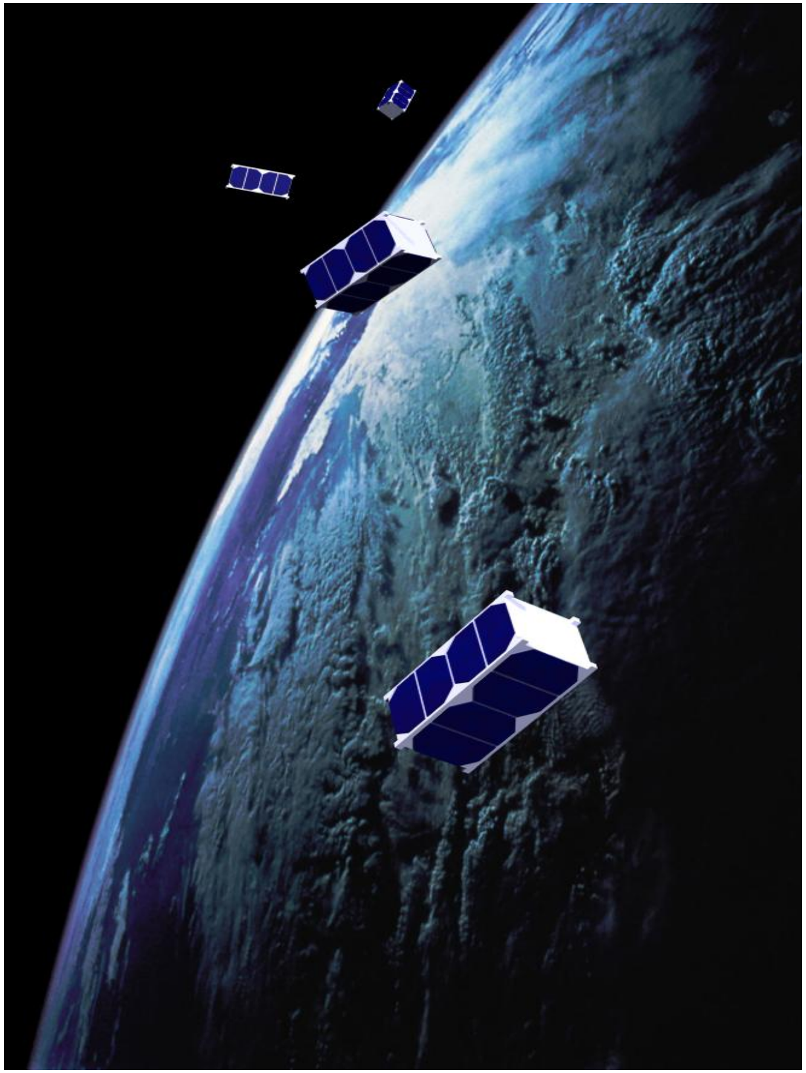
QB50

Satellite Control Software (QB50 SCS)



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Swiss Space Center

6th QB50 Workshop

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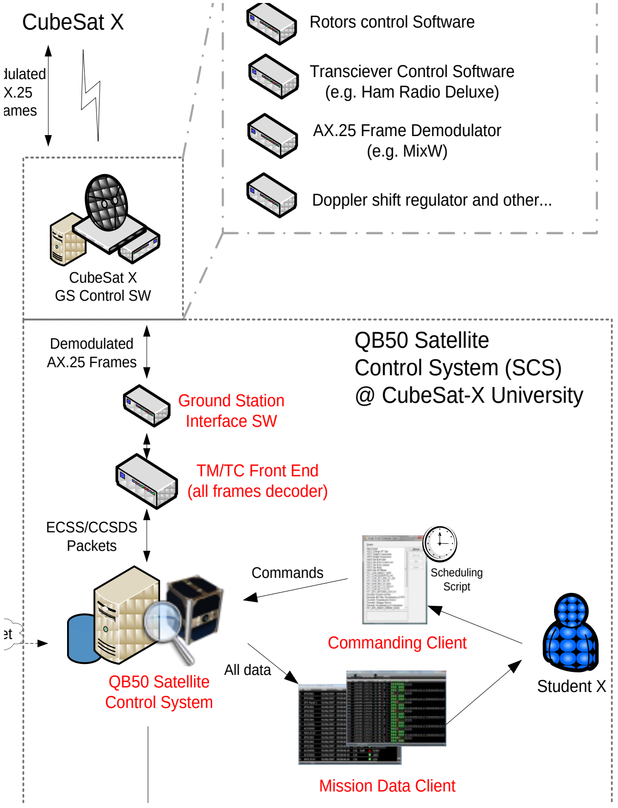
Rhode-Saint-Genèse, Belgium

What is the Satellite Control Software?

- The functions of the QB50 SCS software are fourfold:
  - Decode the AX.25 frames in the UI version of the AX.25 protocol;
  - Provide telemetry archiving and replay functionalities (at frame level);
  - Provide a control system that sends telecommands, receives and process/monitors telemetry and stores the mission data and configuration;
  - Provide interfaces to the control system to command and monitor the CubeSat in real time.

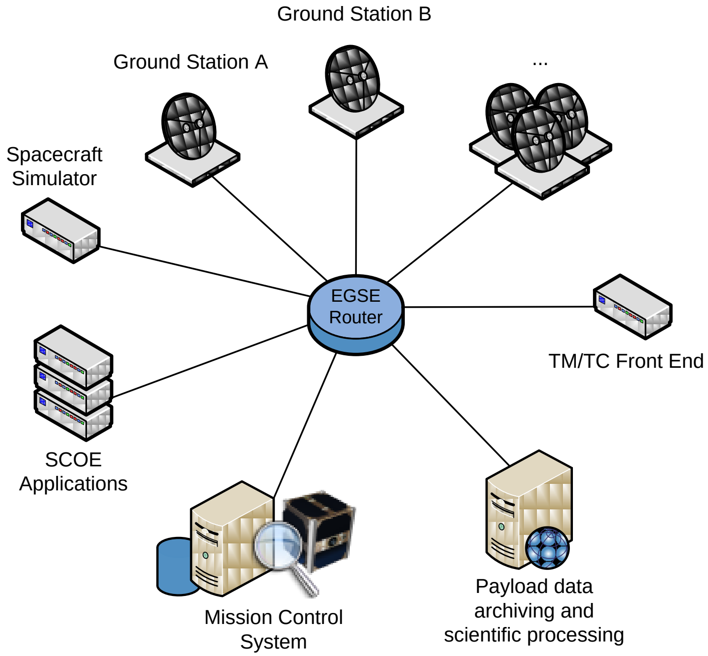
- The SCS software is very flexible and individual teams can integrate their own specifics at many levels, for instance integrate mission-specific data processing or visualization



What is the Satellite Control Software?

- The SCS can be used for ground tests (end-to-end communication) if integrated early in the CubeSat design

- WARNING! The SCS uses a tailored and simplified version of the ECSS-E-70-41A Packet Utilization Standard. An example of the implementation will be provided. This standard specifies services types, which organise and categorise the on-board data in different functions. It is thus recommended to write the flight software in a way that is compliant with this service and packet structure.



SCS Requirements

- Besides the SCS’s regular functionalities, the QB50 SCS shall :
    - Comply with Radio Amateur (RA) regulations
    - Provide the QB50 science data and related Housekeeping to both VKI and to the CubeSat team
    - Interface with timed instrument command files (TBD)
    - Interface with the CubeSat teams ground stations and a ground station network (if applicable)
    - Interface with VKI ground server

RA requirements (G. Shirville)

- Amateur radio communications have to be “open” (Article 25.2A of the Radio Amateur Regulations that have been agreed by all member states of the ITU).
  - There can be no copyright or IPR on data downlinked from a spacecraft using the amateur satellite service
- Command uplinks can be encrypted but nothing else can be.
- The RA service is intended as a “one to many” system so all amateurs should be allowed to receive and decode all transmissions. If the encoding method is not a recognised standard already in use within the amateur fraternity then the developers should make the ground segment software available for free download before launch.
  - Any radio amateur shall have access to decoded data that he/she downlinks

Expected types of data

- QB50 Science data
  - Data generated by the science instruments (ICD – MSSL)
- QB50 Science related Housekeeping data (Sc-HK): what is needed to process the science instrument data
  - Time tagged setting parameters of the science instruments (ICD – MSSL)
  - Time tagged attitude sensors (sun sensors, gyros…) (ICD – Surrey or CubeSat specific)
  - GPS data (ICD – Surrey or CubeSat specific)
  - Time tagged temperature sensors on science packages (TBD)
  - CubeSat status information
- CubeSat HK and science data (not QB50 data)
  - All data relative to the health of the CubeSat, and to the CubeSat specific science

Proposed downlink implementation

- To respond to Radio-Amateur regulations and real-time needs to save QB50 data from any CubeSat, it is proposed to handle the QB50 Science and SC_HK early in the decoding process

- A QB50 frame identifier will clearly separate AX.25 QB50 frame upfront via an “AX.25 Frame Router”
  - The QB50 data contained in the QB50 frame will be routed directly to the VKI Server and to the CubeSat Server
  - The CubeSat specific data frames will be sent to the CubeSat team server

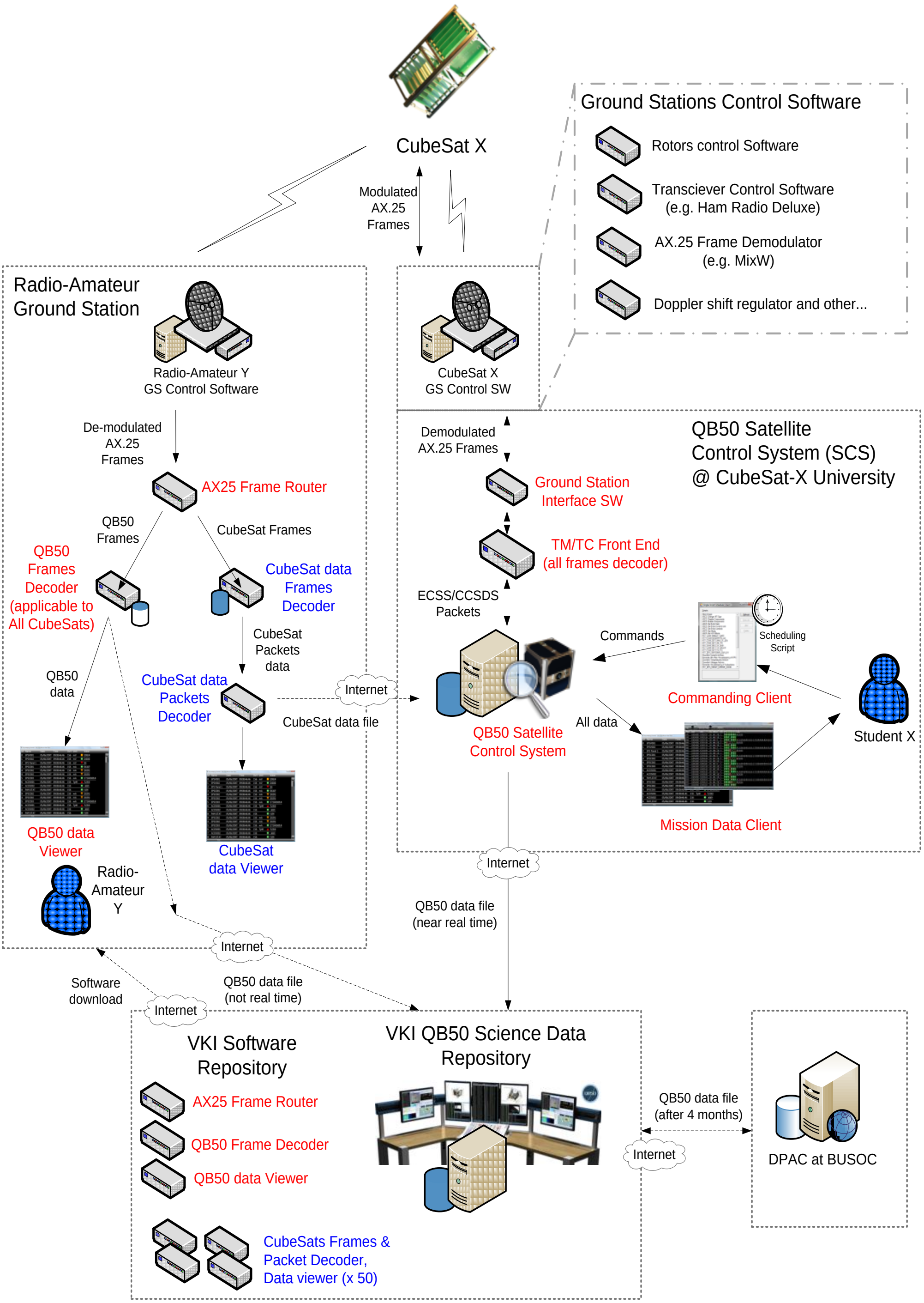
- The “QB50 AX.25 Frame Router” will be provided to the CubeSat teams by VKI/EPFL

Proposed downlink architecture

- This architecture shows the downlink process at a Radio-Amateur ground station and at the CubeSat team university

- The software labelled in red is planned to be delivered by EPFL to VKI after full acceptance by QB50 project

- Delivery to CubeSat teams is planned for a year before launch. Documentation to come before the end of the summer.



CubeSat X
Modulated AX.25 Frames
Ground Stations Control Software
Rotors control Software
Transciever Control Software (e.g. Ham Radio Deluxe)
AX.25 Frame Demodulator (e.g. MixW)
Doppler shift regulator and other...
Radio-Amateur Ground Station
Radio-Amateur Y GS Control Software
CubeSat X GS Control SW
De-modulated AX.25 Frames
AX25 Frame Router
QB50 Frames
CubeSat Frames
QB50 Frames Decoder (applicable to All CubeSats)
CubeSat data Frames Decoder
CubeSat Packets data
QB50 data
CubeSat data Packets Decoder
Internet
CubeSat data file
QB50 data Viewer
CubeSat data Viewer
Radio-Amateur Y
Demodulated AX.25 Frames
QB50 Satellite Control System (SCS) @ CubeSat-X University
Ground Station Interface SW
TM/TC Front End (all frames decoder)
ECSS/CCSDS Packets
Commands
Scheduling Script
Commanding Client
Student X
QB50 Satellite Control System
All data
Mission Data Client
Internet
QB50 data file (near real time)
Internet
Software download
QB50 data file (not real time)
Internet
VKI Software Repository
AX25 Frame Router
QB50 Frame Decoder
QB50 data Viewer
CubeSats Frames & Packet Decoder, Data viewer (x 50)
VKI QB50 Science Data Repository
QB50 data file (after 4 months)
Internet
DPAC at BUSOC

Proposed QB50 frames (1/2)

- For compatibility with amateur radio equipment which uses AX.25 for "high data-rate" digital transmissions, it is recommended to use the AX.25 Transfer Frames protocol based on the Unnumbered Information Frames (UI-Frames)

- To provide the necessary functionalities of space-to-ground transportation in the Transfer Frames (e.g. frame loss detection, on-board arrival detection, time correlation, etc.), a Secondary Header has been added to the Telemetry Transfer Frame in the AX.25 protocol

<table>
<tr><td colspan="11">AX.25 Transfer Frame Information Field (0-2048)</td></tr>
<tr><td colspan="6">Telemetry Transfer Frame Secondary Header (32 bits)</td><td rowspan="3">Data</td><td colspan="4">Telemetry Transfer Frame Trailer (8-72 bits)</td></tr>
<tr><td colspan="3">Frame Identification (8 bits)</td><td rowspan="2">Master Frame Count</td><td rowspan="2">Virtual Channel Frame Count</td><td rowspan="2">First Header Pointer</td><td colspan="3">Frame Status (8 bits)</td><td rowspan="2">Time</td></tr>
<tr><td>Version Number</td><td>Virtual Channel ID</td><td>Spare</td><td>Time Flag</td><td>Spare</td><td>TC Count</td></tr>
<tr><td>2</td><td>3</td><td>3</td><td>8</td><td>8</td><td>8</td><td>0-2008</td><td>4</td><td>2</td><td>2</td><td>0-64</td></tr>
</table>

Proposed QB50 frames (2/2)

AX.25 Transfer Frame Information Field (0-2048)										
Telemetry Transfer Frame Secondary Header (32 bits)						Data	Telemetry Transfer Frame Trailer (8-72 bits)			
Frame Identification (8 bits)			Master Frame Count	Virtual Channel Frame Count	First Header Pointer		Frame Status (8 bits)			Time
Version Number	Virtual Channel ID	Spare					Time Flag	Spare	TC Count	
2	3	3	8	8	8	0-2008	4	2	2	0-64

- If the frame doesn’t contains any packet fragment, i.e. raw payload data, the First Header Pointer shall be set to ‘11111110’ (all ones minus one, 0xFE).
- The QB50 data could thus be implemented as “raw data” and the First Header Pointer set to 0xFE. All other CubeSat data shall be using other allocations of the First Header Pointer. Thus the QB50 data should be contained in a defined way within the Data Field. The maximum length of the frame data field is the maximum size of the I-Field (2048 bits) minus the length of the header and trailer fields, therefore 1952 to 2008 bits (244 to 251 octets) depending of the value of Time Flag.

Open Points

- Decision on proposed downlink architecture
  - Need consensus between VKI / EPFL / RA /All concerned within project

- Uplink architecture specific to QB50: need decision
  - Do the CubeSat team need to execute timed Instrument Command Files? QB50-SYS-1.5.9
  - The format of these commands is TBD.

- Teams that do not want to use AX.25 need to make themselves known

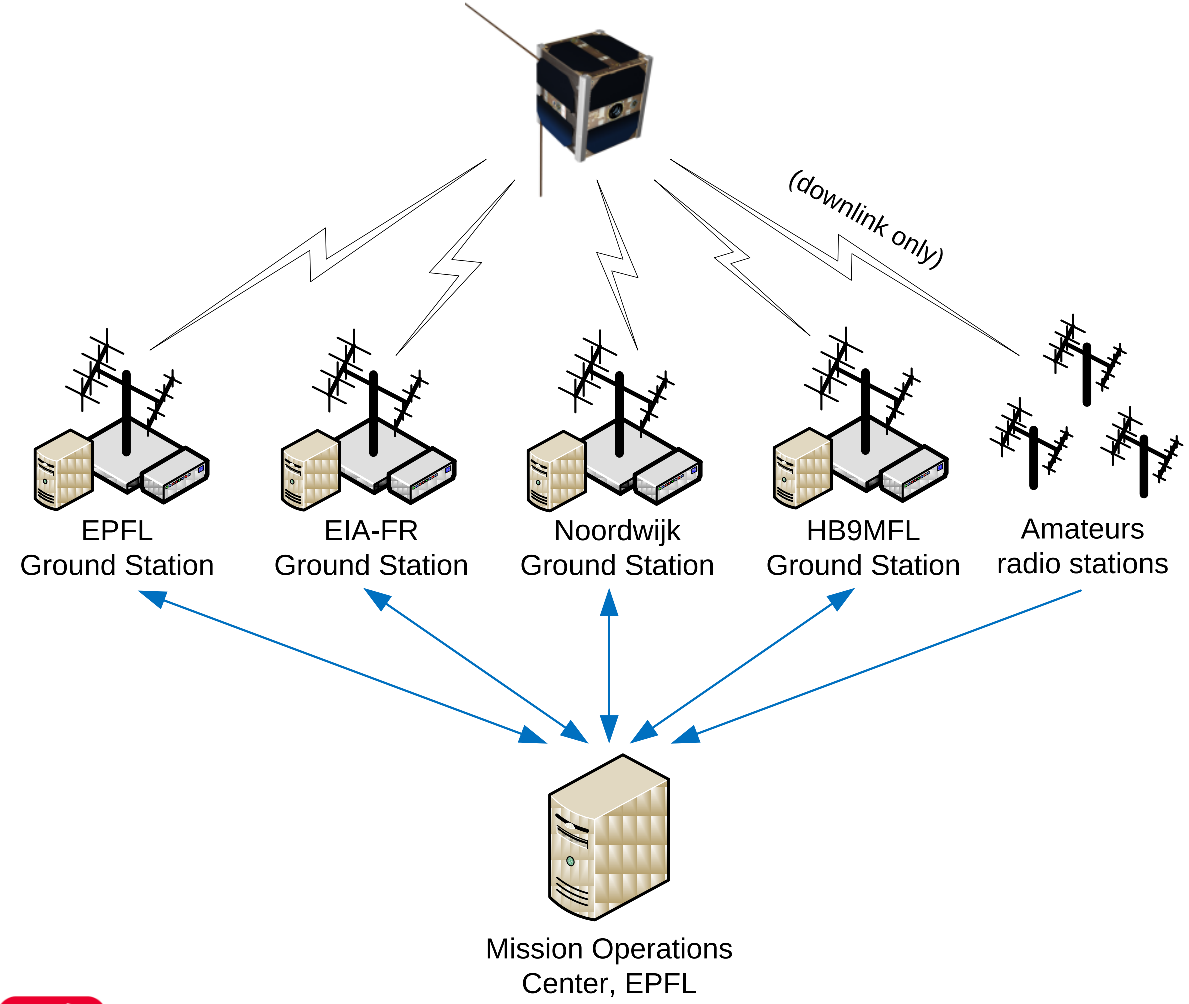
SCS as a Ground Station “Network”

- It is possible to use the SCS with several ground stations simultaneously (uplink through one at a time, downlink from several simultaneously)

- Not an automatic process, one local operator needs to control the ground station. No scheduling of the ground stations available, needs to be planned individually.

- Implementation is simple:
  - QB50 makes a list of available ground stations, their location, capability and a contact point, and distribute it to CubeSat teams
  - CubeSat teams organise link with 3-5 ground stations (other teams or RA)
  - SCS from each team interfaces with these 3-5 ground stations
  - Team commands its CubeSat and download data on either ground stations (planning done ahead of time with appropriate ground station operator)

Example for SwissCube



What do you need to do if you plan on using the SCS?

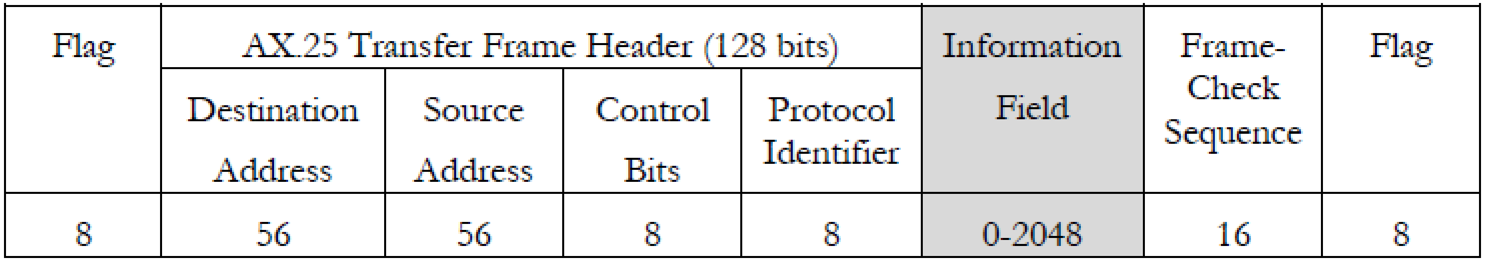
- Prepare a list of all your HK parameters, as well as all other parameters that you want to have available on the ground => name, data type, ID, format, limits…
- Prepare a list of the command that you will use for your CubeSat => Function ID, name, parameter name, parameter size, execution condition, verification errors…
- Read the ECSS-E-70-41A Packet Utilization Standard (CCSDS PUS), understand it. Define functions that are applicable to your CubeSat (we will provide an example of tailored version of PUS).
- Make yourself known: send an email to Thorsten (Thorsten Scholz thorsten.scholz@vki.ac.be) and Muriel (muriel.richard@epfl.ch), with title: “[QB50]-SCS request-CubeSat_name-Country-Universtity_name”, with a contact person for future correspondence

QUESTIONS?

BACK-UP SLIDES

Protocols

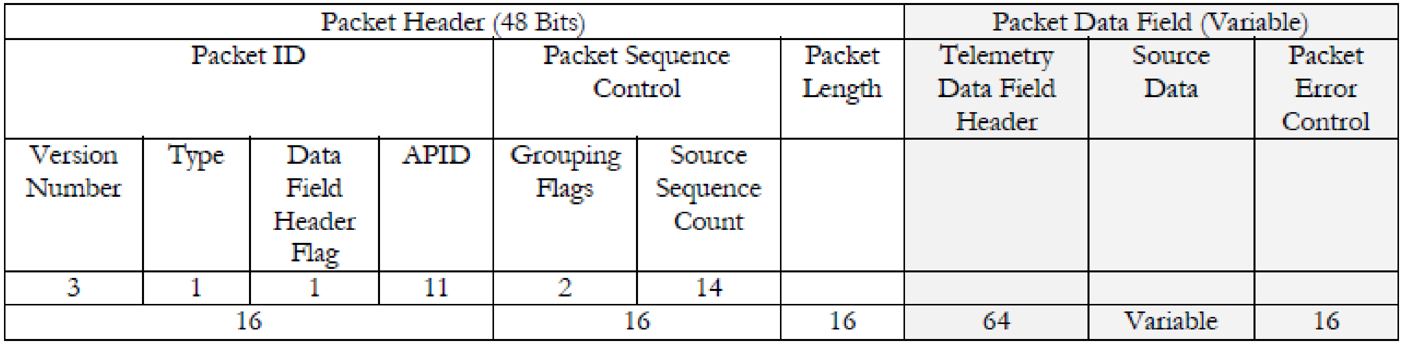
- AX-25 frames



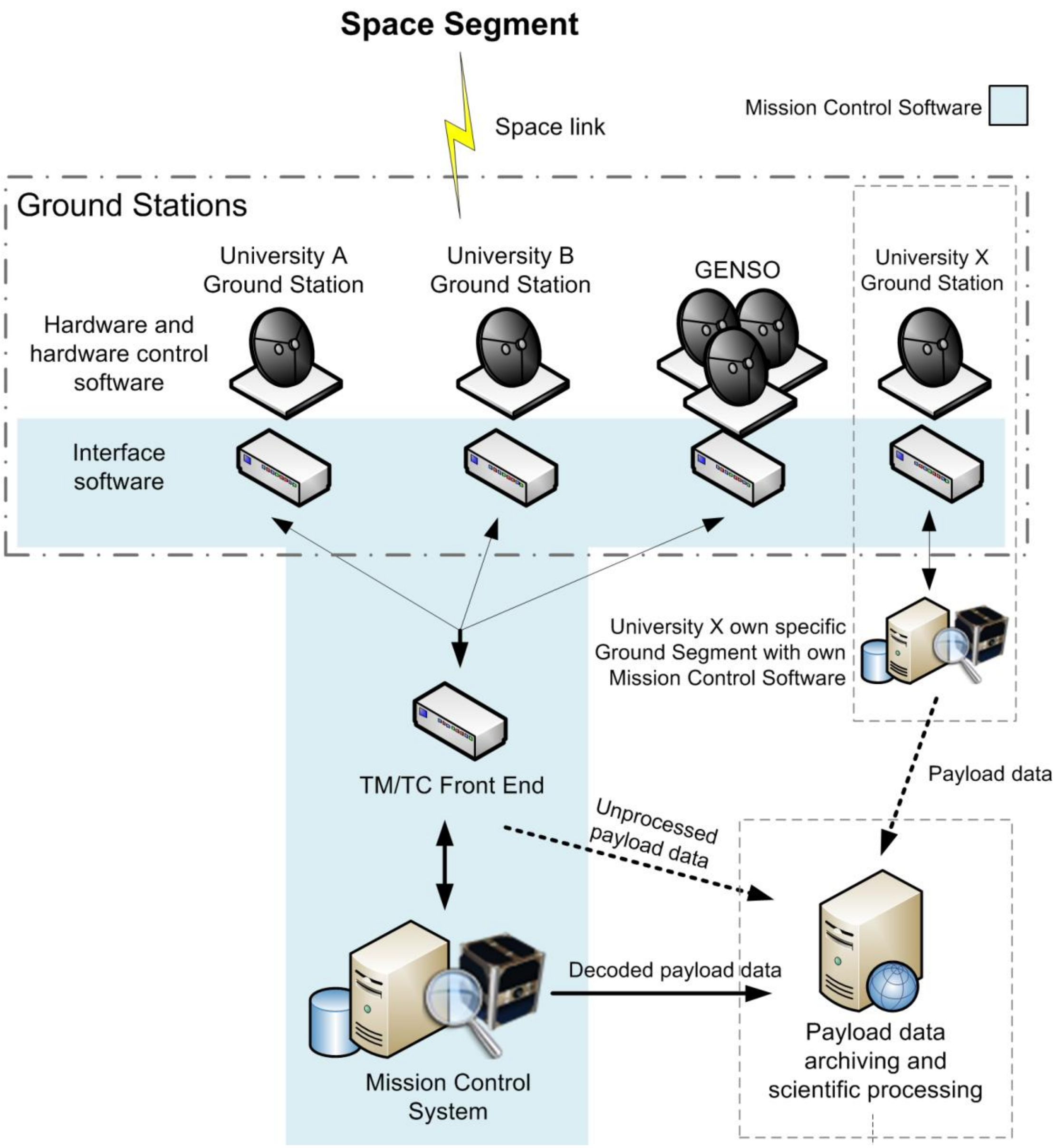
Flag	AX.25 Transfer Frame Header (128 bits)				Information Field	Frame-Check Sequence	Flag
	Destination Address	Source Address	Control Bits	Protocol Identifier			
8	56	56	8	8	0-2048	16	8

- Example of tailored ECSS-PUS - packets

Telemetry



Packet Header (48 Bits)							Packet Data Field (Variable)		
Packet ID				Packet Sequence Control		Packet Length	Telemetry Data Field Header	Source Data	Packet Error Control
Version Number	Type	Data Field Header Flag	APID	Grouping Flags	Source Sequence Count				
3	1	1	11	2	14				
16				16		16	64	Variable	16



Space Segment

Space link

Mission Control Software 🟦

Ground Stations

University A Ground Station

University B Ground Station

GENSO

University X Ground Station

Hardware and hardware control software

Interface software

University X own specific Ground Segment with own Mission Control Software

Payload data

TM/TC Front End

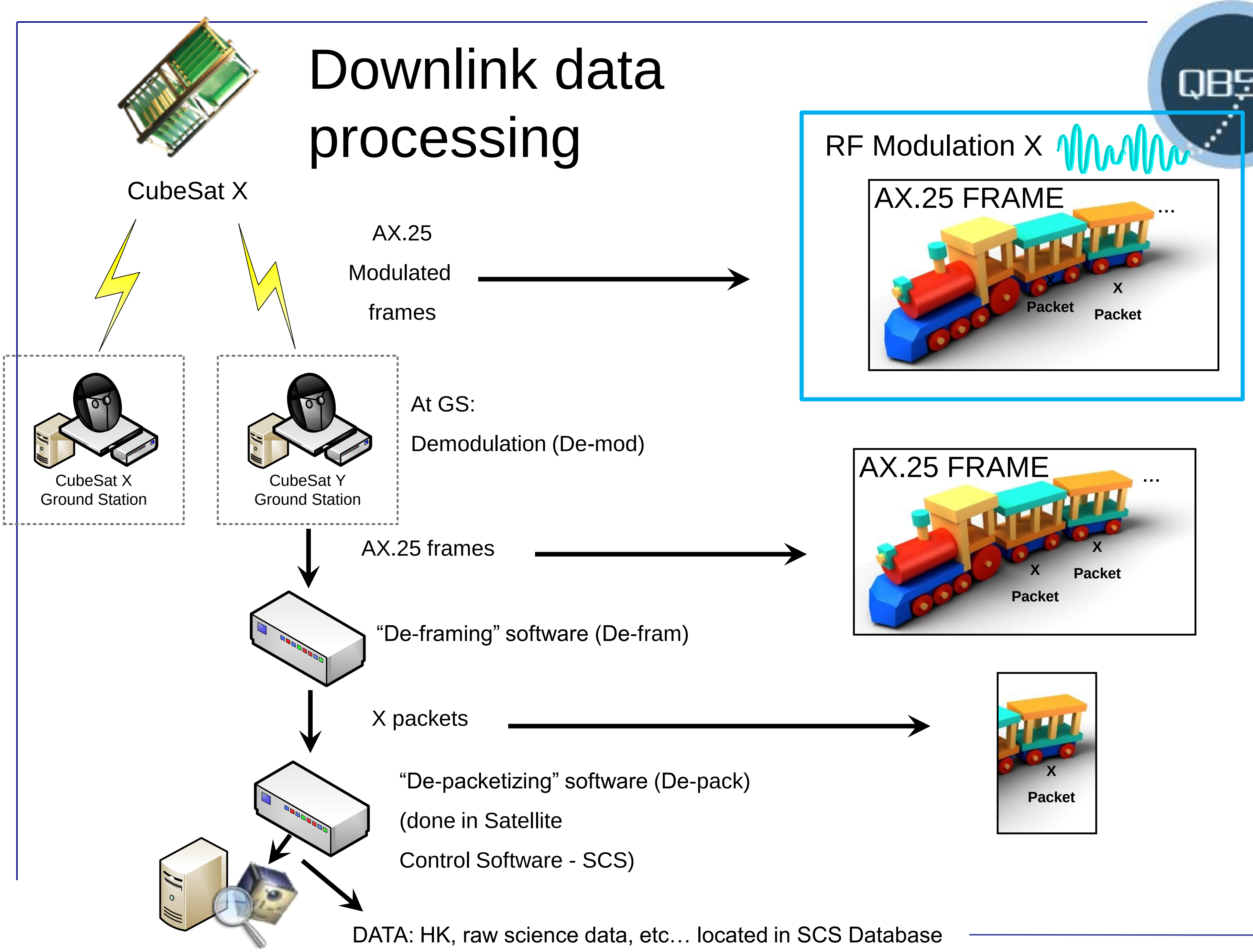
Unprocessed payload data

Decoded payload data

Mission Control System

Payload data archiving and scientific processing

Downlink data processing



CubeSat X

CubeSat X Ground Station

CubeSat Y Ground Station

AX.25 Modulated frames

RF Modulation X

At GS: Demodulation (De-mod)

AX.25 frames

“De-framing” software (De-fram)

X packets

“De-packetizing” software (De-pack)

(done in Satellite Control Software - SCS)

DATA: HK, raw science data, etc… located in SCS Database