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PLATO Payload, Big Data PUS Packets Classifier and Astronomical Digital Imagette Data Decompression

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ABSTRACT

The PLAnetary Transits and Oscillations of stars *(PLATO)* is a space telescope under *ESA* development. The *(PLATO's)* Instrument Control Unit *(ICU)* is an electronics box that is responsible for the management *(MGT)* of the payload *(P/L)*, the communication with the Service Module *(SVM)*, and the compression of scientific data before transmitting them as telemetries *TMs* to the *SVM.* The *ICU* receives data from 2 "fast" *(F-DPU)* each 2.5s and 24 normal Data Processing Units *(N-DPU) each 25s.* In order to reduce the huge data volume produced on-board by the 104 *CCD* (4 *CCD* per camera), for each target star it will be allocated a window, from which all the pixel values will be gathered, forming a small image called "imagette". These cropped images are compressed by means of a lossless algorithm running in the *ICU FPGA* and transmitted as Packet Utilization Standard *(PUS)* packets to *SVM.* These streamlined transmissions require qualified compression and decompression techniques to preserve images.
In this poster we propose a scripting tool that classifies and collects automatically telemetry *PUS* packets, hosting scientific data and metadata, to reconstruct compressed imagettes on-ground.

Keywords: *PLATO Payload, classifier, PUS packets, telemetry, imagette, decompression.*

1. INTRODUCTION

1.1 The Planetary Transits and Oscillations of stars (PLATO)

With the selection and adoption of *PLATO* by *ESA*, exoplanets scientists are now looking forward to a data-rich decade with more data precision. Understanding planets characteristics and habitability is a true multidisciplinary endeavour. It requires knowledge of the planetary composition, to distinguish terrestrial planets from non-habitable gaseous mini-Neptunes, and of the atmospheric properties of planets. With this the necessity in astronomy to improve the actual space telescopes focuses on exoplanet space missions. *PLATO* is planned to be launched in 2026. Its objective is to find and study a large number of extra-solar planetary systems, with emphasis on the properties of terrestrial planets in the habitable zone around solar-like stars. (See figure 1). It has also been designed to investigate seismic activity in stars, enabling the precise characterisation of the planet host star, including its age.[1]

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Figure 1. *Credit: ESA - Artist's impression of PLATO.*

1.2 The PLATO on-board Data Treatment

To search exoplanets, during its mission *PLATO* will be rotated around the mean line of sight by 90° every 3 months, the cameras field-of-view will be rotated and a temporary suspension of the mission will be necessary to reconfigure the *SW*. It will resulting in a continuous survey of exactly the same region of the sky. At the beginning of each pointing full images will be transferred to ground. To reduce the high data volume produced on-board from the 104 *CCDs* (4 *CCDs* per camera) during operation, each assigned target star will be allocated a *CCD* window around it from which all the pixel values will be gathered, forming a small image called "imagette". The imagettes will be sent as compressed raw data to ground or processed onboard to get centroids and light curves to further reduce data volume.[1–3] In configuration mode, some of the *PLATO's ICU (P/L MGT)* main functions are to collect the star catalogues and all other *DPU* configuration parameters, to stack and compress full-frame imagettes sent by the *DPUs*, then to transmits them to the *SVM* for down-link. The on-ground expected data volume during *PLATO's* mission including compression will be about 435 *Gb per day*, resulting in a huge data to be managed. In this paper, an on-ground solution for imagettes reconstruction is presented, consisting on the imagette *TM* packets classification, collection and decompression of the whole image data.

2. OBJECTIVES

In this research, our main goal was to develop a script tool that was able to automatically classify and collect *TM PUS* packets, hosting scientific data and metadata, before reconstructing compressed imagettes on-ground. In particular, we confirmed that this tool is able to extract (merging the content of different packets) compressed data generated by the *ICU* Application SW (*ASW*), containing: saturated imagettes, short/long cadence light curves, short cadence light curves with centre of brightness, *N*- and *F-CAM* images/imagettes, etc.

The second purpose was to research on-ground reconstruction of compressed imagettes and start planning future researches about how to manage the huge quantity of data generated during *PLATO*'s mission as described in paragraph 1.2. The management process is related to massive image/imagette data interpretation, preservation and curation.

3. METHODOLOGY

3.1 On-Board Lossless Hardware Data Compressor

The *ICU* receives the science data over its SpaceWire *(SpW)* router located on the internal Router and Data Compression Unit *(RDCU)*. The data handling is done on the processor and mass memory unit *(CPU/MMU)*, which is the main data processing module of the *ICU*. To reduce the size of imagettes and full *CCD* images acquired by the 24 normal and 2 fast cameras, the *CPU/MMU* is supported by the *HW* data compressor. It is located on the *RDCU* board and connected to the *SpW* router. The *HW* data compressor helps the *CPU/MMU* board in compressing the massive amount of imagette data, which makes roughly 90 % of the total science data.

Each *ICU* Router Unit *(RDCU-A and RDCU-B)* is connected to the *DPS* sub-units through eight *SpW* links: 2 for *MEU*, 2 for *FEU/F-DPU*, 2 for *N-AEU* and another 2 for *F-AEU*.[3–5]

3.2 On-Board Lossless Software Imagette Data Compressor

The remaining science data not processed by *HW* data compressor are compressed in *SW* on the *CPU/MMU* board. In order to reduce the size of the encoded *TM* data packet, data are compressed using the, FPGA based, *RDCU*. To set up compression, the *ICU* software *(SW)* sends the data to be compressed to the *RDCU*. In the next step, the *ICU SW* sets the compression parameters for the compression (such as compression mode, number of samples, etc.). Then the *RDCU* compresses all the data. After compression, the *ICU* reads out the compression information, i.e. how long the compressed data is in bits and which parameters were used for compression (more or less a copy of the setup parameters). With this information, the *ICU* can download the compressed image data packet from the *RDCU*, less in size than the original image.[5,6]

3.3 On-Ground Telemetry PUS Packets Classifier

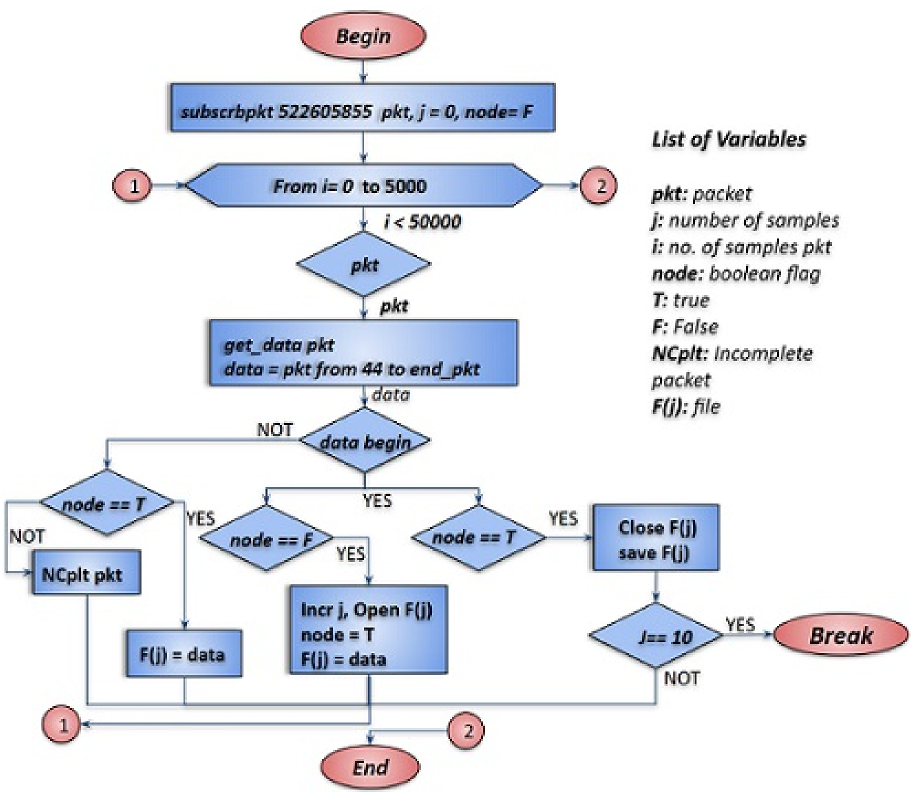

Figure 2. *Telemetry pus packets classifier flowchart.*

The communication between *PLATO* Spacecraft *(S/C)* Interface Simulator *(SIS)* and the Data interface set-up in the ground workstation is done by *PUS-C TM/TC* telecommands packets. These are a series of services tailored to manage the *ICU*. The image data arrives to the Data Interface as *TM* packets. A *TM* consist of a *primary header*, a *secondary header* and *application data*. The *application data* field has a maximum allowed total packet length of 65542 bytes without *CRC*. Due to this limited memory size, imagette obtained by on-board cameras need more than one packet to be transmitted. Each imagette is transmitted using several *TM* packets. The scripting tool "classifier" (fig. 2) separates these packets obtaining the original imagette at a specific time identifying the first and last *TM* packet *(pkt)* and collecting data cargoes. Our script detects when an image transmission is incomplete *(NCplt)* and, in case, it discards all the related image acquired packets and waits for the next image. The *primary and secondary headers* are removed from *TMs* to keep only the useful data.

Compressed data is then stored into a file *f(j)*. If this file is not renamed or saved into another directory, when the script is re-executed it will be overwritten.

3.4 Image/Imagette Data Lossless Decompression

The University of Vienna team provides a set of compression algorithms to support the *ICU* in compressing the different *PLATO* data products. The implemented compression method decorrelates the data in real time through a running average and encodes the residuals with a Golomb code.[5] A program with a command line

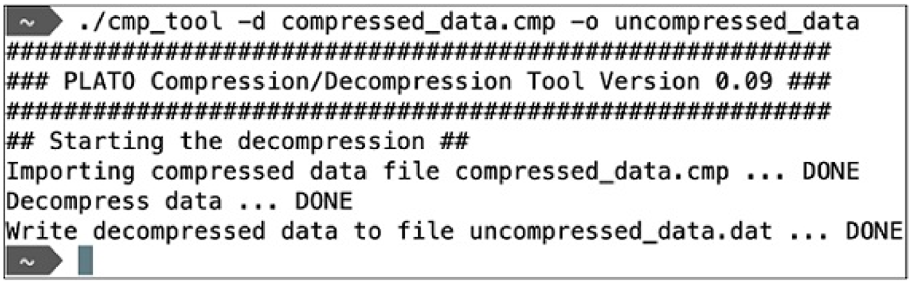

Figure 3. *Usage of the PLATO Compression and Decompression Tool CLI.*

interface *(CLI)* was developed to perform the decompression. In order to run the *(CLI)* tool called *"cmp_tool"* version 0.09, we used a *PC Dell* with Microsoft Windows Pro 10 operative system. In a open Command Prompt windows, on the *CLI's* path the executable is run. Some of the decompression options that can be specified in the *Command Prompt* windows are: $-m < file >$: file containing the model of the compressed data, $-i < file >$: file containing the decompression information (required if −−no_header was used) among others. As shown in fig. 3 the $-o < prefix >$ is used to specify the output files in this case *"uncompressed_data"* and $-d < prefix >$ is used for the file containing the compressed data *"compressed_data.cmp"*.

3.5 On-Ground Process for TM PUS Packets Classifier & Decompression

The whole process consists in receiving the imagette's *(TMs)* packets (fig. 4, *A*) through the Spacecraft Interface Simulator (*SIS*) and classifying them according to the imagette they belong (figs. 2 & 4 *B*). Then, the data is put in the right order by a small program (fig. 4, *C*) that prepares the input (fig. 4, *D*) to data decompression tool *(Cmp_Tool)* (fig. 4, *E*). Finally the data is saved in a file (fig. 4, *F*).

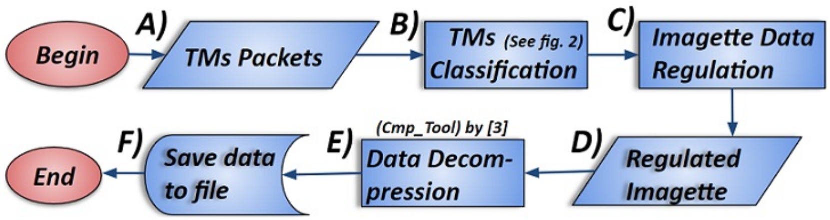

Figure 4. *Imagette data classification and decompression process flowchart.*

4. HARDWARE AND SOFTWARE IMPLEMENTATION

4.1 The PLATO SW running in the CPU shall use three different HW I/F

SpaceWire: only the *CCSDS/PUS* packet will be used over the *SpW* link. Boot *SW (BSW)* is connected to *SVM* through the Low Voltage Digital Signals *(LVDS)* block. ***GPIOs***: the *BSW* uses some *CPU* General Purpose Input/Output *GPIOs* to configure, reset and read the status of the *MRAM*, to enable or disable the specific *LVDS* port used to communicate with the *S/C* and for the watchdog mechanism. Serial Peripheral Interface ***(SPI)***: these *I/F* are used by the *BSW* to acquire environmental data from onboard sensors. These data are related to the power information (voltage and current) of the *CPU/MMU* and *RDCU* and the temperatures of *CPU/MMU*, *PSU* and *RDCU*.

4.2 PLATO's Memories and Configuration

The ***MRAM*** memory is used as a mass memory for the instrument to store ASW images, camera images *"fast" and "normal" Data Process Unit (F-DPU and N-DPU)* and configuration files. When commanded, the *BSW* deploys an *ASW* image in *SDRAM* and execute it. The *BSW* uses a configuration file to fulfill its tasks for what concern the temperature/voltage/current monitoring. The *MRAM* is considered as no critical memory area. The ***PROM*** is a read-only memory where *BSW* image is stored. The *BSW* is not deployed in the *SDRAM*, but it runs directly from this memory. While ***SDRAM*** is a working memory used at run-time to allocate *BSW* data (program stack and working memory). The area used by the *BSW* is defined as critical memory area.

4.3 Virtual Work Environment

Workstation *PC* set-up with a *SIS* Data interface is part of the *PLATO* Spacecraft Interface Simulator *(SIS)* assigned to Kayser Italia for *SW* development. The *ICU* Avionic Validation Model *(AVM)* or Engineering Model *(EM)* will be connected to the *SVM* with four SpaceWire channels but the BSW will use only two of them, the *TC/TM* channels (Main and Redundant) called also *DHS-A* (main) and *DHS-B* (redundant).

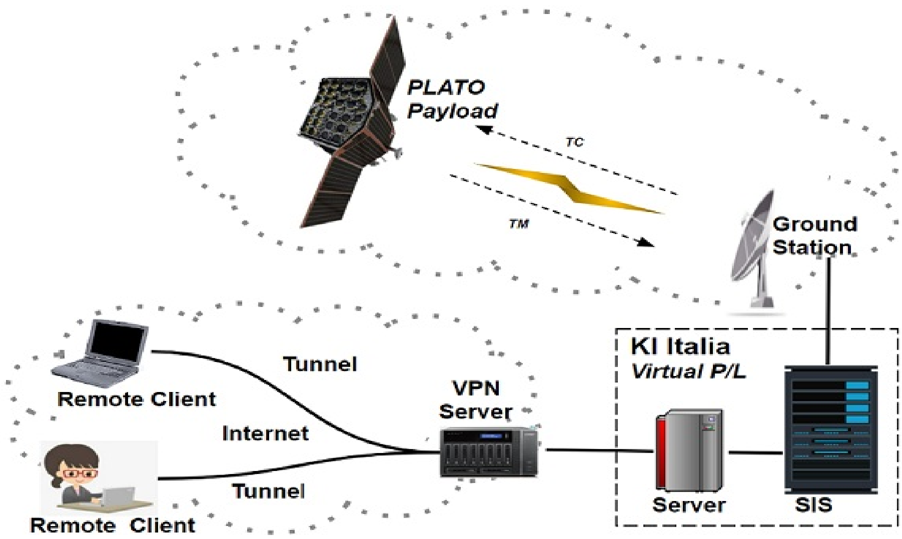

Figure 5. *Kayser Italia, Spacecraft Interface Simulator (SIS) access by VPN Remote-Access.*

We uses a notebook *PC* connected by remote access *VPN* tunnel to the *SIS* of Kayser Italia. The *VPN* enables network security and compliance, it migrates to hybrid cloud environments using *SSL*, Internet Protocol Security *(IPsec)*, or Wireguard Protocol, the secure network protocol suite that authenticates and encrypts data at the *IP* Packet Layer. The *IPsec* negotiates security associations *(SA)* with the Internet Key Exchange *(IKE)* management protocol to create an authenticated and secure communication channel between user devices and network resources. (See figure 5).

5. RESULTS AND CONCLUSIONS

The management of the *PLATOS's P/L* is done by the *ICU*, it is responsible for the compression of scientific data and transmit them as *TMs* to the *SVM* for down-link. In order to reduce the size of the encoded TM data packet, the data is compressed using the *RDCU* supported by: *HW* data compressor and *ICU SW* compressor. The *ICU* can download the compressed image data packet from the *RDCU* which is less in size than the original image. These methods were already developed and implemented by our partners on Ref. 3–5. By using these methodologies the on-board data size is significantly reduced, but, nevertheless, the on-ground expected data volume is still huge it is about 435 Gb per day size, requiring the necessity to search for new strategies to management of large amount of data. For such reason, in this paper we proposed a scripting tool that classifies and collects automatically *TMs PUS* packets, hosting scientific data and metadata, to reconstruct compressed

imagettes on-ground. The *primary and secondary headers* are removed from the whole *TMs* to keep only the imagette data. When all the data packets of a whole image are collected, these will be decompressed to obtain the original imagette. Figure 6 shows a code portion of a compressed (left) and decompressed (right) imagette data (Not whole image data are showed). Our partners on Ref. 5 provides us the *CLI* tool for imagette decompression, used to complete our present research.
Presently, we need to perform further decompression tests accounting for different scenarios (e.g. trying with different setup no. of cameras), to understand if the tool needs further development and improvement to better fit the project requirements.

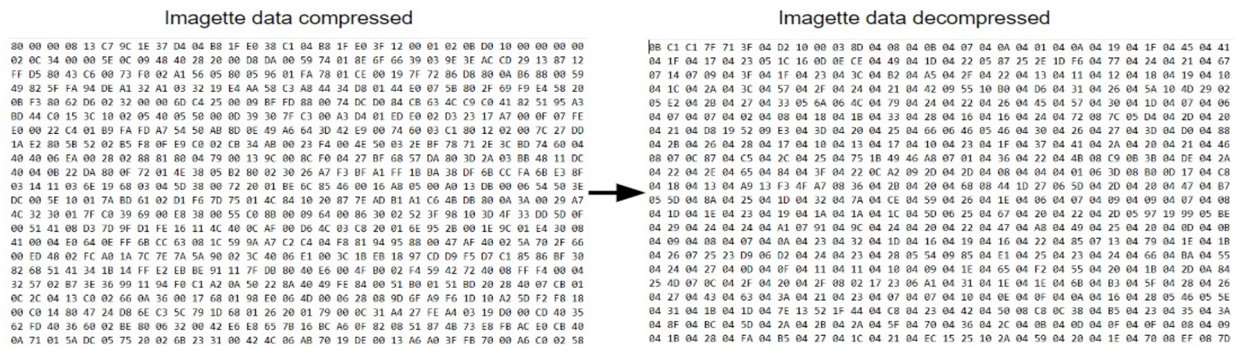

Figure 6. *Compressed and decompressed imagette data coding (only a small portion is shown here).*

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