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FINAL ENGINEERING REPORT, Contract No. FAA/BRD-153

EQUIPMENT MODIFICATIONS AND FEASIBILITY DEMONSTRATION FOR IMPROVEMENT OF THE PHASE I UNIVAC® ATC DATA-PROCESSING SYSTEM

September 1962

This report has been approved for general distribution.

Prepared for

FEDERAL AVIATION AGENCY
SYSTEMS RESEARCH AND DEVELOPMENT SERVICE

by

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EQUIPMENT MODIFICATIONS AND FEASIBILITY DEMONSTRATION FOR IMPROVEMENT OF THE PHASE I UNIVAC ATC DATA PROCESSING SYSTEM

(CONTRACT FAA/BRD-153)

Final Engineering Report

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This report has been prepared by Remington Rand UNIVAC for the Systems Research and Development Service (formerly Aviation Research and Development Service), Federal Aviation Agency, under Contract No. FAA/BRD-153. The contents of this report reflect the views of the contractor, who is responsible for the facts and the accuracy of the data presented herein, and do not necessarily reflect the official views or policy of the FAA.

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EQUIPMENT MODIFICATIONS AND FEASIBILITY DEMONSTRATIONS
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PART I - ABSTRACT

This final engineering report summarizes the work performed under Contract FAA/BRD-153, Equipment Modifications and Feasibility Demonstrations for Improvement of ATC Data Processing System. The tasks (based on UNIVAC Proposal PCR 1156) are divided into four major problem areas: 1) Real-Time Clock Function; 2) Data Recovery; 3) Data Voiding by Character and Field; and 4) FAA System Manual.

As work progressed on the FAA System it became apparent that the proposed design on the Real-Time Clock was not feasible. After thoroughly studying several alternate designs it was found that the only practical means for generating time was to derive a pulse from a one-revolution-per-minute motor. A data register is used to provide storage and counting ability to convert the one-per-minute pulses into computer code time.

The design using the Magnetic Tape Unit for the data recovery system has certain shortcomings such as programming problems and overlap of the data recovered and the data printed during normal operation. It is therefore recommended that data recovery be accomplished by extracting data directly from the General Storage drums. This would avoid duplicate printout of flight strips and programming problems with the implementation of CUE.

Data voiding by character and by field is used to eliminate the time-consuming and error-prone backspacing procedure. The voiding system allows the operator to instruct the T&F Unit to void the previous character or the field that was being filled.

The FAA System Manual enables technical personnel to understand the system and to provide continuing personnel with a more thorough understanding of the complete system.

Each of these problem areas is covered in detail in Part II, Technical Discussion, of this report.

PART II - TECHNICAL DISCUSSION

1. REAL-TIME CLOCK FUNCTION

a. GENERAL. - A Real-Time Clock was to have been designed so that a real-time function could be available to the internal processing section of the ATC computer. This would allow the computer to transmit the output message on a real-time basis. The real-time identification was also required for the Data Recovery magnetic tape file and for the Legal Storage magnetic tape file.

The proposed solution was to connect the Real-Time Clock to a demand station of the computer. This involved adding an additional demand station to the FAA-UFCI. The demand station would have the capability of generating and displaying the correct system time in hours and minutes and would provide means for providing the computer with this data upon demand.

As work upon the FAA system progressed, it became apparent that this design approach could not be utilized because of the relative schedules of the Real-Time Clock and the High-Speed Printer, since without the High-Speed Printer there would be no demand station available to which the clock could be connected. This results from the fact that one High-Speed Printer would replace six of the eight FAA typewriters then connected to the system.

b. ALTERNATIVE DESIGNS. - Because of the lack of demand stations the following alternative designs were considered:

1) A Real-Time Substation to be added to the paper tape input system.

2) A Real-Time Clock that would store the time at a specific address in the UNIVAC File Computer (UFC).

3) An internally designed Real-Time Clock designed in the UFCA Program Control Cabinet.

A discussion of the relative merits of each approach follows.

(1) REAL-TIME INPUT SUBSTATION

(a) ADVANTAGES

1) An input to the system would be available.

2) The unit would be modular in form and similar to the Teletype* substations; therefore, installation would be simple.

3) Time data could be stored in a register or could be punched into a paper-tape buffer loop in a character serial mode.

(b) DISADVANTAGES

1) Programming complications would result from such a design.

a) The Translator and Format Control (T&F) Unit would have to process three different input messages, Teletype Input, Synchrotape Input, and Real-Time Input.

b) The computer would then have to be programmed for two different input messages, flight information message and Real-Time Data.

A study of the over-all programming problems with the T&F Unit indicated that adding another format to the input messages could easily create a problem beyond the capability of the equipment. Case b would be awkward to handle but not unreasonable.

2) Attempts were made to locate or design an electromechanical counter with either decimal or BCD output that would handle 24:00 hours.

After exhausting all possible sources, it was determined that a "code wheel" driven by a one revolution per day shaft was the only thing available and that was on special order.

3) An alternate to the electromechanical counter was a 24-bit register similar to that proposed in PCR 1156. This design would have required too much hardware to fit the available space. Additional problems would occur in generating time codes in the Teletype Code in which the system operated.

Either reason 1) or 3) was sufficient to eliminate the use of the Input Paper Tape System as an input for a Real-Time Clock.

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* Trademark, Teletype Corp.

(2) REAL-TIME CLOCK INPUT VIA GENERAL STORAGE

(a) ADVANTAGES

1) A Demand Station would not be required.

2) Incrementing registers could be utilized by operating in BCD computer code.

3) Space was available to locate the hardware.

(b) DISADVANTAGES

1) Programming difficulty existed.

2) Providing data path was a problem in logical design.

A thorough study of this design approach led to the design that was adapted because of its ease in programming.

(3) INTERNAL REAL-TIME CLOCK. - A study of the computer showed that address 999 was the only internal memory address that was not utilized by Intermediate Storage. If the 999 address could be utilized for a Real-Time Clock address the computer programmers would then have current time available with a single command.

A further study indicated that sufficient empty card jacks to hold the required additional circuits were available, sufficient power was available to drive the additional circuits, and the necessary control problems could be solved.

The sole disadvantage to this design is that the computer must be modified; this is less desirable than connecting another box when the computer system is currently in operation.

c. REAL-TIME CLOCK DESIGN

(1) TIME GENERATOR. - The only practical means for generating time was to derive a pulse of the proper waveform from a one revolution per minute motor. The problems encountered by such a design are listed below together with the solution:

1) Only one pulse must be generated by each revolution of the shaft. This was assured by actuating a microswitch by a cam. The toggling action of a microswitch assures a contact with low bounce duration. The microswitch contact was connected to the coil of a mercury wetted contact relay and the coil was suitably loaded with capacity so that the relay could not follow any microswitch contact bounce that might develop. The contacts of the mercury wetted contact relay were connected to a RLC pulse forming network.

2) The generator must have suitable accuracy. Accuracy was assured by utilizing a synchronous motor to drive the microswitch. Should a centrally controlled time clock system be installed by the FAA, it would only be necessary to add a microswitch contact to the time clock to replace the present switch with the new switch circuit.

(2) DATA REGISTER. - The data register provides the storage capability and the counting ability to convert the once-per-minute pulses into computer coded time.

The diagram on page 20 of PCR 1156 indicates that two registers are required, one for a clock register and one for a shift register. Examination of the two designs shows that the sole difference is that the clock register employs gate circuits to cause the register to count while the shift register employs gates that will allow the register to shift the data in a bit-serial mode. Since it is not necessary to perform both of these functions simultaneously, both sets of gates can be connected to one set of flip-flops. This was done in order to reduce the amount of hardware and thus increase the reliability. The data register has one input from the time generator and two outputs. One output is bit parallel and serves to operate the display driver and decode circuits as well as the error check circuits, the other output is bit serial and is used to transmit data to the data bus of the computer.

The error checking circuitry is a group of logical AND gates arranged to detect any combination of digits that is not a legal time such as 24:37 or 08:66. Detection of an error will cause the computer error bus to be activated the next time the clock is interrogated.

When data is shifted from the register to the data bus, it is necessary that an end-around shift be made or the data register would be empty following a shift and the time count would be lost. Since the shifting occurs at a 6-microsecond bit rate, it is highly probable that errors would occur in shifting prior to errors in counting; thus, the illegal time code check provides a reliable check of the clock.

(3) COMPUTER OPERATION OF CLOCK. - Existing circuitry within the UNIVAC File Computer provides for the transmission of 4-bit characters onto the data bus although the normal computer character is a 7-bit character. This circuitry pads two 0 bits to the existing four bits, and counts the 1 bits to determine the correct parity bit to be added.

Synchronizing of the circuitry so that the clock register is not updated during a shift is accomplished in the following manner.

1) The timing RLC circuit emits a pulse to set a flip-flop.

2) At drum timing position RMB4, the flip-flop is probed and cleared with the probe pulse updating the clock register.

3) At a drum timing position approximately 500 microseconds later, the control circuitry can be enabled to shift clock data to the data bus; thus, no possible interference can occur.

(4) MECHANICAL CONSIDERATIONS. - The requisite pushbuttons and indicators were added to the Arithmetic Maintenance Panel and a swivel base was provided for the clock display at the top front of the Arithmetic cabinet.

Real-Time Clocks have been installed in all FAA UNIVAC File Computers and all are giving satisfactory service.

2. DATA RECOVERY

a. GENERAL. - UNIVAC Engineering prepared a Functional Specification for a Data Recovery System applicable to the FAA UFCI systems. See Appendix A.

The proposed data recovery system was designed around a Type 4950 Magnetic Tape Unit (MTU). In operation, each flight data strip would be tagged with a time identifier and stored on magnetic tape sequentially. Upon computer failure the 4950 MTU would be transferred to the High-Speed Printer and all succeeding strips from a specific time tag would be printed out.

b. PROBLEM AREAS. - This design approach has certain shortcomings and problems which are enumerated below:

1) The existing FAA UFCI program must be modified so that an assembled message is stored upon the tape. At present the computer program assembles the message just prior to printout.

2) Additional programming problems would arise with the implementation of the CUE system. The CUE would update flight strip data before it was printed out resulting in multiple copies of a given flight strip being printed during a data recovery mode.

3) Operational problems would arise following a data recovery printout since it would be impossible to avoid an overlap of the data recovered and the data printed during normal operation.

4) A new design would be required for the Time Comparator and transfer switch. While not a large design effort would be required, it would be desirable from the maintenance standpoint to utilize existing designs with modifications where necessary.

c. RECOMMENDATION. - After consideration of the problems and a review of the then available UNIVAC File Computer designs and modifications, it was recommended that data recovery be accomplished by extracting data directly from the General Storage Drums. No further action has been proposed by the FAA along the lines of data recovery.

A summary of the features proposed in Appendix A is listed below:

1) Computer re-programming would be necessary but not prohibitive.

2) No problem would arise with the implementation of CUE.

3) Printout of duplicate flight strips could be avoided.

4) Flooding the controllers with flight strips could be avoided. (If the computer were down for less than 10 minutes it would be possible to have up to three copies of each flight strip for the one half hour period the computer normally stored data.)

5) Addition of a second General Storage Unit would minimize maintenance problems.

6) With the dual access General Storage system the system processing capacity could be doubled at a later date by adding PCI and PCII and Arithmetic Units to expand the system to a full dual UFC System.

3. DATA VOIDING BY CHARACTER AND BY FIELD

a. GENERAL. - In operation the data input to the system is provided by the FAA Synchrotape equipment. These equipments allow the Assistant Controllers to prepare input messages on punched paper tape for automatic entry into the system.

The Synchrotape has two major modes of operation, format control from a format loop or format control by the operator.

As the system existed at the time of the contract, if the operator entered the wrong character it was necessary to back up the output tape and overpunch the erroneous frame with a delete code and then proceed. If the operator was using the loop format control it was also necessary to backspace the format loop.

To eliminate the time-consuming and error-prone backspacing procedure, a voiding system was proposed that would allow the operator to instruct the T&F unit to void the previous character or the field that was being filled.

Utilization of the character and field void operation would eliminate the need for backspacing the output tape but would require that the format tape be backspaced either one character for character void or to the beginning of the field for field void. For this reason the character and field void was intended only for operation under operator format control. The character and field void cannot be used with the format loop mode.

The following paragraphs provide a detailed description of the Data Voiding modification to the T&F unit.

b. DATA VOIDING BY CHARACTER AND FIELD. - Drawing 199895 (sheets 1 through 7) shows the proposed modification to be made to the T&F Type 6973 (FAA) to meet the requirements of Task 3 (Data Voiding by Character and Field). An explanation of how this feature may be accomplished and used follows.

Essentially the proposal consists of modifying the Program Distributor (PD-1) so that it will step in the reverse as well as in the forward direction. The proposed method to accomplish this feature is shown on sheets 4 and 5 of drawing 199895. A hub PD-REV will be provided at the plugboard so that this feature is selected when a voiding of data by character or field becomes necessary.

Following is an explanation of how the plugboard may be plugged and of how data voiding by character or field is accomplished.

(1) DATA VOIDING BY CHARACTER. - The designated character to perform a "Data Voiding by Character", would be plugged to the input of a function detector. This function detector would be plugged to perform a normal Insert Character function except: the inserted character would be an erase character; the PD-REV Hub and the Buffer Character address reverse hub would be plugged to receive power from the function detector Out Hub; and the Format Reader backspaced one character. Thus, the buffer would receive an erase character in the inserted position, but the buffer character address and PD-1 would be stepped back one character position. In this way, the next incoming character would be written over the character in error that is stored in the Buffer, and the Format Reader would still be in step with the field position.

(2) DATA VOIDING BY FIELD. - The character designated to perform a "Data Voiding by Field", would be plugged to do a normal fill except: the fill character would be an erase character; the PD-REV hub and the Buffer Character Address Reverse hub would be plugged to receive power from the Fill Out hub. Also, the End Fill hub would be plugged to the first PD-1 position of each field. Thus, the PD-1 and the Buffer Character Address would be stepped back to the last character of the preceding field.

The following procedure should be followed in operating the Synchrotape:

1) The character designated for "Data Voiding by Field" should be punched in the program type.

2) The Format Reader should then be backspaced until the last character of the preceding field on the format tape is positioned under the Format Read station.

3) Since the last character of each field is a space character, the Format Reader will re-insert the space code in the last position of the last valid field of information when the space bar of the typewriter is depressed.

4) After the Format Reader stops upon reading the next stop code, all repositioning of the equipment is completed, and the invalid field may be repunched in the program tape.

c. ALTERNATIVE METHODS. - An alternate programming method for programming the "Data Voiding by Field", would operate as follows:

All plugboard functions would be plugged as stated above except the End Fill hub would receive power from the second PD-1 character position of each field. Thus, PD-1 and the Buffer Character Address would be stopped at the first character position of the field in error. In this case the character designated for "Data

Voiding by Field" should be punched in the program tape, and the Format Reader backspaced until the first character of the field in error is under the Format Read station. After this procedure, the field in error may be repunched.

Another method for programming the "Data Voiding by Field", is as follows:

The plugboard would be plugged as stated in the first example; however, another function detector could be used to insert the space character in the last position of the preceding field. Thus, the Format Reader would be backspaced until the first character of the field in error is under the Format Read station, and the field in error would be repunched at this time.

4. FAA SYSTEMS MANUAL

a. PURPOSE. - The FAA Systems Manual enables technical personnel to understand the system after adequate study and to provide continuing personnel with a more thorough understanding of the complete system.

b. SCOPE. - The manual is written in the following sections:

Volume I

Section 1 - General Description

Presents an over-all survey of the equipment, its scope and purpose, and describes its general function and physical characteristics.

Section 2 - System Logic

Traces the logical operation of the system through its two basic operating modes; input and output.

Section 3 - System Operation

Explains input/output equipment, operating controls and indicators, and specifies procedures for operating this equipment.

Appendix A - Glossary of Terms

Contains the definition of terms and abbreviations used in the manual.

Appendix B - Test Routines

Contains test routines for checking out the system.

Appendix C - System Modification

Describes the modifications to the system.

Volume II

Section 4 - Programming

Contains procedures for Translator and Format Control Unit plugboard wiring for input and output, and certain operating instructions for information loading and unloading.

Volume III

Program Flow Charts

Contains the flow charts for a typical control center.

APPENDIX A

FUNCTIONAL SPECIFICATIONS

TASK 2

DATA RECOVERY

FAA/BRD-153

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Prepared for

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by

TELE-CONTROL DEPARTMENT
REMINGTON RAND UNIVAC

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FUNCTIONAL SPECIFICATIONS

TASK 2

DATA RECOVERY

FAA/BRD-153

1. INTRODUCTION

This specification contains the functional specifications for the rapid recovery of data stored in the Air Traffic Control Computer during computer malfunction. This specification has been prepared under Contract No. FAA/BRD-153 in accordance with requirements set forth in Contractor's Document PCR-1156, dated May 1959, and Amendment No. 1 thereto, dated November 10, 1959.

2. DATA RECOVERY SYSTEM

The Data Recovery System will be accomplished by the use of a modified General Storage Control Cabinet, Type 6908M. The Type 6908M General Storage Control Cabinet is presently used in the UFC Dual Computer System. This General Storage Recovery Control Cabinet would be connected to the General Storage Drums. The General Storage Drums would also be connected to the Processing Computer through a General Storage Control Cabinet. Thus, either of the two General Storage Control Cabinets would have access to all the information stored in the General Storage Drums.

During computer malfunction, this recovery system would allow the information recorded in the General Storage Drums to be printed out by a High Speed Printer. It is recommended that two identical High Speed Printers be included in each FAA installation to provide additional backup if a failure should occur in the printer that is on-line.

3. GENERAL REQUIREMENTS

The General Storage Recovery Control utilized for data recovery would require only the following conditions from the computer system to which it was connected to assure satisfactory operation:

(1) All of the General Storage Drums from which data is to be retrieved must be operating within prescribed speed limits.

(2) The Computer's General Storage System must be in normal condition, with no defective chassis or hardware failures.

(3) If conditions under (2) do not exist, then it must be determined if failure in the General Storage System will affect track addressing. If failure does not affect track addressing, then the Data Recovery System will operate satisfactorily. If Computer Storage System failure does affect track addressing, then it will be necessary to disconnect drum cables from General Storage, or remove a specified group of chassis. Computer General Storage need not be energized during Data Recovery operation.

(4) A Control System that will provide control signals and data exchange paths between the General Storage System and the High Speed Printer is required. The Control System may be housed in the General Storage Recovery Cabinet, or it may be housed in its own cabinet.

(5) The FAA High Speed Printer normally used for printing flight strips has provisions for receiving data from File Computer Magnetic Tape Units. During Data Recovery operation, the computer input to the High Speed Printer would be disabled and the Magnetic Tape Unit Channel would be enabled. This channel would be connected to the Recovery Control Unit rather than to a Magnetic Tape Unit.

4. OPERATIONAL RESTRICTIONS

4.1 Format of Critical Data in General Storage Drums

Since the High Speed Printer handles information on a two-blockette basis, and the line length of the printer is less than one blockette, information to be retrieved would have to be stored in either the same format as the information presented to the High Speed Printer during normal flight strip printing, or in a format that could be accommodated by a different plugboard for the High Speed Printer. A single flight strip could not be assembled when portions of the strip are located in different areas of General Storage; therefore, the data must be in the correct format and stored in blockette units. This will require a change in the present computer programs.

4.2 Accessing of Data

Determination of what addresses are to be accessed for printing would be accomplished in the following manner:

A group of six rotary switches would determine the beginning address of the data to be transferred to the printer. The overflow address of that track would determine the next address to be accessed. Thus, the data need not be stored in successive addresses. The overflow address must connect the entire portion of General Storage that is to be recovered into an unbroken sequence. The printout would stop when no overflow address was found in the last track.

An alternate to the above system would utilize a modification to the General Storage Address Register so that the register would also act as a decimal counter of blockette transfers. With this system, the beginning address of the memory "dump" would be specified, and every blockette from that point on would be printed until a stop code was read by the High Speed Printer.

4.3 Tagging of Previously Printed Strips

During normal operation, each blockette would either be cleared to "ignores", or else a tag character would be inserted indicating that blockette has been printed out.

4.4 Time Selecting of Strips

By placing the high order 3 digits of time in the General Storage Buffer, it would be possible to cause the General Storage Recovery Control to send all strips with corresponding times to the High Speed Printer. This will allow the contents of General Storage to be "dumped" in increments of 10 minutes. Selective printing of the most critical strips first would avoid flooding the controllers with unnecessary strips in the event that the outage was of a shorter duration than the time span of the stored flight strips.