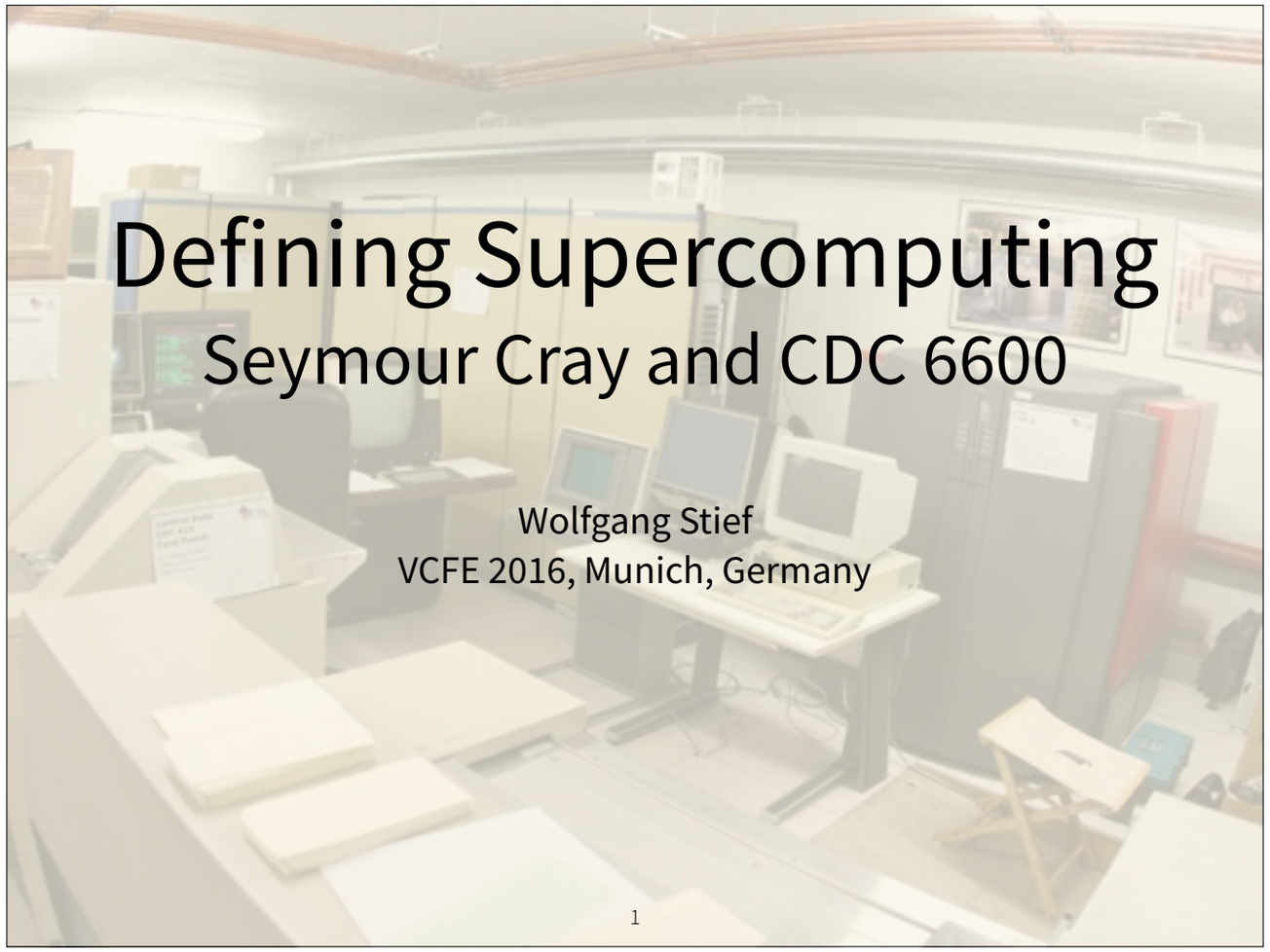


Defining Supercomputing

Seymour Cray and CDC 6600

Wolfgang Stief
VCFE 2016, Munich, Germany

whoami

- Electrician, Degree in Electrical Engineering
- self-employed, sys4 AG
  storage, e-mail, project management
- Computermuseum München, Cray-Cyber.org
  “Everything below 30 A is considered leakage current.”
- https://about.me/stiefkind
  stiefkind

00_README.txt

- Work in Progress
- Cray and Surroundings
  Companies
  People
  Technologies
  Branches and Subsidaries
- Series of lectures on VCFE (Munich) and VCFB (Berlin)
- http://www.speakerdeck.com/stiefkind/

ls -l

- Control Data Corporation
  ca. 1960 - 1970

- CDC6600, CDC7600, CDC8600

What happened so far…

- CSAW (US Navy, WWII) ➛ ERA (1946) ➛ Remington-Rand (1951) ➛ Sperry-Rand (1951) ➛ Control Data (1957)

- 1951: Seymour Cray (∗1925 †1996) starts working for ERA
  B. Sc. Electrical Engineering (1949), M. Sc. Applied Mathematics (1951)

- Control Data Corporation (fall 1957)
  Plan: U$ 600.000 seed money, all shares in private ownership
  seed money reached: U$ 1.2 Mio.

- CDC Little Character (proof of concept for transistor computer)

- CDC 1604 (1959)
  48bit, 0.2 MHz ➛ fastest computer on earth

- ERA — Engineering Research Associates
- Machines at ERA: Goldberg (1947), Demon (1948), Atlas I (ERA-1101, 1950) und Atlas II (ERA-1103, 1953)
  ➛ Tubes, Drum Memory
- Short before ERA, Remington Rand also buys Eckart-Mauchly ➛ UNIVAC

“All I know how to do is build computers, so I’ll do that.”

— Seymour Cray, 1957

CDC6600 — The Beginning

- development starts immediately after finishing the 1604
- design goals
  > 50x faster 1604
  > 1-3 MFLOPS
  > clock cycle 100ns ≙ 10 MHz
- UNIVAC LARC ➛ Goal: 100x faster than predecessor
  > “spectacular flop”
- “Cash Cow” ➛ 1604, 160/160A (“Desktop”), CDC3600

- CDC-1604 ➛ 0.2 MHz = 5μs clock cycle
- Common back then: 4-5x clock cycle to predecessor. 50x war **very ambitious**. Overambitious?

“Five-year goal: Build the biggest computer in the world. One year goal: One fifth of the above.”

— Seymour Cray

- Manager have to write 5 year plans for budgeting.
- Others write pages full with demands and reasonings.
- Cray wants to build computers without management disruption. ➛ To account for, once the machine is done, not earlier.
- Steps back from “Director of Engineering” ➛ Moves to Chippewa with entire laboratory/team.
- Important for CDC: keep Cray as engineer, **never ever loose** him to competitor.

Strutwear Building und Chippewa Falls

- 1960: relocation Cray + developers
  > former underwear factory, “Strutwear Building”
  > in Minneapolis, close to headquarter

- Cray is in great demand because of success 1604
  > (too) much visits from customers and sales
  > needs silence to do his work

- 1962: Cray + team relocates to Chippewa Falls
  > ca. 80 miles away, not easy to reach from Minneapolis
  > long distance calls were complicated (via operator)
  > far away from possible targets of atomic bomb (1962, cold war!)
  > Spring 1962 ➛ Cray + 14 engineers + 4 programmers

- Cray searches several month for possible locations, finds it while visiting relatives in his home town Chippewa Falls.
- Cray does everything himself: buying the land, planning the building, his own house (in walking distance), etc.
- CDC Mgmt agrees to relocation, but doesn’t support it ➛ Engineer in 1962 earns ≈ 8000/9000 U$/year, have to pay relocation on his own.

A supercomputer comes into being — CDC6600

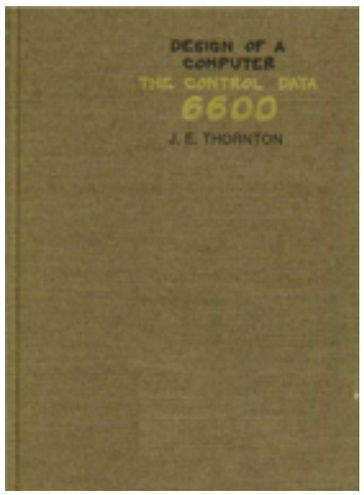
- circuits from 1604, but better transistors (higher quality)
  > only moderate success

- tweaks on circuits
  > many rounds
  > won’t get faster, but reliability gets worse

- “despairingly” changes from Ge to Si
  > new development by Fairchild Semiconductor
  > impressive electrical properties
  > in particular much faster circuit time

- Beginning 1962: CDC3600 very successful, growing pressure from management to release a new machine.
- “fail on a grand scale” bad for an engineer career
- most probably, Si transistors aren’t a complete new development, but the manufacturing process (silicon mesa variety ➛ planar process)

A supercomputer comes into being — CDC6600



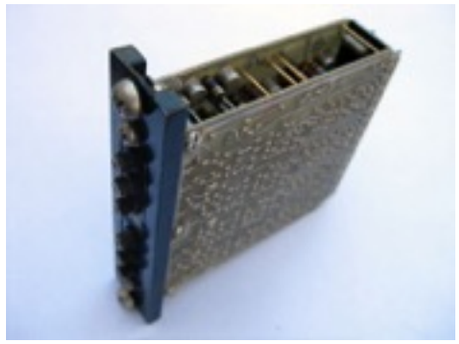
- Si transistor: circuit design by Cray
  > much simpler then 1604 circuits

- faster circuit time of Si transistor
  > faster switching cycles
  > higher clock frequency
  > less signal runtimes
  > bottleneck: propagation delay!

- Jim E. Thornton
  The Control Data 6600 — Design of a Computer
  CPU-Design 6600: Cray/Thornton
  http://ygdes.com/CDC/DesignOfAComputer_CDC6600.pdf

A supercomputer comes into being — CDC6600

- 10x - 20x more gates then 1604
  > cordwood package
  > 64 gates / cordwood
  > high package density ➛ more heat



- air cooling ➛ liquid cooling
  > totally new for computers at this time
  > engineer Dean Roush ➛ built cooling systems before CDC

- 1st draft: hybrid with air/freon
  > not enough cooling power

- 2nd draft: liquid cooling only with Freon
  > prototype gets built

- planned footprint smaller then CDC-1604!
- 1604: 2 gates / circuit board
- Dean Roush ➛ Lab Mechanical Engineer

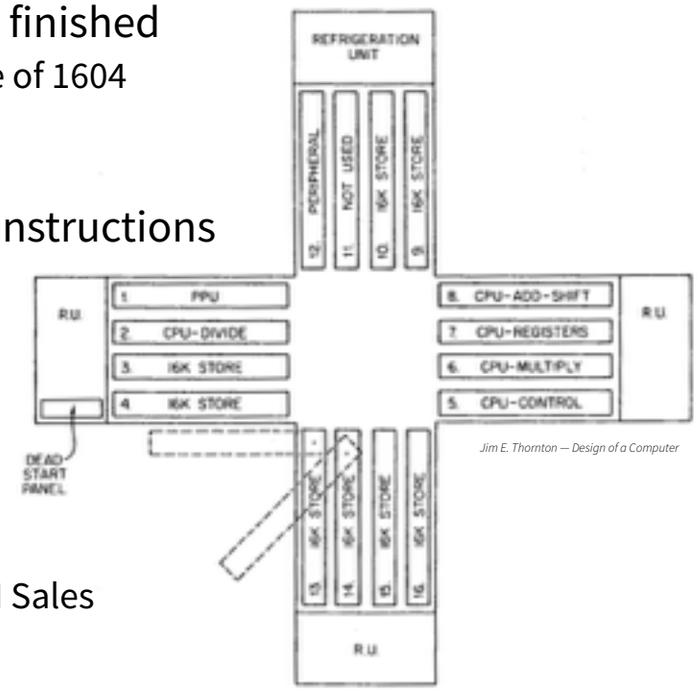
A Supercomputer comes into being — CDC6600

- cooling principle
  > aluminium cap per cordwood modul
  > cap has heat conduction contact to a pipe system
  > for heat transmission: Freon in the pipe system

- 6700 cordwood modules
  ＞400.000 logic gates

A supercomputer comes into being — CDC6600

- mid 1963: development finished
  > first tests: 50x performance of 1604
  > design goal reached
- instruction set: only 64 instructions
  ≈ 20 years bevore “RISC”
- ≈ 3 MIPS
- competition
  > IBM ASC-1 (never finished)
  > IBM S360/90 ➛ FUD by IBM Sales

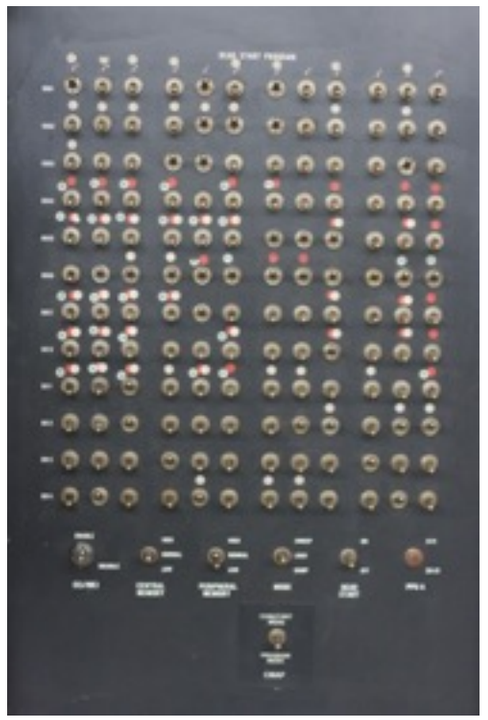


Jim E. Thornton — Design of a Computer

- 3 MIPS is by far the fastest.
- word about speed spread, suddenly all had problems to calculate on, where they needed the speed of a CDC 6600: Los Alamos, NSA, etc.

A supercomputer comes into being — CDC6600

Computer History Museum



Wolfgang Stief, CC0

- left: a typical CDC6600 installation with mainframe (right), operator console (middle), tape drives (left), punch card equipment (top) and disk drives (bottom).
- right: dead start panel, **probably not** that of a CDC 6600.

“Last week Control Data had a press conference during which they officially announced their 6600 system. I understand that in the laboratory developing this system there are only 34 people, including the janitor. Of these, 14 are engineers and 4 are programmers, and only one person has a Ph.D., a relatively junior programmer. Contrasting this modest effort with our own vast development activities, I fail to understand why we have lost our industry leadership position by letting someone else offer the worlds’s most powerful computer.”

— Thomas J. Watson, President IBM Corp.

Goldrush — Rise and Fall

- in ca. 1965
  > computer division
  > research division
  > peripherals division
  > Chippewa Laboratory
  > system sciences division
  > data center division
  > government systems division

	Share
1957	1 U$
1961	126 U$
1964	300 U$

	# employees
1957	11
1959	325
1961	1.500
1962	2.200
1963	3.500
1965	>9.000

- 15 offices: 11x USA, 3x in Europe, 1x Honolulu
- 1965: relocation headquarter to Bloomington
  > suburb Minneapolis
  > stays headquarter until closing down the company

- good total revenue CDC: 1604/160/3600/6600
- Europe: England (Birmingham), Germany, Switzerland.
- growing too fast is a problem still today

Goldrush — Rise and Fall

- CEO Norris: wants to broaden CDC portfolio
  > many acquisitions between end 1950 and end 1960
  > Cedar Engineering, Bendix Corporation (Computer Division), Holley Computer Products, Daystrom (Control Systems Division), Control Corporation, Meiscon Engineers
  > 8 companies in 1963, 12 companies in between january 1964 und 1965

- goak: complete solutions portofolio
  > science/engineering, hardware, software, machine time for rent
  > consulting, software programming

- growth (foo) fast, pressure to succeed

- 1966: 4 key engineers leave the company

- **Cedar:** servomotors, amplifier; **Bendix, Holley:** tapes, printer, monitore, card reader, paper tape reader; **Daystrom, Control Corp., Meiscon:** civil engineering, statics
- three of four key engineers were founding members, amongst others Frank Mullaney, director of engineering

Goldrush — Rise and Fall

- integration of acquisitions ➛ cost-intensive ➛ liquidity (!)

- stability problems with first several delivered CDC6600
  > Delivery to LLNL scheduled February 1964, delivered beginning 1965

- IBM awakens
  > aware of CDC internal problems
  > IBM sales spread *fear, uncertainty and doubt* (FUD)
  > S360/90 allegedly much faster then CDC6600
  > ca. 126 Mio. U$ development costs (1965),
  but still not even a prototype exists

- integration of acquisitions still is cost-intensive nowadays
- IBM FUD impacts CDC6600 sales volume
- spreading FUD still is a popular method in IT sales

Goldrush — Rise and Fall

- IBM 360/90 can’t keep up with promise
  > unreliable, many technical problems, not accepted by market

- CEO Norris mad on IBM
  > unfair marketing, market monopoly, antitrust laws

- lawsuit CDC ./. IBM
  > nobody dared before, IBM is well known for its huge army of lawyers
  > *“they could bury a company in paperwork”*
  > goal Norris: stop IBM business practice to not experience it again with CDC7600

- board and advisory board have to be convinced and finally agreed on the lawsuit

Vor Gericht

- lawyers get permission to read documents of opposite party
  > CDC provides IBM ca. 8 Mio. documents
  > CDC demands ca. 15 Mio. documents from IBM

- CDC employs assistants only for the lawsuit
  > screening and sorting documents
  > “import” documents into computer (with special forms)
  > lawyers then can search for words and strings (on tape)

- first time, that a computer played an important role in a lawsuit
  > 2 years document screening, sorting, extracting

- interviews with IBM Executives: *“I don’t know.” — “I don’t remember.”*

Dissatisfied staff

- engineering becomes more and more dissatisfied
  > integration of acquisition costs money
  > reduction in engineering budgets
  > management is growing and becomes more expensive

- Computer Division extra angry
  > they are responsible for success/revenue (1604, 3600, 6600)
  > massive reductions in budgets

- from startup to large-scale enterprise with all practical constraints

- engineering looses control over their own work

Meanwhile in Chippewa Falls

- CDC6600 not very reliable
  > **but:** better to use CDC6600 nine hours at a stretch, then 40h calculation time of same problem on a competitors machine

- Cray still is reclusive
  > no interviews
  > no visits of management, sales, customers
  > withdrawal from CDC board due to time constraints

- ca. 1969: work on 6600 and variants finished
  > 6600 ➛ high performance CPU, parallel functional units
  > 6400 ➛ less performance, no parallel functional units
  > 6500 ➛ 2x 6400 CPU
  > 6700 ➛ 6600 CPU + 6400 CPU

- today, Cray probably would qualify as “this strange nerd”
- failure IBM: S360/90 and IBM Stretch (model 7030, first transistor computer by IBM, released 1961)
- MTBF CDC6600 ➛ 9h
- on multi CPU systems (6500, 6700) bottleneck always was memory bandwidth (magnetic core memory)

What's next? ➛ n+1 — CDC7600

- development CDC7600 (1965-1969)
  > initially, there should be a 6800
  > microcode incompatible to 6600, therefore name change
  > Cray is head of development

- design goal: 25ns clock cycle (27.5ns?)
  > 25ns ≙ 40 MHz ≃ 4x faster then CDC6600

- introduction into market 1969
  > U$ 8 Mio for 4x performance ➛ often not worth the invest
  > CDC sells only ca. ½ quantity of CDC6600

- 1604: 0.2 MHz (5µs) — 6600: 10 MHz (100ns) — 7600: 40 MHz (25ns)
- 8 Mio U$ (1969) ➛ ca. 50-60 Mio U$
- average salary 1969 USA ca. 3.000 U$, engineer ca. 9.000 U$

CDC7600

- C shape➛ compromise of servicability and signals runtime (25ns = 5m distance / cycle) (5m = 16.4 feet)
- first seen in 7600: instruction pipeline

n+2 — CDC8600

- design goal:
  > no backward compatibility
  > 8ns clock cycle ≙ 125 MHz (1969!)
  > multiprocessor, quad CPU ➛ most problems usually sequential
  > once again higher package density

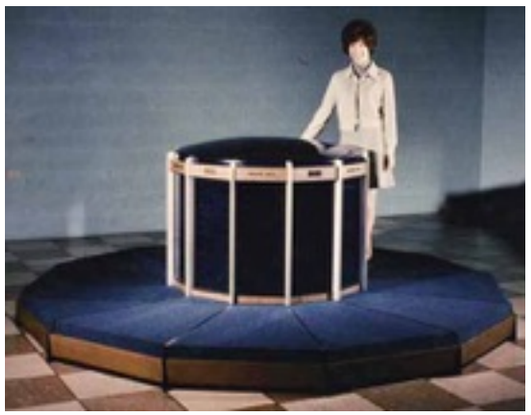
- same proven development team as CDC6600/CDC7600
  > Chippewa Laboratory
  > all but Jim Thornton ➛ Arden Hills, STAR-100 (vector processor)

- 1604: 0.2 MHz (5µs) — 6600: 10 MHz (100ns) — 7600: 40 MHz (25ns) — 8600: 125 MHz (8ns)
- Intel Pentium, beginning 1995, 125/133 MHz
- **multiprocessing** still is a **challenge** for application development **(45! years later)**

Development CDC8600

- higher package density
  > 6” x 8” (ca. 15cm x 20cm)

- first test modules:
  high current drain
  > per module 8 circuit boards
  > per module ca. 3kW (!) power input



By Source (WP:NFCC#4), Fair use, https://en.wikipedia.org/w/index.php?curid=39643859

- liquid cooling
  > copper plates **in** circuit boards for heat conduction
  > heat exchanger approx. 20t, needs space of 2x 7600 or 3x 3600
  > single module quite heavy because of amount of copper

- problem: reliability
  > many discrete components, many solder joints, lots of heat

- circuit board CDC7600 ca. 1/5 of area

Development CDC8600

- mid 1971 ➛ 2 years development, no progress

- budget Chippewa Lab ➛ reduce 10% (mgmt demand)
  > 40 engineers ≙ 4 staff members
  > Cray wants to hold entire staff and offers to work without payment
  > work w/o salary not allowed ➛ minimum wage, 1.25 U$/h

- management/board/Norris: service company
  > future is in services, not hardware

- hardware ➛ services: history repeats itself. See HP, IBM and others

“Everybody wo needs a computer has one.”

— Bill Norris, CEO Control Data Corp., 1971

End of development CDC8600

- Meeting Cray/Norris in Bloomington (HQ)
  > 8600 doesn’t work, fundamentally wrong
  > new design, new development program, new budget
  > Norris: wait 1 year, STAR-100 is expensive, two projects not possible
  > Cray: asks for time to think it over

- Cray back at Chippewa
  > discussions with confidants and ex CDC (among others Mullaney)
  > U$ 2.5 Mio seed money, 20% from Cray
  > hand picked developer team, ca. 25% less salary

- Memo Cray ➛ Norris, February 14 1972
  > irresolvable problems @ 8600 development
  > Cray + 6 engineers leaving CDC and found Cray Research Inc.

End of development CDC8600

“An Employee has only one life, whereas a company could go on and on”

— Bill Norris, CEO Control Data Corp.

Norris/CDC invests U$ 250.000 in Cray Research Inc.

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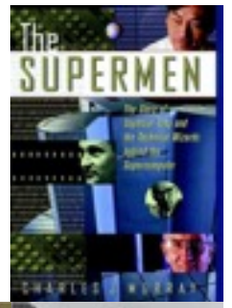
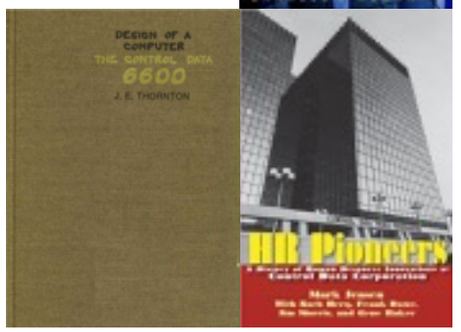
- English Wikipedia
  CDC 6600, CDC 7600, CDC 8600, Engineering Research Associates, Control Data Corporation, Cray, Seymour Cray, William Norris (CEO)



- Charles J. Murray — The Supermen (Buch)
  The Story of Seymour Cray and the Technical Wizards behind the Supercomputer

- Mark Jensen — HR Pioneers
  A History of Human Resource Innovations at Control Data Corporation

- Jim E. Thornton — The Control Data 6600
  Design of a Computer
  http://ygdes.com/CDC/DesignOfAComputer_CDC6600.pdf



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- The CDC 6600 Architecture
  http://ygdes.com/CDC/cdc6600.html
- Oral history interview with William C. Norris (1986)
  http://conservancy.umn.edu/handle/11299//107551
- Oral history interview with Frank C. Mullaney (1986)
  http://conservancy.umn.edu/handle/11299/107538
- Gordon Bell — A Seymour Cray Perspective (presentation)
  http://research.microsoft.com/en-us/um/people/gbell/craytalk/

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- Seymour Cray — Cray-1 Introduction (talk, 1976, LANL)
  https://www.youtube.com/watch?v=vtOA1vuoDgQ

- Seymour Cray — Whats all this about Gallium Arsenide?
  Talk on development of the Cray-3
  https://www.youtube.com/watch?v=xW7j2ipE2Ck

- Cray Research - A Story of the Supercomputer (documentary)
  https://www.youtube.com/watch?v=wn03wn3k47Y

EOF

Thanks!

Questions?

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