Algol

THE FIRST PROGRAMMING LANGUAGE DEVELOPED AT ETH

a Project of

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PG Day, June 4, 2024

Menu

- Early computers at ETH: Z4, ERMETH, CDC 1604 A
- Automatic Production of Calculation Plans
- ALGOL Conferences
- ALGOL 60 and Subset-ALGOL
- Machine Independent Programming
- ALCOR: Predecessor of Open Source Repositories
- Springer Handbook Project
- Programming Computers in 1968

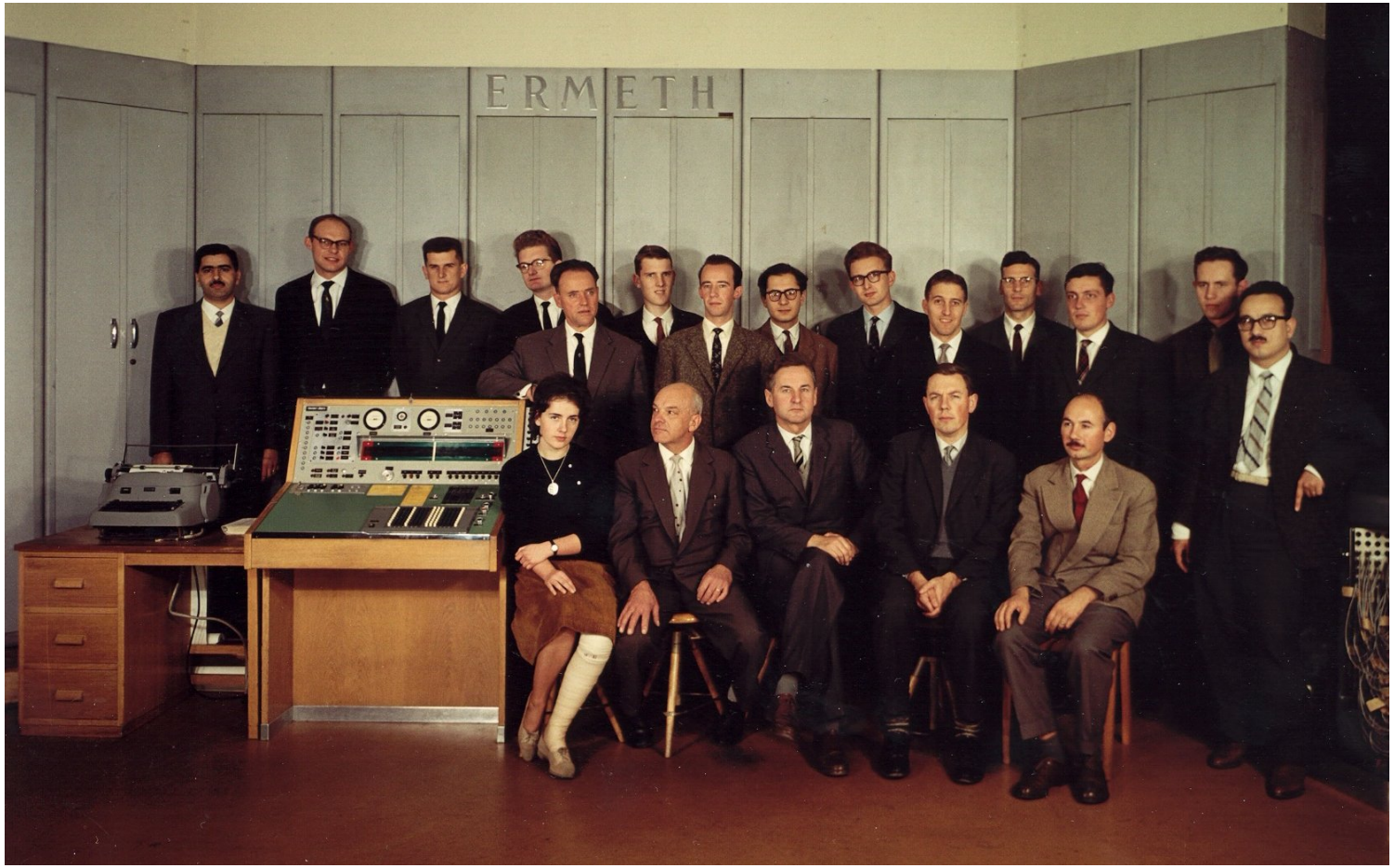
Heinz Rutishauser (1918 – 1970)

Computers at ETH

- October 1949: E. Stiefel rents the Z4 from Konrad Zuse for 5 years.
  Prof. Stiefel and his collaborators for the Z4.

1953–1956: Construction of their own machine

ERMETH is operational 1956–1963.



First Purchased Computer

- 1963: No computer at ETH!
  - ERMETH is dismantled
  - New computer is ordered: CDC 1604 A[a]
- Spring 1964: CDC 1604 A is operational
  - Students of the Department of Mathematics and Physics may voluntarily learn programming.
  - Batch processing, punch cards

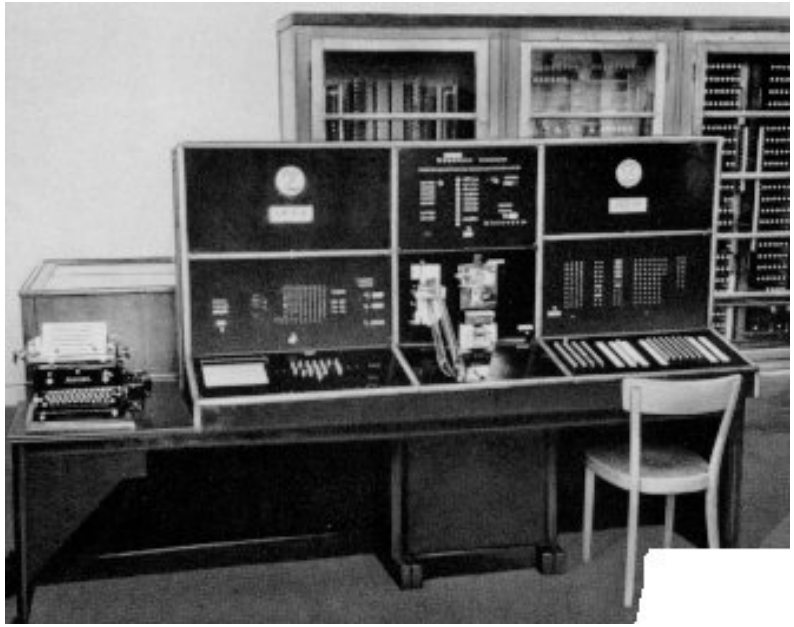
[a] Control Data Corporation, founded 1957 in Minneapolis

Back to Z4

1950 Z4 is the only computer

in operation in continental Europe.

A. Speiser, H. Rutishauser



Programming Example on the Z4 by Prof. H. R. Schwarz

Input and computation of the reciprocal of $\mathbf{a_{66} = x + iy}$

$$\frac{1}{a_{66}} = \frac{1}{x+iy} = \frac{x-iy}{x^2+y^2} = \frac{x}{x^2+y^2} - i\frac{y}{x^2+y^2}$$

↑	Input of $\mathrm{Re}(a_{66}) = x$
Rh	keep in register 1
S61	$x \implies$ store in 61
x^2	Form the square
S 0	$x^2 \implies$ store in 0
↑	Input of $\mathrm{Im}(a_{66}) = y$
Rh	keep in register 1
S 62	$y \implies$ store in 62
x^2	the value y^2 is in register 1
A 0	the value x^2 is in register 2
$+$	$x^2 + y^2$ in register 1

S 0	$x^2 + y^2 \implies$ store in 0
A 61	get x from 61 in register 1
A 0	$x^2 + y^2$ in register 2
:	
S 61	$\mathrm{Re}(1/a_{66}) \implies$ store in 61
A 62	$y \implies$ register 1
(-1)	
A 0	$x^2 + y^2$ in register 2
:	
S 62	$\mathrm{Im}(1/a_{66}) \implies$ store in 62

Automatic Production of Calculation Plan – Compiler!

- GAMM Meeting in Freiburg i.Br. March 21-31, 1951
  Heinz Rutishauser explains his idea, how a computer can translate an algorithmic language in machine code.
- Automatische Rechenplanfertigung bei programmgesteuerten Rechenmaschinen
  Habilitation Thesis, Birkhäuser, 1952

  " *The author of this work was convinced already a long time ago that it should be possible to use the program-controlled calculating machine itself as a plan production device thanks to its versatility.*".
- 22.11.1952 Rutishauser in his inaugural lecture as "Privatdozent"

  "*In view of the considerable loss of time that errors in a calculation plan cause, automatic calculation plan production is of great importance*"

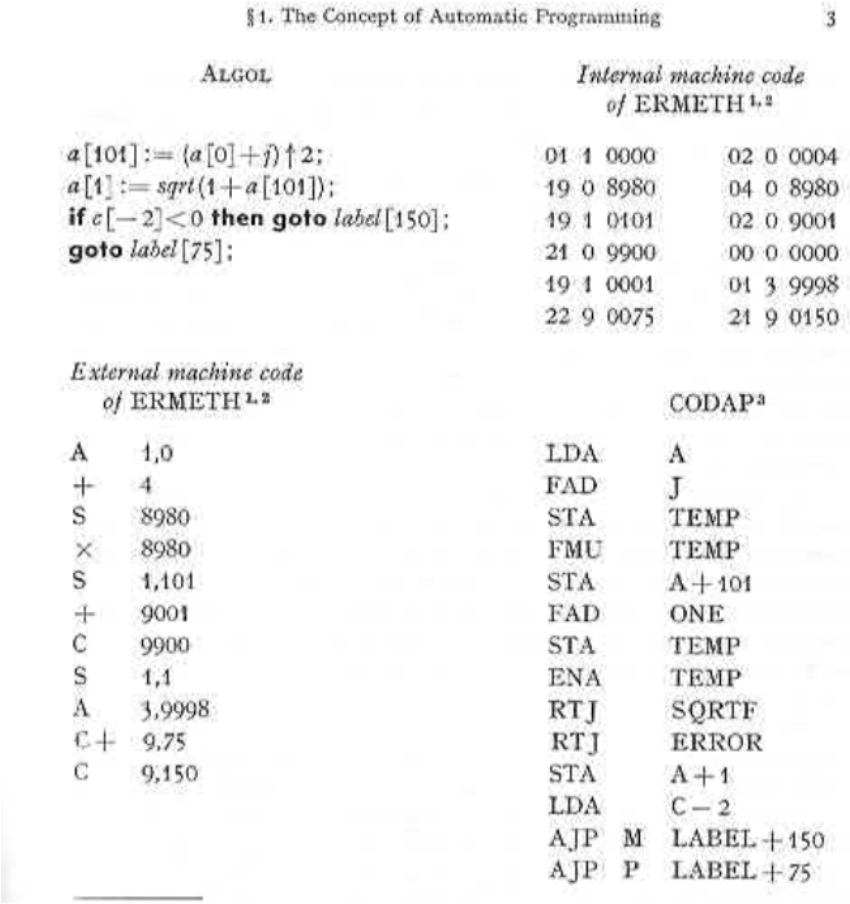
Around 1950: first attempts with "Automatic Programming"

"*Any practice which thus relieves the programmer from writing machine code is called automatic programming*"
(Rutishauser Description of ALGOL 60, Springer, 1967.)

- Heinz Rutishauser *Automatische Rechenplanfertigung bei programmgesteuerten Rechenmaschinen*, Habilitation Thesis, 1952
- Maurice Wilkes (England) The preparation of programs for an electronic digital computer : with special reference to the EDSAC and the use of a library of subroutines, 1951
- Grace Hopper (USA) was involved in the creation of UNIVAC, the first all-electronic digital computer. She wrote a "compiler" to convert English terms into machine code (1952) (Wikipedia) `https://en.wikipedia.org/wiki/Grace_Hopper`

Machine Code, External Machine Code, Assembler

In "Description of ALGOL60" Rutishauser describes the terms::



§1. The Concept of Automatic Programming 3

ALGOL

```
a[101] := (a[0] + j) ↑ 2;
a[1] := sqrt(1 + a[101]);
if c[−2] < 0 then goto label[150];
goto label[75];
```

Internal machine code of ERMETH[1,2]

```
01 1 0000    02 0 0004
19 0 8980    04 0 8980
19 1 0101    02 0 9001
21 0 9900    00 0 0000
19 1 0001    01 3 9998
22 9 0075    21 9 0150
```

External machine code of ERMETH[1,2]

```
A     1,0
+     4
S     8980
×     8980
S     1,101
+     9001
C     9900
S     1,1
A     3,9998
C+    9,75
C     9,150
```

CODAP[3]

```
LDA     A
FAD     J
STA     TEMP
FMU     TEMP
STA     A+101
FAD     ONE
STA     TEMP
ENA     TEMP
RTJ     SQRTF
RTJ     ERROR
STA     A+1
LDA     C−2
AJP  M  LABEL+150
AJP  P  LABEL+75
```

- Internal machine code:
  only numbers
- External machine code:
  commands through symbols
  better readable
- Assembler:
  address and operand can be expressed by symbols
  CDC 1604A

Beginnings of ALGOL (ALGOrithmic Language)

- 1954 ETH dissertation of Corrado Boehm (student of Stiefel): Translation of mathematical formula in computer notation
- 1954 Bauer and Samelson both in Mainz [a]) work at the same problem.
- 1954 Laning and Zierler present their programming language at MIT
- 1954 John W. Backus from IBM starts with a system called FORTRAN (FORmula TRANslation). Manual 1956, Compiler 1957.
- October 1955 Darmstadt, Symposium on Automatic Computing.
  Topic: Algorithmic Languages, Compiler.
  Call for universal, machine-independent algorithmic language, generally usable, instead of competing languages.
  Establishing the GAMM Subcommittee for Programming Languages

[a] till 1958, later TUM

The ALGOL-Conferences

- 1957: GAMM Subcommittee almost finished with definition of the language.

  Given the existence of already many programming languages, request to ACM President J. W. Carr to establish a common algorithmic language.

  Great interest from ACM, form own committee.

- 1958 F. L. Bauer presents the GAMM proposal in Philadelphia. The GAMM and ACM proposals have many similarities. The possibility of a universal language is within reach.

- 1958: Conference in Zurich
  4 members each from ACM and GAMM meet.
  GAMM: F. L. Bauer, H. Bottenbruch, H. Rutishauser, K. Samelson
  ACM: J Backus, C. Katz, A.J. Perlis, J. H. Wegstein

Results of Conference in Zurich 1958: ALGOL 58

- The new language should be as close as possible to the standard notation of mathematics and be easily readable.
- The language should be suitable for describing numerical processes in publications.
- The new language should be easily translated into machine code by the computer itself.
- Definition of 3 representations of the language
  - Reference language **begin** $a[1,k] := 3.2 \uparrow 3$ print
  - Publication language begin `a[1,k] := 3.2^3` typewriter
  - Hardware language `'BEGIN' A(/1,K/) := 3.2**3` punch cards
- Input/output not defined, machine dependent every computer has its own I/O system.
- The conference publishes the ALGOL-Report in the reference-language.

Further Development

- Interest in ALGOL is growing. P. Naur[a] founds the ALGOL-Bulletin, a forum for discussion and dissemination.
- CACM introduces a new section for numerical processes in ALGOL.
- On the other hand, soon clear: certain definitions incomplete, contradictory, even unsatisfactory for describing numerical processes.
- Planning new international ALGOL conference
  - Nov 1959 GAMM Pre-conference in Paris, appointed 7 delegates.
  - ACM nominates also 7 delegates.

[a] Dänemark, BNF-Notation (Backus–Naur Form)

Paris 1960, ALGOL 60

- Conference in Paris January 11—16, 1960:
  J. W. Backus, F. L. Bauer, J. Green, C. Katz, J. McCarthy[a],
  P. Naur, A. J. Perlis, H. Rutishauser, K. Samelson, B. Vauquois,
  J. H. Wegstein, A. v. Wijngaaden, M. Woodger[b]
- P. Naur presents new proposal for discussions.
- Additions to ALGOL 58 not possible.
- Redefinition of language necessary.
- Result: ALGOL 60 Report.

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[a] one of fathers of AI !

[b] Turanski USA had a fatal car accident just before the conference.

Revised Report

- Inconsistencies also in ALGOL 60 report: mostly errors, but also conceptual different opinions.
- 1962 IFIP[a] Meeting in Rom. Opportunity for an ALGOL-Meeting with F. L. Bauer, J.. Green, C. Katz, P. Naur, K. Samelson, J. H. Wegstein, A. v. Wijngaarden, M. Woodger, R. Kogon, R. Franciotti, P. Z. Ingerman, P. Landin, M. Paul, G. Seegmüller, R. E. Utman, W. L. v. d. Poel.
- IFIP takes over further development. Correction of errors and inconsistencies: Revised ALGOL-Report.
- Disagreement on side effects, call by name, own-concept, dynamic for-statement, specifications and declarations
- H. Rutishauser sends H. R. Schwarz to IFIP-Conference. Schwarz talks about: Some Special Problems of the ALGOL-Language. 1960, he built a compiler for ERMETH !

[a] International Federation for Information Processing

ALGOL-Dialects, IFIP ALGOL-Subset

- Compiler builder: not easy to implement full ALGOL 60.
- $\Longrightarrow$ omit difficult features, add I/O: $\Longrightarrow$ dialects emerge.
- Programs no longer universal and interchangeable.
- IFIP W.G.2.1 proposes to define an ALGOL-Subset.
  Conference August 1962 in Munich.
- Further conferences of IFIP W.G.2.1 September 1963 Delft and March 1964 Tutzing decide, which properties of ALGOL 60 to be omitted in Subset-Report.
- SUBSET ALGOL 60 should be available on all computers. Programs written in SUBSET ALGOL 60 run on all ALGOL-Installations.

Advantages of Subset Algol 60

Rutishauser points out in Description of Algol 60:

- Omission of controversial properties of Algol 60.
- Compatible with most Algol implementations.
- Published Subset Algol 60 programs run on all machines without adjustments.
- Compilers for Subset Algol 60 are easier to construct and provide better machine code.

Machine Independent: Important concept of Rutishauser

- **Example:** Given a number $a > 0$ compute $x = \sqrt{a}$
- $\Longleftrightarrow$ solve $f(x) = x^2 - a = 0$ for $x > 0$
- Use Newton's iteration: start with x_0, then iterate

$$x_{k+1} = x_k - \frac{f(x_k)}{f'(x_k)} = \frac{1}{2}\left(x_k + \frac{a}{x_k}\right), \quad k = 0, 1, 2, \ldots$$

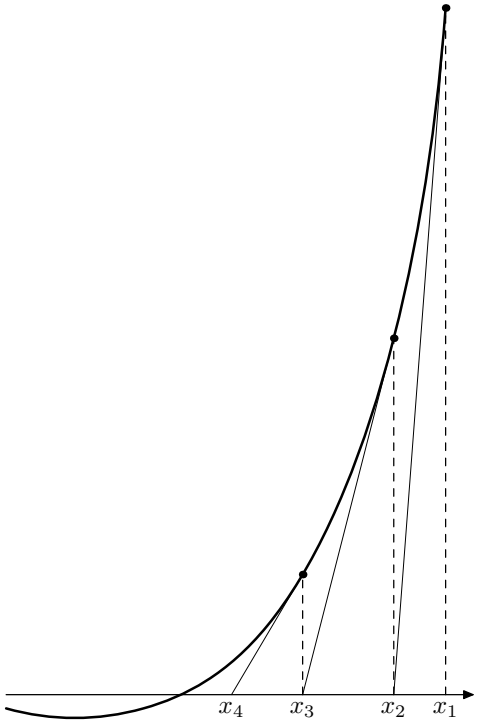
- A textbook solution might look like this:

```
function x=SimpleSqrt(a)
delta=1e-8; x=a; xold=0;     % initialization
while abs(xold-x)>delta      % if iterates are
  xold=x;                    % not close, compute
  x=(xold+a/xold)/2;         % new approximation
end
```

Question: How to choose `delta` for any arithmetic?

- The algorithm should work without changes for
  - IEEE arithmetic (64 bits)
  - smaller precision, e.g. for graphics processors
  - extended precision, like e.g. double precision
  - user defined precision, e.g. in MAPLE for `Digits:=100;`
- Solution: make use of the finite arithmetic !

```
function x=MySqrt(a);
xold=(1+a)/2;          % here: xold > sqrt(a)
x=(xold+a/xold)/2;     % next iterate
while x<xold           % if monotonically
  xold=x;              % decreasing
  x=(xold+a/xold)/2;   % iterate
end
```



Discussion of `MySqrt`

- Uses the fact: every computer is a finite machine
- Floating point numbers on computer are a finite set
- The iteration stops when there is no machine number anymore between $\sqrt{a}$ and `x`
- `MySqrt` does not work in mathematics!
  Would produce an infinite loop.
- Machine independent programs are foolproof

Rutishauser developed and published such algorithms.

An good example is the machine independent and foolproof ALGOL procedure `jacobi` for computing the eigenvalues of a symmetric matrix, published in the Handbook.

ALCOR Program collection service

- Basic idea of ALGOL: machine independence
  Programs written in SUBSETALGOL transferable to other computers
- H. Rutishauser is contact point for ALCOR Programs
- Predecessor of Open Source Repositories

Programmsammeldienst der ALCOR-Gruppe.

(Mitteilung vom 23.6.65).

Gemaess der ihm an der Konferenz vom 12/13. Febr. 1964 von der ALCOR-Gruppe erteilten Auftrag fuehrt der Unterzeichnete in Zusammenarbeit mit dem Rechenzentrum der ETH , Zuerich einen Programmsammeldienst durch. Dieser bezweckt, praktisch bedeutsame Programme zu sammeln und in rechenfaehiger Form unter den Mitgliedern der ALCOR-Gruppe zu verteilen.

A. Diese Verteilung umfasst :

1) Eine rohe Beschreibung der verwendeten Methode (mit Literaturhinweisen) und der Wirkung des Programms und insbesondere genaue Angaben ueber die formalen Parameter (bei Prozedurdeklarationen) und I/O-Daten (bei vollstaendigen Programmen).

. . . . . .

B. Entgegennahme von Programmen zur Aufnahme in den Programmsammeldienst und zur weiteren Verteilung.

1) Die Programme sollen den Bedingungen des IFIP SUBSET ALGOL 60 (siehe ALGOL Bulletin No.16, AB 16.3.1.1) genuegen.

2) Die Programme sollen gemaess DIN-Normblattt 66006 in Karten oder 5-Kanal-Lochstreifen gelocht sein, und es sollen auch die zusaetzlichen Vereinbarungen der ALCOR-Gruppe eingehalten werden.

3) Mit dem gelochten soll auch ein geschriebenes ALGOL-Programm, sowie eine hinreichend detaillierte Benuetzungsanweisung eingesandt werden, aus der dann die unter A genannten Dokumente hergestellt werden koennen.

4) Die Rechenzentren der Technischen Hochschulen Muenchen und Zuerich werden eingesandte Programme wenn immer moeglich auspruefen, behalten sich jedoch vor, solche Programme noetigenfalls abzuaendern.

5) Die Adresse der Geschaeftsstelle des Programmsammeldienstes lautet:

Prof. Dr. H. Rutishauser
Eidg. Techn. Hochschule
Universitaetsstr. 20
CH 8006 Zuerich

Available ALCOR Programs 1966 at ETH Computer Center

R E C H E N Z E N T R U M D E R E . T . H .

Programmbeschreibungen und Listings der folgenden

A l g o l - P r o z e d u r e n

d e r

A l c o r - G r u p p e

001/1-4	Jacobi-Verfahren für reell-symmetrische Matrix	JACORD
002/1-3	Jacobi-Rotation für symmetrische Matrix	ROTSYM
003/1-4	Auflösung linearer Gleichungssysteme (Gauss-Jordan)	GAUJOR
004/1-7	Eigenwertbest. mit Quotienten-Differenzen-Algorithmus	QDPROG
005/1-3	Choleski-Verfahren für Bandmatrizen	CHOLBD
006/1-3	Verfahren von Givens für symmetrische Matrizen	GIVENS
007/1-3	Runge-Kutta für ein System von Diff.-Gleich. 1.Ordnung	RKPSTP
008/1-5	Schmidt'sche Orthonormierung der Kolonnen einer Matrix	ORNACH
009/1-4	Reduktion einer symmetr.Bandmatrix auf Tridiagonalform	BNDRED
MEGE/1-5	Programme für mehrfach genaues Rechnen (0010 bis 0015)	
0016/1-4	Entwicklung nach Tschebyscheff-Polynomen	CHEDEV
0017/1-4	Eigenwerte einer Tridiagonalmatrix durch Bisektion	BISECT
0018/1-5	Beschleunigte Fourier-Analyse und -Synthese	FASTFR

Alle A l c o r - Prozeduren (mit Ausnahme der MEGE-Programme) sind am Rechenzentrum der E.T.H. auf dem System - Band enthalten und können von dorther aufgerufen werden.

September 1966

The Springer Handbook Project

Communication in *The Computer Journal, Volume 2, Issue 4, 1960, Page 169*

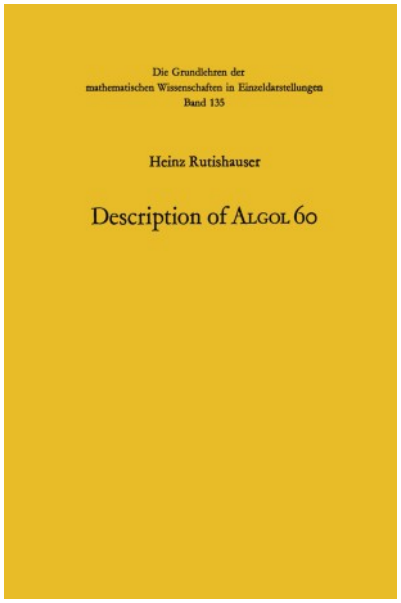
- Preparation of a Handbook for Automatic Computation in five or more Volumes, is now under way for publication by Springer-Verlag. It will appear in F. K. Schmidt's series "Grundlehren der Mathematischen Wissenschaften". Editors are F. L. Bauer, Mainz, A. S. Householder, Oak Ridge, F. W. Olver, N.P.L.Teddington, H. Rutishauser, Zürich, K. Samelson, Mainz, R. Sauer, München, E. Stiefel, Zürich.
- The purpose of the handbook is to provide a collection of tested algorithms for mathematical computations of all sorts . . . These algorithms are to be written in ALGOL hence will be usable on any machine . . .
- Before the appearance of the volumes themselves, the algorithms will be prepublished in a series of supplements to the journal *Numerische Mathematik* . . .

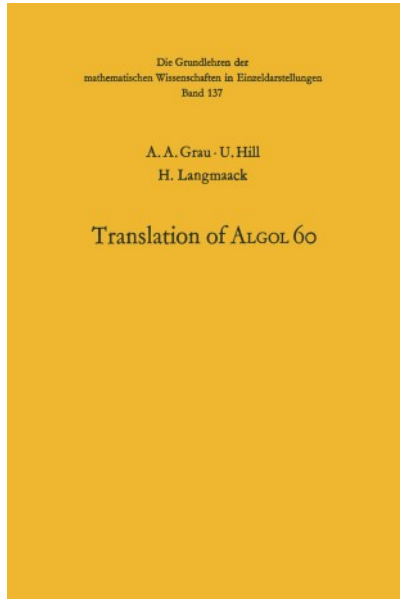
First Volumes of the Series

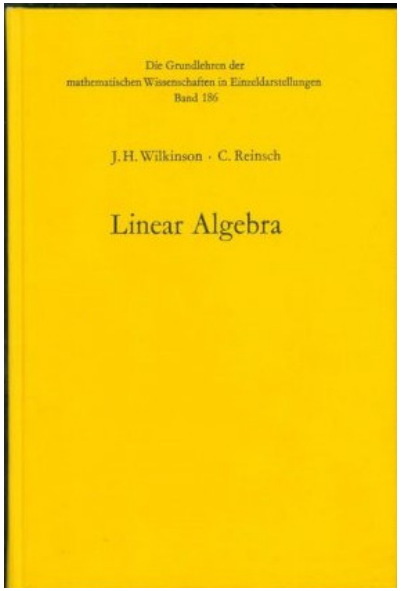
- Volume I, Part a
  Heinz Rutishauser
  Description of ALGOL 60, 1967
- Volume I, Part b
  A.A. Grau, U. Hill, H. Langmaack
  Translation of ALGOL 60, 1967
- Volume II
  J. H. Wilkinson and C. Reinsch
  Linear Algebra, 1971

Planned, but not realized

- Volume III, ODE, PDE, Integral Equations
- Volume IV, Approximation
- Volume V, Evaluation of Special Functions







These programs are the origin for
LINPACK
EISPACK
MATLAB
...

Handbook for Automatic Computation

Volume I, Part A: Description of ALGOL 60 HEINZ RUTISHAUSER

wrote the whole book with the Flexowriter on punched tape!

Events 1968

April, 4 Martin Luther King is murdered

June, 5 Presidential candidate Robert Kennedy is murdered

June, 29 Globus Department Store riots in Zurich (as part of worldwide student unrest)

July, 18 Intel Corporation is founded

August, 21 Prague Spring is ended by the invasion of the Soviet Union and other Warsaw Pact countries

October, 1 Establishment of special CS-group at ETH

October, 1 Swiss television starts color television operation

October, 11 Start Apollo 7: first 11 days flight of Apollo-Program

November, 5 Richard Nixon wins election as US President

Switzerland 1968

- Women in the house: housewife is a job
- Women have no right to vote ("indirect" democracy!)
- Still Fräuleins exist !
- Example of BOOLEAN expressions in ALGOL 60: [a]

– *We only write "Fräulein" on an address if it is a female and single (not married) person.*

– *If the gender is designated as 1 for male and 2 for female, the Swiss voters can be determined by:*

$$\textbf{if } age \geq 20 \wedge gender = 1 \textbf{ then goto } vote$$

[a] From Lecture Notes of Dr. C. A. Zehnder (2nd revision) February 1968)

My 1968

March Dipl. math. ETH, get job offer at Swiss Re

Peter Läuchli, my diploma supervisor has no doctoral position for me, but: "Go to Prof. Rutishauser, in fall a Specialist Group for CS will be founded with new positions"

April Prof. Rutishauser hires me with regard to the Specialist Group

May Heinz Rutishauser organizes an Algol 68 conference in Zurich (for Algol's 10th anniversary).

We assistants notice a young Swiss participant:
Niklaus Wirth: clear votes and his English is the best!

October, 1 Establishing of the Specialist Group. The "old" assistants Willy Kellenberger, and Anton Kühne stay with Prof. Stiefel, Franklin Parkel switches to the computer center.

Winter Semester 1968/69

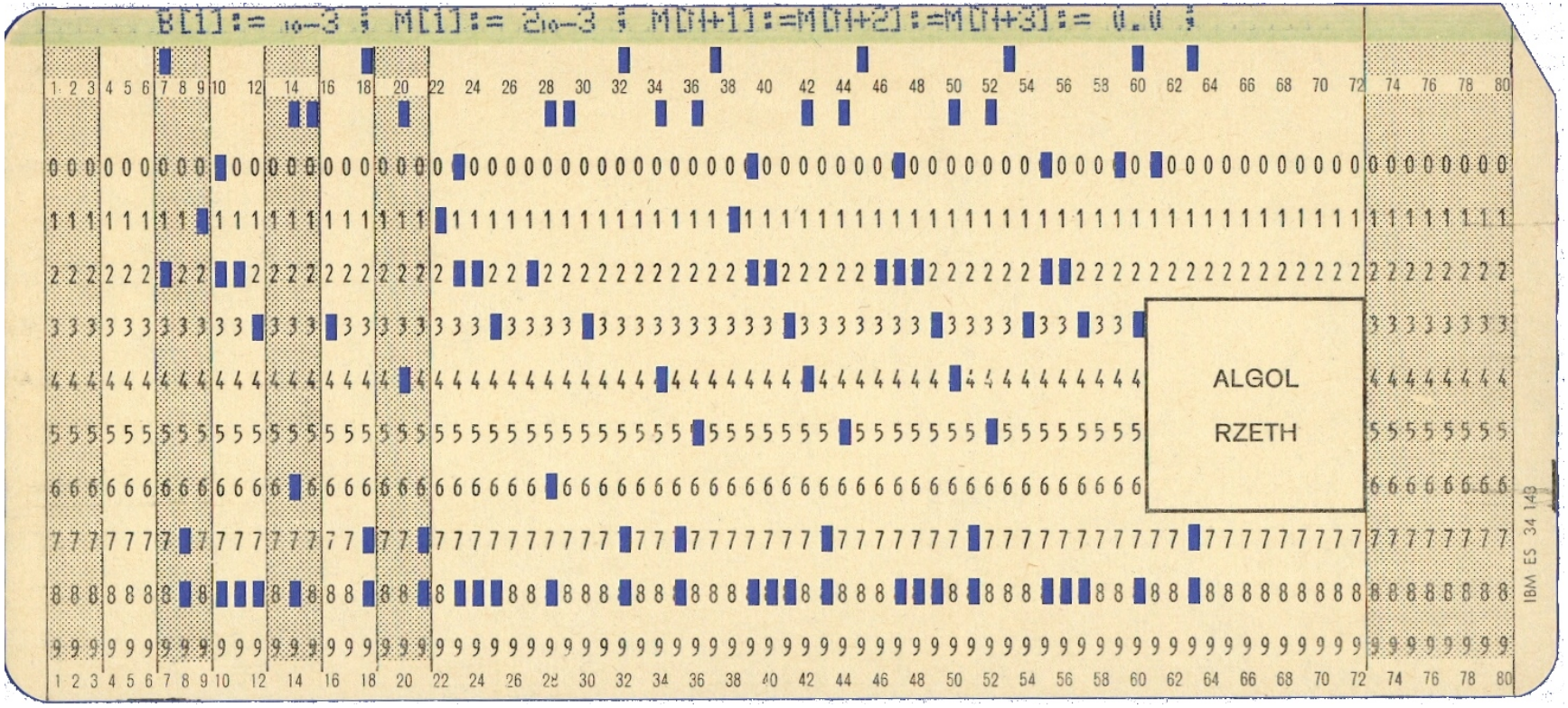
- New assistants: Urs Amman, Johann Joss, Andrea Mazzario, and from Czechoslovakia Hana Švecová (Postdoc).

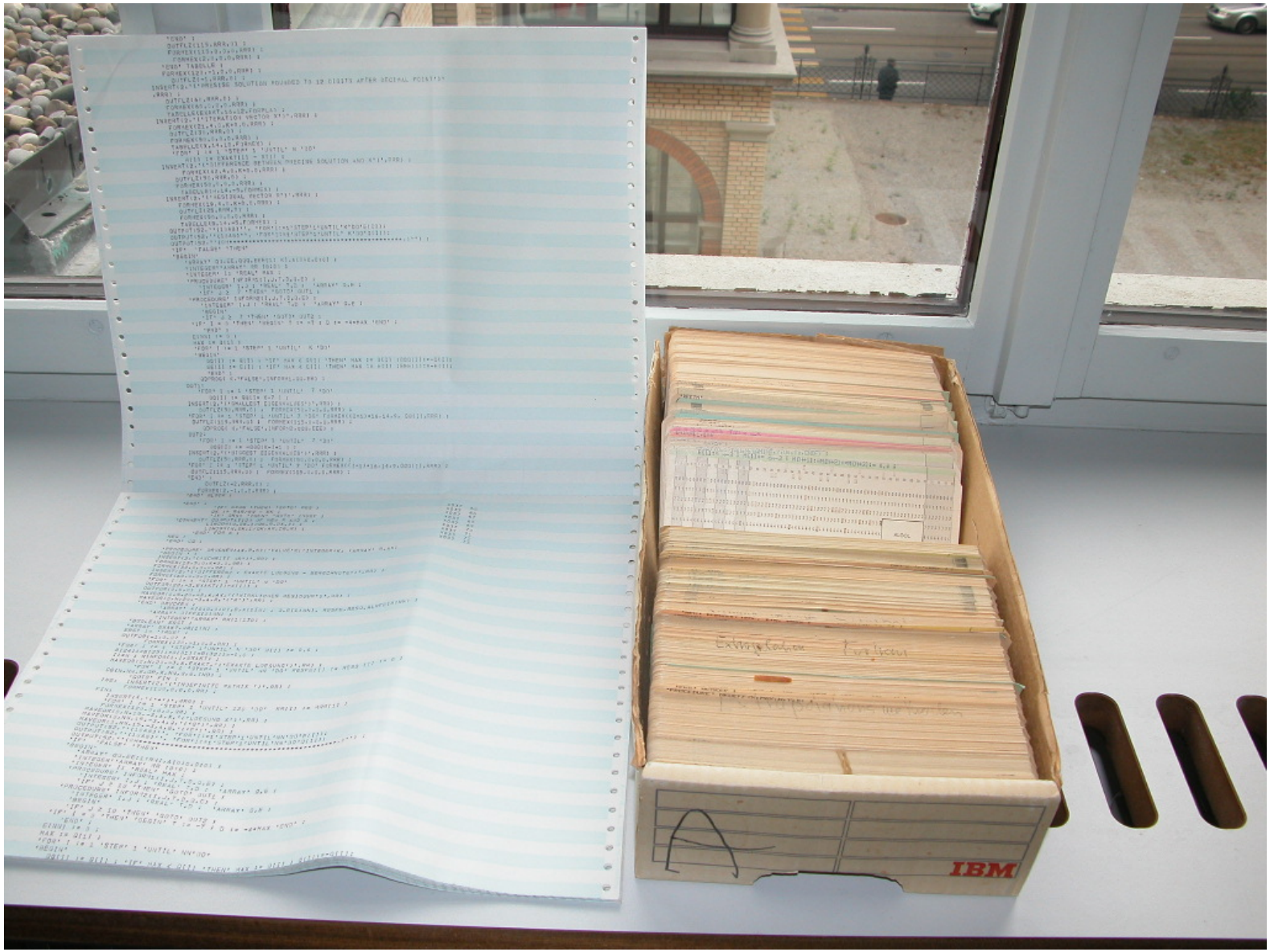
  The assistants are housed in the "monastery" (large room next to the CDC 1604 and the punch card room).

- New lectures:
  - *Computer-systems* by Niklaus Wirth
  - *Automatic Calculation with Formulas* (Symbal) by Max Engeli
  - *Numerical Mathematics I* by Heinz Rutishauser for the students in mathematics and physics
  - Algol by Peter Läuchli for all first semester students of ETH (about 600)

Using the Computer

in 1968, coming into contact with the computers . . . did not mean using computers, but rather programming, punch cards, batch operation




IBM

Programming on the CDC 1604 A

- Machine time CHF 20.– per minute much more precious than salary of an assistant CHF 5.– per hour !
- Program production
  - Program on paper
  - Punching on punch cards
  - Hand in at the Computer Center
  - Hours later or next day: Printed program and results, mostly with error messages!
  - Correct and try again
- Programming technology: minimize storage space, perform as few operations as possible. Much more intensive thought work required – program carefully not to waste machine time.

The End

On November 10, 1970, Prof. Rutishauser dies in his new office at the age of only 52.

Switzerland looses a great pioneer in computer science.

An algorithmic genius (J. H. Wilkinson)

Niklaus Wirth becomes the head of the Specialist Group

1974 Conversion of the Specialist Group into the
Institute of Computer Science

1981 Founding of the Section IIIC:
Start of Diploma Studies in Computer Science at ETH

Summary

- Eduard Stiefel, head of Institute of Applied Math at ETH, runs and improves with his collaborators Heinz Rutishauser and Ambros Speiser the Z4 of Konrad Zuse. They build ERMETH, their own computer.
- Rutishauser explains in his "Habilitation" how to automatically generate a "Calculation Plan", which leads to the idea of a compiler.
- Rutishauser is one of the fathers of Algol.
- Published Subset Algol 60 programs run on all machines without adjustments.
- Springer Handbook and ALCOR: first reliable open source program libraries.