BEFORE THE DEMO

Evaluate the crowd, and especially: how familiar are they likely to be, with retro computers?

If there are kids and 20- and 30-somethings, they may never have heard of a computer that didn't have a screen, keyboard, and hard disk, and may never have seen a mag tape.

For these viewers, be sure to take the time to let them feel the media and soak up the machinery where indicated in the script. Do not assume they will know what you know, they may lack basic concepts like "no operating system".

If the audience is predominantly older, you can skip quickly over basic familiarity items, but on the other hand, they might enjoy the nostalgia effect, too.

INTRO

> Hello and welcome to a business computer center of almost fifty years ago!
>
> Look around: if you worked in what was called "data processing" anytime from 1960 to 1965, you spent your workday in a room like this, with fluorescent lights and a raised floor, among machines very much like these.
>
> Just for a quick orientation, that large box in the middle of the room, with the blue and silver trim, that is The Computer. It is an IBM model 1401.
>
> IBM announced the 1401 line in 1959. By 1965, when its successor, the IBM 360 series, was coming in, IBM had shipped over 10,000 of these machines. Today, that's about how many Dell builds in a few hours, but this was the first computer to be built in such quantity.
>
> Those of you who only know computers that sit on your desk or on your lap might notice a couple of important things missing from this computer. There's no screen! There's no keyboard!
>
> How is it possible to use a computer with no screen and no keyboard?

> Well, the big box to your left, the one with what looks like a playground slide sticking out of it, that is a card reader and a card punch. The primary way to get data INTO our 1401 is by reading punched cards. We'll do some of that in a minute.
>
> This thing behind me is the 1403 line printer. The main kind of output from the 1401 was paper documents -- like bills, invoices, payroll checks -- and they come out of this printer at high speed -- and at a high noise level, as we'll demonstrate today.
>
> Lined up down the wall on your right is a set of five, or as we used to say, a "string" of five tape drives. These are IBM model 729 tape drives that read and write data on half-inch magnetic tape. This is what most 1401 systems used as permanent storage. Any file that you want to keep, you write to a reel of mag tape, so you can read it back later. We'll do some of both today.

In the event someone asks "why didn't they keep stuff on disk?" or "does it have a disk?" you can add:

> There were magnetic disks by 1959. Out in the lobby of this museum you can see a restored RAMAC, which was the very first commercial hard disk. It was introduced in 1956 and a few 1401 installations had them. However, the RAMAC was expensive, and more important, there was no operating system to simplify loading and storing disk files. The programmer had to specify exactly what head and track to write each record on.
>
> It wasn't until the IBM 360 in 1965 that a computer came with a hard disk as standard, and had an OS that managed storing files on disk.

Continuing...

> The rest of this demo is in two parts. First we are going to show

how the 1401 worked in everyday business data processing: input of data, output on the printer, and updating a master tape. That's going to take about half an hour.

In the second part we will get all geeky and talk about the technology behind these machines, how they work and what we had to do in order to restore them. We'll go on with that as long as anybody is interested.

AT THE ACME CORP - INPUT PREP

For the start, let's pretend we work in the data processing center of the famous ACME corporation -- Supplier of Dynamite and Devilish Devices to Discriminating Coyotes Across the Southwest.

Here at ACME we have been taking lots of orders from coyotes eager to blow up roadrunners. The orders come in by phone and in the mail and we need to get them into the computer the only way we can: as punched cards.

Pick up deck of sample unpunched cards and display. Distribute sample cards to younger members of the audience.

People inside IBM called these "punched cards" -- everybody else called them "IBM cards."

A card has 80 columns, and in each column we can put a combination of punched holes to stand for one alphanumeric character.

This card format was standardized in 1928 and it was a familiar part of life up through the 1980s. Utility bills, airline tickets, early credit card slips, all were in this format.

So, sales orders have been pouring in to ACME and we need to punch the details into cards, which we do with these machines, IBM 026 keypunches.

If the audience contains any females, include the following:

Keypunching is almost always done by women. If you were a woman in data

processing in the 50s and 60s, odds are very high that you were a "data entry clerk" and spend your work day sitting at one of these machines, entering data off paper documents at this keyboard. Most other computer jobs went to men.

Select a couple of women (if any, else teens) who look like they have a clue:

So I need you and you to come be data entry clerks for us.

Usher them around to waiting keypunches. Switch the machines on. Hand out data entry instruction sheets to them and to the audience to see.

To start, you press the CARD FEED key once... that fed a card to the entrance station.

Press it one more time.... now you have a card ready to punch. So the first thing to punch is this customer's number, let's say that is one-one-one for you... and you can punch one-one-two.

Great! Now key the letter L...

Good, now for item description just key the letters of your name, one letter at a time.

As they do this say to the audience,

Imagine a room full of these machines, making these sounds, the hum of the motors and the sounds of punching. In the early 60s a big business like PG&E had entire floors of office buildings with nothing but keypunches, banging away.

When the "clerks" have finished typing their names,

OK, our computer program will fill in default values for the other fields, so you can just press the EJECT key... and again... Great! Thank you. A hand for our data entry clerks!

Collect the cards and add to input deck. Switch off the keypunches. The prepared input deck has at least 200 cards.

AT THE ACME CORP - SORTING

Our 1401 has very little memory and no disk, so it cannot do things in random order. The only practical way to handle data is in sequence. Our programmer has designed the sales invoice program handle the sales items in sequence by customer number.

However, these sales record cards are just as we received the orders, not in any special sequence. So before we go to the computer we need to get them in order, and to do that, we use this device, an IBM 082 sorter.

This is not a computer, it is not digital, it is electro-mechanical. And how it works is almost brutally simple.

There is a small wire brush, just the width of one card column. Cards pass under this brush and when the wires fall into a punched hole, it closes a circuit, and that guides the card to one of these pockets.

So let's sort this deck on customer number, which is the first three columns. To do that, I set the reading brush to column 3...

and put the deck in the input hopper...

And now I need a volunteer for a highly technical task, a DIGITAL task, so who wants to help?

Choose the youngest a/o cutest audience member.

Okay, for this digital task I need you to hold up the first digit of your right hand...
(demonstrate)
...good, and place the tip on this button marked START... good, and when I say go, you press down once. OK? You got it? You ready? GO!

All the customer numbers ending in zero are going in this pocket, all the ones in this pocket...

(collect cards in sequence)
...the twos, threes, and so on.

So, now I have the deck sorted on the least significant digit, I put it back in the hopper... and I set the reading brush to column 2... and if our intrepid volunteer is ready? GO!

Now this pocket has all the cards ending in zero-zero to zero-nine,
(collect cards in sequence)
ten to nineteen, twenty to twenty-nine, and so on.

Now the deck is sorted on the last two digits and I put it back in the hopper... and set the brush to column 1... and you get out that digital digit and press START one more time... good!

So now this pocket is getting all the cards with zero-zero-zero to zero-ninety-nine, and all the hundreds here... and the two hundreds...
(collect the deck)
and we are sorted. Thank you, a round of applause for our sort operator!

If you were in data processing in the 50s and 60s, it is possible you might spend all day running a sorter like this one. Sorting really big decks, huge trays of cards. And you would sort on longer fields, nine-digit social security numbers. Or it is possible to sort on alphabetic data, putting a deck into alphanumeric order.

But now we have our input data and we are almost ready to run a program.

AT THE ACME CORP - MOUNT THE TAPES

I said our program is going to update a master tape. This is what computer tapes look like.

Pick up 2400-ft reel and hold up, then pass to nearest audience member.

Pass that around... Our model 729 drives have seven-track heads. They write seven bits across the width of the half-inch tape. That's six data bits and a parity bit.

You might be thinking, wait up, aren't there eight bits in a byte? Why do they write only six?

The answer is, memory in the 1401 is organized for SIX-bit characters. Each memory position can hold one character from a set of 64. The EIGHT-bit byte that holds one of 256 characters came in with the 360 series in 1965. The tape drives for the 360 read and wrote nine bits. But in this earlier generation we do six-bit characters, not bytes.

The 729 can write data at 800 characters per inch. There is a gap after each record, so the final capacity of a 2400-foot reel like this one is just about 20 megabytes of data.

That was certainly a lot of data in 1959. But for perspective, that's about 20 minutes of music in MP3 format. Or, a two-gigabyte memory chip in your digital camera contains the equivalent of 100 of those reels.

Now the key fact to know about tape is, it is not random-access. Well, if you absolutely have to, you can skip around and read one record and then forward space or backward space to another record, but it is painfully slow to do.

And what you absolutely cannot do is update a record in place. The drives are just not able to position the tape precisely enough to update one record and not slop over and damage the next record on the tape.

Our ACME sales program is going to read sales records and we want to update the master record for each customer to reflect total sales to that particular coyote.

When you have a database on disk you can read any record, update it, and write it back, but not when the database is on tape. The only way to update a master tape is sequentially. We READ the master customer list one customer at a time. We update the information for that customer, and we WRITE a new master tape on a second tape drive.

Mount the master tape on one drive, and the output tape on a second drive.

Notice how the drive sucks the tape down into these vacuum columns? If you are curious why it does that we can talk about it later.

AT THE ACME CORP - LOAD THE PRINTER

The other thing our program will do is print an invoice for each customer showing what was ordered, the cost, amount due and so on. That all comes out on our 1403 printer.

Open the printer cover, open chain gate, demonstrate loading paper.

As a data processing operator in the 50s and 60s one of your important jobs was loading forms into a printer like this. The paper feeds up out of a box... you lay it over the forms tractors... align it nicely... snap the tractors shut.

Inside this gate, behind this big ribbon, there is a chain a lot like the blade of a chain-saw. On each link there are a couple of letters sticking up. In operation the chain spins around at high speed.

Behind the paper, facing the chain, is a row of 132 hammers. When the correct chain link comes whizzing past, the hammer fires, and slams the paper against the ribbon and the letter. So if you want to print an A in column 25, the hammer in position 25 waits until an A is coming toward it, and at just the right time it goes "tap!" and bangs on the paper.

Close the chain gate and the printer cover.

AT THE ACME CORP - RUN A PROGRAM

> Now we are ready to run our sales program but...

Point to a younger member of the audience

> If you want to start some program on your computer, what do you do?

Typical answer, click on it, or pick it from the menu...

> Right, and that tells the operating system, go get this program off the disk and load it into memory, right?
>
> Well, the 1401 doesn't have an operating system of any kind, and no disk either. We can load a program from cards or from tape. Today we will run from a card deck.

Pick up program card deck, load in 1402 read side.

> This deck has the machine instructions for our ACME Corp. sales program. We put it in the card reader... press the load button on the 1401...

Talk over the reader

> The 1401 is reading the program deck into memory and... now that it is done, it has given control to the program, and notice a blink of light and a movement over on the master tape, it has read the first customer master record and is waiting for the card reader to come ready with the data deck.

Load the sorted data deck into the 1402 but don't press start.

> Ready? When the card reader starts, the 1401 will copy the master tape until it finds a customer that matches the next card; then it prints an invoice using the customer name and address from tape and the detail items from the cards, and writes an updated customer record on the new tape. Here we go...

Press start. Program runs, hopefully, and cards don't jam and paper doesn't tear... if things go wrong, wing it.

Program should be designed to take at least five minutes to run. Talk over the noise.

> OK in single file, follow me and
> walk through the machine room,
> that's right, follow me...

Lead the group in a file past the tapes, in front of the 1401, past the 1402 and 1403, back to the entrance.

Herd the group back beyond the railing as or shortly after the program ends its run.

N.B. the last thing the program should do is rewind and unload both tapes - that's always impressive.

At the 1403, eject paper once, raise the cover, split the forms, get printout stack from the back.

> OK, just to show we really processed
> this data, let's find the invoices
> for customers 111 and 112...

Find those invoice sheets, tear out, hand to keypunch volunteers.

> There, is that your name in the item
> description?
>
> Anyone else want a souvenir?

Tear off and hand out invoice sheets from the printout as requested.

> And that concludes our visit to the
> data processing center of the ACME
> corporation. Any questions about
> data processing in fifty years ago?

Deal with questions, deferring questions of technology like how much memory does the computer have?

1401 TECHNOLOGY

> Now for the technical part. To begin
> with, here is the flowchart for our
> program...

Pass out copies of the program flowchart.

> You'll see we are basically doing a
> merge between our sorted deck of
> cards and the master tape.
>
> The program was written by a
> volunteer in a sort of Assembly
> language for the 1401 called

Autocoder. You can see the program listing if you want to. If you are interested in learning to program the 1401, we have a mailing list and we are planning in the future to actually have programming classes.

## 1401 - HISTORY OF THE SPECIMEN

This 1401 was built by IBM at its German subsidiary in Boeblingen in 19??. It was sold to the U. S. Army and for several years was used for accounting at the ???? base in ???.

When the machine was retired, one of the IBM employees who had helped maintain it, a Herr Schweinsberg, bought it. He put it in a garage with the idea of running some kind of small-time service bureau (?) and when that didn't work out, the machine just sat for a number of years, gathering some dust and rust but not damaged too much.

It was bought by the Museum in 2003 and shipped here for restoration. A team of volunteers, many of whom worked with 1401s when they were current, have put in many hours since then, restoring the system.

A big issue with this machine has always been that it was built for European power, 220 volt, 60 Hertz. We didn't realize how important this was at first, but it turns out that IBM used frequency tuned transformers in their power supplies -- tuned to 50 Hz -- and it would not be practical to convert these machines to 60 Hz power. So we had to install a rather large power converter over there behind that wall to convert local 60 Hz power to 50 Hz. IBM San Jose donated that equipment.

## 1401 TECHNOLOGY - SMS

Pass out a couple of SMS cards to be handed around.

Here you have a close look at the technology of the 1401.

IBM called this technology SMS, for

Standard Modular System. Each SMS card is a single-sided circuit board that carries discrete transistors, resistors, diodes and capacitors. The did not have integrated circuits in 1959. The first ICs were made in 1960 and 1961. The IBM 360, in 1965, used small-scale integrated circuits, ICs with a few dozen components per chip.

Each SMS card has the function of about one flip-flop or a couple of AND or NAND gates. Originally IBM planned on stocking a couple of hundred specific SMS cards, but eventually they stocked over 2500 different kinds.

Our 1401 contains exactly ???? of these SMS cards. There are a few hundred more of them between the card reader, in the printer, and in the tape drives. In other words, there's a whole lot more logic gates in your typical camera or cell phone than there is in this whole room.

Most of these cards are original as built by IBM in 19?? when this machine was manufactured. We have had to debug and physically repair only ??? of them to get the machine running.

The failures are most frequently not in the transistors but in the diodes. The cards use many Germanium diodes as logic elements. Some of these fail because the metal actually migrated over time across the point-contact. Others failed because the cans that enclose them have some ferrous metal content, which corroded over time and let in atmospheric moisture.

But our volunteers have got SMS debugging and repair down to a pretty good science now, and as long as we have the machines in a low-humidity constant temperature environment it is fairly reliable.
(Reliability figures?)

Questions about SMS cards?

## 1401 TECHNOLOGY - MEMORY

Let's talk about memory. The 1401 uses core memory. There is an EIGHT thousand character memory in the CPU box itself. The smaller box beside it is an extended memory unit with another FOUR thousand characters, for a grand total of twelve kilobytes in all. Thats about ten percent of a megabyte or about a hundredth of a percent of the memory in a cheap PC today.

Does everyone know how core memory works? Here is a so-called core plane, it is very delicate so I'll just hold it so you can peer at it.

Each bit is represented by a tiny iron donut. Fine wires are threaded through the donuts in a mesh. By pulsing certain wires you can read out the magnetic state of a donut. Or by pulsing others you can flip its magnetic state, and that is how you write to memory.

These core planes were assembled manually by women with magnifying glasses and very steady hands. You can imagine they were fairly expensive to make.

The 1401 takes 11 microseconds for a memory read of one character, and about 80 microseconds to fetch a typical instruction. Today we measure CPU speed in MIPS, millions of instructions per second. The 1401 would be measured in KIPS, thousands of instructions per second. And not very many KIPS at that.

Questions about memory and the CPU?

## 1401 TECHNOLOGY - TAPES

The 729 tape drives are important parts of this exhibit, and they actually took the most work to restore.

I'm going to invite you up here to look closely at this. Please don't

stick your fingers into anything because you could get a shock or a pinch.

Remove tape from unloaded #1 drive.

Gather around and have a look at the tape path...

The 729 starts and stops the tape very fast and very precisely using these capstan rollers. The rubber on these, and the bearings that they turn on, had all decayed. The whole tape-movement mechanism in each drive was rebuilt by our volunteers. They had to locate new rollers of just the right elasticity, and find ball bearings of the right dimensions, which was a challenge.

After the rebuild there are a lot of painstaking adjustments to make. This are all standard IBM maintenance procedures but we were fortunate to have volunteers who used to maintain tape drives back in the day and know how to perform these procedures.

Open a side panel so the interior can be seen.

The 729 has a total of ?? different electric motors in it. They were all OK and didn't need rebuilding.

Down at the bottom there is a card cage with ?? SMS cards for logic and communicating to the CPU.

Now if you all just step back behind the railing again...

Close side panel, mount tape reel and punch Load.

Inside the drive is an air pump like a vacuum cleaner. When it loads the tape, the drive actually sucks a loop of tape down into each of these columns.

Those loops of tape act as a buffer, so the capstan motor can yank a short length of the tape back and forth very quickly over the read head, while the reel motors, with these heavy tape reels on them, can

accelerate more slowly.

Questions about the tape drives?

## 1401 TECHNOLOGY - PRINTER

There's not a lot more to say about the 1403 printer. The chain rotates by the paper at 90 inches per second. It can print up to 10 lines per second. It can move paper at 75 inches per second.

This basic design was used for at least 20 years before it was finally superseded by large laser printers.

The 1403 has a lot of hydraulic parts that run on oil, and it sometimes leaks a bit. It seems to be the most reliable piece of gear in the room. It was the first piece of this collection to run, and almost never gives any trouble. Maybe the oil all over it protects it!

Questions about the printer?

## 1401 TECHNOLOGY - READER/PUNCH

The 1402 reader/punch is a huge Rube Goldberg mess of motors, shafts, belts, cams, and bearings. It takes a lot of machinery to move 800 punch cards per minute through the read station.

Under the covers it is very crowded, because this box also contains the power supply for the CPU.

As a punch, the 1402 can punch up to 250 cards per minute. Punching was most often used to output program decks. At the end of a compile, the object deck is punched so you can load it later.

Restoration of the 1402 was not too difficult but it needs a lot of maintenance to keep it working.

Questions about the card reader/punch?

Or any other questions?

Well, I hope you enjoyed this visit
to the technology of the sixties!