InfraRed Imaging of astronomical targets with a Stabilised Camera

IRISC

DLR MORABA, Oberpfaffenhofen

11-15 February 2019

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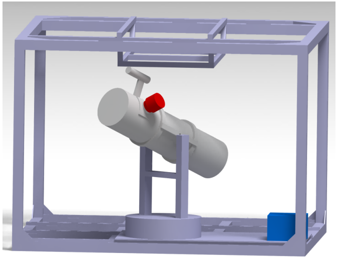
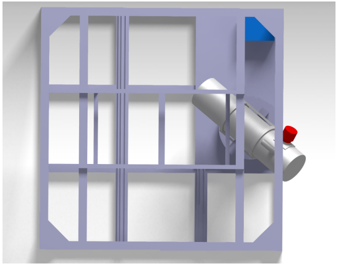
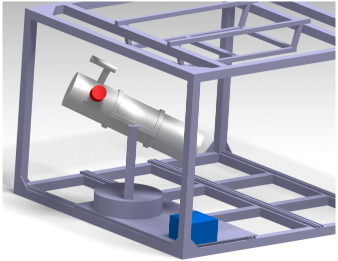
In a Nutshell

Our vision is to make astronomical research more accessible by developing a stabilised balloon-borne telescope

Construction



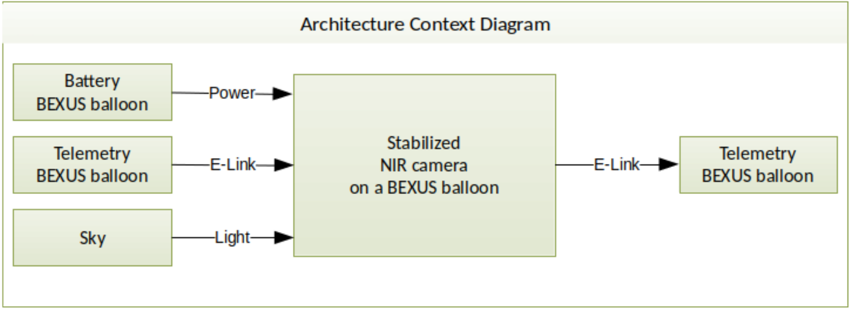




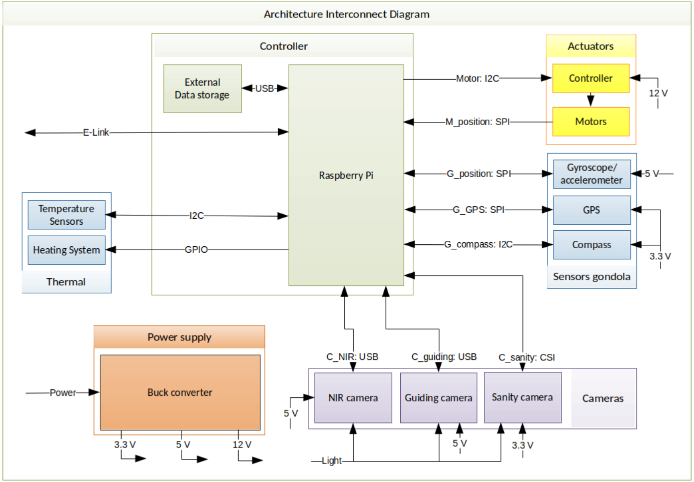
Thermal

- Using a Newtonian telescope gives us the advantage of not needing an added baffle anymore since the primary mirror is situated on the rear part of the telescope, effectively using the telescope's structure as a baffle.
- For the electronics box, FEA analysis will be made in order to determine the heat produced by the components and therefore determine where heating or cooled will be required.

Electrical ACD



Electrical AID



Power Consumption

	Power [W]	**On-time [%]**	**Energy 4h [Wh]**
NIR camera	1.5	100	6
Guiding camera	1.5	100	6
Controller	6.25	100	25
Sensors	1	100	4
Motors	3 x 4.2	100	50.4
Heating system	10	20	8
Subtotal			99.4 Wh
Standby E (6h)			40 Wh
Total			139.4 Wh

Bandwidth

Item	File size*	Downlink rate	Datarate
NIR camera	18 MB	60 sec	2.4 Mbits/sec**
Guiding camera	2 MB	60 sec***	0.27 Mbits/sec
Sanity camera	7 MB	On request	-
Sensors****	30 B	1 sec	240 bits/sec

* File sizes reflect lossless compressing

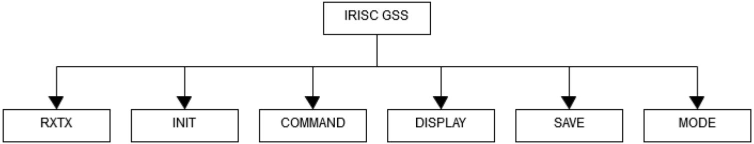
** Not planned to send all pictures down, thus will be reduced

*** Onboard save time is 15 sec

**** GPS; Compass; Gyroscope; Encoders; NIR temp sensor

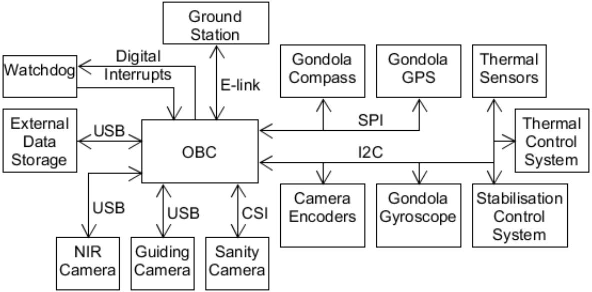
Ground Station

- K.I.S.S.
- Written in C with GTK+



On-board Software

- The glue between the systems
- C on a simple linux distro
- Compression and storage



Control system

- Stabilisation of the gimbal: dynamic control system (e. g. PID)
  Sensor data: gyroscopes, accelerometer
  Includes mechanical model of gimbal, motors

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Control system

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- Selection and tracking of targets:
  Sensor data: magnetometer, GPS, gyroscopes, encoders
  Includes model of movements of astronomical targets

Control system

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- Selection and tracking of targets:
  Sensor data: magnetometer, GPS, gyroscopes, encoders
  Includes model of movements of astronomical targets
- Feedback loop, measured states: utilisation of a Kalman filter to determine exact position & orientation

Control system

Minor objectives of the control system:

- Avoid looking directly into the Sun
- Thermal control of the camera sensor and electronics
- Motor control

NIR Camera

- CMOS Sensor: ZWO ASI183MM (mono-colour)
  resolution: 20.18 MP, sensor size: 13.2x8.8 mm
- NIR-conversion with 720 nm NIR filter
- Sensitivity: 720 nm to 1150 nm
- Rolling shutter: no mechanical shutter, no moving parts

Credits: ZWO ASI183MM (mono)

Guiding Camera

- For verification of the field of view
- Support of ground-based re-calibration of sensors (e. g. magnetometer, gyroscopes)
- Imaging sensor with a high sensitivity, resulting in shorter exposure times (compared to NIR camera)
- Imaging in visible wavelengths

Credits: Guiding camera by ZWO

Telescope

SkyWatcher BKP 130DS (with eyepiece in place of the camera)

SkyWatcher BKP 130DS

- Newtonian telescope
- Focal length: 650 mm
- Aperture: 130 mm
- FOV: 1.16 deg by 0.78 deg
- Diffraction-limited-resolution: 1.94 arcsec
- Pixel size: 0.76 arcsec (in combination with the camera)

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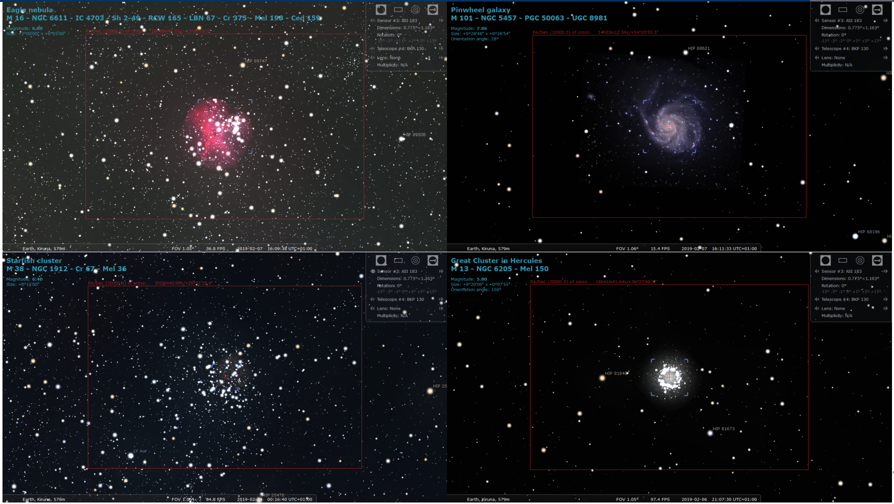
Targets


Eagle nebula
M 16 - NGC 6611 - IC 4703 - Sh 2-49 - RCW 165 - LBN 67 - Cr 375 - Mel 198 - Ced 159
Pinwheel galaxy
M 101 - NGC 5457 - PGC 50063 - UGC 8981
Starfish cluster
M 38 - NGC 1912 - Cr 67 - Mel 36
Great Cluster in Hercules
M 13 - NGC 6205 - Mel 150

Signal to Noise Ratio

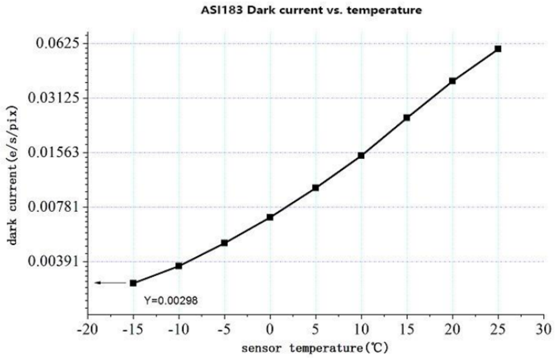
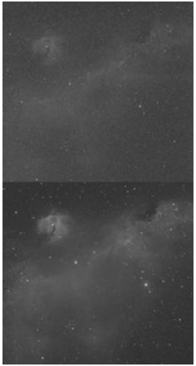


Figure: Dark current vs. temperature as given in the camera manual



Credit: Richard S. Wright Jr., SkyandTelescope.com

Data Analysis

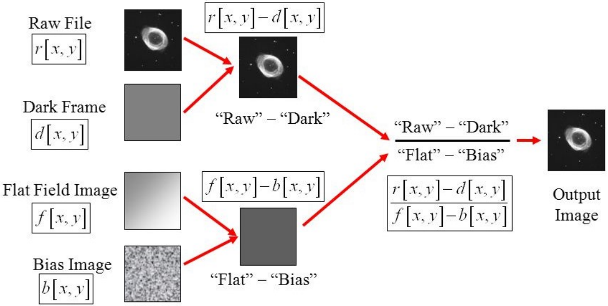
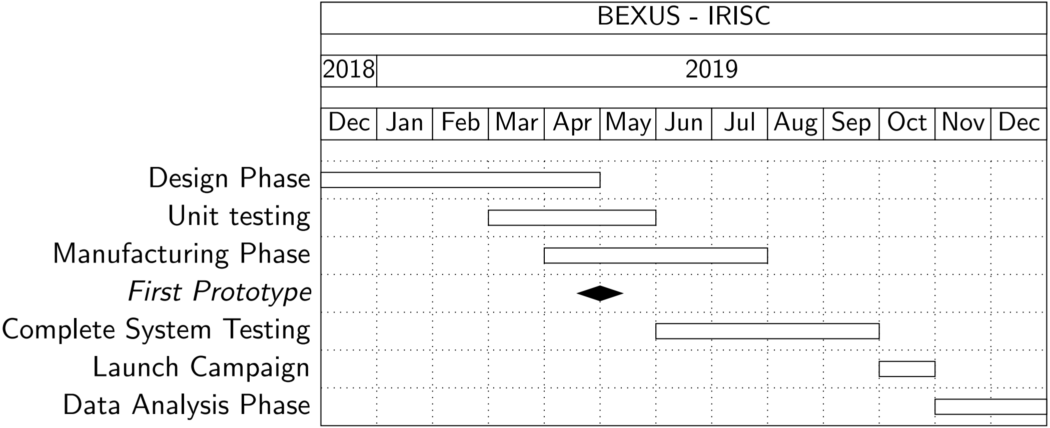


Figure: Standard astrophotography image calibration pipeline

- **Light Frames:** image of the target itself
- **Dark Frames:** aperture blocked of light
- **Flat Frames:** brightness balance of the sensor
- **Bias Frames:** readout noise due to the sensor

Schedule


BEXUS - IRISC
2018
2019
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Design Phase
Unit testing
Manufacturing Phase
First Prototype
Complete System Testing
Launch Campaign
Data Analysis Phase

Outreach

Website and Social media

- Facebook
- Twitter
- Instagram

Summary

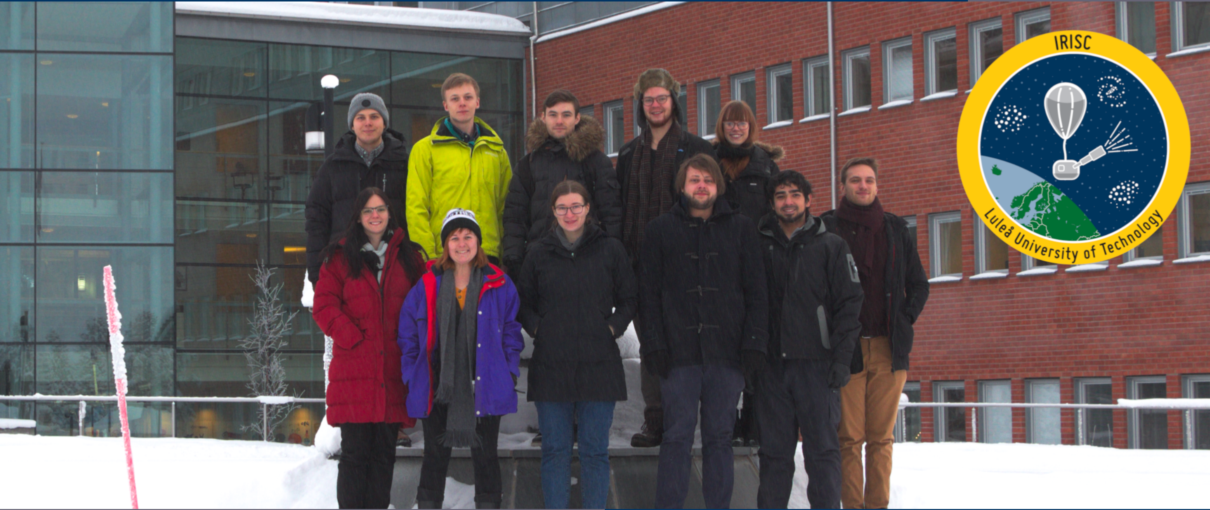
- Proof of concept of a stabilised balloon-borne telescope with an NIR camera
- Empowered by the BEXUS project
- To achieve a higher degree of accessible and affordable astronomical research

Thank you for your attention

Let us explore the NIR universe with a BEXUS balloon together!

A. Möslinger, K. Steele, D. Talavera, N. Ulfvarson, and E.F.M. Weterings

and the rest of the IRISC team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Cooling electrical systems in space

The only way to get rid of thermal energy, outside the lower atmosphere, is radiation. Passive solutions are:

- Highly efficient components.
- Passive cooler with fluid (convection).
- Solid thermal conducting material connected to the heat sources (conduction).

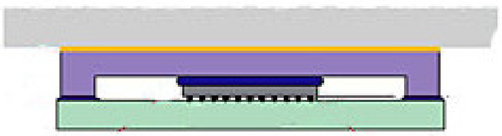
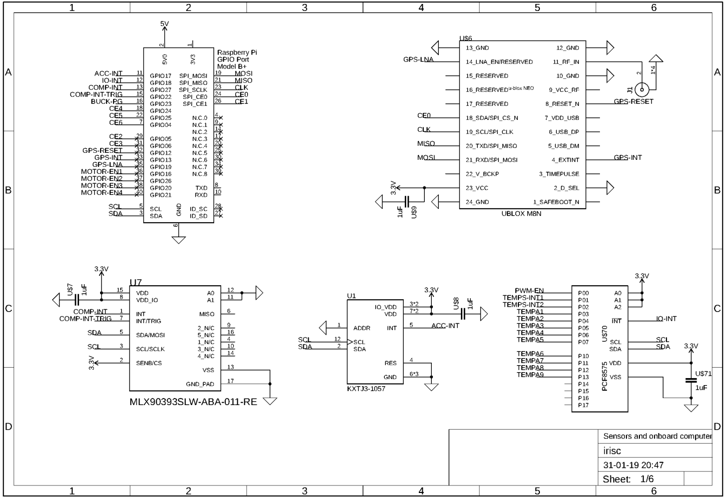
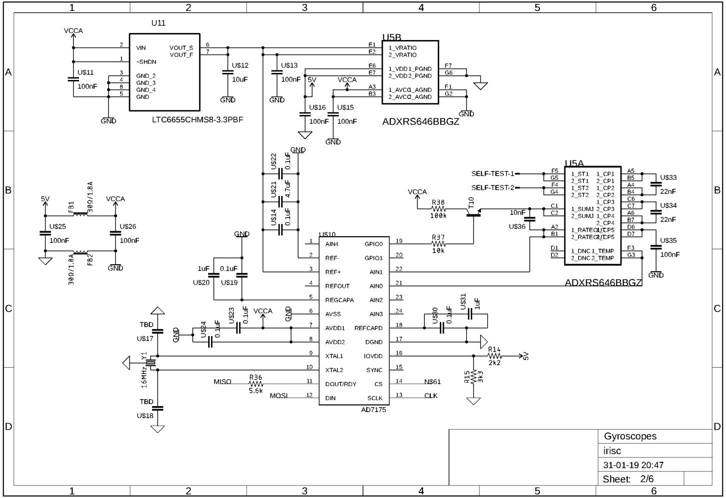


Figure: Clemens J. M. Lasance, cooling electronics

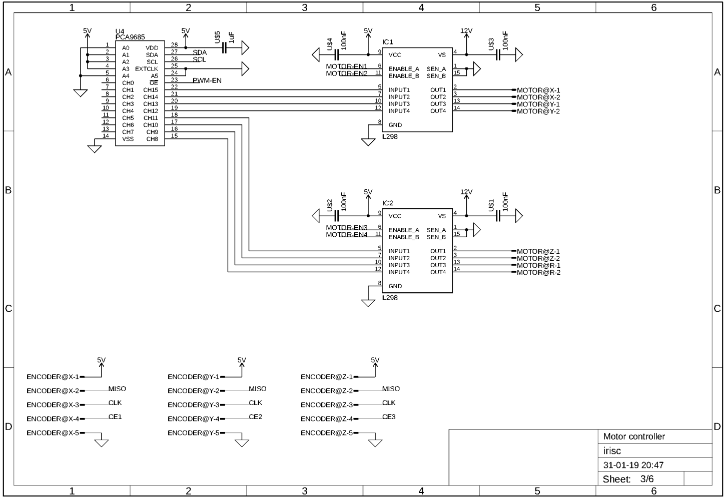
Schematic: Sensors & onboard computer



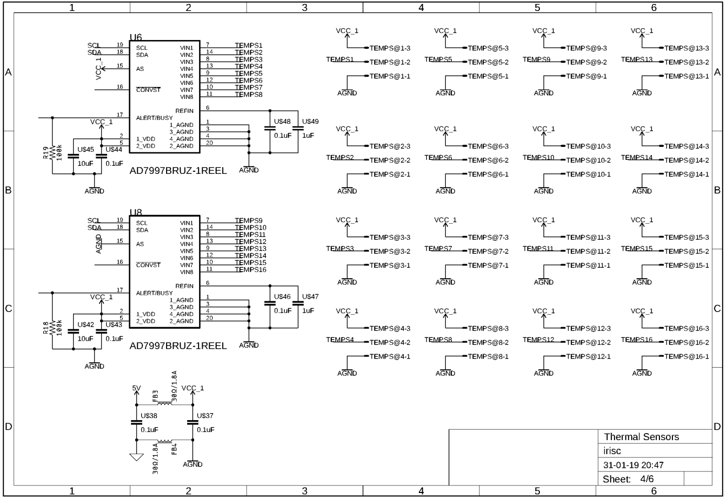
Schematic: Gyroscopes



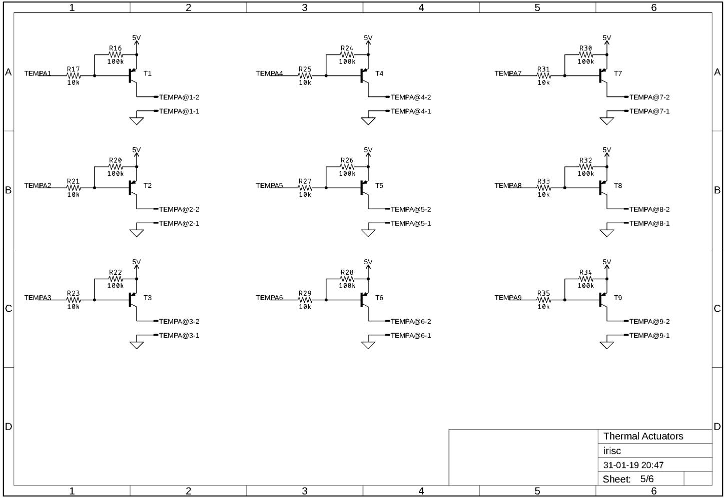
Schematic: Motor Controller



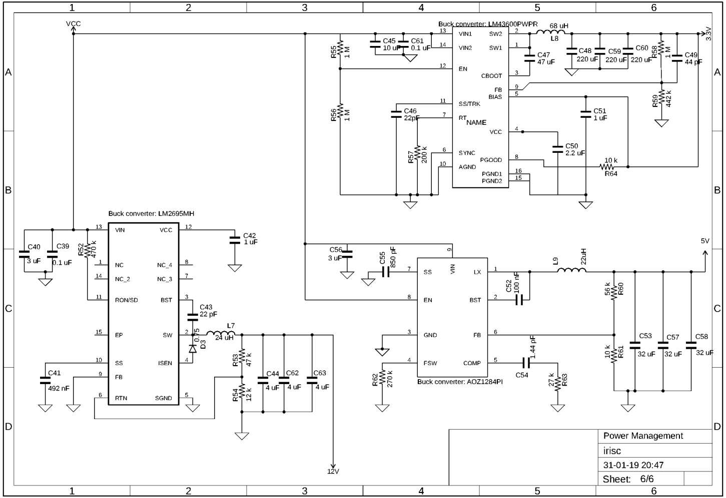
Schematic: Thermal Sensors



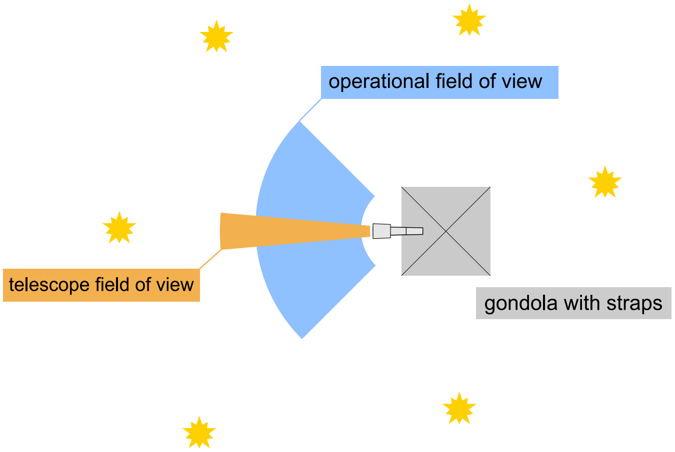
Schematic: Heating System



Schematic: Power Management



Control System



Telescope

SkyWatcher BK MAK127 OTAW (with eyepiece in place of the camera)

SkyWatcher BK MAK127 OTAW

- Cassegrain telescope
- Physical length: 33 cm
- Focal length: 1500 mm
- Aperture: 127 mm
- FOV: 0.5 deg by 0.34 deg
- Diffraction-limited-resolution: 2.01 arcsec
- Pixel size: 0.33 arcsec (in combination with the camera)

Targets (brightness-ordered)

Name	Designation	RA	DEC	Mag	Dim x (arcsec)	Dim y (arcsec)
Andromeda Galaxy	M31	0.70	41.27	3.44	190	60
Open Star Cluster	M52	23.40	61.58	5	13	13
Reflection Nebula	NGC 1333	3.48	31.35	5.6	6	3
Triangulum galaxy	M33	1.55	30.65	5.72	70.8	41.7
Hercules Globular	M13	16.68	36.45	5.8	20	20
Eagle Nebula	M16	18.30	-12.18	6	7	7
Iris Nebula	NGC 7023	21.02	68.17	6.8	18	18
Veil Nebula	NGC 6992	20.75	30.70	7	180	180
The Wizard Nebula	NGC 7380	22.78	58.10	7.2	25	25
Pacman Nebula	NGC 281	0.87	56.62	7.4	20	30
Starfish Open Cluster	M38	5.47	35.85	7.4	21	21
Crescent Nebula	NGC 6888	20.20	38.35	7.4	18	12
Dumbbell Nebula	M27	19.98	22.72	7.5	8	5.6
Pinwheel galaxy	M101	14.05	54.33	7.8	28.8	26.9
Whirlpool Galaxy	M51	13.48	47.18	8.4	11.2	6.9
Cigar Galaxy	M82	9.92	69.67	8.41	11.2	4.3
Intergalactic Tramp	NGC 2419	7.63	38.87	9.06	6	6
Sunflower galaxy	M63	13.25	42.02	9.3	12.6	7.2
Bubble Nebula	NGC 7635	23.33	61.20	10	15	8

Budget

- LTU Project funds
- Trusts and foundations
- Crowdfunding