1 Appendix A: example of data managed by a hypothetical SRDB

In this appendix we detail the data of our hypothetical SimpleSAT SRDB. Although we have been using RangeDB SRDB application [1–3] for managing monitoring and control data of different satellite programs such as METOP-SG[1] and Telecom satellite programs [4], in our illustration, we use graphics or UML object diagrams on purpose. We aim to keep our example generic enough and to link our illustration to specific graphical user interfaces or data storage technology. Additionally, we only show certain objects and certain attributes related to SimpleSAT data objects. We make abstraction of numerous details in order to keep the illustration understandable. We recall that our ultimate objective in this SimpleSAT example is to populate and organize the SimpleSAT SRDB data that will be used to switch on the reaction wheel (RW) and to let the satellite operation manager check its temperature and its status.

1.0.1 OBHW data

First we illustrate the definition of OBHW data. More specifically, the SRDB will manage:

1. The RW calibration $C00001$ that aims to transform Ohm to temperature as depicted in Figure 1. Originally, this calibration would be given as an equation in the RW ICD but it has to be transformed into a lookup table and it has to be named so that the SRDB can manage it as an interpolation.

C00001: calibration $calib_1$

Ohm	°C
40800	-55
71	150

Figure 1: Definition of Ohm to Degree Celcius calibration in the SRDB

2. The RW port that could be used to obtain the temperature of the RW. The objective of defining the RW is to capture the details of the harness when it will be populated in the SRDB.

3. Simlarly, we also capture the RIU port that could be used to connect RIU to RW.

[1] http://emits.sso.esa.int/emits-doc/ASTRIUMSAS/MetOp-SG/Generic/AD13a-MOS.SP.ASF.SYS.00816_Issue1.1_Instrument_GDIR.pdf

4. The RIU calibration $C00002$ that is used to transform raw values into Ohm as depicted in Figure 2. This calibration would be given in the RIU ICD.

C00002: calibration $calib_2$

Raw	Ohm
-2048	119
2048	250000

Figure 2: Definition of a raw to Ohm calibration in the SRDB

5. The RIU telemetry parameter that aims to store the information received by the RIU port cited above as depicted in Figure 3. At this level there is no calibration attached to this parameter because we do not know to which OBHW component the RIU will be connected via this port.

TEMP_PARAM: EngineeringParameter

- Name: TEMP_PARAM
- Description: Temperature
- Calibration:

Figure 3: Definition of an RIU parameter that aims to hold temprature values

6. The PCDU port that is used to connect the PCUD to OBHW to switch it on and off.

7. The PCDU LCL's telemetry parameter that aims to store the status of the OBHW component that will be connected to the PCDU as depicted in Figure 4. At this level, this parameter is not attached to any calibration because the status text depends on the OBHW component connected to the PCDU.

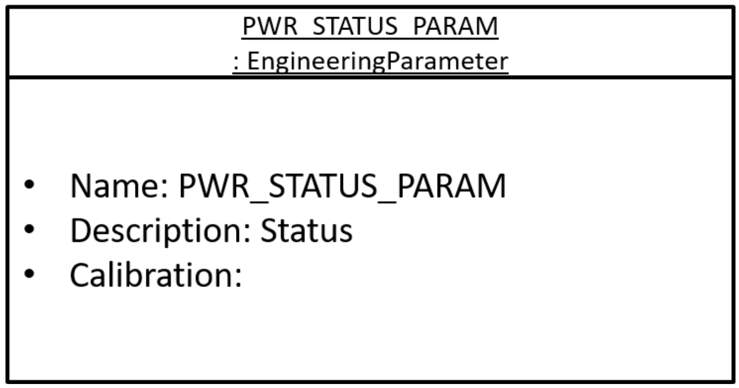

Figure 4: Definition of a PCDU parameter that aims to hold the status of the PCDU's LCL

8. The PCDU calibration $C00000$ that would be used to transform PCDU's LCL raw boolean values into text as depicted in Figure 5.

C00000: calibration $calib_0$

Raw	Text
0	FALSE
1	TRUE

Figure 5: Definition of status raw-to-text calibration in the SRDB

9. The definition of the PCDU Mil-Std-1553 packet that aims to command hardware connected to the PCDU as depicted in Figure 6. This constitutes the generic definition of (BC-to-RT) Mil-Std-1553 TC packets. In the SRDB, we capture the definition of the packet as specified by the standard.

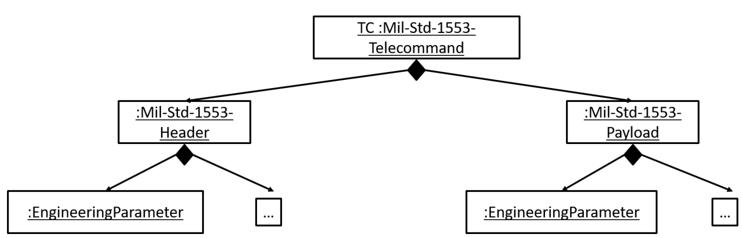

Figure 6: Definition of a generic Mil-Std-1553 TC packet in the SRDB along with its header and parameters

The list of data objects above constitutes the required information from every piece of OBHW to connect the RW to the RIU and the PCDU and also to switch on the RW and to measure its temperature via a CCS.

1.1 OBSW generic data

We assume that the SimpleSAT OBSW is compliant with the PUS standard. In this case, SimpleSAT OBSW data refers mainly to the definition of the structures of PUS Services packets as specified in the ECSS standard. For our SimpleSAT example, the SRDB will manage:

1. A PUS TC packet of **service 2** and **subservice 1**, which is used to embed Mil-Std-1553 TC packets to transfer them from the ground (CCS) to the OBSW[2], along with its parameters as depicted Figure 7. We highlight the parameter that aims to reference the definition of the Mil-Std-1553 TC packet (c.f. Figure 6) that this service is expecting.

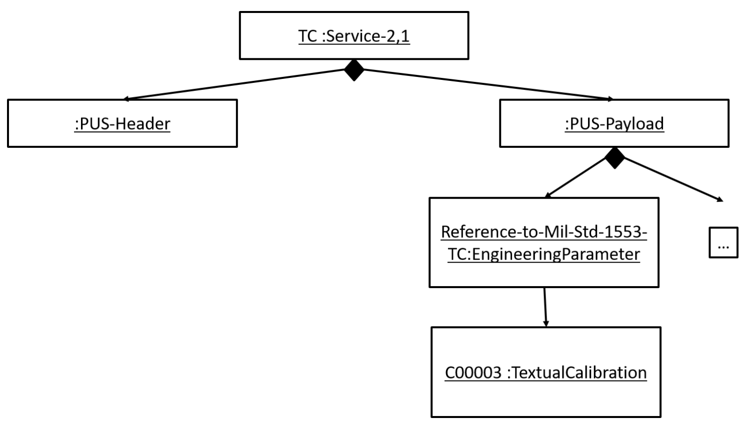

Figure 7: Definition of a generic service 2 TC packet along with its header, and inner parameters

2. A textual calibration $C00003$ that would be associated with the parameter that will embed the Mil-Std-1553 TC packet in the service 2 TC definition. The content of this calibration is depicted in Figure 8. At this stage this textual calibration is empty because the OBSW data is still generic and has not been missionized yet.

[2] https://ecss.nl/standard/ecss-e-st-70-41c-space-engineering-telemetry-and-telecommand-packet-utilization-15-april-2016/

C00003: textual TC calibration

Hexadecimal encoding	Mil-Std-1553 TC
NA	NA

Figure 8: Definition of a calibration that associates an intelligible text with the encoding of a Mil-Std-1553 TC packet that could be embedded in the PUS service 2 TC.

3. A PUS TM packet of **service 1** and **subservice 1** and its parameters as specified by the ECSS standard. This TM packet will be used to decode the acknowledgement that informs the operator that the TC of service 2, which will switch on the RW, has been **well-received** by the OBSW. The definition of this TM packet is depicted in Figure 9. We highlight one single parameter belonging to this TM packet that is the parameter whose value represents the identifier of the TC that will be received by the OBSW.

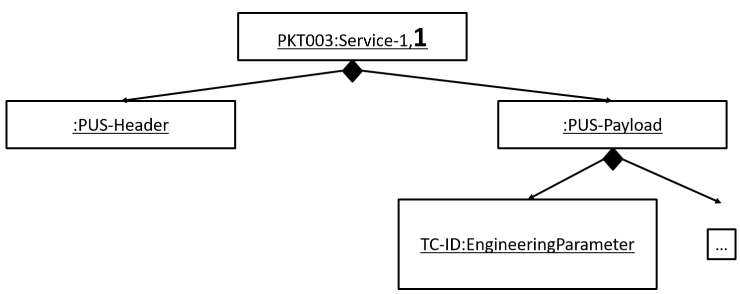

Figure 9: Definition of a TM 1,1 to confirm that the TC has been well received by the OBSW

4. A PUS TM packet of **service 1** and **subservice 7** and its parameters. This TM packet will be used to decode the acknowledgement that informs the operator that the TC of service 2, which will switch on the RW, has been **well-executed** by the OBSW. The definition of the TM packet is depicted in Figure 10. Here also, we highlight one single parameter belonging to this TC that is the parameter whose value represents the identifier of the TC that will be received on-board.

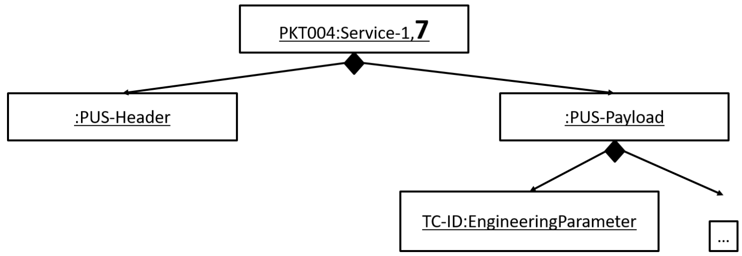

Figure 10: Definition of a TM 1,7 to confirm that the TC has been well executed by the OBSW

5. An unsigned 32-bit engineering parameter that aims to contain the global status of an OBHW component as depicted by Figure 11. At this level, we do not know yet which OBHW component is concerned.

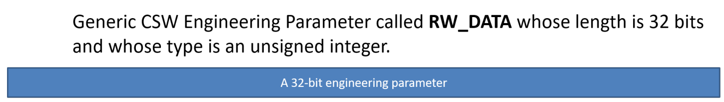

Figure 11: Definition of a generic 32-bit engineering parameter provided by the OBSW for RW data

1.2 Harness and OBSW missionized data

Missionizing the generic OBSW data and considering the impact of the harness will lead to the creation or the tailoring of the following data objects in the SRDB:

1. The connection of the RW with the RIU and the PCDU and the tailoring of the TMTC data to take into account this interconnection.

    - The creation of the connections between the RIU and the RW and between the PCDU and the RW.
    - The creation of the calibration $C00012$ that is the combination of $C00001$ and $C00002$. This calibration aims to transform a raw value in the temperature telemetry parameter of the RIU directly into a degree celcius value. The entries of this calibration are depicted in Figure 12.

C00012: calibration $calib_1 \circ calib_2$

Raw	°C
-2048	150
2048	-39

Figure 12: Definition of a raw to temperature calibration in the SRDB

- The update of the parameter TEMP_PARAM of Figure 3 to take into account the impact of the harness as depicted in Figure 13. We also update its name to make it compliant with the target CCS.

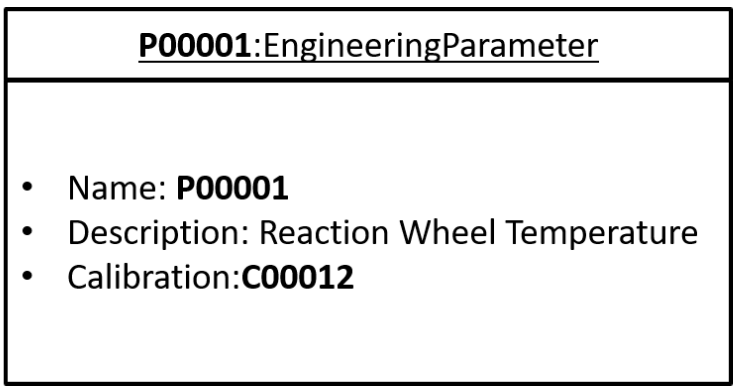

Figure 13: Tailoring of the RIU temperature to take into account the effect of the harness

- The update of the PCDU parameter of Figure 4 that aims to bring the status of the RW connected to the PCDU along with the calibration $C00000$ as depicted in Figure 14.

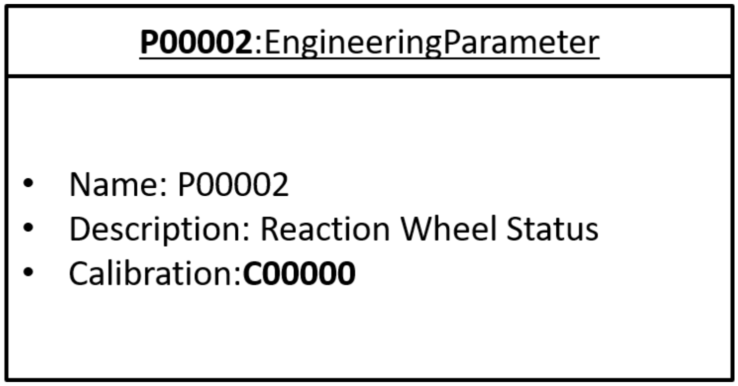

Figure 14: Tailoring of the PCDU status to take into accoun the effect of the harness

2. The creation of an instance of the PCDU Mil-Std-1553 TC packet that aims to switch on the RW. In this TC instance, the values of the parameters of the TC packet are fixed as depicted in Figure 15.

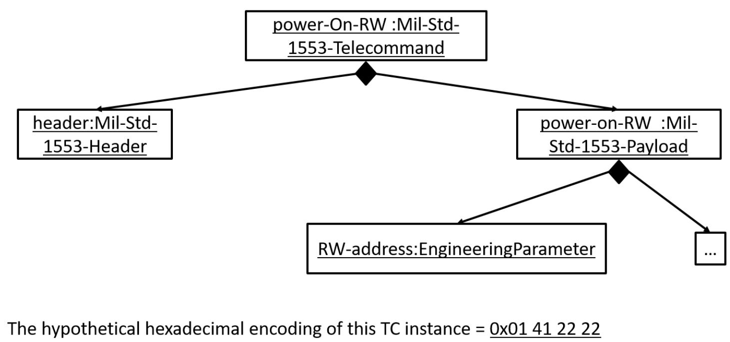

Figure 15: Definition of an instance of the Mil-Std-1553 TC packet to switch on the RW

3. The update of the calibration $C00003$ of Figure 8 used by the service 2 TC in order to include the above Mil-Std-1553 TC instance. Figure 16 shows the content of that calibration after its tailoring.

C00003: textual TC calibration

Hexadecimal encoding	Mil-Std-1553 TC
0x01 41 22 22	Switch-ON-RW-N

Figure 16: Definition of a calibration that associates text with the Mil-Std-1553 TC packet instance that could be embedded in an instance of the service 2 TC.

4. The creation of an instance of the service 2 TC that will be used by the satellite operation engineer to switch on the RW. The parameter that aims to embed the hexadecimal representation of the Mil-Std-1553 TC instance has been tailored to reference the calibration $C00003$ as depicted in Figure 17 and it will have the value *Switch-ON-RW-N*.

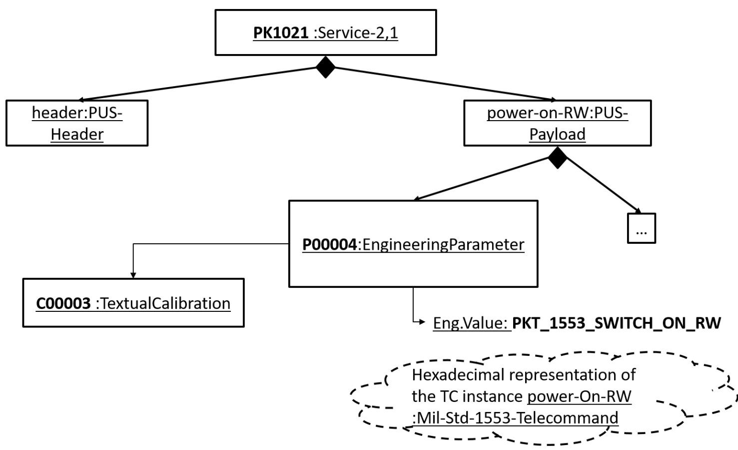

Figure 17: Definition of the TC instance of the service 2 by attaching the appropriate values to its parameters

5. The decomposition and the renaming of the global RW status parameter into 3 parameters to handle the 3 pieces of information that this global RW status parameter will contains as depicted in Figure 18.

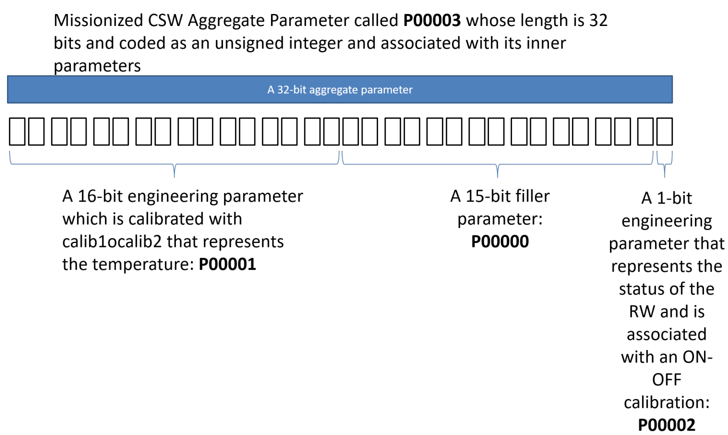

Figure 18: Missionization of the OBSW RW global status parameter

6. The update of the PCDU RW status parameter with the calibration that shows the status of the RW textually as depicted in Figure 19. We also rename this parameter to make it CCS-compliant.

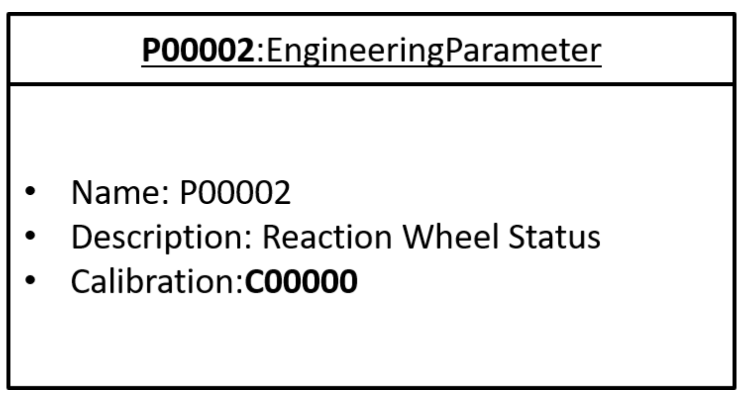

Figure 19: Missionization of the OBSW RW global status parameter

7. The creation of the PUS housekeeping TM packet **service 3** and **subservice 25** that aims to bring to the CCS the global RW status parameter which is illustrated in Figure 18. The definition of this TM packet is depicted in Figure 20.

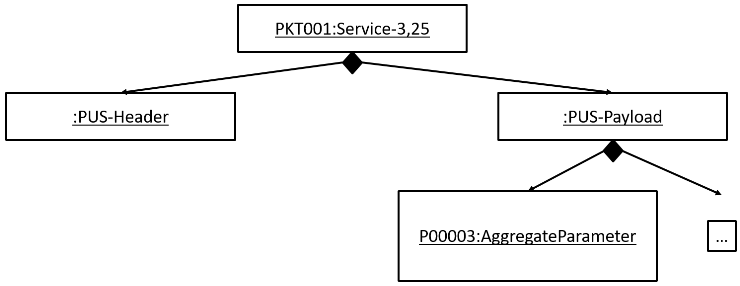

Figure 20: PUS Housekeeping TM Packet to bring global RW status parameter to the operator

8. The definition of the harness interfaces that connect the RIU and the PCDU to the RW.

At this level the harness impacts have been taken into account and the generic OBSW data has been missionized and is now tailored to operate SimpleSAT.

1.3 Data of the as-built RW

In the SimpleSAT example, we suppose that there we bought one single RW that is compliant with the RW ICD whose data have been captured above. We suppose that measuring the calibration of this RW, which transforms ohm to temperature as, gives slightly different values from the definition of the calibration $C00001$ as depicted in Figure 1. We name this new calibration $CR0XYZ$. Its entries are depicted in Figure 21.

CR0XYZ : calibration $calib_1$

Ohm	°C
40800	-55.5
71	147

Figure 21: AS-built reaction wheel calibration

At this level all required information to encode SimpleSAT TC packets and to decode TM packets have been identified. Appendix-B[3] will show how these pieces of information could be organized in the Space System Model (SSM) of the SRDB.

[3] https://github.com/enercom25/SRDBSurvey/blob/main/Appendix-B.pdf

References

[1] E. H, "Rangedb in support for mbse," in *SESP2012*, 2012.

[2] H. Eisenmann, C. Cazenave, and T. Noblet, "Rangedb the product to meet the challenges of nowadays system database," in *9th ESA Workshop on Simulation for European Space Programmes*, 2015.

[3] S. Böning, "The current state of research and technology of digitalization in the space industry," 2021.

[4] C. Cazenave, "Benefiting of digitalization for spacecraft engineering," in *11th ESA Workshop on Simulation for European Space Programmes*, 2017.