

The Hercules System/370, ESA/390, and z/Architecture Systems Emulator

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Agenda

- Introduction
- Capabilities
- Device emulations
- OS compatibility
- Performance
- Installation and configuration
- Operation
- Where to get more information

Introduction

- What is Hercules?
 - Emulates S/370, ESA/390, or z/Architecture CPU and peripherals
 - Runs under Linux, Windows 98/NT/2000/XP, BSD, Mac OS X
 - Portable to different host architectures and Unix-style operating systems
 - Hardware emulation only
 - Freely available
 - OSI Certified Open Source Software
 - Active user community

Hercules emulates the hardware of an IBM mainframe system. It doesn't provide any software services at all, any more than the bare iron does. You have to run some sort of OS on it.

One strength of Hercules is its user base. There are over 5400 members of the Hercules mailing list, and a large number of them are involved in running, fixing, and enhancing the package, and in getting OSes, old and new, running properly on it.

A lot of work has gone into portability. There are no intentional assumptions made about the host processor, and operating system-dependent features are automatically selected during the build process.

Hercules is OSI Certified Open Source Software. The QPL, the license under which Hercules is distributed, is accepted by the Open Source Initiative as an Open Source Definition compliant license. Since they own the trademark, they get to define what is and is not Open Source.

Capabilities

- Today
 - Will run nearly all software written for S/370, ESA/390, and z/Architecture
 - Very few programs are known to not run when required facilities are present
 - Most architectural features that make sense for a single system supported
 - Minor bugs in the corners of the spec remain

The biggest missing architecture features are the ones that aren't documented in the POO and the like in sufficient detail to implement. Some aren't likely to be implemented; others will be if they can be reverse-engineered. A complete list of features implemented and not is in the Hercules FAQ.

Capabilities

- Goal
 - Complete compatibility
 - Limited only by documentation and IP restrictions
 - Priorities
 - > Correct execution
 - > Portability
 - > Performance

The goal is simple: make Hercules conform to the POO definition of a compatible architecture. If it works differently on Hercules from the real iron, we consider that a bug to be fixed.

Performance is definitely a lower priority than correct execution: getting a wrong answer fast is still getting a wrong answer. Performance will also not be gained at the expense of portability.

Device emulations

- DASD
- Tape
- Card reader/punch
- Line printer
- CTCA/LCS
- Terminal
- BSC communications line

Other devices can be implemented, but some (like, say, the 3705) would require a large amount of work, and provide relatively little gain. Others (like the sysplex timer) would be quite a bit of help to users, but aren't documented well enough to emulate properly. Some of this is changing as IBM releases open-source Linux drivers for the latest hardware. I expect the OSA network interfaces to be added fairly quickly.

Device emulations: DASD

- Emulated via image on disk
- CKD, FBA supported
- Classical CKD devices from 2305 to 3390-54
- All known FBA devices
- Regular CKD and FBA files compatible with P/390
- Device files can be compressed, with improved performance and shadowing capability
- Compressed files can reside on read-only media

Regular CKD and FBA devices take up as much disk space as the actual device has; an emulated 3350 will take up 300 MB, for example.

Compressed devices can take up much less, and the actual space used depends not only on how well the data compresses, but also how much space is actually in use. Empty tracks take up no space at all. The smaller space used also means less real I/O needs to be done.

Compressed DASD, especially compressed FBA, is comparatively recent, and there may still be some deeply hidden lurking bugs. I recommend keeping good volume backups if you use it. The shadow file facility is also a great help here.

We believe that every DASD model since the 2305 is present. If not, let us know. The 2305 is a recent addition, and probably doesn't work quite right yet.

Device emulations: card reader/punch

- Card reader
 - ASCII and EBCDIC/binary input files supported
 - Translation automatically enabled if needed
 - Can IPL binary decks
 - Emulates 1442, 2501, or 3505
- Card punch
 - Emulated via output file on disk
 - Can punch with or without translation to ASCII
 - Emulates 3525

Reader file records don't have to be 80 characters long; they'll be padded if necessary, and an option is provided to truncate long lines if present. Multiple files can be sent to the reader either as separate decks or concatenated into one.

Device emulations: line printer

- Emulated via output file on disk or Unix pipe
- Fixed carriage control (3211 FCB support coming)
- Emulates 1403, 3203/3211

3211 FCB support has been “coming” for five years... hopefully, will happen soon.

Device emulations: CTCA/LCS

- Emulated via Linux device or TCP port
- Design allows flexibility in actual facility
- TUN/TAP device support for IP connections under Linux
- WinPCAP driver for IP under Windows 98/2000/XP
- Tunnel driver supplied for Mac OS X (CTC only)
- CTCA-to-CTCA to another Hercules system
- CTCA emulates 3088, more or less
- LCS emulates 8232, 2216, or 3172 running Internet Communications Program

TUN/TAP is a facility provided in the 2.4 and higher series of Linux kernels to allow software to tap directly into the network, below the IP stack.

Networking on OS X requires Matthias Nissler’s tunnel driver. This works well on OS X 10.3, and the beta version of the driver works almost as well on 10.4. This isn’t Hercules’s fault, but rather bugs in the driver.

The 3088 emulation is now mostly complete, but there are still a few holes, mainly due to a lack of documentation. (Heard that before?) It is, however, highly dependent on transporting TCP/IP, so you can’t use it for JES3 global/local links or the like.

Under Windows 98, 2000, and XP, David “Fish” Trout has developed a driver to provide CTC networking. This driver is still in development, but the Hercules part of it is complete.

CTCA connections to another Hercules system use simple TCP sockets, and work in all environments.

Device emulations: terminal

- 3270, 3287
 - Local, non-SNA controllers
 - Emulates 3174-1L
 - Supports capabilities of client program
 - Emulated via tn3270 session
 - Recommended clients
 - > x3270 on Linux
 - > Vista tn3270 on Windows
 - > Brown University tn3270 on OS X (with a minor setting change)
 - > 3174 with Config Support C release 6 and LAN adapter

The actual 3270 emulation provided is limited by the client's capabilities, not Hercules itself. The TN3270 protocol places almost all of the responsibility for interpreting the datastream on the client.

Hercules does not do TN3270E, though this support should be straightforward to add.

The most compatible clients for Hercules are x3270 on Linux, and Tom Brennan's Vista tn3270 on Windows.

Yes, I've used a 3174-61R with Token Ring adapter and Config C r6 as an MVS console. Neat, in a geeky sort of way.

Brown University tn3270, the only one I know of for OS X, has a problem with MVS 3.8J's network solicitor. A setting that enables nonstandard null handling must be turned off. It works fine for everything else I've tried.

Terminal emulation



Device emulations: terminal, continued

- 1052/3215
 - Local console only
 - Emulates 1052 or 3215 console
 - Emulated via regular telnet session

Line-mode terminals, except for local processor consoles, aren't supported because it would require going through the hoops to emulate a 37x5, a major undertaking for a small gain. It might be possible to add line-mode terminal emulation to the 2703 driver, but nobody's tried yet.

Device emulations: BSC line

- 2703 communications adapter
 - Emulated via TCP connection
 - No existing standard, so only communicates with Hercules
 - Implemented by sending entire BSC datastream over the TCP connection
 - Intended mainly for VM RSCS

This is a perfect example of open source at its finest: One developer wanted to get RSCS working, and didn't let a little thing like the absence of a communications adapter emulation stop him.

Nobody's tested this code with anything but RSCS...yet.

OS compatibility

- Public domain OSes
 - OS/360
 - MVS 3.8J
 - VM/370 release 6
 - DOS/VS release 34
 - TSS/370 release 3
- Linux
 - Both 32- and 64-bit
 - Used for kernel development
 - > "BTW grab a copy of Hercules and you can test it at home. It's a very good S/390 and z/Series (S/390 64bit) emulator.." — Linux kernel developer Alan Cox

Hercules is in use for development of Linux/390 and Linux for the z/Series, since it allows developers to participate in work on those systems without access to an actual mainframe.

OS compatibility, continued

- No formal IBM testing
- User reported successes
 - z/OS 1.1 through 1.7, in 31- and 64-bit mode
 - OS/390: from 1.2 through 2.10
 - VM: ESA 2.2, 2.4, 1.1.0 (370 Feature); SP: r5, r6
 - z/VM: 4.1, 4.4, 5.1, 5.2
 - VSE: ESA 1.3.2, 2.2.0 through 2.4.0; AF 3.2

Hercules has not been certified officially as a plug-compatible system, mainly because that takes real money. Because of that, we can't officially claim that newer stuff will run.

That said, users have reported running these OSes with Hercules.

Licensing

- Hercules is NOT intended to be used to pirate IBM software!
- Configuration file parameter required to run ESA and z/Architecture program product OSes
- If you specify PGMPRDOS LICENSED, you accept responsibility for compliance

Hercules acts as an IFL (Integrated Facility for Linux) processor by default. The user can override this and make it appear as a regular CPU by specifying `PGMPRDOS LICENSED` in the config file. This will produce a warning message at Hercules startup:

```
HHCCF039W PGMPRDOS LICENSED specified.  
Licensed program product operating systems are enabled.  
You are responsible for meeting all conditions of your  
software license.
```

This means you! The developers of Hercules are not responsible if you choose to violate the terms of any software license you may be subject to.

If you try to IPL OS/390 from 2.6 on, or z/OS, you'll get a wait state A7A with reason code 7 if you don't have that parameter specified. Some versions of VM/ESA will enter a 9030 wait state; others will run, but only allow Linux guests.

Performance

- Depends on host system
- Will make effective use of multiple host CPUs
 - Emulate multiple CPUs
 - Overlap I/O and CPU activity
- Host RAID subsystem will dramatically improve I/O performance

The biggest boost in Hercules performance comes from using a multiprocessor host system. Hercules overlaps I/O and CPU by using separate threads of execution for I/O and CPU activity. These threads are dispatched on any available CPU in an SMP host.

The next biggest boost comes from speeding up disk I/O. As with real hosts, the system spends a lot of time waiting on I/O, especially when one emulated I/O can take several real ones. Hardware RAID can overlap those I/Os, and caching can save I/Os entirely – a real win, just as with a mainframe.

Building a real box

- Goal: Best Hercules performance as a dedicated engine without breaking the bank
- Dual Opteron (AMD64) motherboard (ASUS K8N-DL)
- Two Opteron 244 CPUs (1.8 GHz)
- 2 GB real memory (two 1 GB PC3200 DIMMs)
- 250 GB serial ATA drive (Western Digital)
- Server case, 550w power supply (Antec Titan 550)
- Cheap video card, IDE DVD-RW, floppy
- Total price: \$1450
- Gentoo Linux, bare bones install (no X)
- 133 MIPS in tight BCTR loop, 55 MIPS peak, 30 MIPS sustained with I/O in 64-bit mode

Installation

- Windows, Linux, or something else?
 - Some features not supported under some OSes
 - > SCSI tape (Linux and Windows only)
 - > LCS (Linux and Windows only)
 - Cygwin libraries no longer needed for Windows
 - Most development done first on Linux
 - GUI available on Windows
 - Mac OS X is just plain cooler!
- What else is that computer used for?

Hercules was originally designed to make use of as much of the host system as it could. It shares its host fairly well, but it's happiest if it has a system all to itself. For best performance and ease of use, it may well be worth it to spend a few hundred bucks on a host to dedicate to it, especially if you're looking to run an older OS, where a very modest host will provide entirely acceptable performance. New 2+ GHz Pentium 4/Athlon XP-class systems can be had for well under \$500, and will outrun anything short of a medium-sized 3090 as long as the I/O load isn't too high. Running Linux on an AMD 64-bit system is an even bigger win.

With the advent of the native Windows version in 3.03, Cygwin is no longer needed. This saves a LOT of headaches.

If you run Hercules on Windows, I highly recommend checking out Fish's Hercules Page, where you can get his GUI for Windows, along with other useful utilities and mods. The URL is on the last page.

Can you tell I've got the Mac religion?

Installation

- Source tarball, RPM file, or Debian package for Linux
- Self-extracting installer for Windows
- Part of the FreeBSD and Gentoo ports collection
- Native installer package for Mac OS X
- Basic installation
 - Build package from source (if desired)
 - Install package
 - Create configuration file
 - Create DASD image files
 - IPL system

The host system architecture is detected automatically by the `autoconf` configuration system.

To compile on Linux: explode the source tarball with

```
tar xzvf hercules-version.tar.gz
```

and then

```
cd hercules-version
./configure
make
```

To install the compiled version: as the `root` user,

```
make install
```

To install a packaged RPM:

```
rpm -Uvh hercules-version.architecture.rpm
```

where `version` is the version of Hercules, and `architecture` is the host system's CPU architecture (`i686` for Intel systems).

On Debian:

```
apt-get install hercules
```

On Gentoo:

```
emerge hercules
```

Versions

- Ongoing development is done collaboratively
- Periodic snapshots
- Bleeding edge available via CVS
- Version numbering:
 - Major releases: `version/release` (3.03)
 - Maintenance releases: `version.release.modlevel` (3.03.1)
 - Development releases: `ver.releaseletter.modlevel` (3.03a.1)

The Hercules development team uses the Concurrent Version System (CVS) to manage its source tree. It allows many developers spread out all over the world to share one view of the source, and to update that view in a consistent manner.

Anyone can get a copy of the current source tree via CVS. See <http://www.cvshome.org> for full details on CVS. The CVSROOT for the Hercules tree is:

```
:pserver:anonymous@cvs.hercules-390.org:/usr/cvs/hercules
```

Note that there is no connection between maintenance releases and development snapshots. Version 3.03.1 and 3.03a.1 are not connected at all except that they're both based on 3.03.

If you're going to compile from CVS, you should run the `util/cvslvck` program the first time to make sure that the required levels of several necessary utilities are installed on your system.

Configuration

- Text configuration file
 - Analogous to IOCDs
 - Specifies system options and devices
 - Selected at Hercules startup by command-line option

Hercules is started by:

```
hercules -f config-file
```

You can have multiple configurations available by having more than one configuration file, but a single copy of Hercules can only use one configuration file. You can dynamically add and delete devices during execution, but some system-wide configuration parameters can only be changed by stopping and restarting Hercules.

A sample configuration file is at the beginning of the Hercules Configuration File web page, and installed with Hercules.

Configuration: system options

- Specify behavior of entire processor
- Provide parameters for emulation facilities
- Most can be changed by control panel commands

A more detailed discussion of the system parameters is in the appendix at the end of this handout.

Configuration: device entries

- Device entries follow system options
- One per device
- Specified as address, device type, device parms
- Parms specify filename and options

Devices can be specified in any order. I recommend putting card readers and tape drives first, then the IPL disk, then any other devices, as this makes controlling them easier in the graphical control panel.

Building DASD images

- Three utilities: dasdinit, dasdload, and CCKDCDSK
- dasdinit makes empty volumes
 - Creates volume label
 - Initialize and load with normal IBM utilities
- dasdload builds volumes with data
 - Builds VTOC, EREP datasets, minimal OS CVOL
 - Creates empty datasets
 - Loads PDSes created with TSO XMIT
 - Optionally writes IPL text

When creating a volume with dasdinit, include alternate tracks for any volume to be formatted with `ICKDSF` or `IBCDASDI`. These programs will seek to the alternate cylinders even if they don't intend to write there, just to make sure they're accessible. If you specify the `-a` option, the alternate cylinders will be included automatically.

Building DASD images, continued

- CCKDCDSK makes CCKD image files
 - Copies existing DASD volumes
 - Creates image file for download
 - Runs on MVS-style OSes
 - Also on CBT tape file 541

Unlike the other utilities, `CCKDCDSK` runs on MVS. It reads a DASD volume and creates a CCKD image file, which you can transfer to your PC (via binary FTP or something similar) and point Hercules at directly.

`CCKDCDSK` is provided as a TSO `TRANSMIT` file. Upload it directly, again via binary FTP or the like, and then use TSO's `RECEIVE INDATASET()` command to place the contents in a PDS.

The `CCKDCDSK` program must be installed in an APF-authorized library.

Building tape images

- AWSUTIL
 - CBT tape file 477
 - Creates AWSTAPE image with RECFM=VB
- RAWSTAPE
 - CBT tape file 478
 - Converts AWSTAPE files to RECFM=U sequential dataset
- VTT2TAPE, VTT2DISK, VTT2CNVU
 - CBT tape file 533
 - AWSTAPE images in RECFM=F/80 format

Brandon Hill's `AWSUTIL` was the first widely available program to deal with AWSTAPE images on MVS. It reads a real tape and creates an AWSTAPE image file.

Jan Jaeger's `RAWSTAPE` is intended to go the other direction: from an AWSTAPE image to a real tape. You can also write to DASD if you like.

Sam Golob's VTT utilities are part of a larger Virtual Tape Transportation System. These are the utilities he uses when working on the CBT tape software collection.

Which set of utilities to use is largely a matter of taste.

Operation

- Four control panels
 - Built in: graphical and command-line
 - Windows GUI
 - Web server
- Most commands available in all
- Usual operator facilities available: IPL, start, stop, interrupt, restart
- Device controls: attach/detach, interrupt, initialize
- Debugging: breakpoint, single-step, trace, register and memory alter/display
- HMC console commands and messages

“Graphical” is a bit of a misnomer; it’s not really graphical, just laid out on one screen in an easy-to-use manner.

Device initialization is also used to mount tapes and card decks on emulated devices during operation.

When devices are added to the configuration via attach, or removed via detach, the OS is notified as well; OS/390 will respond with the

```
IOS150I  DEVICE nnnn  NOW AVAILABLE FOR USE
```

message, just as it does on the real iron.

Information on the web

- Hercules home page:
<http://www.hercules-390.org>
 - Installation and operation documentation
 - Downloads
- Hercules on Windows:
<http://www.bsp-gmbh.com/hercules>
- CBT CD-ROM Collection:
<http://www.cbttape.org>
- Fish’s Hercules Page: <http://www.softdevlabs.com/Hercules/hercgui-index.html> (new URL)

Mailing lists

- Hercules general mailing list:
hercules-390
- OS-specific mailing lists:
 - MVS: H390-MVS
 - Volker Bandke's Turnkey MVS: turnkey-mvs
 - VM: H390-VM
 - DOS/VS: H390-DOS
 - VS/1: H390-VS1
 - OS/360: hercules-os360
- Arguments and advocacy: hercules-advocacy
- All at <http://groups.yahoo.com/group/<name>>

Whenever Google gets the Google Groups 2 service out of beta, these mailing lists will move there. The move will be announced well in advance.

Appendix: system options

- CPUSERIAL, CPUMODEL, CPUVERID
 - Set values returned by STIDP instruction
- MAINSIZE, XPNDSIZE
 - Allocate main and expanded storage
- CNSLPORT
 - Sets the TCP port terminal sessions connect to
- NUMCPU, NUMVEC
 - Number of CPUs, vector facilities online at IPL

The `CPUSERIAL`, `CPUMODEL`, and `CPUVERID` parameters don't change anything in the emulator's behavior beyond the results of the `STIDP` (Store CPU ID) instruction; in particular, no attempt is made to implement any model's specific behavior.

`MAINSIZE` and `XPNDSIZE` allocate that much memory at Hercules startup and hold it as long as Hercules is up. Don't allocate more than your machine's physical RAM and swap space, and if possible don't allocate more than physical RAM for best performance. If you have to page, let Linux or Windows do the paging so page I/Os don't have to be emulated. `XPNDSIZE` is only valid if `ARCHMODE ESA/390` or `ARCHMODE ESAME` is specified.

The same TCP port is used for both 3215 and 3270 connections. Connecting with a regular telnet client will connect to a 3215 device, and connecting with a `tn3270` client will connect to a 3270 device.

The total number of CPUs and vector facilities available in the configuration is set at compile time. Binary distributions from 3.03 on have this limit set to 8. `NUMCPU` and `NUMVEC` set the number online at IPL. Use the facilities of the OS (such as `CF CPU(x)`, `ON` in MVS) to bring others online as needed.

Appendix: system options, continued

- LOADPARM
 - Same as IPL parameter on ESA hosts
- OSTAILOR
 - Turns off reporting for normal program checks
 - Sets other default values
- SYSEPOCH, YROFFSET
 - Sets the year for TOD clock value of zero
- TZOFFSET
 - Adjusts clock to local time if desired

Without `OSTAILOR`, for example, VM will flood the Hercules console with messages about privileged operations exceptions, and OS/390 and Linux will do the same for other program checks. These are perfectly normal during operation for those OSes, and reporting them just wastes time and CPU cycles. `OSTAILOR` turns them off.

`SYSEPOCH` sets the TOD clock epoch. All OSes but OS/360 use a TOD clock epoch of midnight, 1 January 1900; OS/360 uses an epoch of midnight, 1 January 1960. Only values of 1900 and 1960 are recommended; other values will produce a warning message, and may produce incorrect results.

`YROFFSET` is intended to make older, non-Y2K OSes work properly by fooling the TOD clock. A value of -28 is recommended for this purpose, as this makes everything (day of the week, leap year presence, and so on) the same, changing only the year.

Before version 3.04, `SYSEPOCH` did both jobs, and so in 3.04, `SYSEPOCH 1928` and `1988` are also accepted for compatibility. We recommend you change existing configuration files to reflect the changed meaning.

Appendix: system options, continued

- PANRATE
 - Sets refresh rate for Hercules control panel
- TODDRAG
 - Slows rate of emulated clock
- ARCHMODE
 - Selects the architecture to be emulated
- CPUPRIO
 - Specifies execution priority of CPU emulation thread

PANRATE FAST will make the control panel act more like a real mainframe by updating it every 50 milliseconds instead of every 500. This will cost some CPU speed, though. You can also specify a refresh interval in milliseconds directly.

TODDRAG slows down the emulated TOD clock by the specified factor. TODDRAG 2 will make the emulated TOD clock count one minute for every two minutes of real time. This helps with OS/390 performance on slower (below PIII-500 performance) host systems. TODDRAG 1 specifies no slowdown. This parameter is deprecated, and may go away in the future. Current versions of Hercules on anything approaching modern hardware will not need it.

ARCHMODE can be one of S/370, ESA/390, z/Arch, or ESAME. ESAME was the original name for z/Architecture.

Appendix: system options, continued

- IODELAY
 - Adds small delay to I/O completion interrupt processing
 - Needed to work around Linux bug
- PGMPRDOS
 - Must be specified to run OS/390, z/OS
 - Acknowledgment of user's responsibilities
 - A7A wait state at IPL if not specified

Linux/390 and Linux for z/Series, with kernels through about version 2.4.17, cannot handle an I/O interrupt arriving immediately after the I/O is scheduled. IODELAY was added to work around this problem. A fix has been identified, but has not been added to the Linux source tree yet. IODELAY defaults to 0. If you are running an older Linux kernel, you should set this value to 800; this will produce a warning, which you can suppress by adding the parameter NOWARN.

Hercules acts as an IFL (Integrated Facility for Linux) processor by default. The user can override this and make it appear as a regular CPU by specifying PGMPRDOS LICENSED in the config file. This will produce a warning message at Hercules startup:

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Appendix: System options, continued

- HTTPPORT
 - Specifies port number for built-in HTTP server
 - Optionally specifies authentication parameters
- HTTPROOT
 - Root directory for HTTP server files
 - Default set at compile time
- SHRDPORT
 - Port number shared device server listens on

Appendix: System options, continued

- DIAG8CMD
 - Enables Hercules commands to be executed via VM-style DIAGNOSE 8
- DEVTMAX
 - Specifies maximum number of I/O device threads
- CODEPAGE
 - Specifies EBCDIC-ASCII translation code page

DIAG8CMD allows execution of any Hercules control panel command – including the `sh` command, which executes a command on the host system. Be careful when using this!

DEVTMAX defaults to 8 on Windows, and 0 on other platforms. 0 is no maximum; -1 causes a new thread to be launched for every I/O. Otherwise, the thread is kept until it has been idle for 5 minutes.

CODEPAGE defaults to the traditional Hercules code page, or may be specified as 437/037, 437/500, or 850/273.

Appendix: System options, continued

- ECPSVM
 - Enables ECPS:VM feature, sets reported level
- LDMOD
 - Specifies modules to be loaded by Hercules
 - Modules can add devices or instructions

If `ECPSVM YES` is specified, level 20 is reported. As with `CPUMODEL` and friends, changing this changes the reported level but does not change the behavior of the emulation.

`LDMOD` searches the default DLL/shared library path if just the module name is specified.