DIMM Software Overview
SAI MASS/DIMM & tau-tec software modules

General overview, Protocol, Extensions and Installation

Version 1.1

Document ID:

`dev-dimm-general:spec-en`

Revision 250 as of February 7, 2020 10:47:35

Revision history:

Date	Version	Changes
22.01.2020	1.0	Initial Version (mv)
07.02.2020	1.1	Proof-reading (mr, mv)

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Document ID: `dev-dimm-general:spec-en`
Revision 250 as of February 7, 2020 10:47:35 by Michael Ruder

`dev-dimm-general_spec-en.lyx 250 2020-02-07 10:47:35Z ruder`

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1 Preface

This document gives an overview over the Kornilov DIMM software and the tau-tec parts replacing parts of the Kornilov DIMM software (`tt-scope`, `tt-dome-astrohaven`, `tt-meteo`) or fixing/extending it (`tt-master`, `ameba`, `dimm-tool`, `preat`).

The communication structure and therefore the command hierarchy are depicted in figure 1 with `tt-master` on top as the main instance controlling the other programs and the hardware devices at the bottom. `ameba` is enabling the observation, selecting the used target (from a special target catalog[10]) and synchronizing the mount with the camera capturing. `preat` analysis the raw values[3] from `dimm-tool` and creates the log files with final seeing data.

See the preat manual[3] and its bibliography[12, 4, 11] for a starting point of how the data is analyzed and what formulas were used.

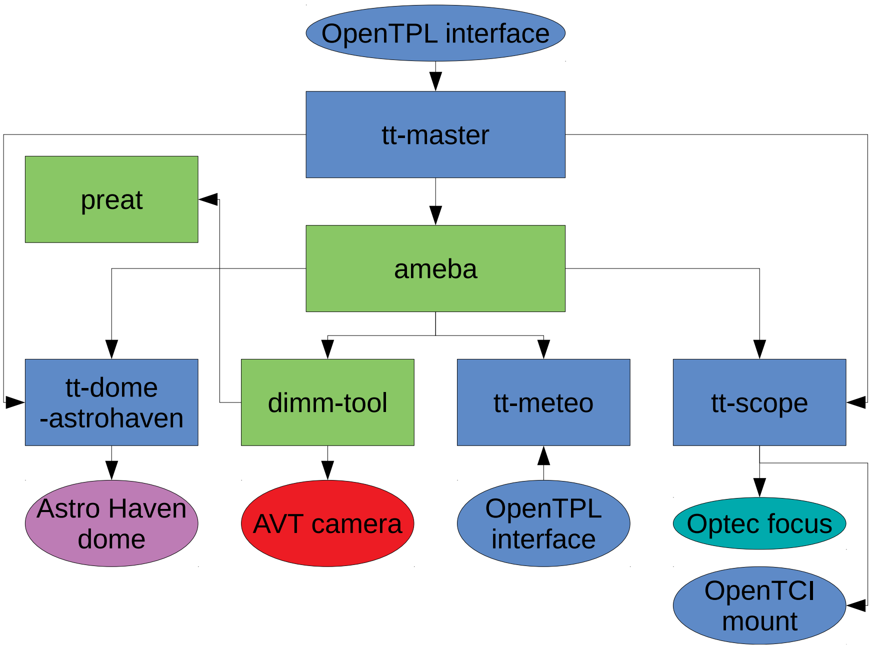

Figure 1: Structure of the programs (Kornilov programs in green, tau-tec software in blue)

2 Accessing the software

2.1 Opened ports

program	port	protocol
dimm-tool	16200	Kornilov
ameba	16201	Kornilov
tt-meteo	16300	Kornilov
	16301	OpenTPL
tt-dome-astrohaven	16302	Kornilov
tt-scope	16400	Kornilov
tt-master	16500	OpenTPL

2.2 Kornilov protocol

The protocol used by the software from Kornilov et al. and the command structure was derived using the software documentation [5], checking the source code of the Kornilov software and running the programs.

2.2.1 Basic protocol

Some extensions/generalizations were made to the Kornilov protocol, used by `tt-scope`, `tt-dome-astrohaven`, `tt-meteo` — this is noted in the explanation below.

Therefore this plain-text, client-server protocol is working this way:

- Commands are send from the client and are prepended with a freely chosen command id (unsigned integer).
- There are three command types and some special commands:
  - *`cmdid`* `GET` *`VAR`*`[ `*`VAR`*`]*` to acquire a value from the server/device. Concatenation of variables might be limited and every program registers its own set of values.

    Note: For tau-tec programs concatenating values can be done freely, as long as the interface provides these values.
  - *`cmdid`* `SET` *`VAR`*`=`*`VALUE`*`[ `*`VAR`*`=`*`VALUE`*`]*` to set a value at the server/device, but this should no alter e.g. any movement. Concatenation of variables might be limited and every program registers its own set of values.

    Note: For tau-tec programs concatenating values can be done freely, as long as the interface provides these values.
  - *`cmdid`* `RUN` *`VAR`*`(=`*`VALUE`*`)[ `*`VAR`*`(=`*`VALUE`*`)]*` runs an action on the device to change the working state, e.g. move to another star. Concatenation of variables might be limited and every program registers its own set of values.

    Note: For tau-tec programs concatenating values can be done freely, as long as the interface provides these values.
  - *`cmdid`* `INIT` the program is initialized and a connection is established. Before triggering this command, other commands, especially `RUN`, might be locked.

    Note: For tau-tec programs sending this command will power up the device — the connection is established beforehand, therefore `GET` commands work right after establishing a connection.
  - *`cmdid`* `PARK` “Park” the device and switch off power (if possible).
  - *`cmdid`* `QUIT` Closes the connection without further notice.
  - *`cmdid`* `STOP` The device is powered down. This is also triggered when no client is connected to the server anymore.
  - *`cmdid`* `SHUTDOWN` The server is shut down cleanly.

    Note: This is an extension by tau-tec and works therefore only for `tt-scope`, `tt-dome-astrohaven`, `tt-meteo`.
- A `RUN`, `INIT` and `PARK` command is answered immediately by the server (if parsing delivered no error) with an estimation of the maximal run-time (in seconds), prepended by the command id chosen by the client:

  - `cmdid OK WAIT=WAITTIME`

- All commands are answered by the server with different finish codes, prepended by the command id chosen by the client:
  - `cmdid ERROR STATUS=ERSYN` Syntax error when parsing the sent command.
  - `cmdid ERROR STATUS=ERFAT` Fatal error preventing the execution of the request, such as device not initialized with `init`.
  - `cmdid [OK|ERROR] STATUS=PARKED` The device is not initialized yet, and the result of the command was either `OK` or delivered an `ERROR`.
  - `cmdid [OK|ERROR] STATUS=BUSY` A blocking `RUN` command is running, and the result of the command was either `OK` or delivered an `ERROR`.
  - `cmdid OK STATUS=READY` The request was executed successfully and the device is up and running.

2.2.2 Common variables

Common commands are available for every Kornilov server.

Available commands are:

- `GET` variables:
  - `STATUS` returns only `cmdid OK STATUS=[BUSY|READY|PARKED]` as like for every other command, but with no more lines afterwards.
  - `IDENT` returns `cmdid IDENT="Polar mount daemon Vers. 0.37"` with an explanation of the connected program embedding the Kornilov server.
  - `ERROR` returns `cmdid STATUS=READY` if no error happened or e.g. `cmdid ERROR="2018-10-11 07:31:03.52 (642) No RS485 device - RS485 status error"` with a detailed error message.

2.2.3 tt-meteo

The values provided to the OpenTPL server (see section 2.3.1 on page 10) can be requested from the Kornilov server.

Available commands are:

- `GET` variables forwarding the values provided to the OpenTPL server:
  - `DATA` returns `cmdid TEMP=FLOAT WIND=FLOAT WIND_DIR=INT RH=[0..100] DEW_P=INT PRESS=INT RAIN=[0|1]`
  - `SKY` returns `cmdid TEMP_AMB=FLOAT TEMP_SEN=FLOAT TEMP_SKY=FLOAT SKY=[1..4]`

2.2.4 tt-dome-astrohaven

The implementation of a Kornilov-server connecting an Astro Haven dome over a serial connection [1] on page 23.

Available commands are:

- `GET` variables:
  - `DOME` returns:
    - `DOME=UNDEFINED` when not fully opened/closed or target position reached
    - `DOME=OPENED` when fully opened
    - `DOME=CLOSED` when fully closed
    - `DOME=STATED` when target position was reached
  - `POSITION` returns *`cmdid`* `SIDE_A=[0.0 .. 1.0] SIDE_B=[0.0 .. 1.0]` with 0.0 being closed and 1.0 being fully opened.
  - `ZENITH_ANGLE` returns *`cmdid`* `SIDE_A_ZENITH_DIST=[0.0 .. 90.0] SIDE_B_ZENITH_DIST=[0.0 .. 90.0]` with 0.0 being closed and 90.0 being fully opened.
- `SET` variables:
  - `SIDEA=[0.0 .. 1.0|OPEN|CLOSE]` Set up the target position for the first dome side.
  - `SIDEB=[0.0 .. 1.0|OPEN|CLOSE]` Set up the target position for the second dome side.
  - `DOME=[0.0 .. 1.0|OPEN|CLOSE]` Set up the target position for the both dome side.
- `RUN` variables:
  - `SIDEA(=[0.0 .. 1.0|OPEN|CLOSE])` Move the first dome side to the given position, or the position set up with the according `set` command before.
  - `SIDEB(=[0.0 .. 1.0|OPEN|CLOSE])` Move the second dome side to the given position, or the position set up with the according `set` command before.
  - `DOME(=[0.0 .. 1.0|OPEN|CLOSE])` Move both dome sides to the given position, or the positions set up with the according `SET` commands before.

    Note: Moving the dome with `OPEN` or `CLOSE` is an extension for `tt-dome-astrohaven`.

2.2.5 tt-scope

This program connects an OpenTCI[7] or OpenTSI[9] mount using the OpenTPL protocol[8], and a Optec TCF-Si focuser by a serial connection[6] and transforms these to a Kornilov scope interface.

Guiding is not implemented, as the tracking precision is way better than the mount used with the original Kornilov software.

Available commands are:

- `GET` variables:
  - `RA` the current pointing in right ascension with J2000 equinox returns *`cmdid`* `RA=hh mm ss`.
  - `DEC` the current pointing in declination with J2000 equinox returns *`cmdid`* `DEC=dd mm ss`.
  - `FOCUS` the current focus position in instrumental steps returns *`cmdid`* `FOCUS=`*`FLOAT`*.
  - `SCOPE` returns:

        - `SCOPE=PARK` when mount is not fully powered up. Powering up fails, if a mount device reports an event preventing it from being switched on. See `GET EVENTS` how to solve this.
        - `SCOPE=SLEW` is reported when the mount is referencing or moving to another position.
        - `SCOPE=STAND` is reported if the mount is currently stopped and not moving.
        - `SCOPE=TRACKING` is reported if the mount is currently following an object.
        - The request fails if the telescope cannot be used see the `GET ERROR` for the detailed explanation.
    - `AZ` the current pointing in horizontal azimuth [degree].
    - `ALT` the current pointing in horizontal altitude [degree].
    - `EVENTS` acquire the currently reported telescope events (in either OpenTCI[7] or OpenTSI[9] format depending on the mount system).

      Note: This is an extension for `tt-scope` not available in Kornilov scopes.
    - `DOME`, `POSITION`, `ZENITH_ANGLE`, `LIGHT` and `TEMP` are supported but not used, as the mount also supports handling a dome, but this is not used for DIMM systems.
- `SET` variables:
    - `RA=`*`VALUE`* the target right ascension in J2000 equinox [hours].
    - `DEC=`*`VALUE`* the target declination in J2000 equinox [degree].
    - `AZ=`*`VALUE`* the target azimuth [degree].
    - `ALT=`*`VALUE`* the target altitude [degree].
    - `DX=`*`VALUE`* add the value to the main0 (HA) instrumental offset [arcsec].
    - `DY=`*`VALUE`* add the value to the main0 (Dec) instrumental offset [arcsec].
    - `FOCUS` add the value to the focus offset [steps].
    - `SIDEA`, `SIDEB`, `DOME` and `LIGHT` are supported but not used, as the mount also supports handling a dome, but this is not used for DIMM systems.
- `RUN` variables:
    - `POINT` starts equatorial tracking at the set up location.
    - `RA(=`*`VALUE`*`)` starts equatorial tracking at the provided or set up right ascension position with J2000 equinox [hour].
    - `DEC(=`*`VALUE`*`)` starts equatorial tracking at the provided or set up declination position with J2000 equinox [degree].
    - `AZ(=`*`VALUE`*`)` starts horizontal tracking at the provided or set up azimuth position [degree].
    - `ALT(=`*`VALUE`*`)` starts horizontal tracking at the provided or set up altitude position [degree].
    - `DX(=`*`VALUE)`* apply the provided or set up value to the main0 (HA) instrumental offset [arcsec].

  - `DY(=VALUE)` apply the provided or set up value to the main1 (Dec) instrumental offset [arcsec].
  - `FOCUS(=VALUE)` apply the provided or set up value to the focus offset [steps].
  - `EVENTS_RESET` acknowledge reported telescope events in order to make the mount usable again.

    Note: This is an extension for `tt-scope` not available in Kornilov scopes and can be executed in parallel to other `RUN` commands.
  - `SIDEA`, `SIDEB`, `DOME` and `LIGHT` are supported but not used, as the mount also supports handling a dome, but this is not used for DIMM systems.

2.3 OpenTPL protocol

The OpenTPL protocol how communication is done is described in [8].

2.3.1 tt-meteo

The available modules and variables with its specific functions how to set up environmental data is described in [15].

2.3.2 tt-master

The available modules and variables with its specific functions how to deal with the DIMM functionality is described in [14].

3 Modifications of the Kornilov software

3.1 dimm-tool

Added features:

- Capturing camera images using the Vimba SDK[2], dropped links to now some unused libraries

Fixed problems:

- Parsing of separated degree format
- enforced termination in case of received signal
- proper unsigned->signed conversion when saving FITS images
- set up of valid initial gain value

3.2 ameba

Added features:

- dome positioning error is made configurable (section “Components”, subsection “Dome”, value “PositionError”)

- Centering the object is done by directly sending *`cmdid`* `RUN DX=`*`VALUE`* `DY=`*`VALUE`* to the scope server, therefore this drops the need for the scope server to communicate with `dimm-tool` to acquire positional data
  - tolerance of centering configurable (section “Camera”, subsection “Geometry”, value “CenTolerance”)
- check `RAIN` from `WEATHER` request and `STATUS` from `SKY`, provided by `tt-meteo`
- link on current log file
- make focus conversion configurable (section “Components”, subsection “DIMM”, values “FocusFactor”, “FocusStepLimit”, “FocusThreshold”)

Fixed problems:

- Parsing of separated degree format
- star list with less then 5 stars
- initialize dome
- parsing of focus position
- handling of shifting sunset and sunrise time (calculation is done in UT) because of stations at very different longitudes

3.3 preat

Fixed problems:

- links created with full path
- regular flushing of seeing file

4 Using the DIMM

4.1 Configuration

For configuration of the Kornilov and tau-tec programs, see the DIMM configuration manual[13].

4.2 Startup

What should be checked regularly:

- `tt-master` provides for every main module (`AMEBA`, `DIMM`, `DOME`, `METEO`, `SCOPE`) a generic `SERVICE` submodule that provides access to the health of the programs and the option to start, stop and restart the programs.

  Note: `AMEBA` is started when a mode is selected by writing to `AMEBA.MODE`. See section 5 in the manual[14].
- It may happen, that the mount encounters a problem, that is preventing it from powering on. Therefore `tt-master` provides the `SCOPE.STATUS.LIST` variable that forward reported events from the mount. If the problem can safely be cleared, `SCOPE.STATUS.CLEAR` has to be called — see section 9.1 in the manual[14] for more details.

Set up environment values:

- ameba is checking environment conditions on the basis of the values delivered by tt-meteo — see section 6.1 in the manual[15] to check what startup prerequisites exists.

Start the DIMM observation by writing to AMEBA.MODE in the OpenTPL interface of tt-master (see section 5 in the manual[14]) — this starts the ameba program by itself that will power up and open the dome as well as the scope. Two possible modes are available:

1 (auto) A target will be automatically selected from the list of targets[10] and re-checked regularly for an even better one by ameba.

2 (manual) A target must be set up in the AMEBA.MANUAL module. It must be ensured that the target can be observed at all.

To check the results of the observation, tt-master provides several variables in the DIMM module — see section 6 in the manual[14]. ameba creates log files that can be parsed, too — see section 4 in the manual[5].

4.3 Shutdown

To check for changing weather conditions, ameba acquires the environmental values regularly. In case of unsuitable conditions, a running observation is stopped and tt-dome-astrohaven is advised to close the dome.

At the end of the night, ameba shuts down observation and closes the dome as well.

When manually shutting down the system, then ameba must be shut down gracefully. This can be done by setting 0 to AMEBA.MODE or AMEBA.SERVICE.CONTROL in the OpenTPL interface of tt-master (see section 4 or 5 or in the manual[14]).

4.4 Calibration

If the pointing quality has degraded, the mount setup or even parts of the optics were changed, then a new pointing model must be created — please refer to the telescope mount manual for details on how to accomplish this task.

For focusing the camera, changing the optics or the telescope, see section 5 in the DIMM configuration manual[13].

4.5 Installation

For the installation of the software, two archives are provided that contains the all needed files in the correct directory layout. The following steps have to be taken to complete the setup:

1. Setup the computer with a suitable Linux distribution, we strongly recommend Ubuntu[1], as the software was developed and tested in that environment:

   a) Create a normal user dimm and add the user to the dialout group in order to enable communication over serial ports — as used for the dome and the focuser:

   ```
   sudo usermod -a -G dialout dimm
   ```

[1] https://ubuntu.com/download

b) Add a Java 8 (or newer) runtime environment and zip tools:

```
sudo apt install default-jre-headless zip
```

c) Install the ufw firewall (optional):

```
sudo apt install ufw
```

2. Install the current Vimba SDK[2] for GigE cameras as it is stated in the instructions[2] .

   Create a file (`/etc/ld.so.conf.d/Vimba.conf`), so that the Vimba libraries can be found by `tt-scope` (adopt for the installed Vimba version) — the program archive contains this file in `opt/dimm/support-files/ld.so.conf/Vimba.conf`:

   ```
   # path to Vimba libraries (goes to /etc/ld.so.conf.d/)
   /opt/Vimba_2_1/VimbaC/DynamicLib/x86_64bit/
   ```

   Note: The successful installation may be checked by trying the Vimba Viewer, if a graphical user interface is available for the Linux installation.

3. Copy the configuration archive (`dimm-config.zip`) to the computer and unpack it:

   ```
   sudo unzip dimm-config.zip -d /
   ```

   It contains data for the following directories:

   /mnt/dimm/config Configuration files for the programs — see the configuration manual[13] for details.

   /mnt/dimm/data/ameba The star catalogs[10] used by `ameba`.

   /mnt/dimm/data/dimm-tool Spectral data for different star types, the CCD spectral response for the used camera and the star catalogs used by `dimm-tool`.

   /mnt/dimm/image/dimm_tool saved camera images and PDF seeing plots.

   /mnt/dimm/log Log files of all programs including raw seeing data from `dimm-tool` and `preat`.

   /opt/dimm The program directories for `ameba`, `dimm-tool`, `tt-scope`, `tt-meteo` and `tt-dome-astrohaven`.

   The different directories below `/mnt/dimm` can reside on different file systems or network shares if desired to allow better archiving of the relevant measurement data.

4. Copy the program archive (`dimm-exec.zip`) to the computer and unpack it:

   ```
   sudo unzip dimm-exec.zip -d /
   ```

   Note: This step must be repeated in case an archive with updated binaries was provided.

5. Create a sudoers file (`/etc/sudoers.d/dimm`) so that the systemd-services can be started and stopped by the otherwise unprivileged `tt-master` process — the program archive contains this file in `opt/dimm/support-files/sudoers/dimm`:

   ```
   #
   # /etc/sudoers.d/dimm
   #
   ```

[2] https://cdn.alliedvision.com/fileadmin/content/documents/products/software/software/Vimba/appnote/Vimba_installation_under_Linux.pdf

```
# allow service restart etc. without password for dimm (goes to /
   etc/sudoers.d/)
#
# Copyright (c) tau-tec GmbH, Hintere Grabenstr. 30, 72070
   Tuebingen, Germany.
#

# tt-master
dimm ALL= NOPASSWD: /bin/systemctl start tt-master
dimm ALL= NOPASSWD: /bin/systemctl stop tt-master
dimm ALL= NOPASSWD: /bin/systemctl restart tt-master

# ameba
dimm ALL= NOPASSWD: /bin/systemctl start ameba
dimm ALL= NOPASSWD: /bin/systemctl stop ameba
dimm ALL= NOPASSWD: /bin/systemctl restart ameba

# dimm_tool/preat
dimm ALL= NOPASSWD: /bin/systemctl start dimm-preat
dimm ALL= NOPASSWD: /bin/systemctl stop dimm-preat
dimm ALL= NOPASSWD: /bin/systemctl restart dimm-preat

# tt-scope
dimm ALL= NOPASSWD: /bin/systemctl start tt-scope
dimm ALL= NOPASSWD: /bin/systemctl stop tt-scope
dimm ALL= NOPASSWD: /bin/systemctl restart tt-scope

# tt-dome
dimm ALL= NOPASSWD: /bin/systemctl start tt-dome
dimm ALL= NOPASSWD: /bin/systemctl stop tt-dome
dimm ALL= NOPASSWD: /bin/systemctl restart tt-dome

# tt-meteo
dimm ALL= NOPASSWD: /bin/systemctl start tt-meteo
dimm ALL= NOPASSWD: /bin/systemctl stop tt-meteo
dimm ALL= NOPASSWD: /bin/systemctl restart tt-meteo
```

6. Create a file (`/etc/ufw/applications.d/dimm`) with firewall rules for ufw that the programs can be accessed from the outside — the program archive contains this file in `opt/dimm/support-files/ufw/dimm`:

```
#
# /etc/ufw/applications.d/dimm
#
# ufw service description for ports used by DIMM software
#
# Copyright (c) tau-tec GmbH, Hintere Grabenstr. 30, 72070
   Tuebingen, Germany.
#

[DIMM]
title=DIMM software
description=ASTELCO/tau-tec DIMM software based on V. Kornilov DIMM
    system
ports=16200,16300,16301,16302,16400,16500/tcp
```

7. Share the service definitions from the programs into the systemd folder — the program archive contains the files in `opt/dimm/support-files/systemd/` and in the program directories:

```
sudo ln /opt/dimm/tt-dome/tt-dome.service /etc/systemd/system/
sudo ln /opt/dimm/tt-master/tt-master.service /etc/systemd/system/
sudo ln /opt/dimm/tt-meteo/tt-meteo.service /etc/systemd/system/
sudo ln /opt/dimm/tt-scope/tt-scope.service /etc/systemd/system/
sudo ln /opt/dimm/dimm_tool/dimm-preat.service /etc/systemd/system/
sudo ln /opt/dimm/dimm_tool/dimm-gnuplot.service /etc/systemd/
    system/
sudo ln /opt/dimm/ameba/ameba.service /etc/systemd/system/
sudo ln /opt/dimm/ameba/ameba-dimm-restart.service /etc/systemd/
    system/
sudo ln /opt/dimm/ameba/ameba-dimm-restart.timer /etc/systemd/
    system/
sudo systemctl enable tt-dome.service
sudo systemctl enable tt-master.service
sudo systemctl enable tt-meteo.service
sudo systemctl enable tt-scope.service
sudo systemctl enable dimm-preat.service
sudo systemctl enable dimm-gnuplot.service
sudo systemctl enable ameba-dimm-restart.timer
```

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