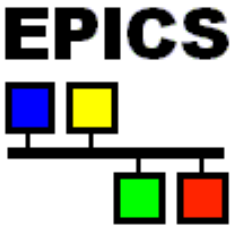
Channel Archiver Manual



March 14, 2006,
for R3.14.4 and higher

Involvements

Bob Dalesio designed the original index file, data file layout, and implemented the first prototype.
From then on, the following people have been involved at one time or another:

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No Warranty

Although the programs and procedures described in this manual are meant to be helpful instruments for archiving, maintaining and retrieving control system data, there is no warranty, either expressed or implied, including, but not limited to, fitness for a particular purpose. The entire risk as to the quality and performance of the programs and procedures is with you. Should the programs or procedures prove defective, you assume the cost of all necessary servicing, repair or correction.

In no event will anybody, including the persons listed above, be liable to you for damages, including any general, special, incidental or consequential damages arising out of the use or inability to use the programs (including but not limited to loss of data or data being rendered inaccurate or losses sustained by you or third parties or a failure of the programs to operate with any other programs).

Contents

Chapter 1

Overview

The Channel Archiver is an archiving toolset for the Experimental Physics and Industrial Control System, EPICS [?]. It can archive any value that is available via ChannelAccess (CA), the EPICS network protocol [?]. We use the term "archiver" whenever we refer to the collection of programs which allow us to take samples, place them into some storage and retrieve them again. The archiver toolset roughly splits into the following pieces:

Sampling: The ArchiveEngine collects data from a given list of ChannelAccess Channels. The details of when a sample is taken etc. can be configured: One may store every change, store changes that exceed a deadband (that is configured on the CA server) or use periodic scanning. The configuration and operation of the ArchiveEngines will obviously require some planning, as only data that was sampled and stored will be available for future retrieval and analysis. Some sensible compromise will have to be made between the urge to store all minuscule changes of all the available channels of a site on one hand and data storage constraints on the other.

Storage: The data is stored in binary index and data files. Most end users need not be concerned about the internals of those files, not even where they are located, because additional indices allow several sub-archives to appear like one, bigger, combined archive. Somebody at each site, though, will need to perform maintenance tasks: Decide where the data sets are located, how they are backed up and how users can access them.

Retrieval: The archiver toolset provides generic retrieval tools for browsing the available channels and values, including simple multi-channel comparisons. An API allows users to write more sophisticated data analysis tools.

Chapter 2

Background

2.1 What is a Channel?

The Channel Archiver deals with Channels that are served by EPICS ChannelAccess. It stores all the information available via ChannelAccess:

- Time Stamp
- Status/Severity
- Value
- Meta information:
  Units, Limits, ... for numeric channels, enumeration strings for enumerated channels.

The archiver stores the original time stamps as it receives them from ChannelAccess. It cannot check if these time stamps are valid, except that it refuses to go "back in time" because it can only append new values to the end of the data storage. It is therefore imperative to properly configure the data sources, that is: the clocks on the CA servers. For more details on the EPICS time stamps refer to section 2.6.
NOTE: If the CA server provides bad time stamps, for example stamps that are older than values which are already in the archive, or stamps that are unbelievably far ahead in the future, the ArchiveEngine will log a warning message and refuse to store the affected samples. This is a common reason for "Why is there no data in my archive?". (There is one more, hard to resolve reason for back-in-time warnings, see page ??).

As for the values themselves, the native data type of the channel as reported by ChannelAccess is stored. For those familiar with the ChannelAccess API, this means: Channels that report a native data type of DBR_xxx_ are stored as DBR_TIME_xxx after once requesting the full DBR_CTRL_xxx information. The Archiver can therefore handle scalar and array numerics (double, int, ...), strings and enumerated types.

2.2 Data Sources

Before even considering the available sampling options, it is important to understand the data sources, the ChannelAccess servers whose channels we intend to archive. In most cases we will archive channels served by an EPICS Input/Output Controller (IOC) which is configured via a collection of EPICS records. Alternatively, we can archive channels served by a custom-designed CA server that utilizes the portable CA library PCAS. In those cases, one will have to contact the implementor of the custom CA server for details. In the following, we concentrate on the IOC scenario and use the analog input record from listing 2.1 as an example.

```
record(ai, "aiExample")
{
    field(SCAN, ".1 second")
    field(ADEL, "0.1")
    field(EGU,  "Volts")
    field(PREC, "2")
    field(HOPR, "4095")
    field(LOPR, "0")
    field(HIHI, "10")
    field(HIGH, "9")
    field(LOW,  "1")
    field(LOLO, "0")
    field(HHSV, "MAJOR")
    field(HSV,  "MINOR")
}
```

Listing 2.1: “aiExample” record

What happens when we try to archive the channel “aiExample”? We will receive updates for the record’s value field (VAL). In fact we might as well have configured the archiver to use “aiExample.VAL” with exactly the same result. The record is scanned at 10 Hz, so we can expect 10 values per second. Almost: The archive deadband (ADEL) limits the values that we receive via CA to changes beyond 0.1. When archiving this channel, we could store at most 10 values per second or try to capture every change, utilizing the ADEL configuration to limit the network traffic.

NOTE: The archiver has no knowledge of the scan rate nor the deadband configuration of your data source! You have to consult the IOC database or PCAS-based code to obtain these.

With each value, the archiver stores the time stamp as well as the status and severity. For aiExample, we configured a high limit of 10 with a MAJOR severity. Consequently we will see a status/severity of HIHI/MAJOR whenever the VAL field reaches the HIHI limit. In addition to the value (VAL field), the archiver

also stores certain pieces of meta information. For numeric channels, it will store the engineering units, suggested display precision, as well as limits for display, control, warnings, and alarms. For enumerated channels, it stores the enumeration strings. Applied to the aiExample record, the suggested display precision is read from the PREC field, the limits are derived from HOPR, LOPR, HIHI, ..., LOLO.

NOTE: You will have to consult the record reference manual or even record source code to obtain the relations between record fields and channel properties. The analog input record's EGU field for example provides the engineering units for the VAL field. We could, however, also try to archive aiExample.SCAN, that is the SCAN field of the same record. That channel aiExample.SCAN will be an *enumerated* type with possible values "Passive", ".1 second" and so on. The EGU field of the record no longer applies! Another example worth considering: While HOPR defines the upper control limit for the VAL field, what is the upper control limit if we archive the HOPR field itself?

It is also important to remember that the archiver — just like any other ChannelAccess client — does **not** know anything about the underlying EPICS record type of a channel. In fact the channel might not be based on any record at all if we use a PCAS-based server. Given the name of an analog input record, it will store the record's value, units and limits, that is: most of the essential record information. Given the name of a stepper motor record, the archiver will also store the record's value (motor position) with the units and limits of the motor position. It will not store the acceleration, maximum speed or other details that you might consider essential parts of the record. To archive those, one would have to archive them as individual channels.

2.3 Sampling Options

The ArchiveEngine supports these sampling mechanisms:

Monitor: In this mode, the ArchiveEngine requests a CA monitor, i.e. it subscribes to changes and we store all the values that the server sends out. The CA server configuration determines when values are sent.

Sampled: In this mode, the ArchiveEngine periodically requests a value from the CA server, e.g. every 30 seconds.

Sampled using monitors: This mode is very similar to the previous one: The ArchiveEngine is again configured to store periodic samples, e.g. one sample every 5 seconds. But instead of actively requesting a value from the CA server at this rate, it establishes a monitor and only saves a value every 5 seconds.

The configuration of the engine in section 3.1 describes how one selects the sampling mechanism for each channel. When selecting monitored operation, you will need to provide an estimate of how many monitors the channel emits,

so that the engine can allocate appropriate buffer space (more on this in sections 3.1.5 and 3.1.9).

The difference between the two sampled modes is subtle but important for performance reasons. Assume our data source changes at 1 Hz. If we want to store a value every 30 seconds, it is most efficient to send a 'read'-request every 30 seconds. If, on the other hand, we want to store a value every 5 seconds, it is usually more effective to establish a monitor, so we automatically receive updates about every second, and simply *ignore* 4 of the 5 values.

When configuring a channel, the user only selects either "Monitor" or "Scan" with a sampling rate. The ArchiveEngine will automatically determine which mechanism to use for sampled operation, periodic reads or monitors (see the *get_threshold* configuration parameter, section 3.1.2, for details).

NOTE: The values dumped into the data storage will not offer much indication of the sampling method. In the end, we only see values with time stamps. If for example the time stamps of the stored values change every 20 seconds, this could be the result of a monitored channel that happened to change every 20 seconds. We could also face a channel that changed at 10 Hz but was only sampled every 20 seconds.

2.4 Time Stamps

Each ChannelAccess Server provides time-stamped data. An IOC for example stamps each value when the corresponding record is processed. These time-stamps offer nano-second granularity. Most applications will not require the full accuracy, but some hardware-triggered acquisition, utilizing interrupts on a fast CPU, might in fact put the full time stamp resolution to good use.

The ChannelArchiver as a generic tool does not know about the origin of the time stamps, but it tries to conserve them. Fig. 2.1 shows the same channel, archived with different methods. When using the "Monitor" method for archiving, we capture all the changes of the channel, resulting in the data points marked by black diamonds. When we use scanned operation, e.g. every 30 seconds, the following happens: About every 30 seconds, the ArchiveEngine stores the current value of the channel *with its original time stamp!*. So while the ArchiveEngine might take a sample at

14:53:30, 14:54:00, 14:54:30, 14:55:00, ...,

it stores the time stamps that come with the values, and in the example from Fig. 2.1 those happened to be

14:53:29.091, 14:53:59.092, 14:54:29.094, 14:54:59.095, ...

2.5 Sensible Sampling

The data source configuration and sampling need to be coordinated. In fact the whole system needs to be understood. When we deal with water tank temper-

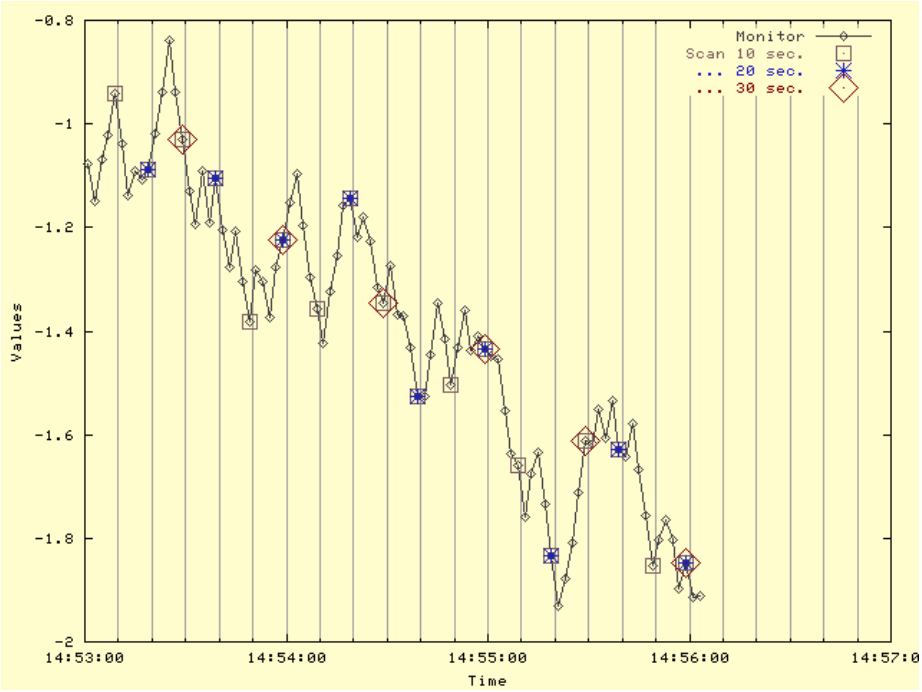

Figure 2.1: Time Stamps and Sampling

atures as one example, we have to understand that the temperature is unlikely to change rapidly. Let us assume that it only varies within 30...60 seconds. The analog input record that reads the temperature could be configured to scan every 2 seconds. Not because we expect the temperature to change that quickly but mostly to provide the operator with a warm and fuzzy feeling that we are still reading the temperature: The operator display will show minuscule variations in temperature every 2 seconds. An ArchiveEngine that is meant to capture the long-term trend of the tank temperature could then sample the value every 60 seconds.

On the other extreme could be channels for vacuum readings along linac cavities. The records that read them might be configured to scan as fast as the sensing devices permit, maybe beyond 10 Hz, so that interlocks on the IOC run as fast as possible. Their deadbands (ADEL and MDEL) on the other hand are configured to limit the data rate that is sent to monitoring CA clients: Only meaningful vacuum changes are sent out, significantly reducing the amount of data sent onto the network. The ArchiveEngine can then be configured to monitor the channel: During normal operation, when the vacuum is fairly stable, it will only receive a few values, but whenever the vacuum changes because of a leak, it will receive a detailed picture of the event.

Another example is a short-term archive that is meant to store beam po-

sition monitor (BPM) readings for every beam pulse. The records on the IOC can then be configured with ADEL=-1 and the ArchiveEngine to use monitors, resulting in a value being sent onto the network and stored in the archive even if the values did not change. The point here is to store the time stamps and beam positions for each beam pulse for later correlation. Needless to say that this can result in a lot of data if the engine is kept running unattended. The preferred mode of operation would be to run the engine only for the duration of a short experiment.

NOTE: The scanning of the data source and the ArchiveEngine run in parallel, they are not synchronized. Example: If you have a record scanned every second and want to capture every change in value, configuring the ArchiveEngine to scan every second is **not** advisable: Though both the record and the ArchiveEngine would scan every second, the two scans are not synchronized and rather unpredictable things can happen. Instead, the ”Monitor” option for the ArchiveEngine should be used for this case.

2.6 Times: EPICS, Local, Greenwhich, Daylight Saving

The EPICS base software that is used by the IOCs and also the archiver deals with time as seconds and nanoseconds since January 1, 1990. This “EPICS Time” is using Greenwhich Mean Time (GMT), also known as Universal Time Coordinates (UTC). So the EPICS Time stamp 0 stands for 01/01/1990, 00:00:00 UTC.

People living in Germany are typically in a time zone one hour east of UTC. For them, the EPICS Time stamp 0 translates into January 1, 1990, at 01:00:00 in the morning. This is one example of “Local Time”. Anybody living in the United States is of course familiar with time zone conversions ever since you tried to match what’s in the TV Guide with what’s actually on TV.

The EPICS base software includes routines for converting EPICS Time into Local Time and vice versa. Before EPICS R3.14, these routines used an environment variable EPICS_TS_MIN_WEST which needed to be set to the minutes west of UTC. “-60” for Germany in the above example. Since R3.14, this environment variable is no longer used. The time stamp conversion code in EPICS base now relies on the operating system and the C/C++ runtime library to handle any time zone issues.

It is important to remember that the data served by CA Servers is in EPICS time, that is based on UTC and *not* your local time. The ArchiveEngine stores that data as received, which is again in EPICS time based on UTC. When the network data server is asked for samples, those are also based UTC, albeit with a slight shift from a 1990 epoch to 1970, simply because this is more convenient to use in most programming languages. C, C++, Java and perl all include routines for converting 1970-epoch seconds to local time and back.

Time stamps are only converted to local time when they are displayed or

entered. The ArchiveExport program will provide you with e.g. a spreadsheet that has a “Time” column in local time. The Java Archive Client will plot the data with a time axis in local time. Whenever you specify start and end times for a data request, this is done in local time.

An example of possible consequences: Assume you live in San Francisco, California (UTC+8), and you receive a CD-ROM with archived data from the SNS in Oak Ridge, Tennessee (UTC+5). I you want to investigate what happened at noon on 01/01/2004 at the SNS, you will have to query for 09:00:00 to adjust for the different time zones.

The EPICS base code also relies on the operating system services for daylight saving time (DST). At least under RedHat Linux 9 this seems to work fine when you are inside the United States. Example: In the US, daylight saving time went into effect on 04/04/2004, 02:00:00, and I archived a ”stringin” record which had device support that converted the time stamp of the record into a string, including daylight savings information. The result looks like this when the data is exported again on the next day, that is at a time where DST is in effect:

EPICS Seconds	Time	Value
449917196	01:59:56	04/04/2004 01:59:56.805984000
449917197	01:59:57	04/04/2004 01:59:57.816036000
449917198	01:59:58	04/04/2004 01:59:58.826102000
449917199	01:59:59	04/04/2004 01:59:59.836110000
449917200	03:00:00	04/04/2004 03:00:00.846121000 (DST)
449917201	03:00:01	04/04/2004 03:00:01.856196000 (DST)
449917202	03:00:02	04/04/2004 03:00:02.867379000 (DST)
449917203	03:00:03	04/04/2004 03:00:03.876315000 (DST)
449917204	03:00:04	04/04/2004 03:00:04.886356000 (DST)

The seconds of the raw EPICS time stamp simply continue to count up though the transition because UTC is not affected by DST. (This test was run in the US Mountain time zone, UTC+7, and the nanoseconds of the EPICS time stamp are omitted.) The Value of the string record, which contains the local time as the IOC saw it, jumps from what would have been 02:00:00 to 03:00:00 DST. When the time stamp is printed (at a later time when DST applies), the “Time” column matches the times in the value string.

After changing the computer’s clock to times in January 2004 and 2005, that is to times outside of DST before and after the data in the archive, the result is the exact same: The EPICS time stamp routines use the DST settings that apply for a given time stamp, not for the current time.

Countries differ in their algorithms for switching to DST, and if your operating system does not follow the rules in your location, you might see sudden offsets in time between the wall clock and the archived data.

2.7 Time Stamp Correlation

We have stressed more than once that the Channel Archiver preserves the original time stamps as sent by the CA servers. This commonly leads to difficulties when comparing values from different channels. The following subsections investigate the issue in more detail and show several ways of manipulating the data in order to allow data reduction and cross-channel comparisons. In short, the options described in the following subsections are:

Raw Data: Provides every archived sample "as is".

Spreadsheet: Staircase interpolation/filling to form a spreadsheet.

Averaging, Linear Interpolation: Maps the raw data onto specific time stamps.

Plot Binning: Reduces the number of samples for plotting.

2.7.1 "Raw" Data

Even when two channels were served by the same IOC, and originating from records on the same scan rate, their time stamps will slightly differ because a single CPU cannot scan several channels at exactly the same time. Tab. 2.1 shows one example.

Time	A	Time	B
17:02:28.700986000	0.0718241	17:02:28.701046000	-0.086006
17:02:37.400964000	0.0543581	17:02:37.510961000	-0.111776
...		...	

Table 2.1: Example Time Stamps for two Channels A and B.

When we try to export this data in what we call raw spreadsheet format, a problem arises: Even though the two channels' time stamps are close, they do not match, resulting in a spreadsheet as shown in Tab. 2.2. Whenever one channel has a value, the other channel has none and vice versa. This spreadsheet does not yield itself to further analysis; calculations like $A - B$ will always yield '#N/A' since either A or B is undefined.

2.7.2 "Before or at" Interpretation of Start Times

When you invoke a retrieval tool with a certain start time, the archive will rarely contain a sample for that exact start time. As an example, you might ask for a start time of "07:00:00" on some date. Not because you expect to find a sample with that exact time stamp, but because you want to look at data from the beginning of that day's operations shift, which nominally began at 7am.

Time	A	B
3/22/2000 17:02:28.700986000	0.0718241	—
3/22/2000 17:02:28.701046000	—	-0.086006
3/22/2000 17:02:37.400964000	0.0543581	—
3/22/2000 17:02:37.510961000	—	-0.111776
...		

Table 2.2: Spreadsheet for raw Channels A and B.

The software underlying all retrieval tools anticipates this scenario by interpreting all start times as “before or at”. Given a start time of “07:00:00”, it returns the last sample before that start time, unless an exact match is found. So in case a sample for the exact start time exists, it will of course be returned. But if the archive contains no such sample, the previous sample is returned.

Applied to Tab. 2.2, channel A, you would get the samples shown in there not only if you asked for “17:02:28.700986000”, the exact start time, but also if you asked for “17:02:30”. It is left to the end user to decide whether that previous sample is still useful at the requested start time, if it’s “close enough”, or if it needs to be ignored.

2.7.3 Spreadsheet Generation

There are several ways of mapping channels onto matching time stamps. One is what we call Staircase Interpolation or Filling: Whenever there is no current value for a channel, we re-use the previous value. This is often perfectly acceptable because the CA server will only send updates whenever a channel changes beyond the configured deadband. So if we monitored a channel and did not receive a new value, this means that the previous value is still valid — at least within the configured deadband. In the case of scanned channels we have no idea how a channel behaved in between scans, but if we e.g. look at water temperatures, it might be safe to assume that the previous value is still “close enough”. Table 2.3 shows the previously discussed data subjected to staircase interpolation. Note that in this example there is no initial value for channel B, resulting in one empty spreadsheet cell. From then on, however, there are always values for both channels, because any missing samples are filled by repeating the previous one. Because of the interpretation of start times explained in section 2.7.2, you would get the result in Tab. 2.3 not only if you asked for values beginning “3/22/2000 17:02:28.700986000”, but also when you asked for e.g. “17:02:30”: Since neither channel A nor B have a sample for that exact time stamp, the retrieval library would select the preceding sample for each channel, resulting in the output shown in Tab. 2.3.

NOTE: While table 2.3 marks the filled values by printing them in italics, spreadsheets generated by archive retrieval tools will not accent the filled values in any way, so care must be taken: Those filled values carry artificial time stamps. If

you depend on the original time stamps in order to synchronize certain events, you must not use any form of interpolation but always retrieve the raw data.

Time	A	B
3/22/2000 17:02:28.700986000	0.0718241	—
3/22/2000 17:02:28.701046000	*0.0718241*	-0.086006
3/22/2000 17:02:37.400964000	0.0543581	*-0.086006*
3/22/2000 17:02:37.510961000	*0.0543581*	-0.111776
...		

Table 2.3: Spreadsheet for Channels A and B with Staircase Interpolation; "filled" values shown in italics.

You did of course notice that the staircase interpolation does not reduce the amount of data. Quite the opposite: In the above examples, channels A and B each had 2 values. With staircase interpolation, we don't get a spreadsheet with 2 lines of data but 4 lines of data. The main advantage of filling lies is the preservation of original time stamps.

2.7.4 Averaging, Linear Interpolation

Both averaging and linear interpolation generate artificial values from the raw data. This can be used to reduce the amount of data: For a summary of the last day, it might be sufficient to look at one value every 30 minutes, even though the archive could contain much more data. Another aspect is partly cosmetic and partly a matter of convenience: When we look at Tab. 2.3, we find rather odd looking time stamps. While these reflect the real time stamps that the ArchiveEngine received from the ChannelAccess server, it is often preferable to deal with data that has time stamps which are nicely aligned, for example every 10 seconds: 11:20:00, 11:20:10, 11:20:20, 11:20:30 and so on.
To accomplish this, the data is binned. For example, the time span of one day, 24 hours, can be divided into 2880 sections, each of which covers 30 seconds. Each of those sections is called a "Bin". The raw samples for the day are then investigated as follows:

- When we select Averaging, the average over all the samples that fall into a bin is returned. The center of the bin is used as a time stamp.
- When we select Linear Interpolation, the value of the channel at the border of each bin is determined via linear interpolation between the last sample before and the first sample after the border of the bin. The border of each bin determines the time stamp.

Fig. 2.2 compares the result of retrieving the raw data with averaging and linear interpolation over 10-second-bins. Averages are determined for the center of each bin, i.e. 08:48:35, 08:48:45, ..., while linear interpolation generates

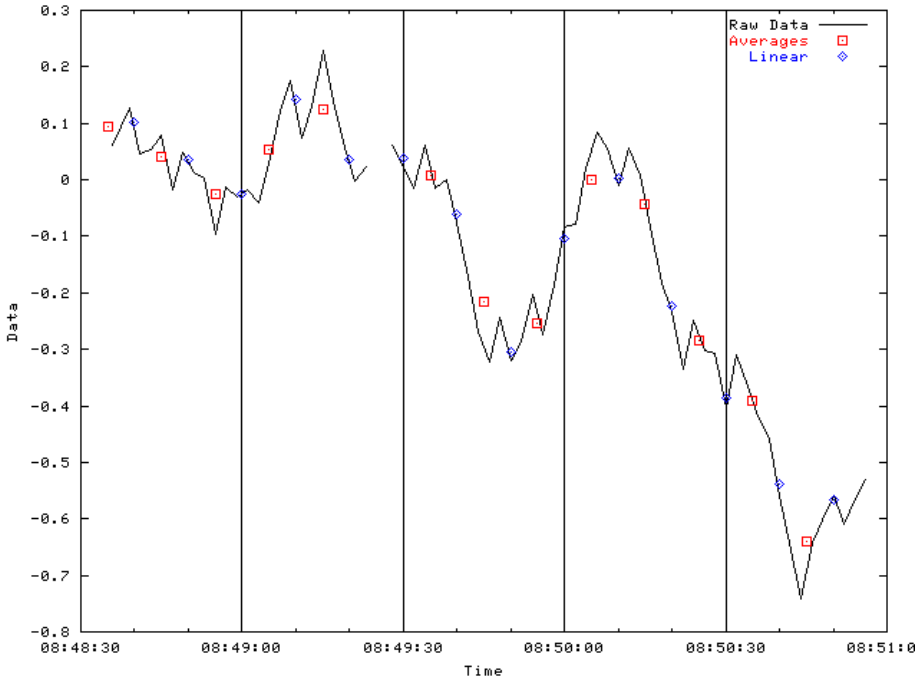

Figure 2.2: Averaging and Linear Interpolation, see text.

values for the bin-borders at 08:48:40, 08:48:50, ... The linearly interpolated values do in fact exactly fall onto the connecting lines between raw samples if you consider the full time stamps, but the plotting program chosen to produce fig. 2.2 rounds down to full seconds.

Note the gap just before 08:49:30: Since the channel was disconnected, no average is returned for the bin from 08:49:20 to 08:49:30. Averaging and linear interpolation are further limited to scalar, numeric samples of type double, float or int. Arrays or strings will not be interpolated.

NOTE: Averaging and linear interpolation must be used with caution. Both methods can hide important details in the raw data, and it is up to the user to determine when to use them and with what bin size. If for example you want to compare several water tank temperatures and you know that the water temperature can only change slowly, linear interpolation for e.g. every 60 seconds might be a reasonable approach.

On the other hand, consider a channel that monitors radiation counts per minute. The raw data will mostly reflect the fairly constant background radiation. Of interest are probably only temporary 'spikes' in the data, since they indicate radiation incidents that need to be correlated with e.g. beam loss. Interpolation of this type of data over 5 minutes will yield useless results. Most temporary increases in radiation within a bin are lost, you will only see val-

ues close to the background radiation as they were measured around the bin borders. Averaging will show a slight increase for those bins that contain a radiation incident, but the magnitude of those 'spikes' will not at all compare to the raw data.

2.7.5 Plot-Binning

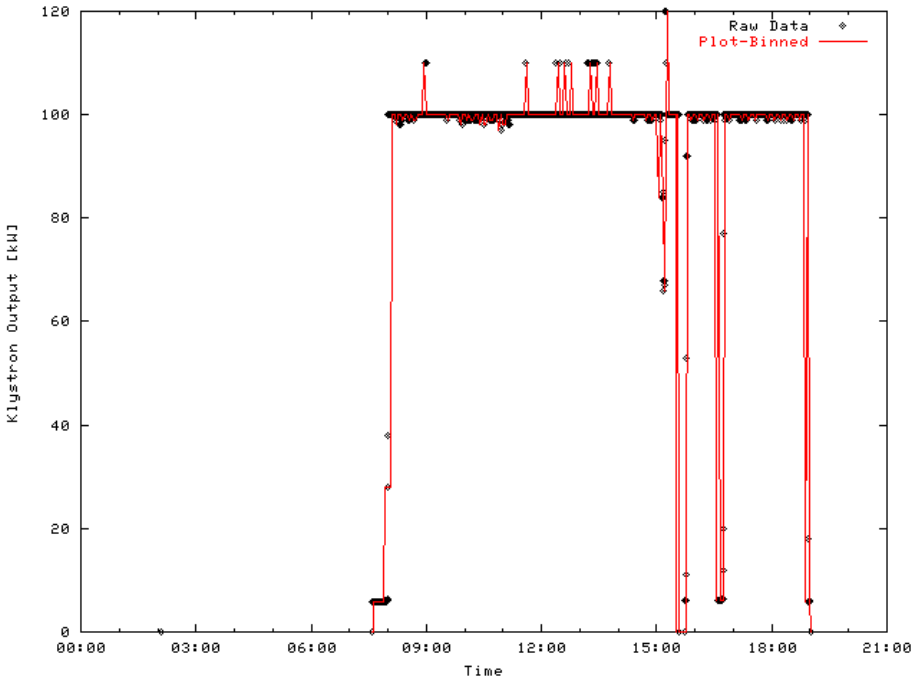

Figure 2.3: Plot-Binning, see text.

This method is meant for plotting, providing data that — when plotted — looks very much if not exactly like the raw data, albeit significantly reducing the number of data points and hence speeding up the plot. To accomplish this, the data is binned as described in the previous section. The following is then applied to each bin:

- If there is no sample for the time span of a bin, the bin remains empty.
- If there is one sample, it is placed in the bin.
- If there are two samples, they are placed in the bin.
- If there are more than two samples, the first and last one are placed in the bin. In addition, two artificial samples are created with a time stamp right

between the first and last sample. One contains the minimum, the other the maximum of all raw samples who's time stamps fall into the bin. They are presented to the user in the sequence initial, minimum, maximum, final.

Fig. 2.2 compares the raw data of a Klystron test run, 2400 samples, with the result of plot-binning, bin size 600 seconds, yielding around 280 samples. While plot binning significantly reduced the sample count, the overall shape of the klystron output as well as the outliers are well preserved.

Note that the "before or at" interpretation of start times does not apply for Plot-Binning: The exact start time of the request is used to determine the beginning of the first bin, and only samples within each bin are considered, there is no interpolation onto bin-boundaries. In general, the use of N bins can result in up to $4N$ data points, since each bin might provide an initial, minimum, maximum and final value. In most cases, this results in a significant data reduction. As long as we plot this such that the width of the plot in pixels is close to the number of bins, there is little visual difference between the raw data plot and the binned plot. Typical numbers for N are around the width of a computer screen in pixels, that is 800...1200. For the special case were 3 raw values happen to fall into every bin, we will get $4N$ instead of $4N$ data points. For typical N, that is a slight but not dramatic increase in retrieval or plotting time. It is neglectable compared to the fact that binning guarantees an upper limit of $4N$ data points, no matter how many raw samples there are.

Chapter 3

ArchiveEngine

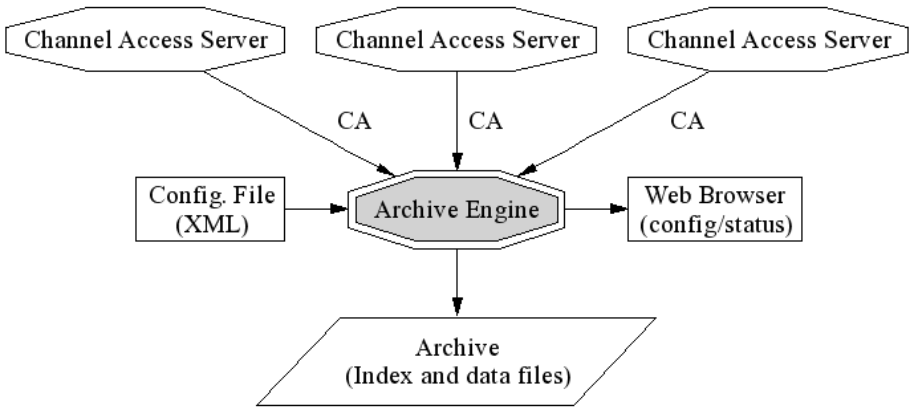

Figure 3.1: Archive Engine, refer to text.

The ArchiveEngine is an EPICS ChannelAccess client. It can save any channel served by any ChannelAccess server. One ArchiveEngine can archive data from more than one CA server. For more details on the CA server data sources, refer to section 2.2 on page 3. The ArchiveEngine supports the sampling options that were described in section 2.3 on page 4. The ArchiveEngine is configured with an XML file that lists what channels to archive and how. Each given channel can have a different periodic scan rate or be archived in monitor mode (on change). One design target was: Archive 10000 values per second, be it 1000 channels that change at 10Hz each or 10000 channels which change at 1Hz.

The ArchiveEngine saves the full information available via ChannelAccess: The value, time stamp and status as well as control information like units, display and alarm limits, ... The data is written to an archive in the form of local

disk files, specifically index and data files. Chapter ?? provides details on the file formats. While running, status and configuration of the ArchiveEngine are accessible via a built-in web server, accessible via any web browser on the network. The chapter on data retrieval, beginning on page 27, introduces the available retrieval tools that allow users to look at the archived data.

3.1 Configuration

The ArchiveEngine expects an XML-type configuration file that follows the document type description format from listing 3.1 (see section ?? on DTD file installation). Listing 3.2 provides an example. In the following subsections, we describe the various XML elements of the configuration file.

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- DTD for the ArchiveEngine Configuration -->
<!-- Note that we do not allow empty configurations: -->
<!-- Each config. must contain at least one group, -->
<!-- and each group must contain at least 1 channel. -->
<!ELEMENT engineconfig ((write_period|get_threshold|
                         file_size|ignored_future|
                         buffer_reserve|
                         max_repeat_count|disconnect)*,
                         group+)>
<!ELEMENT group (name,channel+)>
<!ELEMENT channel (name,period,(scan|monitor),disable?)>
<!ELEMENT write_period (#PCDATA)><!-- int seconds -->
<!ELEMENT get_threshold (#PCDATA)><!-- int seconds -->
<!ELEMENT file_size (#PCDATA)><!-- MB -->
<!ELEMENT ignored_future (#PCDATA)><!-- double hours -->
<!ELEMENT buffer_reserve (#PCDATA)><!-- int times -->
<!ELEMENT max_repeat_count (#PCDATA)><!-- int times -->
<!ELEMENT disconnect EMPTY>
<!ELEMENT name (#PCDATA)>
<!ELEMENT period (#PCDATA)><!-- double seconds -->
<!ELEMENT scan EMPTY>
<!ELEMENT monitor EMPTY>
<!ELEMENT disable EMPTY>
```

Listing 3.1: XML DTD for the Archive Engine Configuration

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<!DOCTYPE engineconfig SYSTEM "engineconfig.dtd">
<engineconfig>
    <write_period>30</write_period>
    <get_threshold>20</get_threshold>
    <file_size>30</file_size>
    <ignored_future>1.0</ignored_future>
    <buffer_reserve>3</buffer_reserve>
    <max_repeat_count>120</max_repeat_count>
    <group>
        <name>Vacuum</name>
        <channel><name>vac1</name>
                <period>0.1</period><monitor/>
        </channel>
        <channel><name>vac2</name>
                <period>1</period><monitor/><disable/>
        </channel>
        <channel><name>vac3</name>
                <period>2</period><scan/>
        </channel>
    </group>
    <group>
        <name>RF</name>
        <channel><name>rf1</name>
                <period>1</period><monitor/>
        </channel>
        <channel><name>rf2</name>
                <period>1</period><monitor/>
        </channel>
        <channel><name>rf3</name>
                <period>1</period><scan/>
        </channel>
    </group>
</engineconfig>
```

Listing 3.2: Example Archive Engine Configuration

3.1.1 write_period

This is a Global Option that needs to precede any group and channel definitions. It configures the write period of the Archive Engine in seconds. The default value of 30 seconds means that the engine will write to Storage every 30 seconds.

3.1.2 get_threshold

This global option determines when the archive engine switches from “Sampled” operation to “Sampled using monitors” as described in section 2.3.

3.1.3 file_size

This global option determines when the archive engine will create a new data file. The default of 100 means that the engine will continue to write to a data file until that file reaches a size of approximately 100 MB, at which point a new data file is created.

3.1.4 ignored_future

Defines “too far in the future” as “now + ignored_future”. Samples with time stamps beyond that time are ignored. Details: For strange reasons, the Engine sometimes receives values with invalid time stamps. The most common example is a “Zero” time stamp: After an IOC reboots, all records have a zero time stamp until they are processed. For passive records, as commonly used for operator input, this time stamp will stay zero until someone enters a value on an operator screen or via a safe/restore utility. The Engine cannot archive those values because the retrieval relies on the values being sorted in time. A zero time stamp does not fit in.

Should an IOC (for some unknown reason) produce a value with an outrageous time stamp, e.g. ”1/2/2035”, another problem occurs: Since the archiver cannot go back in time, it cannot add further values to this channel until the date ”1/2/2035” is reached. Consequently, future time stamps have to be ignored. (default: 6h)

3.1.5 buffer_reserve

To buffer the samples between writes to the disk, the engine keeps a memory buffer for each channel. The size of this buffer is

$$buffer\_reserve \times \frac{write\_period}{scan\_period}$$

Since writes can be delayed by other tasks running on the same computer as well as disk activity etc., the buffer is bigger than the minimum required: buffer_reserve defaults to 3.

3.1.6 max_repeat_count

When sampling in a scanned mode (as opposed to monitored), the engine stores only new values. As long as a value matches the preceding sample, it is not written to storage. Only after the value changes, a special value marked with a severity of ARCH_REPEAT and a status that reflects the number of repeats is written, then the new sample is added.

This procedure conserves disk space. The disadvantage lies in the fact that one does not see any new samples in the archive until the channel changes, which can be disconcerting to some users. Therefore the max_repeat_count configuration parameter was added. It forces the engine to write a sample even if the channel has not change after the given number of repeats. The default is 120, meaning that a channel that is scanned every 30 seconds will be written once an hour even if it had not changed.

3.1.7 disconnect

This global option selects how "disabled" channels (see 3.1.9) are handled. By default, disabled channels will stay connected via ChannelAccess, but no values are archived. When setting the "disconnect" option, disabled channels will instead disconnect from ChannelAccess and then, later, attempt to reconnect once the channel is again enabled.

In general, it is a good idea to stay with the default. That way we leave the connection handling to the ChannelAccess client library, which is optimized to do this. The engine will still receive new data, and as soon as the channel is re-enabled, it can thus store the most recent value.

The disconnect feature was added for the rare case that you have IOCs that are temporarily off-line, and some PV will tell you about the fact. You can then use that PV to disable and disconnect the affected channels, preventing the ChannelAccess client library from continuing to issue connection attempts. Another example would be that you want to reduce the network load of continuing CA monitors for channels that are archived via monitors at a high rate but disabled. Most likely, though, checking your channels' update rates or using a temporary archive engine might be the better solution.

3.1.8 group

Every channel belongs to a group of channels. The configuration file must define at least one group. For organizational or aesthetic purposes, you might add more groups. One important use of groups is related to the "disable" feature, see section 3.1.9.

name

This mandatory sub-element of a group defines its name.

3.1.9 channel

This element defines a channel by providing its name and the sampling options. A channel can be part of more than one group. To accomplish this, simply list the channel as part of all the groups to which it should belong.

name

This mandatory sub-element of a channel defines its name. Any name acceptable for ChannelAccess is allowed. The archive engine does not perform any name checking, it simply passes the name on to the CA client library, which in turn tries to resolve the name on the network. Ultimately, the configuration of your data servers decides what channel names are available.

period

This mandatory sub-element of a channel defines the sampling period. In case of periodic sampling, this is the period at which the periodic sampling attempts to operate. In case of monitored channels (see next option), this is the estimated rate of change of the channel. The period is specified in units of seconds.

If a channel is listed more than once, for example as part of different groups, the channel will still only be sampled once. The sampling mechanism is determined by maximizing the data rate. If, for example, the channel “X” is once configured for periodic sampling every 30 seconds and once as a monitor with an estimated period or one second, the channel will in fact be monitored with an estimated period of 1 second.

scan

Either “monitor” or “scan” need to be provided as part of a channel configuration to select the sampling method. True to its name, “scan” selects scanned operation, where the preceding “period” tag determines the sampling period, that is the time between taking samples. As an example, scanned operation with a period of 60 means: Every 60 seconds, the engine will write the most recent value of the channel to the archive.

monitor

As an alternative to the “scan” tag, “monitor” can be used, requesting monitored operation, that is: An attempt is made to store each change received via ChannelAccess. The “period” tag is used to determine the in-memory buffer size of the engine. That means: If samples arrive much more frequently than estimated via the “period” tag, the archive engine might drop samples. (See also “buffer_reserve”, 3.1.5). Some examples, assuming that channel “fred” actually emits monitors at 1 Hz:

- "fred 1 Monitor"
  Every value sent by fred is archived. Might be a good idea for some channels, but don't try to store every value of every PV of your control system indefinetely unless you are prepared to deal with that amount of data.

- "fred 1"
  The engine will sample once per second, and the channel changes once a second, so you might think that you archive every value just as in the previous example. But think again. The sampling of the engine on the host and the scanning of the channel on the CA server are not synchronized, plus there are additional network delays. So you will sometimes miss values whenever more than one sample arrived between the engine's sampling, or get duplicate values whenever no new value arrived between the engine's sampling. Bad idea.

- "fred 60"
  The engine will sample every 60 seconds. This is a very reasonable setup: The channel samples at 1 Hz, so you get frequent updates for the operator interface, but for the archive we only care about a sample per minute and save storage space by ignoring finer detail.

- "fred 10 Monitor"
  Probably an error. The engine is instructed to save every incoming monitor, but you told it to allocate buffers for only one value every 10 seconds, even though we knew that the channel will emit monitors much more often. So you will get "overrun" errors, the engine will overwrite older samples in its ring buffer with newly arriving samples, and the archive will contain the last few samples that happened to be in the buffer at write-to-disk time.

disable

This optional sub-element of a channel turns the channel into a "disabling" channel for the group. Whenever the value of the channel is above zero, sampling of the whole group will be disabled until the channel returns to zero or below zero (see 3.1.7 for additional disconnection).

This is useful for e.g. a group of channels related to power supplies: Whenever the power supply is off, we might want to disable scanning of the power supplies' voltage and current because those channels will only yield noise. By disabling the sampling based on a "Power Supply is Off" channel, we can avoid storing those values which are of no interest.

NOTE: There is no "enabling" feature, meaning: The channel marked as "disable" will disable its group whenever it is above zero. There is no "enable" flag that would enable archiving of a group whenever the flagged channel is above zero. If you want it the other way around, you typically add a CALC record to handle the inversion.

3.2 Starting and Stopping

3.2.1 Starting

The ArchiveEngine is a command-line program that displays usage information similar to the following:

```
ArchiveEngine Version 2.1.0, EPICS 3.14.4

USAGE: ArchiveEngine [Options] <config-file><index-file>

Options:
  -port <port>          Web server TCP port
  -description <text>   description for HTTP display
  -log <filename>       write logfile
  -nocfg                disable online configuration
```

Minimally, the engine is therefore started by simply naming the configuration file and the path to the index file, which can be in the local directory:

```
ArchiveEngine engineconfig.xml ./index
```

After collecting some data, the ArchiveEngine will create the specified index file together with data files in the same directory that contains the index file.

3.2.2 “-log” Option

This option causes the ArchiveEngine to create a log file into which all the messages that otherwise only appear on the standard output are copied.

3.2.3 “-description” Option

This option allows setting the description string that gets displayed on the main page of the engine’s built-in HTTP server, see section 3.3.

3.2.4 “-port” Option

This option configures the TCP port of the engine’s HTTP server, again see section 3.3. The default port number is 4812.

If you think this number stinks for a default, you are not too far off base: In Germany, there is a very well known Au-de-Cologne called 4711. Since forty-seven-eleven is therefore easily remembered by anybody from Germany, adding 1 to each 47 and 11 naturally results in an equally easy to remember 4812. And for those who fail to appreciate the German-centered default port number, the “-port” option allows you to pick a number of your personal fancy.

3.2.5 "-nocfg" Option

This option disables the "Config" page of the engine's HTTP server, in case you want to prohibit online changes.

3.2.6 The "archive_active.lck" File

You can only run one ArchiveEngine per directory because it creates the index and data files in there. When running, this lock file is created. The ArchiveEngine will refuse to run if this file already exists. After shutdown, the ArchiveEngine will remove this lock file. If the ArchiveEngine crashes or is not stopped gracefully by the operating system, this lock file will be left behind. You cannot start the ArchiveEngine again until you remove the lock file. This is a reminder for you to check the cause of the improper shutdown and maybe check the data files for corruption.
NOTE: This is no 100% dependable check. Data corruption occurs when two engines attempt to write to the same index and data files. The lock file, however, is created in the directory where the ArchiveEngine was started, which could be different from the directory where the data gets written. Example:

```
cd /some/dir
ArchiveEngine -p 7654 engineconfig.xml /my/data/index &

cd /another/dir
ArchiveEngine -p 7655 engineconfig.xml /my/data/index &
```

This is a sure-fire way to corrupt the data in "/my/data/index" and the accompanying data files because two ArchiveEngines are writing to the same archive.

3.2.7 More than one ArchiveEngine

You can run multiple ArchiveEngines on the same computer. But they must

1. be in separate directories. See the preceding discussion of the lock file which is meant to assist in avoiding this problem.
2. use a different TCP port number for the built-in web server

In practice this means that you have to create different directories on the disk, one per ArchiveEngine, and in there run the ArchiveEngines with different "-p <port>" options.

3.2.8 Stopping

While the ArchiveEngine can be stopped by pressing "CTRL-C" or using the equivalent "kill" command in Unix, the preferred method is via the built-in web server. Use any web browser and point it to

http://<host where engine is running>:<port>/stop

Per default, the engine uses 4812, so you could use the following URL to stop that engine on the local computer:

http://localhost:4812

3.3 Web Interface

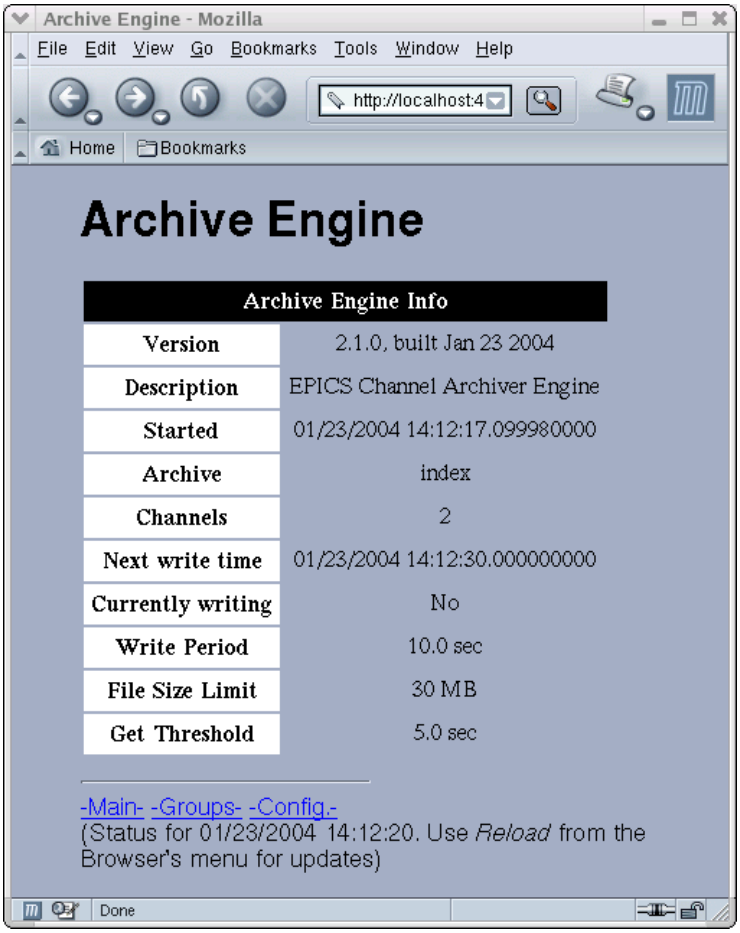

Figure 3.2: Main Page of Archive Engine's HTTPD

The ArchiveEngine has a built-in web server (HTTP Daemon) for status and configuration information. You can use any web browser to access this web server. You can do that on the computer where the ArchiveEngine is running as well as from other computers, be it a PC or Macintosh or other

system as long as that computer can reach the machine that is running the ArchiveEngine via the network. You do *not* need a web server like the Apache web server for Unix or the Internet Information Server for Win32 to use this. The ArchiveEngine *itself* acts as a web server.

You *cannot* view archived data with this mechanism. See the documentation on data retrieval (chapter 4) for that, because the archive engine's HTTPD is meant for access to the status and configuration of the running engine, not for accessing the data samples.

To access the ArchiveEngine's web server, you need to know the Internet name of the machine that is running the ArchiveEngine as well as the TCP port. If you are on the same machine, use "localhost". The port is configured when you start the ArchiveEngine, it defaults to 4812. Then use any web browser and point it to

http://<*host where engine is running*>:<*port*>

Example for an ArchiveEngine running on the local machine with the default port number:

http://*localhost:4812*

The start page of the ArchiveEngine web server should look similar to the one shown in Fig. 3.2. By following the links, one can investigate the status of the groups and channels that the ArchiveEngine is currently handling. The "Config" page allows limited online-reconfiguration. Whenever a new group or channel is added, the engine attempt to write a new config file called onlineconfig.xml in the directory where is was started. It is left to the user to decide what to do with this file: Should it replace the original configuration file, so that online changes are preserved? Or should it be ignored, because online changes are only meant to be temporary and with the next run of the engine, the original configuration file will be used?

Note also that the ArchiveEngine does not allow online removal of channels and groups. The scan mechanism of a channel can only be changed towards a higher scan rate or lower period, similar to the handling of multiply defined channels in a configuration file. Refer to the section discussing the "period" tag on page 20.

3.4 Threads

The ArchiveEngine uses several threads:

- A main thread that reads the initial configuration and then enters a main loop for the periodic scan lists and writes to the disk.
- The ChannelAccess client library is used in its multi-threaded version. The internals of this are beyond the control of the ArchiveEngine, the total number of CA client threads is unknown.

- The ArchiveEngine's HTTP (web) server runs in a separate thread, with each HTTP client connection again being handled by its own thread. The total number of threads therefore depends on the number of current web clients.

As a result, the total number of threads changes at runtime. Though these internals should not be of interest to end users, this can be confusing especially on older releases of Linux where each thread shows up as a process in the process list. On Linux version 2.2.17-8 for example we get process table entries as shown in Tab. 3.3 for a single ArchiveEngine, connected to four channels served by excas, no current web client. The only hint we get that this is in fact one and the same ArchiveEngine lies in the consecutive process IDs.

```
  PID TTY          TIME CMD
29721 pts/5    00:00:00 ArchiveEngine
29722 pts/5    00:00:00 ArchiveEngine
29723 pts/5    00:00:00 ArchiveEngine
29724 pts/5    00:00:00 ArchiveEngine
29725 pts/5    00:00:00 ArchiveEngine
29726 pts/5    00:00:00 ArchiveEngine
29727 pts/5    00:00:00 ArchiveEngine
29728 pts/5    00:00:00 ArchiveEngine
```

Listing 3.3: Output of Linux 'ps' process list command, see text.

The first conclusion is that one should not be surprised to see multiple ArchiveEngine entries in the process table. The other issue arises when one tries to 'kill' a running ArchiveEngine. Though the preferred method is via the engine's web interface, one can try to send a signal to the first process, the one with the lowest PID.

Chapter 4

Data Retrieval

Data retrieval requirements can cover a wide range. One person might be interested in the temperature of a water tank during the last night. For this, it is probably sufficient to retrieve the raw data for the respective channel and plot it. If, on the other hand, we want to look at the same temperature for the last 3 month, the raw data will amount to too many samples and some sort of data reduction or interpolation is helpful. We already mentioned the problems of time stamp correlation that arise when comparing different channels in section 2.7.

The Channel Archiver toolset includes some generic tools that can be used "as is". While those try to cover many data retrieval requirements, certain requests can only be handled in customized data mining programs (which might be e.g. perl scripts). For this, the archiver offers a network data server. In short, these are your options:

- Java Archive Client
  This is meant to be *the* data client. Use it to browse the available data, generate plots, export data to spreadsheets, from any computer on the network by accessing the network data server.
- ArchiveExport
  A command-line tool. Less convenient to use, requires direct access to the data files. Use this when the Java Archive Client or network data server are not available.
- Archive Data Server
  You can access the Archive Data Server via XML-RPC from most programming languages. Use this method for customized data mining programs.

4.1 ArchiveExport

ArchiveExport is a command-line tool for local tests, i.e. it does *not* connect to the archive data server but requires that you have direct read access to the index and data files. It is mostly meant for testing.

When invoked without valid arguments, it will display a command description similar to this:

```
USAGE: ArchiveExport [Options] <index file> {channel}

Options:
  -verbose                  Verbose mode
  -list                     List all channels
  -info                     Time-range info on channels
  -start <time>             Format:
                          "mm/dd/yyyy [ hh:mm:ss [.nano-secs]]"
  -end <time>               (exclusive)
  -text                     Include text column for
                            status/severity
  -match <reg. exp.>        Channel name pattern
  -interpolate <seconds>    interpolate values
  -output <file>            output to file
  -gnuplot                  generate GNUPlot command file
  -Gnuplot                  generate GNUPlot output
                            for Image
```

ArchiveExport produces spreadsheet-type output in TAB-separated ASCII text, suitable for import into most spreadsheet programs for further analysis. Per default, ArchiveExport uses Staircase Interpolation to map the data for the requested channels onto matching time stamps, but one can select Linear Interpolation via the "-interpolate" option. When GNUPlot output is selected, the Plot-Binning method is used, where the bin size is determined by the "-interpolate" argument. See section 2.7 on page 9 for details.

Assuming that your current working directory contains an archive index file that is aptly named "index", the following invocation will generate a spreadsheet file "data.txt" with the data of all channels that match the pattern "IOC" for the date of January 27, 2003:

```
ArchiveExport index -m IOC \
              -s "01/27/2003" \
              -e "01/28/2003" >data.txt
```

To plot this in OpenOffice, you could create a new spreadsheet, then use the menu item Insert/Sheet/FromFile, select the file "data.txt" and configure the text import dialog to use "Separated by Tab". You will notice that even though the original text file contains time stamps with nano-second resolution, for example "01/27/2003 23:57:25.579346999", the spreadsheet program might use a default representation of e.g. "01/27/03 23:57 pm". In order to see the full

time stamp detail, one needs to reformat those spreadsheet columns with a user-defined format like “MM/DD/YYYY HH:MM:SS.000000000”. If you use Microsoft Excel, you might be limited to a format with millisecond resolution: “MM/DD/YYYY HH:MM:SS.000”. For graphing the data, the most suitable option is often an “X-Y-Graph”, using the first row for labels, with the data series taken from the columns.

The following call sequence will generate a GNUPlot data file “data” together with a GNUPlot command file “data.plt” and execute it within GNUPlot:

```
ArchiveExport index -m IOC \
              -s "01/27/2003" \
              -e "01/28/2003" -o data -gnu
gnuplot
        G N U P L O T
        Version 3.7 patchlevel 3
....
gnuplot> load 'data.plt'
```

4.2 Java Archive Client

This tool is meant to be the main data retrieval tool. It provides a graphical user interface to allow data browing. It is based on Java and hence usable on many operating systems. It accesses the data via the DataServer described in section 4.3, which means that it can access the data via the network. You invoke the java archive client with the URL of the web server that hosts the archive data server. The interactive GUI shown in Fig. 4.1 then allows you to select one of the archives served by the network data server, investigate the available channels, perform basic calculations on single or multiple channels, export data in spreadsheet format and much more. A separate manual descibes the viewer.

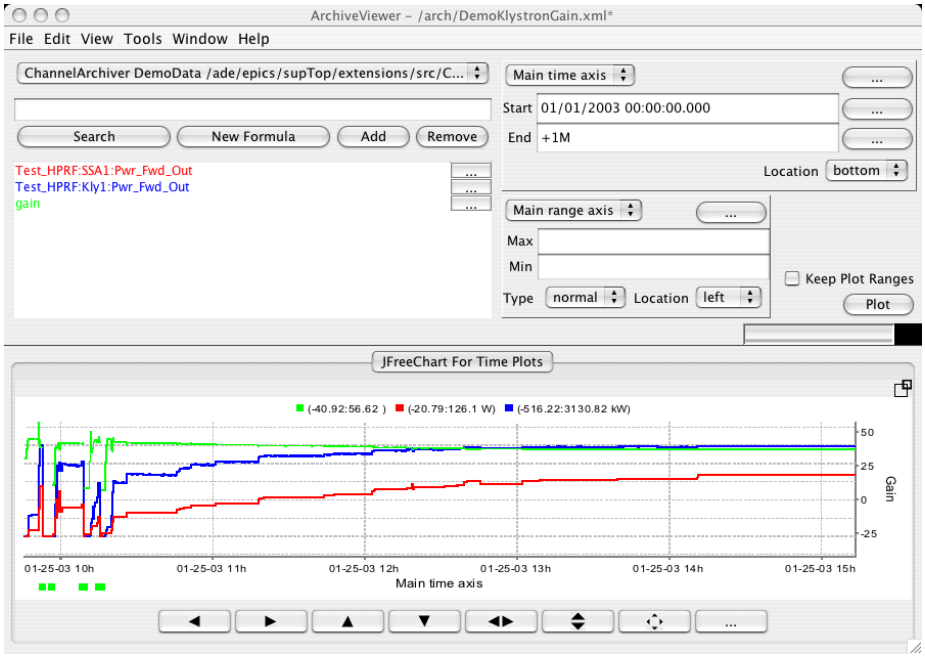

Figure 4.1: Java Archive Cient.

4.3 Data Server

The archiver toolset includes a network data server. By running this data server on a computer that has physical access to your archived data, be it because the data resides on a local disk or an NFS-mapped volume, other machines on the network can get read-access to your data.

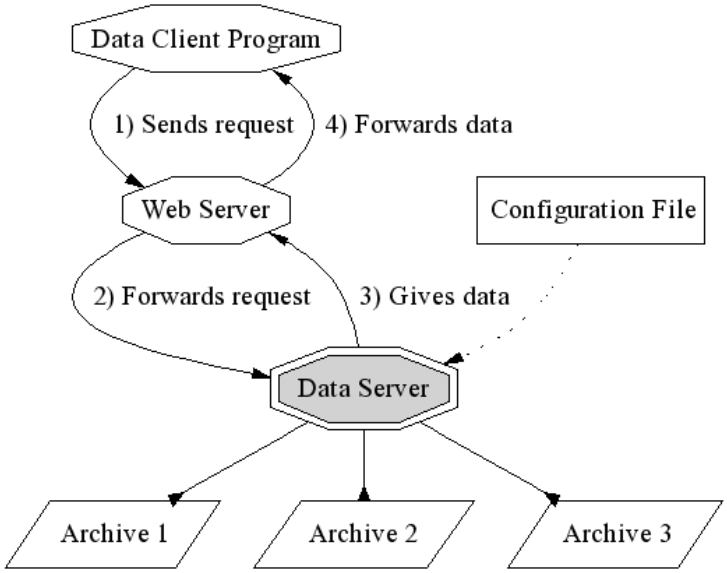

Figure 4.2: Data Server, refer to text.

The data server is hosted by a web server, using the XML-RPC protocol to serve the data. This means that software running on disparate operating systems, running in different environments can access your data over the Internet via a URL. As an example, your data server might be a Linux machine on a subnet behind a firewall. After you configure the firewall to pass HTTP requests, any Linux, Win32, Macintosh computer both inside or outside of the firewall can access the data from within perl, python or tcl scripts, programs written in C, C++ or Java, actually pretty much any programming language. As illustrated in fig. 4.2, the client program sends its requests to a web server, which forwards it to the data server that is running as a CGI tool under the web server. The dataserver accesses the relevant archives — you determine which ones are available via a configuration file — and returns the data though the web server to the client program. You can configure access security via e.g. the Apache web server configuration.
NOTE: The fact that the data server is hosted by a web server, accessible via a URL, does *not* imply that you can use any web browser to retrieve data. You have to use the XML remote procedure call protocol described in section 4.4 on

page 37. XML-RPC handles the network connections, data type conversions, and XML-RPC libraries are available for most programming languages. We provide the Java Archive Client (see section 4.2) as a generic, interactive data client.

4.3.1 Installation

After successful compilation in ChannelArchiver/XMLRPCServer, you should have a program "XMLRPCServer/O.$EPICS_HOST_ARCH/ArchiveDataServer". You have to install it as a CGI tool under a web server, passing an environment variable "SERVERCONFIG" to it which points to a configuration file. This means

- You need a web server like Apache running on a computer with access to the archive data.
- You need to know how to start, stop and configure that web server.
- You need to know how to install, configure and possibly troubleshoot CGI tools under that web server.
- You need to create a configuration file for the ArchiveDataServer.

With all but the last point you are very much on your own, because this manual cannot even try to describe all the possible configurations and errors. What follows is only an example setup for the Apache Web Server under Linux and Mac OS X. Your web server, even if it is also a version of Apache, is likely to be quite different.

1. Locate your web server configuration file. This is is often a variant of "/etc/httpd/conf/httpd.conf". For Mandrake 10, check "/etc/httpd/conf/-commonhttpd.conf", for Mac OS X it's "/etc/httpd/httpd.conf".
2. After each change to the configuration, you will have to restart the web server. This is often done via "/etc/rc.d/initd/httpd restart" or "/usr/sbin/apachectl restart".
3. Create a new web directory for the archiver with a CGI sub-directory. This is typically done under /var/www/html, except for Mac OS X, where you would use /Library/WebServer/Documents. Check the "DocumentRoot" variable in your web server configuration file for the correct location and adjust the following accordingly.

```
mkdir /var/www/html/archive
mkdir /var/www/html/archive/cgi
```

   Change the permissions of those directories to your liking. Usually, "everybody" needs read and execution access, because the web server will

run CGI programs as a low-priviledged user. Our main interest here is the CGI"cgi" subdirectory. You can use the "archive" directory to store e.g. the dtd files or web pages with user information that relate to the archive setup at your site.

4. Copy the ArchiveDataServer binary into the cgi directory as "ArchiveDataServer.cgi". In this example, both the "cgi" directory and the ".cgi" extension of "ArchiveDataServer.cgi" are important, because they identify the binary as a CGI program.

5. Assert that the web server can execute the ArchiveDataServer, that it recognizes it as a CGI tool, by adding the following to the Apache config file:

```
# Check that environment variables are available,
# assert that this directive is not commented-out.
# Your web server might use a different module name
# or location, in my case it happened to be this:
LoadModule env_module  libexec/httpd/mod_env.so
AddModule mod_env.c

# Check that CGI is enabled, i.e. assert that
# these are not commented-out:
LoadModule cgi_module     libexec/httpd/mod_cgi.so
AddModule mod_cgi.c

# This tells Apache that ArchiveDataServer.cgi
# is a CGI program because of the .cgi extension:
AddHandler cgi-script .cgi

<Directory /var/www/html/archive>
    Order Allow,Deny
    Allow from All
</Directory>

# Allow cgi-scripts in the ..../cgi directory:
<Directory /var/www/html/archive/cgi>
    SetEnv EPICS_TS_MIN_WEST 300
    SetEnv LD_LIBRARY_PATH  /usr/local/lib:...
    SetEnv SERVERCONFIG \
     /var/www/html/archive/cgi/serverconfig.xml

    # I also like to enable perl-CGI, but that is
    # unrelated to the archiver
    PerlHandler Apache::Registry
    PerlSendHeader On
```

```
    # This directive enables CGI for this dir.:
    Options +ExecCGI
</Directory>
```

The LD_LIBRARY_PATH needs to list all the directories that contain shared libraries which your ArchiveDataServer.cgi uses. In most cases, this includes the

- install location of the expat and XML-RPC libraries, often /usr/local/lib,
- "lib" subdirectories of EPICS base and EPICS extensions, something like /ade/epics/supTop/base/R3.14.6/lib/linux-x86:...

The SERVERCONFIG variable needs to point to your server configuration file, more about which next. The ExecCGI option is essential to allow CGI functionality. You can skip the Perl configuration for the data server.

4.3.2 Configuration

You need to prepare an XML-formatted configuration file for the ArchiveDataServer that follows the DTD from listing 4.1 (see section ?? on DTD file installation). Note that the ArchiveDataServer might not verify your configuration file, so you are strongly encouraged to use a tool like 'xmllint' on Linux to check your configuration against the DTD. Listing 4.2 shows one example configuration which lists two archives to be served. Client programs will internally use the respective 'key' to access them.

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- DTD for the XML-RPC Data Server Configuration -->
<!ELEMENT serverconfig (archive+)>
<!ELEMENT archive (key,name,path)>
<!ELEMENT key (#PCDATA)>
<!ELEMENT name (#PCDATA)>
<!ELEMENT path (#PCDATA)>
```

Listing 4.1: XML DTD for the Data Server Configuration

4.3.3 Testing, Debugging

Section 4.5 describes a perl client to the network data server. It can be used to see if all the archives you listed in the configuration are actually accessible and so on.

In case that client tool gets nothing but errors, debugging of the CGI ArchiveDataServer can be difficult, since one cannot easily peek into the running (or failing to run) program when it is launched by the web server.

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE serverconfig SYSTEM "serverconfig.dtd">
<serverconfig>
<archive>
      <key>1</key>
      <name>Vacuum</name>
      <path>/home/data/vac/index</path>
</archive>
<archive>
      <key>2</key>
      <name>RF-LLRF</name>
      <path>/home/data/llrf/index</path>
</archive>
</serverconfig>
```

Listing 4.2: Example Data Server Configuration

The XMLRPCServer directory contains some self-tests in test.sh, where the ArchiveDataServer is run without an actual web server. If test.sh works, your ArchiveDataServer program is fundamentally functional.

If it doesn't work from within your web server, try changing your user ID to 'guest' or 'nobody', somebody similar to the user ID used by the web server when it runs your CGI tool. Set the LD_LIBRARY_PATH as you set it for the web server cgi directory, and try test.sh again.
You can also try this to see more of the web server response:

```
telnet my_web_server_host 80
GET /archive/cgi/ArchiveDataServer.cgi HTTP/1.0<RETURN>
<RETURN>
```

You should see an error message about "XML-RPC Fault: Expected HTTP method POST", indicating that the data server was launched correctly and was looking for a proper XML-RPC request. If you see only pages of binary-looking garbage, your web server doesn't recognize ArchiveDataServer.cgi as a CGI program, and instead of running it, you get a copy of it.

4.3.4 Standalone Data Server

The preferred deployment of the network data server is within a standard web server as described in the previous sections. For experiments, however, there is a way to use a version of the data server which combines the simple "Abyss" web server and the network data server into one standalone program.
Advantages:

- Easier to configure than a standard web server. No serverconfig.xml, no serverconfig.dtd, no CGI setup trouble. When running "ArchiveDataServer-

Standalone", you will see right away if e.g. a shared library is missing, while the "ArchiveDataServer" CGI-plugin to a web server would simply not run for reasons harder to diagnose.

- Ordinary users beyond "root" or "Administrator" can run the standalone data server.

Disadvantages:

- The Abyss HTTPD still requires some configuration.
- Compared to e.g. the Apache web server, there is much less control over who can access the data.
- Currently limited to serving a single archive per running instance of the standalone data server. The 'key' of that archive is fixed to '1' and the 'name' to 'Archive'. Under a standard web server, one can run more than one ArchiveDataServer and configure each one to serve multiple archives with selected key and name.

4.3.5 Running ArchiveDataServerStandalone

After successful compilation in ChannelArchiver/XMLRPCServer, you will have a program "ArchiveDataServerStandalone".

1. For starters, you can test in the "ChannelArchiver/DemoData" directory, but typically you would copy all "abys*" files and directories from there into the directory where you intend to run the standalone data server.
2. Edit "abyss.conf" to suit your needs. Most users might only have to adjust the "Port" option, which defaults to 8080, and the "ServerRoot" variable.
3. Run the data server with the abys config file and the path of the archive's index. When inside DemoData, this would be an example:

```
> ArchiveDataServerStandalone abyss.conf index
 ArchiveDataServerStandalone Running
 Unless your 'abyss.conf' selects
 a different port number,
 the data should now be available via the XML-RPC URL
    http://localhost:8080/RPC2
```

The data is now accessible via XML-RPC by pointing the ArchiveDataClient.pl test tool or the Java ArchiveViewer to the URL

```
http://<hostname>:<port>/RPC2
```

Example:

```
http://localhost:8080/RPC2
```

4.4 XML-RPC Protocol

The following is a description of the calls implemented by the archive data server based on the XML-RPC protocol. For details on XML-RPC, including the specifications and examples of how to use it from within C, C++, Java, perl, please refer to http://www.xmlrpc.com.

Users of Java should probably utilize the Java archive data client library provided with the ChannelArchiver. Users of other programming environments need to refer to the following.

4.4.1 archiver.info

This call returns version information. It will allow future compatibility if clients check for the correct version numbers. In addition, it provides hints on how to decode the values served by this server.

```
{ int32              ver,
  string             desc,
  string             how[],
  string             stat[],
  { int32 num,
    string sevr,
    bool has_value,
    bool txt_stat
  }                  sevr[]
 } = archiver.info()
```

ver: Version number. The first released software uses '1'.

desc: Cute description that one can print.

how: Array of strings with a description of the request methods supported for 'how' in the archiver.values() call described further below in section 4.4.4.

stat: Array of strings with a description of the "status" part of the values returned by the archiver.values() call.

sevr: Array of structures with a description of the "severity" part of the values returned by the archiver.values() call.

The result is a structure with a numeric "ver" member, a string "desc" member and so on as listed above. Implementations like perl will return a hash with members "ver", "desc", etc. The strings in "how" describe the request method for how=0, how=1, and so on. The strings in "stat" describe the enumerated status values, the typical result is shown in table 4.1.

The more important information is in the "sevr" array. It also lists severity numbers ("num") and their associated string representation ("sevr"). In addition

to the alarm severities defined by the EPICS base software, the archiver uses some special severity values which have the “has_value” property set to false. They identify situations that have no value because the channel was disconnected or the archiver was turned off. Other special severities identify repeat counts which are used in the periodic scanning modes of the archive engine: If the channel did not change for N sample times, a repeat count of N is logged instead of logging the same value N times. In that case, the “txt_stat” property is set to false because the status (stat) field no longer corresponds to a status string from table 4.1. Instead, it provides the repeat count N. Table 4.2 lists the typical content of the “sevr” array, table 4.3 presents examples for decoding values based on their status and severity information.

Array Element	String
0	NO_ALARM
1	READ ALARM
2	WRITE ALARM
3	HIHI ALARM
4	HIGH ALARM
5	LOLO ALARM
6	LOW ALARM
7	STATE ALARM
...	...
17	UDF ALARM
...	...

Table 4.1: Alarm Status Values returned in the “stat” member of archiver.info()

num	sevr	has_value	txt_stat
0	NO_ALARM	true	true
1	MINOR	true	true
2	MAJOR	true	true
3	INVALID	true	true
3968	Est_Repeat	true	false
3856	Repeat	true	false
3904	Disconnected	false	true
3872	Archive_Off	false	true
3848	Archive_Disabled	false	true

Table 4.2: Alarm Severity Values returned in the “sevr” member of archiver.info()

Severity (sevr)	Status (stat)	Value	Example Text
0	0	3.14	“3.14”
1	6	3.14	“3.14 MINOR LOW”
3856	6	3.14	“3.14 Repeat 6”
3904	0	0	“Disconnected”

Table 4.3: Examples for decoding samples returned from the archiver.values() call based on their Status and Severity

4.4.2 archiver.archives

Returns the archives that this data server can access.

```
{ int32 key,
  string name,
  string path }[] = archiver.archives()
```

key: A numeric key that is used by the following routines to select the archive.

name: A description of the archive that one could e.g. use in a drop-down selector in a GUI application for allowing the user to select an archive.

path: The path to the index file, valid on the file system where the data server runs. It might be meaningful to a few users who want to know exactly where the data resides, but it is seldom essential for XML-RPC clients to look at this.

The result is an array of structures with a numeric “key” member and strings “name” and “path”. An example result could be:

```
{ key=1,  name="Vacuum", path="/home/data/vac/index" },
{ key=2,  name="RF",     path="/home/data/RF/index" }
```

So in the following one would then use key=1 to access vacuum data etc. One can expect the keys to be small, positive numbers, but they are not guaranteed to be consecutive as 1, 2, 3, ... Since the keys could be something like 10, 20, 30 or 1, 17, 42, they are not useful as array indices.

4.4.3 archiver.names

Returns channel names and start/end times. The key must be a valid key obtained from archiver.keys. Pattern is a regular expression; if left empty, all names are returned.
NOTE: The Time Stamps are *not* the raw EPICS time stamps with 1990 epoch, but use the time_t data type based on a 1970 epoch.

```
{string name,
 int32 start_sec,  int32 start_nano,
 int32 end_sec,    int32 end_nano}[]
        = archiver.names(int32 key,  string pattern)
```

The result is an array of structures, one structure per channel that matches the pattern. Start/end gives an idea of the time range that can be found in the archive for that channel. The archive might actually contain entries *after* the reported end time because the index might not be up too date on the end times.

4.4.4 archiver.values

This call returns values from the archive identified by the key for a given list of channel names and a common time range.

```
result = archiver.values(
         int key,
         string name[],
         int32 start_sec,  int32 start_nano,
         int32 end_sec,  int32 end_nano, int32 count,
         int32 how)
```

The parameter ”how” determines how the raw values of the various channels get arranged to meet the requested time range and count. For details on the methods mentioned in here refer to section 2.7 and following, beginning on page 9.

how = 0 (raw): Get raw data from archive (see 2.7.1), starting w/ ’start’, up to either ’end’ time or max. ’count’ samples.

how = 1 (spreadsheet): Get data that is filled or staircase-interpolated, starting w/ ’start’, up to either ’end’ time or max. ’count’ samples (see 2.7.3). For each channel, the same number of values is returned. The time stamps of the samples match accross channels, so that one can print the samples for each channel as columns in a spreadsheet. If a spreadsheet cell is empty because the channel does not have any useful value for that point in time, a status/severity of UDF/INVALID is returned (Tables 4.2 and 4.1).

how = 2 (averaged): Get averaged data from the archive, starting w/ ’start’, up to either ’end’ time or max. ’count’ samples (see 2.7.4). The data is averaged within bins whose size is determined by of (end-start)/count, so you should expect to get close to ’count’ values which cover ’start’ to ’end’. Again refer to section 2.7.

how = 3 (plot binning): Uses the plot-binning method based on ’count’ bins (see 2.7.5).

how = 4 (linear): Get linearly interpolated data from the archive, starting w/ 'start', up to either 'end' time or max. 'count' samples (see 2.7.4). The data is interpolated onto time slots which are multiples of (end-start)/count, so you should expect to get close to 'count' values which cover 'start' to 'end'. Again refer to section 2.7.

The result is an array of structures, one structure per requested channel:

```
result := { string name,  meta, int32 type,
            int32 count,  values }[]
```

name: The channel name. Result[i].name should match name[i] of the request, so this is a waste of electrons, but it's sure convenient to have the name in the result, and we're talking XML-RPC, so forget about the electrons.

meta: The meta information for the channel. This is itself a structure with the following entries:

```
meta := { int32 type;
          type==0: string states[],
          type==1: double disp_high,
                   double disp_low,
                   double alarm_high,
                   double alarm_low,
                   double warn_high,
                   double warn_low,
                   int prec,  string units
        }
```

type: Describes the data type of this channel's values:

```
string   0
enum     1 (XML int32)
int      2
double   3
```

count: Describes the array size of this channel's values, using 1 for scalar values. Note that even scalar values are returned as an array with one element!

values: This is an array where each entry is a structure of the following layout:

```
values := { int32 stat,  int32 sevr,
            int32 secs,  int32 nano,
            <type> value[] } []
```

The values for status and severity match in part those that the EPICS IOC databases use. The ArchiveEngine simply receives and stores them, they are passed on to the retrieval tools without change. In addition, the archiver toolset uses special severity values to indicate a disconnected channel or the fact that the ArchiveEngine was shut down. For details refer to section 4.4.1 and the tables 4.1, 4.2 and 4.3.

4.4.5 Note about Tiny Numbers and Precision

Some systems deal with small numers. Vacuum readings often use numbers like 510^{-8}. The XML-RPC specification is unfortunately unclear how numbers should get serialized and parsed other than specifically prohibiting the exponential notation. The best one could serialize the example number would therefore be "0.00000005".

When the ArchiveDataServer is build with the XML-RPC library for C/C++ as described in the installation section, ??, it will attempt to properly serialize small numbers. When using another XML-RPC library, and this includes the XML-RPC library that your client program uses, small numbers might end up being serialized as zero. The Java Archive Client appears to handle small numbers, as does the "Frontier" XML-RPC library for perl.

A similar issue applies to the precision of floating point numbers: The ArchiveDataServer serializes numbers with a fixed precision that is determined by the XML-RPC library for C/C++. You can patch the library to increase the precision.

4.5 Perl Client

The ArchiveDataClient.pl perl script is provided as a starting point for users who want to write perl scripts that access the ArchiveDataServer via XML-RPC. It requires the installation of the "Frontier" XML-RPC library for Perl. The ArchiveDataClient script might also help you test your ArchiveDataServer setup because it offers a command-line interface that is very close to the underlying XML-RPC calls. What follows is an example session:

```
USAGE: ArchiveDataClient.pl [options] { channel names }
Options:
  -u URL      : Set the URL of the DataServer
  -i          : Show server info
  -a          : List archives (name, key, path)
  -k key      : Specify archive key.
  -l          : List channels
  -m pattern  : ... that match a patten
  -h how      : 'how' number; retrieval method
  -s time     : Start time MM/DD/YYYY HH:MM:SS.NNNNNNNNN
  -e time     : End time MM/DD/YYYY HH:MM:SS.NNNNNNNNN
```

```
  -c count    : Count

$ URL=http://localhost/cgi-bin/xmlrpc/ArchiveDataServer.cgi
$ ArchiveDataClient.pl -u $URL -i
Archive Data Server V 0
Description:
Channel Archiver Data Server V0
Config '/var/www/cgi-bin/xmlrpc/serverconfig.xml'
Supports how=0 (raw), 1 (spreadsheet),
            2 (interpol/average), 3 (plot-binning)
$ ArchiveDataClient.pl -u $URL -a
Archives:
Key 1: 'Xmtr 2002' in '/home/..../2002/index'
Key 2: 'Xmtr 2003' in '/home/..../2003/index'
$ ArchiveDataClient.pl -u $URL -k 1 -m IOC1:Load
Channels:
Channel Test_HPRF:IOC1:Load,
   11/01/2002 17:09:37.616190999
 - 12/31/2002 23:59:45.579346999
$ ArchiveDataClient.pl -u $URL -k 1 \
  -s "12/01/2002" -e "12/31/2002" \
  -h 2 -c 31 Test_HPRF:IOC1:Load
Result for channel 'Test_HPRF:IOC1:Load':
Display : 0.000000 ... 100.000000
Alarms  : 0.000000 ... 80.000000
Warnings: 0.000000 ... 50.000000
Units   : '%', Precision: 0
Type: 3, element count 1.
11/30/2002 23:11:36.774193571 11.820585
12/01/2002 22:25:09.677419377 11.846808
12/02/2002 21:38:42.580645183 12.310933
12/03/2002 20:52:15.483870989 0.000000 ARCH_DISCONNECT
12/04/2002 20:05:48.387096795 12.225621
...
12/29/2002 23:58:03.870967751 11.448704
```

4.6 StripTool

StripTool is primarily a Channel Access client for taking "live" samples from CA servers and plotting them over time. For information on the current version, refer to the section on Host Software: Clients under http://www.aps.anl.gov/epics. A "History" module allows StripTool to access data from a Channel Archiver network data server.

NOTE: This history module is incomplete. At the time, the StripTool API did not provide means for a history data plug-in to create a configuration GUI. There was also no support for asynchronous data retrieval, meaning StripTool freezes while archive data is requested. Use of the history module is discouraged except for testing.

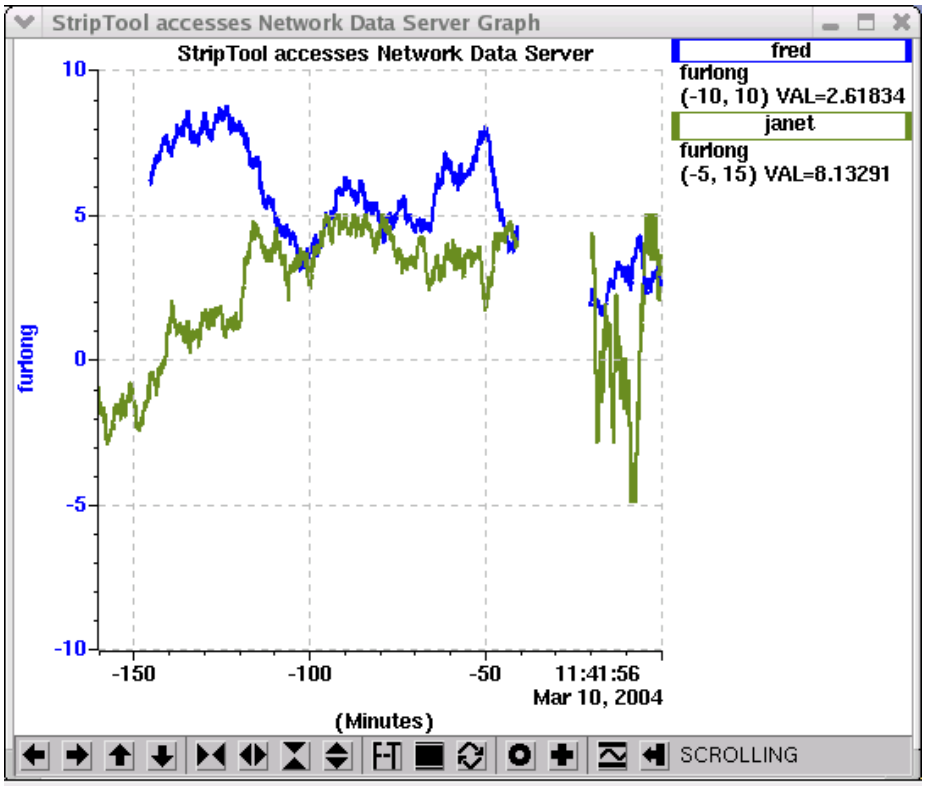

Figure 4.3: StripTool accessing live and archived data.

Fig. 4.3 shows an example of Striptool after running for about 20 minutes. It displays those 20 minutes of live data as well as data retrieved from an archive data server, both types of data clearly separated by a gap of about 20 minutes where the archive was no longer and StripTool not yet running. There will always be a small gap as a result of the ArchiveEngine's buffering between

writes to the archive.

For configuration details, refer to the file README_XMLRPC which is part of the XML-RPC history module for StripTool.

4.7 Matlab

Programs like Matlab or Octave are ideally suited for the more sophisticated analysis of archived data. The ChannelArchiver includes interface code for Matlab and Octave, allowing those two programs to access data from the ChannelArchiver's Network Data Server. Refer to the file ChannelArchiver/-Matlab/README for details on building, installing and using those extensions. **NOTE:** The Matlab/Octave support is experimental. Its use is discouraged except for testing.

Figures 4.4, 4.5, 4.6, 4.7 and 4.8 showcase some examples and provide you with an excuse to print at least this section of the manual on a color printer.

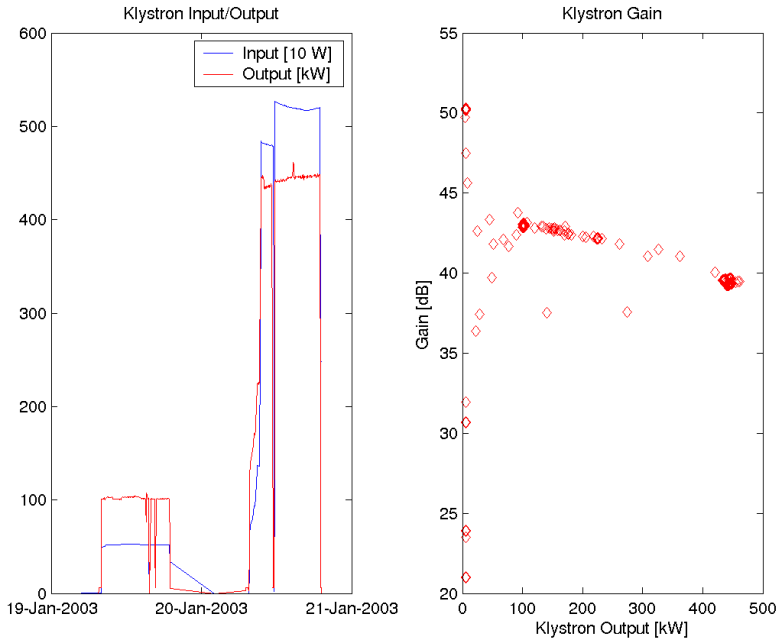

Figure 4.4: Matlab Example: Input and Output power of a Klystron for a two-day test run, combined with a scatter plot of the computed Klystron Gain.

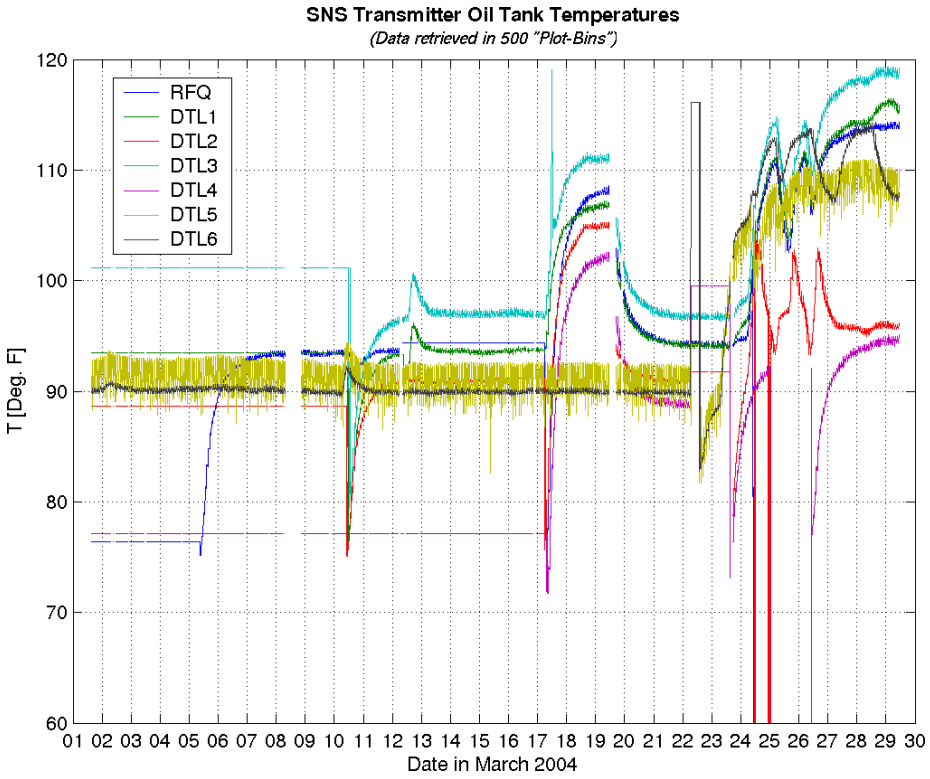

Figure 4.5: Matlab Example: One-month overview of Klystron oil tank temperatures. The Plot-Binning request method as described in section 2.7.5 was used to reduce the amount of data. Interesting features like the noise on the DTL5 signal as well as occasional spikes (which probably result from maintenance work on the oil tank) are preserved.

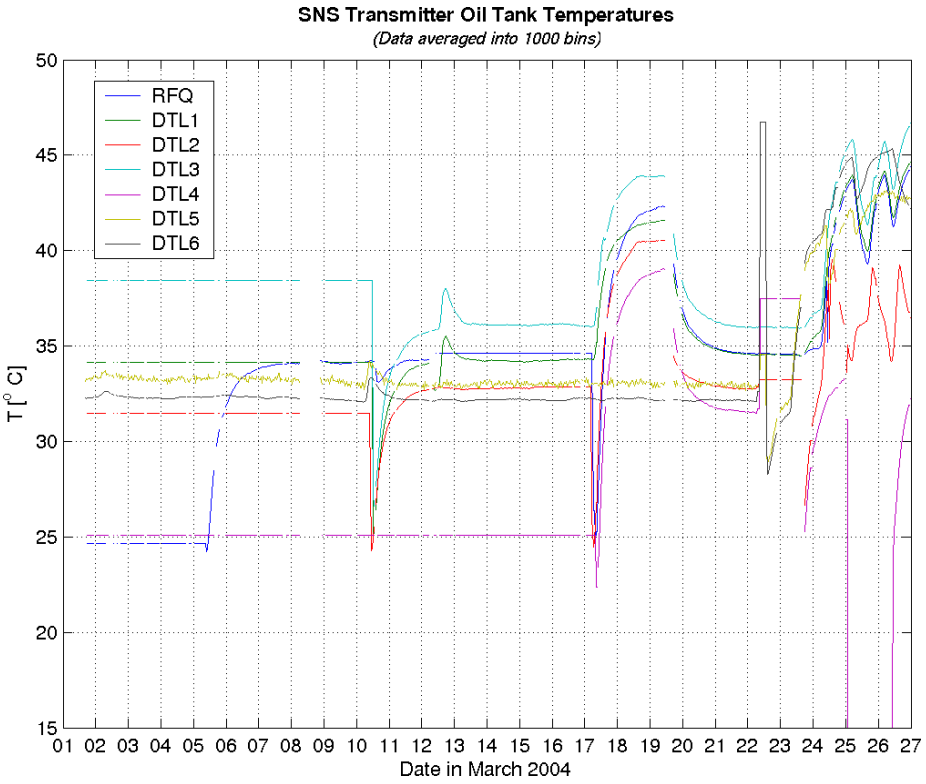

Figure 4.6: Matlab Example: One-month overview of Klystron oil tank temperatures. The raw data was reduced by averaging into 1000 bins as described in section 2.7.4, allowing for easier post-processing, and temperatures were converted to Celsius. Comparison with fig. 4.5 shows how many details can be lost via averaging, so it must be applied with caution.

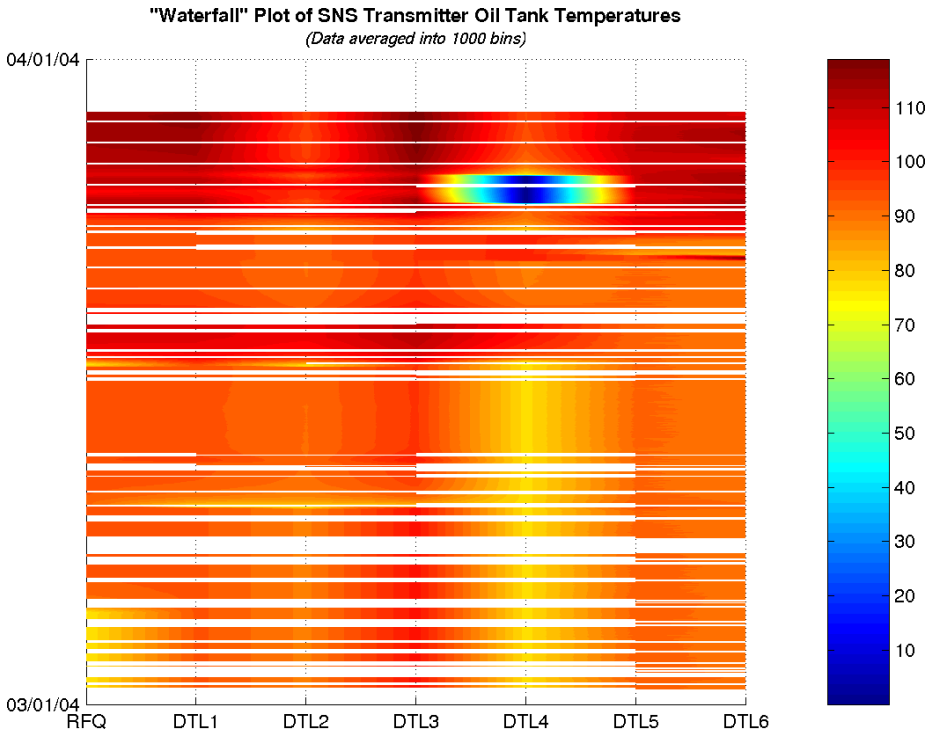

Figure 4.7: Matlab Example: The same data as in 4.6 displayed as a "Waterfall" plot. This type of display hides almost all the detail of the individual channels. Outliers, however, stand out like the possible sensor problem on DTL4, which is why this display method is well suited for an initial investigation of many channels. The example also shows gaps in the data caused by the many times when the archive engine was stopped during the ongoing tests of the new archive engine.

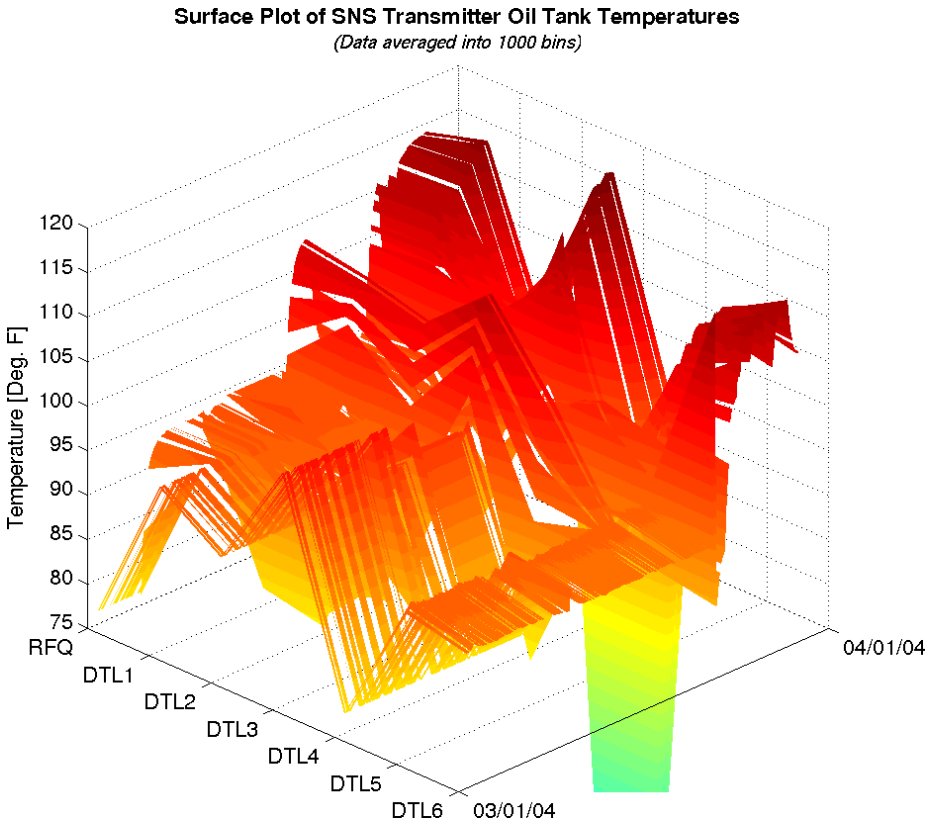

Figure 4.8: Matlab Example: Again the same data as in 4.6 displayed as a surface plot. Tools like Matlab allow the user to rotate this plot in real-time, which might be useful for the inspection of certain channels.

Chapter 5

Example Setup

The following describes how the archiver toolset is used at the Spallation Neutron Source (SNS), and the scripts in the ChannelArchiver/ExampleSetup directory assist with the setup as described in here. We distinguish between two types of computers:

- Sampling Computer:
  A computer that runs ArchiveEngine instances.
- Serving Computer:
  A computer that uses the ArchiveIndexTool to create additional binary indices and runs the ArchiveDataServer.

There might be more than one 'sampling' computer as well as more than one 'serving' computer. A single machine might perform both functions, but in general they can be different computers on the network, and hence some tools are required to make the data collected on the "sampling" computer available on the "server". One could use NFS, but we have decided to use secure copy (scp) in order to decouple the computers as best as possible.

We want to be able to move an engine from one computer to another, and still keep an overview. Therefore a file "/arch/archiveconfig.xml" describes the complete archive setup: Which engines run where, and how the data gets served. On some computers, for example ics-srv-archive1, further subdirectories of "/arch" are used to run engines. On another computer, for example ics-srv-web2, subdirectories contain data copied from archive1 so that the data server can serve it.

5.1 archiveconfig.xml

Each computer needs to have the same copy of /arch/archiveconfig.xml. You might generate and distribute that file manually or use a relational database. People who have used previous releases of the archive toolset might remember

the archiveconfig.csv file. There is a tool convert_archiveconfig_to_xml.pl to convert that file into an archiveconfig.xml skeleton.

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<!DOCTYPE archiveconfig SYSTEM "archiveconfig.dtd">
<archiveconfig>
  <root>/arch</root>

  <serverconfig>/var/www/serverconfig.xml</serverconfig>

  <mailbox>/arch/xfer</mailbox>

  <daemon directory='RF'>
    <run>archive1</run>
    <desc>RF</desc>
    <port>4900</port>
    <dataserver>
      <index type='binary' key='10'>RF</index>
      <host>web2</host>
    </dataserver>
    <engine directory='llrf'>
      <run>archive1</run>
      <desc>LLRF</desc>
      <port>4901</port>
      <restart type='weekly'>We 10:20</restart>
      <dataserver>
        <current_index key='4901'>llrf</current_index>
        <index type='binary'>LLRF data</index>
        <host>web2</host>
      </dataserver>
    </engine>
  </daemon>
</archiveconfig>
```

Listing 5.1: archiveconfig.xml

The archiveconfig.xml file describes the complete archive layout, using the following elements:

- root: Names the root directory, typically '/arch'. This has to be the same directory name on all computers, since they all use the same archiveconfig.xml.
- serverconfig: Location of the server configuration to be created. See section 5.10.1.

- mailbox: Used to communicate from the ArchiveDaemons to the data server.
- daemon: Configures an archive daemon and its engines, described in section 5.2.2, as well as how that data should be indexed and served, see sections 5.10.1 and 5.10.2.

5.2 "Sampling" Computer

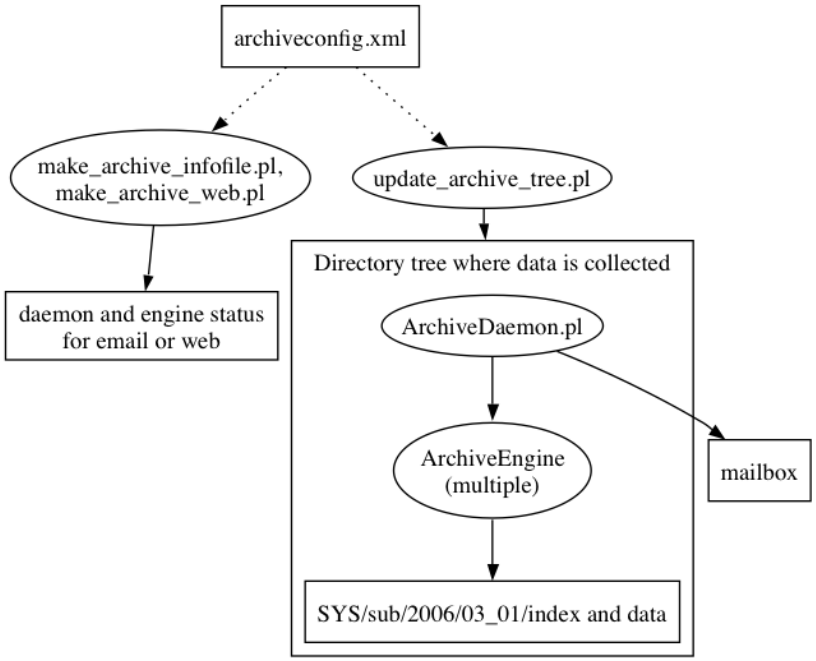

Figure 5.1: Tools used on a sampling computer, refer to text.

Instead of running just one archive engine, it is often preferred to run several, and even restart them weekly. This way, people working on different subsystems can each use configure engines for only their systems without interfering with each other. The periodic restarts, creating different sub-archives for example each week, limit the possibility for data loss in case an engine crashes or creates corrupt archives.

For each subsystem (examples: Vacuum, Cooling, ...), a "Daemon" program manages one or more engines. Initially and after every change to the configuration, the update_archive_tree script is used to create the necessary infrastructure.

5.2.1 update_archive_tree.pl

This script will read archiveconfig.xml and create all the subdirectories, daemon config files, and skeleton engine configurations. Run it with ”-h” to see available options.

5.2.2 ArchiveDaemon

ArchiveDaemon.dtd ArchiveDaemon.pl ArchiveDaemon.xml start_daemons.pl stop_daemons.pl

Figure 5.2: Archive Daemon, refer to text.

The ArchiveDaemon is a script that automatically starts, monitors and restarts ArchiveEngines on the local host. It includes a built-in web server, so by listing all the ArchiveEngines that are meant to run on a host in the ArchiveDaemon's configuration file, one can check the status of all these engines on a single web page as shown in Fig. 5.2.

Chapter 5, “Example Setup”, on page 50, gives more details on the suggested use of the ArchiveDaemon. The daemon will attempt to start any ArchiveEngine that it does not find running. In addition, the daemon can periodically stop and restart ArchiveEngines in order to create e.g. daily sub-archives. Furthermore, it adds information about each sub-archive of newly created ArchiveEngines to a mailbox directory so that the index mechanism can create the necessary indices and update the data server configuration.

Before using the ArchiveDaemon, one should be familiar with the configuration of the ArchiveEngine (sec. 3), and how to start and stop it. Furthermore, one needs to be familiar with the ArchiveIndexTool (sec. ??).

5.2.3 Configuration

The ArchiveDaemon expects to find a configuration file called “ArchiveDaemon.xml” in the directory where it is started. That configuration file, an example of which can be found in listing 5.2, needs to follow the DTD from listing 5.3.

In many cases you might not configure the daemon yourself, but instead use the mechanism described in chapter 5.

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<!DOCTYPE engines SYSTEM "ArchiveDaemon.dtd">
<engines>
    <engine>
        <desc>Demo</desc>
        <port>4813</port>
        <config>/arch/RF/llrf/llrf.xml</config>
    </engine>
    <engine>
        <desc>Demo 2</desc>
        <port>4814</port>
        <config>/arch/RF/hprf/hprf.xml</config>
        <daily>02:00</daily>
        <copy>dataserver:/arch/RF/hprf</copy>
    </engine>
</engines>
```

Listing 5.2: Example Archive Daemon Configuration

The configuration lists all the ArchiveEngines that the daemon should manage on the local computer. One “engine” element per ArchiveEngine specifies the configuration of each engines. Specifically, the following tags are allowed:

desc

This mandatory element is used for the “-description” option of the Archive Engine, see section 3.2.3.

port

This mandatory element determines the port number of the engine’s HTTP server, see section 3.2.4.
NOTE: The ArchiveDaemon itself requires a TCP port number for its HTTP server. The port numbers used by the ArchiveDaemon and all the Archive Engines need to be different. You cannot use the same port number more than once per computer.

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- DTD for the ArchiveDaemon Configuration -->
<!ELEMENT daemon (port, mailbox?, engine*)>

<!ELEMENT port    (#PCDATA)> <!-- TCP port number    -->
<!ELEMENT mailbox (#PCDATA)> <!-- /path              -->

<!ELEMENT engine (desc, port, config, restart?, dataserver?)>
<!ATTLIST engine directory CDATA #REQUIRED>

<!ELEMENT desc    (#PCDATA)> <!-- Text               -->
<!ELEMENT config (#PCDATA)> <!-- path               -->

<!ELEMENT restart (#PCDATA)> <!-- path               -->
<!ATTLIST restart type (weekly|daily|hourly|timed) #REQUIRED>
<!-- weekly  Mo|Tu|...|Su HH:MM
     daily   HH:MM
     hourly  (double) hours
     timed   HH:MM/HH:MM
             (start/duration)
  -->

<!ELEMENT dataserver (host?)>
<!ELEMENT host (#PCDATA)>
```

Listing 5.3: XML DTD for the Archive Daemon Configuration

config

This mandatory element must contain the path to the configuration file of the respective ArchiveEngine, see section 3.1. This can be either the full path to the engine configuration file or a path beneath the current working directory in which the ArchiveDaemon is running.

daily

This optional element configures the ArchiveDaemon to restart the ArchiveEngine periodically. The element must contain a time in the format “HH:MM” with 24-hour hours HH and minutes MM. One example would be “02:00” for a restart at 2 am each morning.

weekly

Weekly is similar to daily, but using an element that contains the day of the week (Mo, Tu, We, Th, Fr, Sa, Su) in addition to the time on that day in 24-hour

format, e.g. “We 08:00”. In this example, the daemon will attempt a restart every Wednesday, 8’o clock in the morning.

timed

In this case, the element needs to contain a start/duration time pair in the format “HH:MM/HH:MM”. The first, pre-slash 24-hour time stamp indicates the start time, and the second 24-hour time, trailing the slash, specifies the runtime. The engine will be launched at the requested start time and run for the duration of the runtime. As an example, “08:00/01:00” requests that the daemon starts the engine at 08:00 and stops it after one hour, probably around 09:00.

hourly

This optional element configures the ArchiveDaemon to restart the ArchiveEngine periodically. The element must contain a number specifying hours: A value of 2.0 will cause a restart every 2 hours. The hourly restart is quite inefficient and primarily meant for testing.

5.2.4 Starting and Running

The ArchiveDaemon is a perl script that is typically started like this:

```
$ cd whereever_you_placed_ArchiveDaemon.xml
$ perl ArchiveDaemon.pl -f ArchiveDaemon.xml
Read ArchiveDaemon.xml, will disassociate from terminal
and from now on only respond via
          http://localhost:4610
You can also monitor the log file:
          ArchiveDaemon.log
```

One can use any web browser to connect to the daemon’s HTTP server under the URL shown in the above status message. Fig. 5.2 shows one example. The ArchiveDaemon offers a command line option for selecting a specific TCP port. Whenever running more than one ArchiveDaemon per computer, they need to be started with different TCP port numbers. Furthermore, each ArchiveEngine needs a different TCP port number.

```
USAGE: ArchiveDaemon [options]
Options:
  -p <port>     : TCP port number for HTTPD
  -f <file>     : config. file
  -i <URL>      : path or URL to indexconfig.dtd
  -u <minutes> : Update period for master index
  -d            : debug mode (stay in foreground etc.)
```

The first few lines of the ArchiveDaemon.pl script contain numerous configuration variables. They allow fine tuning of e.g. how often the daemon queries the Archive Engines and other customization options. In there you can also change many of the file names from their defaults up to the point where none of the following applies. With the original settings, the ArchiveDaemon will create or use the following files in the directory in which it was started:

- ArchiveDaemon.log
  The log file of the ArchiveDaemon.

- indexconfig.xml
  This is a configuration file for the ArchiveIndexTool. If the file already exists, the ArchiveDaemon will add every new sub-archive that it creates to the file. If the file does not exist, one will be created the next time a new sub-archive is started.

  Note that the ArchiveDaemon will *not* search for sub archives or index files and automatically add them to indexconfig.xml. It will only add newly created sub-archives. If you already have sub-archives that need to be included in the master index, your initial indexconfig.xml needs to list them. Also note that the ArchiveDaemon reads this file on startup. In order to *remove* indices from indexconfig.xml, it is therefore required to stop the running daemon, since it will otherwise overwrite indexconfig.xml with its in-memory version.

- indexupdate.xml
  This file is similar to indexconfig.xml, except that the index files for sub-archives that are older than the master index file are commented out, assuming that the master index already contains all the information from those older sub-archives. Running ArchiveIndexTool with this indexupdate file is naturally faster than using indexconfig.xml. The ArchiveDaemon uses the full index configuration from indexconfig.xml once after startup, and then switches to indexupdate.xml.

- ArchiveIndexTool.log
  The log file of the last run of the ArchiveIndexTool.

- master_index
  The ArchiveIndexTool is run with indexconfig.xml to update this master index file.

The ArchiveDaemon configuration file must list the full path names to the configuration files for the ArchiveEngines or use a path that is below the current working directory of the ArchiveDaemon. Within each of those directories, an ArchiveEngine is run and the following files will be created:

- ArchiveEngine.log
  A log file for the ArchiveEngine running in that directory

- archive_active.lck
  Lock file of the ArchiveEngine

- YYYY/MM_DD/index
  A subdirectory for index and data files of the sub-archive. If the ArchiveDaemon is configured to perform daily restarts, the format uses the year, month and day to build the path name.

5.2.5 Daemon's Web Pages

The main web page of the ArchiveDaemon's HTTPD looks similar to Fig. 5.2. You can use any web browser to look at the daemon's web pages. The URL follows the format

```
http://host:port
```

where "host" is the name of the computer where the ArchiveDaemon is running. More often than not you will use "localhost". "Port" is the TCP port that was specified as a command-line option to the ArchiveDaemon program, otherwise it defaults to 4610. So the default URL will be http://localhost:4610.

The main page lists all the archive engines that this daemon controls with their status. The first column also contains links to the individual archive engines. The status shows any of the following:

- "N/M channels connected"
  This means the ArchiveEngine is running and responding, telling us that N out of a total of M channels have connected. If not all channels could connect, you might want to follow the link to the individual engine to determine what channels are missing and why: Is an IOC down on purpose? Is an IOC disconnected because of network problems? Does a channel simply not exist, i.e. the engine's configuration is wrong?

- "Not Runnnig"
  This means that the respective ArchiveEngine did not respond when we queried it, and there is no "archive_active.lck" lock file. This combination usually means that the engine is really not running (except for the Note below).

  The first step in debugging would be to check the engine's directory for a log file. Does it indicate why the engine could not start? Then check the daemon's log file. It should list the exact command used to start the engine. You can try that manually to check why it didn't work.

- "Unknown. Found lock file"
  This means that the respective ArchiveEngine did not respond when we queried it, but there is an "archive_active.lck" lock file. This could have two reasons. It could mean that the engine is running but it was temporarily unable to respond to the daemon's request. An example would be that

the engine is really busy writing and dealing with ChannelAccess, so that its web server had to wait and the daemon timed out. All should be fine again after some time.

If, on the other hand, the situation persists, it usually means that the engine is hung or has crashed, so that it does not respond and the lock file was left behind. See Crashes on page ??.

NOTE: The daemon queries only every once in a while and leave the engines alone for most of the time. Especially after startup, all engines will show up as "Not Running" in the daemon's web page while in fact most of them are already running. Then you will see many disconnected channels while the engines did in fact already connect to all channels. If you are impatient, you can click on the links to the individual engines to get a more up-to-date snapshot of each engine's status.

5.2.6 Disabling Engines

The web interface of the daemon contains a link for each engine that disables the engine. This places a file "DISABLED.txt" in the engine directory and stops the engine. The daemon will not attempt to start engines as long as the "DISABLED" file is found. This is a convenient way for temporarily disabling engines without removing them from the daemon's configuration.

5.2.7 Stopping and More

To stop the ArchiveDaemon, access the "/stop" URL of the daemon's HTTPD, e.g. "http://localhost:4610/stop". Similar to the ArchiveEngine's HTTPD, this URL is not accessible by following links on the HTTPD's web pages. You will have to type the URL. This is to prevent web robots or a monkey who is sitting in front of the computer and clicking on every link from accidentally stopping the daemon. Finally, the daemon will respond to the URL "/postal" by stopping every ArchiveEngine controlled by the daemon, followed by stopping itself.

5.2.8 Status Information

engine_write_durations.pl make_archive_infofile.pl make_archive_web.pl show_engines.pl show_sizes.pl

5.3 Indices

update_indices.pl

5.4 Data Server

update_server.pl

ALL THE REST NEEDS TO BE REVIEWED!

We intend to run one "ArchiveDaemon" for the Integrated Control System (ICS) and one for the channels related to Radio Frequency (RF). ArchiveDaemon, described in full detail in chapter 5.2.2, starts archive engines and monitors their operation. The ICS daemon should maintain one ArchiveEngine for the timing system (tim) and one for the machine protection system (mps), while the RF daemon has one engine for the low-level and one for the high power RF (llrf, hprf).

This separation is somewhat arbitrary. We could have made "llrf" and "hprf" channel groups under one and the same engine. In fact all the above could reside within one engine. It is, however, advisable to spread the channels over different daemons and engines whenever different people deal with the IOCs that host the channels, so that the engineers can independently configure their archiving. In addition, you want to keep the amount of data collected by each engine within certain bounds, for example: not more than one CD ROM per month, one DVD per year, or whatever you plan to do for data maintenance. Another reason is data safety: You can reduce the damage caused by crashes of the engine by limiting the number of channels per engine.

5.5 Current Archive Status

The perl script "make_archive_web.pl" creates a web page displaying the current status of all the archive daemons and engines that are listed in the file "archiveconfig.csv" (you could use other names for the main configuration file, but we will stick with "archiveconfig.csv" in this manual). For the SNS, this script is periodically executed with the result being redirected into the web server's document tree, so you can usually reach the recent status from this web page:

http://ics-srv-archive1/archive

Fig. 5.3 shows one example of that web page: A tabular display of what engines are running, how many channels are connected, and more.

5.6 Directory Layout

The perl script "make_archive_dirs.pl" creates or updates a directory tree based on the file "archiveconfig.csv". For the preceding example, it would create subdirectories "ICS" and "RF" for the two daemons, plus the following engine directories:

ICS/tim
ICS/mps

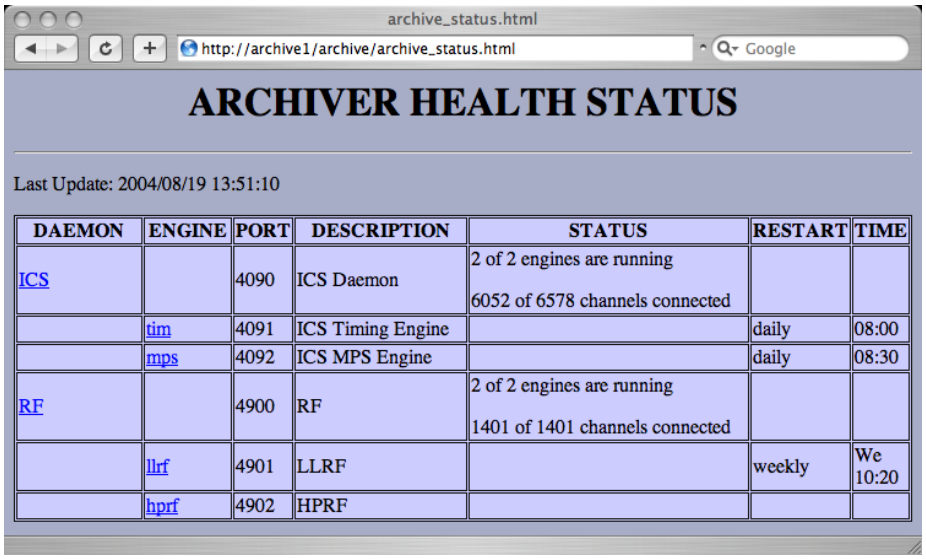

Figure 5.3: Example of the archive status web page generated by the make_archive_web.pl script.

RF/llrf
RF/hprf

Each daemon directory contains a daemon configuration file as well as start/stop scripts. Each engine directory contains a script to stop the engine. Note the absence of a script to start the engine: You should not manually start engines which are under the control of an archive daemon. Each engine directory also contains an "ASCIIConfig" subdirectory with a script "convert_example.sh" that you might use to create the XML configuration file for the ArchiveEngine from ASCII configuration files, though the engineer responsible for the subsystem is free to use any method of his/her choice as long as the result is a configuration file for the engine that follows the naming convention

Daemon-Name/*Engine-Name*/*Engine-Name*-group.xml ,

resulting in these for our example:

ICS/tim/tim-group.xml
ICS/mps/mps-group.xml
RF/llrf/llrf-group.xml
RF/hprf/hprf-group.xml

As long as you end up with engine configuration files of these names, you can employ any text editor, a copy of the example script, or a sophisticated toolset utilizing a relational database. If you want to use the ASCIIConfig directory, check section ?? for the format of the ASCII configuration files.

5.7 Sub-Archives

Based on the configuration from the beginning of this chapter, the daemon will

1. Start an ArchiveEngine in “RF/llrf” that writes to a sub-archive named after the current day, e.g. “RF/llrf/2004/02_11/index”. Same for a second engine in “RF/hprf”.
2. Periodically verify if engines that are supposed to run are actually running, attempting to start engines which are found missing.
3. Stop the ArchiveEngines each Wednesday at 10:20 respectively 10:30 and restart them in new subdirectories (using the data of the restart for the path to the index file).
4. Generate or update “RF/indexconfig.xml” whenever a new sub-archive is created for the vacuum or cooling data.
5. Periodically run ArchiveIndexTool on “RF/indexconfig.xml”, generating or updating “RF/master_index”.
6. Provide a web page that lists the status of the two archive engines.

As a result, we create separate sub-archives for the LLRF and HPRF, a new one once per week, which provides some insurance against crashes of an ArchiveEngine. If you are paranoid, you can choose daily sub-archives; compare the ICS setup from the beginning of chapter 5. After running for a while, we will have created sub-archives like these:

```
RF/llrf/2004/02_11/index
RF/llrf/2004/02_18/index
RF/llrf/2004/02_25/index
...
RF/hprf/2004/02_11/index
RF/hprf/2004/02_18/index
RF/hprf/2004/02_25/index
...
```

In addition to each index file, there will of course also be associated data files, but for retrieval purposes we identify an archive solely by its index file: We can invoke e.g. ArchiveExport with the path to any of the index files. This is, however, inconvenient because we will only see data for one week of that one subsystem at a time. The periodic invocation of the ArchiveIndexTool allows us to view all the RF data as a whole via the RF/master_index.

5.7.1 ArchiveDaemon Details

The “Restart” and “Time” columns of the “archiveconfig.csv” file are passed on to the ArchiveDaemon, which is explained in more detail in chapter 5.2.2. In many cases it might be sufficient to know these two options:

- Restart="daily", Time set to the time of day in 24-hour format HH:MM, e.g. 08:00 for 8'o clock in the morning. The daemon will stop and restart the engine in a new sub-archive each day at the given time.
- Restart="weekly", Time set to a string that combines the day of the week (Mo, Tu, We, Th, Fr, Sa, Su) with the time of day in 24-hour format into "DD HH:MM", e.g. "We 08:00" for Wednesdays, 8'o clock in the morning. Similar to the daily setup, but reduced to once a week.

It is advisable to stagger the restart times of your engines such that they don't all restart at the same day and time in order to reduce the CPU and network load for the ChannelAccess re-connects.

5.8 Common Tasks

5.8.1 Check Daemon, Engine, Connected Channels, ...

See section 5.5. That web page links to all the ArchiveDaemons, which in turn link to all the ArchiveEngines.

5.8.2 Modify Engine's Request Files

Locate your archive engine on either the main archive status page (section 5.5) or in /arch/archiveconfig.csv. According to the example at the beginning of this chapter, the "High Power RF" engine would be run by the "RF" daemon and be called "hprf", so we need to modify /arch/RF/hprf/hprf-group.xml. This is often done via a conversion script in /arch/RF/hprf/ASCIIConfig. If you used another method to create the engine configuration, this is a good time to remember what you did.

Then, to actually use that new config file, the engine needs to restart. We could simply wait for the next scheduled restart, in our example the next Wednesday, 10:30. Alternatively, we can run the script /arch/RF/hprf/stop-engine.sh. Watch the RF daemon via the link on the main archive status page. Within a few minutes, it ought to detect that the engine had stopped and then restart it.

5.8.3 Add Engine or Daemon

Add a line to archiveconfig.csv to define the new engine under an existing demon. Or add a line for a new daemon, then add the new engine under it. Invoke make_archive_dirs.pl. Per default, it will re-create all daemon and engine directories, so you might want to use the "-s" option to limit its operation to the new or modified subsystem. In case the daemon was already running, it won't learn about the new engine unless you restart it. So run the "stop-deamon.sh" and then invoke the "run-daemon.sh" script in the daemon directory to start the daemon (which will then start any missing engines).

5.8.4 An Engine isn't running

Check the process list to assert that the engine in question is really not running (on UNIX, try "ps -aux"). Look again. If the engine is actually running but not responding via its HTTPD, remove the process. Check the log file of the engine, generated in the engine subdirectory, for any clues. If you are convinced that the engine is not running, but find an "archive_active.lck" lock file in the engine directory, remove it. Now the daemon should be able to start your engine.

5.8.5 I want to stop a Daemon

Run stop-daemon.sh in the daemon directory, or check section 5.2.2 for more on the daemon's HTTPD.

5.8.6 A Daemon isn't running

Run start-daemon.sh in the daemon directory. If the daemon keeps quitting, check its log file for clues.

5.8.7 Re-building a Master Index

Whenever you add or remove a sub-archive, the master index in the daemon directory could be obsolete: It might still list data in a sub-archive that you removed, or it might not yet include the new sub-archive. Another szenario: you suspect that the master index is broken, because you can retrieve data from the individual sub-archive but not via the master index. The recipe:

- Stop the daemon
- Check, maybe rebuild indexconfig.xml, either manually or by using the helper script make_indexconfig.pl (see section ??).
- Start the daemon, which causes it to invoke the ArchiveIndexTool.

5.9 Data Management

The generation of daily sub-archives reduces the amount of data that might be lost in case an ArchiveEngine crashes and cannot be restarted by the ArchiveDaemon to one day. In the long run, however, it is advisable to combine the daily sub-archives into bigger ones, for example monthly. The smaller number of sub-archives is easier to handle when it comes to backups. Is also provides slightly better retrieval times. Depending on your situation, monthly archives might either be too big to fit on a CD-ROM or ridiculously small, in which case you should try weekly, bi-weekly, quarterly or other types of sub-archives.

In the following example, we assume that it's March 2004 and we want to combine the two daily vacuum sub-archives from the previous section into one for the month of February 2004:

```
cd vacuum/2004
mkdir 02_xx
ArchiveDataTool -copy 02_xx/index 02_19/index \
    -e "02/20/2004 02:00:00"
ArchiveDataTool -copy 02_xx/index 02_20/index \
    -s "02/20/2004 02:00:00" -e "02/21/2004 02:00:00"
```

Note that we assume a daily restart at 02:00 and thus we force the ArchiveDataTool to only copy values from the time range where we expect the sub-archives to have data. This practice somewhat helps us to remove samples with wrong time stamps that result from Channel Access servers with ill-configured clocks.

There is a perl command make_compress_script.pl that aids in the creation of a shell script for the ArchiveDataTool, but you need to review it carefully before invokation. After successfully combining the daily sub-archives for February 2004 into a monthly 2004/02_xx, we need to

1. Stop the ArchiveDaemon because we are about to edit indexconfig.xml. The ArchiveEngines controlled by the daemon can run on.
2. Edit indexconfig.xml that listed the daily sub-archives for Feb. 2004 and replace them with the single 2004/02_xx/index.
3. Remove or rename the master index file and re-create it with the new indexconfig.xml. This step is required because the ArchiveIndexTool will only add new data blocks to the master index, it will not remove existing ones. Since we no longer want to refer to the daily sub-archives, we need to recreate the master index.
4. Start the ArchiveDaemon again, check its online status.
5. One may now move the daily sub-archives that are no longer required to some temporary location. A month later, when we are convinced that nobody is still trying to use them, we can delete them.

5.10 "Serving" Computer

5.10.1 update_server.pl

.

5.10.2 update_indices.pl

.

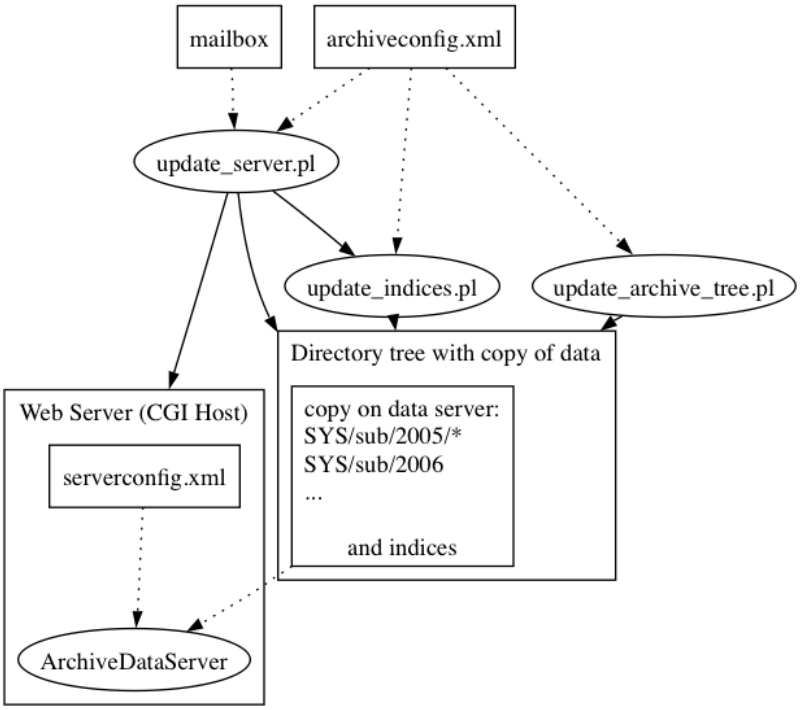

Figure 5.4: Tools used on a serving computer, refer to text.