Airborne Calibration for CTA

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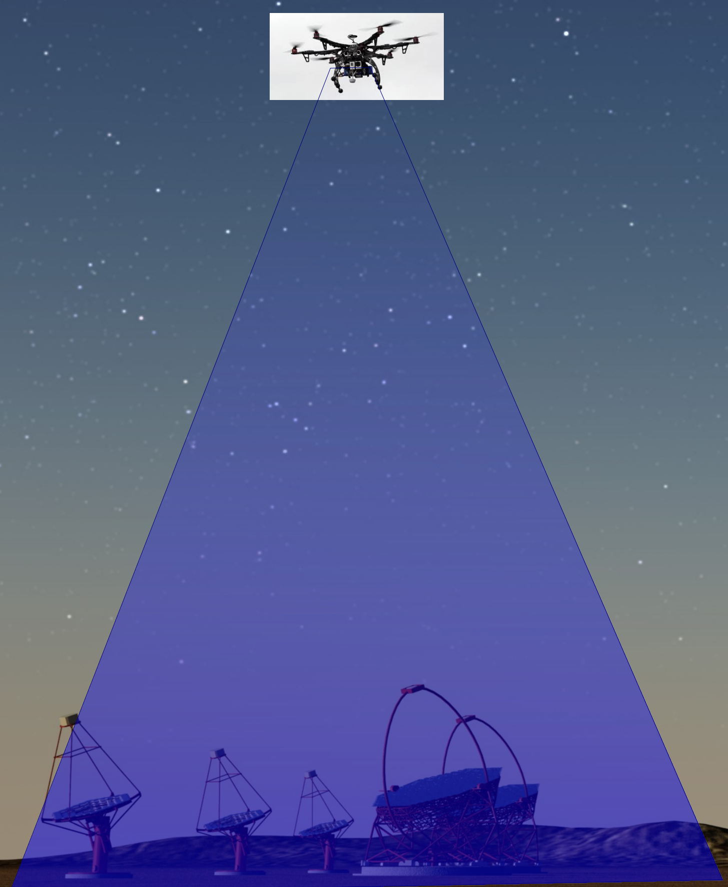
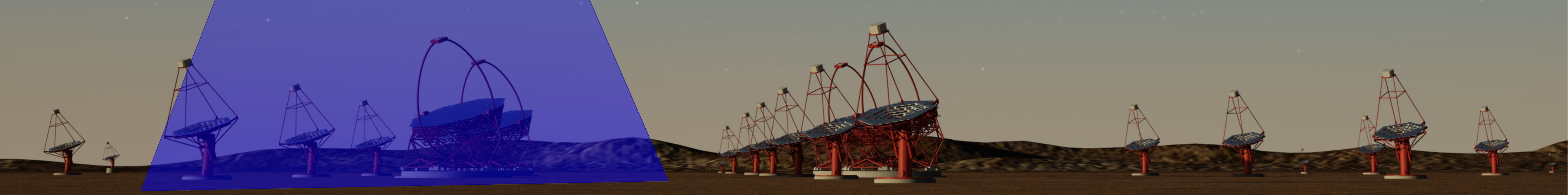


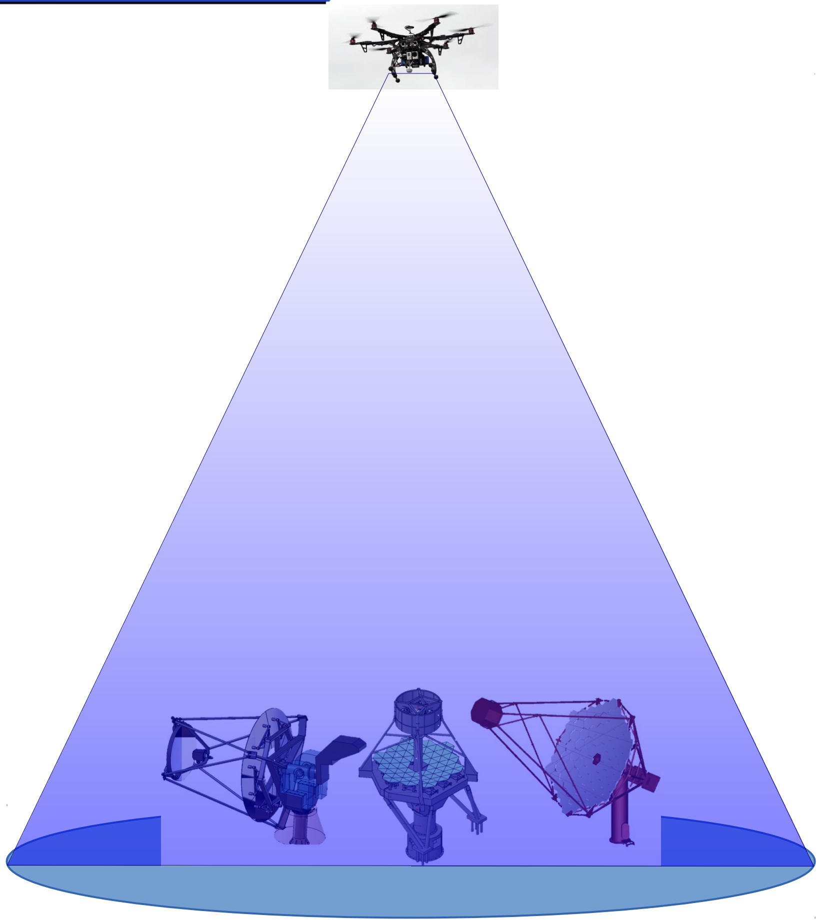


For the next 20 minutes...

- Where/what/how/why and whats new?
- Feasibility study
  - GNSS/RTK performance
  - Aerodynamic performance
  - Nephelometer
  - Safety & Legalities
- Possible designs/timelines

UAV Concept for CTA

- Use a multirotor UAV as a positionally stable, versatile platform on which to mount calibration payloads
  - Primary: UV flasher capable of 5-10ns pulses and >100pe at scope (MWL?)
  - Secondary: nephelometer to sample atmospheric dust content



Benefit to CTA?

Cross-calibrate telescopes with a well defined light Source.

Map the dust 3D distribution in the first 1km of atmosphere above the array.

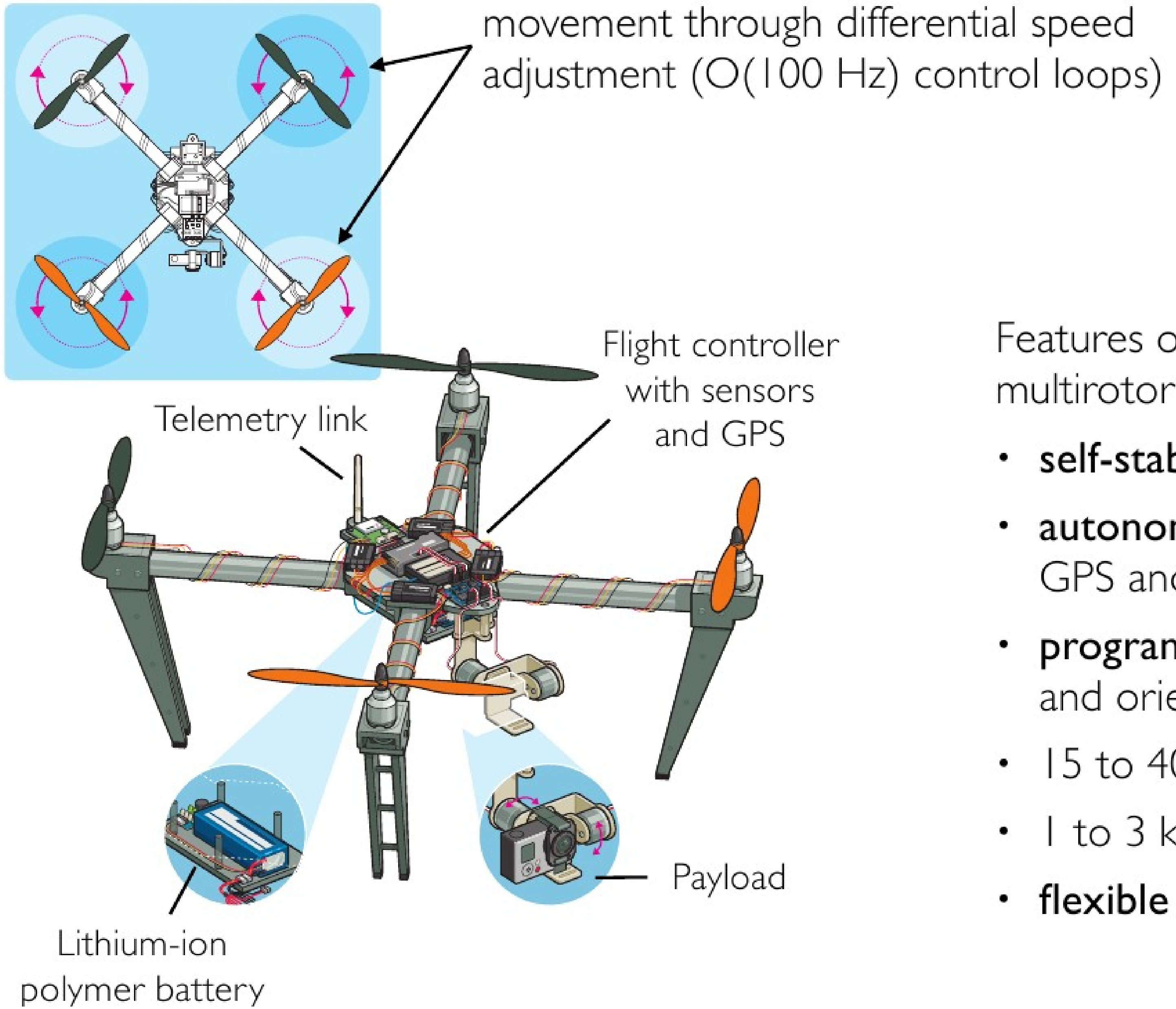
Why?

Study the MWL dependency of the degradation of the optical systems.

High intensity light source (I_{max}>1Kpe)

DC light source (for eg pointing calibration)

Flight platform



Features of a (modern) multirotor:

- **self-stabilising** platform
- **autonomous** flight using GPS and 3-d compass
- **programmable** flight path and orientation
- 15 to 40 min flight time
- 1 to 3 kg payload
- **flexible** configuration

What one to go for?

Quadcopter

Payload

Flight time

Altitude

Redundancy

& Cost

Hexacopter

Octocopter

Will defer decision on drone to use until later

Whats new in the airborne calibration WG?

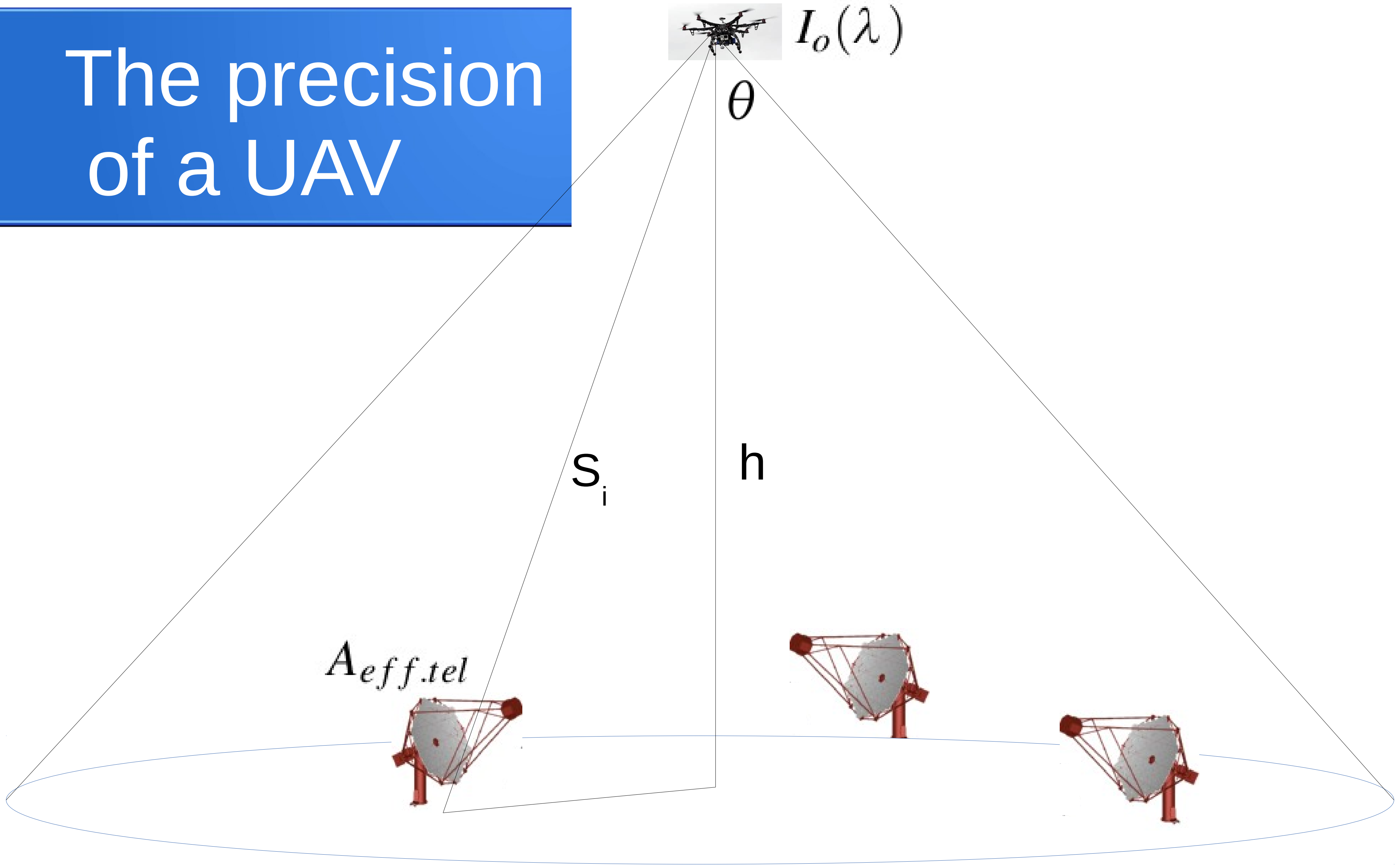
A new Honours student (though lost Felix due to other commitments...)

2 grant applications submitted

Feasibility study ongoing

- Looking to submit as a publication (like Markus' CLF paper)

The precision of a UAV



$$I(\lambda,s) = I_o(\lambda) \cdot \frac{A_{eff.tel}}{s^2} \cdot \mathcal{T}_{aero}(\lambda,s) \cdot \mathcal{T}_{mole}(\lambda,s) \cdot (1+f) + F_{bgr}$$

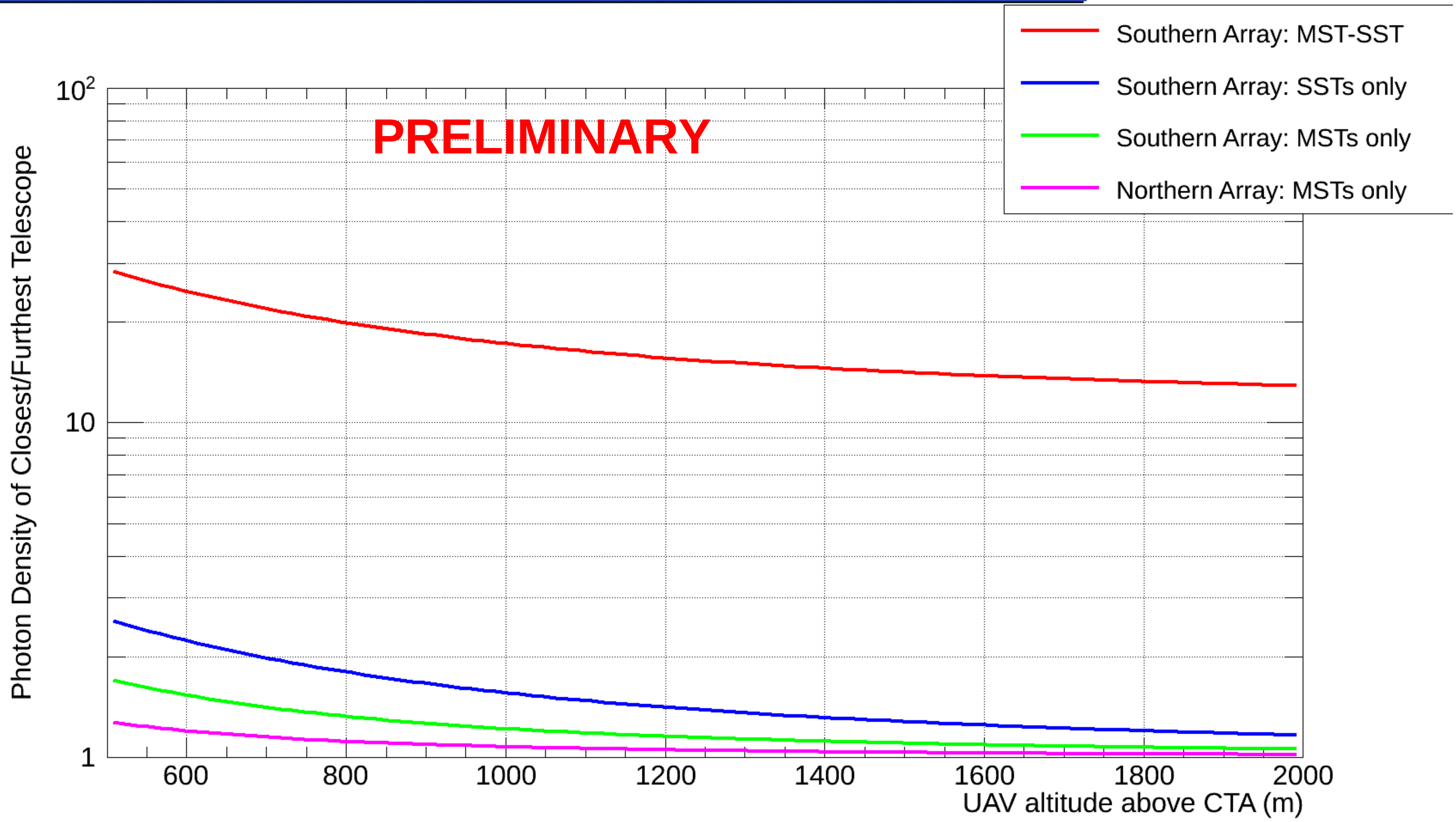
Differences it what seen...

There is a distance dependency here

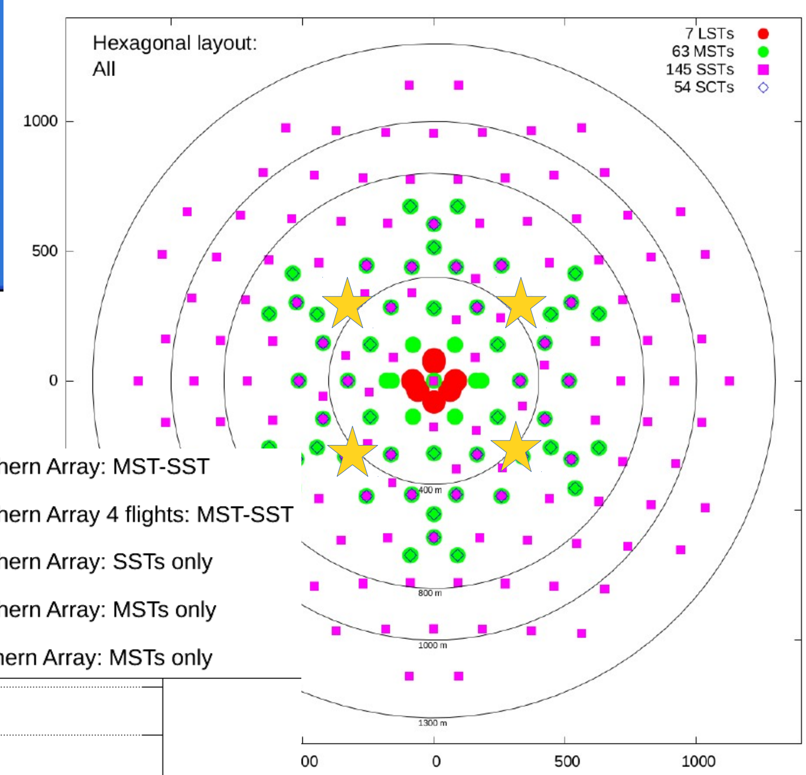
~1

$$I(\lambda,s) = I_o(\lambda)\cdot\frac{A_{eff.tel}}{s^2}\cdot\mathscr{T}_{aero}(\lambda,s)\cdot\mathscr{T}_{mole}(\lambda,s)\cdot(1+f)+F_{bgr}$$

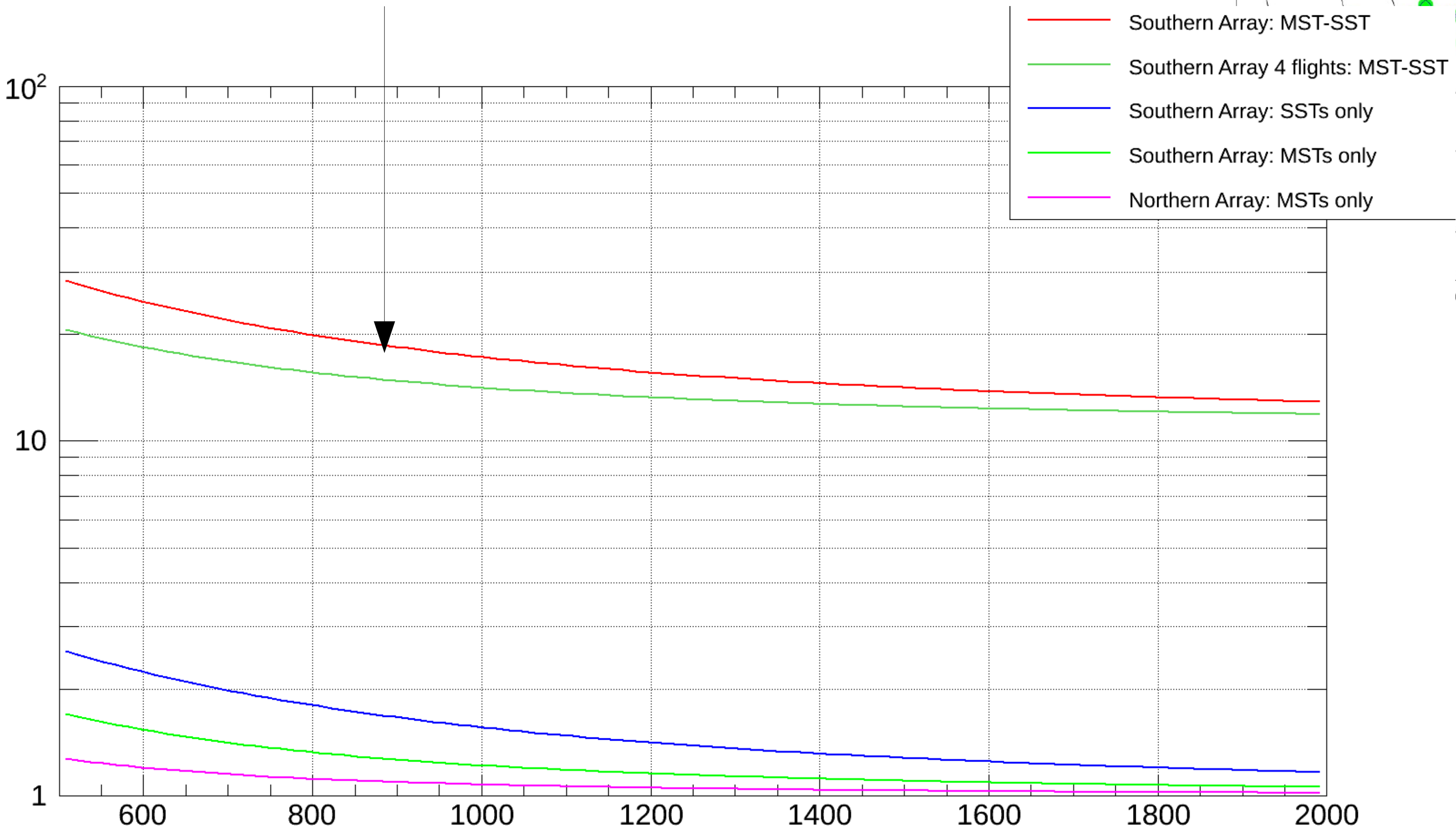
1 flight above array center



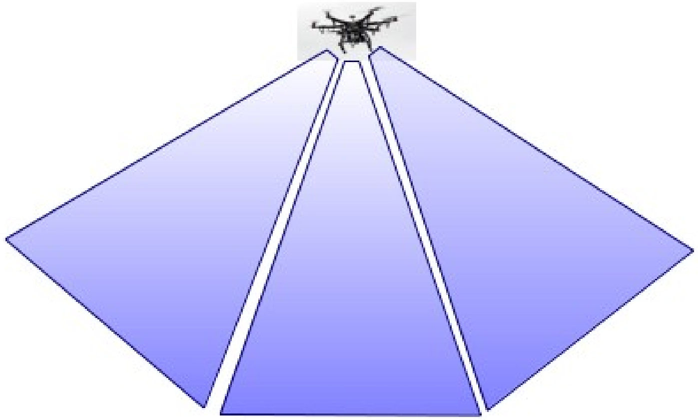
4 flights?



Small reduction in the ratio



Visibility for all telescopes...



•Glowing/pulsing ball (aka AUGERs oktocopter).

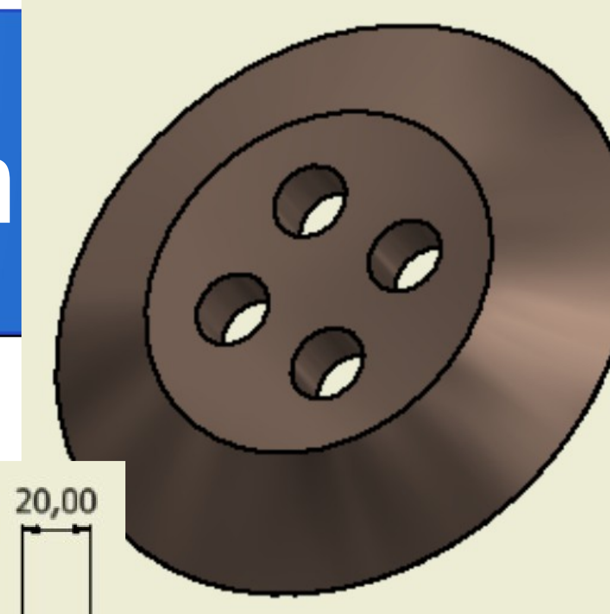
Array of diffusers with large opening angles.

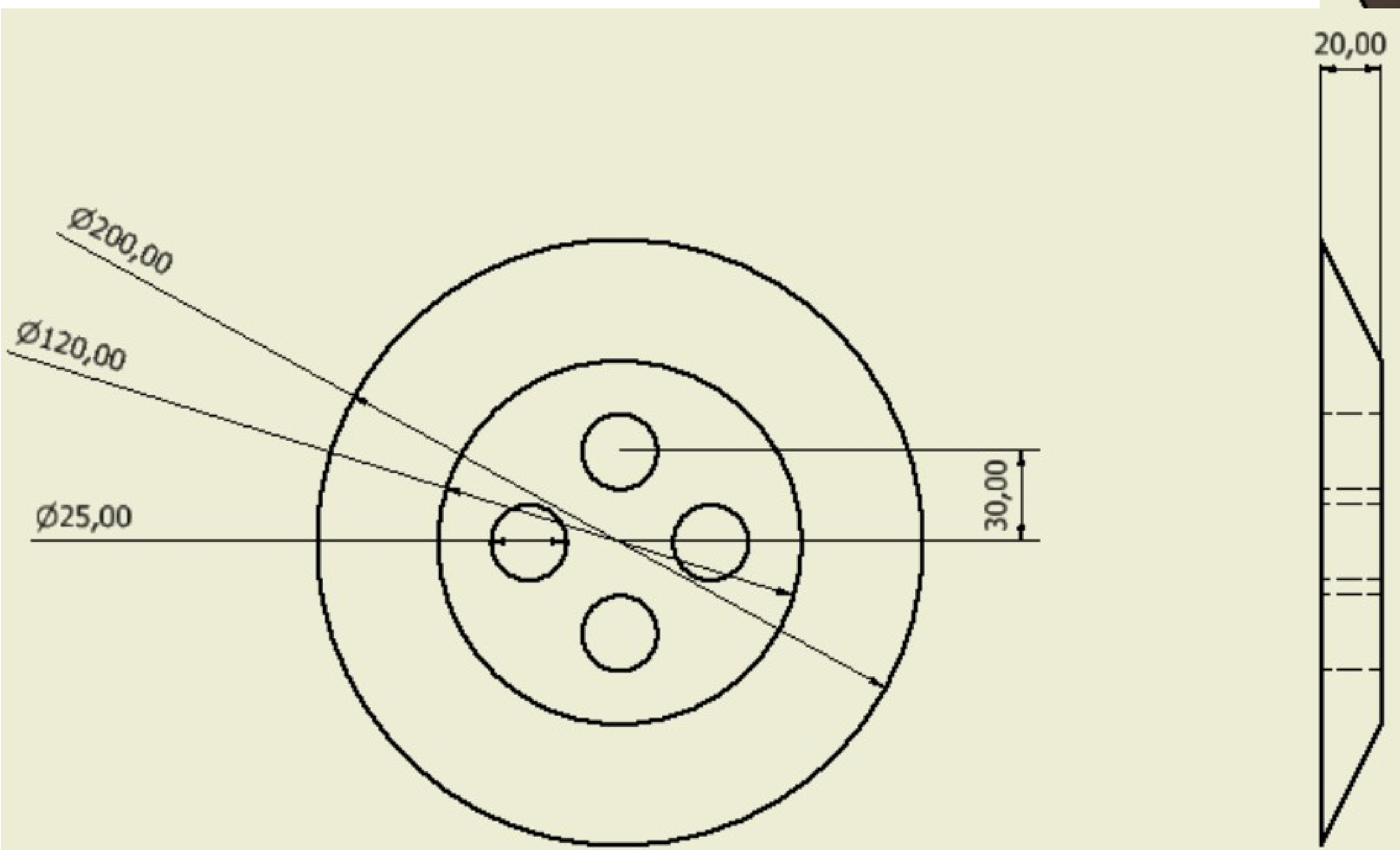
Which one is best?

Aerodynamic performance

- To achieve unprecedented 3-D positional stability and accuracy, consideration must be given to aerodynamic performance of the payload.
- Large cross-sectional areas create large wind loading, thus reducing positional accuracy and flight capability.
- Eg, a 1000cm^2 cross-section payload in a 10m/s wind will experience a positive wind load of 150N. And then there is negative pressures from vortices, all resulting in a large amount of buffeting.
- An array of diffusers option has the lowest cross-sectional area.

Housing for diffuser option





Positional Uncertainty

Using GNSS alone: can get to 1.4m accuracy

- Equates to a 0.28% difference in light at ground if 1.4m uncertainty is vertical
- 0.05% if uncertainty is horizontal

However, combining GNSS with RTK information, can get down to ~4cm accuracy

- Equates to <0.0004% variation in light

Also note, 1.4m is sufficient for remaining within the smallest pixel FOV (for SCT).

Other uncertainties

- LED output: temperature dependence
  - Use a photodiode to monitor (can get to <2%)
- Atmospheric transmission: molecular dominates on clear nights
  - Use LIDAR (can get <2%)
- Background light: NSB and background stars
- FoV
- Statistical

Legalities & Safety

Spain: governed by EASA, need to apply for airworthiness. EASA states that UAV “operating in remote areas have the best chance of success”. A PPL may possibly further chances of success.

Chile: recently passed laws to allow it. Need to consider ESO. However, for a flight of 1km above CTA, only 400 m above horizon for VLT.

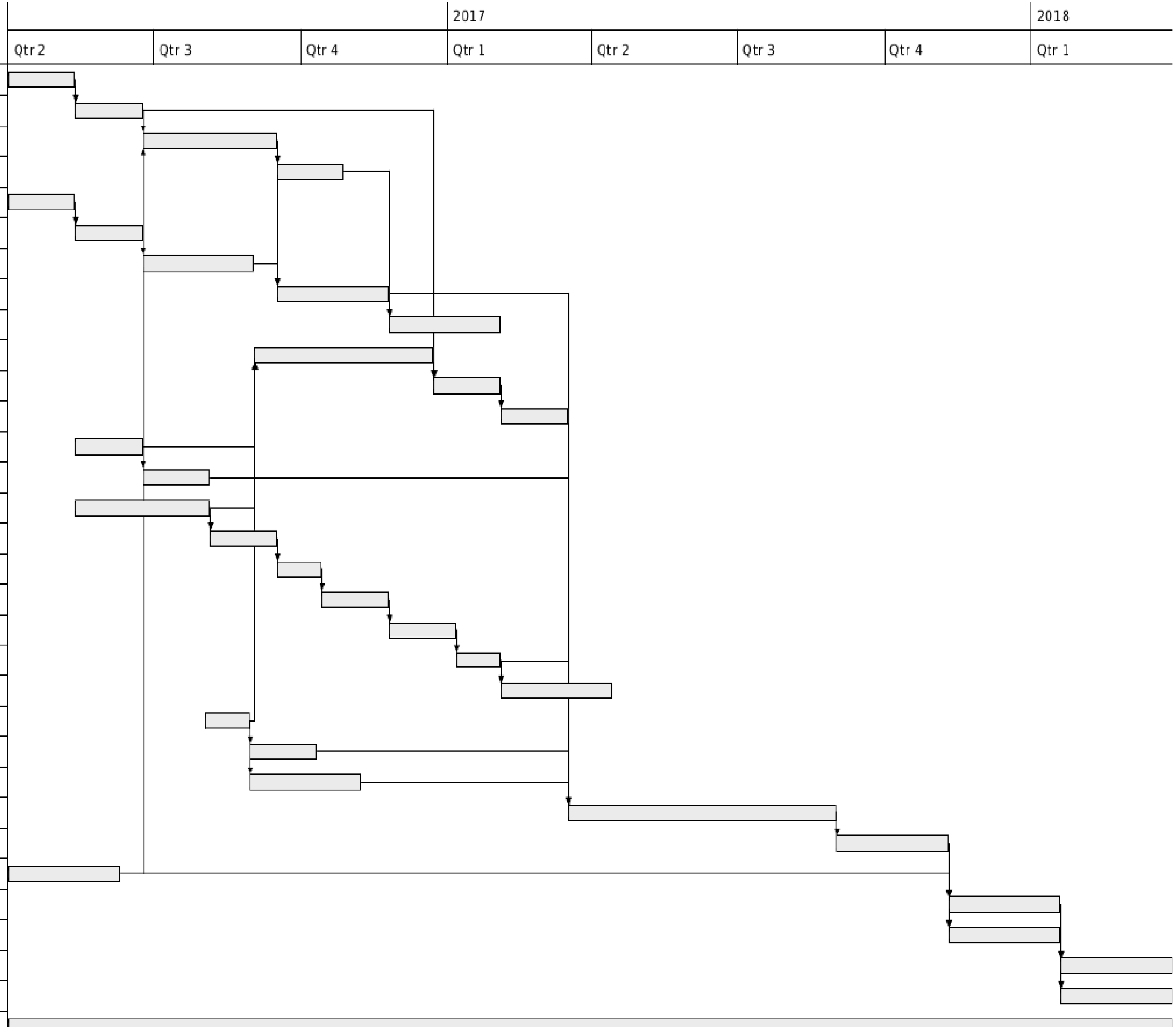
Legalities & Safety

For the safety of CTA

- Hardwired automated return flight path should battery voltage drop or RF link lost
- Have a parachute to minimise impact of uncontrolled decent

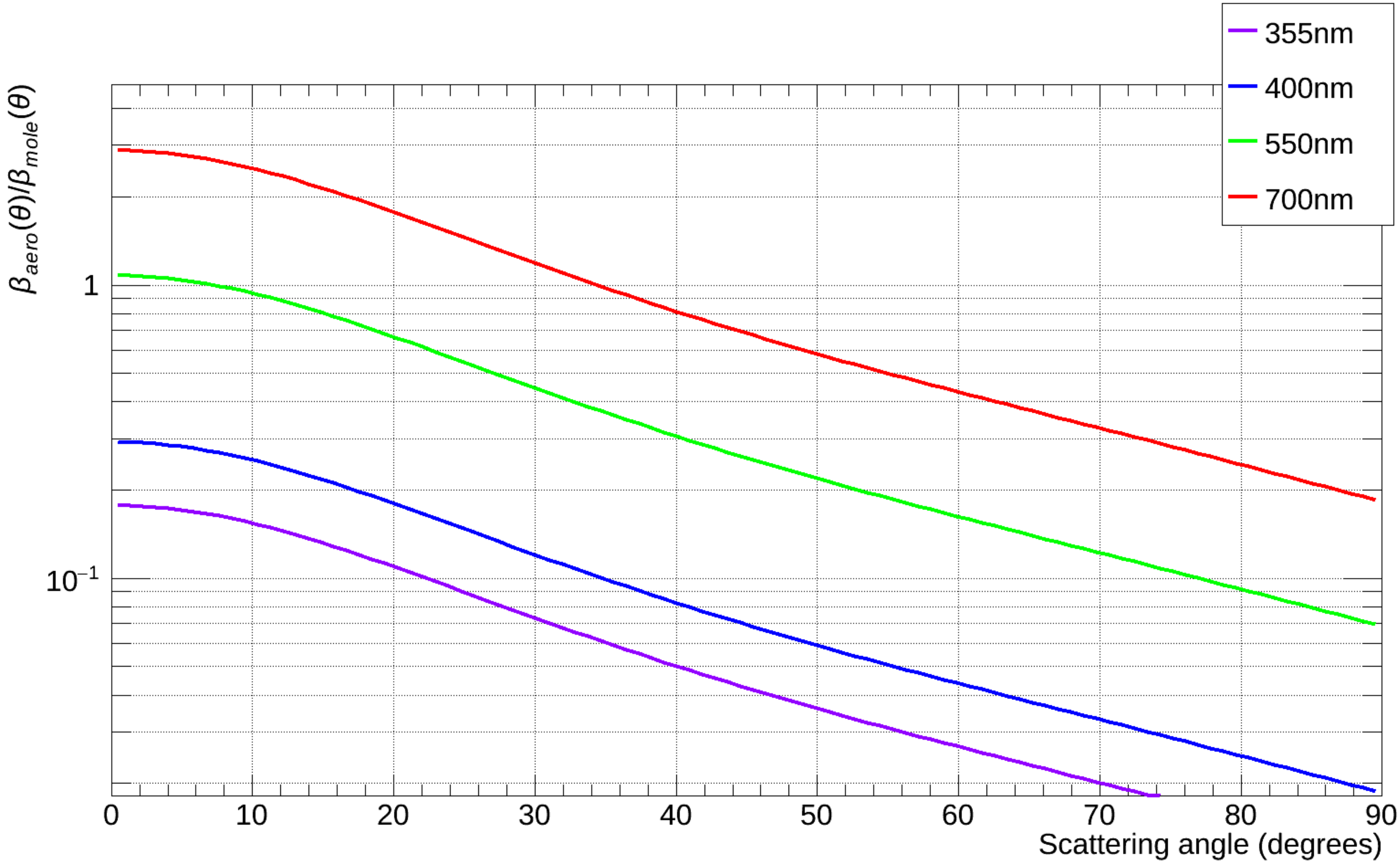
Timelines...

Name	Work
UAV specification	30d
UAV delivery	30d
UAV flight testing and evaluation	60d
UAV fail-safe development	30d
Positioning system specification	30d
Positioning system delivery	30d
Positioning system evaluation (in lab)	50d
Positioning system evaluation (flight)	50d
Flight + positioning characterisation publication	50d
Aerodynamic: Payload housing optimisation	80d
Aerodynamic: Wind-tunnel testing	30d
Aerodynamic: Payload housing re-optimisation	30d
UV flasher optimisation	30d
UV flasher manufacture	30d
Multi-wavelength (MWL) flasher design	60d
MWL flasher manufacture	30d
MWL flasher characterisation	20d
MWL flasher re-design	30d
Final MWL flasher design manufacture	30d
Final MWL flasher design characterisation	20d
Flasher characterisation publication	50d
Nephelometer specification	20d
Nephelometer delivery	30d
Nephelometer air-intake studies	50d
Full-system Integration	120d
Laboratory system testing	50d
Legalities	50d
On-sky flasher testing (at telescope site)	50d
On-sky nephelometer testing (at telescope site)	50d
On-sky testing publication	50d
Reporting and Future proposal development	50d
Outreach & Public Engagement	520d

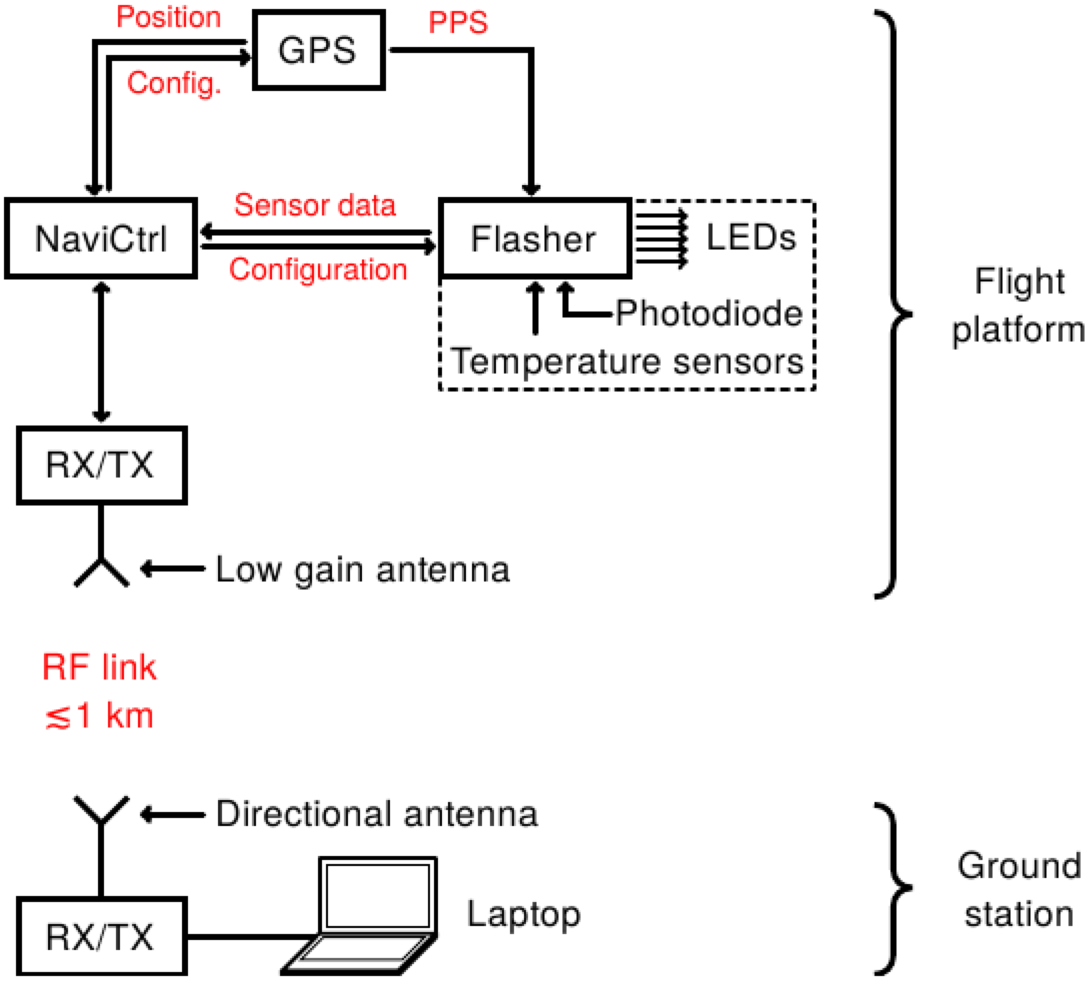


Back up

MWL capability



Set-up


Position
GPS
PPS
Config.
Sensor data
NaviCtrl
Flasher
LEDs
Configuration
Photodiode
Temperature sensors
Flight platform
RX/TX
Low gain antenna
RF link
≲1 km
Directional antenna
RX/TX
Laptop
Ground station