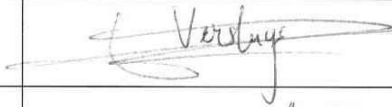
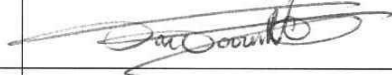



MARS EXPRESS

VISUAL MONITORING CAMERA

**DEBAYERING RAW IMAGES AND
CONVERSION TO RGB IMAGES**

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1 INTRODUCTION

1.1 SCOPE

Colour CCD's (such as those in commercial digital camera's) possess a complicated structure of pixels and colour filters in order to record all necessary luminance and colour information in a single shot. This is a completely different mechanism as normal scientific full colour imaging, in which for each colour a different exposure is made through different colour filters, hereafter called as a true colour image. For a detailed discussion about the advantages and disadvantages of both techniques, one is referred to the widely available literature.

In a true colour image, the colour information is available from the recording mechanism itself, and no complicated image processing tools are needed in order to construct a real colour image.

The situation is somewhat difficult in a colour image with a Bayer grid. In order to get a real colour image, the normally three colour layers (Red Green and Blue) need to be extracted from the image, separately processed and recombined in order to end up with a normal RGB colour image.

This document describes the transformation from the Bayer image to the final RGB colour image.

1.2 ABBREVIATIONS

AD	:	Applicable Document
CCD	:	Charge Coupled Device
EIDP	:	End Item Data Package
ESA	:	European Space Agency
FITS	:	Flexible Image Transport System'
IMEC	:	Interuniversity Micro-Electronics Centre
IP	:	ImagesPlus
IRIS	:	Integrated Radiation-tolerant Imaging System
MEX	:	Mars Express
OIP	:	Optronic Instruments and Products
P/N	:	Part Number
RD	:	Reference Document
RE	:	Report
RGB	:	Red Green Blue
S/N	:	Serial Number
TBC	:	To Be Confirmed
TBD	:	To Be Defined
TIFF	:	Tagged Image File Format
VMC	:	Visual Monitoring Camera

1.3 APPLICABLE DOCUMENTS

N°	TITLE	REFERENCE
[AD1]	End Item Data Package VMC IRIS camera (S/N 05)	RE-VMC-0048-OIP/99; issue 1

1.4 REFERENCE DOCUMENTS

N°	TITLE	REFERENCE
[RD1]	Technical report: Debayering raw images and conversion to RGB images	RE.1947/07
[RD2]	IRIS-1 detector data sheet	P60280-MS-TN-003; issue 1.1
[RD3]	VMC image (provided by Mr T Ormstrong) (26/02/2007)	VMC Img 1 (07-057 03.51.15).bmp
[RD4]	VMC image (provided by Mr T Ormstrong) (21/02/2007)	VMC Img 27 (07-028 21.50.00).png

2 EXPERIMENTAL

In the following discussion two different software packages are shown which are capable in debayering raw images. The results are shown with an image from a commercial digital camera and with a VMC image provided by ESA.

The first software used is ImagesPlus v2.8 (IP). This package is specifically developed to process astronomical images captured with a digital camera. The software is windows based, easy in use, and extremely powerful and versatile in processing astronomical images. It is commercially available from MLUnsold Digital Imaging (<http://www.mlunsold.com/>) and costs about \$180.

The second software used is IRIS. This package is completely free of charge and can be downloaded from <http://www.astrosurf.com/buil/us/iris/iris.htm>. Basically it has nearly the same functionalities as IP, is also windows based, but is not as user friendly as IP.

Also the possibility exists in writing your own software for debayering images for example based on Matlab, but this possibility is not described here.

For this manual two different images are used. The first one is delivered by ESA and is originating from a VMC camera on board of the Mars Express [RD3]. This image is delivered in PNG-format, so probably this is not the real raw data of the camera. It is therefore not guaranteed that the results will be realistically regarding luminosity and colour.

The second image is an image taken with a commercially available digital camera (Canon 20Da) and shows a single frame of an image sequence of the Horse Head Nebula located in the constellation Orion.

3 METHOD

3.1 CONVERSION FROM RAW BAYER TO TIFF BAYER

The first step to process raw files is the conversion of the RAW-format to a format which can be read in every software, for example TIFF or FITS. The problem with raw images is that every manufacturer of digital camera's and CCD's has its own protocol in storing RAW data from the CCD to a RAW file. If this protocol is known, one can convert every file to a more accessible format such as TIFF ('Tagged Image File Format') or even better FITS ('Flexible Image Transport System'), although this last format is only known to astronomical people.



Figure 1: TIFF Bayer images of the Horse Head Nebula (crop of the original image) photographed with a Canon 20Da dSLR and Mars photographed with Mars Express' VMC camera. The enlarged images show clearly the Bayer pattern of the imaging sensor (visible as a grid).

This is a very crucial step in the processing of the image as valuable data can get lost during this conversion. Check the intensity range (histogram) of the image before and after conversion and make sure no change in the histogram can be seen.

After this conversion, the image is easily read with a package such as PhotoShop, PaintShop Pro, The Gimp, etc. The images in Figure 1 show the converted images of the VMC image and the Horse Head Nebula.

Note that these are still grey scale images as no debayer algorithm is already performed. If one enlarges the images, one can easily see the Bayer pattern on the image visible as a matrix (see enlarged part of the image)

3.2 DEBAYERING

In order to extract the colour data from the image, one needs to understand how a Bayer grid on a CCD forms an image. A Bayer grid is a grid of colour filters located on top of the monochrome CCD in such that every pixel sees one of the three basic colours. This grid has a regular returning pattern. The VMC CCD Bayer grid has the same layout as the Canon 20Da image sensor, which is RGGB (see §4). The layout is seen in Figure 2.

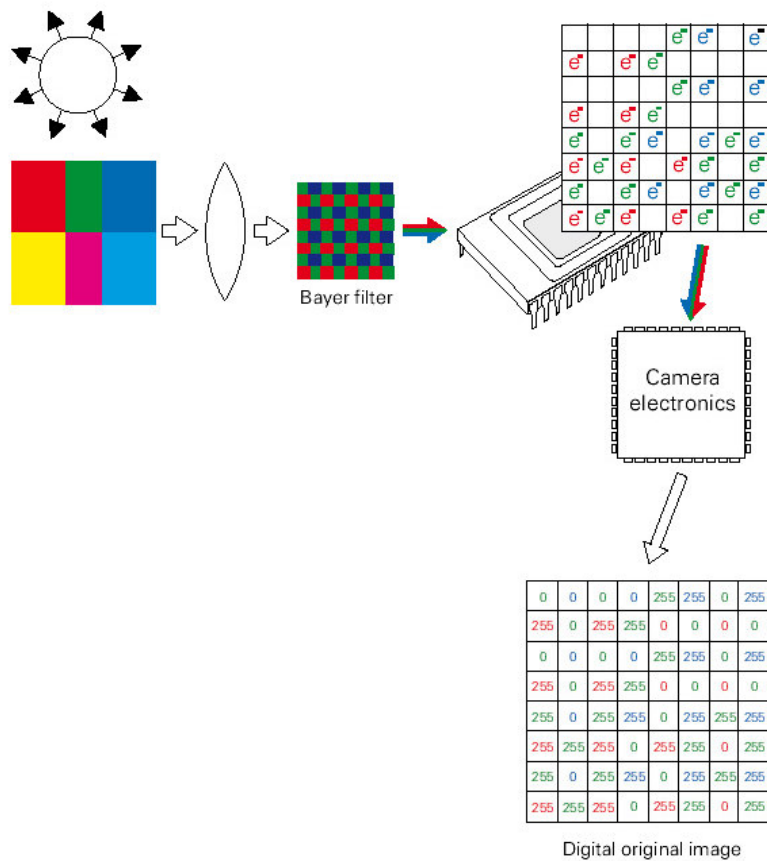


Figure 2: Colour acquisition in a single sensor Bayer camera.

The debayer process generates the different colour layers from the Bayer image by extracting the true colour information available and recalculating the missing colour information by interpolation. The separate colour layers are then recombined to a single RGB colour image. Note the difference with a Bayer image: in a Bayer image every pixel contains colour information of one specific colour, while every pixel in an RGB image contains colour information of every colour.

As the Bayer grid layout is the same in the VMC as in the Canon dSLR D20a, one can use the same debayer scheme for both cameras. To perform this debayer process, one chooses “**File > Image File Operations > Bayer CFA Interpolate/Split Files**” command in IP (see Figure 3). One remark: this command only works with standard image formats such as TIFF, FITS, JPEG,...

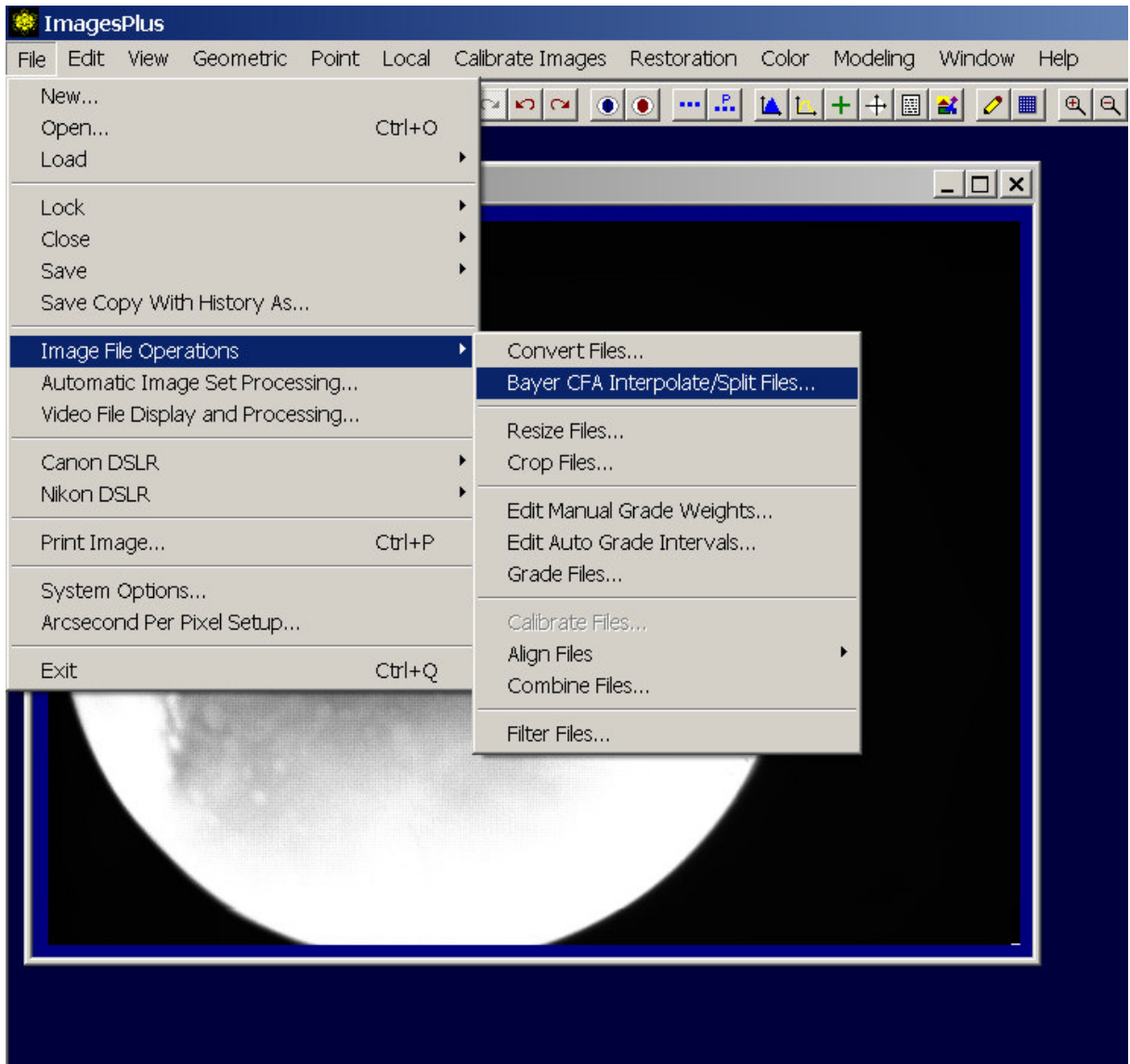


Figure 3: Debayering an image in ImagesPlus, first part.

A dialog appears (see Figure 4) where several choices can be made regarding the input type of the file. As this program is written for commercial digital cameras, only those cameras are available. Luckily for us, they Bayer layout of the Canon dSLR-series is identical to the VMC Bayer layout. The output file type can be chosen as well as the path and the colour space (RGB, Red, Green or Blue). In this case, 16bit TIFF RGB is chosen.

By pressing “**convert**”, the Bayer image is converted into a true RGB image.

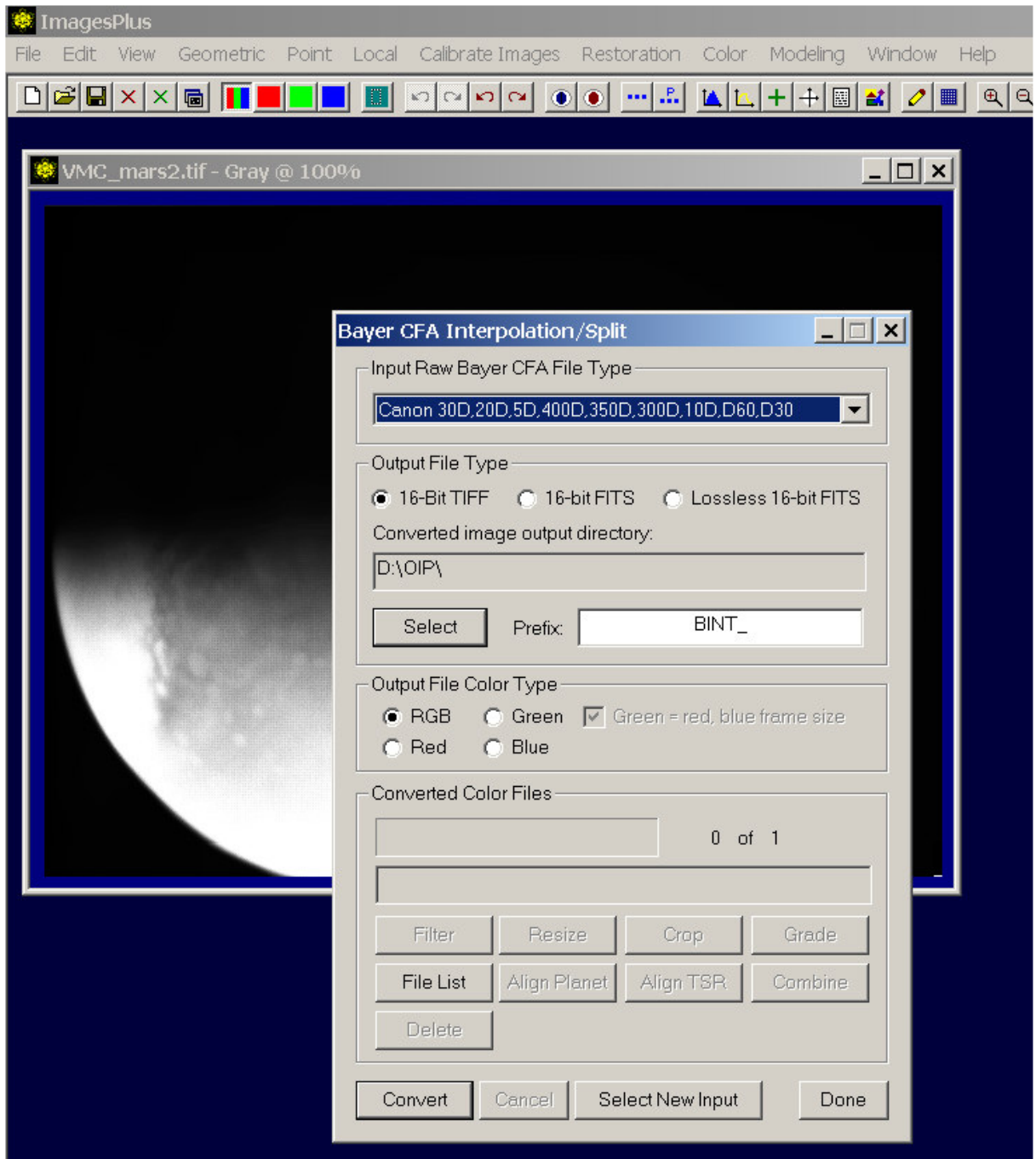


Figure 4: Debayering an image in ImagesPlus, second step.

In IRIS one uses the command "**Digital photo > Convert a CFA image**" (see Figure 5). The image is converted automatically. Afterwards the file needs to be saved.

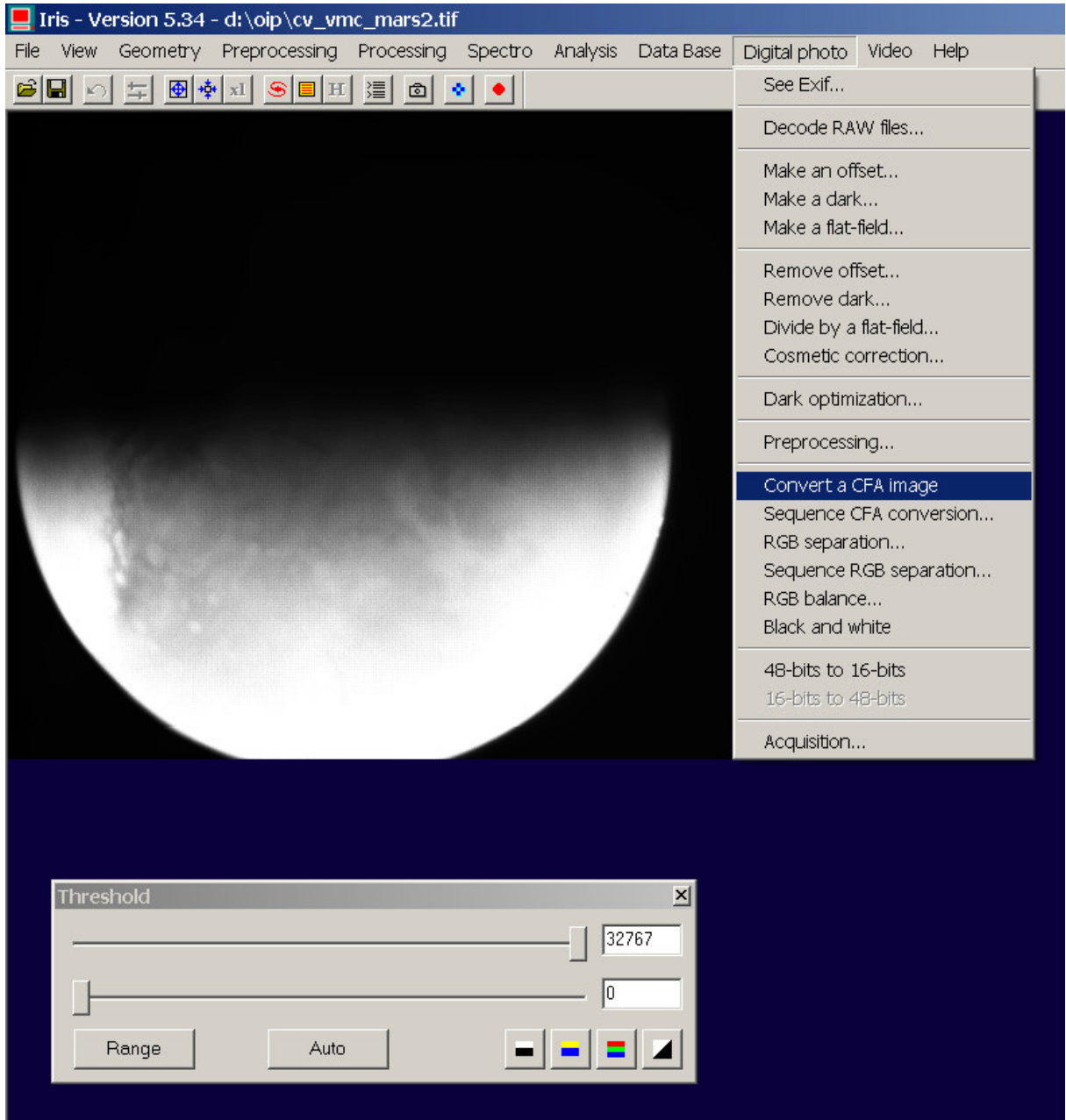


Figure 5: Debayering an image in IRIS.

As a first example, the image of the Horse Head Nebula was transformed into a 16bit TIFF RGB image from the converted 16bit TIFF Bayer image. Additionally, contrast and brightness is adjusted in order to balance the intensities in the image. In IP this is performed by Digital Darkroom Processing (which contains additional image enhancement algorithms), in IRIS only brightness and contrast is adjusted. The results are shown in Figure 6.

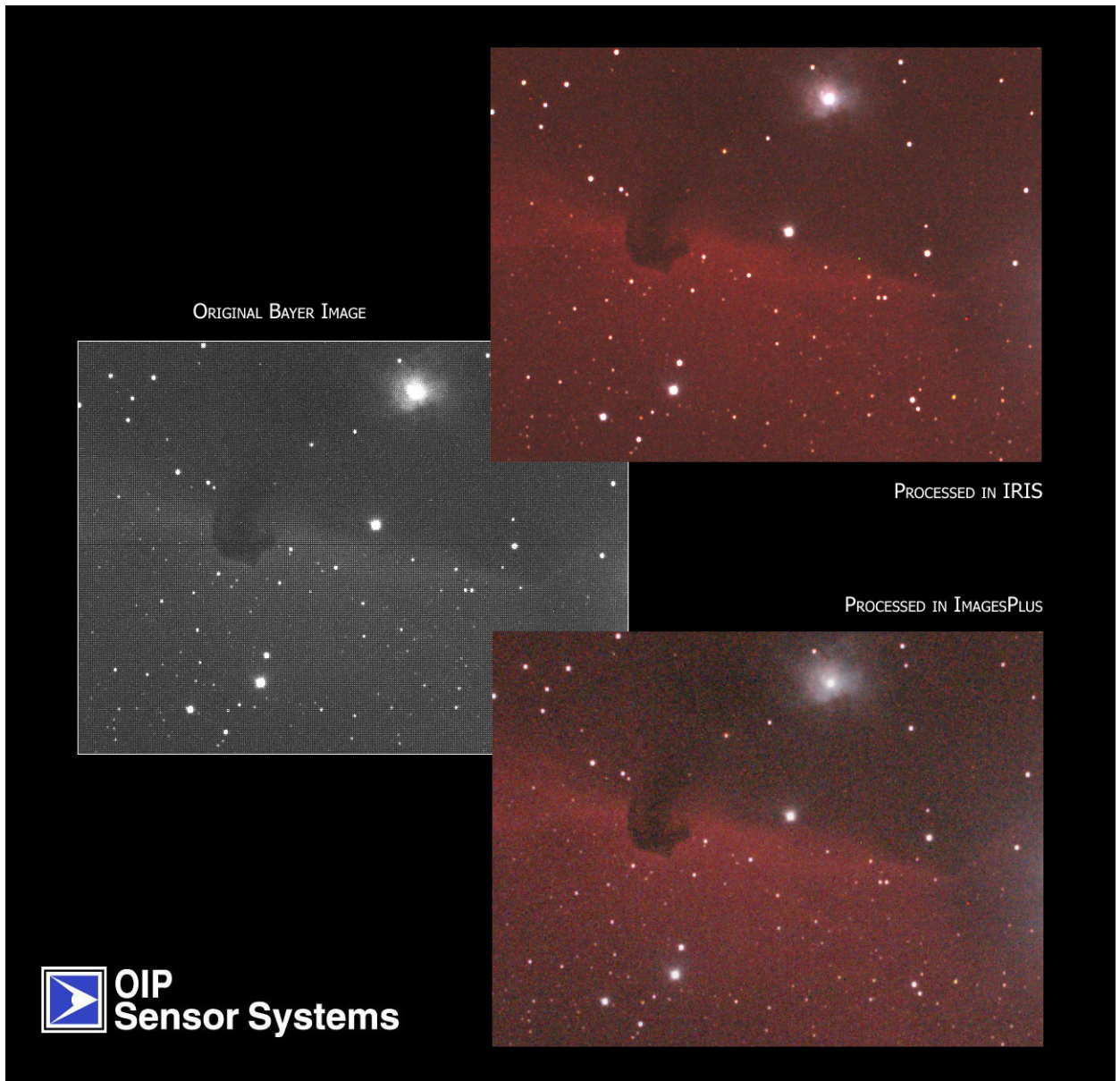


Figure 6: Overview of the debayer algorithm in IRIS and ImagesPlus. Left the original 16bit Bayer TIFF is shown, up right the resulting 16bit TIFF RGB image from IRIS, down right the resulting 16bit TIFF RGB image from ImagesPlus. Some difference in intensity and saturation can be seen in both images, but basically both images contain the same colour information.

As a second example, the VMC Mars image is transformed into a 16bit TIFF RGB image from the original VMC 16bit TIFF Bayer image¹ with both software packages. No additional processing is performed. The results can be seen in Figure 7.

¹ This was originally a PNG image format, which was converted to a 16bit TIFF RGB file in PhotoShop.

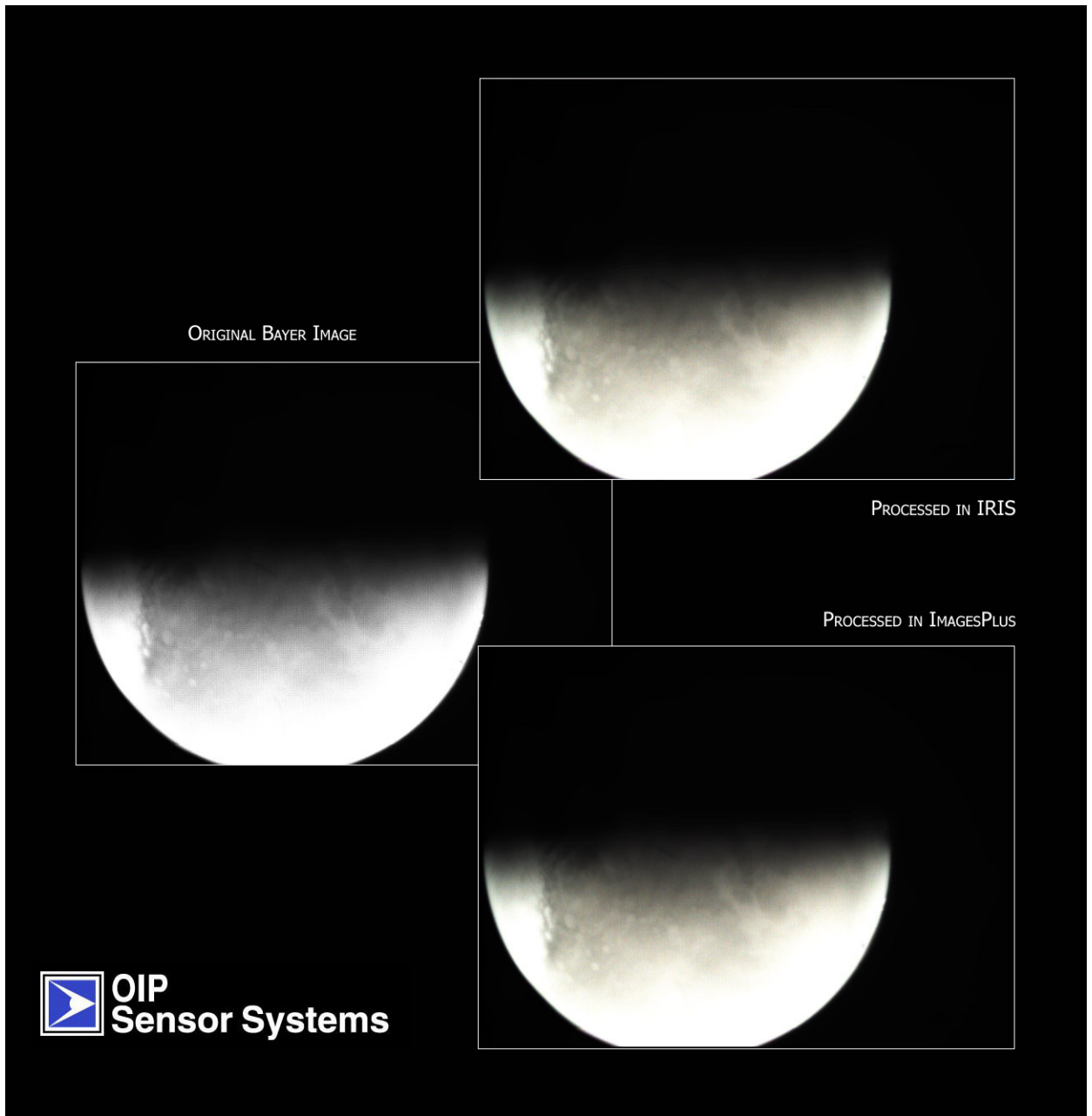


Figure 7: Overview of the debayer algorithm in IRIS and ImagesPlus. Left the original 16-bit Bayer TIFF is shown, up right the resulting 16-bit TIFF RGB image from IRIS, down right the resulting 16-bit TIFF RGB image from ImagesPlus. Not much difference can be seen.

3.3 ADDITIONAL PROCESSING

It is noticed that the colour in the VMC Mars image is not that obvious and very subtle in appearance. Several explanations are possible. For example, during the conversion from the raw image to the PNG image we received, some image information was somehow lost, with a loss of colour as a result. It is also possible that the illumination (read: exposure time) was not perfect with a loss of colour information as a direct result.

In order to show some more colours in the image, the Hue and Saturation settings were adjusted in PhotoShop. The result can be seen in Figure 8. Of course, one has to be very careful in scientifically interpreting such a result.



Figure 8: Colour enhanced image, debayering and Digital Darkroom Processing in ImagesPlus, additional colour enhancement in PhotoShop.

4 ANNEX – IRIS1 COLOUR IMAGE SENSOR BAYER PATTERN

The following information is extracted from [RD2].

The IRIS-1c colour image sensor features on-chip deposited red-green-blue (RGB) colour filters in the Bayer-pattern. From the top-left corner of a full image the colours are configured as follows:

R	G	R	G	...
G	B	G	B	...
R	G			
G	B			
...	...			

The reconstruction of colour images at full resolution is not included; this operation is to be done off-line on retrieved raw images.