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# Automatic Exposure Control (AEC) for EIS

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## CHANGE RECORD

| ISSUE | DATE | PAGES CHANGED | COMMENTS |
|---|---|---|---|
| 01 | November 2001 | All new | First release |
| 02 | 04/6/2003 | Various<br><br>4<br><br>6 | Various clarifications in response to issues raised since the last release<br>Modified AEC exposure time table such that times are in units of 10 ms [1]<br>Added implementation detail section |

## Applicable references:

These references appear in [] brackets in this document.
1 – EIS Science requirements: MSSL/SLB-EIS/SP007.07
2 – MDP ICU interface document: NAO/SLB-EIS/SP/MDP3.4
3 - EIS Telecommanding Structure: MSSL/SLB-EIS/SP016.03
4 - EIS sequence structure overview: MSSL/SLB-EIS/TN014.03

## 1.0 - Scientific Justifications:

Different solar phenomena display a wide spectrum of intensity ranges. In order to achieve the maximum performance from EIS, both under and over-exposures should be dynamically tracked.

Previous observations have shown that most solar features requires a high cadence, while retaining count rate statistics for line diagnostic information, e.g. Doppler velocities. For example, when using the highest cadence observations from TRACE, a few seconds cadence showed very significant dynamic activity.

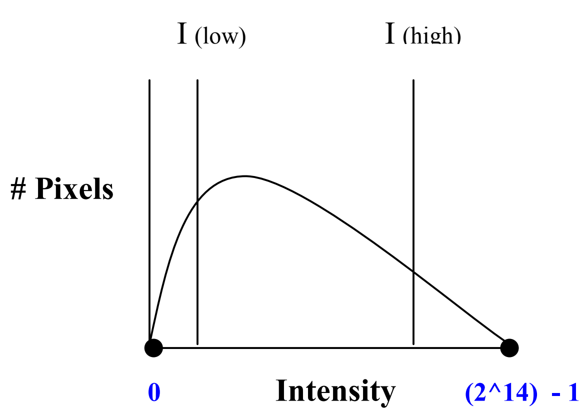
From a solar flare science point of view, the pre-flare phase is currently probably the most interesting. Nevertheless, it is desirable to have a more comprehensive view of flares with useful observations in all evolving phases. Depending on line selection and size of the flare, pre-flare count rates can be an order of magnitude lower than the peak count rate (cf. George Doschek's observing flares document). To get the best combination of statistics and time cadence requires automatic adjustment of the exposure time with changing intensities.

The AEC will not only be useful for flare observations, but also to obtain the best performance when observing highly dynamic active region loops.

## 2.0 - Functionality and implementation:

AEC is not proposed to be the default mode of operation for EIS and must be specifically requested in the planning tool. It only makes sense to use the automatic exposure controller when in **slot** observations. When rastering using a slit, it is envisaged that continuous exposure time changes will be encountered. For example, bright network emissions, coronal hole boundaries, or a different part of an active region will result in the exposure time changing. Different exposure times at different parts of the field of the view would be undesirable.

The proposed implementation of the AEC would involve adjusting the exposure time based on two intensity thresholds, a low and a high intensity, as illustrated below.



The algorithm would work as follows:

Following each exposure, determine the number of pixels either exceeding the higher intensity threshold (over-exposed), or falling short of the lower threshold (under-exposed). The new exposure time would be adjusted accordingly (see exposure time table in section 2.1). If over-exposed, then the exposure time is reduced. Similarly, if under-exposed, then the exposure time is increased. Of coarse, if not over or under-exposed, then the present exposure time is kept.

In the simplest case, the upper threshold could be the intensity that fills the full well of the CCD. In terms of defining a less stringent condition that would allow greater control over performance, we expect the selected thresholds will evolve through experience of the observations. Based on John Mariska's throughput calculations, 500 counts would provide adequate statistics to measure line widths were we using a narrow slit. Thus it seems likely that an upper limit, i.e. I (high) of 1000 counts would probably be more than adequate as the higher intensity threshold when using a slot.

One of the main science goals of EIS is the measurement of velocities. While we will be sacrificing some spectral resolution by using the 40" slot, we should be able to get some velocity information. A lower intensity threshold, i.e. I(low) of 200 counts is then probably an appropriate limit, again based on John's throughput calculations, at least as a first cut.

In determining the number of pixels that should exceed the threshold in order to trigger changing the exposure time, it seems reasonable to consider the size of a typical network and the pre-flare brightening observed with TRACE by Warren & Marshall (2001). The TRACE brightening is typically 20″x2″ while blinkers observed with CDS are 10-20 CDS pixels in size. The CDS pixel size for these observations is 2.04″x1.68″. Based on the EIS pixel size of 1″ a reasonable number would then be 20-40 pixels. Similarly, from the CDS experience approximately 85% of an active region observed on the limb consists of emission of intensity < 5% of the maximum when observed in coronal lines. For transition region lines this fraction would be higher. Based on this, and given that a lower threshold of 200 counts would probably constitute a somewhat smaller fraction of pixels, a reasonable point to adjust the exposure time upwards might be when 90% of the pixels have intensities < 200 counts.

Note that both the intensity thresholds and the number of pixels exceeding the upper threshold or falling below the lower intensity threshold can be changed by ground command.

## 2.1 – AEC default exposures time setting:

The algorithm that is used for calculating the default exposure time (modified from Solar-B XRT AEC) is as follows:

**Exposure Time =** $\sqrt{\mathbf{2 \wedge (EXPOSURE\ ID - constant)}}$

Where the constant = 9 which determines the minimum exposure time setting, i.e. 50 ms. And the EXPOSURE ID is a variable ranging from 0 to N, which determines the maximum exposure time setting.

| EXPOSURE ID | EXPOSURE TIME (10 MS UNITS) [1] |
|---|---|
| 0* | 5 |
| 1 | 6 |
| 2 | 8 |
| 3 | 12 |
| 4 | 17 |
| 5 | 25 |
| 6 | 35 |
| 7 | 50 |
| 8 | 70 |
| 9 | 100 |
| 10 | 141 |
| 11 | 199 |
| 12 | 282 |
| 13 | 399 |
| 14 | 565 |
| 15 | 799 |
| 16 | 1130 |
| 17 | 1598 |
| 18 | 2259 |
| 19 | 3195 |
| 20 | 4517 |
| 21 | 6388 |
| 22 | 9033 |
| 23 | 12772 |
| 24 | 18060 |
| 25 | 25538 |
| 26 | 36111 |
| 27* | 51061 |

* The minimum and maximum exposure time are 50 ms and 8.5 minutes, respectively.

NB. counts≡photons/s

The change of exposure time is triggered when the over or under-exposed criterion is encountered. For example, if the current exposure time were set to 7.9 seconds (exposure

ID 15), then the change in exposure time would be either exposure ID 16 or 17, depending on the cause of the trigger (over or under exposure).

We propose that the initial default exposure time is set somewhere in the centre of a table which would allow adjustment of the exposure time in either direction (up or down) to deal with the initial under and over-exposures.

**3.0 - Impact on operations:**

Since the AEC is not the default mode of operation, its impact on most operations will be negligible. Therefore, the main impact on operations of using the AEC would be the restriction to use of the slot, although potentially either the 40" or the 250" slot can be used. Thus there would be a loss of spectral information. The other main restriction would be the need to identify a `reference' line to which the intensity thresholds will be applied. However, this reference line can be changed, depending on the study [4].

Depending on line selection there may be a requirement to sum together exposures in the weaker lines on the ground. However, a judicious selection of lines could avoid ever having to make this trade-off.

There is potential to use the AEC as a simple flare response, and this may circumvent the need for an additional internal EIS trigger, or could at least form part of its implementation.

**4.0 – Implementation details:**

In order to perform AEC operations, the following parameters must be set, as part of EIS observation table [2, 3]:

**Bit 0** **Bit 31**

<table>
<tr><td colspan="2">Upper threshold, I (high)</td><td>Lower threshold, I (low)</td></tr>
<tr><td colspan="3">High-energy pixel count limit</td></tr>
<tr><td colspan="3">Low-energy pixel count limit</td></tr>
<tr><td>Exposure ID</td><td>Binning</td><td>AEC maximum run time (seconds)</td></tr>
</table>

Where:

Bit 0 – Bit 15: Upper threshold, **I** (high), range 0 to (2^14 – 1)
Bit 16 – Bit 31: Lower threshold, **I** (low), range 0 to (2^14 – 1)

Bit 0 to 31: High-energy pixel count limit, range 0 to (2^32 – 1). This parameter specifies the high-energy pixel number beyond which the exposure time is reduced (over-exposed condition)

Bit 0 to 31: Low energy pixel count limit, range 0 to (2^32 – 1). This parameter specifies the low-energy pixel number beyond which the exposure time is increased (under-exposed condition).

Bit 0 to 4: Exposure ID, range 0 to 27 that represents the AEC start-up exposure time
Bits 5 to 14: Binning factor (average pixels in the Y-direction), range 1 to 512. It is unlikely that binning is required, however, in the event of "too many" dead pixels or columns near the end of the mission, binning may need to be introduced.
Bit 15 to 31: AEC run time, range 0 to (2^17 –1) in seconds, i.e. **36.4 hours**, maximum. If 0 seconds run-time is specified then the AEC will run until either stopped (the specified number of exposures is completed) or aborted via Manual mode transition. Specifying a non zero run-time will result in the sequence being terminated internally (aborted) when the run time has lapsed or via Manual mode transition, which ever comes first.

In **addition to setting the AEC control parameters**, an AEC reference line **must** be specified in the line list [4]. Failing to do so will result in the raster running at a **fixed exposure time**, as specified by the Exposure ID parameter.