RTS2 - Remote Telescope System, 2^{nd} version

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Introduction

BART is a small remote controlled robotic CCD telescope, devoted to rapid observation of prompt gamma ray burst transients. During its operation since early 2001, it had three prompt observations with world-competitive response time. The constraints to object magnitude were estimated and published in GCN circulars. Telescope is located in Astronomical Institute of the Czech Academy of Sciences in Ondřejov. This poster describes its new control system, named RTS2, which is in service since February 2003.

RTS2 is designed as a networked system for driving of robotic telescopes. It is composed of several device servers, central server and various observational clients cooperating over a TCP network. For the communication, there is a private protocol, ensuring speed and reliability. It is intended to be independent on used astronomical HW, with access points for controlling of different types of mounts, domes and CCDs. Observation entries, requests and results are kept in database. Positions of GRBs are received from the Internet, and observed either in prompt mode, or added to list of observation targets, depending on weather and other conditions influencing the observation. The idle time, when there is not any request for GRB observations, spends the telescope monitoring various active galaxies. The database lookup entry point is accessible at http://lascaux.asu.cas.cz/bartdb.

New system has been recently implemented also for cooperating Spanish-Czech BOOTES experiment. It is installed and performs well on stations BOOTES-1 and BOOTES-2 in southern Spain.

The system may be used on most Linux distributions. The vast majority of the code is written in C programming language and uses PostgreSQL database.

System code

The system consists of three kinds of programs:

central server
server/client programs for accessing and controlling devices like cameras, telescope or weather controller paired with dome/roof controller
client programs to control an observation - currently there is scheduler client for regular observations, gamma ray burst client for prompt observations of GRB optical transients, console based monitoring client, stream based monitoring client and focus client for camera focusing

Central server holds list of all connected devices and clients. Every new device register to central server in order to be accessible to clients, and every client connect and authorise itself to central server in order to be able to access devices.

Access to devices is priority-based - only client with the highest priority can access state-changing functions of a device - such as mount moving, or exposing and readout of camera. During a long-running operation, if a client loses priority, the operation is cancelled and devices are able to serve a new request of a client having higher priority. That is important for GRB observing, where the lowest response time is the most tentative criteria.

Priority requests are being sent from clients to the central server. It holds a list of priorities of all connected clients. If it finds that the priority has to be changed, it informs all connected devices about such change.

We are able to control whole family of SBIG parallel port based CCD cameras. We work on USB based SBIG, Apogee and FLIcam CCDs. We are able to control LX200 family of telescopes by Meade, and we have an alpha level driver for the Paramount.

Implementing a driver-layer of nearly any device daemon should be relatively easy thanks to a well-elaborated design of the upper layers.

Database structure

The basic structure of database can be seen on Figure 1. The main tables are TARGETS, OBSERVATIONS and IMAGES.

Possible targets are kept in TARGETS table. Each target entry has a type, used by scheduler when selecting a target. Each target can have an expanding table of constraints (or properties) defining how it is to be observed. Such properties involve a minimum nightly images expected, minimal temporal difference between observations etc.

OBSERVATIONS table form a relation between TARGETS and IMAGES. It may be thought as a log of all light images performed by telescope. In IMAGES table there are stored only images which have got astrometry computed by the real-time processing software (ie have at least basic scientific value).

Image analysis

Observed images can be processed with any image analysis software, which is able to run on UNIX based operating system. Currently we use modified Opera package, which was developed at Madrid. It writes sky coordinates in standard World Coordinate System (WCS) header to processed images. Coordinates of processed images are being sent to the telescope driver, to be used to fine-tune its tracking.

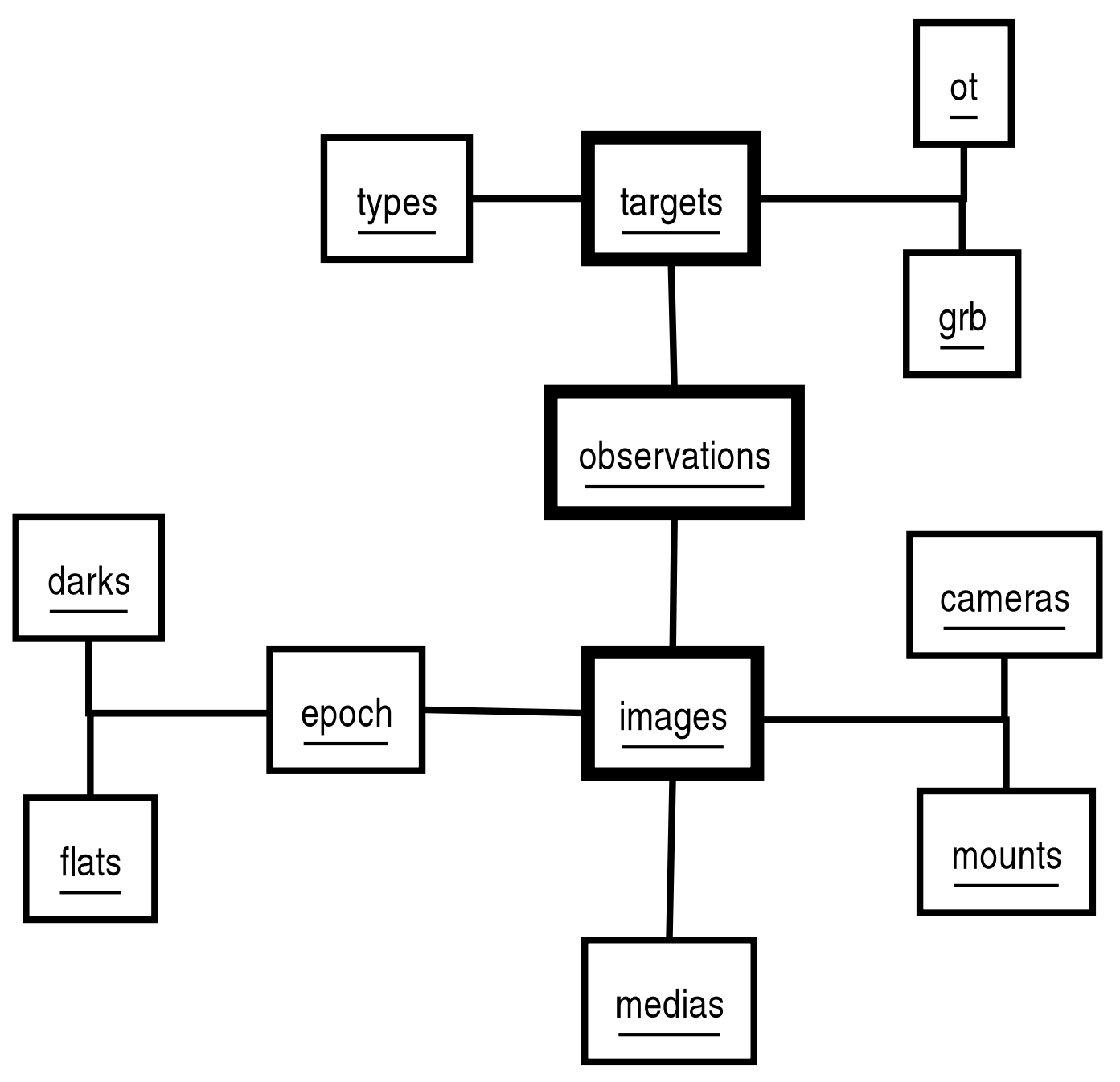

Figure 1: Database structure overview

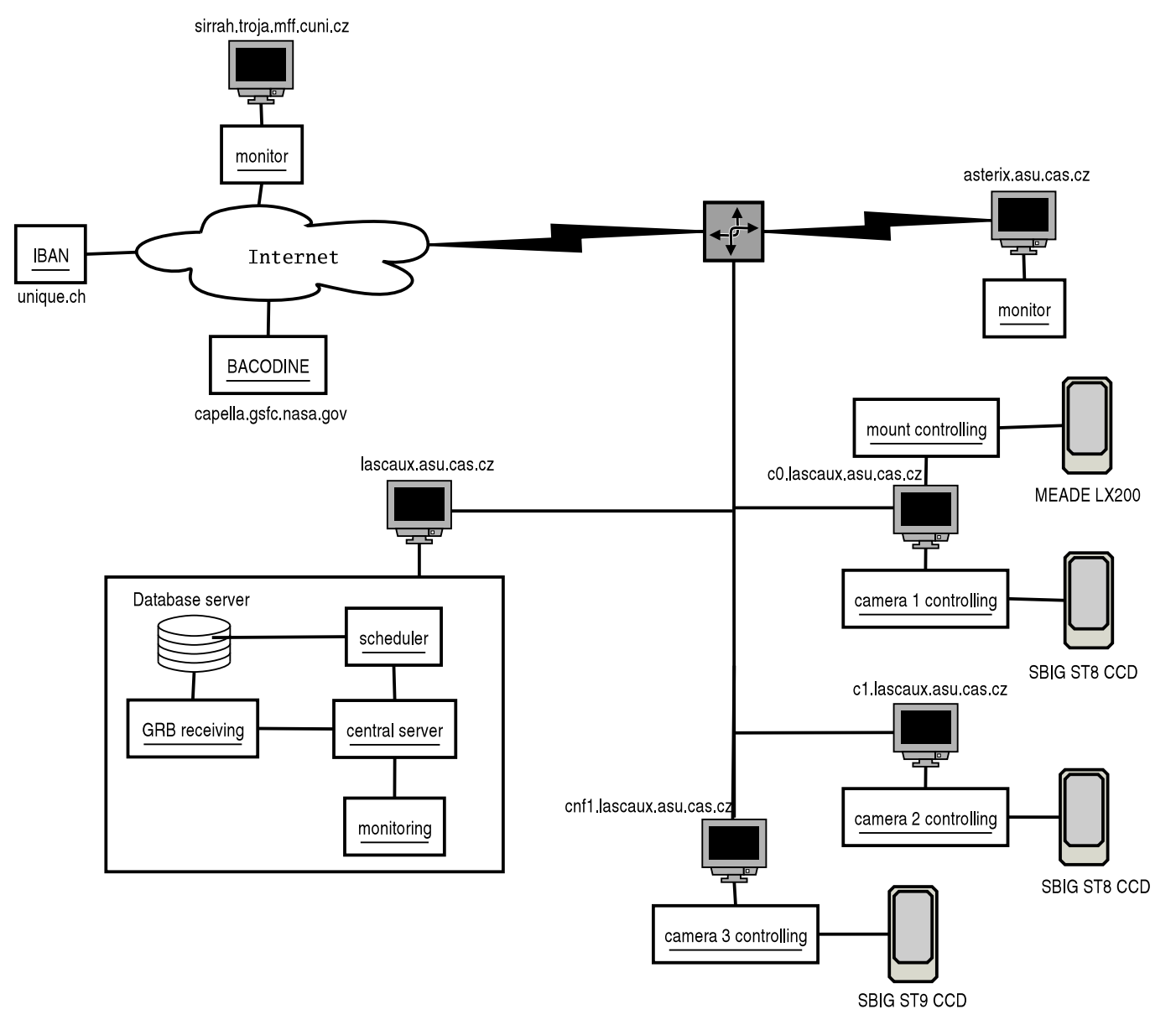

Figure 2: BART - system structure

Addresses

BART	http://lascaux.asu.cas.cz
BART database	http://lascaux.asu.cas.cz/bartbd
BOOTES-2 database	http://193.146.150.58/bootes2db
Petr Kubánek	petr@lascaux.asu.cas.cz
Martin Jelínek	mates@asu.cas.cz

System operation

Main scheduler takes care of obtaining pictures for flat-fields during dusk and dawn. It also obtains dark-frames at predefined time interval.

Composition of system can be at best understand from an example. On Figures 2 and 3 is described current configuration of Ondřejov BART.

Lascaux is an 2GHz Intel Celeron PC compatible computer running Debian GNU Linux. There resides central server, database, web server for database access and from there observations clients are usually run.

Other PCs are low-end Pentium or 486 class computers. They run stripped-down Debian, which occupies vast majority of theirs hard-drive.

The computers are interconnected by an industry standard 100Mb switched Ethernet network. Possible network bandwidth largely exceeds the needs of our system, the readout speed of our cameras is 30kHz at 16 bits per pixel, not exceeding 4% of possible network throughput per camera.

GRB receiving

Primary GRB receiving is done through dedicated client. It's connect through socket to GCN server in NASA-GSFC. If it get GRB event, which is currently visible, it ask central server for priority, move mount and after mount movement have been finished, it ask for camera exposures. Pictures from cameras are downloaded during readout through network to computer running GRB client. There they are stored, get WCS, and keep in database.

In case that socket connection fails, backup system uses reliable e-mail receiving. GRB event is then observed from main scheduler. Main scheduler also takes care of observing GRB error box, which were bellow horizon when they occurred, or which were received when system wasn't operational due to bad weather conditions.

System stability

RTS2 is observing in Ondřejov for half a year. Majority of errors in program code have been tracked down. System is running there in semi-automatic mode, with staff available to check it 24 hours a day. The restriction is given by the lack of automatic roof control, thus the need of person to watch the weather nightly. This will change after complete roof automatization in beginning of 2004.

In Spain, at BOOTES-2, RTS2 have been implemented recently, without any trouble in a few days, it performs well until the moment of this writing. Here it works in fully automatic mode, without human intervention in place, controllable only through the Internet.

The RTS2 is based on experience gained from RTS1, which had been running on BART for two years.

Documentation

The whole RTS2 package is available on request to download, with complete source code included. There is slow progress on manual pages for whole system, but we expect to improve manuals as we don't have to track any errors now.

The code is covered by GNU license, which enables anybody under modify it, if certain conditions are being held.

The system development is tracked in CVS versioning system. RTS2 uses GNU automake and autoconf tools for Makefile creation.

Current results

Between 15^{th} and 18^{th} August 2003, RTS2 responded to following GCN triggers:

Telescope	GCN #	RTS-2 #	Delay	first image	Notices
BART	2805	5740	1d 10:15	08-16 20:06:47	(1)
BOOTES-2	2805	67	09:18:26	08-15 19:10:05	(1)
BART	2808	5741	00:10:07	00:36:34	(2)
BOOTES-2	2808				(3)
BART	2809	5742	17:53:37	20:28:49	(2)(4)
BOOTES-2	2809				(3)
BART	2812	5743			no observation, bad weather
BOOTES-2	2812	78	00:00:21	23:16:49	(5)

(1) Daytime GCN, burst localisation observed from scheduler during night.
(2) Due to problems with rights on log file, GRB client wasn't running, all observations were from scheduler. That's reason for such long delay.
(3) GRB client crashed at 2003-08-16 around 16:30 UT, leaving no traces. Code review will follow.
(4) GRB was bellow horizon at receiving time.
(5) GRB was on horizon, images are sometimes disrupted with trees.

Exact timing of GRB-2812 processing on BOOTES-2

Time (UT)	Event
23:16:01	Burst detected on HETE
23:16:11	GCN without localisation
23:16:21	First GCN with localisation
23:16:22	Beginning of observation
23:16:22	GRB client ask for priority and get it
23:16:22	GRB client start moving telescope from 01:36:58, +15:49:12
23:16:22	scheduler request for common observation is ignored
23:16:48	Mount reach its position
23:16:49	Start of first 30 sec exposure
23:19:xx	First image with on-line astrometry

Limiting magnitude on NF was about 13 at the beginning of observation. No new object was found.

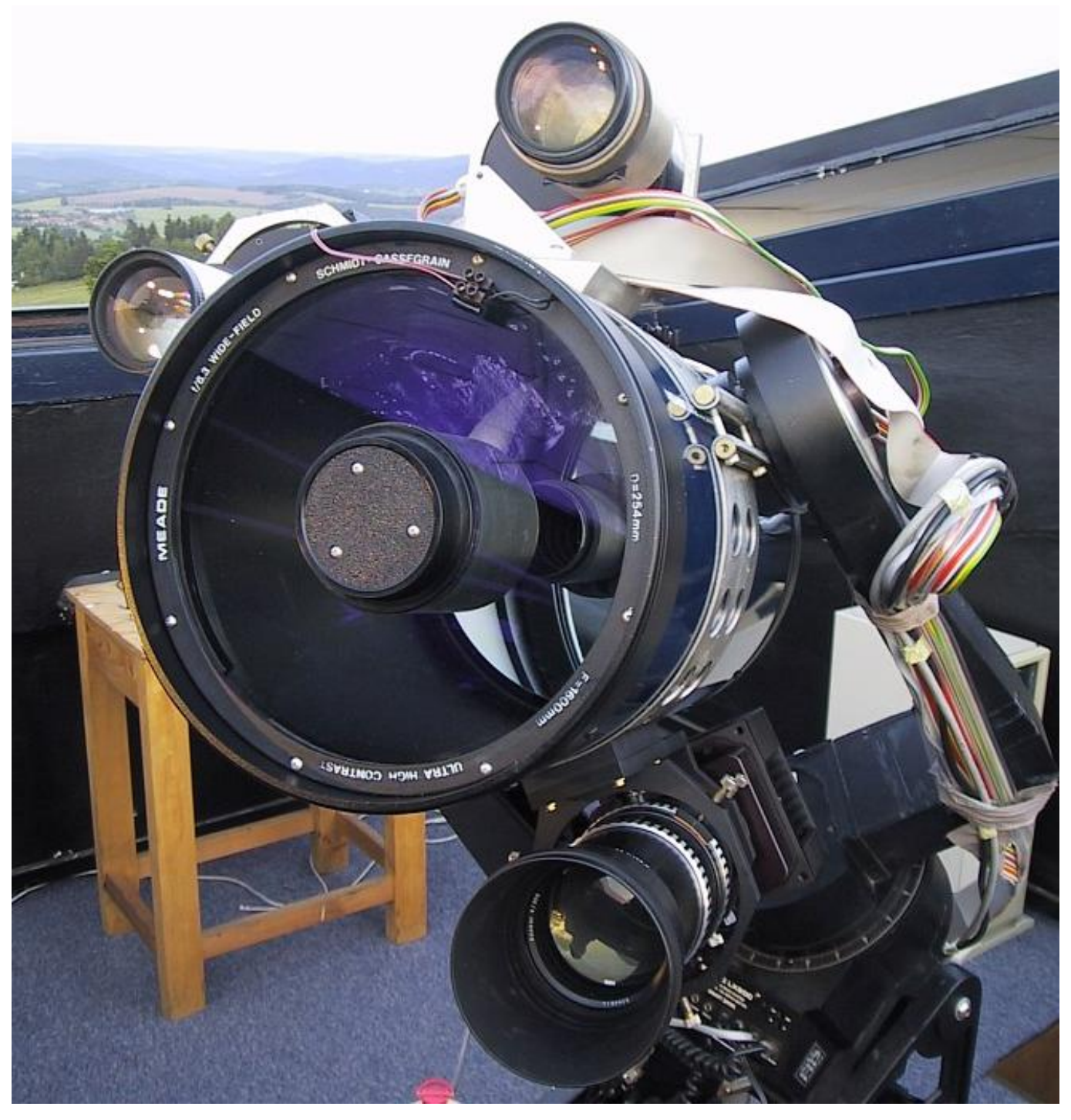

Figure 3: BART - telescope picture

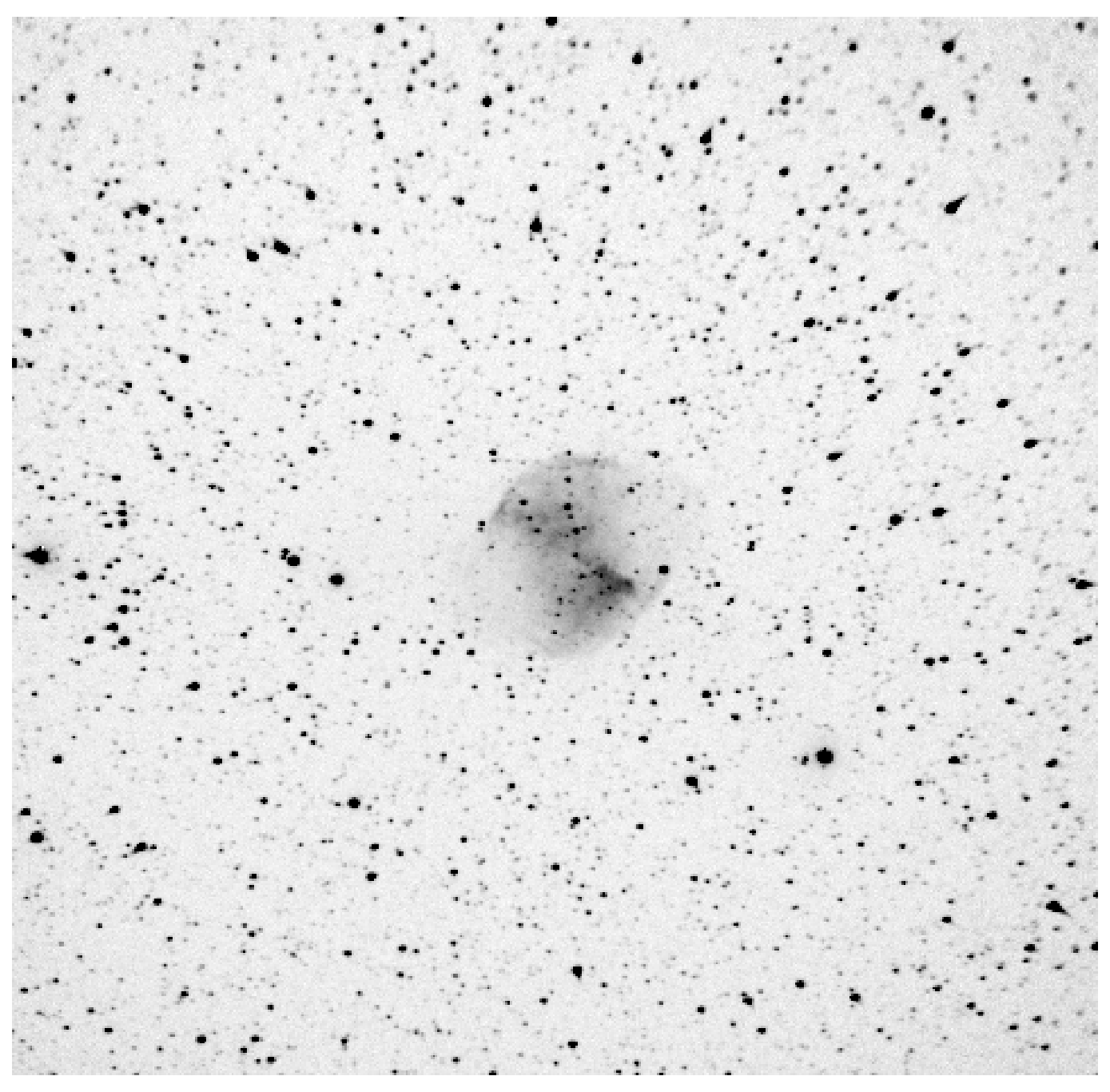

Figure 4: BOOTES 2 - Narrow-field M27 (Dumbell) picture (30 sec exposure)