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THE AN/FSQ-7A COMPUTER

January 20, 1959

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INTERNATIONAL BUSINESS MACHINES CORPORATION
KINGSTON, NEW YORK

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FOREWORD

The importance of the AN/FSQ-7's role in air defense can hardly be overestimated. Yet the rapidly changing weapons situation and the increasing burden being assumed by our defense facilities make it imperative that we constantly reassess the mounting threat to our security and our own capabilities to meet this threat. This booklet reviews the increased demands on our defense data processing, compares the AN/FSQ-7A with the AN/FSQ-7, and shows how the AN/FSQ-7A computer can be used to strengthen our air defenses.

INTRODUCTION

Jet aircraft and missiles are making ever more complex the job of air defense. Not only have ranges and speeds been multiplied, but nation's arsenals are no longer adequate without counter-systems and counter-counter-systems of increasingly greater complexity and sophistication. The AN/FSQ-7A computer has been designed to up-date the state of the data-processing art to the latest demands of the new military technology.

The AN/FSQ-7A is an extremely fast, large-capacity, solid-state digital computer. New, powerful facilities will make it more capable of monitoring and directing the air defense networks of our nation than any machine complex ever before built. The outstanding features of the AN/FSQ-7A computer are:

- High computing speed
- Solid-state components, except in display equipment, for increased reliability
- Simultaneous operation of I/O devices
- Facilities for simplified and sophisticated programming
- Extensive error-detection circuitry
- Expandability
- Standardized, high-density packaging based on military specifications

A COMPARATIVE ANALYSIS OF THE AN/FSQ-7A COMPUTER

A comparison of the AN/FSQ-7A computer with the AN/FSQ-7 emphasizes the potentialities of the new, powerful, transistorized machine. As compared with the AN/FSQ-7, the AN/FSQ-7A will have the following:

- Word length: 1-1/2 times as long, permitting greater accuracy.
- Instruction rate: 4 times as fast, with programming innovations that will increase computational speed even more.
- Main memories: 4 instead of 1, with overlapped operation; expandable to 8.
- **Computer I/O units: as many as 7 instead of only 1. I/O**
- Drums: 2 times as much storage and 4 times the transfer rate.
- Tapes: 4 times as much storage and 4 times the transfer rate.

- Input system: computer receives telephone line inputs 3 times as fast, through the use of an input memory instead of drums.

- Card reader: 1-1/2 times as fast.

- Printer: 3 times as fast.

- Reliability: increased by the use of transistors instead of tubes, more error-checking circuitry, and greater capability for programmed error correction.

Although the AN/FSQ-7A gains tabulated are impressive, they fall far short of telling the complete story. The following detailed comparative analysis will show more clearly how the AN/FSQ-7A is equipped to meet the increasing challenge of our nation's defense.

THE CENTRAL COMPUTER

Feature	AN/FSQ-7	AN/FSQ-7A
1. Clock rate (mc)	2	6.25 6.7
2. Length of machine cycle (usec)	6	2.56
3. Word length (bits)	32 + 1 parity	48 + 2 parities
4. ~~Approximate~~ instruction rate (instruction per second)	85,000	~~375,900~~ 400,000
5. Arithmetic operations		
a. Full Word	No	Yes
b. Half Word	Yes	Yes
c. Byte manipulation	No	Yes
d. Bit manipulation	No	Yes
e. Floating point	No	Yes
6. Micro instructions	No	Yes
7. Intermachine communications		
a. Between memory blocks	No	Yes
b. Switchable tape adapter	No	1
c. Switchable drums	No	4 (2 per computer)
8. Overlapped memory operation	No	Yes

SIGNIFICANT ADVANCES

SPEED, ACCURACY

The much shorter machine cycle of the AN/FSQ-7A, as compared with the AN/FSQ-7, will more than quadruple the instruction rate. At the same time, the accuracy of computations will be increased by more than 50 percent.

PROGRAMMING SOPHISTICATION

As significant as the increased speed, capacity, and accuracy of the AN/FSQ-7A is the greater sophistication with which the computer will be programmed. The AN/FSQ-7A, unlike the AN/FSQ-7, will carry out full-word as well as half-word arithmetical operations, and will also operate on bytes and single bits. Since in

the AN/FSQ-7 program an estimated 65 percent of all items are six bits or less, the division of the AN/FSQ-7A computer word into bytes and single bits will accelerate and simplify data processing. These different word units will be used in conjunction with the following special facilities that will permit short cuts in programming and the use of a more powerful logic:

- Configuration control. This is a type of instruction modification that will accelerate arithmetic operations by selecting and/or positioning selected bytes. One type of modification will make it possible to process selected numerical data without disturbing the rest of the memory word. This facility will eliminate most of the Extract, Deposit, and Cycle instructions needed in the present Direction Center Active programs.

- Instruction and address modification. Besides the modifiers that will be used in configuration control, additional modifiers will provide such new techniques as limited double indexing, indexing and Branch instructions, indirect addressing, and inclusion of real data operands in the instruction word.

- Logical instructions. These new instructions will allow logical program control without using the arithmetic registers, by making decisions based on the contents of individual bytes or portions thereof.

- Micro instructions. A number of sense and operate codes will be used to gain finer instruction control. Micro instructions will increase diagnostic capability by allowing simpler instructions, using less equipment, to be substituted for more complex instructions.

FLOATING POINT

Another improvement of the AN/FSQ-7A Central Computer, as compared with the AN/FSQ-7, will be the capability to use either fixed or floating point notation. The position of the binary point will be indicated by a characteristic carried in the first 11 bits after the sign bit. The use of the floating point will simplify certain programs and will permit the handling of larger numbers without the use of external scaling factors. Special instructions will allow conversion from fixed to floating point notation.

MAIN MEMORIES

	Feature	AN/FSQ-7	AN/FSQ-7A
1.	Cycle time (usec)	5.8	2.2
2.	Multiple memory operation	No	Yes
3.	Number of main memories (blocks)	1	4
4.	Registers per core memory block	65,536	16,384
5.	Total core memory registers available	69,632	65,536
6.	Designed for further expansion	No	Yes
7.	Total core memory bits available	2,297,856	3,276,800

SIGNIFICANT ADVANCES

SPEED

The AN/FSQ-7A will have a 2.2 usec memory access time, as compared with 5.8 usec for the AN/FSQ-7. Since memory access time is the most important factor in determining computer speed, this advance is one of the most important in the entire computer.

MULTIPLE MEMORY OPERATION

The main memory will be divided into four blocks of 16,384 registers each. Access to two memories at one time will give an even larger effective increase in computer speed.

EXPANDABILITY

Initially, four core memory blocks for instruction and data storage will be delivered. However, sufficient transfer paths and controls for expansion to eight memory blocks are being included in the Central Computer. One input memory block will also be delivered, but it has not been included in the table above because of its special-purpose function.

DRUMS

Feature	AN/FSQ-7	AN/FSQ-7A
1. Transfer rate (registers/sec)	100,000	400,000
2. Number of fields (per drum)	6	17
3. Number of drums	12	1 display 1 auxiliary
4. Number of registers per field	2,048	8,192
5. Number of registers per physical drum	12,000	140,000
6. Total number of drum registers available	144,000	280,000
7. Number of bits per physical drum	384,000	6,700,000
8. Total number of drum bits	4,600,000	13,400,000
9. Maximum access time (msec)	20	20
10. Floor space required, excluding aisle space (sq. ft)	278	85
11. Power required (kw)	53	13
12. Expandability	No	Yes

SIGNIFICANT ADVANCES

CAPACITY SPEED

Bit density of the AN/FSQ-7A drum is double that of the AN/FSQ-7. The new features which have been the most responsible for this increased bit density are the floating head (with its close and uniform spacing giving high bit resolution), the use of only one read-write head, and the improved drum surface coating. Doubling the bit density will reduce the time between consecutive registers to one-fourth that of drums now in use. This increased density and speed, plus the use of a longer drum, makes it possible to double the storage capacity while reducing the number of drums from 12 to 2.

The capacity and flexibility of each computer will be further increased by its ability to use the drum system of the other computer in the duplexed installation.

RELIABILITY

A number of the new features in the AN/FSQ-7A drums which increase their reliability are:

- Reduction in the number of drums from 12 to 2.
- All-transistor circuits.
- Floating head. The built-in capability of this head to maintain its own spacing eliminates the necessity for any manual adjustment and minimizes the effects of temperature, humidity, and drum eccentricity.
- Etched timing track. The improved track eliminates the present optical and electronics system needed for producing drum timing signals, and allows erasing the drum surface without affecting the timing disc

EXPANDABILITY

The control logic associated with the auxiliary drum is assembled in an adaptor similar in concept to a tape adaptor. Initially, the adaptor will be delivered with one drum, and with control circuits for three additional drums.

COMPUTER INPUT-OUTPUT SYSTEM

Feature	AN/FSQ-7	AN/FSQ-7A
1. Number of I/O Operations at one time	1	1 drum plus any number of the following: card reader, printer, card punch, I/O typewriter, and two tape drives.
2. Number of tape adapters	2	3
3. Number of tape drives initially delivered	8	11
4. Maximum number of tape drives	12	24
5. Tape speed (characters per second)	18,750	62,500
6. Card reader speeds (cards per minute)	150	250
7. Line printer speed (lines per minute)	150	500
8. Card punch speed (cards per minute)	100	100
9. I/O typewriter	No	Yes

SIGNIFICANT ADVANCES

The peripheral system of the AN/FSQ-7A computer will include an I/O control unit, which will control all I/O operations, and the following peripheral equipment:

High-speed devices -

Two drums, manual inputs matrix, input memory, burst-time counters, warning lights system, and I/O register.

Low-Speed devices -

Eleven tape drives (8 permanent tape drives per computer and 3 switchable tape drives) card reader, card punch, printer, I/O typewriter, and test channel.

SIMULTANEOUS OPERATION

The capacity, speed, and flexibility of the computer will all be extended by the use of a separate I/O unit which will control the I/O equipment independently of the central computer, and also will permit simultaneous operation of several I/O devices. If the central computer and the I/O control unit require the same memory, a break cycle gives the I/O control unit priority. The control unit, in turn, assigns priority to the I/O devices according to their word rate by always servicing first the fastest device that is waiting for the I/O control unit. One high-speed device and any number of the low-speed devices may be operated at one time.

A comparison of the I/O capabilities of the AN/FSQ-7 and the AN/FSQ-7A graphically shows the increased number of operations that will be possible with the new I/O control unit See figure 1.

NEW TAPE SYSTEM

Increased Capacity and Speed

The AN/FSQ-7A will use new, completely transistorized tape adaptors and tape drive units which will have a tape speed of 50 percent greater and a character density of more than twice that of the tape units in the AN/FSQ-7. Thus, the character rate for reading and writing will be more than tripled. A computer may have the use of three switchable tape drives in addition to the four permanent units now used. Nearly twice as many tapes having more than twice the character density of the tapes used in the AN/FSQ-7 will approximately quadruple the capacity of the tape system. The comparative tape speeds and character densities are as follows:

	Tapes in AN/FSQ-7	Tapes in AN/FSQ-7A
Characters per inch	250	555
Tape speed (inches per second)	75	112.5

NUMBER OF OPERATIONS COMPLETED IN 6,000 USEC *

AN/FSQ-7	1000 COMPUTER CYCLES OR HIGH-SPEED TRANSFERS OR LOW-SPEED TRANSFERS OR ANY COMBINATION TOTALING 1000.		
AN/FSQ-7A	772 LOW-SPEED TRANSFERS	2,340 DRUM TRANSFERS	2,340 COMPUTER CYCLES

* WITH PROPER PROGRAMMING

FIGURE 1.

A COMPARISON OF COMPUTER I/O TRANSFERS OF THE AN/FSQ-7A AND AN/FSQ-7

Increased Versatility

The new tape system will be given increased versatility, which will extend the capabilities of the computer, by such changes and additions as the following:

- Programming simplifications. The elimination of many programming restrictions will make tape programming more compatible with the programming of other I/O devices.

- Binary-coded Hollerith mode. This additional mode, for both reading and writing, will make the tapes more compatible with existing commercial IBM off-line equipment which will be used for program debugging and assembling, and data reduction.

- Record identification. The first word of each record will be used to identify any record within a file. Such identification will provide a valuable new programming tool.

- Tape loading. Loading the computer from tapes has been simplified and accelerated by use of a load-from-tape button instead of a card-loaded or test memory program.

Increased Reliability

Reliability will be increased by the all-transistor circuits, and by a 2-gap head in the drive unit that will be able to write and then verify the information just written.

Expandability

The tape adapters in the AN/FSQ-7A will be designed to accommodate up to eight tape drives each, or a total of 24 in the duplexed system.

CARD PUNCH AND READER

The AN/FSQ-7A card punch and reader will be capable of using either one of two card codes: conventional Hollerith or a new code known as vertical-coded binary. In the new code, words are punched into cards by columns and read out by rows, and all 80 columns of the card, instead of only 64, are used. Vertical coded binary will permit storage of 20 48-bit words (960 bits) instead of 24 33-bit words (792 bits), and will also make the card machines used with the computer more compatible with off-line equipment.

PRINTER

The AN/FSQ-7A printer will be more than three times as fast as the printer used with the AN/FSQ-7. The latest printer will be more reliable because it uses transistors and fewer moving parts; this printer will also require less floor space.

INPUT-OUTPUT TYPEWRITER

The AN/FSQ-7A, unlike the AN/FSQ-7, will use an I/O typewriter, which will have a fixed or variable number of registers assigned in memory, as selected by the operator.

TELEPHONE-LINE INPUT-OUTPUT SYSTEM

Feature	AN/FSQ-7	AN/[redacted]-7A
1. Input telephone lines (maximum)		
a. Crosstell	16*	32
b. Long-range radar	24*	40
c. Gap-filler radar	16*	Shares LRI lines**
d. Low rate Teletype data		32
2. Output telephone lines (maximum)		
a. Ground to ground	5	25
b. Ground to air (frequency division)	6	0
c. Ground to air (time division)	2	8
d. Teletype	25	25
3. Storage (number of registers)		
a. Crosstell	4,096	3,840
b. Long range radar	4,096	10,000
c. Gap filler radar	2,048	Shares LRI storage
d. Area discriminator	2,048 (shared with manual inputs and computer entry punch)	1,154
e. Low rate teletype data	--	960
f. Outputs	6,144	8196

*Crosstell, long-range radar, and gap-filler radar input frames of the AN/FSQ-7 can be expanded respectively to 24, 36, and 18 channels; however, practical limitations of the AN/FSQ-7 reduce the figures to those given.

**According to present plans.

SIGNIFICANT ADVANCES

INPUT MEMORY

The greatest innovation in the AN/FSQ-7A telephone line system will be the use of an input memory instead of input drums. The input memory will have two important advantages over the input drums:

- In the AN/FSQ-7, telephone line data is stored in the drums by site identification and read out according to a fixed priority (status). A full drum revolution, requiring 20 msec, is used for each site identity.

Average access time is about 10 msec. In the AN/FSQ-7A, telephone line data will be stored in the input memory location associated with a particular site, giving random access The computer will be capable of reading out a word each machine cycle (2.5 usec).

- In the AN/FSQ-7, sufficient channel equipment is required to temporarily store a message (1092 bits) before it is transferred broadside into a drum. In the AN/FSQ-7A, only enough channel equipment will be needed to transfer a message serially (bit by bit) into input memory.

LOW RATE DATA

In the AN/FSQ-7, low rate teletype data has to be punched into cards, usually by an operator, and loaded into the computer. In the AN/FSQ-7A, teletype inputs are automatically made into computer words and sent directly to the computer without the intervention of any operator.

DISPLAYS*

Feature	AN/FSQ-7	AN/FSQ-7A
1. Number of digital displays	121	154
2. Number of situation displays	85	106
3. Number of categories	32 (5 spare)	64
4. Number of wing units	86	135
5. Number of display assignment bits	90 (8 spare)	96
6. Number of light guns	65	104 (including some used only for off-centering)
7. Number of consoles		
a. Situation displays	85	106
b. Auxiliary displays	46	45

*These figures will vary with application. Maximum figures are given.

SIGNIFICANT ADVANCES

Faster and more reliable tracking than in present equipment will be made possible by such new features as light-gun off-centering, more expansion levels, and more situation display categories.

LIGHT-GUN OFF CENTERING

The operator will be able to select a center area within the display sector much faster, by using the light gun instead of 4 off-centering switches. Incorporated also into the light-gun off-centering are two switches (**FRAME-UP-FRAME-DOWN** and **FRAME-RIGHT-FRAME-LEFT**) which will enable the operator to follow a moving target when it goes beyond his selected display area. Throwing these switches will shift the next frame into referencing position from the appropriate direction. The target will now be seen in relation to this new frame and will be brought back into the view of the operator.

ADDED DISPLAY EXPANSION LEVELS

The use of six instead of four expansion levels will make it possible to display a larger sector, which will enable the operator to follow more targets, faster targets, and to follow them longer. The added levels will also ensure more reliable tracking by preventing the overlapping of displayed characters.

OPERATOR'S CONSOLE
SIGNIFICANT ADVANCES

INTERRUPT SYSTEM

A powerful new feature of the AN/FSQ-7A is the interrupt system which, with a recovery program, will enable the computer to remain in operation during a majority of computer malfunctions. The interrupt system automatically branches the computer to an error-recovery program whenever an alarm is generated. A FIX program, much more elaborate than the one used with the AN/FSQ-7*, will, whenever possible, supply missing information and repeat or otherwise compensate for operations producing an error.

Another function of the interrupt system will be to notify the computer whenever a situation arises that requires an interruption of the program. An example is a request for a tape that is rewinding. The interrupt system will allow the computer to bypass the tape and return to it later; the system will also interrupt low-priority operations to permit servicing a request for a high-priority operation.

ERROR DETECTION

An important function of the operator's console is alarm display when an error occurs. In the AN/FSQ-7, only parity errors, which constitute only a few of the total number of possible errors, can be detected. Many more errors can be handled in the AN/FSQ-7A, and also many more types of errors. In addition to parity errors, operational errors can also be handled, such as illegal selections, timing errors, missing or extra pulses, etc. Errors can be more accurately and speedily located in the AN/FSQ-7A.

ALARM DISPLAY

The AN/FSQ-7A operator's console will include an elaborate alarm display. The display of several hundred alarms and the capability to identify the instruction and program step, or data address, when an error occurs will greatly reduce diagnostic time. In addition, the operator's console will be able to furnish to the operator the machine time pulse at which the error occurred and will provide a count of errors occurring, if more than one.

*See the IBM Journal for January, 1959, for a description of this program.

PACKAGING AND COMPONENTS

SIGNIFICANT ADVANCES

One of the most attractive features of the AN/FSQ-7A will be the high density of its components. One pluggable unit in the AN/FSQ-7A will contain the equivalent circuitry of one module in the AN/FSQ-7 This physical condensation will be made possible by the following practices:

- The use of transistor logic
- Miniaturization of components
- The use of a minimum number of circuit types
- The use of a unique building block, the Q-PAC I

The Q PAC I is a component package, 1.9 by 2.6 by 1.3 inches, in which the components, excluding diodes and transistors, are placed in layers in an insulating compound. The pluggable units will be divided by heat conducting separaters into 100 cubicles that will hold the Q PAC I's. Cooling will be accomplished by a fluid that will flow within the walls (cold plates) separating the pluggable units. The use of twisted-pair wiring will improve the driving capabilities and eliminate the expense of coax. The substitution of wire wrap for solder connections will permit automated manufacture and increase circuit reliability.

Miniaturization and standardization will be incorporated whenever possible. The volume of pulse transformers will be reduced to one-fifth the volume of those used in the AN/FSQ-7. The use of monolithic, ceramic decoupling capacitors (three capacitors in one case) will reduce inductance and improve frequency response. Diodes approximately 10 times as fast as those in the AN/FSQ-7 will be employed. New techniques have been devised for packaging delay lines and tape cores. The transistor most used in the AN/FSQ-7A will be the micro-alloy drift transistor (MADT) developed to IBM requirements by Lansdale Tube Company

FLOORSPACE, REQUIREMENTS (SQ FT)*

	Feature	AN/FSQ-7	Underground Installation AN/FSQ-7A Expanded	Aboveground Installation AN/FSQ-7A Expanded
1.	Duplexed central computer room	---------	7,800	7,800
2.	Units with nonsolid components	---------	9,200	9,200
3.	All unit equipment except display consoles	23,000	17,000	17,000
4.	Operating and programming area	2,500	3,100	3,100
5.	Additional space required underground for 32 ft columns	---------	3,00	---------
6.	Service area (IBM office spare parts, maintenance and storage areas)	9,200	18,500	9,200
7.	Operational room (includes display consoles except in computer area)	38,600	38,600	38,600
8.	Air conditioning equipment for the building	9,000	9,000	9,000
9.	Communications equip.	12,000	12,000	12,000
10.	Power plant	18,000	18,000	18,000
11.	Total miscellaneous area	11,000	11,000	11,000
12.	Total installation area	123,000	130,000	117,900

*The figures given in this table are only approximate [illegible] unless correctly interpreted.

The space requirements of the initial AN/FSQ-7A will be less than indicated in the table because only figures for the expanded version are given. It should also be noted that the figures in the table are for duplexed equipment. Although the AN/FSQ-7A will be a much more powerful and versatile computer than the AN/FSQ-7 it will require less floor area. However, the support areas (storage, spare parts, air conditioning for the building, etc.) have grown. The additional area indicated for an underground installation will be needed for the supporting columns and to ock pile spare parts and supplies for an emergency.

POWER STATISTICS FOR DIRECTION CENTER (KW)*

Feature	AN/FSQ-7	AN/FSQ-7A
1. Operational building	(Redesigned Direction Center Building)	
a. Computer power requirements	1,064	720
b Telephone	122	122
c. Computer maintenance	50	36
d. Equipment cooling (fans and pumps)	224	149
e. Lighting and convenience outlets	465	465
f. Transformer loss	58	38
2. Power building (Redesigned Direction Center Building)		
a. Water chillers	540	360
b Circulating water pumps and cooling fans	100	67
c. Power house auxiliary equipment	283	283
d. Light and miscellaneous power	58	58
e. Transformer loss	24	16
Total power requirements	2,988	2,314

* As in the case of floor space requirements, these figures are for duplexed and include support areas not directly connected with the AN/FSQ-7A.

IN CONCLUSION

The AN/FSQ-7A embodies the most significant advances of Kingston Engineering programs. Since the overall gain of the new computer will be in the order of magnitudes rather than of increment, there is every reason to believe that the AN/FSQ-7A will be capable of effectively directing our nation's defenses in any foreseeable future.

A final brief listing of the AN/FSQ-7A's technological gains over the AN/FSQ-7 would seem in order.

- A greatly accelerated instruction rate plus new programming techniques increases computing capacity.
- Added drum and tape storage capacity, speed and accessibility multiply computer capability.
- Faster, more flexible, simultaneously operated I/O devices increase capacity and versatility.
- Solid-state components and numerous improvements throughout the machine, plus error-checking facilities and an interrupt system, improve reliability.