RTS2-F Primer Version 08

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ABSTRACT

This document describes the current version of the RTS2-F system for autonomous operation of the FLWO 1.2m telescope with Keplercam. An initial version of the system is operational but not yet in regular use.

We divide RTS2-F users in two categories with two distinct levels of requirements. Category 1, the majority, will need to know the properties of the target database, how to add the contents of input catalogs to the database, how to monitor the progress of observations and how to retrieve data. Category 2 includes observers on-site, such as the 1.5m remote observers and occasionally Category 1 users, who may need to monitor the state of the system and interact with its controls. This primer provides instructions on the usage of RTS2-F for both categories of users.

If you have comments or requests, please send them to Emilio Falco.

1. Introduction

Petr Kubanek developed the RTS2 system over the past several years (see www.rts2.org). RTS2 is a software package that operates telescopes autonomously. It runs telescopes at several observatories, as detailed in the web site. A primary goal of RTS2 is to observe GRBs autonomously, and to react to detections such as by SWIFT as quickly as possible. Other targets of opportunity (TOOs) such as SNe are also good targets for RTS2. RTS2-F is Petr's adaptation of RTS2 to the FLWO 1.2m. We envision observations with the 1.2m similar to other RTS2 TOO observations, in addition to a queue that will direct the telescope to observe non-TOO targets as approved by the TAC.

Petr spent about 2 weeks at FLWO and he has been working remotely on updates and corrections as we tested RTS2-F. The current version has operated the telescope successfully during several engineering nights in September-November 2010. Petr will visit again in early 2011, but he continues working remotely on updates.

RTS2-F uses a database of targets to observe each night. Each target is inserted into the database with constraints that determine the modes of observation (e.g., priority, when, filters, exposures). Weather constraints (humidity, wind and precipitation) measured with our Vaisala station also determine whether RTS2-F may operate, or whether the telescope must be shut down.

The development of RTS2-F is currently in what we call Phase 2. Items in this phase that will be available shortly are:

1. Automatic guiding.

2. Automatic astrometry matching with astrometry.net software.

3. An upgrade of the RTS2-G visual interface.

4. Automatic email to observers announcing their observations are acquired.

5. Automatic verification of input catalogs.

6. Additional weather sensing such as sky temperature to detect clouds.

7. An LN2 autofill system.

We are also implementing additional functionality:

1. An automated TOO response capability (e.g., GRBs and SNe).

2. Means to restrict observations to specific dates.

3. A pipeline system that will provide a standard reduction using standard calibrations of each night's data. The science data and the calibrations will be available at CfA in Cambridge, in the archive area.

The following sections describe the RTS2-F database, the input catalogs used to build or update the database, the online means to monitor the status of observations, the scripts that run the telescope, and other tools to address nightly operations when necessary.

2. Category 1 users

This section describes the parts of RTS2-F and the procedures that Category 1 users need to know to obtain useful observations.

2.1. RTS2-F modus operandi

Each night it is enabled to operate, RTS2-F follows a prescribed daily sequence with appropriate waiting periods between activities (e.g., between dome and sky flats). The core of the system is its database of targets, built from user catalogs. The database and the catalogs are described in the following sections. RTS2-F divides its time into 6 states: day, evening (twilight), dusk,

night, dawn, morning (twilight); at the end of morning the state is day again. RTS2-F records each Telshell command as it is executed, in the directory /home/observer/RTS2-F/LOGS/ and files run-YYMMDD.

2.1.1.   Summary of an observing sequence

1. Day: during the afternoon and before the onset of twilight, with the dome slit closed and starting from the stow position, acquire dome flats for standard calibrations, as described above.

2. Day: stow the telescope to allow a local observer to fill the Keplercam dewar (eventually this step will be automatic and will require no local intervention).

3. Evening: open the dome slit.

4. Evening: reference the telescope position (find zenith); not required each night, the periodicity is weekly for now.

5. Dusk: about 20 minutes after the onset, acquire sky flats in the u band.

6. Dusk: focus the telescope from measurements of the FWHM of stars (see below).

7. Night: observe accessible targets from its database and constraints (see below). Weather measurements may dictate that the telescope be shut down. Adjust focus after each exposure, as described below.

8. Dawn: about 20 minutes after the onset, acquire sky flats in the u band if evening sky flats were not possible.

9. Morning: stow the telescope and close the dome slit to allow for a second dewar fill (eventually this step will be automatic and will require no local intervention).

10. Day: starting about 9am MST, transfer the night's data to the archive in Cambridge. The process takes up to about 3 hours, depending on the number of files.

2.2.   RTS2-F database

The RTS2-F database contains one entry for each target. The contents may be viewed from any browser at CfA in Cambridge or at FLWO. The home page is viewed with RTS2-G (G for GUI) on flwo48.sao.arizona.edu:8889. Access is restricted by username (rts2obs) and password (please request it from the staff). The database keeps track of observations and provides snapshots of the data.

The RTS2-G main page displays the links shown in Fig. 1. These links are not all functional yet. The most useful link to users, "Targets," lists the contents of the database, as shown in Fig. 2.

The columns in Fig. 2 are an internal ID number, Target Name, NOBS or number of observations in the database, the Priority of the target, the status (Enabled), RA, DEC, and live altitude, azimuth and Violated or Satisfied constraints (airmass or lunarDistance).

2.3.   Science targets

Targets in the RTS2-F database may be viewed via the "Targets" link in RTS2-G. The description of each target includes an index (assigned automatically), a name, a priority value, a flag indicating the target is enabled or disabled, RA and DEC, as well as airmass and lunar distance constraints. For each target, the system lists the current number of observations, as well as its live altitude and azimuth. It also shows whether the constraints are currently violated or satisfied.

Observers may monitor the progress of observations during the night with RTS2-G. For each target, there is a link with detailed information, such as the target RA, DEC, Alt, Az, Priority, as well as LST and JD. Additional links shown in Fig. 3 provide more detailed target information ("info page"), thumbnails ("images"), a list of "observations" and a nightly "altitude plot."

The "info page" link provides all the information necessary for observations of the target, based on the input catalog that provided the target to the database. The Images link provides thumbnail JPG views of the existing observations. The Observations link shows the existing observations with links to the thumbnails. The Nightly elevation plot shows what its name suggests, for each target and the current night.

2.4.   Calibration targets

In addition to science targets, the RTS2-F database contains permanent calibration targets, including one for sky flats (with variable coordinates optimized for each night and time when sky flats are acquired) and photometric standards that may be specifically requested, or are observed automatically if no other targets are accessible and conditions are photometric. The science targets are inserted in the database using input catalogs as described in the following section.

2.5. RTS2-F input catalogs

The RTS2-F database is built from input catalogs in a format derived from the old .mct catalogs, with extension .mctR to indicate they are RTS2-F catalogs. Appendix 1 shows an example catalog.

The input catalogs contain target names with coordinates and proper motion values (if applicable), as well as filters, exposure times and number of repetitions for each filter. In addition, for each target, catalogs require values for: the CCD amplifier centering, autoguide flag, priority, and limits for seeing, airmass and lunar angular distance.

RTS2-F skips observations in the database when a requested filter is not one of the 8 filters on the filter wheel. Observers should request other filters by email to the staff, well in advance of when they expect their observations to take place.

Once the TAC allocations for a given trimester are posted in the schedules, users who were awarded time may submit input catalogs via sftp to flwo48 as observer. Catalogs must be placed in the directory /home/observer/RTS2-F/CATALOGS. The system automatically harvests catalogs daily at 2 pm MST (an arbitrary time that may be changed if it proves unpopular) and adds their contents to the RTS2-F database.

2.6. RTS2-F Targets of Opportunity

TOOs by definition may not be in the RTS2-F database until shortly before they need to be observed. There are two different timescales: for targets such as SNe (daytime before observations are requested), and for targets such as GRBs (minutes before observations are requested or even less time within the constraints for observations that would be interrupted).

We are developing the mechanism that will interrupt the observing queue for TOOs. Such interruptions may be disabled, e.g., in the case of a planetary transit that requires uninterrupted exposures. The priority of each target will also determine the possibility of interruption.

2.7. RTS2-F calibrations

RTS2-F acquires a standard set of calibrations each night, as follows.

1. It takes a standard set of 10 biases and BVri dome flats (10 for each filter) each afternoon. The dome flats achieve a median level of about 10,000 counts. RTS2-F also takes u-band sky flats each evening, again with a median level of about 10,000 counts. Other bands may be requested. RTS2-F is also able to take sky flats in the morning. Sky flats start about 20 minutes after dusk or dawn, or 80 minutes after (before) sunset (sunrise) and end

about 10 minutes later. RTS2-F records statistics and the numbers of biases and dome (sky) flats it acquires in the directory /home/observer/RTS2-F/FLATS/ and files labeled domes-YYMMDD (skies-YYMMDD).

2. It references the telescope to zenith at the beginning of each night.

3. It focuses the telescope based on measurements of the FWHM of stars with the same method as the standard kfindfwhm script, which requires acquisition of exposures after twilight. It first sets the focus with the tempfocus script as a starting point; it then acquires a sequence of exposures and uses Sextractor to measure the FWHM of stars in the sequence. If the measurement fails, e.g., because of clouds, RTS2-F tries again after each sequence of exposures. After it is successful, it switches to tempfocus to adjust the focus as a function of temperature. The script uses a linear function that was fitted to a run of several months of measurements of temperature and focus with kfindfwhm. After each exposure, tempfocus adjusts the telescope focus if the temperature changes by more than 0.4C since its last adjustment.

2.8. RTS2-F data archive

All data obtained with the 1.2m and Keplercam are automatically transferred at the end of each night to the archive in Cambridge, directory /data/kepler/Archive/rawdata/keplercam/ in the TDC storage system. Data obtained with RTS2-F will be similarly archived.

Eventually a pipeline system bsed on the current system for SN will produce standard reductions of all data that will also be archived. Once we begin to address the pipeline system, we will also address issues of proprietary data.

3. Category 2 users

This section describes the parts of RTS2-F and the procedures that Category 2 users need to know to control the system when necessary.

3.1. RTS2-G controls

RTS2-G may be used to change the state (ON/OFF/STANDBY) of RTS2-F, e.g. in case of sudden inclement weather requiring an immediate shutdown although its constraints (see below) are not violated, or to enable RTS2-F. The controls are accessed via the "View or change current state" link in the home page. The options are shown in Fig. 4. You change the state by clicking on one of the 3 buttons shown.

3.2.   RTS2-F controls

In addition to RTS2-G, a number of scripts are available under RTS2-F to control and monitor the system from the observer account. It is generally not necessary for the observer to exercise the controls, but remote monitoring may be useful, especially during TOO observations that may require a rapid response, e.g., to acquire additional data or to communicate results.

Detailed descriptions of the RTS2-F control scripts may be viewed with the *man* command in any xterm on flwo48. These are the most commonly used scripts:

1. *rts2-mon* is an "ncurses" (see http://www.gnu.org/software/ncurses/) xterm tool for controlling devices available in RTS2-F. One may read and modify the values of system variables in these categories: ephemeris, weather, dome status and database status. Just as under RTS2-G, one may also change the state of the system, but with the F2, F3 and F4 keys for OFF, STANDBY and ON, respectively. To view the available menu entries, use F9 and to quit F10 or CTRL-C if F10 fails. Note that this script runs as a client and provides a visualization of the hardware, but it does not control observations. Fig. 5 is a snapshot of rts2-mon running in an xterm.

2. *rts2-nightreport* provides a report of events and observations for a given night, by default for the current date. One may use the options -n YYYY-MM-DD to specify a log from the night of YYYY-MM-DD, or -f YYYY-MM-DD and -t YYYY-MM-DD to specify a range of nights.

3. *rts2-targetinfo X* lists the database information for target X.

4. *rts2-targetlist* lists all the targets in the database.

5. *rts2-target* manages targets in the RTS2-F database. For example, one may enable/disable targets in the database (-e/-d options), delete targets (–delete-targets option) **with care**, change target priorities (-p option) and perform various other target management tasks.

3.3.   RTS2-F hardware controls

RTS2-F controls telescope hardware such as the dome slit, mirror covers and flat lamps as needed. New Telshell commands operate the hardware and are used by RTS2-F, but are also available at the Telshell window:

- *opensesame/closesesame* (aliases to *openslit/closeslit*)

- *opencovers/closecovers*

- *tele incandon/incandoff*

The close and open commands save the status of the slit or covers after they have executed. There are also commands to control the dome slit and check its status and that of the mirror covers:

- *closeslit* may also be issued in any xterm to close the dome slit; it is useful for an emergency shutdown.

- *openstatus* in any xterm prints out OPEN/CLOSED for the dome slit and the mirror covers, depending on their status.

RTS2-F uses the Vaisala weather station and its output stream (temperature, wind speed and direction, RH). If RH rises over a threshold set as a parameter in *rts2-mon* (normally 90 %) or the wind speed rises above a similarly set threshold (normally 40 mph sustained, or 45 mph gusting), it sets the state of RTS2-F to STANDBY, stopping exposures as soon as possible, stowing the telescope, closing the mirror covers and closing the dome slit.

3.4.   How to Start RTS2-F

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For now, you need to become username petr to proceed with steps 1 and
2 below. If you need to, please ask how to do that.  Steps 1 and 2
are only necessary if RTS2-F becomes unresponsive during a run
started with step 4 below.

1) If the system is stuck and needs to be restarted, type:
/home/petr/rts2-sys/etc/init.d/rts2 stop
This command stops the RTS2-G XML web server.

2) To restart the server and the monitoring, type:
/home/petr/rts2-sys/etc/init.d/rts2 start

3) To make sure it's all working, type: rts2-mon
This command drives an xterm and shows the status of the whole
system. Navigate with the arrow keys on the left column (5 items
should be visible); tab to the right panel, where you can change
states where you see a W to the left of a variable; use the F9 key to
see and interact with menu items at the top: e.g., to change the
status of the system (ON/STANDBY/OFF) under States. Use F10 to quit
(CTRL-C if that fails). 2 tabs from the right panel get you back to
the left column.  Try man rts2-mon for a complete description.

4) In the Telshell window, type: goRTS2-F
That will start the main script to run the full system.  As a safety
precaution, the default status of the system is OFF, so it must be
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switched to ON to start the nightly sequence. Once we are confident of the weather response and overall behavior of the system, RTS2-F may be left to run more than one night at a time.

3.5.   How to Stop RTS2-F

Normally, the robot will take sky flats and then close up the telescope by itself. Sky flats start about 20 minutes after dusk or dawn and take about 10 min for u band. Check the Telshell window. If it succeeded as indicated by the normal Telshell prompt, skip to step 5.

If everything is not closed up when you are ready to leave, you will need to stop the robot. But if you're not falling down tired, please bear with it if it's still doing sky flats, it knows to stop once it's too bright.

Here's how:
1) In any xterm type: rts2-abort
It takes a couple of minutes to complete the abort. If it succeeds and you get a prompt in the Telshell, skip steps 2-3.

2) If it doesn't respond, try CTRL-C in the Telshell. If this works, skip step 3.

3) If CTRL-C doesn't do it, kill the system. Before you do this, please try to copy and paste the Telshell window and email it to me or save it in a file and email where you put it.

To kill the system, type killcom in any xterm (you may have to type it twice) then gokep in any xterm to restart the system. Wait until you see the prompt in the Telshell and the yellow ntcs window is up.

4) In the Telshell type: shutall
This command stows the telescope, then closes the covers and then the slit.

5) Once it's all closed, disable the drives and fill the dewar.

Appendix 1: RTS2-F input catalog

```
# Example catalog for RTS2-F
#Key
#Col 01: ID = object name
#Col 02: RA to 100ths
#Col 03: Dec to tenths
#Col 04: Epoch to tenths
#Col 05: Proper Motion Ra sec-cen.nn
#Col 06: Proper Motion dec sec-cen.nn
#Col 07: Comma-separated list: Filter-ExpTime-NumExp,...
#Col 08: Repeats for Col 07
#Col 09: Time between repeats given in Col 08
#        (-1=disable; else time in sec if no units, otherwise give h,d,m,y)
#Col 10: AmpCen (0-4, 0 is centered)
#Col 11: Autoguide (0 or 1)
#Col 12: Priority, (User), 1-10
#Col 13: Seeing Limit
#Col 14: Airmass Limit
#Col 15: Moon Limit: 0 to 90 deg, 90 no observation if moon is up
#
#next 2 lines are REQUIRED keywords in each catalog, start with !
!P.I.: Falco
!Program: RTS2-F tests
test1  10:45:51.92  30:40:56.5  2000.0 0.00 0.00  U-360-3,B-30-4,V-35-4 3 3d 0  0   10 3  2.5 5
test2  11:21:08.25   6:01:45.6  2000.0 0.00 0.00  B-30-1,V-45-2,R-35-3 1 -1 0  0    8  3  2.7 10
```

Fig. 1.— RTS2-G main page.

Fig. 2.— Sample RTS2-G targets page, top and bottom.

Name   sn10it
RA DEC   03:41:57.500 -04:42:21.10
ALT AZ   -26°48'27.13" 258°14'19.75"
Bonus   690.879944
Priority   800.000000
Sidereal Time 03:10:28.96
JD   2455539.41687103
Enabled   yes

Camera KCAM:ampcen=2 autoguide=OFF tempdisable 1d filter=B E 300 filter=V E 300 filter=r E 300 filter=i E 300

Fig. 3.— RTS2-G single target page.

Current state is: HARD OFF

Set state to:

[OFF]

System is off, telescope parked (and not powered, if system allows that).

[STANDBY]

System is prepared to take observations, but dome is closed. This state is used to end observations in case of bad weather.

[ON]

System is up and running, taking images during night.

Fig. 4.— RTS2-G state switching page. For parked read stowed, and ignore the statement within parentheses.
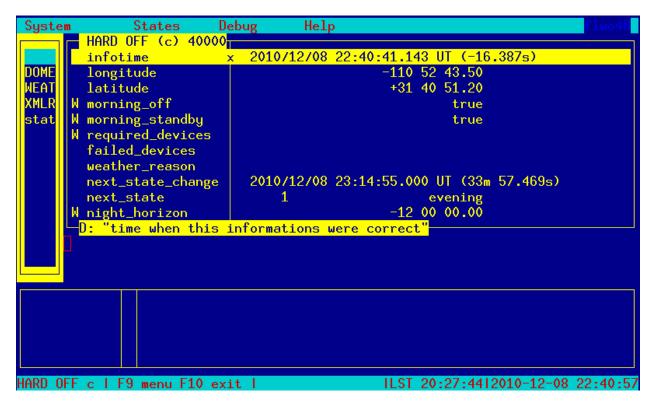
Fig. 5.— A view of rts2-mon in action (clearer labels forthcoming).