



InfraRed Imaging of astronomical targets with a Stabilised Camera IRISC



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LULEÅ
TEKNISKA
UNIVERSITET

Table of Contents

① IRISC: In a Nutshell

② System

- Construction
- Thermal
- Electrical Setup
- Ground Station
- OBSW
- Control System
- Cameras
- Telescope

③ Science

- Targets
- Expected Results
- Data Analysis

④ Project Management

- Schedule
- Outreach

⑤ Summary

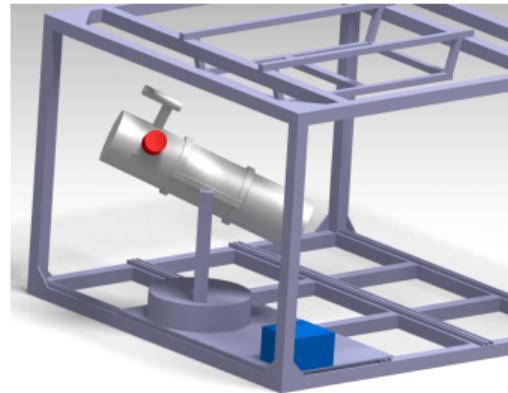
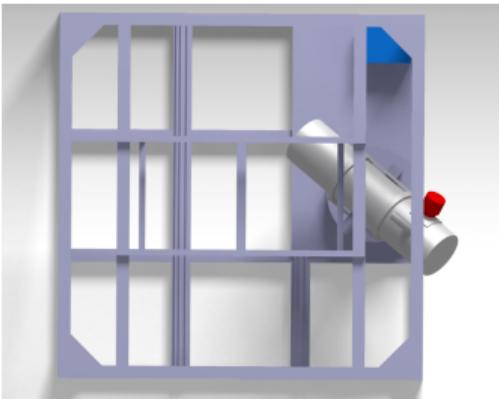
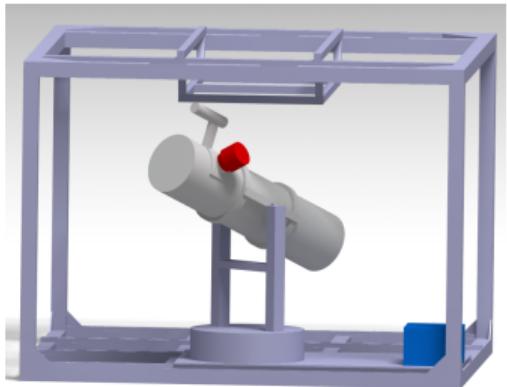
⑥ Questions

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

Construction

IRISC: In a Nutshell
System
Science
Project Management
Summary
Questions

Construction
Thermal
Electrical Setup
Ground Station
OBSW
Control System
Cameras
Telescope

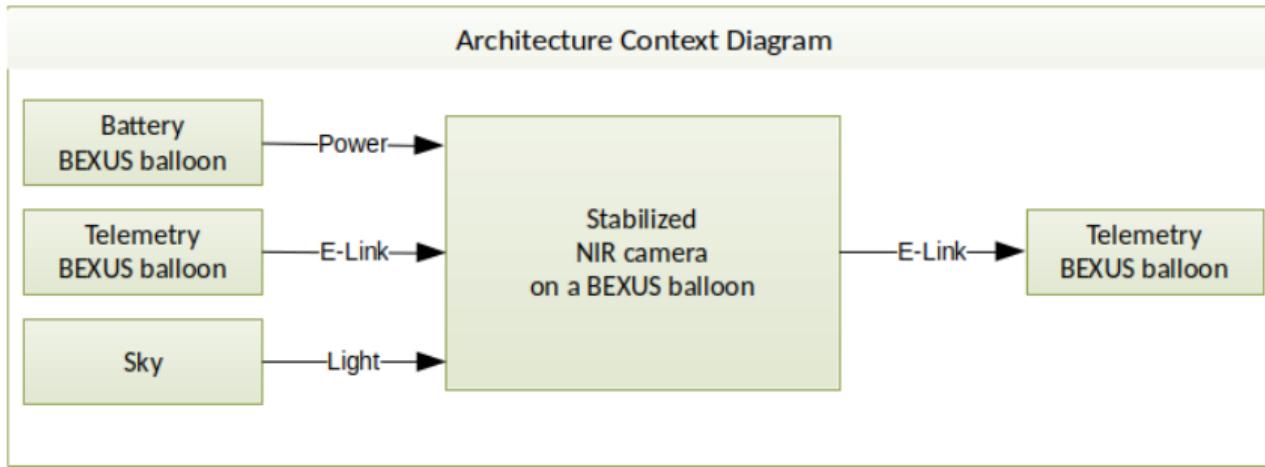


- Additional baffle not needed since a newtonian Telescope will be used
- FEA will be used to determine cooling or heatin requirements of the electronic components
- Heating pads will be used to prevent the motors from freezing
- cooling will be provided for the NIR camera to ensure good performance

Electrical ACD

IRISC: In a Nutshell
System
Science
Project Management
Summary
Questions

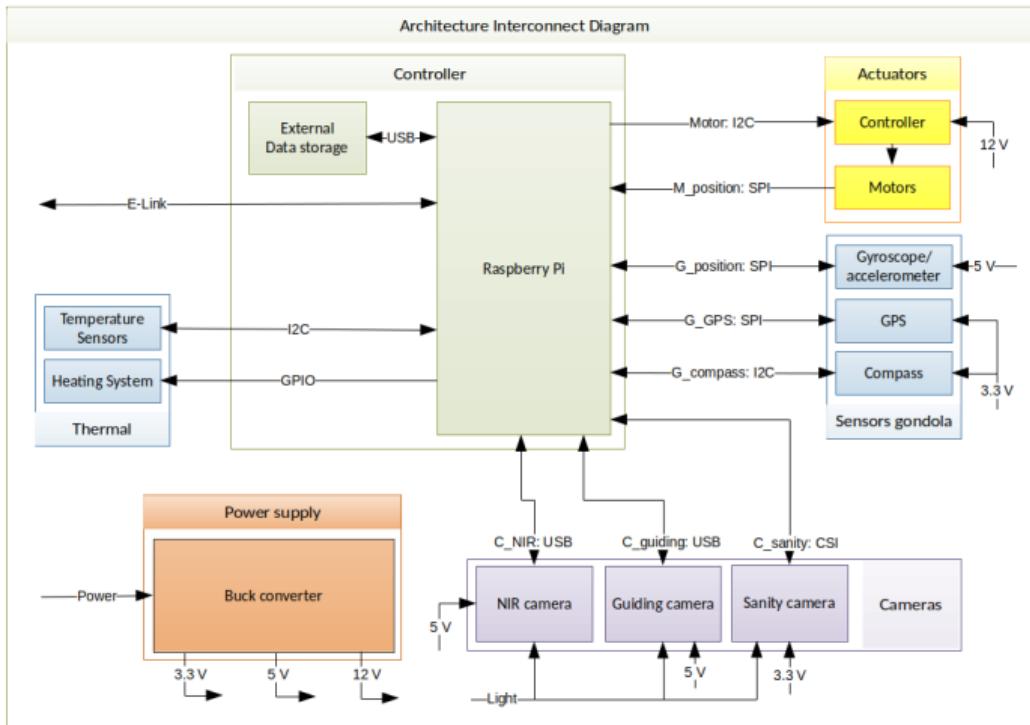
Construction
Thermal
Electrical Setup
Ground Station
OBSW
Control System
Cameras
Telescope



Electrical AID

IRISC: In a Nutshell
System
Science
Project Management
Summary
Questions

Construction
Thermal
Electrical Setup
Ground Station
OBSW
Control System
Cameras
Telescope



Power Consumption

IRISC: In a Nutshell
System
Science
Project Management
Summary
Questions

Construction
Thermal
Electrical Setup
Ground Station
OBSW
Control System
Cameras
Telescope

	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	3×4.2	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

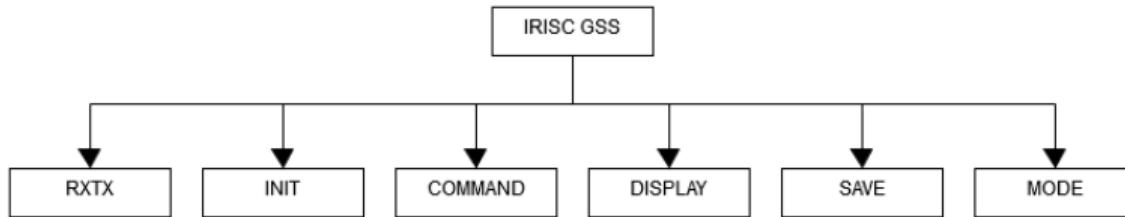
**** GPS; Compass; Gyroscope; Encoders; NIR temp sensor

Ground Station

IRISC: In a Nutshell
System
Science
Project Management
Summary
Questions

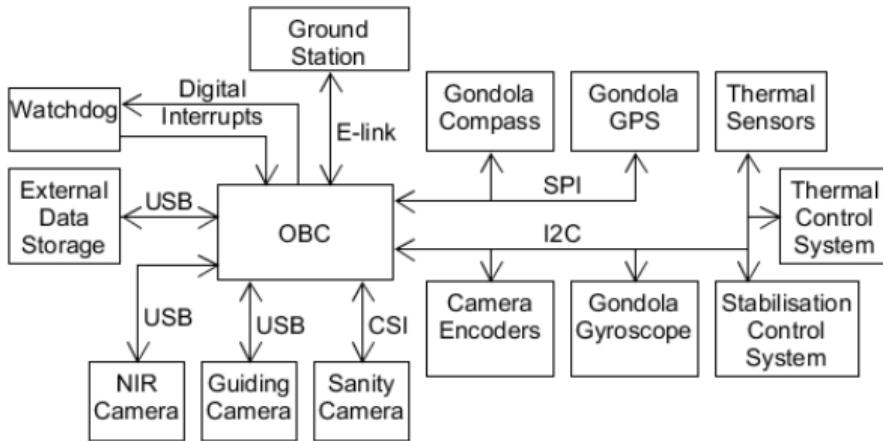
Construction
Thermal
Electrical Setup
Ground Station
OBSW
Control System
Cameras
Telescope

- 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

IRISC: In a Nutshell
System
Science
Project Management
Summary
Questions

Construction
Thermal
Electrical Setup
Ground Station
OBSW
Control System
Cameras
Telescope

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

Control system

IRISC: In a Nutshell
System
Science
Project Management
Summary
Questions

Construction
Thermal
Electrical Setup
Ground Station
OBSW
Control System
Cameras
Telescope

- Stabilisation of the gimbal: dynamic control system (e.g. PID)
Sensor data: gyroscopes, accelerometer
Includes mechanical model of gimbal, motors
- Selection and tracking of targets:
Sensor data: magnetometer, GPS, gyroscopes, encoders
Includes model of movements of astronomical targets

Control system

IRISC: In a Nutshell
System
Science
Project Management
Summary
Questions

Construction
Thermal
Electrical Setup
Ground Station
OBSW
Control System
Cameras
Telescope

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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

IRISC: In a Nutshell
System
Science
Project Management
Summary
Questions

Construction
Thermal
Electrical Setup
Ground Station
OBSW
Control System
Cameras
Telescope

Minor objectives of the control system:

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

NIR Camera

IRISC: In a Nutshell
System
Science
Project Management
Summary
Questions

Construction
Thermal
Electrical Setup
Ground Station
OBSW
Control System
Cameras
Telescope

- 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

IRISC: In a Nutshell
System
Science
Project Management
Summary
Questions

Construction
Thermal
Electrical Setup
Ground Station
OBSW
Control System
Cameras
Telescope

- 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



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)

Targets

IRISC: In a Nutshell
System
Science
Project Management
Summary
Questions

Targets
Expected Results
Data Analysis



Signal to Noise Ratio

IRISC: In a Nutshell
System
Science
Project Management
Summary
Questions

Targets
Expected Results
Data Analysis

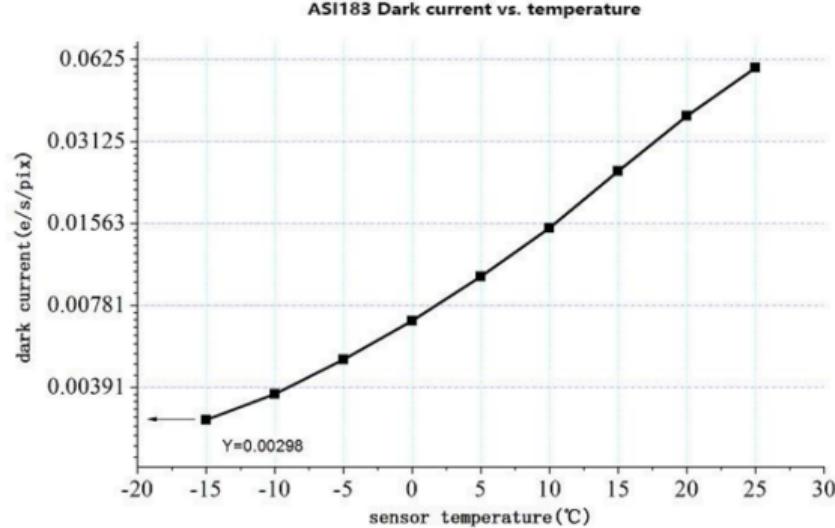
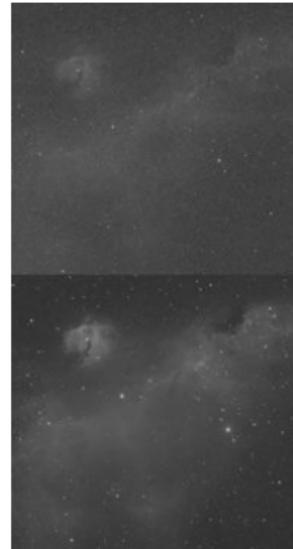


Figure: Dark current vs. temperature as given in the camera manual



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

Data Analysis

IRISC: In a Nutshell
System
Science
Project Management
Summary
Questions

Targets
Expected Results
Data Analysis

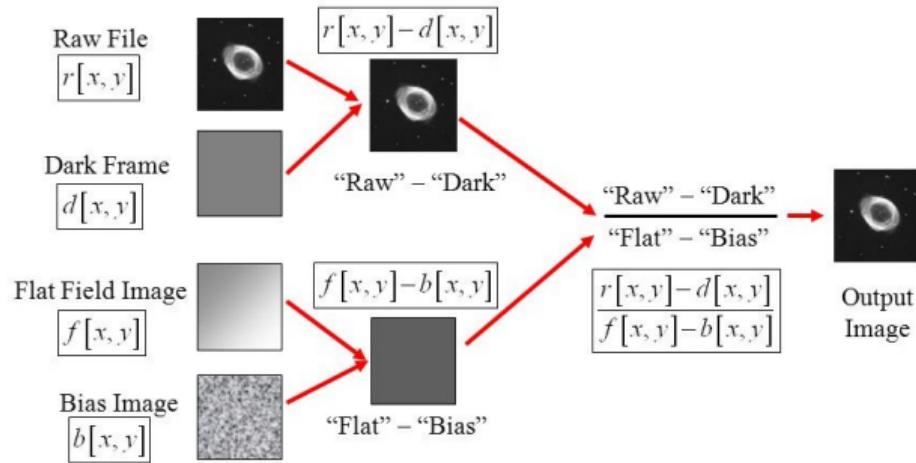
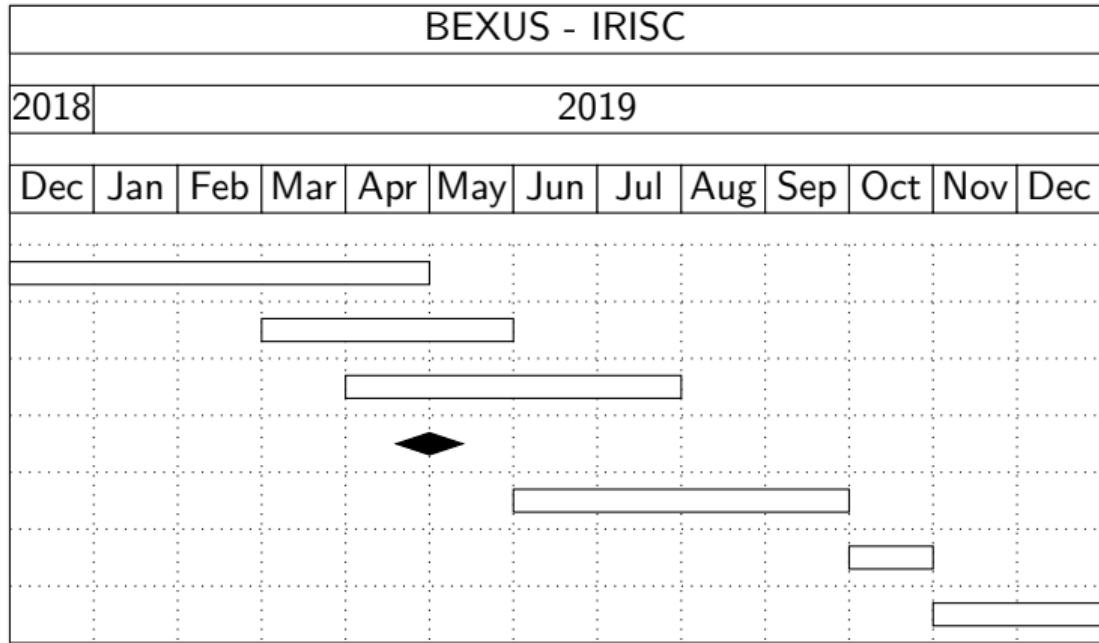


Figure: Standard astrophotography image calibration pipeline

- **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

Design Phase
Unit testing
Manufacturing Phase
First Prototype
Complete System Testing
Launch Campaign
Data Analysis Phase



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



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).

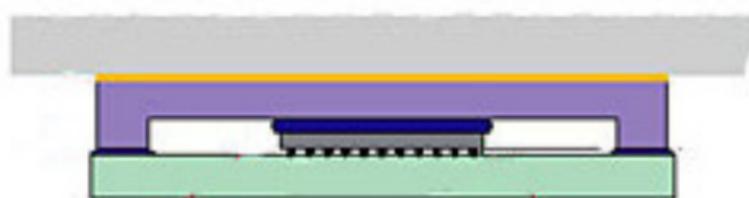
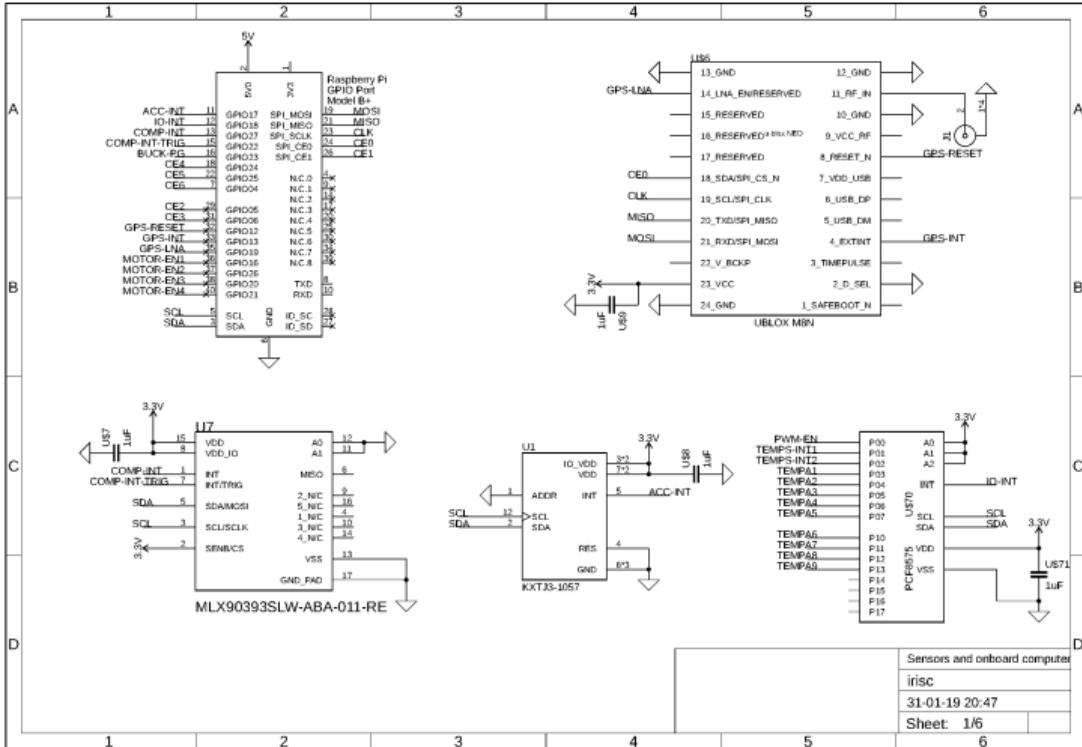
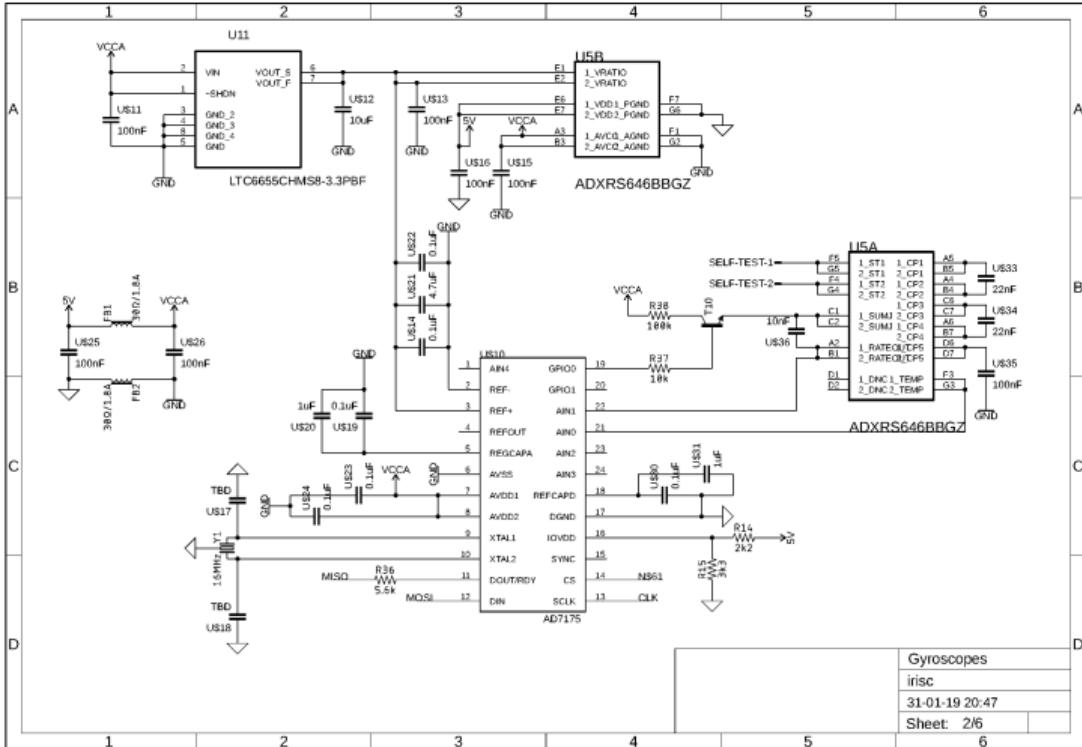


Figure: Clemens J. M. Lasance, cooling electronics

Schematic: Sensors & onboard computer



Schematic: Gyroscopes

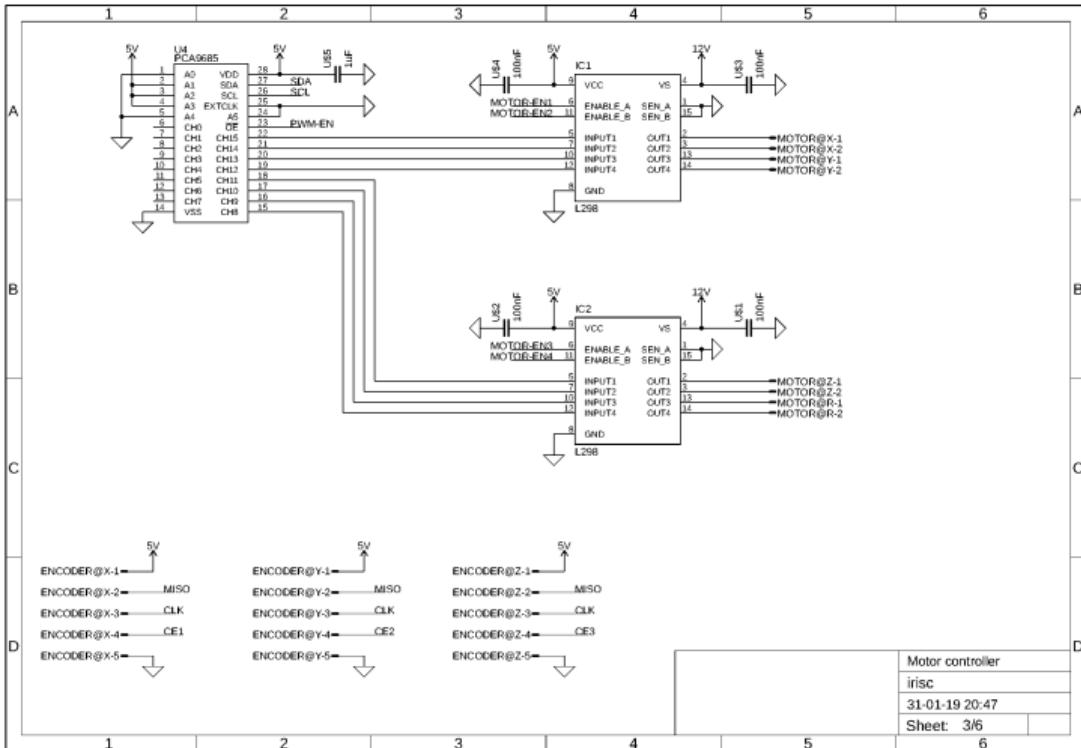


Schematic: Motor Controller

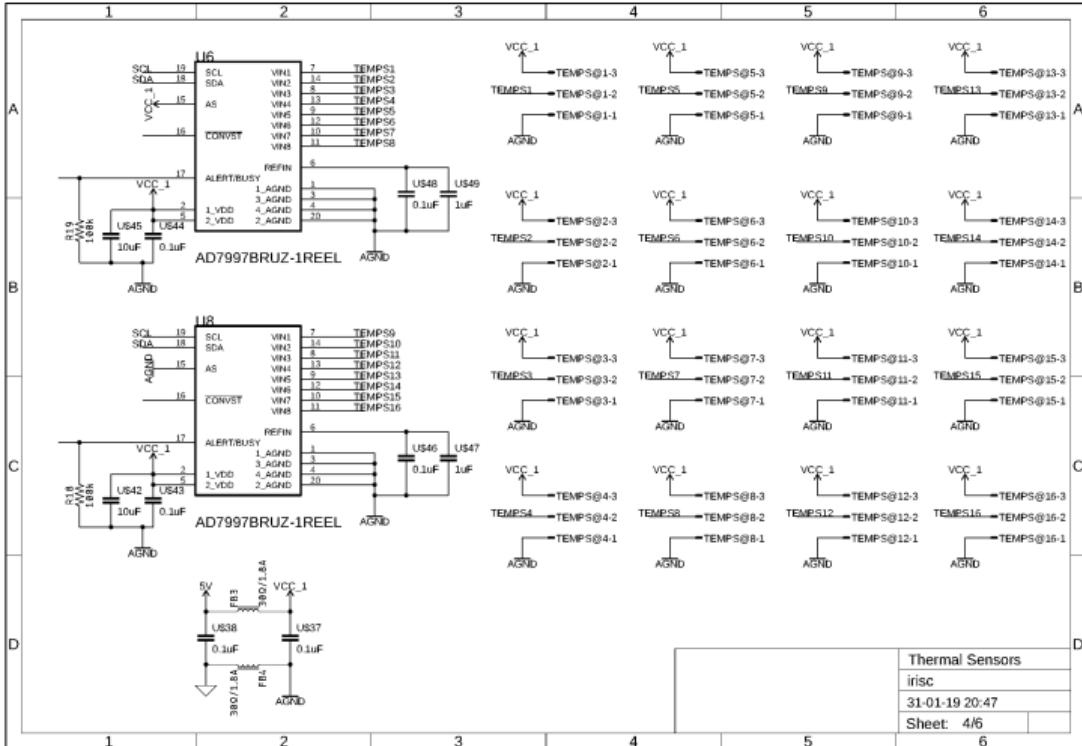
IRISC: In a Nutshell

System Science Project Management Summary Questions

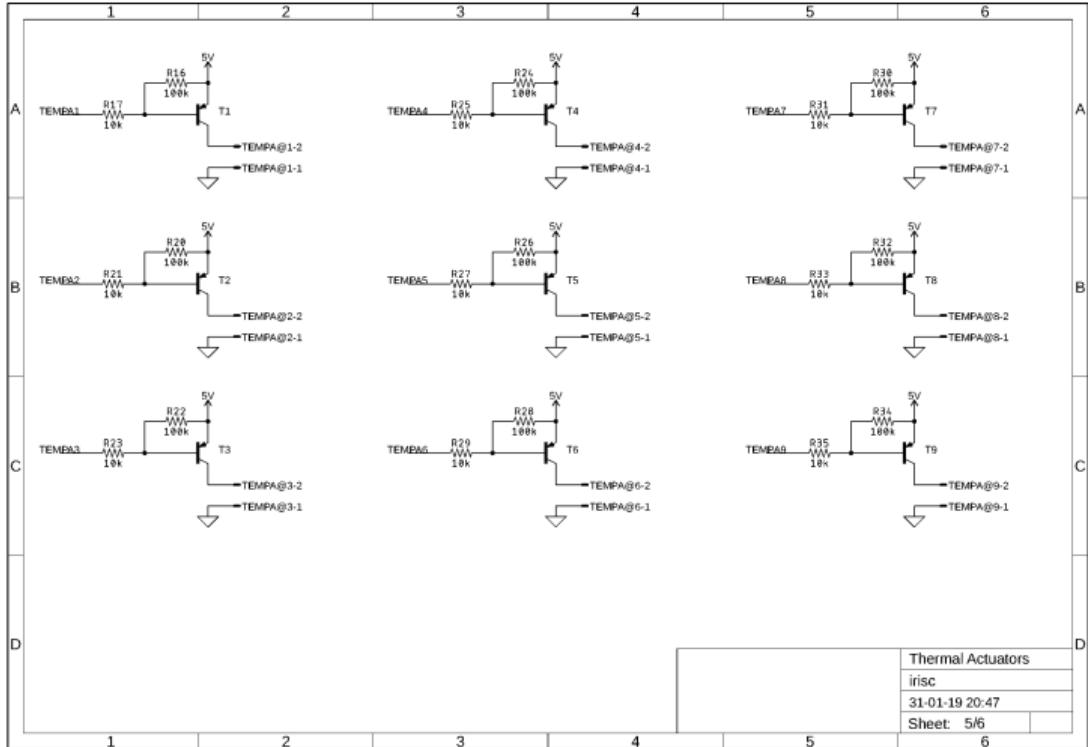
Electrical
Control System
Science
Budget



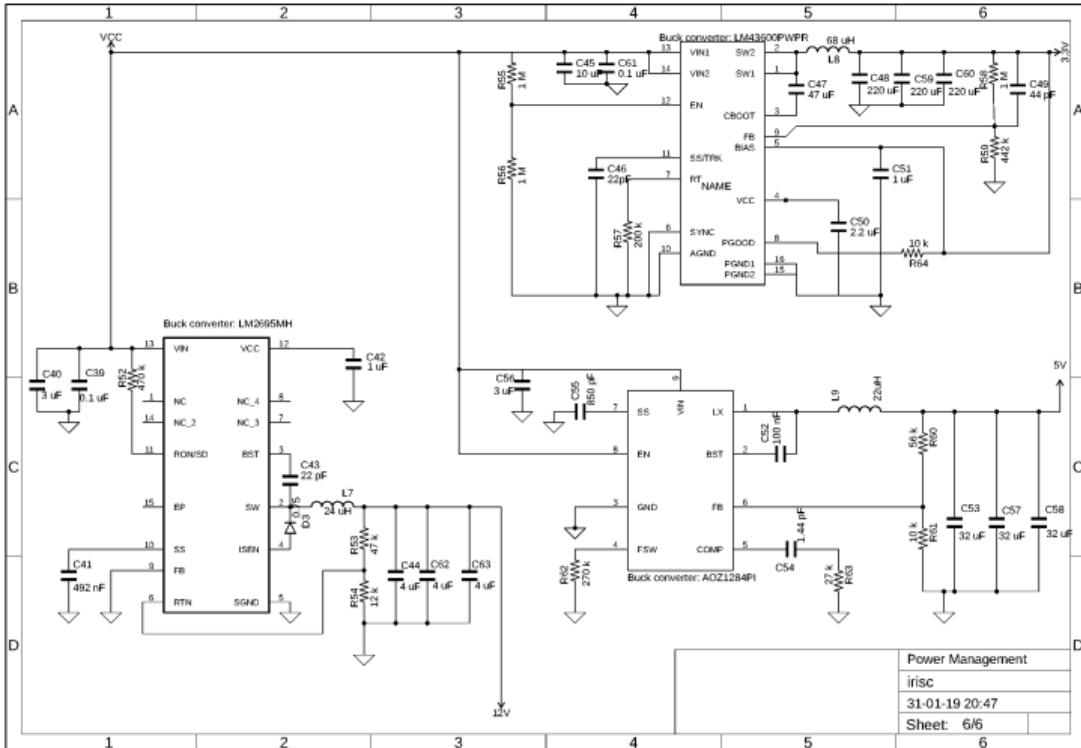
Schematic: Thermal Sensors



Schematic: Heating System



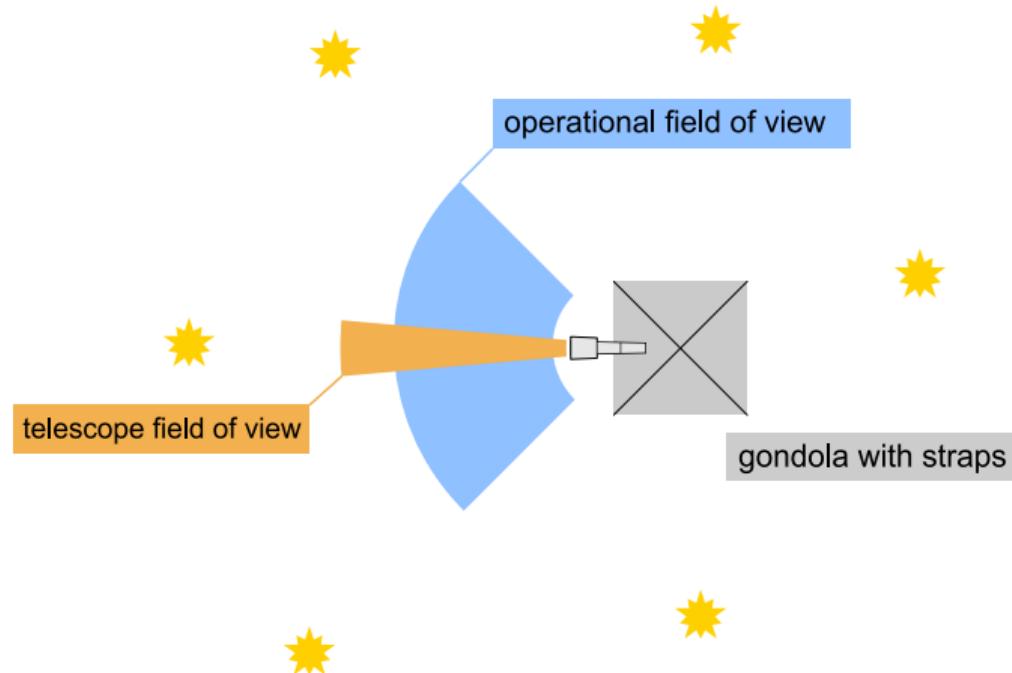
Schematic: Power Management



Control System

IRISC: In a Nutshell
System
Science
Project Management
Summary
Questions

Electrical
Control System
Science
Budget



Telescope

IRISC: In a Nutshell
System
Science
Project Management
Summary
Questions

Electrical
Control System
Science
Budget



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

IRISC: In a Nutshell
System
Science
Project Management
Summary
Questions

Electrical
Control System
Science
Budget

- LTU Project funds
- Trusts and foundations
- Crowdfunding