

# IBM 1401 CHM Restoration Project Status

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## Overall Status:

The 1401 system (and unit-record-equipment) restoration volunteers have worked for ~10,000 hours (307 sessions, 1,888 person-sessions) since the start of the project in April, 2004. The 1401 CPU itself has been powered up for 1,681 elapse hours. Programs have been successfully run both in the simulator (ROPE) and on the system, including the demo program BIG PRINT, numerical calculations, diagnostics and even some 40-year dusty decks.

The project's key restoration objective—defined by an operational 1401 CPU, 1402 reader/punch, 1403 printer, 1406 extended memory, one 729 tape drive and several 026 card punches operational—has been achieved. All units have been restored to an operational state; however we still see some of the units needing adjustment or failing about once a month (e.g., the 1402 card reader and the 729 tape drive). Nevertheless, we are ready to begin training docents for demo'ing of the system to Museum visitors (although it may not be sufficiently reliable enough to do so regularly without significant technical assistance).

The plan going forward is to deemphasize some 729 restoration activities until the "Connecticut 1401" system is in house, now projected to be in the May time frame. Although the current 1401 will be operational and available for training and demos, if the CT 1401 comes up smoothly (as expected) and its model II 729s are in good shape, restoration efforts will likely shift to the CT 1401.

With acquisition of the CT 1401 system, we will also (finally) have a complete duplicate set of components and SMS cards for the *entire* system, including the 729s, TAU, and 1402. For the CT 1401 acquisition report and rationale see:

<http://www.ed-thelen.org/1401Project/Connecticut1401ProposalV2-.pdf>

## 1401 CPU:

The 1401 CPU has been operational for about two months without any new failures! All of its 34 instructions are fully operational, based on execution of many of the standard diagnostic decks. The CPU front panel, CPU diagnostic switches, and TAU diagnostic switches are all operational (except for "Full Storage Print").

Outstanding CPU issues:

- Occasionally the inter-unit power chain trips off due to an unknown cause. Also one of the CPU's 12V supplies is overloaded and thus occasionally trips off.
- There are undoubtedly still many slow edge transitions and marginal transistors, diodes, etc that will probably exhibit faults at unpredictable moments.

There are no plans to perform a CPU voltage margin test, given the large expected number of failures that would be maddeningly hard to locate. (Note that the CT 1401 still has its margin power supply.)

Elapsed time meter:  $70,441 - 68,730 = 1,681$  power-on hours since 1401 arrived March, 2004.

### **SMS Cards:**

It's been slow going finding faulty and marginal SMS cards via system level "bug shooting", especially since some of the faults are temperature dependent. Out of the total of ~3,000 SMS cards (~223 types) in the entire system, 117 have been found defective to date. Many have been repaired. This corresponds to an annual failure rate of ~1/8 % per year since the system was last operated 31 years ago in 1977.

Most of the SMS cards still need to be cleaned of dust, dirt and grime, as it increases thermal resistance and is a substrate for moisture condensation. (A few card gates did have their cards vacuumed and connector edges wiped.)

To help us to decide whether to employ particular corrosion inhibitor/lubricants on the SMS card edges, we surveyed the connector corrosion literature and enlisted the help of IBM Poughkeepsie's Materials and Process Engineering group to analyze the SMS edge connector metallurgy and to recommend a corrosion control approach. Their X-ray fluorescence analysis revealed that the SMS edge connectors comprise a very-robust Au-Ni-Cu metal stack-up with 100 microinches of Au that shows no signs of porosity or surface wear. Given the very thick (unheard of in today's connectors) Au layer, their recommended approach to corrosion control is to only clean the connector surfaces with isopropyl alcohol. Full report:

[http://www.ed-thelen.org/1401Project/SMS\\_Tabs\\_IBM\\_Report\\_Dec2007.pdf](http://www.ed-thelen.org/1401Project/SMS_Tabs_IBM_Report_Dec2007.pdf)

The team has found that SMS card failures have been caused by:

- Broken component leads due to corrosion (of their iron content);
- Faulty Germanium transistors and diodes due to moisture infiltration due to cracked and corroded (iron) TO-5 cans & glass enclosures. Moisture infiltration, to which Ge transistors are very susceptible, results in leaky junctions, weak beta's, "loopy" IV curves--possibly due to base "pinching/heating", and shifted avalanche breakdown voltages causing latch up; and

- Failed inductors, marginal resistors, broken board traces, and open fuses.

The power supplies, inter- and intra-unit cabling and wire-wrap backplanes have generally been free of trouble!

Assuming we've exercised all of the SMS cards, the cumulative, total card failure rate is about  $117 / 3000 = 3.9\%$ , which corresponds to an annual, constant SMS failure rate of  $0.128\%$  per year since the 1401 was last operational, 31 years ago in 1977. (Annual failure rate calculation is " $1 - (1 - 0.039)^{(1/31)}$ ")

There is a detailed proposal for the design a stand alone SMS card tester that would stimulate input terminals with a variety of different waveforms and measure output terminal current, voltage, and time characteristics, margin high/low supplies, and margin high/low temperature, etc. Such a tester would be very useful as it's impossible to know for certain how many (and which) cards operate "on the edge".

#### **1402 Card Reader/Punch:**

The 1402 card reader and punch units are fully operational! However, the reader has been temperamental about once a month, requiring adjustments and fine tuning. (We're expecting the CT 1402 to be more reliable with its optical timing mechanism.)

#### **1403 Printer:**

The 1403 line printer is fully operational and has been rock solid for four years!

#### **729 Tape (2 model II, 1 model IV, 2 model V):**

Through Alan Palmer and the tape team's efforts, a single Model V unit and the TAU are now fully operational, including record backspacing!

Beginning with the second Model V, the four remaining 729 units are partially through reinstallation of their rebuilt drive motors, magnetic clutches, capstans, rewind motors, and prolays. (Thanks to Grant Saviers for his mechanical mastery and expansive shop).

Grant built a remarkable test fixture in his shop which, while the capstan motors were powered/turning, he diamond milled true to their mounted center of rotation, removing the capstans' 3-4 mil deep tape groove marks and other imperfections. Also, several rubber stop capstans were successfully reformed by Lynn Liebschutz at HDS.

Other pending 729 mechanical work includes new carbon clutch contact brushes, additional reformed rubber stop capstans, and flex coupling for rewind motors. However, except for the second model V, most of these activities are now on hold until the CT 729s arrive and are evaluated.

## **TAU Analyzer/729 Emulator:**

As spearheaded by Bob Feretich, a full-custom "TAU Analyzer/729 Emulator" hardware/software unit has been built and is being debugged. The TAU/Emulator comprises a PIC-based control unit, USB interface, a tape channel analog interface (incl a ribbon cable with modified 1401 tape biscuit connector), and real-time control software running under Windows(!), made possible by a custom kernel driver.

So far, the TAU/Emulator has demonstrated that it can:

- Properly run Ron's Write-Backspace-Read diagnostic test programs.
- Write records from the 1401 to a PC hard drive. (Files are stored in BCD SIMH format).
- Read records passing them from the PC to the 1401.
- Perform Backspace and Rewind operations.

When the TAU/Emulator is fully operational, we should be able to:

- Punch card decks to the 1402 from a PC
- Copy card decks from the 1402 to PC disk files.
- Boot a program from a PC via the 1401 Console's "Tape Load" function.
- Run 1401 programs that require tape drives to function, like the Fortran compiler. (The Tape Drive Emulator should be able to emulate 1 to 6 drives and share the tape channel with real tape drives.)
- Copy 7-tracks tapes to PC files.
- Copy PC files to 7-track tapes.

The following tasks remain for the TAU/Emulator team:

- Bring-up the BCD SIMH to/from ASCII converters.
- Complete and debug the GUI controls for the emulator.
- Fix a buffer overflow issue in the firmware.
- Test the Autocoder assembler's loadable tape generation feature.
- Prepare some 1401 utilities: Card to Tape(PC), Tape(PC) to Punch, and Tape(PC) to Printer - modified versions of the 53xx diagnostic to use moves instead of loads and to boot from the PC.

## **026 Printing Card Punch:**

There are now four, fully functional 026 punch units! These punches are used by the team and will be used by visitors as part of the sessions.

## **077 Collator:**

The 077 Collator is fully operational (except for nine comparator positions due to faulty relays which will not be repaired.) The machine now has plastic covers so its multitude of gears and shafts can be viewed while operating.

### **083 Sorter:**

The German 083 Sorter was swapped with the one donated by Wermer in Oregon last year. It is great shape and is fully operational and used in demos!

### **513 Summary Punch Reproducer:**

The 513 Reproducing Punch was entirely restored and is now fully operational! The team has used it regularly to reproduce diagnostic and other card decks. It was a heroic and successful effort by Bob Erickson and Judith Haemmerle to restore its (originally thought to be beyond repair) punches and interposers.

### **AC Power Converter:**

The 18-kVA Pacific Power static power converter suffered an "incident" due to our mis-wiring of the 1401's AC return line: unintentional, unbalanced return current (due to a new 729 load) smoked/damaged a connector and trace on the main control board. (The converter changes the building's 60-Hz "delta" 208 VAC to the system's 50-Hz "Y" 380 VAC line-to-line.)

### **Simulator (ROPE):**

Ron Mak developed and maintains ROPE/1401, a fully operational 1401 integrated development environment (IDE) that runs under Windows and Linux. ROPE is a Java-based graphical user interface that incorporates Van Snyder's Autocoder assembler (written in FORTRAN) and Bob Supnik's SIMH 1401 simulator (in C).

ROPE is can be used to edit and assemble a 1401 Autocoder program. One then runs the program with debugging controls that include single and auto stepping, breakpoints (set by clicking on a statement), execution flow monitoring, and live console and memory displays. ROPE's simulated console has working sense switches and it displays simulated line printer output in a window. ROPE was enhanced during the past year to support runtime I/O with a simulated card reader/punch and simulated tape drives.

You can download the latest version 0.5 of ROPE from:

[www.apropos-logic.com/ROPE1401v05.zip](http://www.apropos-logic.com/ROPE1401v05.zip)  
which includes some installation and operating instructions.

You must have the Java Runtime Environment (JRE) installed, which you can download from:

<http://java.sun.com/>

You can view screen shots of ROPE in action at:

<http://ed-thelen.org/1401Project/SimulatorStatus.html#ROPE>

### **PC-2-Keypunch:**

There is now a much better way to get object decks into the 1401 via Stan Paddock's new, fully operational, USB-based "PC-2-KeyPunch" punch interface, which punches card images on a modified 026 card punch, details here:

<http://ed-thelen.org/1401Project/SimulatorStatus.html#Punching>

(When the TAU Analyzer/729 Simulator is working, we'll be able to upload binaries directly from ROPE.)

### **Software Activities (and PC-2-Keypunch):**

Van Snyder, 1401 programmer exemplar, had analyzed and modified the 1401 tape diagnostic 5300 so that it can write the following arbitrary (diagnostic) cards onto an executable diagnostic tape. This will allow us to easily run the diagnostic decks without having to rely on the card reader. Van has also manually keyed in the Autocoder source listing (while writing a disassembler and cross assembler to verify binaries), and reverse engineered and verified many of the 1401 diagnostic decks, a 1401 FORTRAN "II" compiler, the SORT7 source tape, an exerciser/demo deck from HzG's 1401, and two dump programs. Waiting for reverse engineering is SSPS and key-in/assembly an original Fortran source listing from Gary Mokotoff.

Ed Thelen and Dan McInnis have written, debugged and run several programs, including computing pi to 2000 digits (8K) and the demo program BIG PRINT for printing visitor's card-punched name and stock 1401 history/info as a demo takeaway. Chris Reid brought in a 40-year old Autocoder program and ran it! Ron Williams has written many short diagnostic test programs, including a powers-of-2 table printout (actually power of 2 to 9) and several 729 tape test routines.

### **1401 System Background:**

The "German 1401" was built May 1964 and operated 24/7 by Volkswohl Versicherung ("People's Welfare"), an insurance company in Dortmund, Germany until 1972. Its IBM Customer Engineer (CE), Arnold Schweinberg, procured the 1401 and formed his own accounting services company catering to small businesses such as newspaper and magazine publishers. Arnold operated the system in two 8-hour shifts until 1977, when it was retired to a shipping company warehouse for 11 years. In 1988 it was moved to his automobile garage in the hamlet of Hamm, Germany where it remained for 16 years. It first came to our attention when Arnold listed it on Deutsche eBay in 2003. After acquisition by donated funds, it was crated and shipped (for 8,580 Euros, paid by IBM Almaden Research), via a shipping container, arriving on March 18, 2004.

### **1401 Restoration Objectives:**

The goal of the restoration project is to bring the entire 1401 system and peripherals up to full and normal operation and to reliably present live demonstrations and even possibly offer programming and instructional classes. The intention is to also run other card/unit record handling equipment, including several 026's for visitors to submit data during demo sessions and to operate the 077 collator and 083 sorter.

After restoration, we expect the system to be operated several times a week, for as long as an active and involved team of volunteers is willing and able to maintain and keep it running. The goal is to continue to recruit "younger" people to the team. There is a written plan to offer public hands-on demonstrations and programming classes.

About 5 - 12 retired IBM customer engineers (CEs) and volunteers regularly attend restoration work sessions every Wednesday. In the past, there was also a Thursday tape tea session and occasionally there are Saturday work sessions.