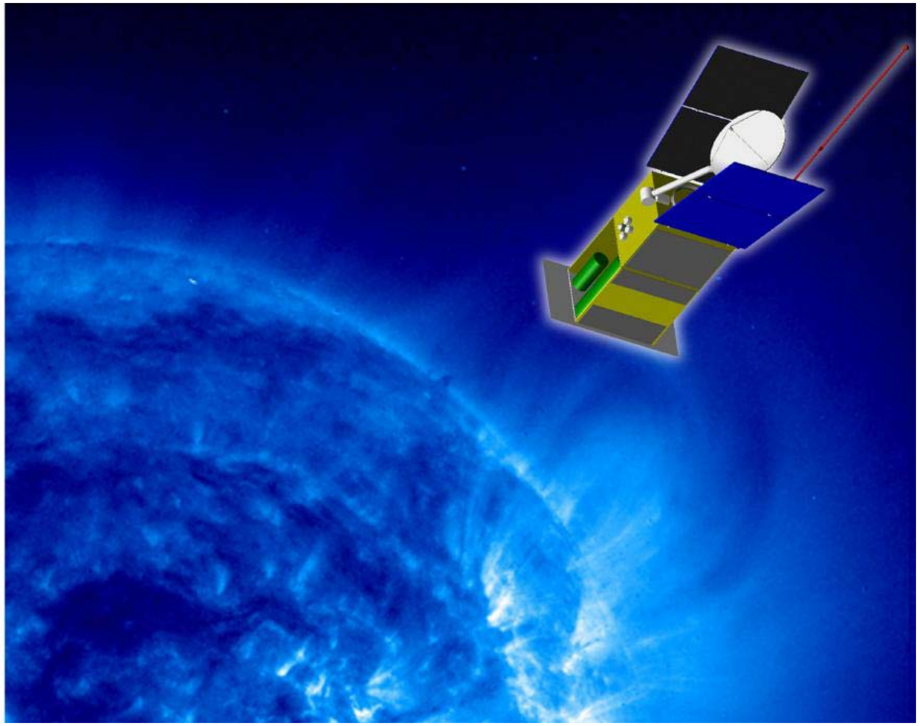
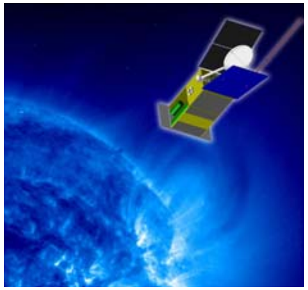
# Solar Orbiter: Status and Schedule

Richard Harrison, Rutherford Appleton Laboratory



**A high-resolution mission to the Sun and inner heliosphere**

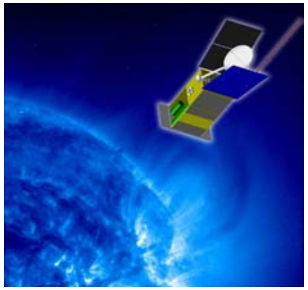


# 1. Status Since Last Meeting

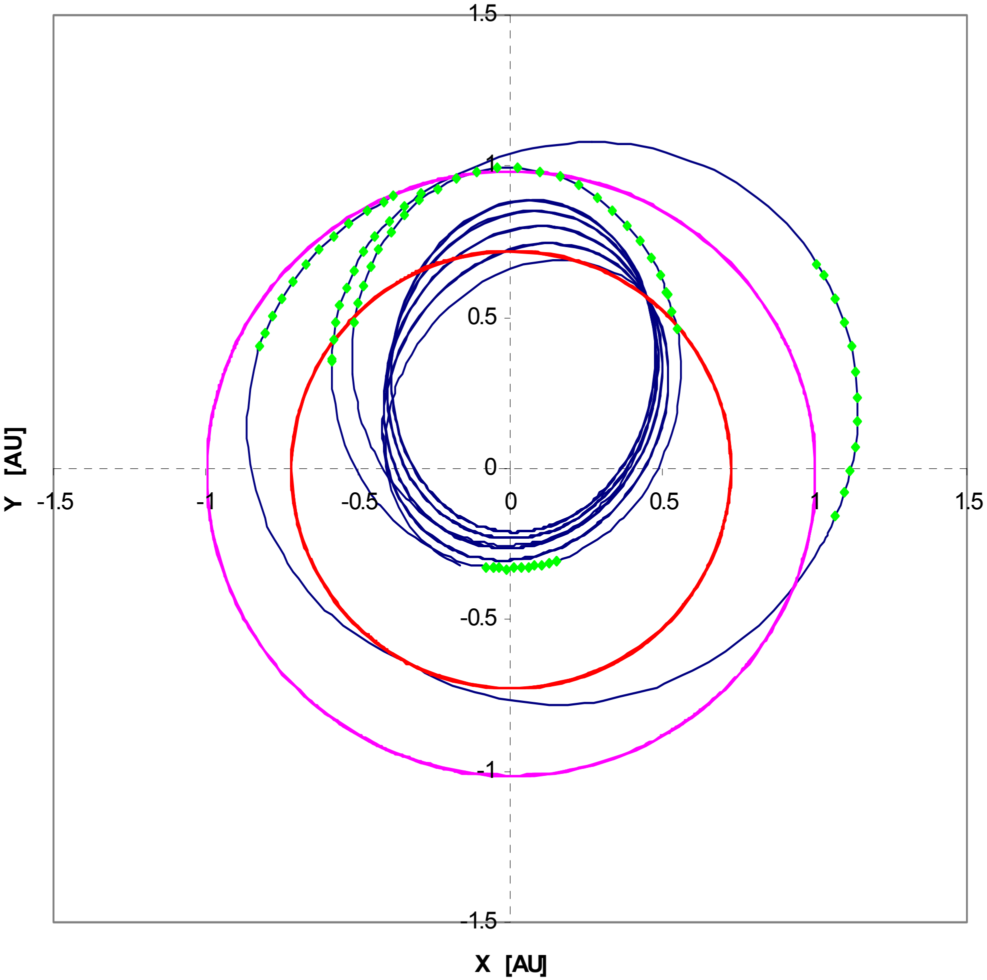
- ESA Review of Missions: 'Cosmic Vision' - the new ESA Science Programme - released May 27 2002 - Confirms Solar Orbiter as approved mission, in single 'project' with BepiColombo

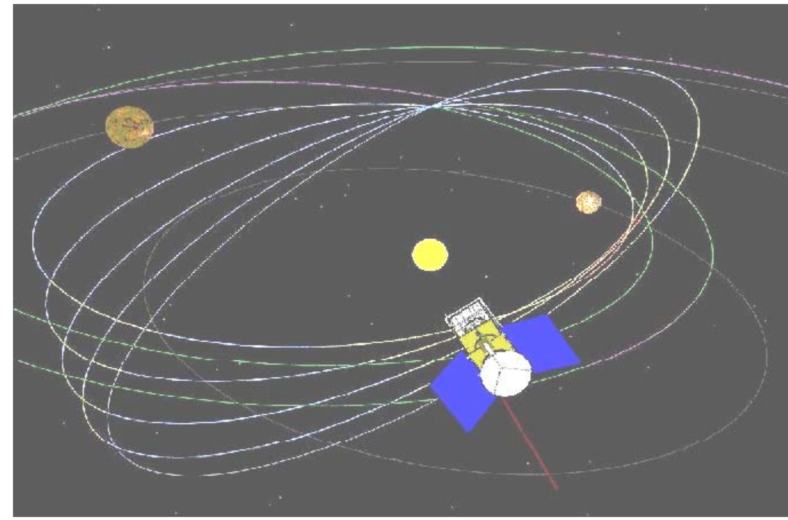
- AO 2005(ish), Launch 2011-2012

- Solar Orbiter Payload Working Group - Set up by ESA; kick-off meeting 16/17 May 2002 [Remote sensing: Richard Harrison (chair), Udo Schühle, Alan Gabriel, Luca Poletto, Louise Harra]



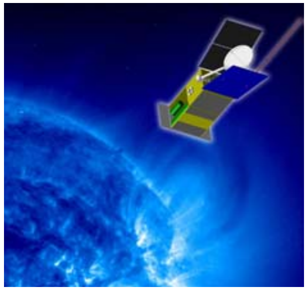
# 2. Mission Concept



SEP & planetary flybys, to achieve 150 day, 0.2 AU perihelion orbit, climbing out of ecliptic.

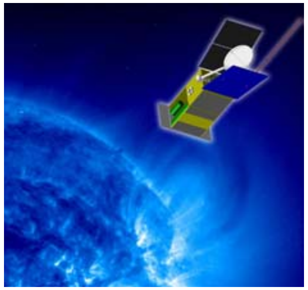
**Solar Orbiter**



# 3. Scientific Goals & Mission Firsts

## Mission Firsts

- Explore the uncharted innermost regions of our solar system
- Study the Sun from close-up (45 solar radii or 0.21 AU)
- Fly by the Sun tuned to its rotation and examine the solar surface and the space above from a co-rotating vantage point
- Provide images of the Sun's polar regions from heliographic latitudes as high as 38°



# 4. Mission Overview

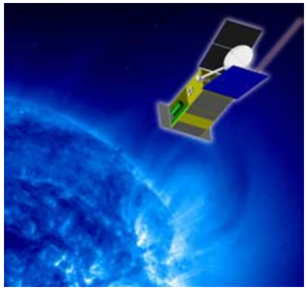
Orbit : solar orbits achieving high heliographic latitudes (up to 38°) with perihelion ~0.2 AU, and co-rotation phases

Launch: 2011-2012 (three launches in Bepi/Orbiter project); windows in principle every ~ 19 months; Soyuz-Fregat from Baikonur assumed

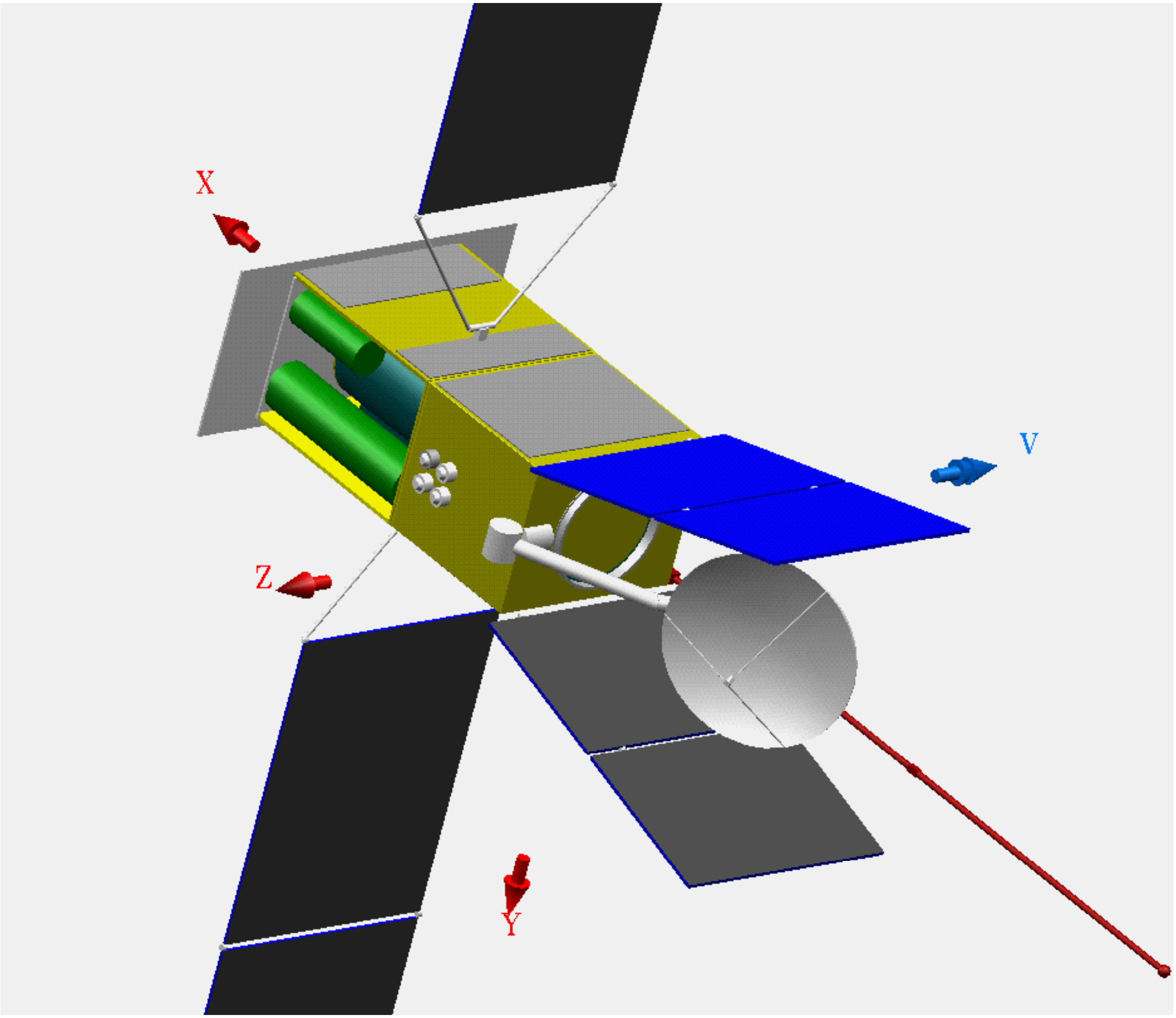
Mission duration: cruise phase ~1.9 years (3 orbits); nominal mission ~2.9 years (7 orbits); extended mission ~2.3 years (6 orbits)

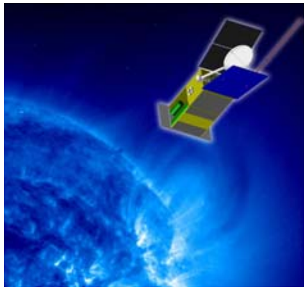
Spacecraft: 3-axis stabilised, Sun-pointed (absolute ± 3arcmin, stability ± 0.7 arcsec/15min. SEP technology benefits from BepiColombo; 1296 kg lift-off mass

Payload resources: 130 kg, 127 W, 74.5 kbit/s.



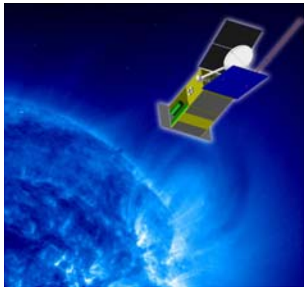
# 4. Mission Overview





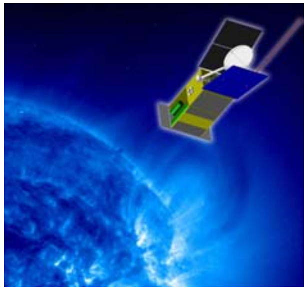
# 5. Strawman Payload

| Instrument | Mass kg | Power W | kb/s |
|---|---|---|---|
| Solar Wind Plasma Analyser (SWA) | 6 | 5 | 5 |
| Radio & Plasma Waves Analyser (RPW) | 10 | 7.5 | 5 |
| Coronal Radio Sounding (CRS) | 0.2 | 3 | 0 |
| Magnetometer (MAG) | 1 | 1 | 0.2 |
| Energetic Particle Detector (EPD) | 4 | 3 | 1.8 |
| Dust Detector (DUD) | 1 | 1 | 0.05 |
| Neutral Particle Detector (NPD) | 1 | 2 | 0.3 |
| Neutron Detector (NED) | 2 | 1 | 0.15 |



# 5. Strawman Payload

| Instrument | Mass kg | Power W | kb/s |
|---|---|---|---|
| Visible Light Imager & Magnetograph (VIM) | 26 | 25 | 20 |
| Extreme UV Spectrometer (EUS) | 22 | 25 | 17 |
| Extreme UV Imager (EUI) | 36 | 20 | 20 |
| UV & Visible Light Coronagraph (UVC) | 17 | 25 | 5 |
| Radiometer (RAD) | 4 | 6.5 | 0.5 |



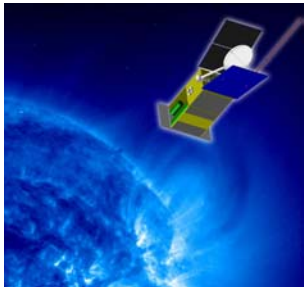
# 6. Aims of This Meeting

To tackle specific technical issues which are fundamental to the design concept of the EUS or which are necessary to demonstrate feasibility. This must be done before the AO!

This includes:

- Optical design approach
- Thermal design/strategy
- Detector approach

The meeting is a workshop - i.e.  We <u>need</u> open discussion to reach decisions!



# The EUS Instrument

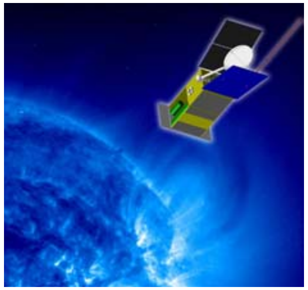
## Requirements

The Need for a UV/EUV Spectrometer

1. UV/EUV spectral range critical for solar plasma diagnostic analysis; provides foundation for exploring the physics of a huge range of phenomena.

2. Current and near-future UV/EUV capability:

| | |
|---|---|
| **Yohkoh** | None |
| **SOHO** | EUV 2-3″ and 0.1 Å & UV 1″ and 0.02 Å. |
| **TRACE** | None |
| **STEREO** (2005) | No spectroscopy. |
| **Solar-B** (2005) | EUV 1″ & 0.01 Å; on 2″ platform; coronal $\lambda$ selection with little TR capability. |
| **SDO** (2007) | Possibly none; EUV/UV spectroscopy - low priority. |
| **Solar Probe** (??) | None |
| **Solar Orbiter** (20011/12) | Yes!!!!! |



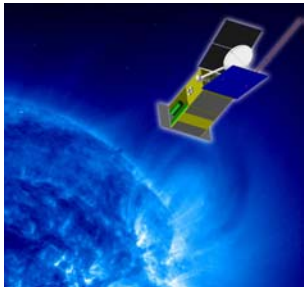
# The EUS Instrument

## Requirements

### Proposed Requirements

| | | |
|---|---|---|
| Spatial Resolving Element (pixel) | 0.5 arcsec | 75 km at perihelion |
| Spectral Resolving Element (pixel) | 0.01-0.02 Å/pixel | lower the better |
| Field of View (minimum) | 34 x 34 $arcmin^2$ | AR size at perihelion |
| Exposure time (minimum) | <1 s | |
| Maximum Exposure Time | Few 100 s | cosmic ray limit |
| Wavelength Bands | 170-220 Å<br>580-630 Å<br>> 912 Å | Prime bands from Tenerife meeting |
| Pointing | To anywhere on Sun and low corona | |

The Sun's atmosphere is a truly dynamic, fine-scale environment. Current imaging resolutions (0.5" & few S) are restricting; A consideration of filling factors and basic processes shows that we need to do better. Target: OM improvement in spatial resolution, and 5x better than the best imager capability (75 km on the Sun's surface, i.e. 0.1" from 1 AU, is 0.5" at 0.2 AU)



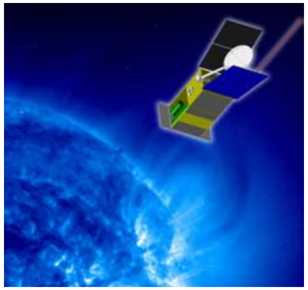
# The EUS Instrument

## Requirements

### Proposed Requirements

| | | |
|---|---|---|
| Spatial Resolving Element (pixel) | 0.5 arcsec | 75 km at perihelion |
| Spectral Resolving Element (pixel) | 0.01-0.02 Å/pixel | lower the better |
| Field of View (minimum) | 34 x 34 $arcmin^2$ | AR size at perihelion |
| Exposure time (minimum) | <1 s | |
| Maximum Exposure Time | Few 100 s | cosmic ray limit |
| Wavelength Bands | 170-220 Å<br>580-630 Å<br>> 912 Å | Prime bands from Tenerife meeting |
| Pointing | To anywhere on Sun and low corona | |

We need to separate emission lines, but the spectral resolution is driven by velocity, which is a major parameter for this mission; we will have good viewing of the polar outflows for the first time. A value of order 5 km/s would be a reasonable target, i.e. about 0.01 Å/pixel. Use of centroiding could allow some relaxation of this to 0.02 Å/pixel.



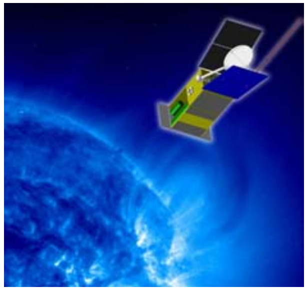
# The EUS Instrument

## Requirements

Proposed Requirements

| | | |
|---|---|---|
| Spatial Resolving Element (pixel) | 0.5 arcsec | 75 km at perihelion |
| Spectral Resolving Element (pixel) | 0.01-0.02 Å/pixel | lower the better |
| Field of View (minimum) | 34 x 34 $arcmin^2$ | AR size at perihelion |
| Exposure time (minimum) | <1 s | |
| Maximum Exposure Time | Few 100 s | cosmic ray limit |
| Wavelength Bands | 170-220 Å<br>580-630 Å<br>> 912 Å | Prime bands from Tenerife meeting |
| Pointing | To anywhere on Sun and low corona | |

The FOV is important, especially for a mission in such an eccentric solar orbit. The requirement is for the FOV to cover an active region at the 0.2 AU perihelion, and to cover the full Sun at aphelion. This can be achieved with a FOV of 34′ and upwards (300,000 km square field at 0.2 AU, which is larger than the CDS 200,000 km field; at 1 AU this is 1,500,000 km square.



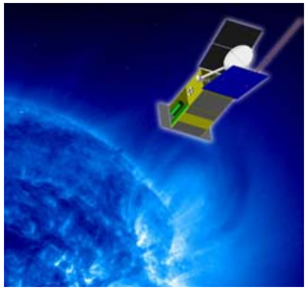
# The EUS Instrument

## Requirements

### Proposed Requirements

| | | |
|---|---|---|
| Spatial Resolving Element (pixel) | 0.5 arcsec | 75 km at perihelion |
| Spectral Resolving Element (pixel) | 0.01-0.02 Å/pixel | lower the better |
| Field of View (minimum) | 34 x 34 $arcmin^2$ | AR size at perihelion |
| Exposure time (minimum) | <1 s | |
| Maximum Exposure Time | Few 100 s | cosmic ray limit |
| Wavelength Bands | 170-220 Å<br>580-630 Å<br>> 912 Å | Prime bands from Tenerife meeting |
| Pointing | To anywhere on Sun and low corona | |

The dynamic nature of the solar atmosphere demands significantly better temporal resolution than currently available. There is a play-off between exposure time and temporal resolution; reasonable counting statistics must be obtained. The actual resolution will depend on the line used and the solar target. The instrument must have flexibility, down to under 1 s.



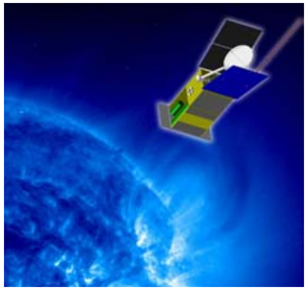
# The EUS Instrument

## Requirements

### Proposed Requirements

| | | |
|---|---|---|
| Spatial Resolving Element (pixel) | 0.5 arcsec | 75 km at perihelion |
| Spectral Resolving Element (pixel) | 0.01-0.02 Å/pixel | lower the better |
| Field of View (minimum) | 34 x 34 $arcmin^2$ | AR size at perihelion |
| Exposure time (minimum) | <1 s | |
| Maximum Exposure Time | Few 100 s | cosmic ray limit |
| Wavelength Bands | 170-220 Å<br>580-630 Å<br>> 912 Å | Prime bands from Tenerife meeting |
| Pointing | To anywhere on Sun and low corona | |

We have to consider a maximum exposure time. Normal operations would require exposures of order 1-50 s. Long exposures will suffer from excessive cosmic ray hits and values in excess of 100 s (e.g. on SOHO) would tend to be swamped by particle hits. Long accumulations can be achieved by summing consecutive images. 100 s is a reasonable upper limit.



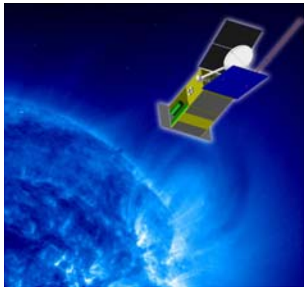
# The EUS Instrument

## Requirements

<u>Proposed Requirements</u>

| | | |
|---|---|---|
| Spatial Resolving Element (pixel) | 0.5 arcsec | 75 km at perihelion |
| Spectral Resolving Element (pixel) | 0.01-0.02 Å/pixel | lower the better |
| Field of View (minimum) | 34 x 34 $arcmin^2$ | AR size at perihelion |
| Exposure time (minimum) | <1 s | |
| Maximum Exposure Time | Few 100 s | cosmic ray limit |
| Wavelength Bands | 170-220 Å<br>580-630 Å<br>> 912 Å | Prime bands from Tenerife meeting |
| Pointing | To anywhere on Sun and low corona | |

We require a wavelength range to cover a good temperature range from chromosphere to flare plasmas, with sufficient diagnostic tools. This most likely requires several bands. The bands listed are those favoured at the 2001 Tenerife workshop.



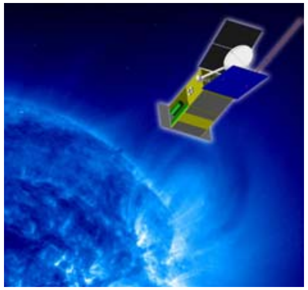
# The EUS Instrument

## Requirements

Proposed Requirements

| | | |
|---|---|---|
| Spatial Resolving Element (pixel) | 0.5 arcsec | 75 km at perihelion |
| Spectral Resolving Element (pixel) | 0.01-0.02 Å/pixel | lower the better |
| Field of View (minimum) | 34 x 34 $arcmin^2$ | AR size at perihelion |
| Exposure time (minimum) | <1 s | |
| Maximum Exposure Time | Few 100 s | cosmic ray limit |
| Wavelength Bands | 170-220 Å<br>580-630 Å<br>> 912 Å | Prime bands from Tenerife meeting |
| Pointing | To anywhere on Sun and low corona | |

We require that the instrument can be pointed to anywhere on the solar disc or low corona. Most likely to be done using the spacecraft - i.e. all pointed instruments work together.



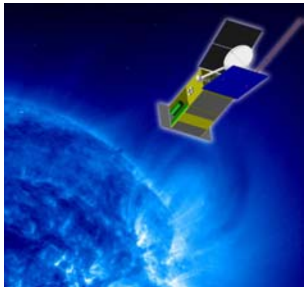
# The EUS Instrument
# Requirements

## Other Factors Which Influence the Design

| | | |
|---|---|---|
| Instrument Size | Max. Length 2.5 m | Due to spacecraft size |
| Mass | 25 kg target | Under 30 kg |
| Telemetry | 20 kbit/s target | Demands large on board memory |
| Power | 30 W target | |
| Thermal Environment | Varying and high levels of heat input requiring careful control . | Due to solar proximity and eccentric orbit. |
| Particle Environment | Varying levels of particle events with some extreme 'storms'. Includes solar neutrons. | Cosmic ray background and solar events. |
| Autonomy | Pre-planned sequences in deferred command store. | No contact for solar passes |
| Optical Correction | May require active image stabilisation system. | Spacecraft stability to be defined. |

Under 2.0 m more realistic (Instrument Size)

Includes ability to cope with latch-up (Autonomy)



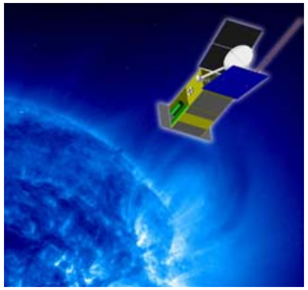
# The EUS Instrument

## Web site/documentation


1. Concept document ('Blue Book')

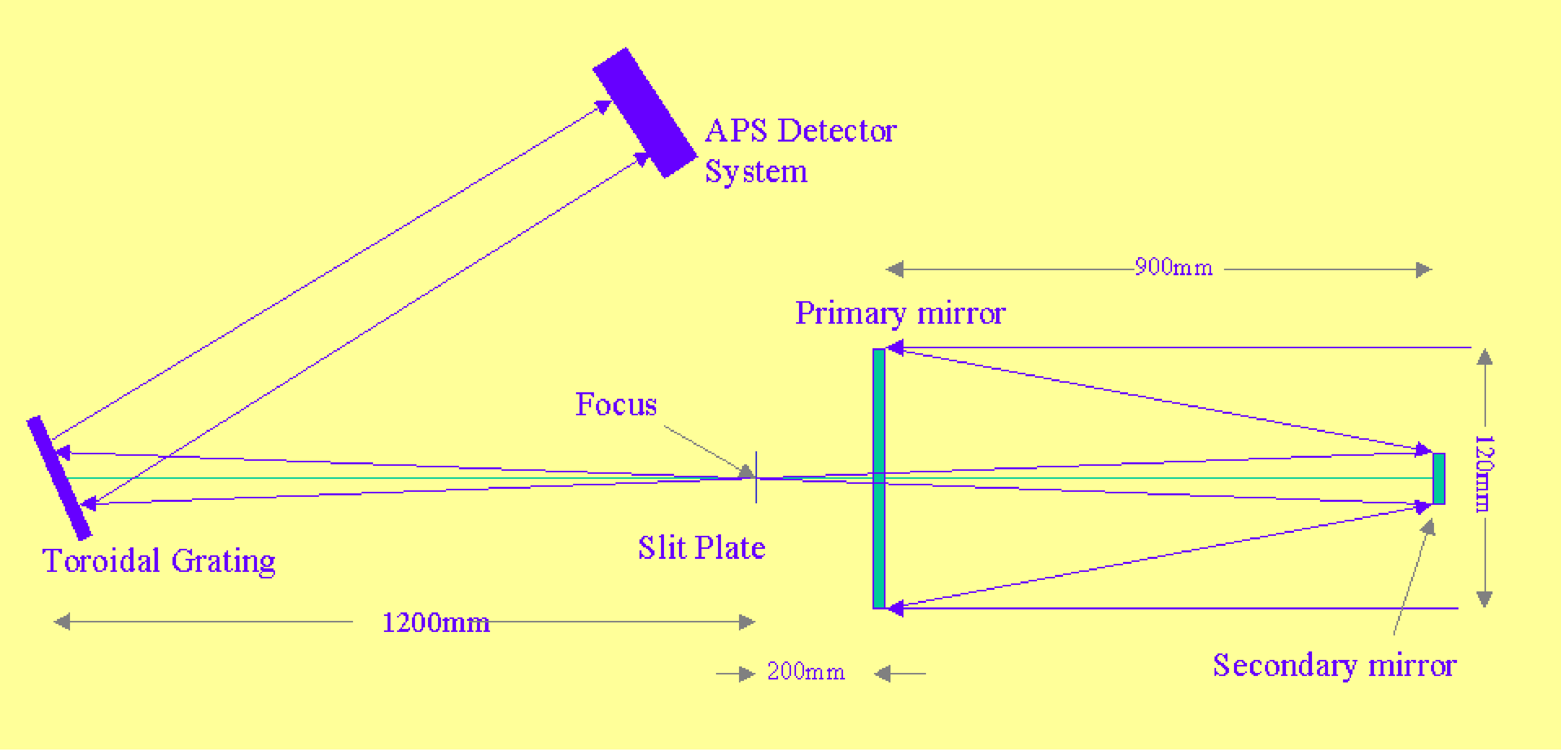
2. Technical notes (TN1 - Wavelength selection; TN2 - Orbiter goals; TN3 - Optical design requirements; TN4 - Detector requirements etc…)

3. Contact info., links, Solar Orbiter information, notes/documents…

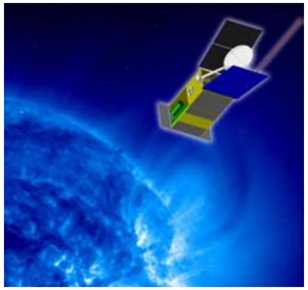


# The EUS Instrument

## Concept & Initial Design Strategy

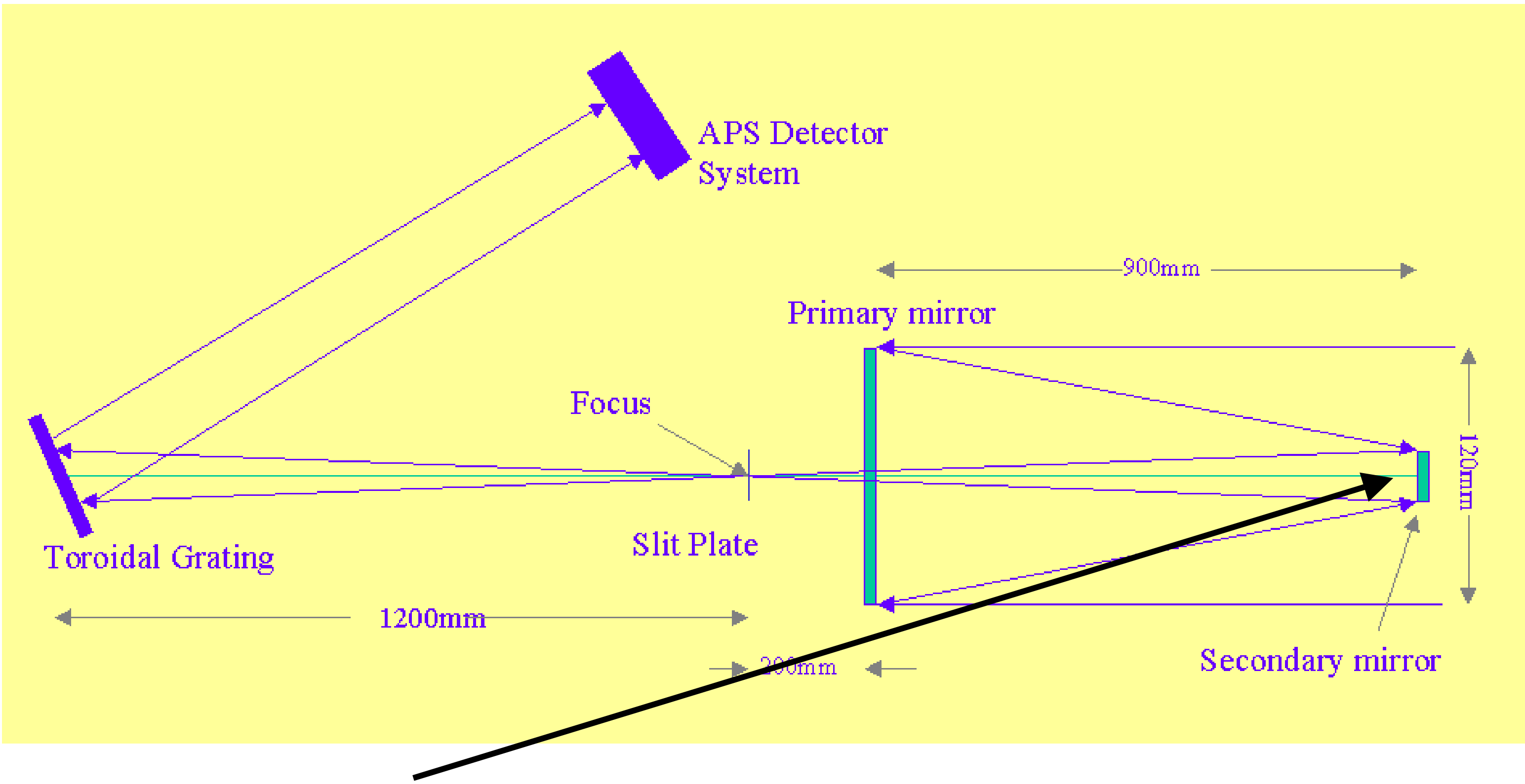



<u>The Original Strawman Design:</u> Ritchey-Chretien feeding spectrometer - 2 reflections to restrict length - retains desired resolution. EFL = 3.7 m. Size: 15cm x 230cm x 55cm.



# The EUS Instrument

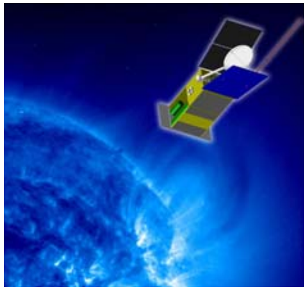
## Concept & Initial Design Strategy

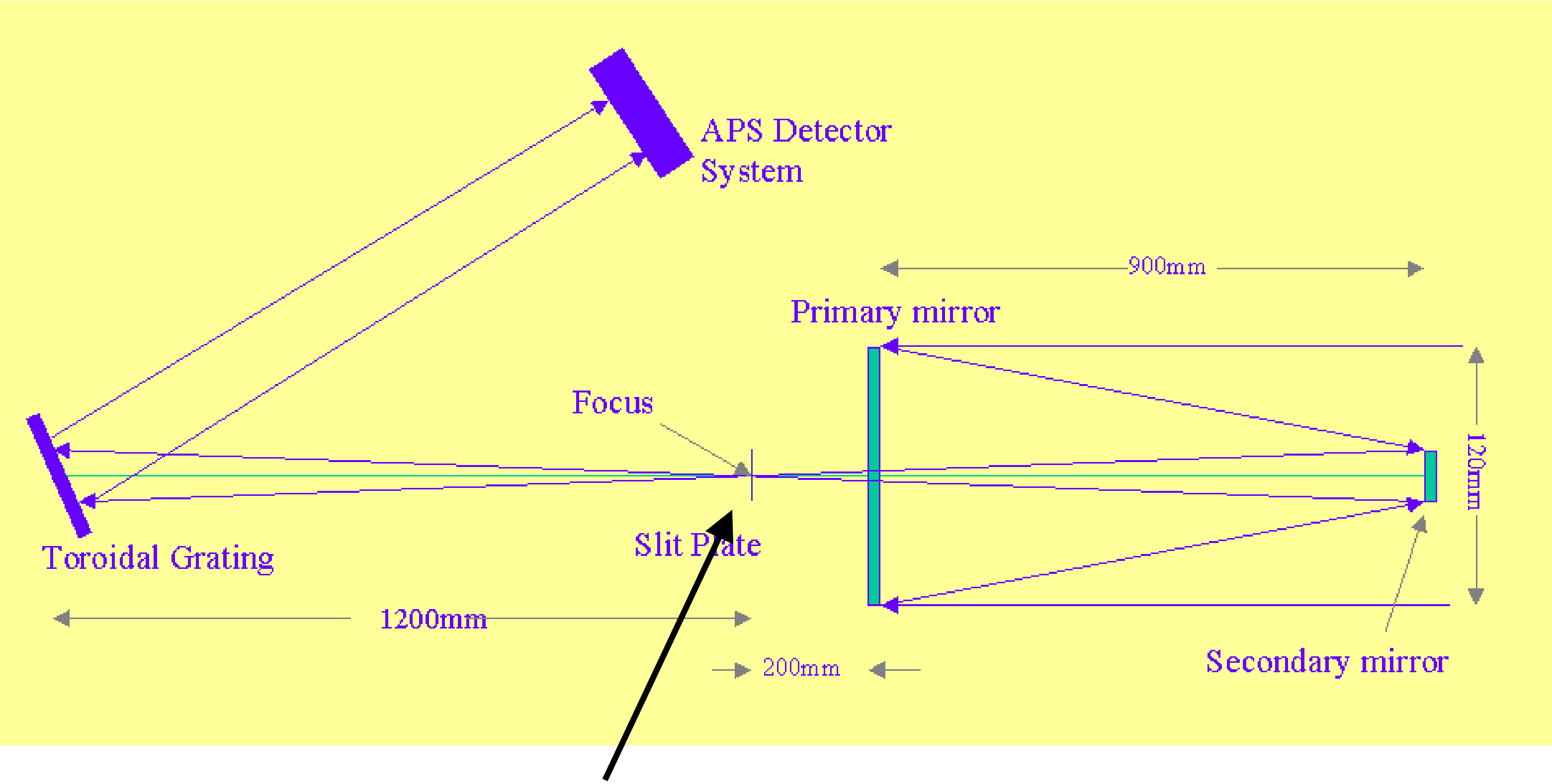



Secondary mirror can be rotated to 'raster' image across slit. Other options include rotation of primary, scan mirror or pointing instrument.

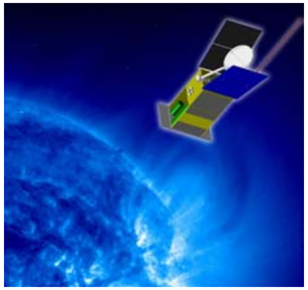
# The EUS Instrument

## Concept & Initial Design Strategy



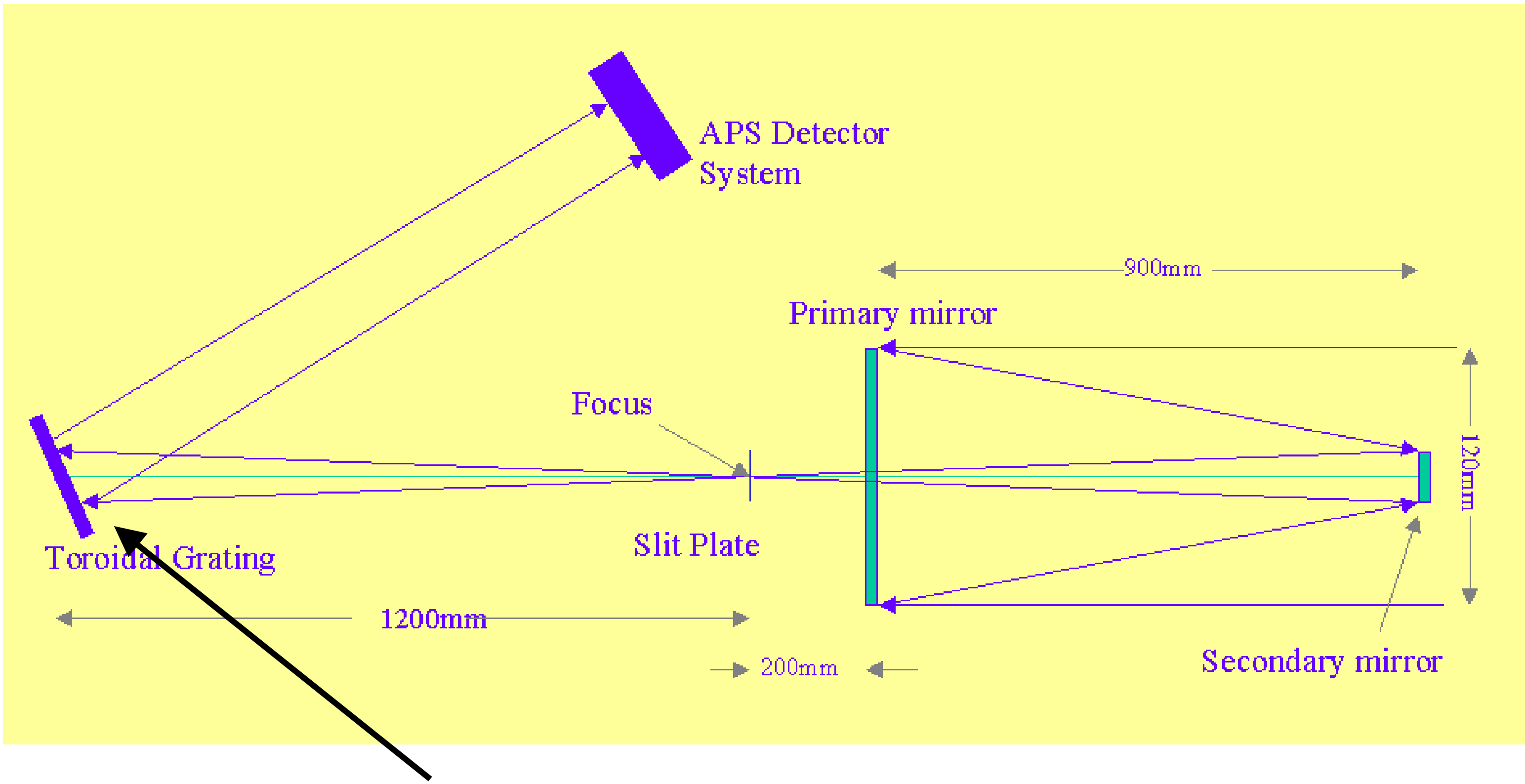



Selection of slits? Slit plane 'imager'.

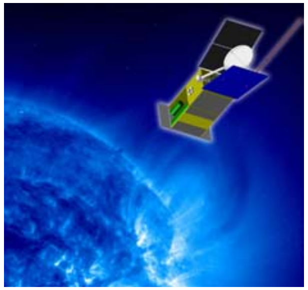


# The EUS Instrument

## Concept & Initial Design Strategy

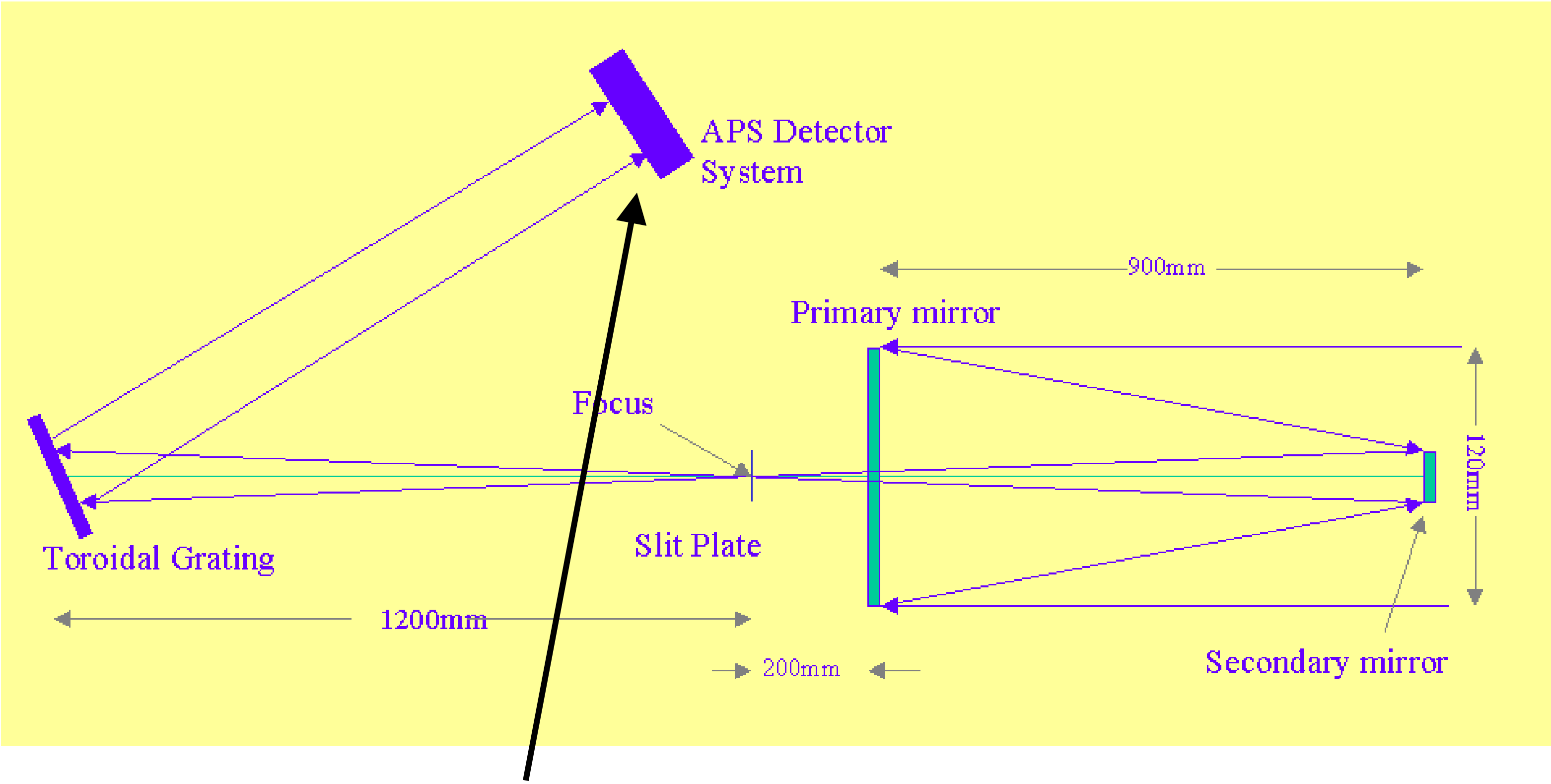



Grating baseline was 4800 l/mm but spherical VLS grating option is most likely choice (reduces off-axis aberrations; reduces instrument envelope)

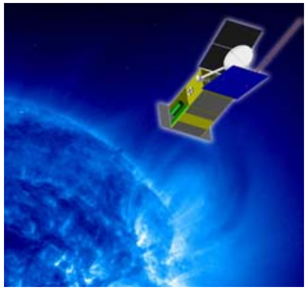


# The EUS Instrument

## Concept & Initial Design Strategy

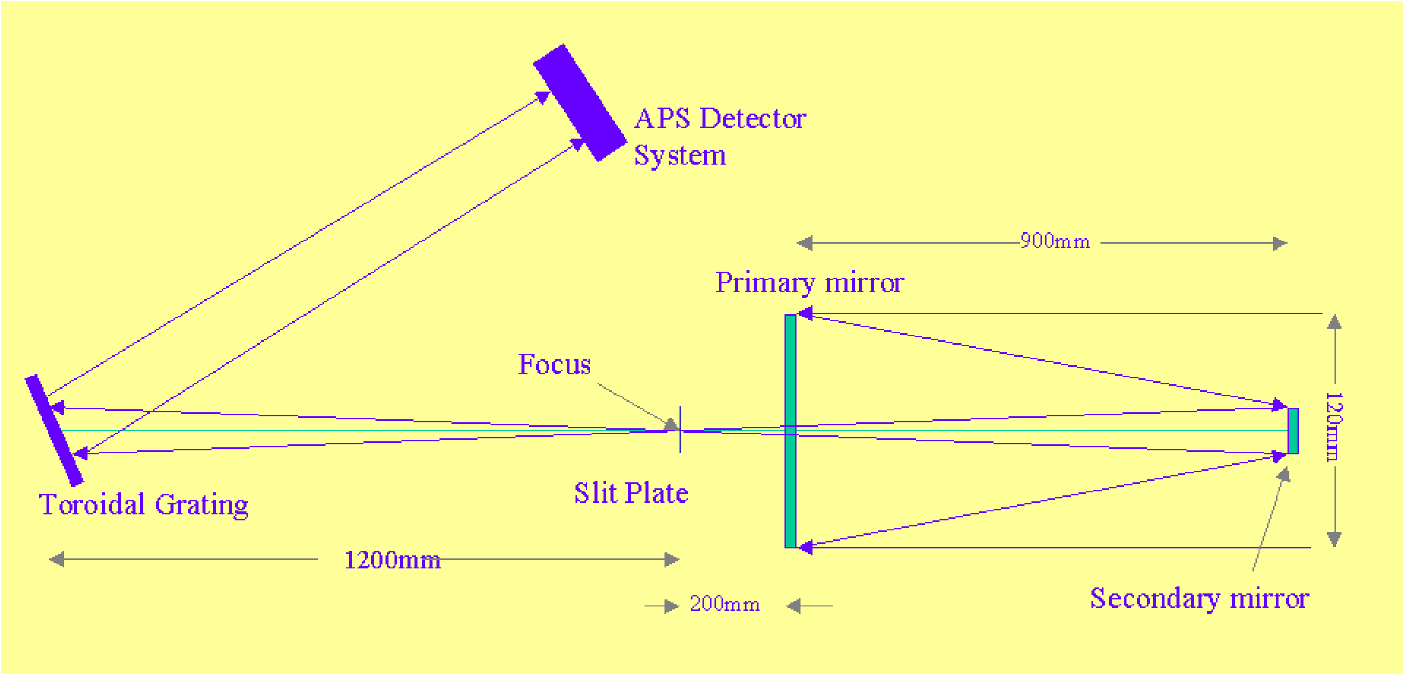



Active Pixel Sensor detector baselined. Better suited to particle environment. Initial design: 9 micron 4kx4k array. Considering: 5 micron.



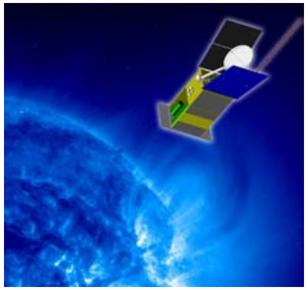
# The EUS Instrument

## Concept & Initial Design Strategy




Solar 'constant' 34,275 W/m² to 2,142 W/m² on 149 day cycle (1 AU = 1,371 W/m²)

Initial Thermal concept: Dedicated radiators to primary, secondary and detector, reduced secondary mirror, gold-coating.



# The EUS Instrument

## Concept & Initial Design Strategy

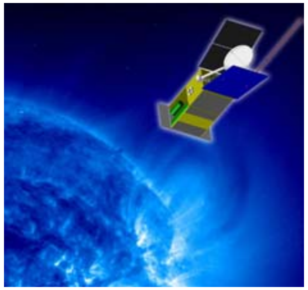
- ➢ Two design concepts now under discussion

- Off-axis NI telescope with VLS grating (Martin Caldwell)

- Wolter II GI telescope with VLS grating (Luca Poletto)

- ➢ We must consider the merits of both options equally

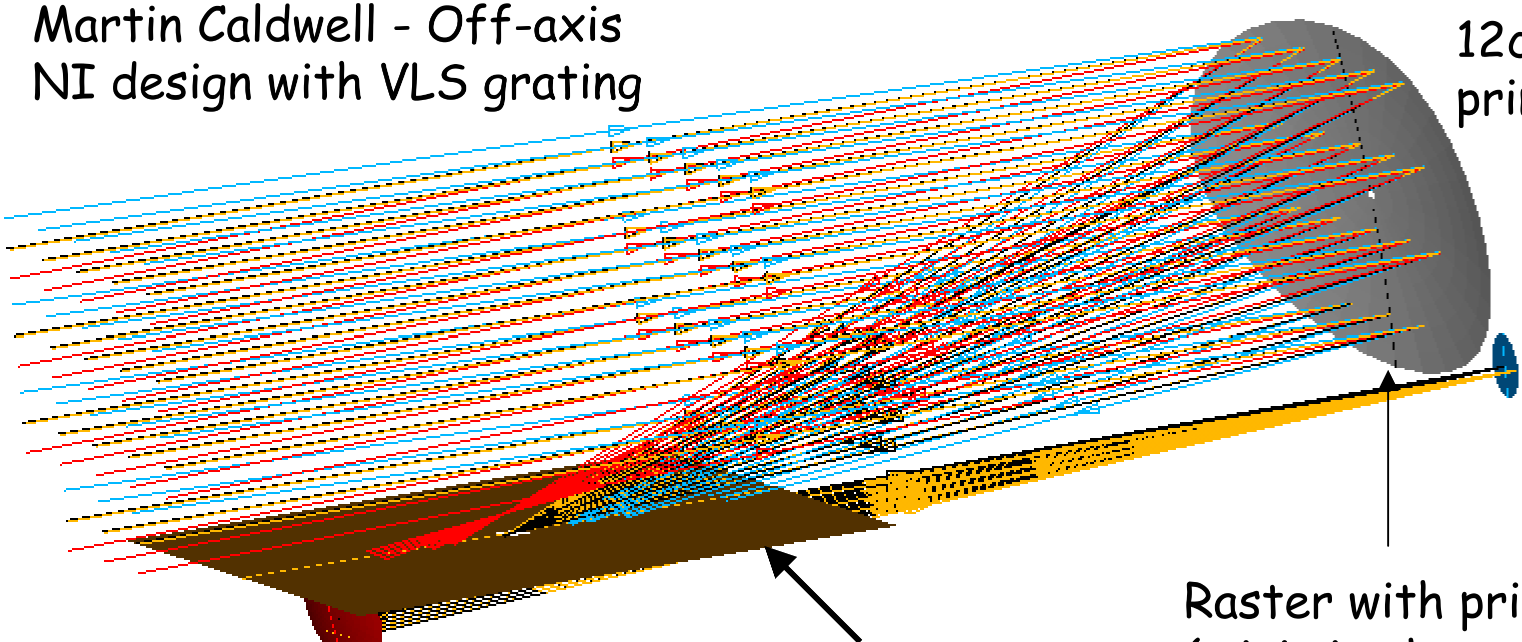
- ➢ We must keep in mind that any one option may not cater for the requirements - are there any hybrid options?

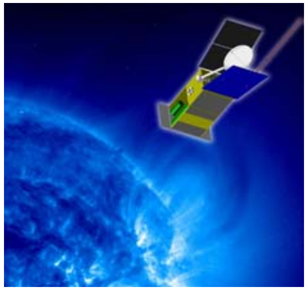


# The EUS Instrument

## Concept & Initial Design Strategy

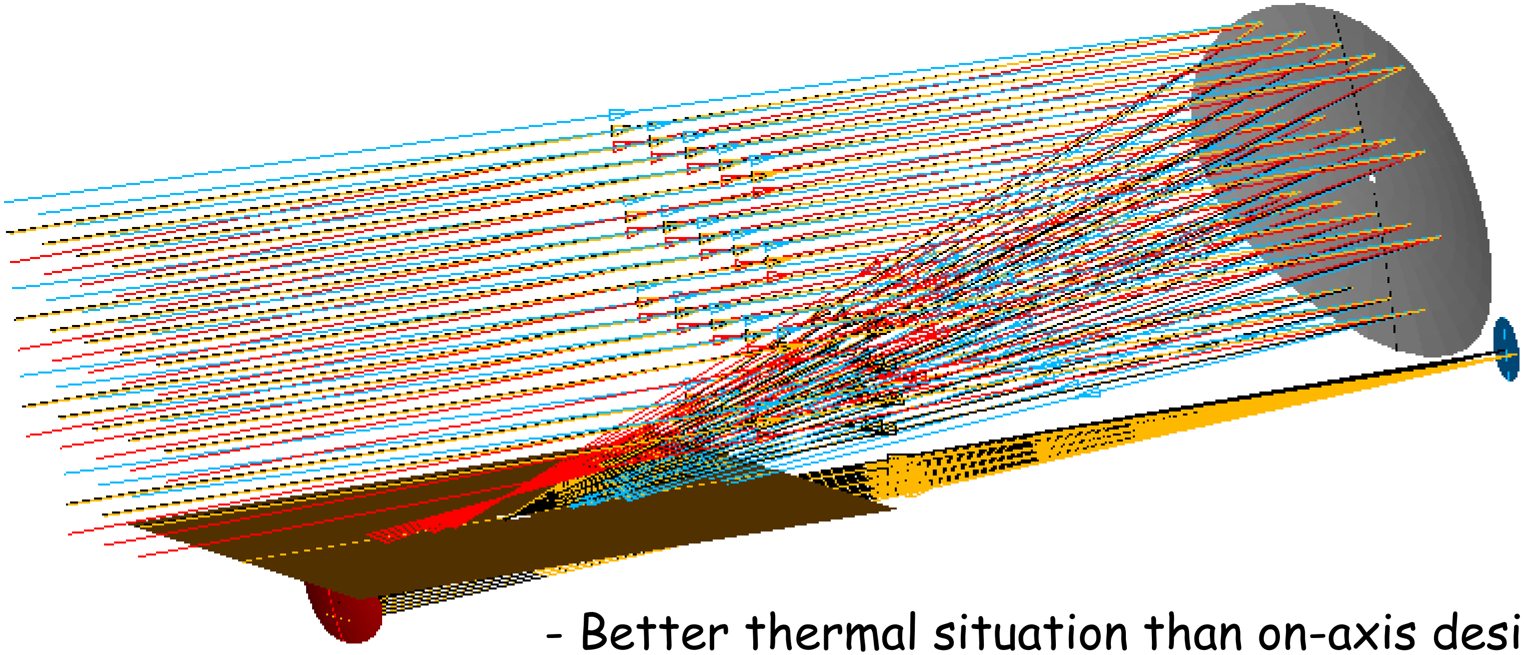
Martin Caldwell - Off-axis
NI design with VLS grating





# The EUS Instrument

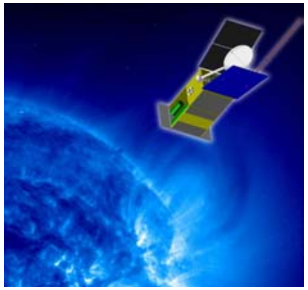
## Concept & Initial Design Strategy



- Better thermal situation than on-axis design - but feasibility not yet demonstrated!

- With 5 micron pixels = 1.4m length ⇒ OK

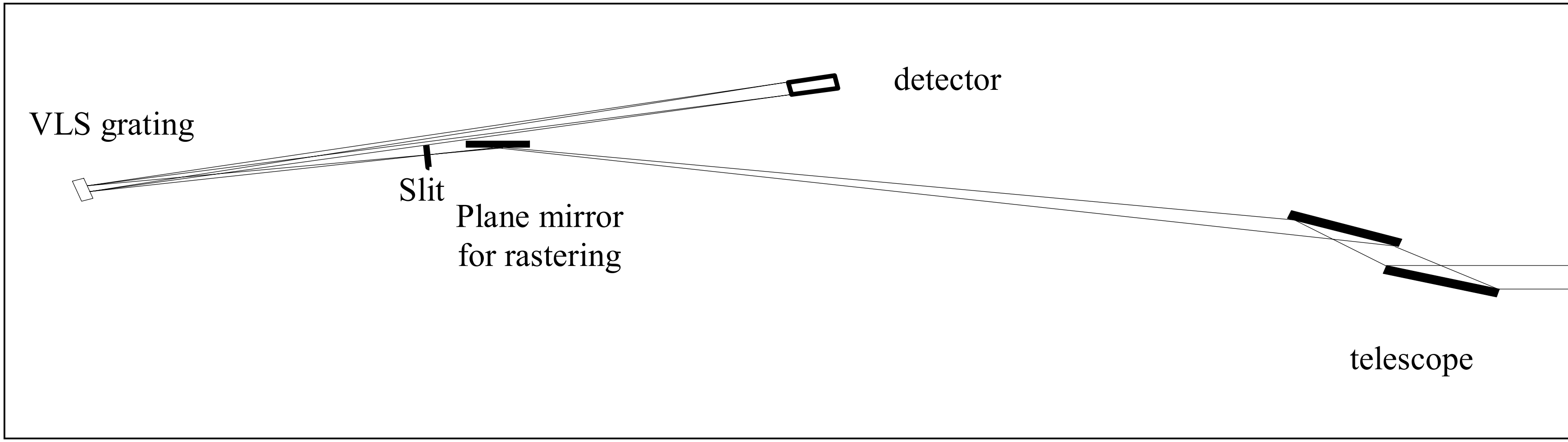
- Problem: Achieves 0.5" on-axis. Aberrations such that performance off-axis considerably worse than pixel size ⇒ can we optimise design?



# The EUS Instrument

## Concept & Initial Design Strategy

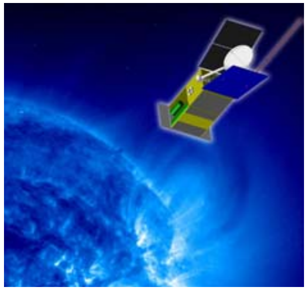
Luca Poletto - Wolter II GI design with NI VLS grating



# Configuration C: grazing-incidence telescope and normal-incidence VLS-grating spectrometer (2/3)

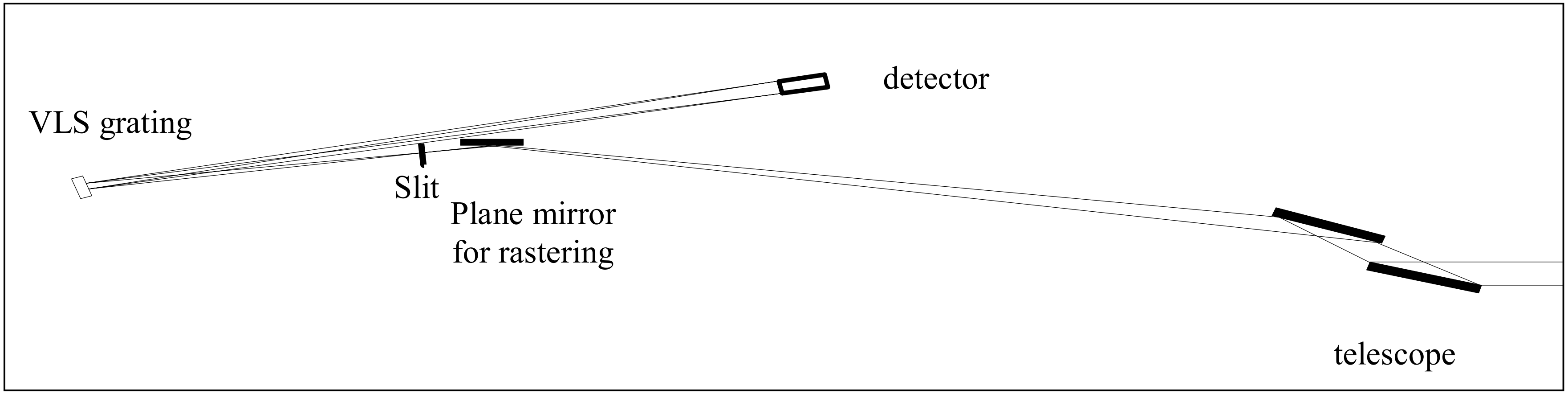
| | |
|---|---|
| **Telescope** | Wolter II |
| *Field of view* | 34 arcmin (\|\| to the slit, simultaneous)<br>20 arcmin (⊥ to the slit, acquired by rastering) |
| *Entrance aperture* | |
| Size | 55 mm × 55 mm |
| *Primary mirror* | Paraboloid |
| Size | 200 mm × 55 mm |
| Incidence angle | 74° |
| *Secondary mirror* | Hyperboloid |
| Distance from the primary | 200 mm |
| Distance from the slit | 1550 mm |
| Size | 190 mm × 40 mm |
| Incidence angle | 78° |
| *Focal length* | 2310 mm |
| **Mirror for the rastering** | Plane |
| Distance from the slit | 100 mm |
| Size | 110 mm × 24 mm |
| Incidence angle | 82° |

| | |
|---|---|
| **Slit** | |
| Size | 10 μm × 23 mm |
| Resolution ⊥ to the slit | 0.9 arcsec |
| **Grating** | Spherical VLS |
| Central groove density | 2400 lines/mm |
| Wavelength | 1160-1260 Å (I order)<br>580-630 Å (II order) |
| Entrance arm | 600 mm |
| Exit arm | 1200 mm |
| Incidence angle | 10° |
| Radius | 790 mm |
| Size | 15 (⊥ to the grooves) × 45 mm |
| Coating | SiC |
| **Detector** | |
| Pixel size | 18 μm |
| Format | 1600 × 2600 pixel |
| Area | 29 (⊥ to the slit) × 47 mm |
| Spectral resolving element | 62 mÅ (I order)<br>31 mÅ (II order) |
| Spatial resolving element | 0.8 arcsec |



# The EUS Instrument

## Concept & Initial Design Strategy

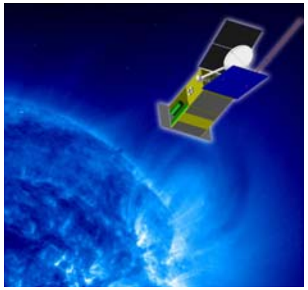



- Good thermal capability - much better than NI option.

- So far, optimised to 18 micron pixel (0.8arcsec). Can it be optimsed to 5 micron?

- Overall length = 2.5 m. Too long? Reduced pixel size would help?

- Off-axis aberrations still too great - need optimising.

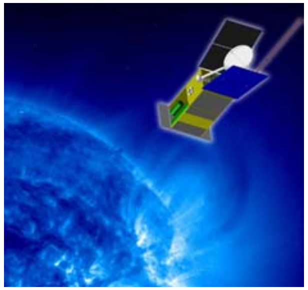


# The EUS Instrument

## Concept & Initial Design Strategy

Key Issues:

- Is 0.5 arcsec critical? TRACE does it now!
- Can the designs cope with the thermal load - especially NI??
- How does each design cope with the thermal variability?
- Will degradation and contamination of optical surfaces, especially in NI, be a critical issue in deciding between NI and GI?
- Is the image stabilisation demand too great for a 0.5 arcsec pixel?
- What about flux?



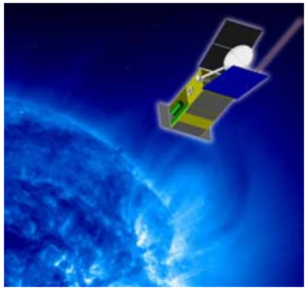
# The EUS Instrument

## Concept & Initial Design Strategy

Flux:

| | CDS/SOHO | S.O./NI | S.O./GI |
|---|---|---|---|
| Area ($mm^2$) | 3,430 | 11,300 | 3,025 |
| Efficiencies: | | | |
| - Telescope | 0.25 | 0.04 | 0.25 |
| - Scan Mirror | 0.80 | - | 0.80 |
| - Grating | 0.02 | 0.02 | 0.02 |
| - Detector | 0.13 | 0.40 | 0.40 |
| Filter | 1.00 | 0.20 | 0.20 |
| Eff. Product | $5.2 \times 10^{-4}$ | $6.4 \times 10^{-5}$ | $3.2 \times 10^{-4}$ |
| Eff. Area ($mm^2$) | 1.78 | 0.72 | 0.97 |
| Pixel Size | 2"x1.68" | 0.5"x0.5" | 0.5"x0.5" |
| Pixel Ratio | 1 | 0.074 | 0.074 |

Note 1: CDS area is per grating for NIS. Total CDS effective area consistent with Lang et al. (2002, ISSI Intercal. Workshop)



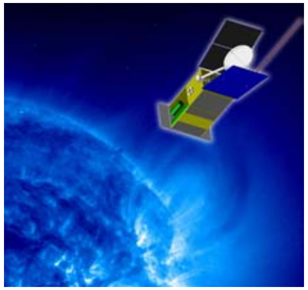
# The EUS Instrument

## Concept & Initial Design Strategy

Flux:

| | CDS/SOHO | S.O./NI | S.O./GI |
|---|---|---|---|
| Area ($mm^2$) | 3,430 | 11,300 | 3,025 |
| Efficiencies: | | | |
| - Telescope | 0.25 | 0.04 | 0.25 |
| - Scan Mirror | 0.80 | - | 0.80 |
| - Grating | 0.02 | 0.02 | 0.02 |
| - Detector | 0.13 | 0.40 | 0.40 |
| Filter | 1.00 | 0.20 | 0.20 |
| Eff. Product | $5.2 \times 10^{-4}$ | $6.4 \times 10^{-5}$ | $3.2 \times 10^{-4}$ |
| Eff. Area ($mm^2$) | 1.78 | 0.72 | 0.97 |
| Pixel Size | 2"x1.68" | 0.5"x0.5" | 0.5"x0.5" |
| Pixel Ratio | 1 | 0.074 | 0.074 |

Note 2: S.O./NI aperture circular 12 cm diam. Assume NO multilayer and assume filter, for both S.O. options. Real difference is in telescope, scan mirror & area. ASSUMES SAME DETECTOR FOR BOTH S.O. OPTIONS.



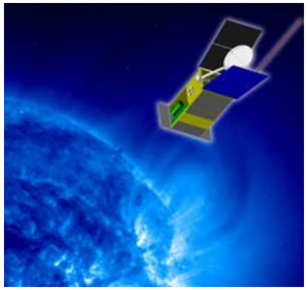
# The EUS Instrument

## Concept & Initial Design Strategy

Flux:

| | CDS/SOHO | S.O./NI | S.O./GI |
|---|---|---|---|
| Area ($mm^2$) | 3,430 | 11,300 | 3,025 |
| Efficiencies: | | | |
| - Telescope | 0.25 | 0.04 | 0.25 |
| - Scan Mirror | 0.80 | - | 0.80 |
| - Grating | 0.02 | 0.02 | 0.02 |
| - Detector | 0.13 | 0.40 | 0.40 |
| Filter | 1.00 | 0.20 | 0.20 |
| Eff. Product | $5.2 \times 10^{-4}$ | $6.4 \times 10^{-5}$ | $3.2 \times 10^{-4}$ |
| Eff. Area ($mm^2$) | 1.78 | 0.72 | 0.97 |
| Pixel Size | 2"x1.68" | 0.5"x0.5" | 0.5"x0.5" |
| Pixel Ratio | 1 | 0.074 | 0.074 |

Note 3: MCP burn-in in CDS shows selective sensitivity drop to, say, 40-50% in line cores. Effective area = $2.6 \times 10^{-4}$?



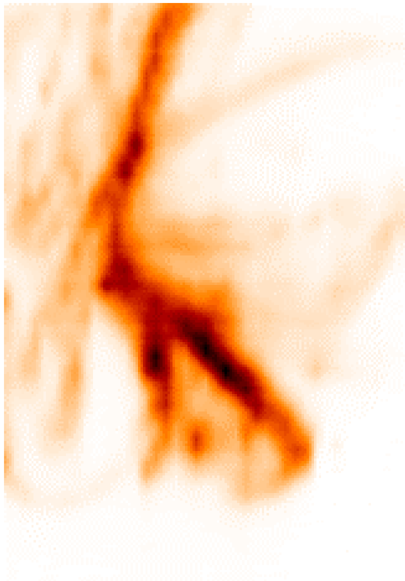
# The EUS Instrument

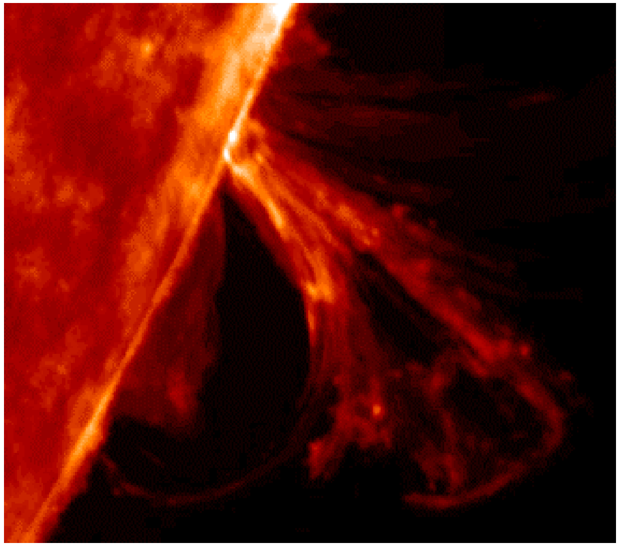
## Concept & Initial Design Strategy

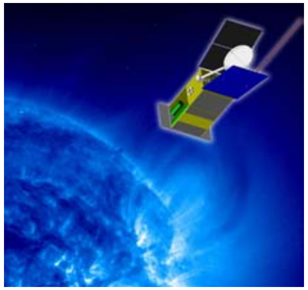
• Relative effective areas CDS = 1.0, SO/NI = 0.4, SO/GI = 0.54

• S.O. figures could improve given an appropriate application of multilayers, more refined figures for detectors etc… Perhaps the removal of the filter?

• There are 13.5 S.O. pixels per CDS pixel. Can we cope with this? Could we live with a CDS with reduced intensities representative of this level? The intensities will NOT be evenly distributed so we are NOT talking of reducing exposure times by factor 13.5! See TRACE/CDS comparison.







# The EUS Instrument

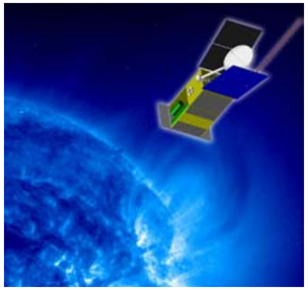
## Environment

1. Thermal Loads

149 day cycle = 2,142 to 34,275 W/m$^2$ (0.8 to 0.2 AU).

Need to address thermal balance for high load values and for variation of thermal input.

We must validate the designs through extensive modelling. Can we define test activities and facilities which could be used for such testing? What about optical degradation?



# The EUS Instrument

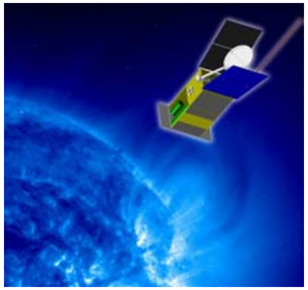
## Environment

2. Particle Environment at 0.2 AU

Cosmic Rays:- Non-solar cosmic rays about the same as for SOHO, or less.

Solar Wind:- Projecting naively from 1 AU values (~10 p/m$^3$) we might expect 250 p/m$^3$ in 'normal' conditions at 0.2 AU, with v ~ 400 km/s. Thus, we expect $10^6$ hits/cm$^2$.s (25x SOHO flux). Is this a worry? Perhaps not so much if the detectors are 'buried' (don't view space directly) and if the protons are low enough energy (will be plenty of 100 keV protons, for example). (Note: $10^9$ direct proton hits 'will kill a CCD' - not so an APS…)

Neutrons:- We might expect to see some. 15 min half life means that we may expect them - possibly only from flares but more often than for 1 AU. Concern over their cross section at the silicon lattice relative to protons. Needs investigation.



# The EUS Instrument

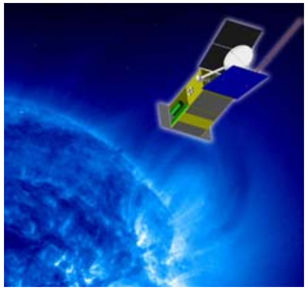
## Environment

2. Particle Environment at 0.2 AU (continued…)

Flares and shock (CME) particles:- Dose difficult to predict. Could argue that the chance of being hit by a flare proton(/neutron) 'beam' is the same as for, e.g. SOHO. What about from larger shocks? Would suggest that there is a greater chance of seeing energetic particles, but hard to calculate.

Note: Hadrons can cause damage to the silicon lattice which causes traps that can 'steal' charge which can be transferred to other parts of the image. The APS minimises the problem by not transferring charge.

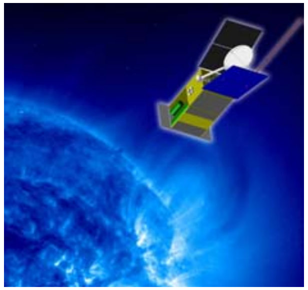
Note: What about particle effects on optical surfaces? See CDS proton-gold coating study (subsurface bubbling).



# The EUS Instrument

## Detectors

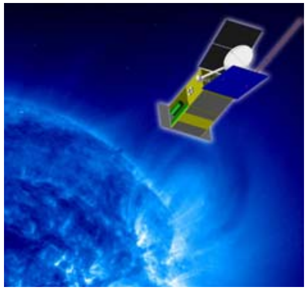
| | |
|---|---|
| Array Size | Ideal: 4kx4k<br>Restricting: 4kx2k<br>Limit: 2kx2k<br>Note: Spatial direction (along slit) 34 arcmin at 0.5 arcsec pixel; Spectral direction 0.01-0.02 Å/pixel over about 50 Å. If FOV reduced, we lose ability to view full Sun at aphelion or complete active region at perihelion. If wavelength band reduced to less than a ~40 Å, we would have problems obtaining temperature range required. |
| Number of detectors | Maximum: 3<br>Workable: 2<br>Limit: 1<br>Note: One for each wavelength band. Only one band would be VERY restricting. 2 bands would be OK but the call from the community has been for 3. We could use different orders but 2 detectors appears to be the only workable approach. |
| Minimum Exposure times | Ideal: 0.1 s<br>Target: 1s<br>Unacceptable: >1 s<br>Note: Should be selectable in range between minimum and maximum (see below). |
| Maximum Exposure times | Ideal: 100 s |



# The EUS Instrument

# Detectors

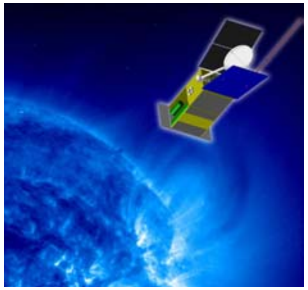
| | |
|---|---|
| Wavelength of Operation | Ideal: Sensitive to range 170-1200 Å<br>Workable: Sensitive to range 170-650 Å<br>Limit of acceptability: Sensitive to either 170-220 or 580-630 Å bands.<br>Note: EUV Prime Bands are: 170-220 Å, 580-630 Å, and above 912 Å. |
| Dynamic Range | Ideal: 0 to 4096 counts (14 useful bits)<br>Limit: 0 to 2048 counts (as long as we can cope with any saturation with some events)<br>Note: This includes quiet Sun to flares. For the former, we may expect counts of tens per pixel per exposure, for the latter, counts of hundreds to even thousands per exposure. |
| Read out time | Ideal: 1 s<br>Workable Limit: 2 s<br>Note: Images are made by rastering. For a 10 location raster of exposure 1 s and read out 1 s, we have total cadence of 20 s. The Sun is highly dynamic; the cadence must be as low as possible. |
| Pixel Size | Ideal: 5 micron<br>Workable/limit: 9 micron<br>Note: Smaller pixel size reduces size of the instrument. The 9 micron pixel option produced a 2.3m long instrument – probably too large. |



# The EUS Instrument

# Detectors

| | |
|---|---|
| Thermal Environment | Variable (150 day) solar 'constant' in range 2000 to 34000 $W/m^2$ on front of instrument with thermal control maintaining detector temperature (cold finger to radiator, local heaters etc…). |
| Particle Environment | <u>Solar Background Protons:</u> Factor of 25 increase in background protons (9 $cm^{-3}$ at average of 300 km/s and $4x10^4$K (3.5 eV)) at 1 AU gives 225 $cm^{-3}$ at 0.2 AU.<br><u>Solar Events:</u> Increased chance of 'storms' from solar events due to vicinity, with increased dose (25 times) – anticipate storms with thousands of hits per $cm^{-2}$.<br><u>Solar Neutrons:</u> Neutron half life of 15.5 min means that only flare neutrons seen at 1 AU. Neutron flux is anticipated to be of order a few 100 $cm^{-3}$ at 0.2 AU.<br><u>Cosmic Rays:</u> Anticipate up to 30 particle hits of about 1 GeV protons/$cm^2$s (same as at L1). |
| Mass | Baseline: 2.5 kg<br>Workable: 3.5 kg<br>Note: 2.5 kg was estimated for detector head plus electronics in original proposal. Mass is severely restricted for Orbiter. |



# The EUS Instrument

## The consortium

Rutherford Appleton Laboratory, UK

Mullard Space Science Laboratory, UK

Birmingham University, UK

Max Planck, Lindau, Germany

Padua University, Italy

Goddard Space Flight Center, USA

Oslo University, Norway

IAS, Orsay, France

NRL, Washington, USA