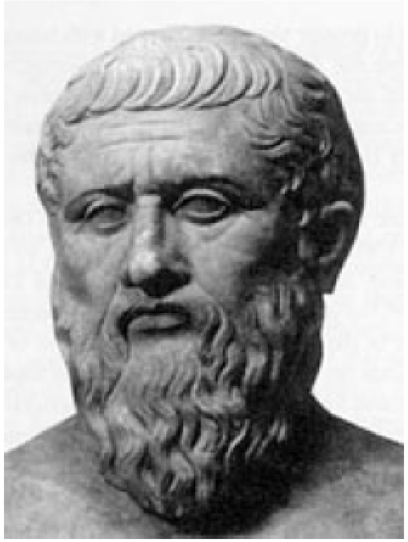
PLATO

Summary of Internal CDF Mission Study



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Outline

1. Introduction
2. Payload
    - Telescope:
        - Opto-mechanical design
        - Focal plane array / Front-end electronics
        - Instrument Controller
    - Payload Module (PLM) design
3. System
    - Service Module (SVM) design
    - Mission Operations
4. Performance Model
5. Conclusions

Objectives

Background:

To conduct a mission study of PLATO based on the staring concept, taking into account (from last PSST meeting):

- 6 year mission lifetime
  - Observing two fields of 2.5 years each
  - 1 year of re-observation of candidate transits
- Non-dispersive optical system
- Increased field-of-view
- Identified critical areas and open points – to be used in industrial assessment

Today:

- Present results of CDF study (new PLM + SVM)
- Finalise Science req. summary for industrial studies

Mission Objectives

Perform high accuracy photometry to:

- Detect and characterize transiting exoplanets and to measure seismic oscillations of their parent stars

Top level science requirements

- Visible wavelength band
- 100 000 stars measured at 1 ppm/month photometric accuracy

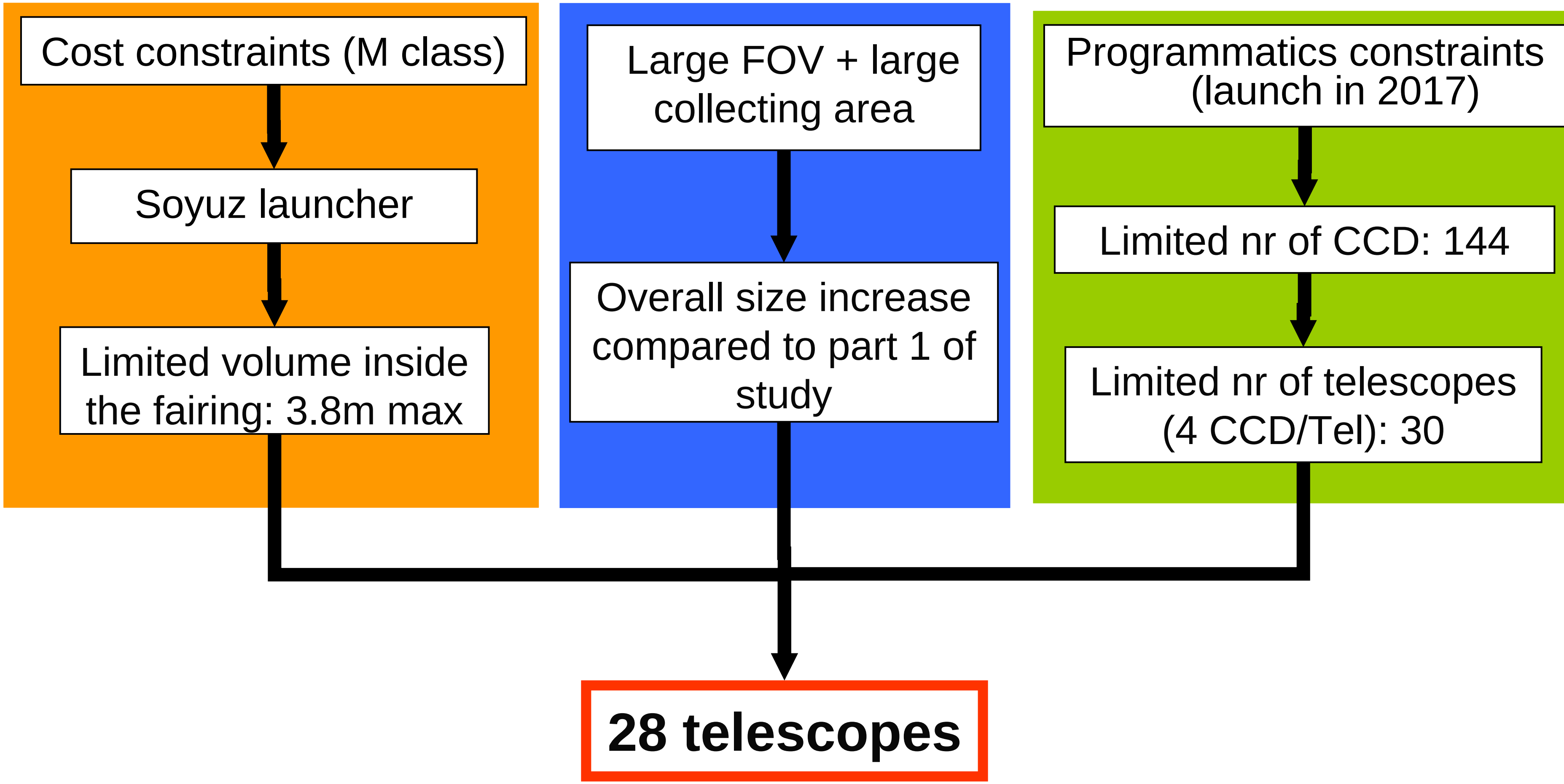
Top level mission requirements

- Soyuz-Fregat
- L2
- Staring concept (Based on PSST meeting Dec. 21)
- Non dispersive optics (Based on PSST meeting Dec. 21)
- Useful Field of View (surveyed FOV) > 500 sq deg
- Launch date 2017
- Operations: 2.5 years (Field 1) + 2.5 years (Field 2) + 1 year step&stare = 6 yrs sizing case
- Target cost to ESA (300 MEuros)

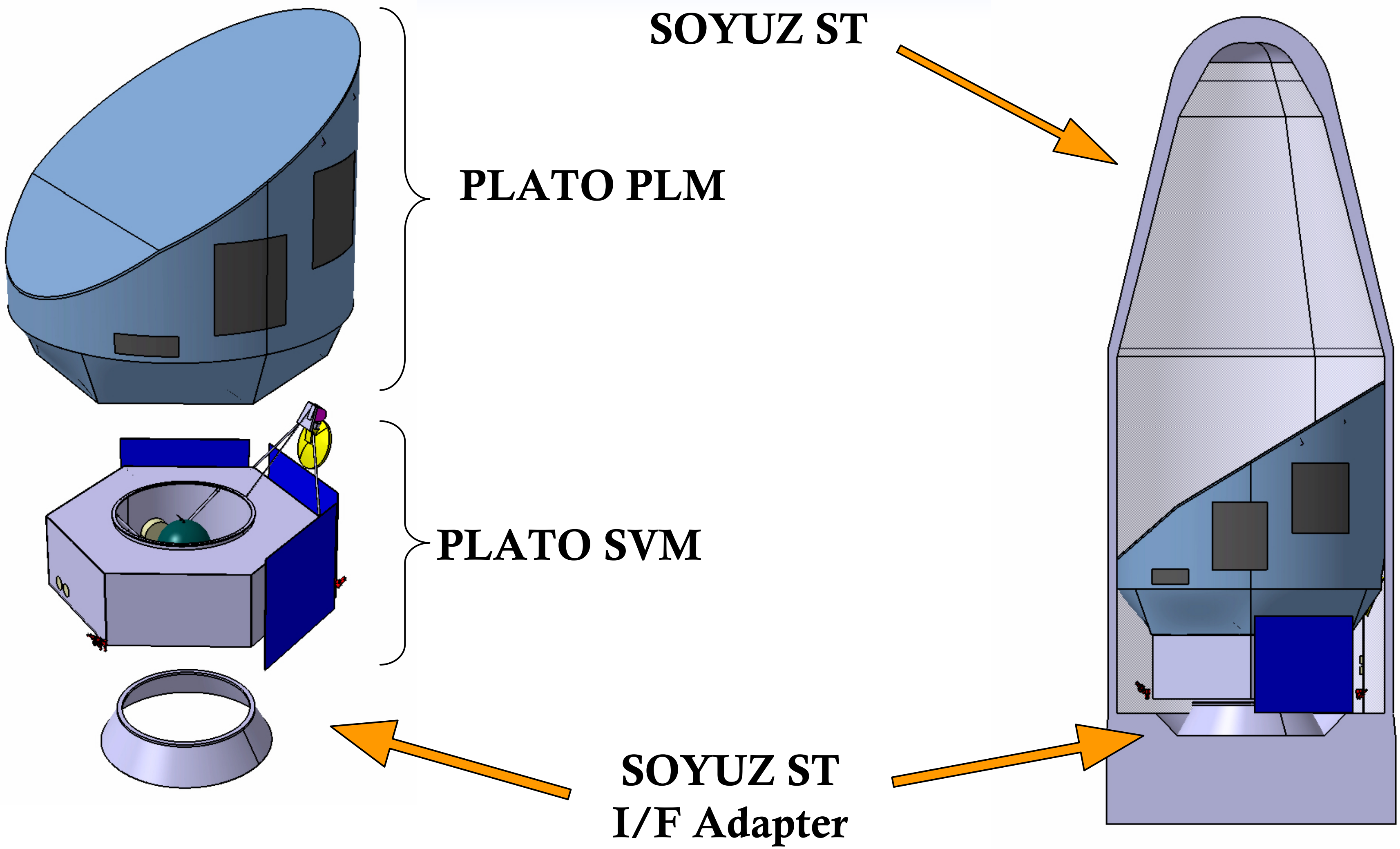
Hypotheses

- 26+2 telescopes
- Observed Field 1: (+210, -60)
- Observed Field 2: (+306, +67)

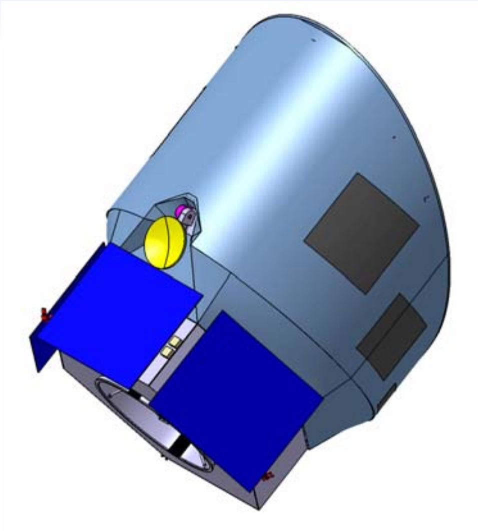
Mission Drivers

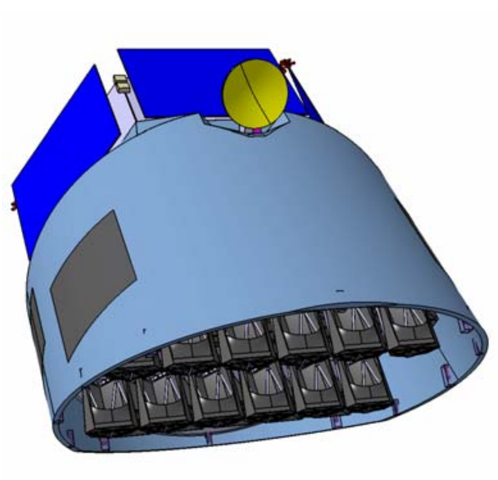


PLATO Spacecraft + Fairing



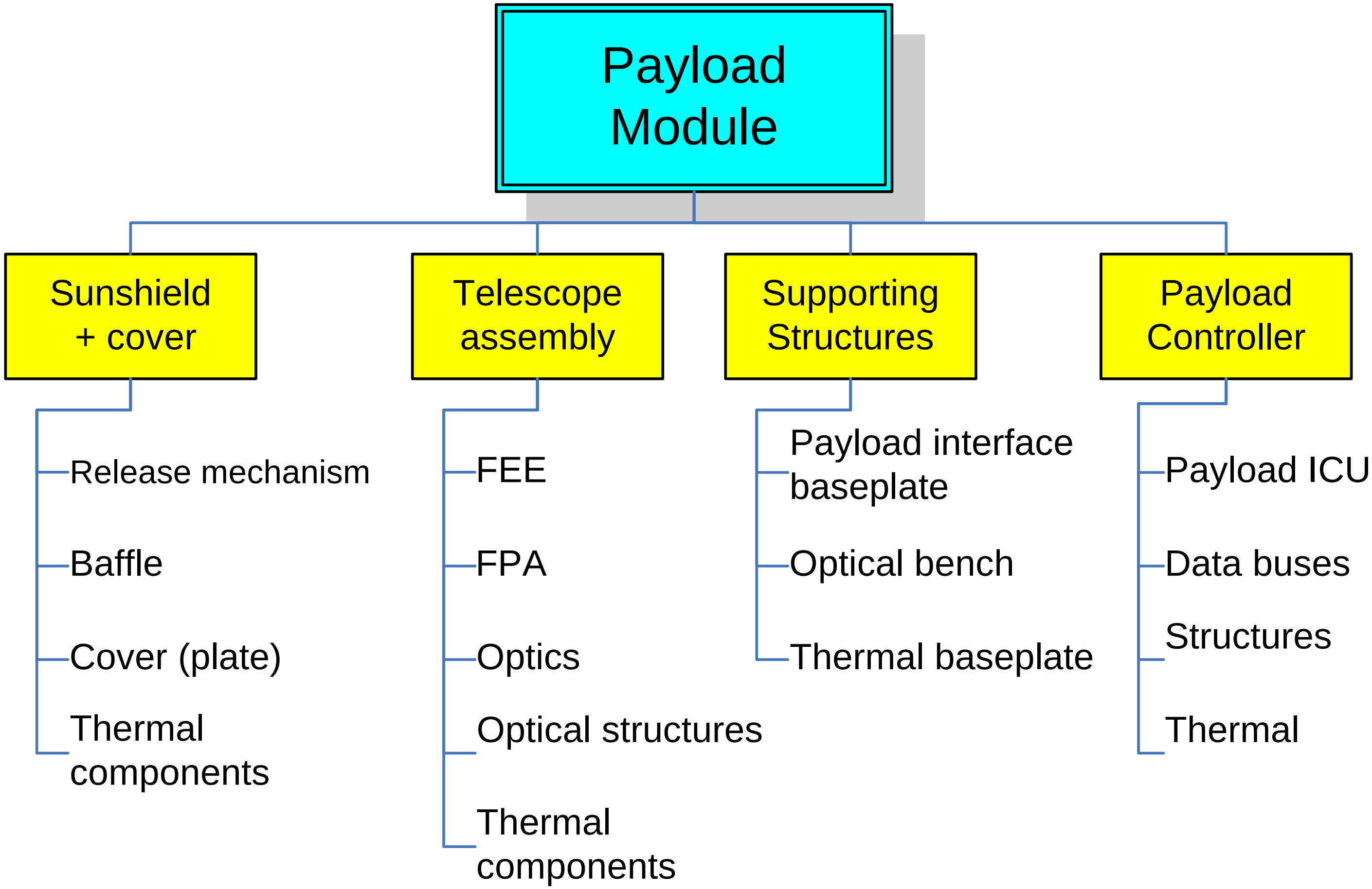
PLATO Product Tree



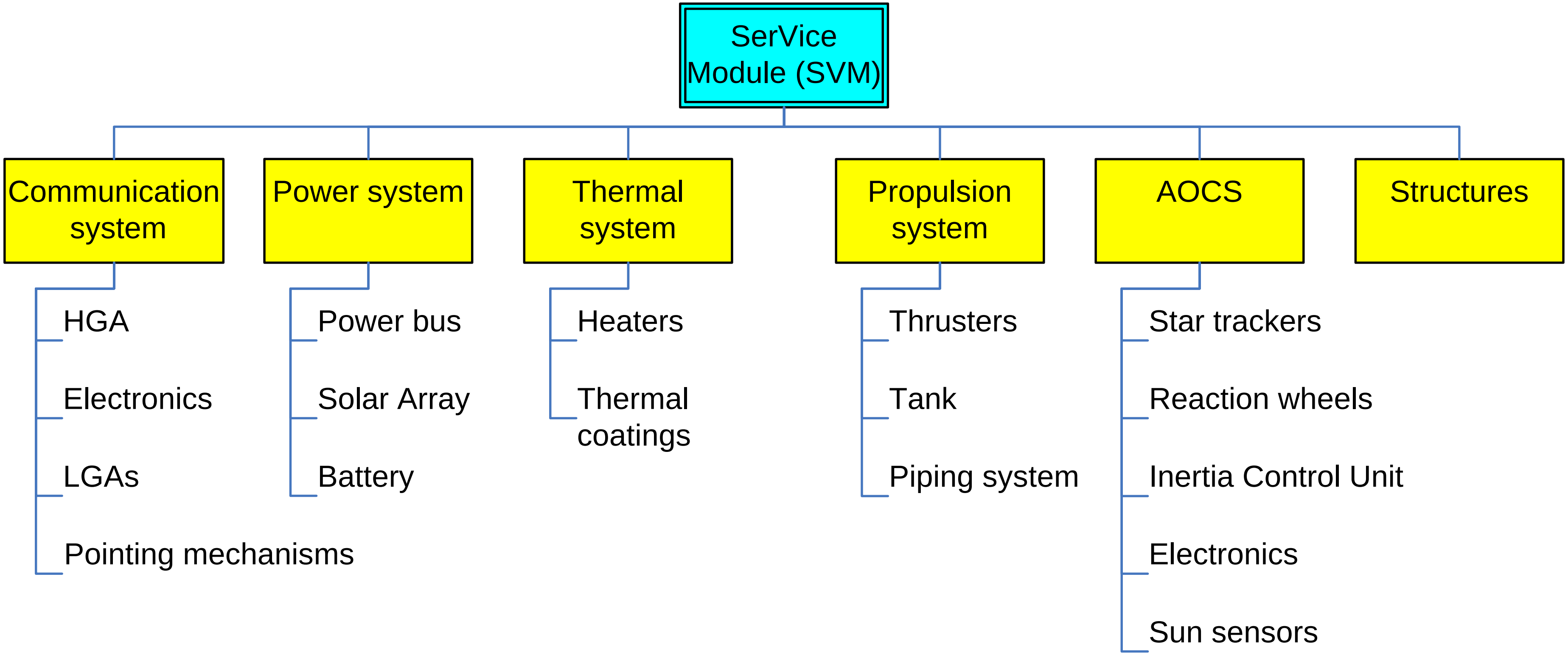


- **PLATO Mission**
  - Ground segment
  - **PLATO Spacecraft**
    - SerVice Module (SVM)
      - Communication system
      - AOCS
      - Thermal system
      - Propulsion system
      - Power system
      - Structures
    - PayLoad Module (PLM)
      - Supporting Structures
      - Sunshield + Cover
      - Telescope assembly
      - Payload Controller
      - Thermal system
  - Launcher vehicle

PLM Product Tree



SVM Product Tree

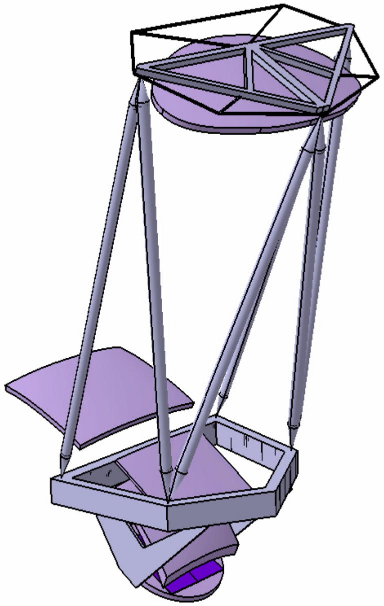


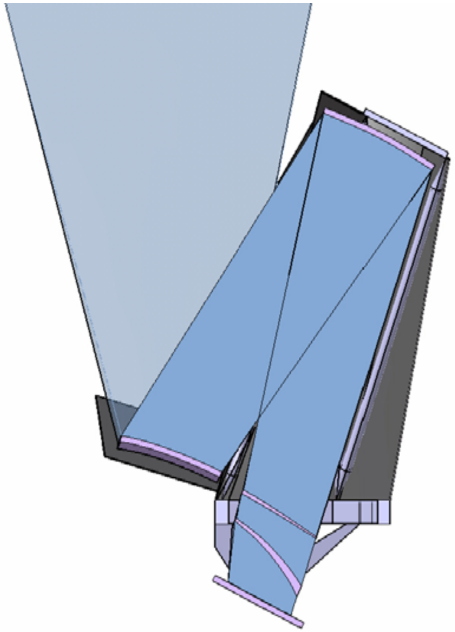
Telescope

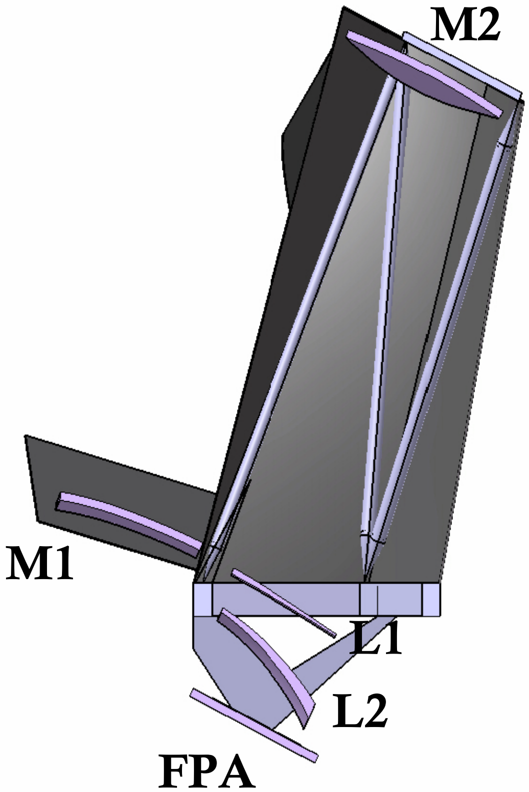
Inputs for CDF Study

- **Starting with the instrument baseline presented Dec 2007**
- **Recommendation to study enhanced field of view**
- **Remove requirement to support colour discrimination and implement non-dispersive optics design**
- **Investigate details of instrument design requiring modification as a result of the SVM design activity**
- **Elaborate operations, calibrations etc. aspects**

Telescope Layout



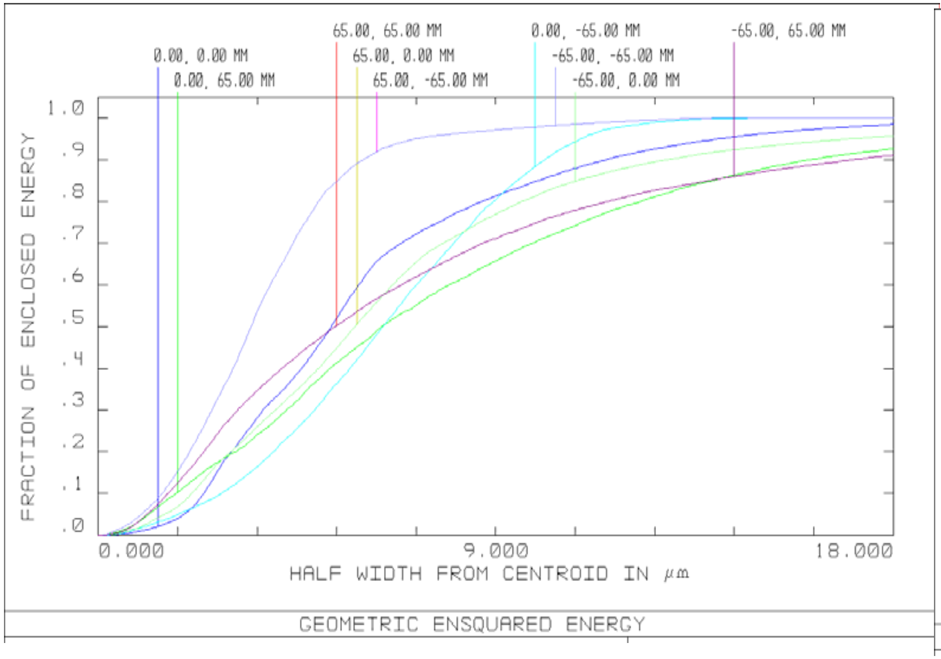


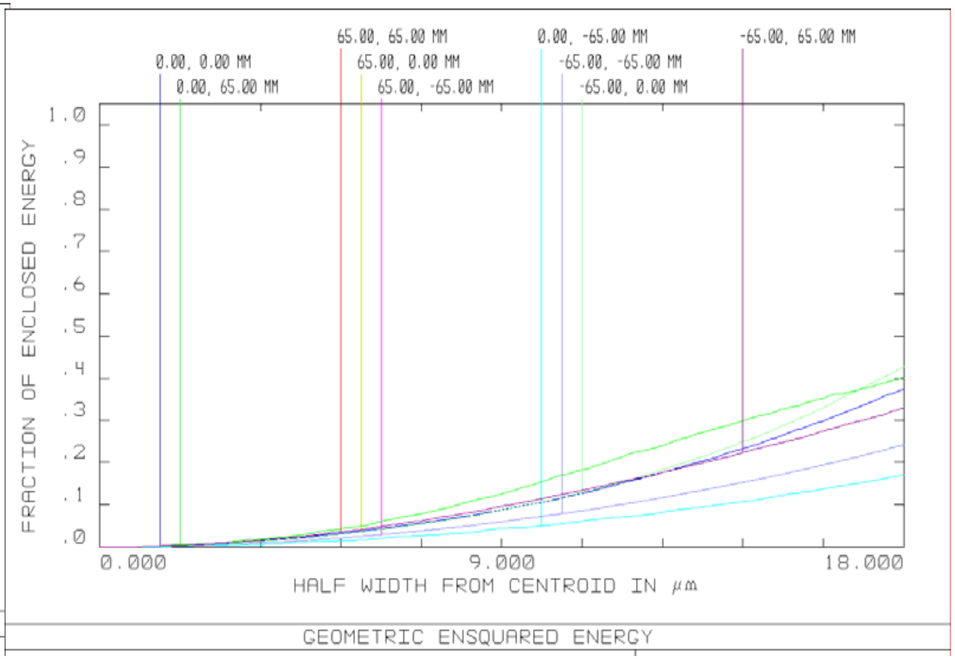


PLATO Telescope
•Mirror Elements, M1 & M2
•Lenses, L1 & L2
•Focal Plane Assembly, FPA
•Structure: SiC

En-squared energy

Focused position | De-focused position (+0.2mm)

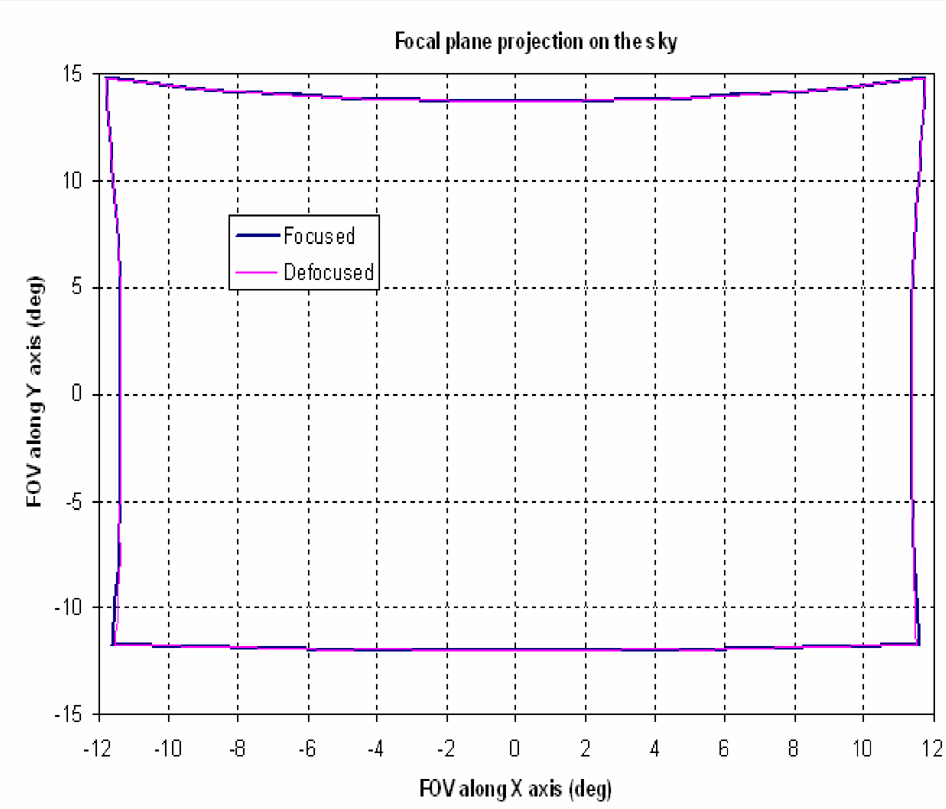




De-focus to be optimised between confusion and photometric stability

Distortion

- Projection of the CCDs on sky is not a square
- Local change of the focal length => change of the plate scale
- FOV defined as the area in the sky continuously imaged on the CCD after a rotation of 90 of the spacecraft => FOV ~550 deg^2
- Needs to be traded with PSF defocusing and envelope



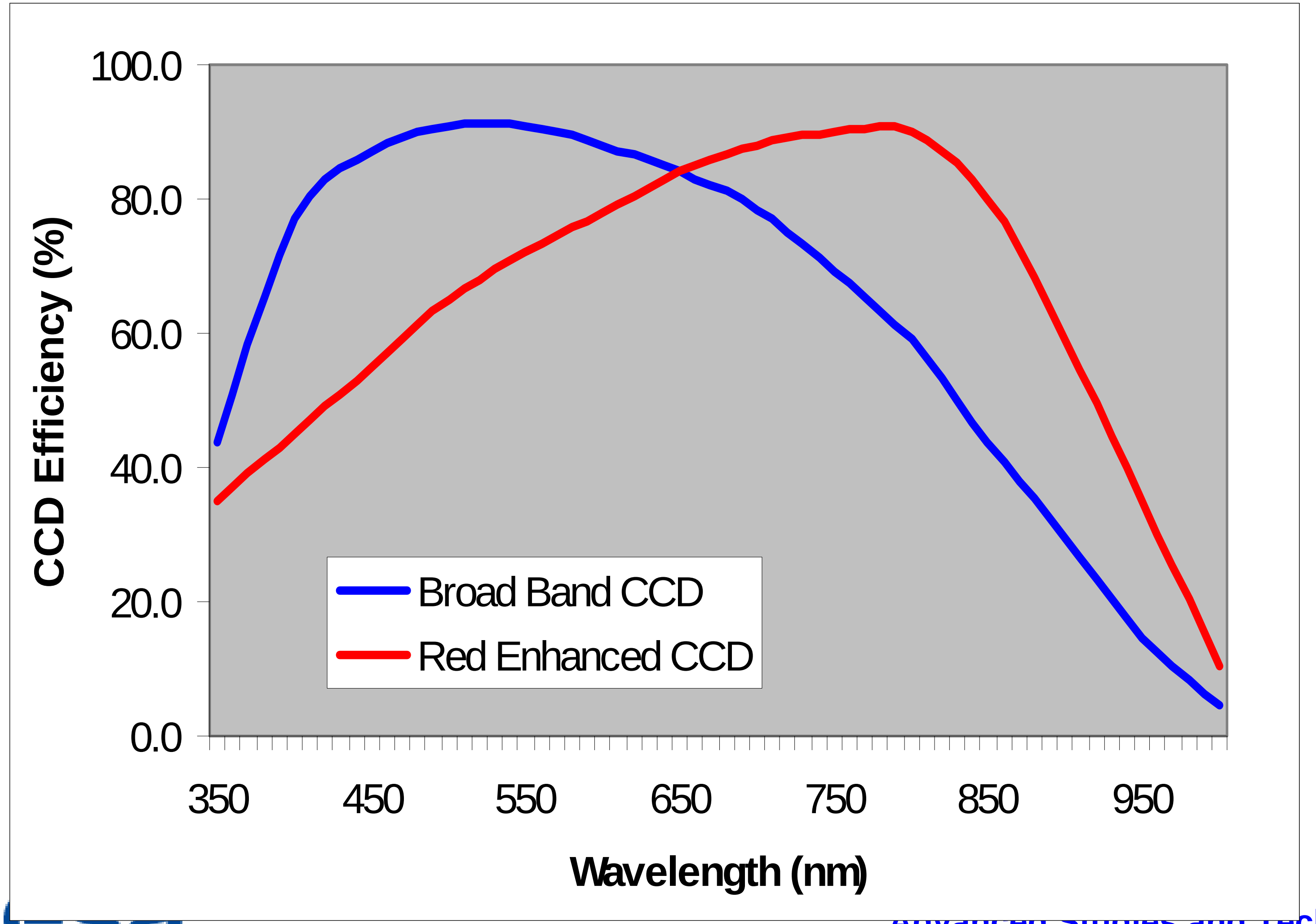
Extremes fields :

X axis : +/-11.8

Y axis : -12.02;+14.83

Red or Blue CCDs

Makes ~10% difference in final stellar counts



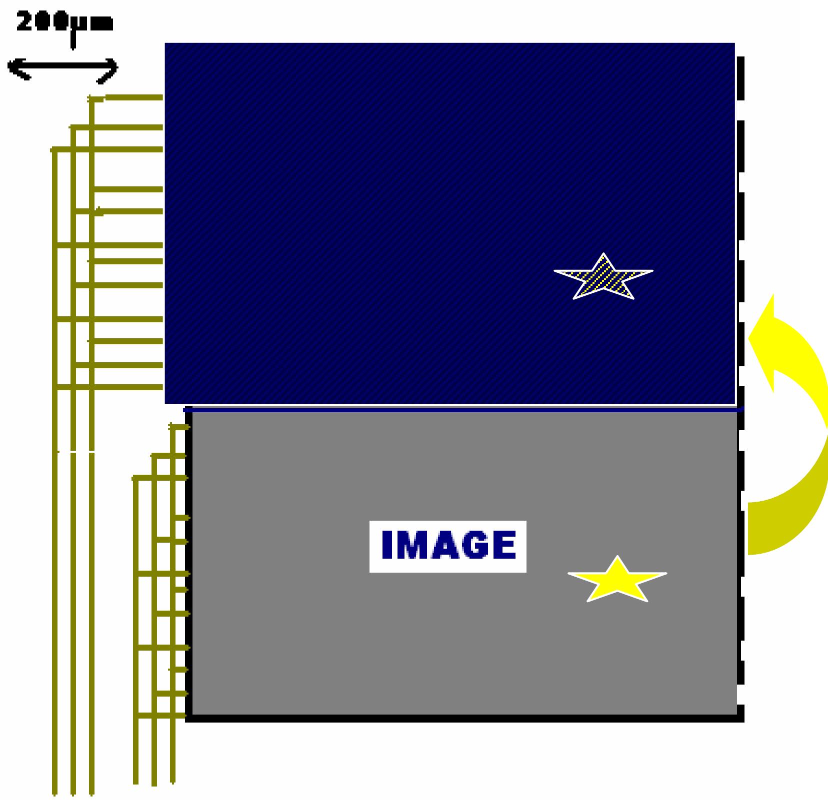
CCD Summary Performance

Parameter	Nominal value
Pixel Size (am)	18
Pixel Format	3584 x 3584 (+TBD over clock pixels)
CCD Dimensions	Image area 64.5 x 64.5 mm^2
Field of View (cont.)	550 sq°
Pixel size (arcsec)	12 – 14.5
Readout Frequency	4 MHz
Number of Read outputs	2 per CCD
Readout Noise	<20 electrons r.m.s.
Full Well Capacity (4 phase)	600 k electrons
Full Frame Readout Time	2 s
CCD Exposure Duration	20 s
Fraction Signal Smeared	10%
Dynamic Range (*to 30ppm/hr*)	m_v 9.2– 11.1

Frame-store mode CCDs

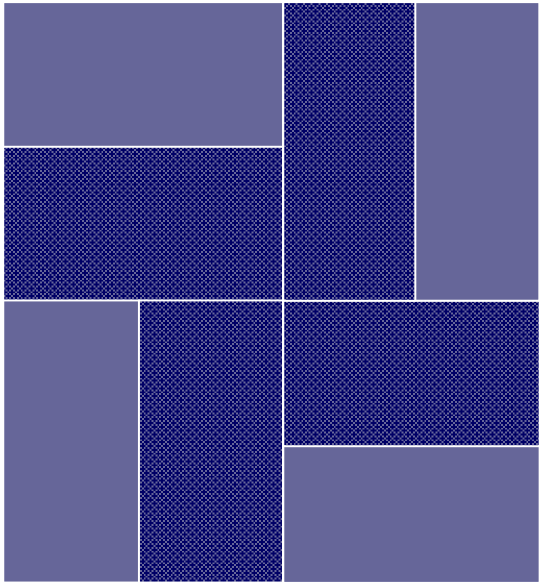
- For bright-mode telescopes need significantly enhanced brightness limit
- But prefer identical CCD design to normal telescopes to keep qualification and AIV simple
- CCD separated in two halves with redundant bus lines
- Connected in parallel for full frame CCD
- Unconnected with shielded store for a frame-store CCD
- Slight increase in peripheral dead area

Extra bus lines are connected in FEE for Full Frame or Framestore operation



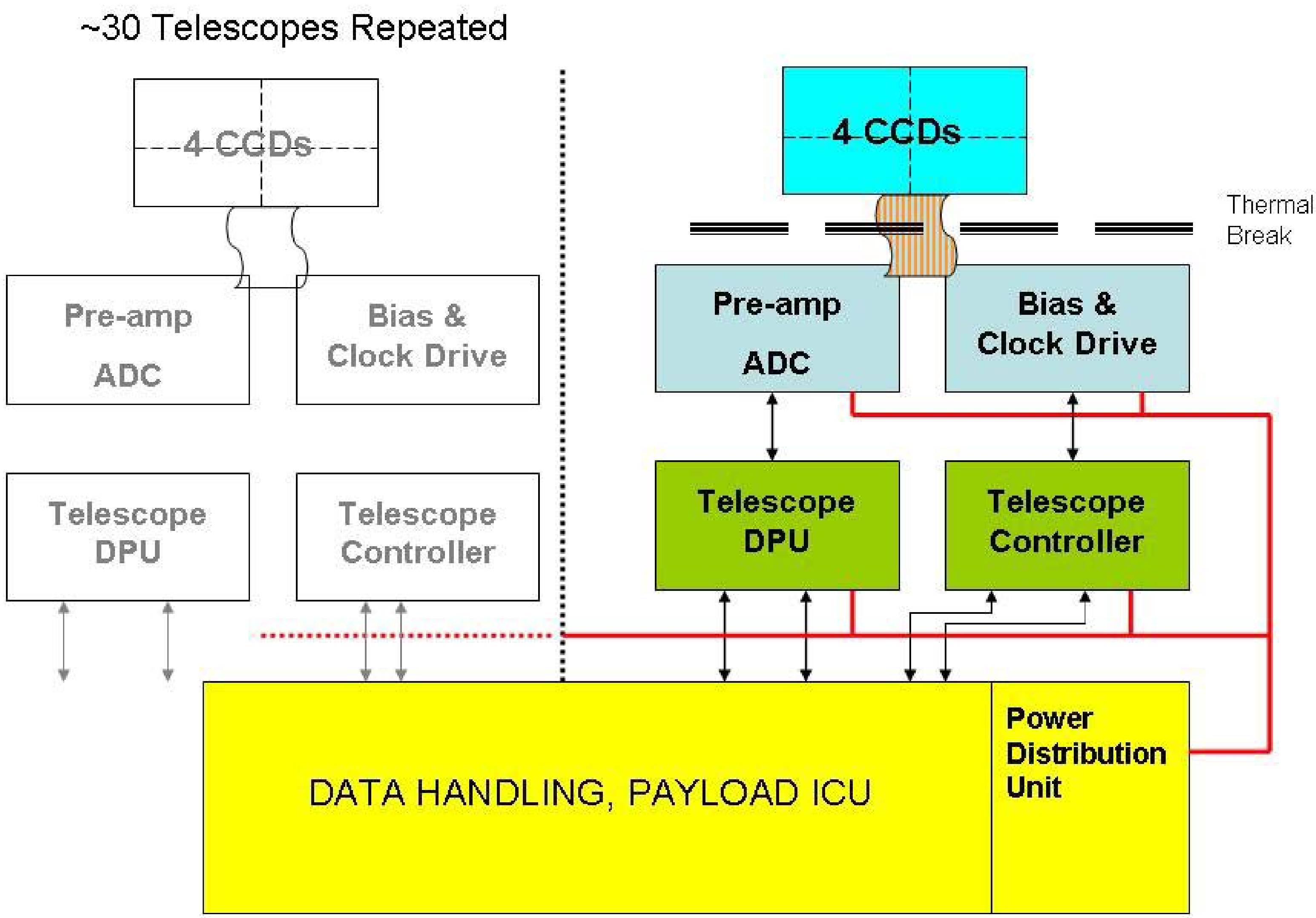
Bright Mode (Star Tracker) Telescopes

- **Orient 4 CCDs orthogonally**
- **Total field ~340 sq°**
- **Readout time ~1.0 s identical with frame exposure time & smearing still 10%**
- **If no vignetting of these telescopes the brightness limit ~5.8mag**
- **Can improve with windowing**
- ***Statistically* this system has centroid accuracy <0.2 arcsec for brightness greater than 8 mag**
- **30ppm in 1 hour for m<8.2**



Defocused PSF simulated with simple moments calculation, but unknown calibration effort for systematic component ? Need to be aware that the interface between payload and system for such a critical function can become very critical later !!

FEE Functions



FEE Controller Functions

Bias / Clock:

- To drive and read out 4 CCDs of 3584x3584 pixels through either or both of its 2 readout amplifiers at up to 4 Mpixels/s each.
- To provide bias stability and current load stability to maintain CCD gain to 1ppm (TBC)

Signal Processor/ADC:

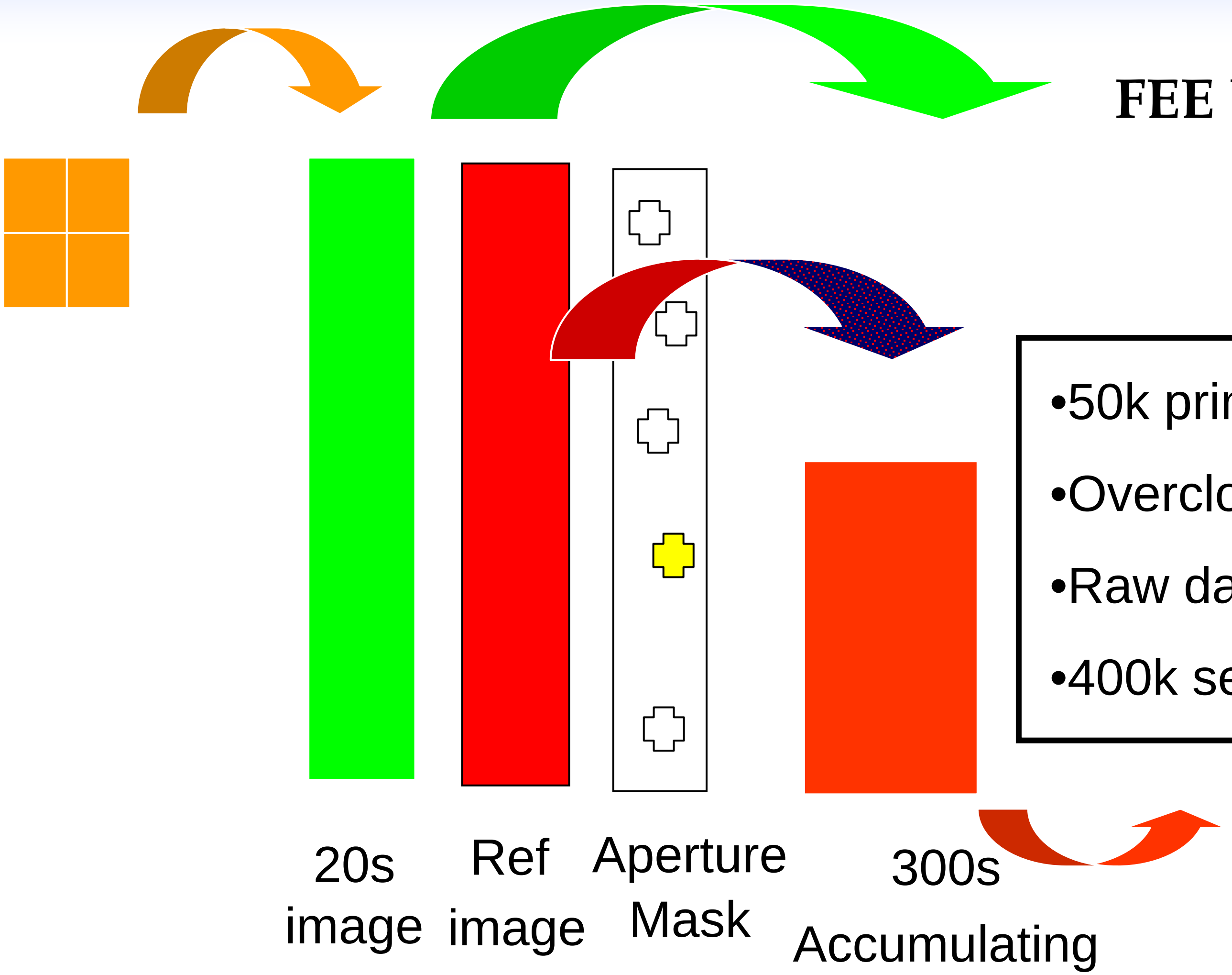
- Provide band-limiting and noise reduction with correlated double sampling
- To digitise the CCD video data to 16 bits precision.
- To match the video digitisation and dynamic range to an anticipated CCD full well capacity of 600k electrons, and a CCD readout noise of ≤ 20 electrons rms.
- To provide programmable CCD video gain and video DC offset level on each readout channel.
- Provide gain stability to 1ppm TBC

ESA-developed VASP Controller (and others) available "off-shelf" at 3MHz

Heritage from GAIA PEM, STEREO SECCHI etc……

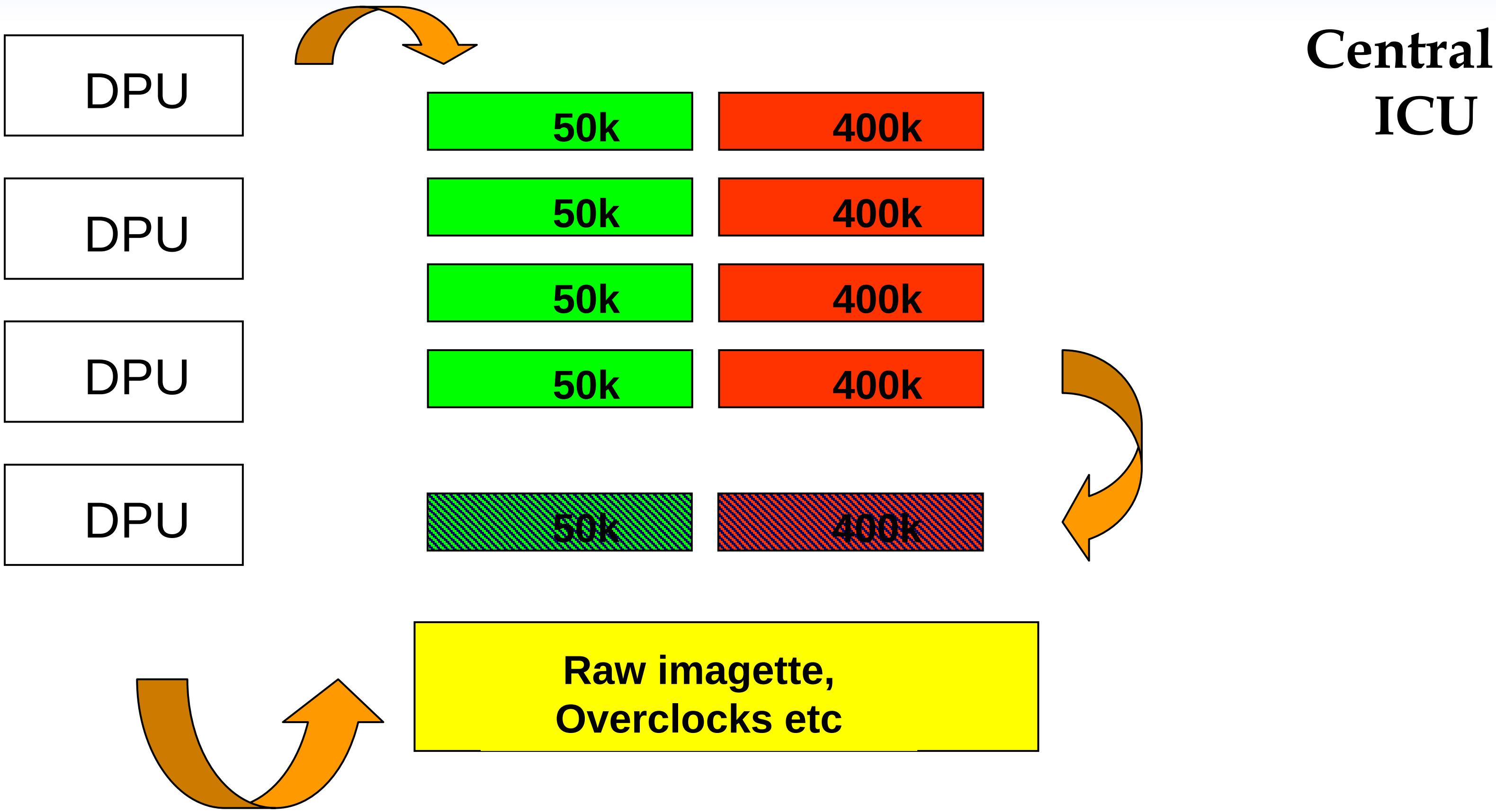
Telescope DPU – LEON based processor + Power conditioning etc..

Normal Science Ops



- 50k primary queue
- Overclocks queue
- Raw data imagette queue
- 400k secondary queue

Normal Science Ops



Field Acquisition - Initial

- ICU receives up-linked star positions for guide star patterns and high priority targets (~50k objects)
- Telescope DPU collects ~10 (TBC) images with median filtering.
- Perform TBD pattern recognition algorithm to determine pointing & targets
- ICU calculates interim aperture locations & DPU populates star aperture mask data.
- Collect N images with median filtering, & store as reference data.
- ICU cross-checks between telescopes for targets locations & acceptable offsets. Identify all high and secondary target windows.
- Report modified aperture locations to Telescope DPUs. Report TBD parameters to ground. Near Real time science assessment implied ?
- Configure instrument for normal acquisition

Field Acquisition - Interim

- Before RW off-load, suspend the photometry gathering operation
- Bright mode telescopes continue to track preferred stars (TBC the small slew speed ?)
- During off-load, AOCS will be sole data source in the active control loop
- At the end of off-load, AOCS will attempt to recapture pointing to original field to within +/- 5 to 12 (TBC) arcseconds.
- Bright mode telescopes determine pointing error and enter the AOCS control loop to bring S/C back to nominal pointing (+/- 0.2 TBC arcseconds).
- Science telescopes return to original window configuration with and reports outputs from windows to ICU to verify window locations)
- Science mode continues, with photometry data calculated against the original reference image data per window.

Calibration-Darks & flats

- We propose to accumulate a reference set of darks and flats before door opening, and then achieve a verification check over time, via parasitic measurements.
- During cruise to L2 & after venting allow the focal plane operating temperature to be reached and stabilised. Before the payload module door opens, perform calibrations 1 set at 1 temperature ~1 week
- But several repeated - dark frames and flat field illumination can be accumulated at a number of temperatures and TBD other conditions.
- Essentially the data can be accumulated with nominal readout modes and the multiple exposures per CCD median filtered to remove cosmic rays. Assume the Telescope FEE DPU will be used to make the local calculations.

Preliminary Mass Memory Sizing & Data Rate

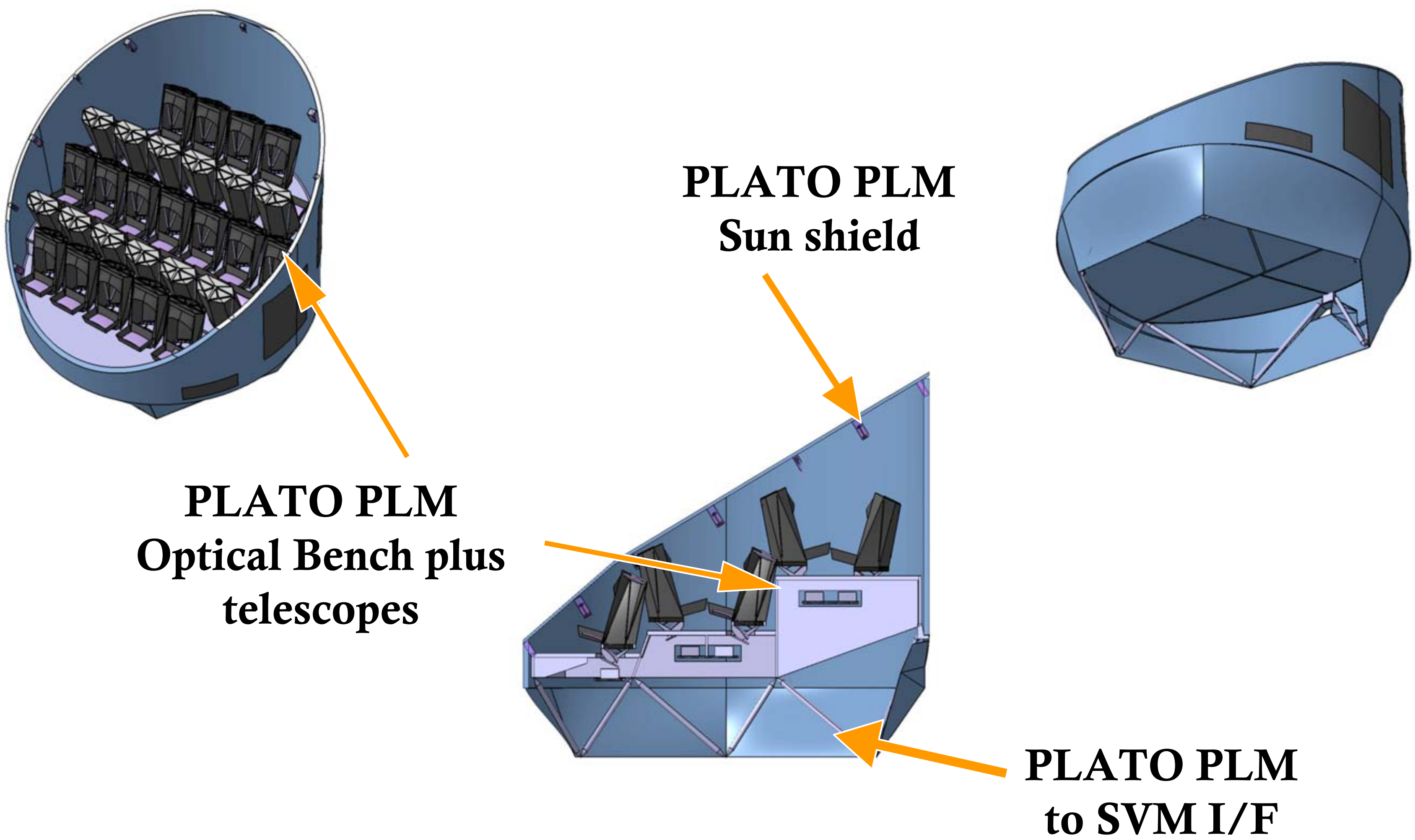
50k stars / 20s @ 32bit	combined all telescopes	80kbps
400k stars / 300s @32 bits	combined all telescopes	43kbps
5k bright stars / 20s @ 32bit	separate 2 telescopes	16kbps
Imagettes 128x128 pixels 16 bit/20s		13kbps
Overclock 17 data/CCD/20s 16 bit		1.5kbps
Centroid 128 stars/telescope 16bit/20s		3kbps
Housekeeping		10kbps
Total (continuous)		166kbps

8% packet overhead
180kbps = 1h/day comms
15 Gbit /day total

Acquisition data (interleaved) 46 Gbit before compression
to be down-linked with high priority at start of observation
(estimates 1.5 hours dedicated)
Mass memory also needs acquisition memory store of 46GBits
+ 4 days total saved science telemetry = 106 G Bits

Payload Module Design

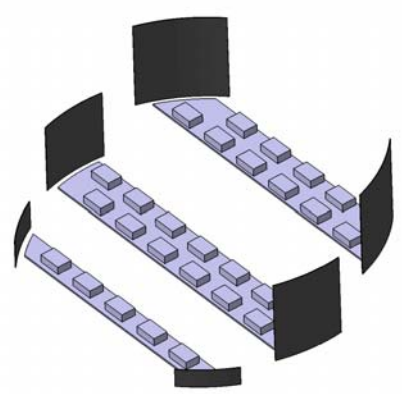
PLM - Configuration



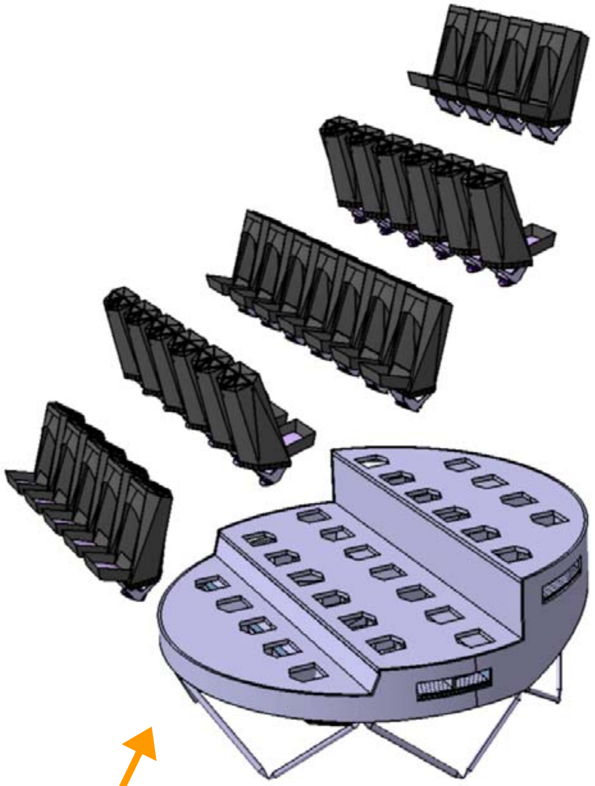
PLM Design – Thermal

Design drivers:

- FPA at 170 K
- FEE at 230 K
- SVM equipments at room temperature
- Minimize temperature gradients when changing attitude among the different telescopes
- Minimize gradients among different elements on the same telescope (M1, M2, Lens)
- Open point: Connection between FPA and FEE in terms of structure and thermal coupling



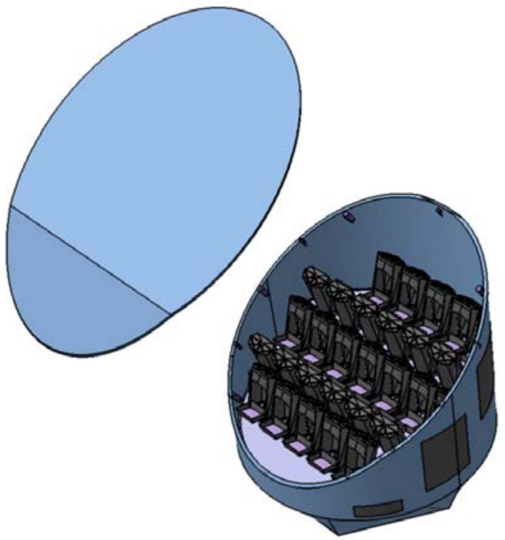
PLM Radiators + FEE assembly



PLM optical bench + telescopes

PLM Design: Mechanisms

- Cover needed to protect telescopes from contamination (labyrinth seal proposed)
- Baseline is to eject cover from spacecraft during cruise phase to L2
- Achieved using pyro release-nuts which offers quick homogenous release of cover
- Further analyses to study impact of release shock needed



Service Module Design

SVM Subsystem Overview

Communication system

All the parts needed to communicate with Earth, including the different pointing mechanisms

AOCS

All the sensors and electronic elements needed to monitor the satellite motion, plus the reaction wheels, as an actuator for fine trajectory corrections.

Thermal system

The system used to control the SVM temperatures, including the radiators and the MLI coating

Propulsion system

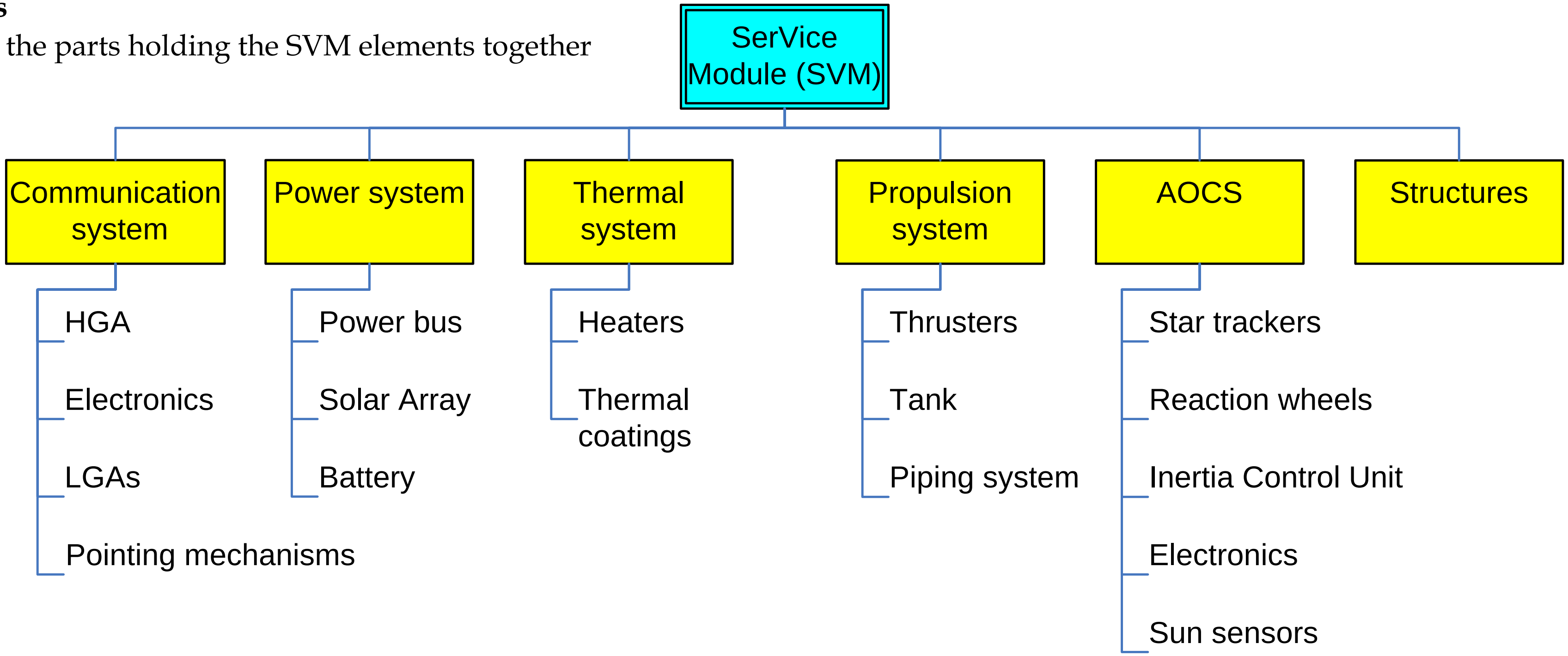
System needed to fire and control the thrusters plume in order to correct the orbit of the spacecraft. This is mainly the tank, the thrusters and the pipes

Power system

The SA, the battery and the power lines providing the spacecraft with electrical power

Structures

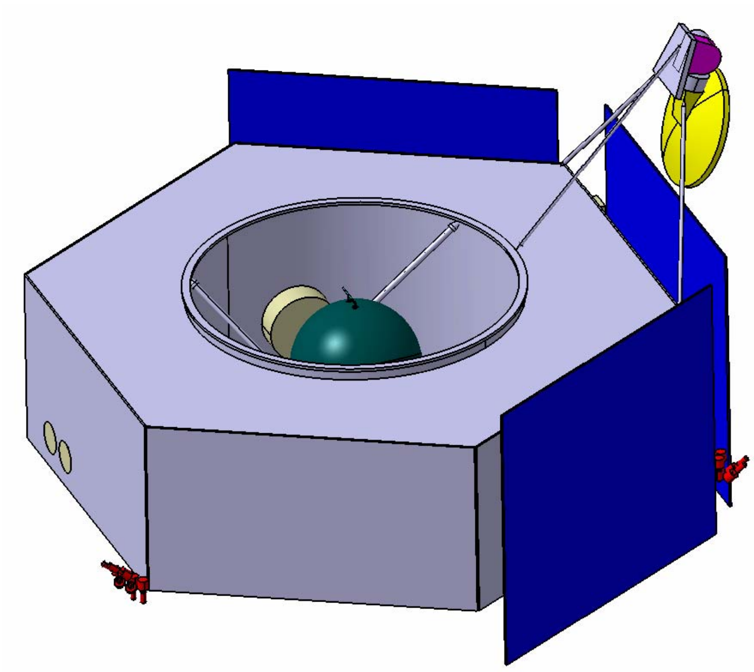
All the parts holding the SVM elements together



SVM Subsystems Overview cont.

Structure

- Aluminium core
- Internal facesheets of CFRP
- Hard points to support PLM



Communication

- Steerable high-gain antenna (HGA) 0.3 m diameter
- 2 low gain antennas (LGA)
- X-band at 4.36 Mbps
- Earth viewing angle: ±75° azimuth, ±50° elevation

Propulsion

- 14 mono-prop thrusters (5N thrust)
- Single propellant tank (from Herschel); max. capacity 177L
- 104.45kg hydrazine mono propellant

SVM Subsystems Overview cont.

Thermal

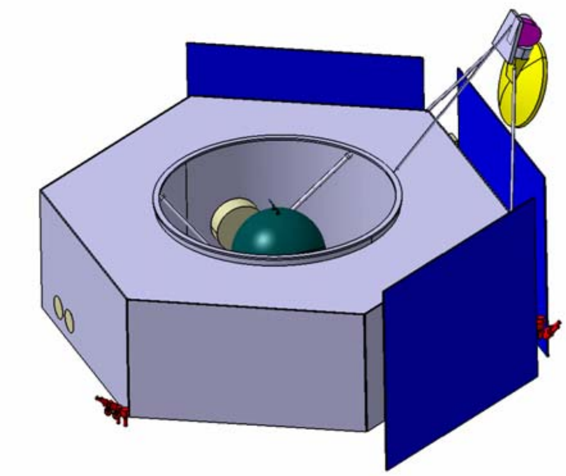
- External surfaces covered with MLI, internal surfaces painted black
- SVM radiator (0.88 m^2)

Mechanisms

- 2-axis pointing mechanism for the High-Gain Antenna

Data-handling

- Single SMU with CAN bus
- Data from payload used in AOCS



Power

- 6.4 m2 solar array GaAs TJ cells
- Three body-mounted solar arrays (1.60 m x 1.33 m)
- 656 Wh battery for one hour safe mode (and launch mode)
- Regulated bus (back-up solution: non regulated bus)

SVM Subsystems Overview cont.

AOCS

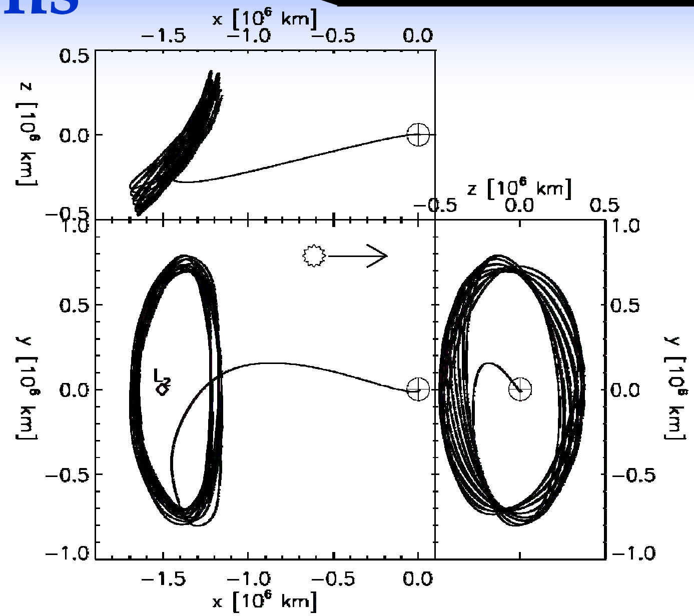
- 3 axis stabilized using reaction wheels
- Inertial Pointing during operation,
- Orbital maintenance provided by chemical propulsion system
- Dedicated (TBC) telescope(s)
  - To achieve Absolute Pointing Error of ~0.2 arcsec (TBC) by using telescopes to provide input to AOCS loop
  - This is used after RW off-loading and in monthly orbit maintenance in order to be avoid to uplink new target images
  - Also used to achieve Relative Pointing Error (RPE) over periods of ~10 minutes
  - Fine gyro used to keep RPE ~0.2 arcsec / 20 sec (during single exposures)

Mission Operations

Mission Analysis and Operations

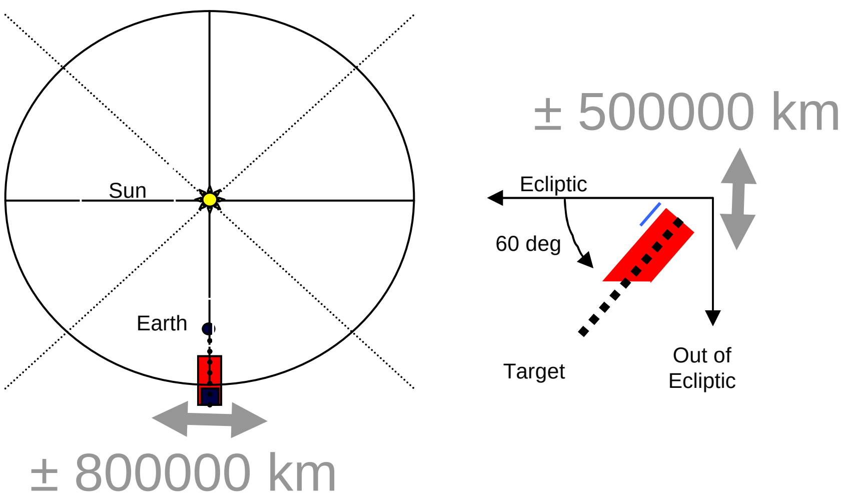
Observation Strategy

- Inertial pointing on 2 fields of 2.5 years each + 1 year step and stare
- Field 1: $(210, -60)_{ecliptic}$; Field 2: $(306, 67)_{ecliptic}$



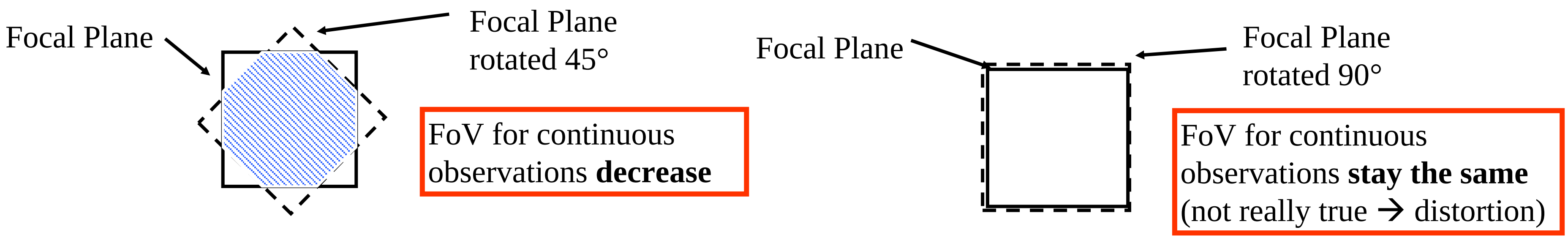
Orbital Geometry

- Spacecraft orbiting around L2
- Total delta-V ~75 m/s
- High amplitude orbit, excursions of up to
  - ± 500000 km out of the ecliptic
  - ± 800000 km in plane perpendicular to the sun earth direction

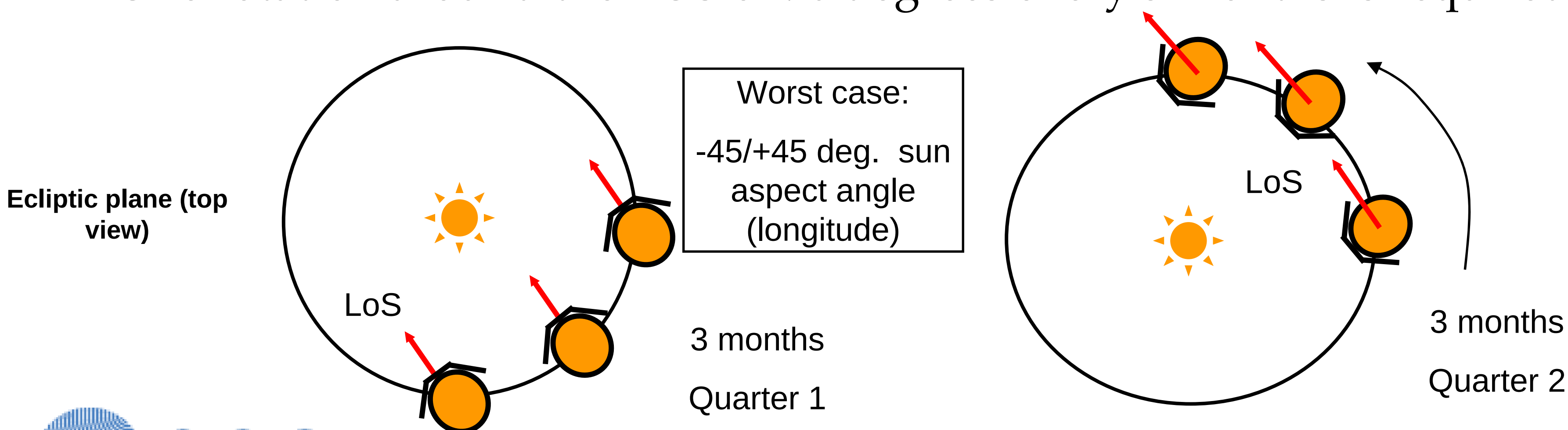


Mission Analysis and Operations

- Square field of view
  - ⇨ Only rotations of 90 degrees possible to maintain the same field of view



  - ⇨ One rotation around the LOS of 90 degrees every 3 months is required



Duty Cycle

- Gaps longer than 10 minutes (TBC) must represent less then 7% (goal 5%) of the total elapsed time (the elapsed time is the time between the first observation and the last one of a given target for a given observation sequence), up to 2.5 years

63.7 days (45 days goal) per 2.5 years,

- For seismic studies, periodic gaps of any duration must represent less than 5% of the total elapsed time, up to 5 months

7.5 days in 5 month (45 days in 2.5 years)

- For seismic studies, non periodic gaps of any duration must represent less than 5% of the total elapsed time, up to 5 months

7.5 days in 5 month (45 days in 2.5 years)

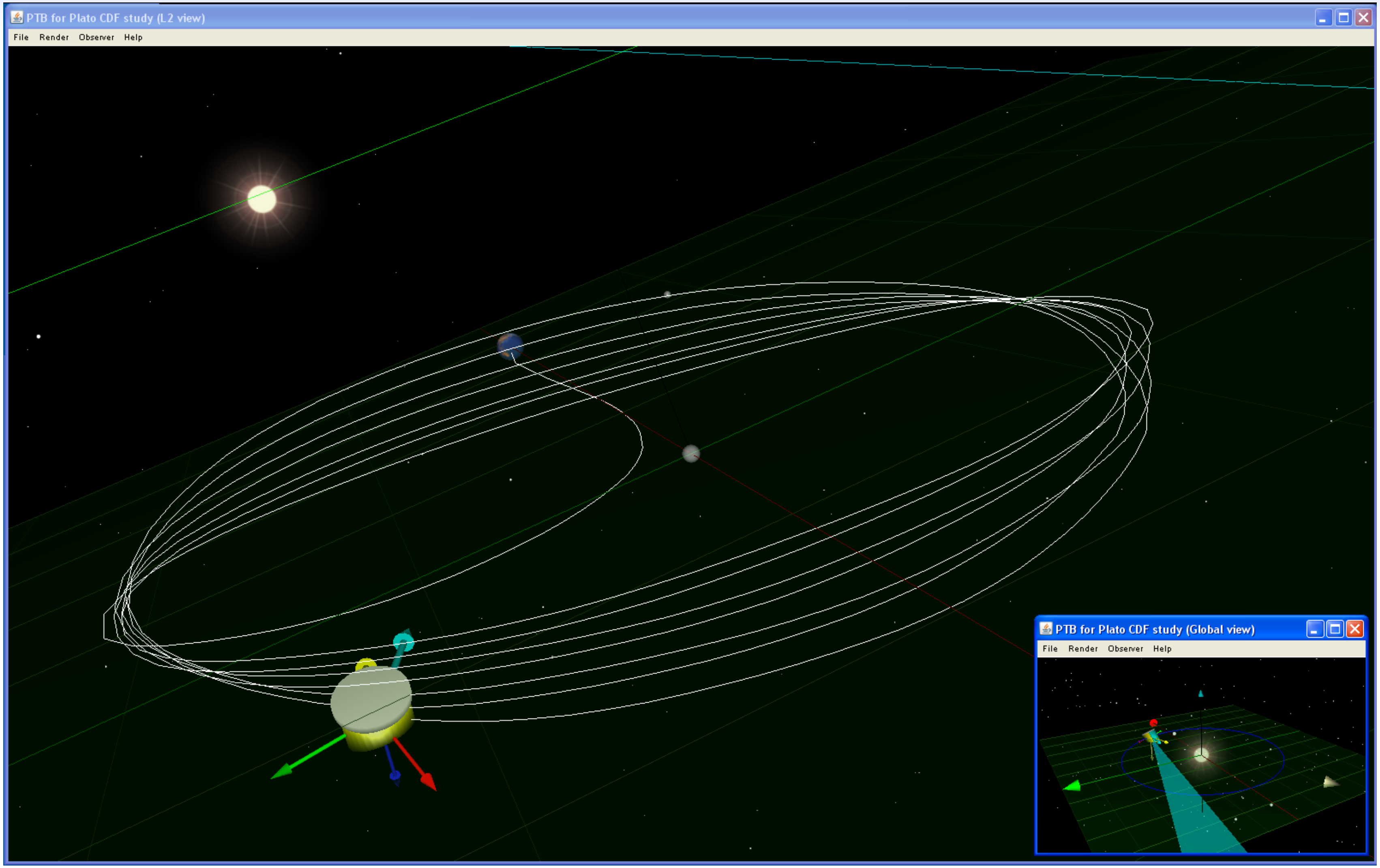
Duty Cycle cont.

Events	Type	Frequency [days]	Duration [s]	Stabilisation (Thermal and fine pointing) [s]	Re-calibration [s]	Total time per manoeuvre [s]	Total time per manoeuvre [days]	Periodic: Total time in 30 months [days]	Non-Periodic: Total time in 30 months [days]	All Gaps: Total time in 30 months [days]
Antenna pointing	Periodic	1E+37	600	300	0	900	0.01	0.0		
Wheels offloading	Periodic	3.5	600	300	0	900	0.01	2.7		2.7
Roll manoeuvre	Periodic	90	1800	43200	86400	131400	1.52	15.2		15.2
Orbit maintenance	Periodic	30	7200	43200	0	50400	0.58	11.7		11.7
Safe Mode Recovery	Non Periodic	365	604800		0	604800	7.00		17.3	17.3

	Periodic	Non-Periodic	All Gaps
Total	29.6	17.3	46.8
Max	45.0	45.0	63.0
Margin	34%	62%	26%

- No disruption due to the antenna movement
- 10 min to de-saturate and re-point and 5 min to achieve fine pointing after reaction wheels de-saturation
- Roll manoeuvre in 30 min, but thermal stabilisation (12 hours) and windows re-acquisition (24 hours) required
- Orbit maintenance in 3 hours, thermal stabilisation may be required, 12 hours allocated
- Conservative numbers used → allows for further optimisation in order to increase duty cycle margin

Orbit Simulation cont.



Ground Segment (preliminary assessment)

- 43 Gbit/day science data
- 8 kbit/s housekeeping data => 0.8 Gbit/day
- 5% packaging overhead (min: 0.8%) => 46 Gbit/day
- X-Band (for science and HKTM and TC)
- No ranging assumed (ranging is not compatible with high data rate modulation)
- Link Setup 0.5 h/pass (operational margin)
- Basic downlink data rate 4.4 Mbit/s (assumed as for GAIA)
- Daily passes of 4 h duration
- New Norcia is single baseline station for operational phase
- 3 LEOP stations, second station for selected passes for transfer

Performance Model

Performance model (staring concept)

Steps taken:

- Extracted 25 0.6° × 0.6° fields from the USNO B1.0 catalogue, with B, R and I magnitudes, claimed to be complete down to V=21…
- Filled in missing BVI data using main sequence B-R, V-R, and R-I colors based on Allen's Astrophysical Quantities
- Converted V magnitudes to counts /sec., using stellar temperature estimate
- Accumulated population statistics
- Applied following (oversampled) PSFs:
  - Gaussian PSF, with 90% of the ensquared energy inside 2x2 pixels
  - Non-dispersive PSF, defocussed by 200 µm
  - Dispersive PSF, defocussed by 100 µm
- CCD properties consistent with e2v prospects by DL
- Included saturation, smearing, pixel gain variations, read-out noise
- Combination of 28 images with small pointing differences
- Applied sampling of stellar light with various apertures
- Analysis of saturation and confusion
- Analysis of static noise / signal performance
- Collection of statistics of targets fulfilling noise requirements
- Variation of parameters: sampling time, pixel size, FoV, red and blue CCD
- Cross check with Kepler performance (comparing apples with apples)

Baseline model assumptions

Optical:

- # telescopes: 26 - 28
- Coll. area: 0.0103 m^2
  with vignetting: 0.00975 m^2
- FoV: 557 sq. deg.
- η_{ND} : 0.77, 0.77, 0.81, 0.83
- η_{Dsp}: 0.78, 0.78, 0.83, 0.84
  for λ= 400, 550, 700, 850 nm

CCD detector:

- Pixelsize: 18 μm
- Well capacity: 616 ke^-
- QE_{RED} : 0.45, 0.72, 0.88, 0.80
  for λ= 400, 550, 700, 850 nm
- Plate scale: 12.5 ″/pixel
- # pixels: 3584^2
- Sampling time: 25 sec.
- R/O freq.: 4 MHz
- R/O noise: 17.4 e^- rms
- Smearing: 7.9%

Astronomical:

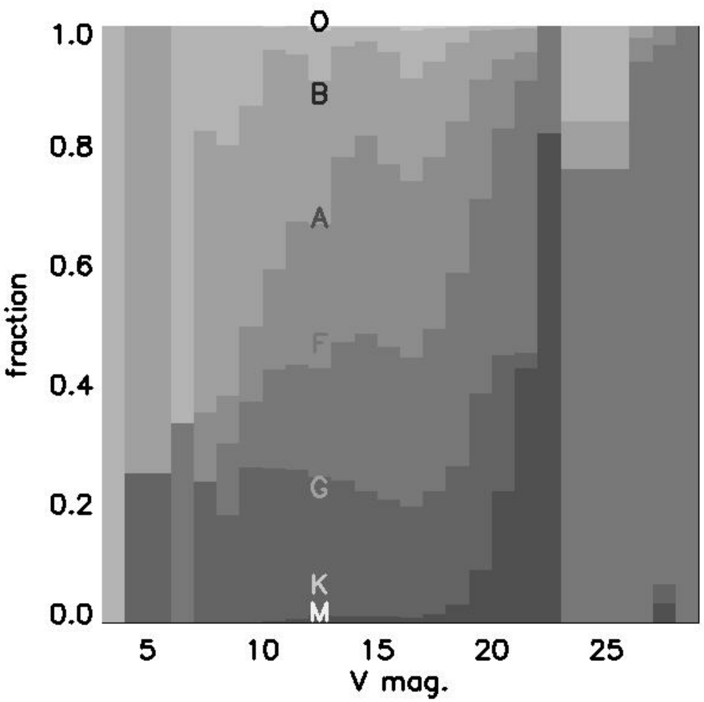
- Fraction of stars in MS: 61%
- Two fields observed in sequence
- GAIA will provide sub-pixel accurate stellar positions
- Planck function for T_{eff} underestimates stellar flux by 0.125 mag

Star catalogue

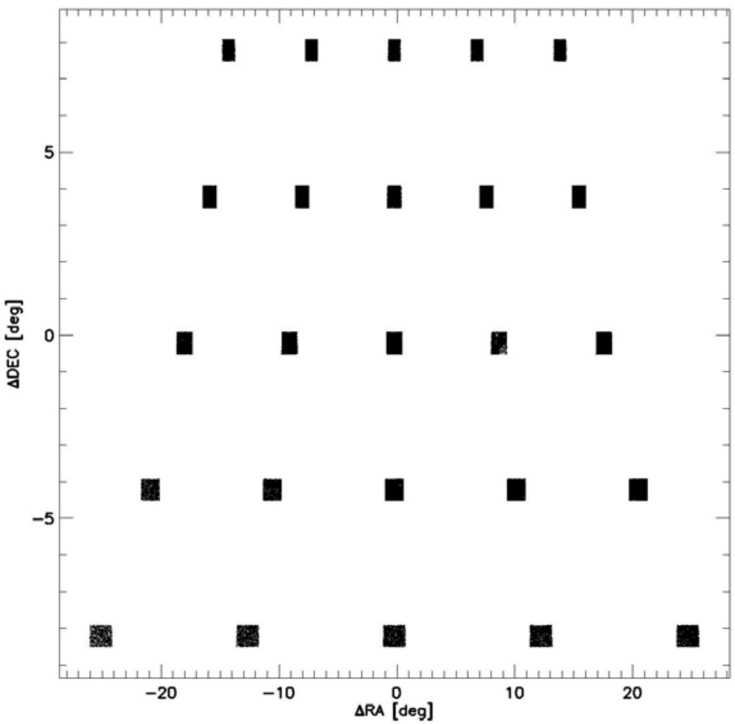
Catalogue definition based on multiple detections:

- USNO B1.0: 5 mags (R1, R2, B1, B2, I) based on multiple plate scans:

  search criteria: $R1 < 30 \cap R2 < 30 \cap |R1 - R2| < 1$
- R colors match the PLATO sensitivity better than e.g. 2MASS
- 25 fields of 0.6° x 0.6° (i.e. 9° in total) were collected for both definitions:



USNO B1.0	
O	0.38 %
B	4.6 %
A	15.3 %
F	27.4 %
G	28.1 %
K	21.5 %
M	2.8 %



Star counts

- Single field with FoV of 557 square degrees
- 61% of field stars are main-sequence dwarfs

there are:

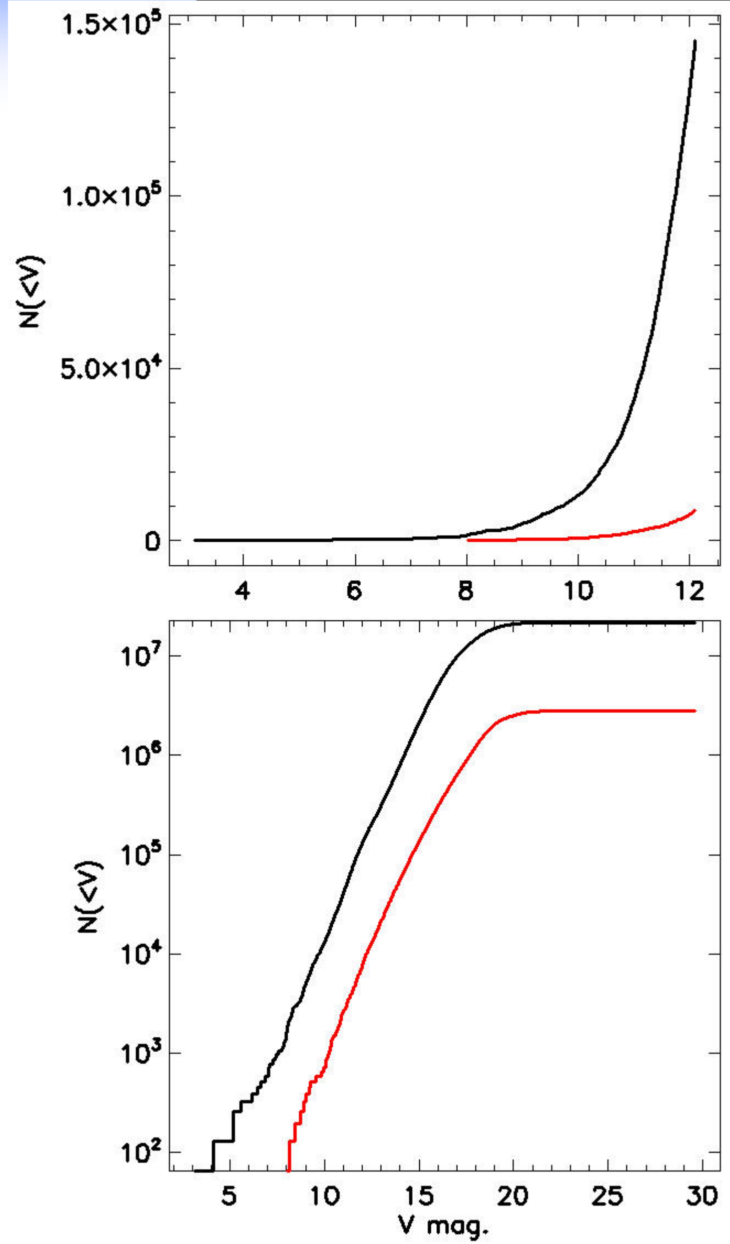
~123,000 stars with $m_V < 12$ (R1a)

~ 75,000 MS dwarf stars with $m_V < 12$

~767,000 stars with $m_V < 14$

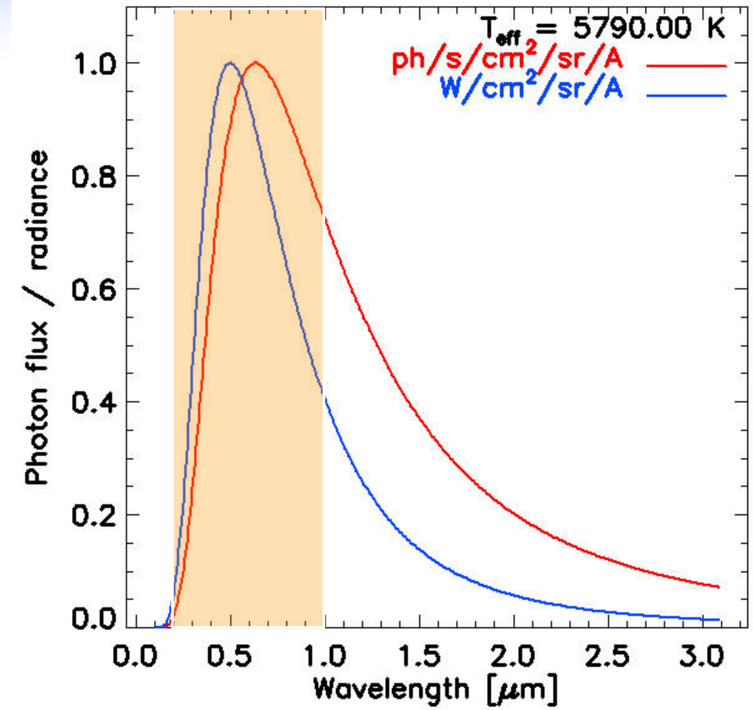
~468,000 MS dwarf stars with $m_V < 14$ (R1b)

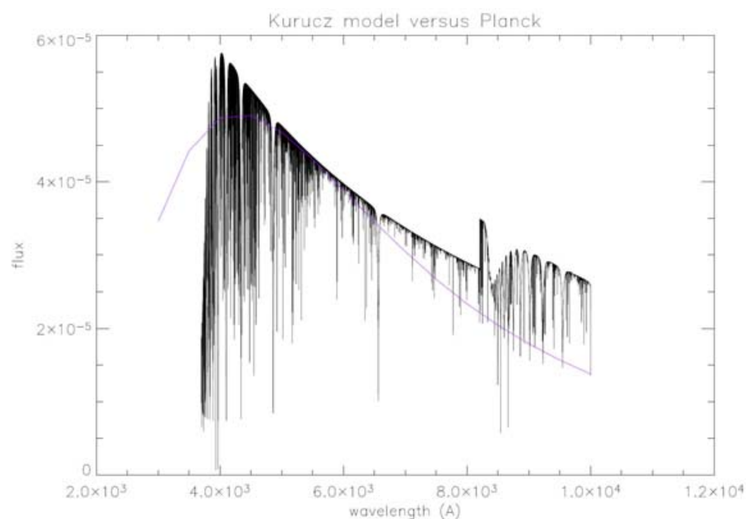
~ 1,500 stars with $4 < m_V < 8$ (R1c)



Magnitude – count conversion

- Bolometric:
  - Convenient: just m_V + BC
  - Provides conversion to photons / sec
  - But, large portion of Planck photon flux lies outside PLATO sensitivity range ⇒
    count rates overestimated by 0.3 – 0.35 mag
- Magnitude:
  - Calibration based on energy / s / area / sr
  - Requires Planck functions to convert to photon flux: uncertainty in T_{star}
  - Planck function is not an accurate description of actual stellar spectrum ⇒
    count rates underestimated by 0.1 – 0.15 mag
- Compromise used below:
  - Visual magnitude calibration based on T_{star}
  - Corrected by a systematic shift of 0.125 mag

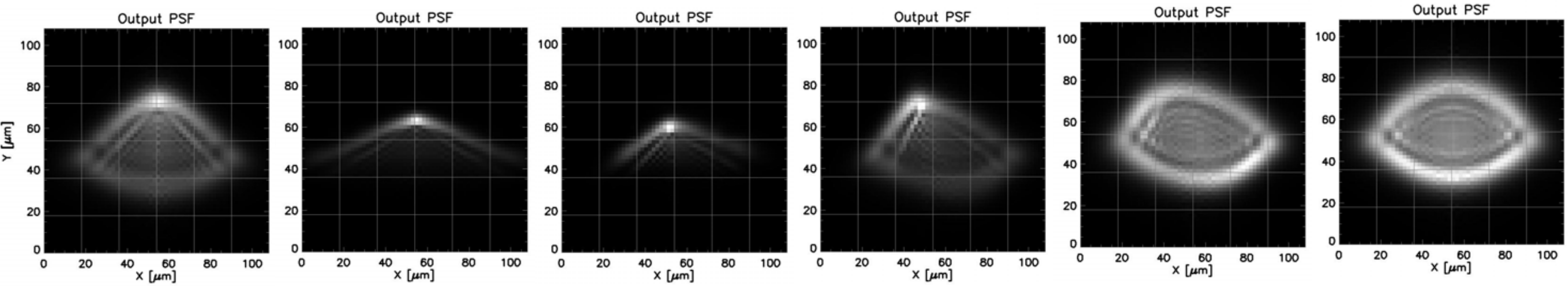




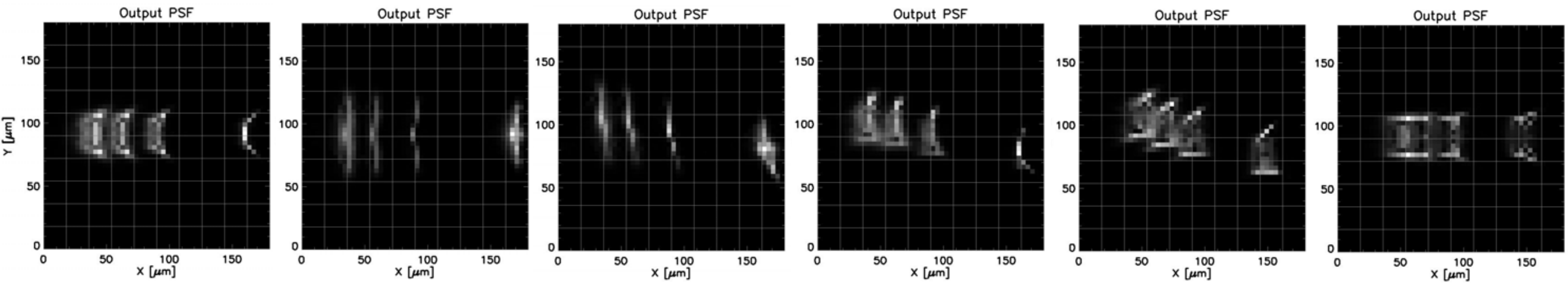
Point-spread functions

at non–extreme positions in the field!

Non-dispersive, 200 μm defocus

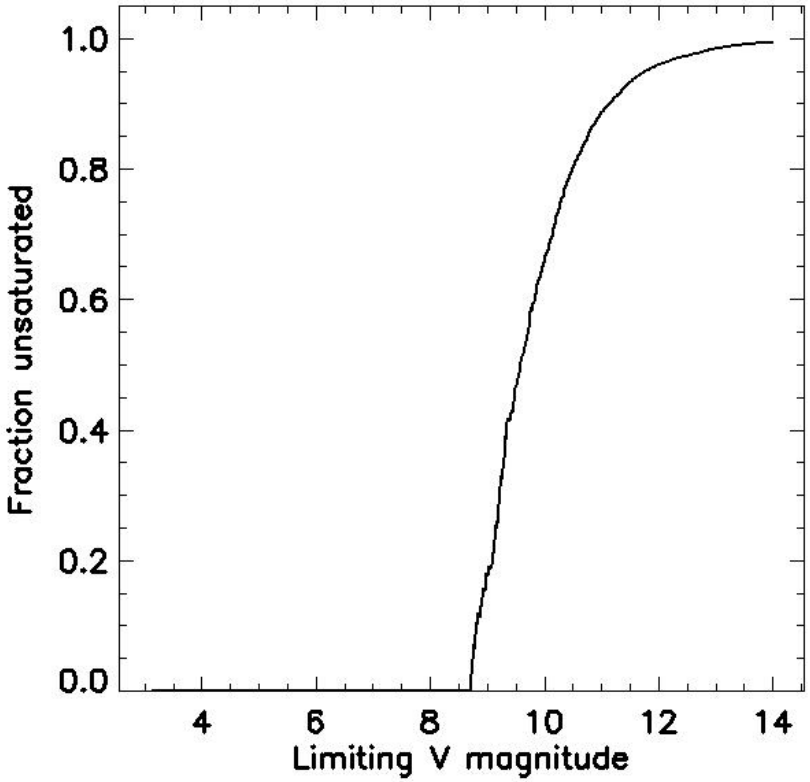


Dispersive, 100 μm defocus: necessarily non-continuous



Saturation

- 18 μm pixels
- 616 ke$^-$ well capacity
- Gaussian PSF with 90% EE in 2x2 pixels
- t_{sample} = 25 sec.



Definitions

weights that define aperture function

Confusion:

$$Conf = \frac{\sum_i w_i D_i}{\sum_i w_i C_i}$$

'dirty' pixels, incl.:
- target signal
- confusing background
- smear (out & in)
- saturation (out & in)
- R/O noise
- pixel-to-pixel variation

Noise / Signal ratio:

$$\frac{N}{S} = \frac{\sqrt{\sum_i w_i D_i}}{\sum_i w_i C_i}$$

'clean' pixels, incl.:
- target signal
- smear (out of pixel)
- saturation (out of pixel)

Optimal aperture

PROBLEM:

Try to combine signals S_i in individual pixels i in order to maximize combined SNR

Aperture is given by weights w_i for each pixel i, given noise levels N_i:

$$SNR = \frac{\sum_i w_i S_i}{\sqrt{\sum_i w_i N_i^2}}$$

SOLUTION:

Find weights w_i such that $\partial SNR / \partial w_i = 0 \Rightarrow$

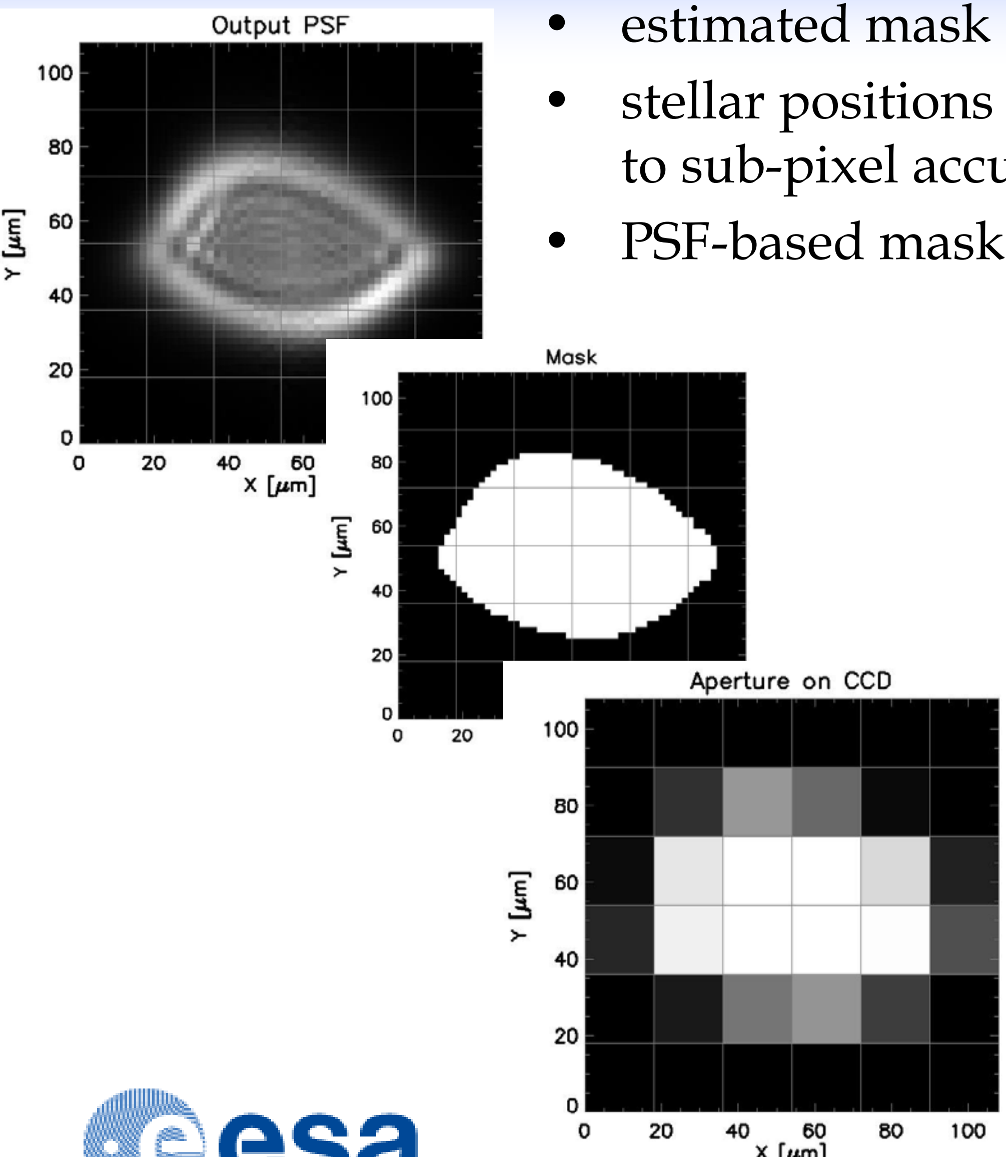
$$w_i = \frac{S_i / N_i^2}{\sum_j w_j S_j / \sum_j w_j N_j^2} = \frac{1}{\max(SNR)} \frac{S_i}{N_i^2} \propto \frac{S_i}{N_i^2}$$

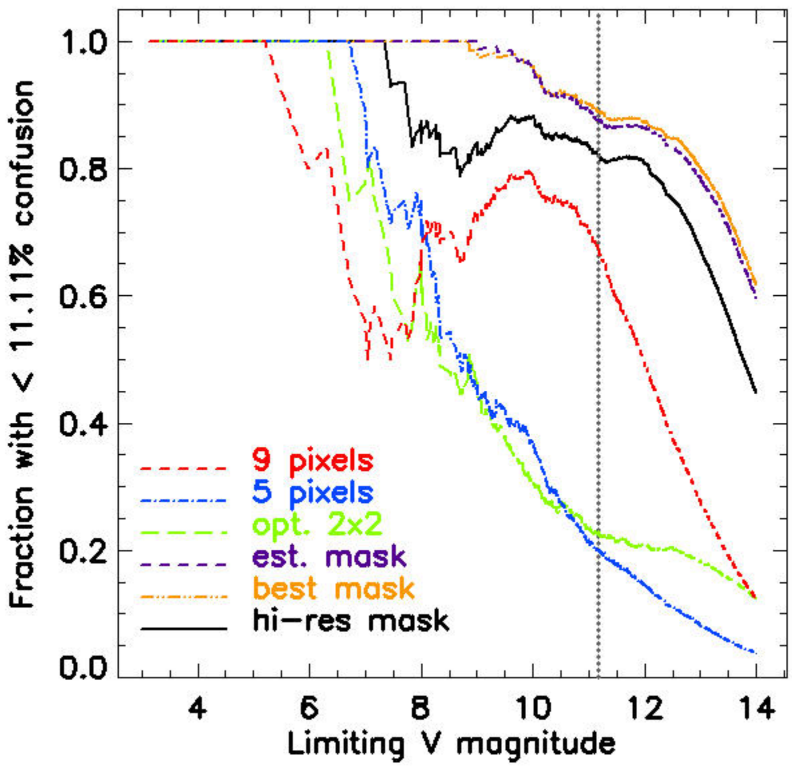
When confusion dominates, the N_i are approximately independent of signals $S_i \Rightarrow$ weights $w_i \propto PSF(x_i, y_i)$

Aperture constructed from the PSF itself should work best

Impact on confusion

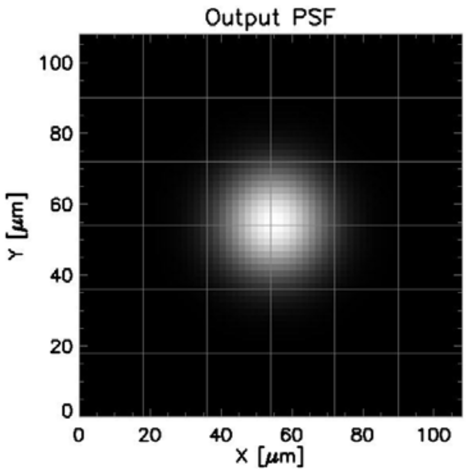
- estimated mask = best mask + 10% errors
- stellar positions are assumed to be given by GAIA to sub-pixel accuracy
- PSF-based mask outperform standard apertures

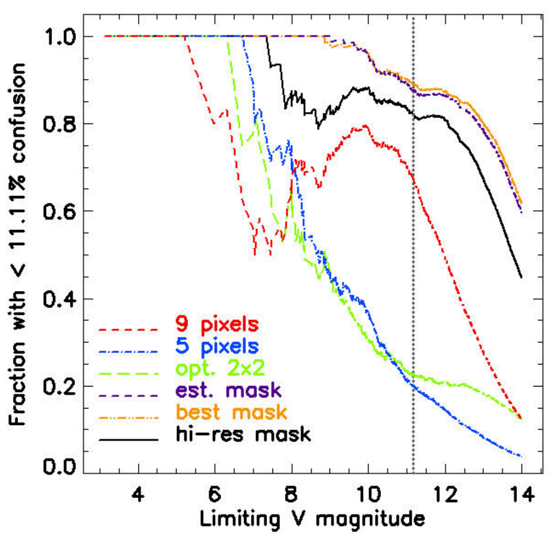




Confusion and PSF

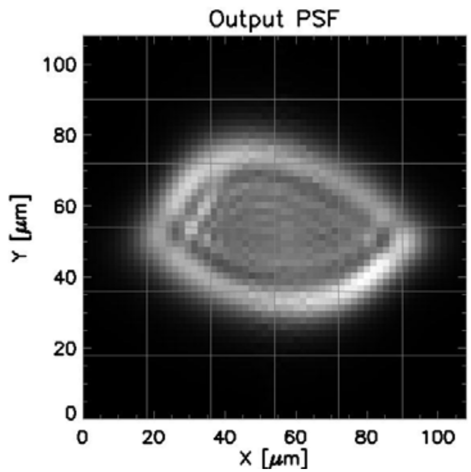
Gaussian PSF

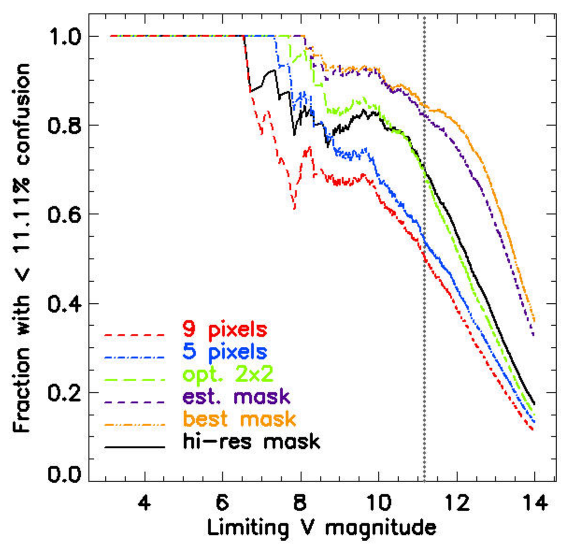




Non-dispersive PSF

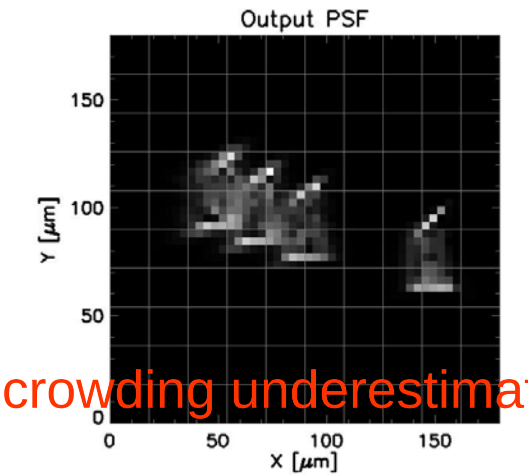
200 μm defocus



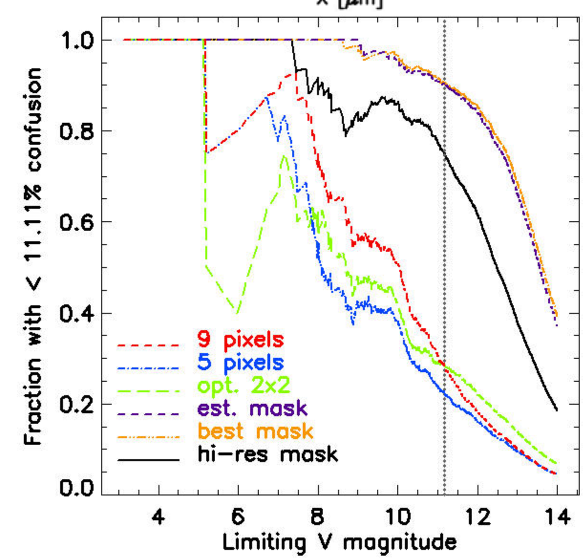


Dispersive PSF

100 μm defocus



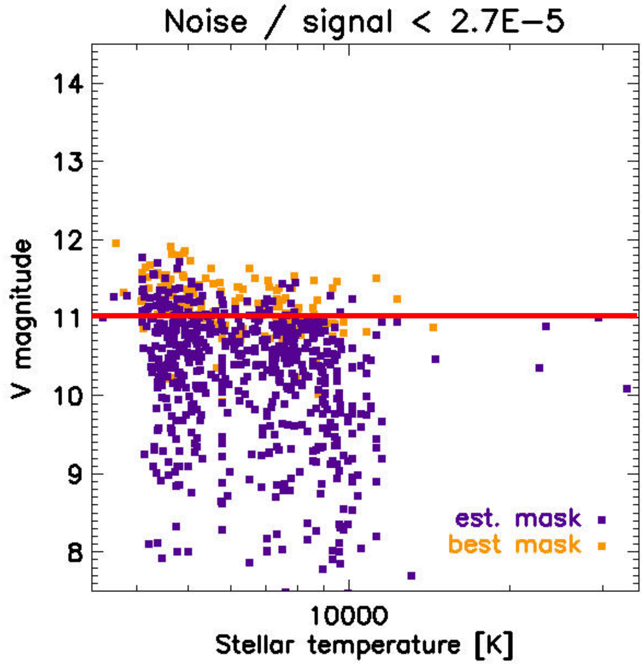
crowding underestimated

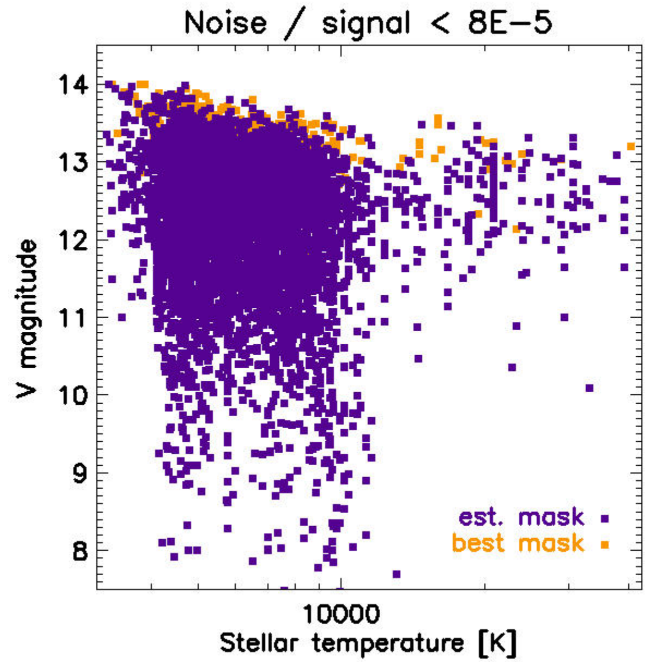


Science performance

Re-interpretation of science requirements R5a and b:

- Magnitude limit of $m_V \leq 11 - 12$ is superseded by inherent limit resulting from noise requirement $N/S < 2.7\ 10^{-5}$
- Analysis of secondary targets requires the eff. mag. limit to lie beyond $m_V = 11$
- Count all stars which are unsaturated, have confusion < 11.11% and fulfill the noise requirement
- Still need to correct by factor of 0.61 for non main-sequence stars in sample





Preliminary Science performance

all targets in 2 fields:	N=26	N=28	N=34	
Gaussian PSF, red sensitive CCD, t_{sample}=25				
< 2.7 10^{-5}	71,000	80,000	108,000	
< 8.0 10^{-5}	533,000	561,000	649,000	

	N=26		N=28	
Non-dispersive PSF, 200 µm defocus				
< 2.7 10^{-5}	77,000 ± 11,500	(66,500 – 100,000)	82,500 ± 21,000	R5a
< 8.0 10^{-5}	473,000 ± 100,000	(253,500 – 530,000)	492,000 ± 104,500	R5b
Dispersive PSF, 100 µm defocus (crowding underestimated)				
< 2.7 10^{-5}	55,500 ± 27,500	(49,000 – 134,500)	91,500 ± 16,500	
< 8.0 10^{-5}	391,000 ± 115,000	(347,000 – 691,000)	453,000 ± 68,500	

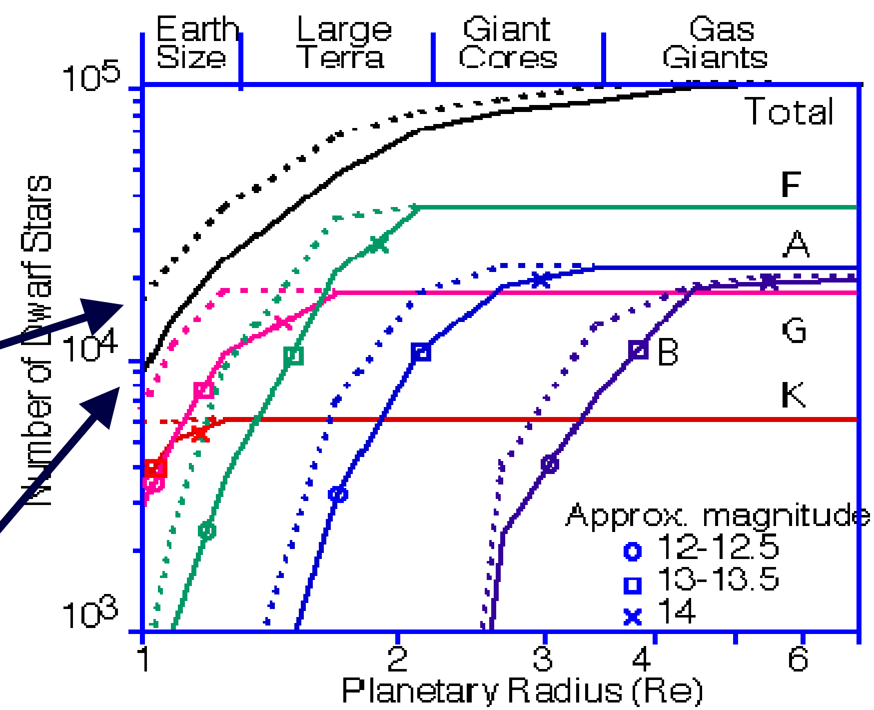
Comparison with Kepler

# MS targets < 3.6 10^{-5} after full mission	N=28	N=26	Kepler
Gaussian PSF	98,500	89,500	
Non-dispersive (200 µm)	97,000	90,500	<16,000
Dispersive (100 µm)	96,500	68,000	

- Kepler analysis does not address saturation or confusion
- Kepler observes fainter objects

4 near- central transits with 1 year period

4 near- grazing transits with 1 year period



Internal Study Conclusions

Conclusions

Telescope Properties			
CCD size (one side of square)	3584	pixels	
Number of Telescopes	28		
Mass per Telescope	21.41	kg	(including margins)
Structures	9.40	kg	
Optics	6.77	kg	
Electronics	5.14	kg	
Thermal	0.11	kg	

Mission Lifetime		
Total operational lifetime	6.0	years

Masses		
Soyuz payload mass	2146	kg
PLM Mass Target	1396	kg
PLM Mass	1263	kg
SVM Mass Target	750	kg
SVM Mass	721	kg
Total Spacecraft Mass	1983	kg
Total Below Budget	163	kg

Observed Field		
Circular Large FOV	630	sq deg
Useful FOV	557	sq deg
Field 1 Coordinates	(+210, -60)	
Field 2 Coordinates	(+306, +67)	

Communications and Data Handling		
Downlinked data	47.02	Gb / day
Daily Transmission Time	4.00	h / day
Data Rate	4.36	Mbit / s

Temperatures		
Focal Plane Assembly (FPA)	170	K
Front End Electronics (FEE)	230	K

Pointing Requirements	
Absolute Pointing Error (APE)	0.2 arcsec
Relative Pointing Error (RPE): a	0.2 arcsec / 25 sec
Relative Pointing Error (RPE): b	0.2 arcsec / 10min (TBC)

Conclusions

- A mission/spacecraft design that fits with the given technical requirements and constraints has been found
- The design includes robust margins and allows for further optimization, including science performance
- The Service Module design does not pose major challenges
- Limited development required for CCDs. An effort has been done to use off-the-shelf technologies as much as possible in some areas or to use technologies at sufficient TRL for the launch date.
- A launch date at the end of 2017 is feasible with early procurement of the CCDs

Programmatics: Draft schedule

ID	Task Name	Duration
1	**PLATO_PLM**	**2605 days**
2	Internal assessment	80 days
3	Industry assessment	358 days
4	Phase A studies for the instrument	355 days
5	Preliminary SRR	0 days
6	Instrument AO and selection	152 days
7	Instrument definition	283 days
8	Selection of Mission Definition	0 days
9	Definition Phase ITT	110 days
10	Definition phase B1 (2 parallel studies)	412 days
11	SRR	0 days
12	Selection of Mission iimplementation	0 days
13	ITT time	125 days
14	**Implementation phase**	**1464 days**
15	Design phase	343 days
16	PDR Subsystem	0 days
17	PDR PLM+SVM	0 days
18	CDR Subsystem	0 days
19	CDR PLM	0 days
20	CDR PLM+SVM	0 days
21	QR telescope	0 days
22	STM review	0 days
23	AR PLM + SVM	0 days
24	Launch date	0 days
25	**PLM Procurement**	**1069 days**
26	**PLM Procurement under National funding**	**983 days**
36	**PLM Procurement under ESA funding**	**457 days**
45	**SVM and sub-system Procurement**	**680 days**
46	**Structure and thermal subsystem**	**462 days**
51	**Power sub system**	**543 days**
55	**Propulsion subsystem**	**675 days**
58	**DHU**	**674 days**
60	**AOCS subsystem**	**500 days**
63	**Telecomm**	**360 days**
66	**Mechanism**	**676 days**
70	**AIV campaign**	**425 days**
71	STM test campaign SVM + PLM (including 2 QM Telesc	151 days
72	AIT of PLM (FM)	153 days
73	AIT of SVM (FM)	153 days
74	**Spacecraft AIV**	**485 days**
75	System AIV and functional test	160 days
76	TRR	0 days
77	Environmental test campaign	145 days
78	Contingency	120 days
79	Launch campaign	60 days