The Origins of
Burroughs Extended Algol

Paul Kimpel

2019 UNITE Conference

Session MCP 4059

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It All Started in Pasadena…

Who Is this Guy?

Herbert Hoover

31st President of the United States

1874-1964

Herbert Hoover, Jr

1903-1969

- Herbert Hoover, Jr
  - Engineer (Stanford, 1925)
    - Lifelong interest in Radio
    - Built radio guidance network for Western Air Express
  - Entrepreneur
    - Started U.S. Geophysical, 1935 – explore for oil using radio
    - Spun off Consolidated Engineering Corp (CEC), 1937
    - Renamed Consolidated Electrodynamics Corp, 1955

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Consolidated Electrodynamics (CEC)

- Instrumentation for seismic exploration
  - Sensors, recorders
  - **Mass spectrometer**, 1942
- Mass spectroscopy analyzes compounds
  - Goal is to determine chemical composition
  - Ionizes a sample – passed through magnetic field
  - Yields a spectrum of mass/charge ratios (m/z)
  - Spectrum analysis requires solving *simultaneous linear equations* (*n* equations with *n* unknowns)
  - It's a *lot* of calculations

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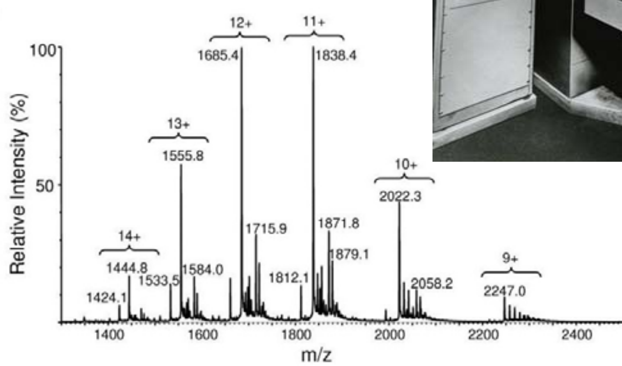
Mass Spectroscopy

CEC model 21-103
Mass Spectrometer



Typical mass spectrum

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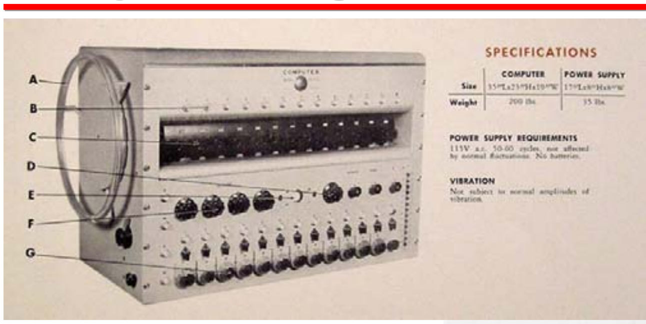
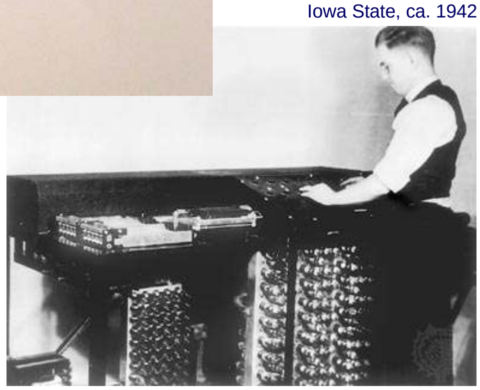
Berry's Analog Solution



CEC Analog Computer for
12 x 12 Equations

Berry at the Atanasoff-
Berry Computer (ABC),
Iowa State, ca. 1942



Clifford Berry

John Atanasoff

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From Analog to Digital

- Analog computer worked, but was insufficient
  - Limited number of equations/unknowns (12 max)
  - Time-consuming, limited precision (~3 digits)
- CEC started researching digital computation
  - Initially intended to design a specialized calculator
  - Assumed 8 digits of precision adequate
  - Discovered customers did not want just a calculator
- CEC altered course to develop a full computer
  - Hired Harry Huskey to teach engineers digital logic
  - Hired Norwegian mathematician Ernst Selmer to design the arithmetic and control logic
  - Resulted in CEC 30-201, 30-202 prototypes (1952-54)

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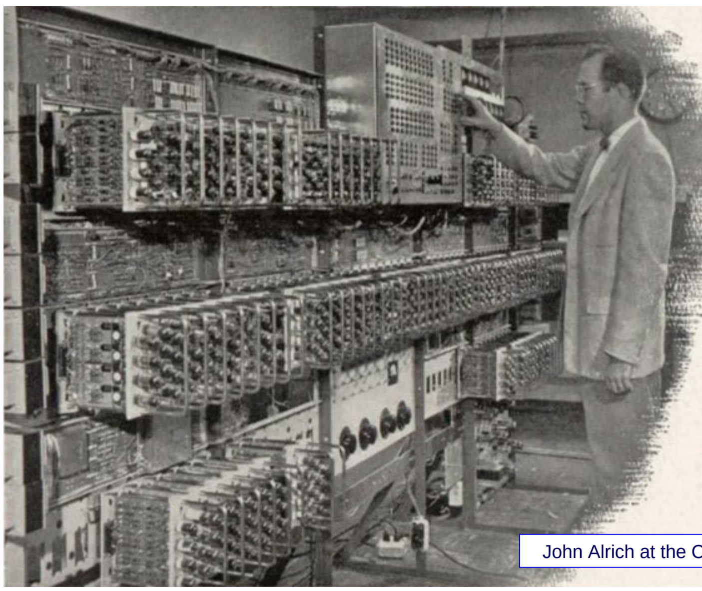
CEC 36-101 "Breadboard" System



John Alrich at the Controls

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CEC → ElectroData → Burroughs

- CEC decided computers weren't their thing
  - Very capital-intensive, outside their main business
  - Spun off ElectroData as public corporation (1954)
  - Moved to 460 Sierra Madre Villa in Pasadena, CA
- ElectroData's success
  - Production model "Datatron 203" announced 2/1954
  - Models 204 (mag tape) and 205 ("Cardatron") by 1955
  - For a while, 3rd largest computer manufacturer in U.S.
- Financial pressures became overwhelming
  - Burroughs having trouble entering computer business
  - Offered to buy ElectroData in 1956
  - ElectroData became the "ElectroData Division"

ElectroData Datatron 205 (1955)

Datatron 20x Details

- Vacuum-tube, decimal, drum memory
  - 4000 11-digit words, 8.4ms access time
  - 80 words, 0.84ms access ("high-speed loops")
  - 142.8 KHz clock rate
  - Digit-sequential operation internally
  - First index register in U.S. ("B register")
  - Optional hardware floating-point
- Peripherals
  - 203 – paper tape, Flexowriter typewriter
  - 204 – adds fixed-block, dual-lane magnetic tape
  - 205 – adds Cardatron buffered card interface to IBM tabulating equipment (089, 523, 407)

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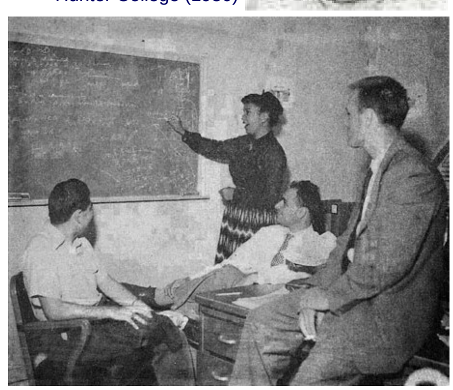
It Wasn't Just Guys

Sibyl Rock
Mathematician, Analyst, Customer Liaison, Algorithm Designer
UCLA (1931)

Gloria Bullock
Mathematician,
Customer Education
First Datatron Programmer
Hunter College (1950)



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A Second Life for the 205

Angry Red Planet, 1959

See: http://starringthecomputer.com/computer.php?c=45

Lost in Space, 1965

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Burroughs 220 (1957)

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Burroughs 220

- Follow-on to the Datatron 205
  - Larger core memory replaces drum memory
  - Still vacuum-tube, decimal, internally digit-sequential
  - 200KHz clock (up from 143KHz)
- Burroughs trying to make strong showing in both commercial and scientific applications
  - Same 11-digit words, hardware floating-point
  - Sophisticated magnetic tape subsystem
  - Cardatron buffered punched-card interface
- Automatic Programming group in Pasadena
  - Developing assemblers and programming aids
  - Working on IBM-compatible FORTRAN compiler

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Enter Algol

Programming Was Hard in the '50s

- Difficult machines, primitive tools
  - Lots of programming in absolute machine code
  - Simple assemblers began to appear
- Most computation was numerical
  - Scientific, engineering, mathematical problems
  - Growing interest in automatically translating standard math notation to computer instructions
    - Short Code, Schmitt & Mauchly (BINAC/Univac I, 1950)
    - AUTOCODE, Glennie (Manchester Mark I, 1952)
    - A-0, Hopper (UNIVAC I, 1952)
    - I.T., Perlis (Purdue University, 1955, Datatron 205)
    - FORTRAN, Backus (IBM, 1957, IBM 704)
  - Growing interest in exchanging programs among different computer systems

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The International Algebraic Language

- 1955-1957
  - German GAMM society working on general computing and formula translation
  - Conference in Los Angeles on exchanging computer data and programs
    - ACM, SHARE, USE, DUO
    - Concludes a universal programming language very desirable
- 1958
  - GAMM and ACM meet to exchange proposals
  - Joint session in Zurich to resolve differences
  - Result is "Preliminary Report – International Algebraic Language" (IAL)
  - Becomes known as "Algol-58"

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Algol-58 Example

```
procedure Simps (F(), a, b, delta, V);
          begin
     Simps:
          Ibar := V×(b-a);
          n := 1;    h := (b-a)/2;
          J := h×(F(a) + F(b));
     J1:
          S := 0;
          for k := 1 (1) n;
               S := S+F(a + (2×k-1)×h);
          I := J + 4×h×S;
          if (delta < abs(I-Ibar));
               begin
               Ibar := I;
               J := (I+J)/4;    n := 2×n; h := h/2;
               go to J1
               end;
          Simps := I/3;
          return;
          integer (k, n)
          end Simps

area := Simps(poly(), x, x+20, 2₁₀-5, 5₁₀25);
```

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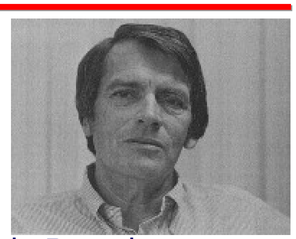
Meanwhile, Back in Houston…



- Robert S. ("Bob") Barton
  - 1954 – Takes job with Shell Development Research
  - 1957 – Working with young team on "Shell Assembler" for the 205
  - 1959 – Leaves Shell for Burroughs in Pasadena
- Part of team ("the arthropods") follows Barton
  - Joel Erdwinn
  - Clark Oliphint
  - Dave Dahm (still a summer-student employee)
- Barton heads Automatic Programming group
  - Now responsible for the ambitious IBM-compatible FORTRAN compiler project for the 220

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220 BALGOL Compiler

- Barton realizes FORTRAN project is impossible
- Arthropods abandon FORTRAN, start on Algol-58
  - Erdwinn, Dahm
  - Later – Oliphint, Merner, Crowder, Speroni, Knuth
  - Initial compiler released March 1960
- The Burroughs Algebraic Compiler
  - Officially, "BAC-220"
  - Better known as Burroughs Algol, or **BALGOL**
  - Follows Algol-58 more closely than other dialects:
    - JOVIAL (SDC)
    - NELIAC (Naval Electronics Lab, San Diego)
    - MAD (University of Michigan)
    - ALGO (Bendix)

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BALGOL Example

```
2 COMMENT SIMPSON-S RULE$
2 PROCEDURE SIMPS(A, B, DELTA, V$$ F())$
2   BEGIN
2   INTEGER K, N$
2   IBAR = V(B-A)$
2   N = 1$
2   H = (B-A)/2$
2   J = H(F(A) + F(B))$
2 J1..
2   S = 0$
2   FOR K = (1, 1, N)$
2     S = S + F(A + (2K-1)H)$
2   I = J + 4H.S$
2   IF DELTA LSS ABS(I-IBAR)$
2     BEGIN
2     IBAR = I$
2     J = (I+J)/4$
2     N = 2N$
2     H = H/2$
2     GO TO J1
2     END$
2   SIMPS() = I/3$
2   RETURN$
2   END SIMPS()$
```

```
2 FUNCTION TORADS(X) = 3.1415926X/180$
2 FUNCTION DARCTAN(X) = 1/(X*2 + 1)$
2 PROCEDURE LOGISTICSIGMOID(X)$
2   BEGIN
2   LOGISTICSIGMOID() = 1/(1 + EXP(-X))$
2   RETURN$
2   END LOGISTICSIGMOID()$
2
2 SUM = SIMPS(TORADS(30.0), TORADS(90.0),
      0.00001, 2.0$$ SIN())$
2 WRITE($$ RESULT, F1)$
2 SUM = SIMPS(0.0, 1.0, 1**-5, 2.0$$
      DARCTAN())$
2 WRITE($$ RESULT, F2)$
2 SUM = SIMPS(0.5, 3.0, 1**-5, 2.0$$
      LOGISTICSIGMOID())$
2 WRITE($$ RESULT, F3)$
2
2 OUTPUT RESULT(SUM)$
2 FORMAT
2    F1(*SINE INTEGRAL =    *,X10.6,W0),
2    F2(*DARCTAN INTEGRAL = *,X10.6,W0),
2    F3(*LOGISTIC INTEGRAL =*,X10.6,W0)$
2 FINISH$
```

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BALGOL Features Over Algol-58

- Input-Output
  - Free-field input of numerics, strings
  - INPUT/OUTPUT list declarations for READ/WRITE
  - FORTRAN-like FORMAT declarations for output
- Language features
  - Implied multiplication: **`(X+Y)/2SQRT(Z)`**
  - UNTIL iterative statement
  - OTHERWISE clause for EITHER IF statement
  - Generic type declarations
  - Initialization of arrays
  - Code segmentation with program-controlled overlay
  - MONITOR, TRACE, DUMP diagnostics
- Linkage to machine-language routines

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BALGOL Operational Advantages

- Fast, single-pass compiler (mag tape-based)
- Optimized for compile-and-go environment
- Configurable compiler environment
  - Generator program → compiler tape
  - Customize device types and I/O routines
  - Use larger memories (min 5000 words)
  - Augment/replace standard library
- Save and rerun object programs
  - Mag tape
  - Punched cards
  - Paper tape

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Impact of BALGOL

- Proved value of compiler operational efficiency
  - Fast, one-pass compilation
  - Compile-and-Go environment
  - Monitoring and debugging aids
- Made the case for *regular use* of higher-level languages over assembly language
- *Customers loved it*
- Convinced Burroughs that Algol was viable
  - Planners believed it would displace FORTRAN
  - Showed that a different architecture was needed
- Provided much basis for design of B5000

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Then There Was the *Other* BALGOL…

- Burroughs wanted a compiler like BALGOL for the 205
- They contracted with a Caltech grad student to write a compiler for $5500
- Donald Knuth wrote it *over the summer* in 1960

Donald Knuth

- Knuth continued to consult with Burroughs while at Caltech, until moving to Stanford in 1968
  - Worked on BALGOL (and wrote the comments)
  - Wrote first memory allocation scheme for the B5000

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Burroughs B5000 (1962)

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Burroughs B5000 / B5500

- Radical departure in hardware architecture
  - Specifically designed for Algol-60
  - Stack-oriented operation, code & data descriptors
  - Hardware support for Call-by-Name ("thunks")
  - Automatic segmentation & overlay ("virtual memory")
  - Multiprogramming & multiprocessing (2 CPUs)
  - Comprehensive operating system (MCP)
  - Programmed exclusively in high-level languages
- Reintroduced as B5500 in 1965
  - Large, fast Head-per-Track disk subsystem
  - Several new instructions, mostly for MCP use
  - Ancestor of B6x00/7x00, A Series, ClearPath MCP

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Writing Algol in Algol

- If the compiler is written in itself…
  - How do you compile the compiler?
- B5000 method – *bootstrapping*
  - Defined a temporary implementation language: OSIL
  - OSIL used for B5000 MCP and Algol compiler
  - Assembler-like processor
  - Generated B5000 code, *but ran on the Burroughs 220*
- Wrote two compilers, side-by-side
  - Official one in Algol, then hand-compiled into OSIL
  - Debugged and updated both versions in parallel
  - Once the OSIL version could compile Algol – then the Algol version could compile itself

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System Programming in a HLL

- The surprise when Algol could compile Algol…
  - Original compiler was about 8000 lines of Algol
  - OSIL "compile" on the 220 took ***9 HOURS***
  - Algol compile on the B5000 took ***4 minutes***
  - Algol-generated codefile was smaller, too
- Writing Algol in Algol worked so well…
  - Needed to rewrite MCP for the new HPT disk
  - MCP team took the Algol compiler, and…
    - Ripped out all the stuff for storage allocation, I/O, etc.
    - Added a few low-level features for hardware control
  - Called the result **ESPOL**
- MCP systems have never had an assembler

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Issues with B5000 / B5500 Algol

- Array rows limited to 1023 words
- Lexical scope addressing
  - Cannot address intermediate nested environments
  - Can address outer-block and local-procedure only
- Character manipulation
  - B5x00 used high-order bit in word as a "flag" (tag)
  - Flag bit indicated control words (descriptors, etc.)
  - Implemented Word-Mode and Character-Mode states
    - Character-Mode originally intended to support COBOL
    - Implemented in Extended Algol as **Stream Procedures**
    - *Ignores flag bits and all memory address protection!*
    - Extremely useful – extremely dangerous
    - Prompted development of **POINTER**s, **SCAN**, **REPLACE**, etc.

Lexical Scoping Example

```
begin comment Knuth's Man-or-Boy Test;
    real procedure A (k, x1, x2, x3, x4, x5);
    value k; integer k, x1, x2, x3, x4, x5;
    begin
        real procedure B;
        begin k:= k - 1;
              B:= A := A (k, B, x1, x2, x3, x4);
        end B;
        if k <= 0 then
            A:= x4 + x5
        else
            B;
    end A;

    file dc (kind=remote, units=characters, maxrecsize=72);
    write (dc, <"Result = ",j11>, A (10, 1, -1, -1, 1, 0));
end.
```

Not allowed on B5000/5500

Note: Result = -67; run with STACK=9000

Stream Procedure Example

```
INTEGER STREAM PROCEDURE GETCHAR(A, OFFSET);
  VALUE OFFSET;
  BEGIN COMMENT
      RETURNS THE CHARACTER CODE AT THE LOCATION OF "A" OFFSET BY
      "OFFSET" CHARACTERS;
  LOCAL REP;                      % HOLDS DIV-64 REPEAT COUNT
  SI:= LOC OFFSET;                % SOURCE IS ADDRESS OF OFFSET WORD
  SI:= SI+6;                      % ADVANCE SOURCE BY 6 CHARACTERS
  DI:= LOC REP;                   % DEST IS ADDRESS OF REP WORD
  DI:= DI+7;                      % ADVANCE DEST BY 7 CHARACTERS
  DS:= CHR;                       % MOVE OFFSET 7TH CHAR TO REP 8TH
  SI:= A;                         % SOURCE IS ADDRESS IN A
  REP(SI:= SI+32; SI:= SI+32);    % SI:= *+ (OFFSET DIV 64)×64
  SI:= SI+OFFSET;                 % ADVANCE SOURCE BY (OFFSET MOD 64)
  DI:= LOC GETCHAR;               % DEST IS ADDRESS OF GETCHAR RESULT
  DS:= 7 LIT "0000000";           % CLEAR HIGH-ORDER 7 CHARS OF RESULT
  DS:= CHR;                       % MOVE SOURCE CHAR TO 8TH OF RESULT
  END GETCHAR;
```

Equivalent in B6700 Algol to: **`REAL(A[OFFSET],1)`**

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Burroughs B6500/6700/7700 (1969)

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Burroughs B6500/6700/7700

- Solved all major problems with B5500 Algol
  - Lexical scoping (32 "D" address registers, now 16)
  - Moved flag bit to separate 3-bit "tag" field
  - String instructions (**`POINTER`**s, **`SCAN`**, **`REPLACE`**)
  - Longer array rows (orig. 2^{20}, now 2^{32} words)
  - Segmented arrays, resizing of arrays
- Other Algol extensions
  - Powerful and convenient sub-tasking capabilities
  - DOUBLE, COMPLEX data types
  - Eventually – object-oriented structures
- Enhanced over time to become A Series and current ClearPath MCP systems

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Extended Algol Anecdotes

The DEFINE

- Richard Waychoff, 1961
  - One of original B5000 Algol compiler authors
  - Was discussing symbol table design with Don Knuth
  - Knuth thought for a minute and said,

    "With that organization of a symbol table, you can allow one symbol to stand for a string of symbols."
- Originally, DEFINE was non-parametric
  - Dave Dahm implemented parametric DEFINEs in the late 1960s

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Dollar Cards and Sequence Numbers

- It all started with a bad B5000 card reader…
  - As Algol grew above 2000 cards
  - Compilation from cards became a nightmare
  - So, Waychoff and Bobby Creech went to a bar…
    - Worked out a scheme to keep source on tape
    - Set aside columns 73-80 for sequence numbers
    - Merged tape with correction cards by sequence number
- Created $-card to signal source mode, e.g.,
  - **$ CARD**
  - **$ TAPE**
- Later, more options added
  - Listing control
  - Void cards from tape
  - Resequence, create NEWTAPE, etc.

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Percent-Sign Comments

- Standard Algol comments
  - **COMMENT BLAH, BLAH, BLAH ;**
- B5000/5500 Algol
  - Used a Stream Procedure for scanning source
  - Needed an efficient way to detect end-of-card
  - Compiler overwrote column 73 of card image with "**%**"
  - Called the "stoplight" character
  - When "**%**" detected, compiler advanced to next card
- Didn't take long to figure out a free "**%**" anywhere on a card would stop the scan
- Effectively made rest of the card comments

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Partial-Word Syntax

- Bit-field manipulation in Algol
  - **X:= A.[30:22];**
  - **Y:= A & B[7:8] & C[39:7:8];**
- Burroughs 220 had a similar feature for digits
  - Some instructions could operate on part of a word
    - Designated as the "sL" field (start-Length)
    - Start with digit "s" and use "L" digits *to the left*
  - Digit numbering: **± 1234 56 7890**
  - Example: **STA WD,63**

A Register: **+7631450822**

sL = 63

Memory at address WD: **+1719825634**

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Array Row I/O

- B5000 Algol/MCP did not have array-row I/O
  - FORTRAN-like formatted I/O with lists
  - RELEASE statement for files
    - Buffer-level I/O (somewhat like modern Direct I/O)
    - Buffer only accessible as a Stream Procedure parameter
    - No blocking/unblocking support
    - Inefficient, a pain to use
- B5500 Disk File MCP introduced new I/O scheme
  - Read into and write from Algol array rows:

```
READ (F, 30, A[*]) [EOF];
```

  - Supports blocking and unblocking of records
  - Supports intelligent buffer handling (e.g., read-ahead)
  - Significantly more efficient

Input-Output List Declarations

- Algol formatted I/O has a LIST declaration
  -
```
LIST L1 (A, B, C+2, FOR I:=1 STEP 1
UNTIL N DO [ M[0,I], M[I,0], M[I,I] ]);
WRITE (LINE, FMT, L1);
```
  - Used with formatted READ & WRITE statements
  - On B5000, literal list could not be in the READ/WRITE
- Another carry-over from 220 BALGOL
  - INPUT and OUTPUT declarations
  - Created a co-routine called by the I/O formatters
  -
```
OUTPUT L1 (A, B, C+2, FOR I=(1,1,N) (
     M(0,I), M(I,0), M(I,I) ))$
WRITE ($$ L1, FMT)$
```

References

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END

The Origins of

Burroughs Extended Algol