

MASS Software Version 2.04 User Guide

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December 30, 2003

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Introduction

This document presents the information on the use of the MASS Software. It is created for the control of the operations with the LITE Version of the Multi-Aperture Scintillation Sensor device designed at Sternberg Astronomical Institute, according with a Proposal to ESO [1]. The project was implemented in frame of the ESO contract No. 69255/ODG/02/9124/GWI

The document consists of several Chapters first of which presents an overview of what can be done with the program and what are the general ideas of implementation of its functionality in form of its *modes*. Next chapter is more practical – it describes how to install and prepare the software for a particular use. Chapter 3 tells about the composition of the program interface and gives more details on how the device works in its numerous modes and which settings affect its performance. Chapter 4 describes in brief the usual observational sequence (details are given already in previous chapters) and explains the data output in details. Finally, the last chapter 5 gives a helpful list of changes introduces in the version 2.04 of the program Turbina which resulted from the first experience of automated way of use of the device. The drawbacks which still persist are mentioned as well.

Compared to the previous versions of the current document, more details and practical advises are given, which allow to call it a real User Guide for the first time.

Chapter 1

MASS software operation overview

1.1 Main features of measurement process with MASS instrument

The software for control of MASS operations and data acquisition and reduction provides both reliable scintillation indices and atmospheric turbulence profile measurement and an ease of control and handling. The software supports all operational modes needed for making measurements, including testing, calibration and auxiliary measurements.

In order to measure correctly scintillation indices (SI), series of separate star flux measurements with integration time less than scale time of scintillation (a few milliseconds) must be obtained. This is done by photometric modules of the device which output is then transmitted to the MASS-machine where data flow is processed.

One can see ([4] and [5]) that there are a few physical parameters, which define the values of SI calculated on the base of statistical moments of the incoming data. In each channel such parameters are: background value, non-Poisson and non-linearity. The first one depends on sky condition, the last two are detector characteristics.

Reduction of calculated SI and integral characteristics of the atmospheric turbulence to standard condition requires a star spectral energy distribution and its airmass. This information as well as instrument geometry are needed for turbulence profile restoration.

During measurement, the star light flux variation depends not only on scintillation but on other factors: atmospheric transparency changes, tracking errors, wind pushes. To eliminate the influence of these factors, the incoming data must be filtered from side of low frequencies. Such a filtering may be implemented by calculation of the statistical moments around a sliding average flux value. In practice, the measurement data are obtained and reduced by separate segments of about 1 s duration each (so called *base time*).

To obtain a reliable output values with appropriate accuracy, the additional averaging of the computed SI and other values is used. The full time, needed to obtain separate measurement value (e.g. atmospheric turbulence profile, or background level, and so on) , is an *accumulation time* at a minute scale.

In order to provide stable star image position in the instrument field of view, a special centering control is needed if CCD camera is not available.

Finally, to ensure the correct performance of the MASS electronics and data processing, a number of tests must be provided by the software.

1.2 The basic operations

To supply a full scope of the needed data for measurements and subsequent reduction, MASS software (the program **Turbina**) includes a set of operational modes. Some of them represent measurement modes themselves, other — preparation modes. Below follows a short description of implemented operational modes.

Recall that all measurement modes are using three different integration times for their temporal organization:

Exposition – the micro-exposure duration in milliseconds during which one individual count is integrated in the photometric modules for each channel (elementary exposure);

BaseTime – the duration of the single block of counts in seconds by which the individual statistical moments (and, for some mode, scintillation indices) are produced;

AccumTime – the duration of the mode working in seconds; during this time $N = \frac{AccumTime}{BaseTime}$ individual sets of statistical moments are accumulated and then averaged to produce the single output result.

The results of each mode are displayed on the screen and saved in the output file. Note that all fluxes in the program refer to 1 ms integration time (i.e. scaled to this value if the actual **exposition** is different).

1.2.1 Scintillation indices measurement (or, historically, normal mode)

This is a major (scientific) mode of measurements. During **AccumTime** the measurements are done by blocks of the duration **BaseTime**. For every block, statistical moments and then scintillation indices are computed. For SI, the last-obtained background values are taken, or, if no Background mode was started before, the values from configuration file are adopted. From these instantaneous scintillation indices, the respective (basetime-related) atmospheric turbulence *integral moments* are computed (powers 0, 1, 5/3 and 2 of altitude).

For the whole **AccumTime** measurement, the average values of the scintillation indices and the estimates of their errors are computed and saved. Turbulence integral moments are similarly averaged and the atmospheric integral characteristics (free seeing, isoplanatic angle, effective turbulence altitude etc) are derived and corrected for non-zenith star position. Then the turbulence profile is restored from average SI using two methods (see [5]).

1.2.2 Background measurement

For correct calculation of the scintillation indices, the sky background level (non-scintillating) must be known. The star must be removed from the field aperture before starting the mode. The sky background is estimated by measuring the flux during the **AccumTime**. Subsequent scintillation indices calculations use these background values. If they are wrong by some reason (bad or outdated measurements) — check situation and repeat the background measurement.

1.2.3 Flux estimation

In some cases (star identification, pointing checking etc), the brightness of a star (or any other light source) is needed. This auxiliary mode allows to get such an estimation. Its results do not play any role in interpretation of results of subsequently run modes.

The duration of measurement is determined by the parameter `FluxEstimationTime` which has a sense of accumulation time for this mode. Data accumulation goes in the same way as in scintillation measurements. Meanwhile, data reduction is restricted to calculation of the average value and its error over the complete data set.

1.2.4 Star centering

Control of the star position within the field aperture is performed by means of scanning (with help of a triangle knife moving across aperture). See [2] and [3]. Scan represents the sequence of flux measurements obtained in a following way: knife is one-step shifted by stepper motor, flux is measured, knife is shifted again and further on. For this mode solely, the exposure is given in a configuration file separately from other modes. Star position is determined from the knife positions when the flux crosses the level of 1/2 of the maximal flux (when knife is out of the aperture).

The referencing of the knife position to the center of the aperture is made by separate calibration scanning of a uniformly illuminated field of view (starless twilight sky). The positions for 1/2 flux level obtained during calibration must be written in configuration manually.

1.2.5 Tests

There are three tests implemented in the program – Detector test, Exchange test and Statistic test. They allow to check the state of both hardware and software.

Exchange test Idea of this mode is to check the state of communication with device. Using settings for normal mode measurements (exposition, base time etc.) the photometric modules transmit the predefined test data, to be checked by the program. First, each module is tested separately (one after other). Then, all modules are tested simultaneously (work like in real measurement conditions).

Detectors test Check the PMT sensitivity. The control LED is activated and, after a small pause, the flux measurements are done. The control light is then switched off. The measured fluxes and detector non-Poisson parameters are compared with those written in configuration file.

Statistic test This test models the process of measurement of scintillation with help of blinking control LED. Instrument works like in the real SI measurements. The derived indices are compared with those calculated from the known LED flux variation. The LED is blinking synchronously with measurements with a period of 4 microexposures: 1) middle level 2) max level 3) middle level 4) min level. Masking of respective microexposures allows to derive these levels explicitly and to predict the value of scintillation index.

1.2.6 Detector counting measurement

This complex auxiliary procedure provides measurement of the PMTs count rate as a function of HV and pulse discrimination threshold for a specified grid control light levels. The mode consists of three embedded loops. The outer loop is over the light fluxes, the intermediate loop is over the HV levels, and the innermost loop is over the discrimination level. The dark counting,

if needed, should be specified explicitly (with the light level 0). For every point, the average flux value, its error and a non-Poisson coefficient are computed. Duration of the mode depends on product of number of points in the grids over HV, discrimination and light levels.

The detector counting measurement is intended to define optimal work condition for detector PMTs. As a final result, a series of dependences of the count rate and non-Poisson parameter on HV value may be plotted [3].

1.2.7 Detector statistic measurement

This procedure provides measurement of the main statistical parameters of the detector – non-linearity coefficient and non-Poisson parameter. The measurements are done when optimal HV and discrimination threshold were defined and set in the system.

This mode includes separate measurements for specified set of the control light levels. The resulting dependence of the current non-Poisson parameter on the flux level permits to compute non-linearity coefficient and non-Poisson parameter for each detector channel [3].

1.2.8 Initialization

Device initialization mode is a preparation mode which activates initial settings of the instrument electronic modules. Some program variables are initialized, too.

Also, the initialization may involve a number of modes specified in the initial scenario script (see 1.2.10). The initialization is an obligatory first step before any other measurement modes after the program start-up.

1.2.9 Device parking

This mode shuts down the device in a safe waiting state with a well defined status. As a rule, high voltage turns off. The mode is called automatically before the normal exit from the program. To continue the measurements with a program after parking, it is obligatory to do the Initialization.

1.2.10 Operations with scenaria

Scenario is a simple mechanism which provides an execution of a sequence of operation modes. The desired sequence is defined by the scenario script which is an expression involving the symbols denoting the modes (or commands) and operations with them: grouping the subexpressions (parentheses (. . .)), grouping the modes (addition sign +) and repetition of modes or subexpressions (multiplication sign *).

Normally, the scenario script is composed and written in the configuration file to simplify (automate) routine well tested measurements during long time period. Redefinition of the scenario script upon work is possible as well. Before scenario launching the software always checks the scenario content and estimates its execution duration.

1.2.11 Device direct control

Device direct control itself is not a separate operational mode. It provides a possibility of manual control of the device auxiliary functions: turn on/off high voltage, field aperture illumination, control light etc. Mainly, these are needed during device installation, preparation tasks, alignments and etc. The settings done under such a control are valid until parking the device.

1.2.12 Configuration possibilities

An interactive GUI provides possibilities to change program configurations during Turbina program execution. Similarly to the direct device control options, changed configuration parameters are active during current session if they are not saved. Once saved, new values are written into the main configuration file and become active upon the next program run as well.

Chapter 2

Installation, tuning and startup

2.1 Installation of the MASS software Turbina

The MASS device is operated by the program `turbina` written in C++ language for the real-time communication with the system hardware.

Both desktop or laptop PC computer running under Linux OS can be used. So far as MASS device is designed to be connect to the PC via parallel port and special RS485/LPT converter [2], computer must have LPT port working in EPP mode. The MASS software itself doesn't require a large disk free space (1 Gb is enough) or powerful PC hardware, and in general, requirement to PC follows the one for modern Linux distribution with XWindows graphic shell.

Installation procedure is roughly following:

1. **Install the Linux distributive.** The software was tested with SuSE 7.2, 8.2, Slackware 8.0 and RedHat 8.0 Linux distributions.

The following components are obligatory to install:

- XWindows with any window manager (KDE or whatsoever)
- gcc/g++ compilers
- ncurses text dialogs package
- Qt graphic libraries versions 2 and/or 3, development package
- sources of the installed Linux kernel
- xmgrace and xfig utilities for output data analysis

Normally, using the standard installation option, the first three components are installed by default, but others, especially, the development libraries and include files of Qt are not. Note, that this MASS software does not demand Real-Time Linux installation contrary its early version.

2. **Login as root**

3. **Insert the compact disk with Turbina distributive** and make the following actions:

```
# mount /dev/cdrom /cdrom
# cd /cdrom
# ./unpack
```

The last command starts the script which just takes the archives from the CD and unpacks them in the right places of the file system.

The components of the Turbina program are put in following places:

```
/usr/share/turbina/ - working directory: input and output data (star list, spectra,
weight functions etc.), configuration files, etc.
/usr/src/rs485-X.X.X - the sources of the RS-485 interface driver
/usr/share/doc/turbina/ - MASS and Turbina documentation
/usr/src/turbina/ - source files of Turbina to make executable
/usr/share/supervisor/ - Supervisor manager program package
```

They must be compiled and built which is described in following steps of installation.

4. Compile of the RS-485 driver.

Go to the sources directory, make a link to current kernel sources directory, to the current (provided) version of the RS-485 driver sources. Then enter the driver directory, configure, compile and install the driver and make the device for the RS-485 interface:

```
# cd /usr/src
# ln -s [kernel-source-code-directory] linux
# ln -s rs485-3.X.2 rs485
# cd rs485
# make
# make modules_install
# make create_dev
```

Notes:

- Do `make menuconfig` before `make` if your LPT port address and IRQ are different from 378H and IRQ7, respectively.
- The installation command copies the driver `lpt.o` from the `/modules` subdirectory to `/lib/modules/[kernel-version]/misc`.
- The device-making instruction (last "make") actually does `mknod /dev/mcua0 c 28 0` and creates the devices `/dev/mcua0` and `/dev/mcua1`; this is needed only if you install the driver for the first time in the system.

5. Install the RS-485 driver.

Try to say

```
# modprobe lpt
```

or

```
# insmod lpt
```

The driver is installed instead of the parallel port driver. Thus, the driver is installed if parallel port is not occupied. Otherwise, unload all drivers that use it by the command `rmmmod [driver-name]`. The command `lsmod` lists all loaded drivers. The name of low-level LPT driver is `parport`, but firstly unload the high-level drivers that use it (they are listed by `lsmod` in 4-th column of `parport` row), then unload `parport`.

If the kernel is compiled with the LPT driver already built in (not loaded as a module), boot the computer with the option `parport=0` in `/etc/lilo.conf` (in the section that contains the parameters of the chosen kernel, this is a case of loading the linux with LILO).

These steps of "cleaning" the unnecessary drivers and installing the `lpt` should be written in one of the system start-up script (normally somewhere in `/etc/rc.d/`, consult your system administrator how to do this). Otherwise, the cleaning of LPT-drivers and `insmod lpt` must be done each time the Linux is restarted.

6. Test the driver and communication.

- Make sure that the LPT port is in the EPP mode (check in BIOS settings). The LPT port address normally is: 378H IRQ7.
- Connect the electronics to LPT port through the RS485/LPT converter. Power the electronics with +12V (green LED on).
- Compile and start the low-level program for direct communication with the electronic modules of MASS:

```
# cd /usr/rs485/test/  
# make  
# ./lmox
```

The screen message shows the version of the driver and `<` prompt if the communication is established. Write `10 a2`. The answer should be `Data 2 bytes 0b 07`. Then press Enter to exit. If either device `mcua0` or driver `lpt` or PS485/LPT converter are not found or the electronics is not accessible, there will be appropriate error message.

7. Compile the Turbina program.

Go to the Turbina source directory, copy the Makefile which represents the use of your version of Qt (see whether it is `/usr/lib/qt2` or `qt3`), and compile the program:

```
# cd /usr/src/turbina  
# cp Makefile.qt2 Makefile  
# make clean  
# make
```

Thus, the compilation of Turbina is started. When finished, the `turbina` executable is created in the current directory. Try to start it:

```
# ./turbina
```

If starts, install the executable:

```
# make install
```

This way, the program may be started as simply typing `turbina` from any directory.

Potential problems:

- Absence of symbolic link to the real Qt library in `/usr/lib`. The symbolic directory `/usr/lib/qt2` must point to the actual Qt2 directory, like `/usr/lib/qt2.1`. The same for Qt3 library: the link `/usr/lib/qt3` to point to the real Qt3 directory.
- Sometimes the links to specific library modules are required when compiling turbina. Put the required links: `libqt-mt.so -> libqt-mt.so.3 -> [real file]`.
- Incomplete Qt libraries. In some Linux installations the Qt directories are not complete. In this case, use the Linux distribution and update the system to install `qt-devel`.
- Error messages at linking saying that some Qt libraries are not found. In this case, make symbolic links to the missing libraries in `/usr/lib`.

8. Check the Supervisor program.

The Supervisor is a Tcl script which does not require compilation. Thus, if you need such a functionality, follow the instructions in the Supervisor User Guide document.

9. **Check the PC clock**, which must be set to local time, as usual, with a proper value of the time-zone set. In this case, the Universal Time (UT) is computed properly for writing the output file records and object visibility calculations (autonomous Turbina functioning and Supervisor).

2.2 Editing the configuration file

All parameters which control both the hardware and software characteristics of the program Turbina are stored in text configuration files `turbina.cfg` (main CFG, changeable from Turbina menu) and `device.cfg` (“engineer” settings only, inaccessible from the program). Both files have the same structure of hierarchical levels. Upper level consists of Sections; each section may have any number of Subsections. Thus, there are up to two levels of enclosure (no ”SubSubsections”). Lowest level of hierarchy is a list of parameters. Names of (sub)sections (given in quotes) and names of parameters are fixed and cannot be changed.

The values of parameters may be of following types:

- numerical (integer or floating point)
- character (strings)
- set of values separated by commas or spaces (no matters)
- Logical: On/Off or Yes/No

The values of parameters are validated by the program on startup and the message is given in case when the non-allowed value is encountered or some field is absent or non-recognized. Character-type parameter values (except for the scenario mode symbols) are case-insensitive. Parameters cannot be removed from the file, in this case they disappear also from the menu. Sections and parameters with unrecognized names are ignored.

The line starting with ‘#’ as a first non-blanc character is a comment string not interpreted by the program. The part of line *after* semicolon ‘;’ is also a comment but displayed by the program as a short help in the dialog for the respective parameter modification. When the file is written by the program back to disk (after a modification via the menu tree), the latter comments are retained but comment lines started with ‘#’ are not. Therefore, keep the original `turbina.cfg` file as a reference to prevent loss of some parameters string.

File `device.cfg` contains important device constants. Some lines (parameters) may be modified during MASS installation and alignment procedure (see [3]). First of all, the `Magnification` parameter is very important for correct turbulence profile restoration and must be written after MASS installation at the feeding telescope and measurement of magnification (see [3]). It is also useful to have a `FocalLength` parameter close to true one, but it does not affect at the output results.

After careful studying of the the MASS detectors [3] with help of the program tools: `Detector count measurements` and `Detector statistic measurements` (see Sect 3.6), a need for correction of some electronics parameters can arise. These are:

- working high voltage `HighVoltage` in `Auxiliary/Common` subsection;
- non-linearity parameters `NonLinearityA/B` of the detectors in the `Bicounters/Bicounter 1 or 2/` subsections;
- non-Poisson parameters `NonPoissonA/B` in the same sections;
- discrimination thresholds `DiscriminationA/B`.

Also, the module identifications must be changed after their re-programming. Never edit the `Module/Command` sections!

Third configuration file is `status.dat` placed in the directory `config/`; it contains program service information only for its auto-validation of the `turbina.cfg` content.

Below we describe section-by-section the content and edition of the MASS main configuration file `turbina.cfg`. Note, that the structure of the configuring file corresponds in general to the Turbina GUI menu tree (see Chapter 3).

2.2.1 Preferences section

Section "Preferences"

```

SubSection "Text window settings" ;
    WindowGeometry          auto ;left top width height in pxs
    FontSizeLarge           12 ;fontsize of text window
    FontSizeSmall           10 ;fontsize of data and message text
EndSubSection
SubSection "Graphic window settings";
    WindowGeometry 640 -45 620 960 ;left top width height in pxs
    FontSize        10 ;fontsize of graphic window
    Background      darkGreen ;background color for graph window
    AxesColor       lightGray ;color of axes
    PointSize       1 ;size of point in pxs
EndSubSection
EndSection

```

This section helps to adjust the appearance of the program windows. `WindowGeometry` allows to set the desirable dimensions of the program windows on the X-windows screen or set `auto` for default behavior. Large font in `Text window settings` manipulates the sizes of Menu item names, Small font is used for the output data numbers and message text. `Graphic window settings` refer to the result plots. The color names in the configuration file are standard and include: `black`, `white`, `darkgray`, `gray`, `lightgray`, `red`, `green`, `blue`, `cyan`, `magenta`, `yellow`, `darkred`, `darkgreen`, `darkblue`, `darkcyan`, `darkmagenta`, `darkyellow`.

2.2.2 General section

```
Section "General" ;
  SubSection "Program version" ;
    Version          2.04 ;TURBINA version number
    Date             26.12.03 ;date of introduction, DD.MM.YY
    Modified         0.Voziakova ;who modifies the program
  EndSubSection
  SubSection "Configuration version" ;
    Version          1.18 ;version of this conf. file
    Date             16.12.03 ;date of introduction DD.MM.YY
    Modified         V.Kornilov ;who modifies this conf. file
  EndSubSection
  SubSection "Site" ;
    SiteName         LaSilla ;observatory or site name
    Longitude        -04 42 56.5 ;longitude of the site: h,m,s
    Latitude         -29 15 14 ;latitude of the site: d,m,s
    TimeZone         -4 ;tmZone (Local-UT)
  EndSubSection
  SubSection "Inputs" ;
    StarData         data/star.lst ;list of stars for measurements
    SpectraDir       spectra/ ;set of energy distributions (SED)
    Response         data/mass_dimm.crv ;spectral response of detectors
    WeightDir        weight/ ;weightDir
    LutDir           lut/ ;lutDir
  EndSubSection
  SubSection "Outputs" ;
    TempDir          working/ ;directory for temporal files
    DataDir          out/ ;directory for mass, cnt, stm files
    LogDir           log/ ;directory for logging files
  EndSubSection
  SubSection "Socket" ;
    Port             16007 ;Turbina port number for SV usage
  EndSubSection
EndSection
```

This section contains the general information on the observational process and environment. The first two subsections are not interpreted by Turbina but serve for control of the “freshness” of configuration file with respect to the program version. Being changed, the program version will be restored by the Turbina program. Note also, that the real program version is written in the output *.mass-file as well.

The subsection `Site` has to be filled with the observation place information. It is used for calculations of star positions and UT from the computer clock. Since star position (its airmass) is used for turbulence profile restoration, incorrect values in this subsection lead to biases in output results.

The next two subsections are the input and results files location and names counted from the Turbina working directory (`/usr/share/turbina/`, see Sec. 2.1). The last subsection `Socket` contains a port number using for TCP connection to Turbina.

2.2.3 Operations section

```

Section "Operations"
    SubSection "Common"
        WithDevice          Yes ;Is the MASS device connected?
        MirrorPollingTime   1 ;polling period in s
        TemperPollingTime   20 ;polling period in s
        HighPollingTime     2 ;High voltage polling period in s
        FluxEstimationTime  4 ;sec
        SciCountsSave       On ;save the Normal/Generalized mode counts
        TechCountsSave      On ;save the Detector Stat. meas. counts
        LogSave             On ;save the log of the session
    EndSubSection
    SubSection "Initialization"
        IlluminationLevel   0.5 ;default illumination level(0.0-1.0)
        Illumination        On ;turn illumination on/off
        HighVoltage         Off ;turn HV on after start up
        Safety              On ;automatic HV turn-off if overlight occurs
        InitialScenario     X+D+S ;scenario to do automat-ly on startup
        ScenarioRun        Off ;on/off making InitialScenario
    EndSubSection
    SubSection "Star Pointing"
        CoordinateSystem    HA ;Show RightAsc (RA). or HourAngle (HA) of star
    EndSubSection
    SubSection "Normal mode"
        Exposition          1.0 ;micro-exposition time in ms (>=1)
        BaseTime            1.0 ;base time in sec.
        AccumTime           60 ;accumulation time in sec.
        Cn2Method           X ;Cn2 restor.: fi[X]ed, f[L]oating layers
    EndSubSection
    SubSection "Background measurement"
        Background          0.01,0.01,0.02,0.06 ;previous measurement results
        AccumTime           10 ;full time of the measurement
    EndSubSection
# This subsection parameters for star centering control
    SubSection "Star centering"
        AccumTime          10 ;accumulation time in sec for centering
        Exposition         2 ;micro-exposition time for centring mod
        PositionAngle      90 ;deg from N to E, to MASS viewer direction
        Mirror             No ;if No => dRA * (-1)
        CentralZone        10 ;"Good zone" size in arcsec
        WorkZone           20 ;"Bearable zone" size in arcsec
        CenterX1           212 ;X1 constant for image centering
        CenterX2           70 ;X2 constant for image centering
        SpeedRA            -8 ;''/s telescope offset during 1-sec correction
        SpeedDec           5.0 ;''/s telescope offset during 1-sec correction
    EndSubSection

```

```

SubSection "Detectors counting measurement";
    Voltage      650 750 850 900 950 ;voltage set for counting characteristics, V
    Discrimination 0.3 0.4 0.5 0.6 ;level set for counting characteristics, mV
    Light                0.2 ;light level for counting
    AccumTime           40 ;accumulation time in sec for a point.
EndSubSection
SubSection "Detectors statistics measurement";
    Light 0 0.1 0.2 0.4 0.6 0.8 1.0 ;light levels for measurements
    AccumTime           60 ;accumulation time in sec for a point.
EndSubSection
SubSection "Tests" ;
    ExchangeTestTime    40 ;exchange test duration in sec.
    DetectorTestTime    60 ;
    DetectorLight        0.53 ;reference light level for detector test
    TestCounts           70 120 300 700 ;reference counts in channel A
    FluxTolerance        0.2 ;allowed tolerance for real counts
    NonPoisTolerance     0.2 ;allowed tolerance for non-Poissonity
    StatisticLight       0.5 ;light levels for statistical test
    Modulation           0.1 ;modulation amplitude for statistical test
EndSubSection
SubSection "Parking" ;
    Illumination        Off ;illumination turn on/off
    HighVoltage         Off ;leave-state for HV
EndSubSection
SubSection "Scenario" ;
    Scenario_1          4*(50*D+U+L)+Q ;measurement sequence n*+( )BCVXDULSNGQ
    Scenario_2          X+Q ;second sequence
    StopOnError         No ;stop or not on a failed measurement
EndSubSection
SubSection "SVScenario" ;
    Measurement         N ;measurement sequence n*+( )BCVXDULSNGQ
    Scenario_1          B ;background
    Scenario_2          F ;flux estimation;
EndSubSection
EndSection

```

This is the main section in configuration file which drives the measurements with MASS. It consists of the subsection **Common** which is followed by subsections each specifying the parameters of the particular mode of MASS functioning. The last two subsections give a number of scenaria (mode sequences) which can be selected in the program for execution (subsection **Scenario**) and which are executed upon the Supervisor request (subsection **SVScenario**). Flag **StopOnError** defines a software reaction if some kind of errors appear upon a scenario execution.

Subsection **Common** includes flag **WithDevice** which, being set to **No**, permits to run program without a MASS device, e.g. for a debugging purpose. Other flags — **SciCountsSave** and **TechCountsSave** — should be set **On** for special measurements only, since the counts saving consumes a large space on the hard disk, normally this flags are **Off**. The flag **LogSave**, being set **On**, opens the logging of the exchange with device. During initial usage period it is recommended

to set the flag On. Polling period parameters help to achieve a wanted reaction time on device status changes.

First of the mode subsections is `Initialization`. It specifies the behavior of the program when either the menu item `Initialization` is selected or SV command `INIT` is received. Flag `ScenarioRun` controls whether the `InitialScenario` will be executed during Initialization or not.

A counterpart of this subsection is the subsection `Parking` which specifies what is done to put the device in a waiting state.

Table 2.1: MASS measurement modes and the CFG parameters which affect their performance

Mode	Section	Parameters
Normal	Operations/Normal mode	(all)
	Operations/Common	SciCountsSave
Flux Estimation	Operations/Normal mode	BaseTime, Exposition
	Operations/Common	FluxEstimationTime
Star centering	Star centering	(all)
Background	Operations/Normal mode	BaseTime, Exposition
	Operations/Background measurement	(all)
Exchange Test	Operations/Tests	ExchangeTestTime
	Operations/Normal mode	BaseTime, Exposition
Detector Test	Operations/Normal mode	BaseTime, Exposition
	Operations/Tests	DetectorTestTime
		DetectorLight, TestCounts
		FluxTolerance NonPoisTolerance
Statistic Test	Operations/Tests	AccumTime, Modulation StatisticLight
	Operations/Normal mode	BaseTime, Exposition,
Detector Statistics measurement	Operations/Normal mode	BaseTime, Exposition
	Operations/Detectors statistics measurement	(all)
	Operations/Common	TechCountsSave
Detector Counting measurement	Operations/Normal mode	BaseTime, Exposition
	Operations/Detectors counting measurement	(all)
	Operations/Common	TechCountsSave

Each following subsection corresponding to separate operational mode has a "standard" parameter `AccumTime`. Parameters `DetectorTestTime` and `ExchangeTestTime` have the same meaning. For complex modes, such a `Detector counting measurement` and `Detector statistic measurement`, the parameter defines a time needed to obtain one point of a measured dependence. Note, that parameters setting the control LED light intensity (`Light`, `DetectorLight`,

StatisticLight, and IlluminationLevel) is normalized to its maximal value and belong thus to [0,1] range.

We present a table which relates the MASS operation modes to the CFG parameters which alter their performance (Table 2.1 and Table 2.2). The meaning of other, more specific parameters, is described in the Sec. 3.2.

2.2.4 Display section

```

Section "Display"                                ;Results display representation
  SubSection "Scan"                              ;show a servo-scan
    EntityList      A,B,C,D ;channel IDs A..D
    Show            F,F,FG,FG ;full, full, full+graphic, full+graphic
    Color    blue,yellow,white,green ;color names, white by default
    Size          1,1,1,2 ;relative size of graph, integer def=1
    ReferVal      1000 ;
  EndSubSection
  SubSection "Flux"                              ;Average fluxes, -> 0-mag in graphics
    EntityList      A,B,C,D ;channel IDs A..D
    Show            F,N,F,BG ;full, no,full,brief+graphic
    Color    yellow,green,blue,red ;color names, white by default
    Size          1,1,1,1 ;relative size of graph, integer
    ReferVal      100,100,2000,1000 ;
  EndSubSection
  SubSection "Index"                            ;Scintillation indices
    EntityList      A,D,AB,CD ;chans IDs A,D, AB, CD
    Show            B,B,B,B ;all the brief
    Color    red,red,cyan,gray,cyan ;color names
    Size          1,1,1,1 ;relative size of graph, integer
    ReferVal      1,1,1,1 ;
  EndSubSection
  SubSection "DESI"                             ;Scintillation indices
    EntityList      A,C,D ;chan(s) IDs A,AB,+s(hifted)
    Show            n,n,n ;all the none
    Color    red,green,blue,yellow ;color names, white by default
    Size          1,1,1 ;relative size of graph, integer
    ReferVal      1,1,1 ;
  EndSubSection
  SubSection "Integral"                        ;Atmospheric integral parameters
    EntityList      FSEE,FHEFF,TAU,ISOPL ;Any integrals
    Show            FG,B,B,FG ;full+graphic,brief,brief,full+graphic
    Color          red,green ;color names, white by default
    Size          1,1,1,1 ;relative size of graph, integer
    ReferVal      0.5,1,1,2 ;
  EndSubSection
  SubSection "Profile"                         ;Restored Cn2 profile
    Show            Bg ;brief+graphic
    Type            Smooth ;Smooth OR Bars

```

```

        Color                cyan ;only bars type
        LUT                  heat ;Look-up table name, only smooth type
        Size                 2 ;relative size of graph, integer
        ReferVal             6.0e-13 ;
    EndSubSection
EndSection

```

For any kind of output data, the user can list the parameters for display in the field `EntityList`: e.g. `A,B` for `Scans`, `Fluxes`, `Indices` or `DESI` or `FSEE` as free seeing for `Integrals`. Thus,

- `A ... D` denote the MASS channel identifiers; `AB` – the channels combination (for differential indices);
- `FSEE`, `FHEFF`, `ISOPL`, `M0` and `M2` denote the integrals of seeing, effective altitude, isoplanatic angle, turbulence integral over free atmosphere and second moment of turbulence.

Parameters in this section affect the way the results of measurements are visualized. The file output does not depend on any of these parameters.

The SubSections denote here the kinds of the output information which can be displayed. Within each subsection, the different results (output parameters) which can be displayed are all of the same sense, so the general principles of their visualization are the same.

The list `EntityList` determines the number of displayed results (at least in the graphic window) for each *kind* of parameter. It should be stressed that if either of parameters in a particular row/column of the Main Results Window is ordered here to be shown, all the rest data in the same column and row are also shown even if they weren't listed in entity list.

For all the entities listed in `EntityList`, the display mode "Show" is used to describe how to visualize the data:

- `N` – do not show results;
- `B` – "brief" data: with no errors in main results window;
- `F` – "full" data: with errors;
- `G` – may accompany any of `N`, `B` or `F`: show graphically in graphic window.

The last subsection `Profile` specifies the way to display graphically the C_n^2 -profile. If the `Bars`-type is selected, each layer of the restored profile is shown as a narrow bar which vertical size is proportional to the strength of the layer.

`Smooth` way shows the dithered picture of the turbulence in a selected look-up table (input field `LUT`).

`Size` is an integer-type parameter which specifies the relative height of the shown graph. E.g., if the given parameter is shown with `Size=2`, the Y-axis of its graph will be two times longer than that for a parameter with `Size=1`. The absolute size of axis (say, in pixels) is adjusted for all shown graphs (i.e. for *entities* which have `G` in `Show` parameter, see above) in such a way that they together occupy all the area of the graphics window.

The control over the scale of displayed data is given the field `ReferVal` which directly affects the range of correctly displayed values. The data points of the value equal to `ReferVal` are plotted exactly in the middle of the graph along the plotted delimiting line; values which are above $2 \times ReferVal$ are plotted always at the top margin.

The `Show` and `Size` describing parameters are listed in the same order as the entities for which they are given. In case of absence of a parameter or its wrong value, the default is used (`N` for `Show`, `white` for `Color`). The excessive descriptors are ignored.

Table 2.2: MASS preparing modes and the CFG parameters which affect their performance

Mode	Section	Parameters
Initialization	Operations/Initialization	(all)
Star Select	General/Site	Longitude, Latitude, Timezone
Star show	Operations/Star Pointing	(all)
Scenario Select	Operation/Scenario	(all)
Scenario Run	Operations/SVScenario	(all)
Parking	Operations/Parking	(all)

2.3 Local start up

Switch on the PC and start Linux as usual.

There are two user groups which can work with Turbina. The users from first `mass_root` group have full program possibilities, the `mass` users have restricted possibilities (they can perform measurements, but cannot modify most part of the configuration parameters). As a rule, `mass_root` group is identical to `root`, and `mass` — to `users` group. Nevertheless to satisfy the observatory security politics, it is possible to change this correspondence in a source program module `names.h` redefining `massRootGroupName` and `massUserGroupName` constants. Do not forget then add the new group into `/etc/group` file with help of your system administrator and recompile Turbina.

Login as `mass_root` or `mass` user and open/select the X-terminal. If machine has booted into the text mode, login and start first the X-windows (normally by typing `startx`). Make sure that MASS is powered up and connected to PC via the line cable with DB9 connectors. On the PC side, the cable is inserted in the RS485/LPT converter. Then start the program typing:

```
> turbina
```

It is assumed that all the parameters of the site and observations are properly assigned in the configuration file. Be sure that parameters in `General/Site` subsection are correct (see Sec 3.8 and 2.2.2).

It is desirable to check that there is a space free for writing the output files.

When Turbina starts, the console message

```
TURBINA Ver.2.04  
rs485 driver ver.3.0.2
```

appears first. Any extra-message means the possible problem with communication with the MASS device or RS-485 driver. The message "bind: Address already in use" means that the initialization of the Turbina server socket fails which happens when the program is restarted soon after connection shutdown. In this case, wait for a couple of minutes and start the program again.

In case some files or directories mentioned in the Turbina configuration files or configuration files themselves are missing, the corresponding message appears saying so. After passing the files checking, the program checks the correspondence of the scintillation weighting function files to the optical parameters (magnification, geometry etc) in the configuration. In case the

mismatch is found (which is a case when the magnification value is significantly modified), the window dialog appears which requests for permission to recalculate the weighting function. Press "Calculate all" to avoid this message further. The weights calculations may take a few minutes, depending on the machine speed.

Then program main window shown in Fig. 2.1 appears. Another window, for graphic results output, is opened automatically. At this stage, the message may come which reports the problem of communication or identification for a specific hardware module of the device. The identification mismatch usually arises after the module reprogramming or usage of the `device.cfg` file written for another device. It may be Ignore-d for a while but the correct `device.cfg` file must be maintained afterwards (see [2]). Other problems demand a special treatment.

If no messages appeared the Turbina is ready for work. Please note that, contrary to previous versions, **no Initialization is done at program start**. Hence, first action which must be performed, is the device Initialization. The initialization can be done either manually via GUI command `Tools/Initialization` (see Sec 3.6) or via the SuperVisor command `INIT` after `SV start` (see Sect 2.5). Initialization includes the device initialization stage and `InitialScenario` playing, the latter takes place only if the flag `Operations/Initialization/ScenarioRun` is set On in `turbina.cfg`. Normally, the `InitialScenario` contains some device tests (e.g. `D+S`) but this is completely arbitrary.

The user should wait until the message `It's Ok` is indicated and the buttons on the left side of the window become bright (active). This means that the measurements with MASS can be started. If Initialization is started from SV, the further actions should take place after the `INIT-command` returns `OK STATUS=READY`.

2.4 Remote and automatic running

In previous section we considered the manual Turbina starting-up, which is usually needed in the testing phase, measurements under operator control, installation and debugging of the robotic system and so on.

Naturally, it is the same possible to run Turbina from remote machine in such a manual mode. If the MASS device is powered and line cable and converter are connected, the most convenient way is to enter to MASS-machine using `ssh -X` connection under either `mass_user` or `mass_root` login. Since the exporting of X-windows at remote host involves extensive traffic, the delayed reaction problems may arise if your link capabilities are restricted. In other respects the program will work in the same way as started locally.

2.4.1 X-windows starting for Turbina

When system is fully debugged, work without observer intervention becomes possible. Such work can be controlled either by the scenario mechanism of the Turbina itself or under the external SuperVisor control via TCP socket connection. For these cases an automatic or remote start-up is necessary.

Since Turbina requires X-windows graphics, the main problem is how to provide the suitable X-server. There are three principal situations:

1. no X-server started on MASS machine;
2. X-server works from `mass_user` name, and Turbina must be started by the same user.
3. X-server works from `somebody` user, but Turbina must be started by `mass_user`.

Solutions for these cases differ by a single detail: use an existent X-server or run a new X-server. In the Case 2, the existent X-server can be used by Turbina. For this, the command `export DISPLAY=0:0` must be executed before Turbina run. For cases 1 and 3 X-server must be started before Turbina start for which, as described above, a script `startx` may be executed. Note, meanwhile, that this script creates the server with default display screen 0:0. To initiate additional server with another display screen, say `:1`, it is easier to use the command `xinit`. This way, the X-server can be run for the single particular client program, such as Turbina:

```
xinit /full/path/to/turbina -- :1
```

In this case, the screen `:1` is created and the program starts within it immediately, omitting any other services like window manager. When Turbina finishes, the X-windows shut down as well. This method works for both automatic and remote start-ups.

2.4.2 Automatic start-up

For non-assisted systems, it's essential to be able to revive after (possibly occasional) reboots. In our case this means that execution of the Turbina program must be somehow appended to the chain of the system startup scripts.

One of the ways to perform such a chain is to make following:

1. Configure the login screen program (such as GDM or KDM) to make `mass_user` auto-logging, optionally after a specified timeout. For example, the configuration of the graphic login manager in RedHat is located in `Start/System settings/Login screen` graphics menu item; in SuSE – in the program Control Center (see `System administering/Login manager/Options`).
2. Write a script which launches Turbina (and, possibly, other components of your robotic system) and place it in the Autostart area of your window manager (for KDE, this is the `~/.kde/Autostart` directory). If the SuperVisor program is needed for the system management, it must be started after Turbina call on a background.

The machine configured like this behaves like following: when the system boot scripts are completed, the X-windows are started with the login screen manager program. At this point, the `mass_user` is logged in automatically and its preferred window manager is launched. When the screen is ready, the Turbina windows appear, provided that there is no problem with the hardware and service files (see Sec. 2.3).

Alternatively, Turbina can be started automatically in pre-defined time with help of CRON-daemon. As considered above, two situations emerge: start on behalf of a user who is already running X-windows and start opening the new X-server.

First case requires preparation of a shell script (E.g. `turbina_cron_start`), which executes `export DISPLAY=0:0` and then launches Turbina. The call of this script must be written in CRON table specifying the start time and the user name. An example of a respective `crontab` line is following:

```
13 19 * * *      mass_user /usr/share/turbina/config/turbina_cron_start
```

In this case Turbina starts daily at 19 hours 13 minutes of the local time. In order to start the new X-server, add the next line in `crontab` file:

```
13 19 * * *      mass_user xinit /usr/X11R6/bin/turbina -- :1
```


It is necessary to extend `crontab` `PATH` environment variable with `/usr/X11R6/bin` to provide correct execution of `xinit` script. Turbina starts from `/usr/X11R6/bin` directory, which is the destination of its `make install` instruction. Instead of direct call of `xinit`, the corresponding script may be written and executed by `CRON-daemon`. Before starting Turbina, this script may check whether it is already running or not.

2.4.3 Remote start-up

Now it is clear from Sec. 2.4.1 how to start Turbina execution without display exporting to the remote host used. Depending on situation, the possibility with either display export to the existing X-server on MASS-machine or starting there the new X-server specially for Turbina execution, can be used.

To prevent non-authorized actions at MASS-machine the Turbina screen can be locked. For this the start-up script must include a sequence of background calls to 1) any Windows manager (E.g. `Windowmaker` as a very simple manager), 2) Turbina, and 3) `xlock` display locking utility.

2.5 Working under the Supervisor control

If the Turbina program is used as a component program in a system driven by the **Supervisor manager program**, it is started as usual and Turbina port number and MASS machine IP address are written in the Supervisor configuration file. Port number is specified in `General/Socket` of `turbina.cfg`, it must not coincide with the port of any active service in the system. Consult the file `/etc/services` for selection of a free port number.

When SV acquires the connection to Turbina, the socket connection is created and Turbina immediately switches into the SV-controlled state when it is

- ready to execute the commands translated via created socket connection;
- insensitive to the local user control.

The latter means that the menu items in the Turbina window are disabled and all the buttons in the window are not active as well. The only active button is the special upper-left "Red Button" with a logo **SV** in the main Turbina window (becomes bright when SV is connected) which allows to switch back into the local control mode. If it is pressed, any command from SV is not executed and replied as `ERROR STATUS=LOCAL`. All the GUI controls become active and allow to operate MASS-device locally.

To allow back the SV-control, the button must be pressed again – other buttons on the screen become again disabled and SV-commands are executed.

As described in Sec. 2.3, Turbina starts with device in the non-initialized state. In this state, any command from SV (see below) which involves the work with the device except for `INIT` is replied as `ERROR STATUS=PARKED`. The command `PARK`, naturally, does not cause any action and replied as `OK STATUS=PARKED`. And the commands `SET`, `GET` are executed; `SET` replies with a notification `OK STATUS=PARKED`.

While running, Turbina switches between the following states denoted by its status (returned by `GET STATUS` command) driven by the mentioned commands:

`PARKED` – start-up state, `PARK` command (`QUIT` - before termination)

`READY` – `INIT` command, after completion of `RUN`, `STOP`

BUSY – INIT, PARK, RUN commands: lasts from reply OK WAIT=nnn till reply OK STATUS=READY upon completion of the respective action.

LOCAL – state with the local control activated (see above)

Some commands may cause the error state which is lasts normally until the next valid command supplied (except for ERFAT). These are:

NOSTAR – RUN-commands issued without an object selected (see SET OBJECT=nnnn below)

ERANG – specified parameter value is not allowed (e.g. non-existent star number or invalid scenario script supplied)

ERSYN – command or parameter name is not recognized

ERFAT – error during execution of the RUN, INIT, PARK commands due to bad data or device/program malfunction

Below we list the commands which may be used by SV to perform robotic-mode measurements with MASS:

```
INIT           - initialize device (not program!), play INIT scenario
PARK           - park device
QUIT          - park and terminate Turbina execution
GET STATUS    - request of Turbina status
GET IDENT     - request of the program identity (name and version)
GET BKGR      - get last obtained values of the background
GET CENTER    - get last obtained values of the star centering control
GET FLUX      - get last obtained fluxes (format of F-prefixed line in mass-file)
GET INTEGRAL  - ... atmospheric parameters (A-prefixed line)
GET SCIND     - ... scintillation indices (I-prefixed line)
GET XPROFILE  - ... turbulence profile with fixed altitude grid (T-prefixed line,
                Meth=X)
GET LPROFILE  - ... turbulence profile with floating layers (T-prefixed line, Meth=L)
GET SCEN1     - current script of Scenario_1 of the SVscenario
GET SCEN2     - ..... of Scenario_2
RUN           - run the main scenario of SVscenario ("measurement", cannot be SET)
RUN SCEN1     - run Scenario_1
RUN SCEN2     - run Scenario_2
STOP          - stop current scenario execution
STOP NOW      - break the current measurement and scenario execution
SET OBJECT=nnn - set current star HR nnn number
SET SCEN1=xxxx - set new xxxx-script for Scenario_1 (say, B+2*D+F,
                no spaces or quotes!)
SET SCEN2=yyyy - similarly for Scenario_2
```

Note that scenaria Scenario_1 and Scenario_2 mentioned above are the usual scenaria similar to those described above in Sect. 4.1.2. They are destined for the dynamic re-loading during work under SV control and are suited to particular special needs of the system. For example, they may help to organize the star searching procedure, start centering and background measurement, or testing of the device. Note also that GET-commands may be used in any state of the program, including polling of data during scenario execution. Format of returned data is described in Sec. 4.2.

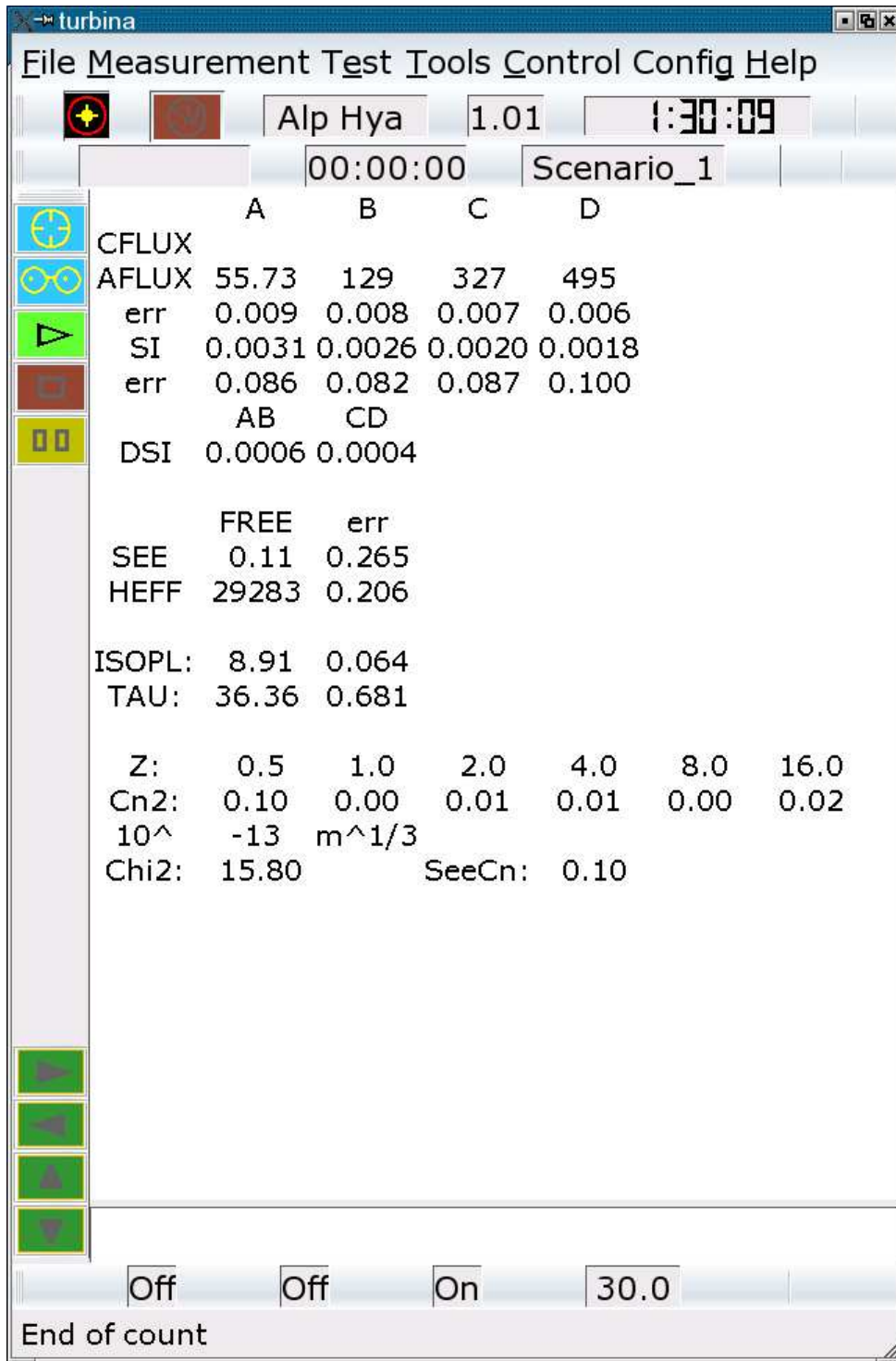



Figure 2.1: The view of the Turbina program main window. The results of the scintillation measurement mode are presented.


Chapter 3

Main Turbina program window and menu tree






3.1 Main window

The **top line** of the main window is a Menu bar. Any action with MASS may be performed by selecting the necessary item in the pop-up Menu tree (see Sect. 3.2). Also, some shortcuts are available to execute frequently used action via a combination of keystrokes.

The **second line** gives an information on the supervisor connection status, selected object of observations and current time. On the startup of Turbina, the star is not selected (*undefined*) and observer must use the Select Star menu. The current star name (**Alp Hya**), its current airmass (1.01) and the Local Time (1:30:09) are displayed and updated continuously. The Supervisor logo  (on the left) changes its color from dark red (as shown in Figure) to bright when the Supervisor program connects to Turbina and the latter starts to execute its commands. It is a button by which the user may give a command to ignore Supervisor command and take GUI command (**Red button**).

The leftmost icon  represents the symbolic image of a star (yellow bold point) in the working diaphragm of MASS (red circle).

The **third line** specifies the name of the current mode (or *template*) started (**Run measurement** for example) and the time left until its completion. Last two windows inform on the currently selected *Scenario* and scenario time left.

Below the mode line, the **results output** window follows. Its content depends on the started mode and is described in Sect. 4.2. To the left of this window, the **Tool buttons** are placed. The upper button **Show Star**  opens the window where the current star parameters are displayed (it's a short-cut of **File/Show Star** menu item). The next button **Select Star**  allows to select the object in the star list (equivalent of **File/Select Star**). Last three buttons mimic the audio-player functions and make easy to **Start** , **Stop**  and **Pause**  the selected scenario.

Just below the results window, there is a narrow **message window**. In this place, the messages from the program about the completion of a mode, some measurement result (as shown in Figure) or about some abnormal system state are shown.

The last two lines in the Main window are the **Device Status line** and a **Program Status bar**. In the former, the position of the viewer mirror, field Illumination, High Voltage state

and the device interior temperature. The last line indicates normally the action of the program which is under evaluation. In this line, the help-texts on the configuration file parameter are displayed while accessing them via menu items in Config/....

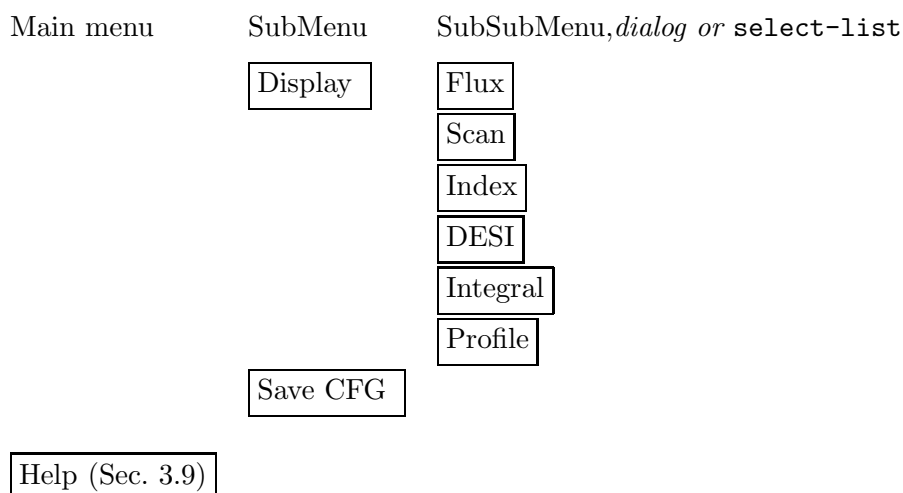
3.2 The Structure of the Main Menu Tree

The main menu tree allows to make all the operations with MASS. Some menu items are disabled (marked in grey color) if they are not accessible in a current context state or not suited for usage/modification by a ordinary user. In latter case, they are available for root user only.

Below we give the explanation on what is done upon the selection of the menu items. The described operations depend on the values of parameters listed in a configuration file (CFG) which we give in quotes specifying the section of CFG from which they are taken.

Main menu	SubMenu	SubSubMenu, <i>dialog or select-list</i>	
File (Sec. 3.3)	Comment	<i>User's comment input</i>	
	Select star	Program star selection	
	Show star	<i>Selected star information</i>	
	Exit		
Measurements (Sec. 3.4)	Center control		
	Run measurement		
	Background		
	Flux estimation		
	Select Scenario	Initial + 2 work scenarios	
	Run scenario		
	Stop scenario		
	Pause scenario		
	Tests (Sec. 3.5)	Exchange test	
		Detectors test	
Statistic test			
Tools (Sec. 3.6)	Initialization		
	Detectors counting meas.		
	Detectors statistic meas.		

Main menu	SubMenu	SubSubMenu, <i>dialog or select-list</i>
	Talk	
	Break accumulation	
	Parking	
Control (Sec. 3.7)	Turn HV On/Off	
	Turn Safety On/Off	
	Turn Light On/Off	
	Set Illumination Level...	<i>Adjust the diaphragm illum.</i>
	Set Light Level...	<i>Set the control light level</i>
	Set Hight Voltage...	<i>Set the HV level</i>
Config (Sec. 3.8)	Preferences	Text Window Settings
		Graphic Window Settings
	General	Program version
		Configuration version
		Site
		Inputs
		Outputs
		Socket
	Operations	Common
		Initialization
		Star pointing
		Normal mode
		Background measurement
		Star centering
		Detectors counting meas.
		Detectors statistics meas.
		Tests
		Parking
		Scenario



3.3 File menu item

The menu item File includes possibilities to add comments during observations and for work with a star list and data bases.

Comment

The dialog for adding a single line user's comment in the mass-file. The comment is appended to the file with a time stamp after finishing the current measurement. Shortcut is [Ctrl]-[C].

Select star

The item opens the list specified in the `turbina.cfg/General/Inputs/StarData/Star.lst` containing 130 stars brighter than 3 mag available for MASS measurements. This file can be replaced by another file having the same format. The displayed list is normally sorted by airmass, but can be resorted by any field (such as: HR number, Name, Hour Angle (HA), Decl. AirMass (restricted to be less than 10), Vmag, Spectrum) by clicking on the field name (header). You can select star by double-click on the star row or by pressing button [Select]. The star information is refreshed in the program at the moment of closing of the window. The parameter `CoordinateSystem` from the CFG section `Operations/Star Pointing` specifies the selection between Right Ascension and Hour Angle for displaying. Button 2 on the left border of the program window does the same.

Show star

The item shows information on selected star. Button 1 [Show] on the left border of the program window does the same. Information for pointing at the selected star contains the Name, coordinates (HA/RA, Decl), Vmag, Spectrum and comment. The field HA can be changed by field RA depending on flag `General/Inputs/CoordinateSystem` in the `turbina.cfg` file. The information is updated every second.

Exit

Exit the program, the instrument is parked. Shortcut is [Ctrl]-[Q].

3.4 Measurements menu item

The menu item Measurements contains several commands for making observations. All commands run immediately except for the Select Scenario. Remember, that the measurement modes don't check if high voltage is turned on or turned off.

Center control

Run center control procedure to calculate a star image shift from center of the field aperture. Counters are in the mode determined by the parameters from the section `Operations/Star centering` in CFG. During `AccumTime` the scanning of field area is done by triangle knife. The scanning speed is set equal to `Exposure`. Limits of scanning are defined by parameters from `device.cfg` file. After the measurements are finished, the settings for scintillation measurements are restored.

Run measurement

Immediately run measurement of scintillation indices (further — Normal mode, see Sect. 1.2.1). Counters are in the mode determined by the parameters from the section `Operations/Normal mode` in CFG. Full results scope is saved in the file `*.mass` (see Sect. 4.2) while a part determined in `Display/Index`, `DESI`, `Integral`, `Profile` sections of CFG is also displayed in the results window and in the graphic window.

The individual counts from blocks are saved in the binary *count-file* if the scientific count-saving is enabled (`Operations/Common/SciCountsSave=On` in CFG).

Background

The sky background is estimated from measurement started immediately (see Sect. 1.2.2).

The results of the command are displayed in the message window and saved in the file `*.mass`. Next indices calculations use these background values. Also, if `Config/Save CFG` is pressed, these values are saved in `turbina.cfg` and used in the next Turbina call as default values before the first run of Background mode.

If the obtained background values are seemingly wrong — check situation and repeat the background measurement, otherwise the subsequent SI measurements will be severely violated.

Flux estimation

The brightness of a star (or any other light source) is estimated (see Sect. 1.2.3). Accumulation time is set by the parameter `FluxEstimationTime` from the section `Operations/Common`. The current values of fluxes and their errors are displayed; note that the error of an average decreases while measurements progress. Shortcut to call this mode is [Ctrl]-[F].

Select scenario

Select a script from the list specified in the `Operations/Scenario` section of the CFG.

Run scenario

Execute the selected script (also duplicated by the button 3).

Stop scenario

Abort the current script (duplicated by the button 4). It waits until the current mode is finished. If the script is re-started after this, its starts from the beginning of the script.

Pause scenario

Suspend the current script (e.g. to re-center the star), duplicated by the button 5. It waits until the current mode is finished. After the second press of the button, the script execution is resumed.

3.5 Tests menu item

The item Test of the main menu contains three tests of the instrument and software. The parameters of these tests are specified in the section `Operations/Tests` of the CFG.

Exchange test

This test consists of two parts. First part: all counting modules are separately tested during one base time in the Normal mode. Second part: during the `ExchangeTestTime` all 4 counters are tested in the working configuration. Normal mode settings is restored and kept active after the test finishes. The results of the tests (percentage of the packets loss or "Ok") are displayed on the screen and saved in the data file.

Detectors test

Check the PMT sensitivity. The control light with the level `TestFlux` is activated and, after a small pause (to warm up the LEDs) the measurements are done during `DetectorTestTime`. The control light is then switched off. The measured fluxes must correspond to the `TestCounts` to within a `FluxTolerance` relative error. The counts are displayed on the screen. If they do not correspond to `TestCounts`, the message is given: "Invalid fluxes!". The resulted non-Poisson parameters of detectors are also checked to correspond to the `NonPoisson` parameters of counters (in `device.cfg`) to within a `NonPoisTolerance` relative error.

Statistic test

For Statistic Test (see Sect. 1.2.5), the intensity of the control light is set to the level specified in the parameter `StatisticLight` of the section `Operations/Tests` and modulated with `Modulation` relative amplitude. Before measurements, the pause is done to stabilize the flux of the LED. Test duration and settings are the same as for the normal mode. When the test is finished, the control light is switched off.

The format of the displayed and saved results is identical to the normal mode. The expected index values, computed from the measured modulation levels for comparison, are displayed for examination and stored in the file in the same format as measured indices. No formal test result is produced, the judgment has to be done by operator.

3.6 Tools menu item

Item Tools in the main menu contains the commands for auxiliary measurements and control.

Initialization

Initial settings of the instrument are activated as specified in the `Operations/Initialization` section. Initialization must be repeated after change of some parameters through the `Config` item of the main menu and after "Parking" function.

Detector counting measurement

The counting measurement is started (see 1.2.6) according the parameters specified in the subsection `Detectors counting measurement`. The its outer loop is over the light fluxes listed in `Light`. HV levels and discrimination levels are set according `Voltage` and `Discrimination` lists. Other settings are the same as for Normal mode.

Every point of this mode is measured during the `AccumTime`. For every point, the average flux value, its error and a non-Poisson parameter are computed. After inner loop is finished the results for current HV and light are displayed on the screen and written to the output file.

Detector statistic measurement

This procedure provides a measurement of the main statistical parameters of the detector (Sec. 1.2.7). The mode parameters are specified in the subsection `Detector statistic measurement`. The loop over light level list `Light` is done. Every point is accumulated during `AccumTime` after warming of the LED for 30 s.

For every point, the average flux value, its error and a non-Poisson parameter are computed. The resulting table is written to the file.

Talk

It open the dialog window for sending the commands of the low level to micro-controllers for debugging purposes and abnormal states. The modules replies are shown in the same window.

Break accumulation

Stop the current measurement after the end of the Base-time count series acquisition.

Parking

To shut down the device in agreement with section `Parking` parameters (e.g HV Off etc). Done automatically before the (normal) exit from the program. To continue the measurements with a program, it is obligatory to do the Initialization.

3.7 Control menu item

Control – a folder for making the operations with a device without changing the CFG.

Pay attention that menu items don't indicate current status of the device, only possible function in time. For example, if the string `HV On` is shown, it's mean that High voltage is

off and can be turned on by pressing this menu item. These settings will be valid until new **Initialization** command.

HV On/Off

Switch the high voltage unit (see the initialization procedure after the program startup)

Safety On/Off

Enable/disable the shutting down the high voltage upon the detection of the too high photo-current in any channel.

Turn light on/off

Item switches the control light for testing purposes.

Set illumination level

Set the intensity of lighting with a logarithmic intensity step. Additional sub-window will appear.

Set light level

Modify the relative intensity of the control light. Additional sub-window will appear.

Set HV

Set the new value of high voltage in Volts. Additional sub-window will appear.

3.8 Config menu item

The item **Config** permits for user to change the program and device parameters situated in the CFG. The vertical menu structure mimics the one of the configuration file, the headings repeat the names of Sections. The next level menu reflects the Subsection of the Section. The dialog window content lists only the parameters resided in **turbina.cfg**. The dialogs themselves are not shown in the figure of Menu Tree.

The new parameters begin work immediately, if no message is appeared: **Field: Active after restarting**. Setting are not saved in **turbina.cfg** if user don't press **Save CFG** which is placed in the vertical menu bottom. Also, question about the saving of the changed parameters will arise during program exiting.

Preferences

Menu item permits to change the text window parameters (**Text Window Settings** Subsection) and of the graphic window (**Graphic Window Settings** Subsection). Both allow to define manually the dimensions of the program and graphics windows in X-display units or put **auto** for default "optimal" settings. Font sizes should be adjusted experimentally (depend strongly on X-window settings). Graphic settings include additionally the choice of the axes and background colors from a list and the size of the datum point on a graph.

General

Here observer can change the parameters in following Subsections:

Program version – program version number, date of introduction, who modifies the program.

Note, that the Turbina always write correct version number, even one will change it.

Configuration version – configuration file version number and date, author of modification.

Site – observatory/site name, longitude of the site: h, m, s , latitude of the site: d, m, s , time zone.

Input – input data: the list of stars for measurements, file with a spectral response of the MASS, weight functions directory for atmospheric calculations.

Output – output data: temporary data placement, output data directory (**mass-**, **stm-** and **count-** files) and **log-** file placement.

Socket port – number of the port for connection from SuperVisor program.

Operations

Items permit to change a number of parameters in following Subsections:

Common — pooling periods, flux estimation integration time, modes of data saving.

Initialization – initial device status and actions after **Initialization** command.

Star pointing – switch between I and II coordinate systems.

Normal mode – parameters of the scintillation indices measurements (see Sec. 1.2.3).

Background measurement – accumulation time and adopted background values. Observer can use the item to control a current background.

Detectors counting measurement – a lot of parameters for counting functions measurement.

Detectors statistics measurement – the same for non-Poisson functions measurement.

Tests – parameters for Exchange, Detectors, and Statistic tests.

Parking – the device status upon the parking.

Scenario – editing the measurement scenarios.

Display

Enable or disable the output of indices and atmospheric parameters and turbulence profile in the main results window and in graphic window. Five kinds of output parameters exist:

Scan – show the merged scan obtained in Star Centering modes

Flux – show the stellar fluxes in channels. The main results window shows the actual average counts per millisecond. The graphics shows the plots reflecting the time dependence of the flux *converted to the zero magnitude*. For this, the V-magnitude of the star from the input catalogue is used together with its $B - V$ color to convert the V-magnitude into the MASS photometric system [3]. Thus, the graphic curve of fluxes (called "F_*") reflects the history of atmospheric transparency during the night and must not (in principle) be very sensitive to the change of the target star.

Index – show the normal or differential indices.

DESI – show the differential exposure indices.

Integral – show the integral atmospheric parameters (seeing, isoplanatic angle etc.)

Profile – show the restored turbulence profile.

SaveCFG

SubMenu item forces the changes of the working parameters made during the program execution to be saved in the configuration file.

3.9 Help menu item

Help – a brief help on the program usage: actions which are performed by the system on selection of menu items.

3.10 Results Window content

During the measurements with MASS, the intermediate and the final results are displayed in the *results output window* (see Sect. 3.1) as a table. The columns normally refer to the MASS channels (A, B, C and D), sometimes to other derived parameters. The leftmost column gives the headings for the table lines, the upper row - the table column headings.

Normally, during the star measurements (after each Base-time), the flux values in [pulses/ms] are displayed for each channel. Then, after the Accumulation Time measurements are completed and the results are averaged, all the derived information is displayed. The content of the output is described below. It depends on which parameters are selected for display in the section **Display** of the configuration file. In principle, the output is self-explanatory; nevertheless, the meaning of all displayed parameters is summarized in Table 3.1.

Profile measurement

Current fluxes are displayed each Base-time; each Accumulation time the average fluxes and indices are given for all channels; differential cross-channels indices (DSI) are displayed for some (normally up to four) selected channel combinations.

The turbulence moments computed each base-time are averaged. If not negative, they are converted into atmospheric parameters and shown in the bottom part of a table - free-atmosphere seeing (FSEE), effective altitude (FHEFF), isoplanatic angle etc.

Finally, if the obtained set of average indices allows to restore the turbulence profile, it is displayed in last four lines of the table – the altitudes, their respective C_n^2 integrals, the units of the integrals (usually $10^{-13} \text{ m}^{1/3}$), chi-square quality of the restoration, seeing estimate from this profile (it is usually close to FSEE). If no restoration is possible, the message is displayed in a message window.

Flux estimation, Background measurement

Only the current average fluxes with their relative errors are displayed.

Exchange test

No display of output; only the message window is active

Detector test

The current average fluxes with their relative errors and non-Poisson parameters are displayed

Statistic test

The current fluxes (CFLUX) are displayed during measurements. The average indices and expected indices are displayed after the end of Accumulation Time. The indices are output as for Normal mode, but the expected values (non-zero for indices) are added with names having the 'E' prefix. SI-s and ESI-s must be statistically equal. The cross-channel differential indices should be close to zero. Naturally, no atmospheric information is displayed.

Detector statistic measurements

The extended table for channel parameters is displayed which columns show the Control LED light relative level, and fluxes, their relative errors and non-Poisson parameters for each channel.

Detector counting measurements

The output is similar to that described for the **detector statistic measurements** mode, but instead of light level, the high voltage and discrimination level are given. Light level is shown in a separate line.

Table 3.1: The dictionary of the MASS output parameters displayed in the results output window

Table columns content:

A, B, C, D	Parameter for a specified channel
AB, AD etc.	Parameter for a specified combination of channels
U	High Voltage level (Detector counting characteristics mode)
Level	Discrimination level (–”–)
Light	Relative control LED illumination level (detector measurement modes)
Param	Name of the parameter displayed to the right (–”–)
FREE	Atmospheric parameters for the free atmosphere (above 0.5km)
err	The relative error of the value given in a column to the left

Table rows content:

CFLUX	Current flux in [pulses/ms]
AFLUX	The flux averaged over an Accumulation Time
err	The relative errors of values given in a previous line
SI	Scintillation index
DESI	Differential exposure index
DSI	Differential (cross-channel) scintillation index
FSEE	Free-atmosphere seeing in [arcsec]
FHEFF	Effective altitude of turbulence in [meter]
ISOPL	Isoplanatic angle in [arcsec]
M2*1e5	Second moment of turbulence $M_2 = \int C_n^2 h^2 dh$ in [$m^{4/3} \times 10^5$]
TAU	Atmospheric time constant computed from DESI in [ms]
Z	Altitude of layers of the restored turbulence profile, [km]
Cn2	Restored profile: integrals of C_n^2 in layers in [$m^{1/3} \times 10^{Order}$]
Chi2	χ^2 of the profile restoration presented
Order	Order of magnitude of the displayed Cn2 values
Light	Relative control LED illumination level (detector test modes)
P	Non-Poisson parameter

Chapter 4

Measurements and results

4.1 Measurements with MASS

4.1.1 The observational procedure

After having the system started and passed the tests, the observations may begin. The **File/Select Star** menu item (or the **Select star** button) is activated and the star with a small airmass is selected from one of the top lines of the list (sorted by airmass). It's better to select the object with a negative hour angle value of the order of -2 to -1 hours. The parameters of the star are normally recalled by the **Show star** button.

Then the selected *modes* may be started manually or automatically via the preset *scenario* sequence. If clouds appear, the scenario can be paused or stopped; in case of the full disappearance of a star, the resulting zero scintillation indices will occur and then the program will stop the scenario automatically (if **Stop On Error** is **On** in the configuration file).

To change the star, the scenario should be stopped and **Select Star** procedure should be called again. In order to stop the measurements completely, simply make **File/Exit**: the program will shut the device down and exit.

The output files in `/usr/share/turbina/out/` should be copied for safety elsewhere. These are normally the mass-file `*.mass`, the statistical-moments file `*.stm`, and (optionally) the *count-file* `*.cnt` with the individual millisecond counts from the MASS channels.

4.1.2 Writing a new scenario

Normally, the optimal sequence of modes is written in `turbina.cfg` configuration file in the section `Operations/Scenario/Scenario_1/2`. This sequence may be modified either in the file or in the program (menu item `Config/Operations/Scenario`) and subsequently saved in configuration file with **SaveCFG** command. Some actions not tied with the measurements can also be included in a scenario as *commands*. Note that the scenarios which manage the mode(s) started on the command from Supervisor are different from those described here and not visible in the Config-menu of the program.

The scenario is an expression which involves the symbols denoting the modes (or commands) and operations with them: grouping the subexpressions (parentheses `(...)`), grouping the modes (addition sign `+`) and repetition of modes or subexpressions (multiplication sign `*`).

The mode signs are following:

B – Background measurement

C – Centering control
N – Profile measurement (normal mode)
D – Detector test
S – Statistic test
X – Exchange test
L – Detector statistic measurements
U – Detector counting characteristics registration
Q – Command: park the device and exit

The example of the scenario: $B+C+5*(2*N)+D+S$. Here the sequence begins with the Background measurement and Star centering control, then five cycles follow which consist of two profile measurements. The scenario is finished with the Detector and Statistic tests evaluation. The parentheses may be used freely with an arbitrary degree of enclosure.

4.2 Output data in MASS Software

The output of Turbina program operating the MASS device is directed to an ASCII file called *mass-file*. It contains the scope of all measured “scientific” parameters – scintillation indices, atmospheric integral parameters and turbulence profiles – together with the accompanying information (software messages and observer’s comments) and the device test results.

The statistic moments (means, dispersions and cross-correlations) of the counts in channels and their combinations, used to compute the scintillation indices, are saved in the separate moments-file (**.stm*).

Finally, the individual counts from the device PMTs may be stored in a *count-file* (**.cnt*) to allow their external re-processing (if such an output is enabled in the configuration, see 4.2.4).

Apart from these main output files, there is a number of service files (logging, temporary information, test-time output etc.) which are not described here.

The mass-file, moment-file and count-file contents are described in sections below.

4.2.1 Mass-file structure

General principles of organization of the mass-file

The mass-file is an ASCII file which normally has a name representing the UT date of the *evening* of observations in format *YYMMDD.mass*, where YY stays for the two-digit year, MM is month (01 – 12) and DD is day (01-31).

Each line of file (with a single carriage-return character at the end) contains the starting character(s) or prefix and alphanumeric-type fields delimited with blanks (spaces, tabs). The lines may be of the different *types*; each type describes the data of particular kind and has a fixed associated format specifying the sense and sequence of the fields.

The line *types* are grouped into a few *classes* by their place in the hierarchy of the data processing pipeline:

1. *averaged measurements* output with Accumulation-time periodicity – the values obtained as a result of averaging of a number of base-time results; they may include the computed relative errors and other derived parameters

2. *circumstance records* – reflect the change of measurement conditions, target star, comments of observer etc.

Each of described *classes* of output data may be represented by several *types* of data lines. The general features of these types are following:

- Each line of a certain type is started with a **unique prefix** – a single character which allows to collect the data of particular kind from the mass-file for external processing (i.e. in electronic tables, databases etc.). Thus, the type of line (i.e. kind of data) is determined by this prefix (see Sect. 4.2.1).
- The only prefix which may be followed by another (second) prefix is a comment-type prefix #: e.g. #I. In this case, the rest of line gives the header-line for the data type given in the file with a second prefix (I in example) to describe explicitly the format of lines of this type. All other prefixes are separated from the rest of line by at least one blank character.
- The second field in the line is a moment in Universal Time in a fixed format YYYY-MM-DD HH:MM:SS which specifies the moment of acquisition of data given in this line.
- The third and subsequent fields give the data of a given kind.

The interpretation of data in mass-file needs some information on the parameters set in the system via Configuration File or directly from the menu of the program. The set of relevant parameters read from the Configuration File (`turbina.cfg`) is extracted in the so-called *preamble* given at the beginning of each mass-file. Also, upon the change of any relevant parameter during the program execution, it is written in a single *preamble-type* line (see the list below).

Comments to the UT field in mass-file

1. It is assumed that all information in a single file is related to one night of measurements. The *evening* date (see above) gives a name for a file. The evening date is assumed to change in the local mid-day.
2. For *averaged data* results UT gives the middle-time of respective *accumulation-time*; for *circumstance records* it is the moment of appearance of a given circumstance.

The list of prefixes for the *averaged measurements* types:

- I – average scintillation index values with relative errors obtained in Normal mode
- J,K – reserved
- E – average expected scintillation index values with relative errors
- F – average channel fluxes with relative errors
- U – average channel fluxes, relative errors, coefficients of non-Poissonity with associated high-voltage levels and discrimination levels
- L – average channel fluxes, relative errors and coefficients of non-Poissonity with associated light intensities
- A – a set of atmospheric parameters (*seeing, isoplanatic angle* etc.) computed from averaged Cn2 turbulence *moments* with respective relative errors
- T – restored turbulence profile intensities $C_n^2(z)$ with respective altitudes z , χ^2 values, C_n^2 -derived seeing etc.

R – the differences of observed and restored (by C_n^2) scintillation indices normalized by the observed indices. Currently not active in a ‘live’ output. Given for all normal and differential indices, but not for DESI.

The list of prefixes for the *circumstance record* types:

- P – the preamble record in the block in the beginning of file for all relevant parameters or originated from the change of respective parameter in the program. The format is: `SectionName\[SubSectionName\]]ParameterName = value`. An example of such a variable parameter is a background in channels.
- O – the target star information: name, spectrum, coordinates, respective Weight Function ID
- M – the declaration of the started mode: identification, parameters etc.
- C – measured shift of the star relative to the center of the field aperture in arc secondes.
- > – software originated message about some event, abnormal state, error
- # – the comment entered by the program or by the observer.

This list of types is not exhaustive in principle and may be easily expanded in future versions. The sample output in the mass-file according to the format given above is presented below:

```
P 2003-10-08 14:15:57 General\Program version\Version=2.03
P 2003-10-08 14:15:57 General\Site\SiteName=CTIO
P 2003-10-08 14:15:57 General\Site\Longitude=-4 43 15.5
P 2003-10-08 14:15:57 General\Site\Latitude=-30 09 55
P 2003-10-08 14:15:57 Segmentator\Channel A\Outer=1.27
O 2003-10-08 17:05:56 8425 Alp Gru    22  08  14    -46  57  40    B55 1.10
M 2003-10-08 17:07:35 Flux
#F      UT          FLUX_A e_FLUX_A FLUX_B e_FLUX_B FLUX_C e_FLUX_C FLUX_D...
F 2003-10-08 17:09:33 32.88  0.004 50.48  0.003 189.4  0.002 324.0 ...
##2003-10-08 17:20:05 User's comment is here
M 2003-10-08 18:19:03 ExchangTest
> 2003-10-08 18:19:05 IndividTest It's OK
> 2003-10-08 18:19:46 ExchangTest It's OK
M 2003-10-08 18:19:52 DetectTest
#L      UT          Light FLUX_A e_FLUX_A P      FLUX_B e_FLUX_B P      FLUX_C...
L 2003-10-08 18:20:01 0.20 518.6  0.000 1.073  3213  0.000 1.056 4248...
> 2003-10-08 18:20:07 It's OK
M 2003-10-08 18:50:23 StatisMeas
#L      UT          Light FLUX_A e_FLUX_A P      FLUX_B e_FLUX_B P      FLUX_C...
L 2003-10-08 18:51:23 0.20 496.6  0.000 1.073  2971  0.000 0.946 3912 ...
M 2003-10-08 18:52:23 Exchang Test
> 2003-10-08 18:53:13 Individ Test It's OK
> 2003-10-08 18:53:34 Measurement aborted!
M 2003-10-08 19:07:34 Background
P 2003-10-08 19:07:39 Operations\Background measurement\Background=0.751, 1.125...
M 2003-10-08 20:15:26 Normal 1.09
#I      UTbeg          SI_A  e_SI_A  SI_B  e_SI_B  SI_C  e_SI_C  ...
I 2003-10-08 20:15:26 0.1533 0.029 0.1100 0.025 0.0597 0.022 ...
```

```

#F      UT      FLUX_A e_FLUX_A FLUX_B e_FLUX_B FLUX_C e_FLUX_C FLUX_D...
F 2003-10-08 20:15:56 32.91 0.003 50.55 0.002 189.5 0.002 323.4...
#A      UT      fSee e_fSee See e_See fM0 e_fM0 M0 ...
A 2003-10-08 20:15:56 0.74 0.030 0.00 0.000 4.41e-13 0.050 0.00e+00 ...
#T      UT      Met Nz Chi2 SeeCn z_1 Cn2_1 z_2 Cn2_2 z_3 ...
T 2003-10-08 20:15:56 L 3 3.22 0.75 0.5 6.20e-14 2.9 3.17e-13 15.3 ...
R 2003-10-08 20:15:56 L -0.012 0.015 0.007 -0.002 0.004 0.009 ...
T 2003-10-08 20:15:56 X 6 4.09 0.73 0.5 4.33e-15 1.0 2.58e-16 2.0 ...
R 2003-10-08 20:15:56 X -0.028 0.005 -0.012 0.016 0.009 -0.036 ...
# 2003-10-08 20:23:26 Temperature: 14.5

```

4.2.2 Statistic moments file

The statistics moment file (`YYMMDD.stm`) stores the intermediate data used for the average indices and derived atmospheric parameters calculations. For each base-time (1-second exposure), the line gives the statistical quantities of the counts in channels.

The structure of the file is similar to that to mass-file: the line starts with a prefix (which is fixed to `m` in `stm`-file), then go the UT date and time and then mean fluxes and auto- and cross-covariances of the counts in channels, with lags 0, 1 and 2. The last parameter in the line gives a hexadecimal address (offset) of the counts in the binary count-file prefixed by a '@'-symbol. This address appears only if the counts writing was enabled at the moment of making the measurements.

4.2.3 Relation of prefixes to the MASS operation modes

Each *mode* of MASS can produce some data written in the mass-file as lines with particular prefixes. Below we give a summary of the modes (which can be started from the menu or from the scenario) and the types of output data which are produced by these modes. These types are given as lists of prefixes. The first column `M` gives the symbol by which the mode specified in the second column is denoted in scenarios.

M	Mode	Prefixes in mass-file
N	Normal	I, F, A, T, R
B	Background Measurement	F
C	Star centering control	C
X	Exchange test	–
D	Detector test	L
S	Statistic test	I, E, F
L	Detector Statistics	L
U	Counting Characteristics	U
Q	Park and Quit	–
O	Object airmass check	(O to be implemented)

Formats of the data output in mass-file and display

In this section we give the technical information on the data representation in the main window result of Turbina and in the mass-file. It was introduced already in Table 3.1. The list of parameters, both measured and set in the system for the measurements, is presented. Some

parameter names may have prefixes and/or suffixes; they are given separately in two additional tables.

List of formats of MASS output measured parameters

Param	C-format	Range	err	Comment
err	%.3f	0..1	no	Relative error of any parameter >0 (length '*' is 5 for display, 7 for ATMOS and 8 for SCIND). e_ in file.
FLUX	%6.*f	0..2e4	yes	Instant. or average flux [pulse/ms] (precision '*' is <4, computed)
P	%5.3f	0.7..2	no	Non-Poisson parameter of detector
SI	%6.4f	1e-3..1	yes	normal or differential scint.index
SEE	%5.2f	0.1..20	yes	Seeing [arcsec], "Seeing" in display
ISOPL	%5.2f	0.1..20	yes	Isoplanatic angle [arcsec]
HEFF	%5.0f	1..3e4	yes	Effective turb.altitude [m]
M2	%8.2e	1e-6..1e-4	yes	Second turb.moment ("isokinetic") [m ^{4/3}], 1E5-scaled in display,
M0	%8.2e	1e-17..1e-10	yes	Zero turb.moment: full integral [m ^{-2/3}], file only
TAU	%5.2f	0.1..20	yes	Atmospheric time constant [ms]
Z	%4.1f	0.1..30	no	Altitude of the Cn2 profile layer [km]
CN2	%8.2e	1e-16..1e-12	no	Strength of Cn2 prof. layer [m ^{1/3}] ORDER-scaled in display
Met	%c	'X','L'	no	Cn2 profile restoration 'X':fixed, 'L':floating layers, file only
ORDER	%3d	-17..-10	no	Logarithmic Scale-factor of Cn2 (display only)
Chi2	%6.2f	0.9..999	no	Chi-square of restored Cn2 profile

List of formats of MASS output setting parameters

Param	C-format	Range	err	Comment
U	%4d	500..1500	no	High Voltage [volt]
Level	%3.1f	0.5..1.5	no	Discrimination level in detector [mv]
Light	%3.1f	0.0..1.0	no	Control LED intensity level [rel.unit]

List of prefixes

Prefix	Parameters	Comment
e_	having err	relative error of parameter in file ("err" in display)
C	FLUX	Current (instantaneous) flux
A	FLUX	Average flux
D,DE	SI	Differential indices: cross-aperture and expositional
F	SEE, HEFF	Free atmosphere parameter (integral above 1km), used in file only (FREE column in display)

List of suffixes (file only)

Suffix	Parameters	Comment
_A,_B,_C,_D	FLUX,SI,DESI	Value measured in a channel

<code>_AB, ..., _CD</code>	DSI	Value for a pair of channels
<code>_1, ..., _6</code>	Z, CN2	Layer number

4.2.4 Count-file handling and data re-calculation

The PMT counts of the MASS channels can be saved for external processing during the scientific measurements or during the device Detector measurements (both counting and statistic). If the counts are saved or not depend on the value of the parameters `Operations/Common/SciCountsSave` and `Operations/Common/TechCountsSave`, respectively.

The counts (detector pulses per micro-exposure, usually per about one millisecond) are stored individually for all four MASS channels in a binary *count-file* which is created with the same base-name as the mass-file (i.e. like `YYMMDD.cnt`). Its location is the same as that of the mass-file (normally, `/out` subdirectory of Turbina working catalogue).

The binary file consists of the records with non-fixed length, since the length of the count series depends on the settings in the CFG (`BaseTime*1000` and `Exposition` parameters ratio). Each record has thus the two-number descriptor which specifies the reverse-order index of the MASS channel for the following buffer and its length. In order to read this count-file, the separate program `cnt2asc` is provided with Turbina package. In order to compile it, go to the Turbina source directory and, being root, say there:

```
# make utils
```

It is needed to make after Turbina compilation, because the common object modules are used. During compilation of `cnt2asc`, two other utilities `atmos`, `weif` are compiled, too. They serve to restore turbulence profile from `mass-` and `stm-` files independently of Turbina run, when some parameters of the MASS are needed to change.

The reading of the count-file needs the starting address of the first channel buffer to be known. It is written in hexadecimal form in the mass-file after the `@`-character (e.g. `@1acef240`, see `mass-` and `stm-` file description) for the base-time originated records. This address has to be provided, after the count-file name, to the program `cnt2asc`. The third parameter is the number of successive base-time data blocks to be read (by default, the single block for *each* MASS-channel is read). The counts are printed to the standard output as, normally, 4 columns of integer numbers separated with blanks. The counts from different channels written in one line refer to the same moment of time. The output has to be redirected to the file for further processing.

Chapter 5

Version 2.04 features with respect to 2.03 version

5.1 Changes

To improve functionality of the MASS software, some changes were made during updating the Version 2.03 to Version 2.04. These changes concern mainly Turbina interaction with SuperVisor programs and are following

- To provide an externally controlled program exit, a dialog "Save CFG file" at exit was removed. Such a dialog appeared if a background measurement (also saved in `turbina.cfg`) have been carried out during observations while no other parameter was changed at all. Thus, the menu item `Config/Save CFG` has to be selected now each time when a significant change is introduced in the configuration via GUI.
- To provide independence between program start and observation start, critically needed for robotic observations, device Initialization was excluded from the program start-up sequence. Thus, before making any measurement, **do not forget to do INITIALIZATION**, either manually via GUI menu or with help of SV command `INIT`, after program start and if a command `PARK` was given before.
- Also, `InitialScenario` runs each Initialization if the flag `ScenarioRun` is On, independently on a command source (GUI or SV).
- For uniformity, two scenario invoked by SV `RUN`-commands (see subsection "`SVScenario`" in `turbina.cfg`), were renamed: `Background` into `Scenario_1` and `Flux` into `Scenario_2`.
- Accordingly, respective SV commands `RUN BKGR` and `RUN FLUX` were renamed in `RUN SCEN1` and `RUN SCEN2`.
- Overloading of these two scenario was provided with newly introduced `SET SCEN1` and `SET SCEN2` commands.
- Since the SV command `RUN`, `RUN SCEN1`, `RUN SCEN2` initiate a scenario running rather than execution of some specific measurement mode, they **do not return any data**, the Turbina current status only.

- Instead, a set of `GET` commands was extended considerably (see Sec. 2.5) to retrieve the output data of interest.
- Take into account, that reaction of the Turbina program at some `SV` commands is modified due to mentioned changes.

Apart of listed major modifications, a number of bugs was fixed as well.

5.2 Further modifications

Some modifications, needed for further optimization of MASS software operation as a component of the MASS + DIMM + Telescope + Dome + Meteo + ... robotic system, are foreseen in next Turbina versions. They are not implemented in frame of Version 2.04 because they require a considerable program re-structurization.

Short list of such drawbacks, to be removed in future, is presented below.

- In current state, the MASS device **must not be powered off** between its parking and initialization, since the communication with the device is installed upon the program start-up only.
- Now, the Turbina program opens output files on its start-up. If Turbina is executed during a few days, output files named by the date of start are appended with the results of many days. No valid graphics is produced in second and further nights.
- Errors with configuration, software and input files, found upon start-up are reported in graphic-mode windows and one-by-one, allowing user to exit the program only. There is no way to see neither all problems together nor their reason while starting Turbina remotely.
- Sometimes, when Turbina is terminated by `SV` command, one of QT child process don't finish its work. The reason is still uncovered, but this is potentially dangerous.
- Some of the current state fatal errors (which lead to stopping of the program) can be handled successfully without observation stop. Also, many errors are not reflected in the output file.

The mentioned imperfections lead to obligatory Turbina restart before next night observations.