX.

--> language: Foxbase + 2.10 programming language

--> input: Smddhhmm.DBF (Foxbase database format)

--> process: Collected, unpacked, analyzed, and produced a statistical report on the quantity and quality of the Parrot transponder data

--> output: A printout of a report containing values for the mean and standard deviation of both range and azimuth, and the ACP skewness and kurtosis of the azimuth

APPENDIX C

MASTER DATA BASE

Prior to data analysis all unpacked data was merged into a data base that identified each approach collected. This data base was referred to as the MASTER data base. Data used to construct the MASTER data base consisted of information about each track and the weather at the time of the track's collection. The MASTER data base did not contain the tracks' radar position data however. The radar position data for each track was instead stored in the individual track files (refer to Appendix A.2.1).

The MASTER data base contained one record for each approach. The record had a field for each track characteristic. Since the format of the MASTER data base was developed for an earlier data collection effort, there were some fields in the data base not used for the San Francisco International Airport (SFO) data collection effort.

C.1 MASTER DATA BASE FIELDS.

The MASTER data base record fields are shown on a single page in figure C.1.

C.2 MASTER DATA BASE GENERATION.

The MASTER data base (_MASTER.DBF) was generated in a multi-step process. Only the following fields were used in the SFO data collection.

Field Description

- 1 test or session name (eg. S2131453)
- 2 SRAP channel # (0 or 1)
- 3 aircraft ID (eg. UAL9253),
- 4 user type (Military, Commercial,...)
- 5 aircraft type (eg. B727)
- 6 beacon code (0000 thru 7777)
- 7 month/day/year of collection
- 8 time of day of first scan for the track
- 9 time of day of last scan for the track
- 10 altitude of first scan for the track
- 11 altitude of last scan for the track
- 12 number of scans for the track
- 13 runway being approached
- 28 temperature in degrees fahrenheit during track
- 29 dewpoint in degrees fahrenheit during track
- 30 ceiling type (M or E or W)
- 31 ceiling height in feet
- 32 visibility in nautical miles
- 33 weather (Fog and/or Rain and/or Snow,...)
- 34 wind speed in knots
- 35 wind direction in degrees from true north
- 42 barometric pressure in inches of mercury
- 43 X at which A/C is stabilized on localizer

<u>Field</u>	<u>Name</u>	<u>Type</u>	<u>Lnth</u>	<u>Description</u>
1	SESSION	Chr	8	test name (e.g., S2131453) (see Appendix A.1.1)
2	CH	Num	1	channel # (0 or 1) of SRAP
3	AC_ID	Chr	7	aircraft ID (e.g., UAL9253)
4	USER_TYPE	Chr	1	user type (Military or Commercial or ...)
5	AC_TYPE	Chr	5	aircraft type (e.g., B727)
6	BEACON	Chr	4	beacon code (0000 thru 7777)
7	DATE	Date	8	month/day/year of collection
8	START_TIME	Chr	11	time of day of first scan for the track
9	STOP_TIME	Chr	11	time of day of last scan for the track
10	START_ALT	Num	6	altitude of first scan for the track
11	STOP_ALT	Num	6	altitude of last scan for the track
12	TARGET_CT	Num	4	number of scans for the track
13	RUNWAY	Chr	3	runway being approached
14	MIN_X	Num	8	minimum distance from threshold
15	T_AT_4_NMI	Chr	11	time of day at 4 nmi from threshold
16	MAX_Y_TNTZ	Num	6	maximum lateral deviation from ILS towards NTZ
17	XMAXY_TNTZ	Num	8	distance from threshold at MAX_Y_TNTZ
18	MAX_Y_ANTZ	Num	6	maximum lateral deviation from ILS away from NTZ
19	XMAXY_ANTZ	Num	8	distance from threshold at MAX_Y_ANTZ
20	MAX_Z	Num	6	maximum altitude for the track
21	MIN_Z	Num	6	minimum altitude for the track
22	MEAN_Y	Num	6	average ILS deviation from stabilization to TD
23	MEAN_XDOT	Num	8	average velocity of A/C during ILS approach
24	STD_DEV_Y	Num	6	standard deviation of ILS lateral deviation
25	IN_NTZ	Log	1	.TRUE. if A/C in NTZ after stabilization
26	NTZ_DIS	Num	6	width of NOZ in feet
27	X_AT_VIO	Num	8	distance from threshold at first NTZ violation
28	TEMP	Num	3	temperature in degrees fahrenheit during track
29	DEWPT	Num	3	dewpoint in degrees fahrenheit during track
30	CEIL_TYPE	Chr	1	ceiling type (M or E or W)
31	CEILING	Num	5	ceiling height in feet
32	VISIBILITY	Num	5	visibility in nautical miles
33	WEATHER	Chr	4	(Fog and/or Rain and/or Snow and/or ...)
34	WIND_SPEED	Num	2	wind speed in knots
35	WIND_DIR	Num	3	wind direction in degrees from true north
36	LLWAS_SPD	Num	2	low level windshear alert system speed in knots
37	LLWAS_DIR	Num	3	low level windshear alert system direction deg.
38	LLWAS_GUST	Num	2	low level windshear alert system gusts in knots
39	CFA_SPD	Num	2	low level windshear alert system center field ws
40	CFA_DIR	Num	3	low level windshear alert system center field wd
41	RVR	Num	4	runway visual range in feet
42	BRMTR	Num	5	barometric pressure in inches of mercury
43	STBL_X	Num	5	X at which A/C is stabilized on localizer
44	PAIR_LDR	Chr	7	leading adjacent localizer AC_ID (if it exists)
45	PAIR_TRL	Chr	7	trailing adjacent localizer AC_ID (if it exists)
46	GAP_START	Chr	11	raw track file start time (as determined by GAP)
47	GAP_STOP	Chr	11	raw track file stop time (as determined by GAP)
48	GAP_STRT_R	Num	6	raw track file initial range
49	GAP_STOP_R	Num	6	raw track file final range
50	GAP_NUM	Num	3	number of scans in raw track file
51	GAP_MS_SCN	Num	3	number of missing scans in raw track file
52	GAP_DOUBLE	Num	3	number of double scans in raw track file
53	GAP_ALT	Num	3	number of missing or unreasonable altitudes

total of 282 bytes/record.

FIGURE C.1 --- MASTER DATA BASE RECORD STRUCTURE

The processes that generated the MASTER database are identified and described in the following:

C.2.1 TRACKS.FOX.

TRACKS.FOX was the same process identified and partially described in Appendix B.1.1. In addition to the identification and unpacking of the individual track files, it also appended one record to the MASTER data base for each track. TRACKS.FOX filled in data fields 1 through 13; (1) session, (2) channel, (3) ACID, (4) user-type, (5) AC-type, (6) beacon code, (7) date, (8) start time, (9) stop time, (10) start altitude, (11) stop altitude, (12) target count, and (13) runway for each aircraft track.

C.2.2 WX_APP.FOX.

This process appended fields (28) temperature, (29) dewpoint, (30) ceil_type, (31) ceiling, (32) visibility, (33) weather, (34) wind speed, (35) wind direction, and (42) barometer pressure by time and date to records in the MASTER data base.

```
--> input:      WX_mmm.DBF (weather database files, see Appendix B.3.4)
--> process:    Merged fields from weather data base with the appropriate
                fields in the MASTER data base
--> output:     Modified MASTER database weather fields cited above
```

C.2.3 STABLE_X.

STBL_X (43) was the distance from the end of the runway on the X axis at which the approaching aircraft is considered stabilized on the localizer. This value was not calculated for SFO tracks. However, a value was needed in this field to run the analysis software; for this purpose, a value of 4 nmi was used.

APPENDIX D

SFO DATA COLLECTION REFERENCE MANUAL

D.1 SRAP DATA COLLECTION.

The automatic Sensor Receiver and Processor (SRAP) data collection software ran at the Bay Terminal Radar Approach Control (TRACON) in support of the Visual Approaches Data Collection Project (F20-06G). The data collection software consisted of various programs invoked by a batch file on the SRAP data collection computer (XT). The batch file, RUN_SFO.BAT, was initiated by an appointment scheduling program each day at 0600 (Pacific time). The batch program initiated the following steps.

D.1.1 BATCH FILE CREATION.

RUN_SFO.BAT initiated MAKE_BAT.PRG. MAKE_BAT.PRG was an ACD-340 written Foxbase program which created three batch files (FILENAM.D.BAT, ARC_REST.BAT, and DELE_CHK.BAT). These files renamed, set file attributes, and deleted the data collection files at the appropriate times. The filenames created by MAKE_BAT.PRG were based on the current date and time of day in order to uniquely identify the daily SRAP data collection files. For more information on these batch files see Appendices D.1.3, D.1.4.2, and D.1.4.4.

D.1.2 DATA COLLECTION PROGRAM.

FASTSRAP.EXE was an ACD-340 written 8088 assembly language program which collected and stored SRAP, DASI, and message data (SRAP.DAT, RCMS.DAT, and MESS.DAT) to the C:\DATA subdirectory. For more information on the SRAP and DASI data files see Appendices A.1.1 and A.1.3. The message data file was a listing of messages generated by FASTSRAP.EXE during execution. These messages were not used during the data analysis. FASTSRAP.EXE ran from whenever it was started to 2200 hours.

D.1.3 FILE TRANSFER.

FILENAME.BAT renamed the SRAP, DASI, and message data files, created by FASTSRAP.EXE, to Smdhmm.DAT, Smdhmm.RCM, and Smdhmm.MES respectively (for more information on "mddhmm" see Appendix A.1.1). FILENAME.BAT then checked that the network was up, if so, then it copied the renamed SRAP, DASI, and message data files to the J:\ directory.

D.1.4 FILE BACKUP.

The file backup process consisted of a Primary backup, setting the archive bit of the day's collected SRAP data files, and a secondary backup. After this, the SRAP data files were deleted from the C:\DATA subdirectory only if they were successfully copied to the network J: drive when FILENAME.BAT executed.

D.1.4.1 Primary Backup.

PRIMARY.BAT performed a primary tape backup of the SRAP data files in the C:\DATA subdirectory which had not been backed up previously; i.e. those files that had their archive bit set. The primary tape's subdirectory was then stored in the C:\DATA\BACKUP subdirectory as TAPEDIR1.TXT.

D.1.4.2 Setting Archive Bits.

ARC_REST.BAT set the archive bit of the SRAP data files collected that day. The archive bit was used as a flag during the secondary tape back up to ensure that only these files were saved.

D.1.4.3 Secondary Tape Back Up.

SECONDARY.BAT backed up on to the secondary tape drive the SRAP data files saved during the primary back up. The full secondary tape's directory was then stored in C:\DATA\BACKUP subdirectory as TAPEDIR2.TXT.

D.1.4.4 Deletion of SRAP Data Files on C:\DATA.

DELE_CHK.BAT checked that the day's SRAP data files were successfully copied to the J: drive (see Appendix D.1.3). If the files existed on J: then DELE_CHK.BAT went ahead and deleted the files from the C:\DATA subdirectory.

D.2 INTERFACILITY DATA COLLECTION.

The following is an explanation of the Landrum & Brown (L&B) ARTS IDentification Data Acquisition System (ID-DAS) ran at the Bay TRACON. This process was invoked by ISFO_RUN.BAT on the Interfacility data collection computer (IQ-Plus XT compatible). ISFO_RUN.BAT was initiated by an appointment scheduling program each morning at 0500 (Pacific time). Interfacility data collection began one hour before SRAP data collection because of the possibility of up to one hour difference between the receipt of interfacility data for an aircraft and its arrival time. The batch program initiated the following steps.

D.2.1 DELETION OF OLD INTERFACILITY DATA FILES.

DOS code was used to check for the presence of Interfacility data files (Imddhmm.AOL, see Appendix A.1.1) on the C:\AOL subdirectory. If data files were present, they were deleted from C:\AOL.

D.2.2 DATA COLLECTION PROGRAM.

IDPTC.EXE was the executable program IDentification Processor/TC that collected and stored the interfacility data to the C:\AOL subdirectory. IDPTC.EXE always started interactively. IDP.INP was a re-directed input ASCII file containing the responses needed to initialize IDPTC.EXE. The responses are explained below:

```
2           Processing mode - ARRIVALS
N           Include all aircraft Id's
```

Y	Copy all ARTS Interfacility (IF) messages pertinent to ID-DAS to a buffer file
SFO DATA	Processing title
Y	Specify Start and Stop time
B	Begin data collection immediately upon program execution
S	Specify Stop time
22,00	Stop time - 2200 hours
SFO	Output filename for buffer file (SFO.AOL)
<rtn>	Sets default output filename for data file (default Imddhmm.AOL)
C:\AOL\SFODATA	File root for buffer file

D.2.3 FILE BACKUP.

The daily Interfacility data file was backed up on the C:\AOL\ARRIVALS subdirectory and on the A: drive.

D.3 WEATHER DATA COLLECTION.

The following is an explanation of the San Francisco International Airport (SFO) Weather Data Collection. The process was invoked by WXSFO.BAT running on an IBM compatible computer. WXSFO.BAT was initiated by an appointment scheduling program each day at 0100 hours Eastern time (2200 hours Pacific time). The batch file executed software that logged onto the Kavouras weather network, requested the previous 30 SFO weather reports, and saved these reports to a data file (WXmmddy.TXT, see Appendix A.1.3). The batch program consisted of the following steps.

D.3.1 DELETION OF OLD WEATHER DATA FILES.

DOS code was used to check for the presence of old weather data files in the C:\WEATHER subdirectory. If data files were found, they were deleted from C:\WEATHER.

D.3.2 DATA COLLECTION PROGRAM.

PCWX started the communications program that accessed the Kavouras Weather data base. Since PCWX ran interactively, an Extended Batch Language (EBL) batch file was needed to provide the necessary response to log on to the system, send the command "SA/RPTS=30 SFO," save the 30 SFO weather reports to a weather data file, and log off the system.

D.3.3 FILE BACKUP.

If the network was up, the weather data file was copied to the K:\SFO\DATA subdirectory. The data file was also copied to the C:\WEATHER\SFO_RPTS subdirectory and to floppy disk.

