GOVERNMENT OF DUBAI

MOHAMMED BIN RASHID SPACE CENTRE

T11- CAN Bus usage in High Resolution earth Observation Missions

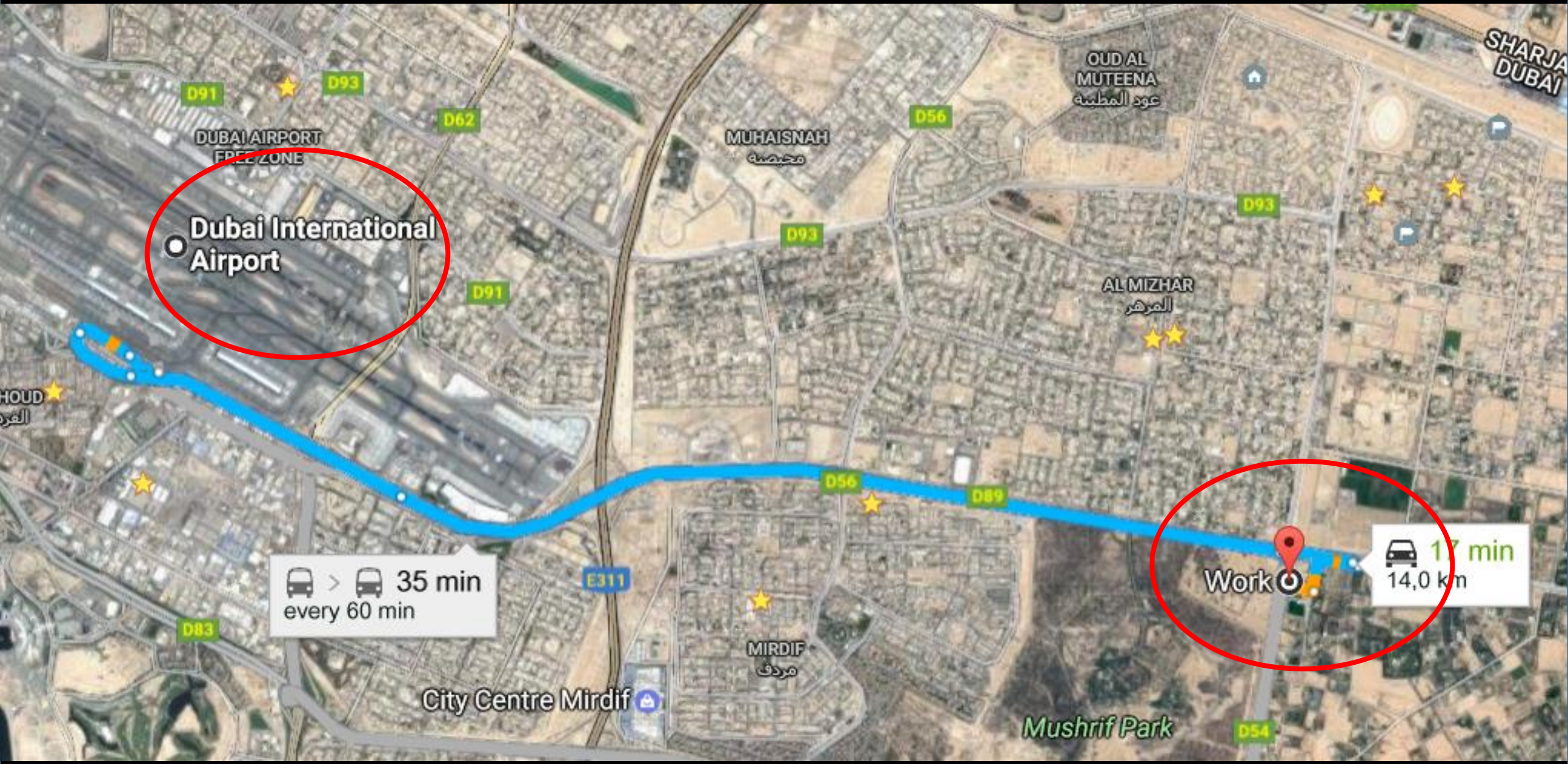
By Ahmed Salem

Outline

- Introduction to MBRSC
- DubaiSat System Architecture
- CAN-Bus Protocol
- Verification
- Upcoming Work

Introduction to MBRSC

- Started in 2006 with Decree from Dubai Government
- Less than 300 employees.
- Total Launched Satellites 4 (3 Small Sats <500kg + 1 Cube Sat)



MBRSC Location

MBRSC Location

High Big Clean room class 100,000

High Big Clean room class 100,000

Mission Control Room

GOVERNMENT OF DUBAI

MOHAMMED BIN RASHID SPACE CENTRE

وكالة الإمارات للفضاء
UAE SPACE AGENCY

KHALIFA SAT

The Most Technologically Advanced Satellite And The First Satellite Fully Manufactured By Emirati Engineers In The Clean Rooms At MBRSC In The UAE...

HOPE MARS PROBE

In an historic announcement in July 2014, the President of the UAE, His Highness Sheikh Khalifa bin Zayed Al Nahyan revealed the formation of the UAE Space

http://www.emm.ae/

DMSAT-1

DMSAT-1 Earth Observation mission launched in LEO orbit to monitor aerosols, dust. Green house gases. Launch window in 2019

MBRSC PASSIVE HOUSING

An -energy plus house that provides sustainability and uses smart technologies and sensors, innovative techniques for wall insulation...

NAYIF-1

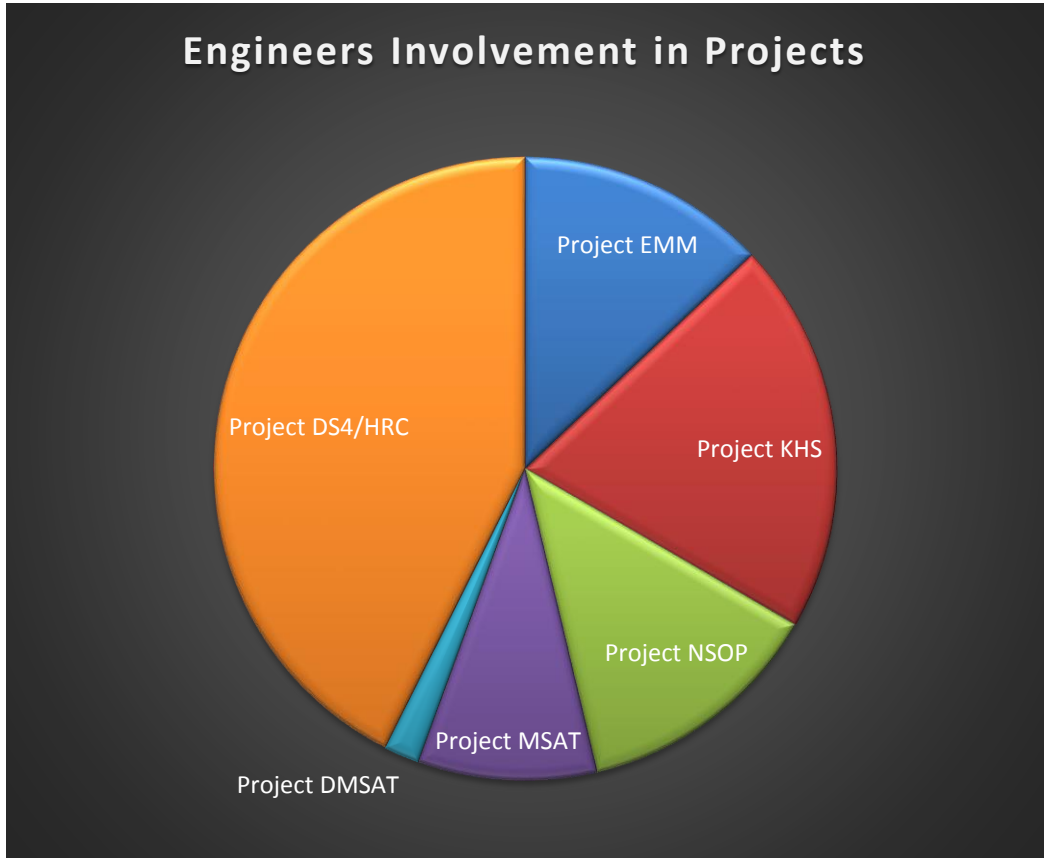
Nayif-1 is the first Nanosatellite that provides scientific and practical training for engineering students in the field of space science and advanced technology...

Dubai International Airport Taken by DubaiSat-2

Abu Dhabi International Airport Taken by Khalifasat

Abu Dhabi International Airport Taken by Khalifasat

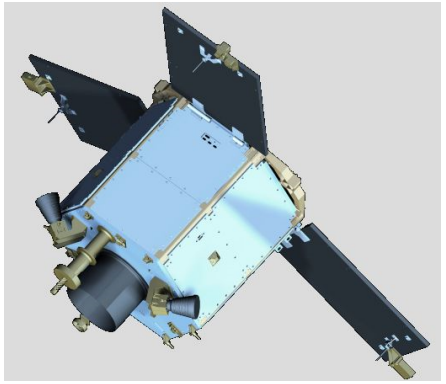

مختبرات تقنيات الفضاء
SPACE TECHNOLOGIES LABORATORIES
مركز محمد بن راشد للفضاء
MOHAMMED BIN RASHID SPACE CENTRE



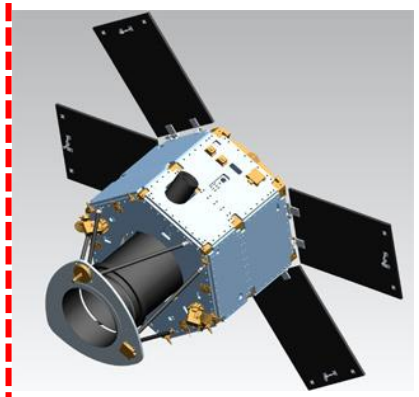
CAN Bus is a key element in the MBRSC's success story

DubaiSat System Architecture

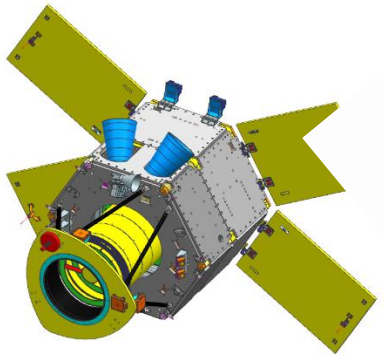
Point-to-Point System



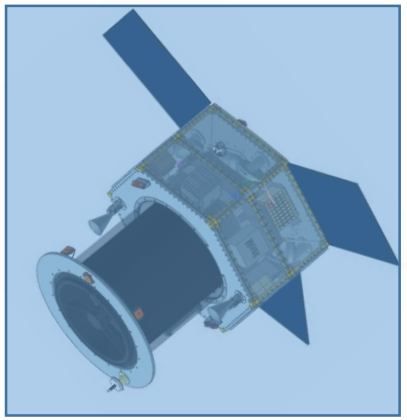
DubaiSat-1



DubaiSat-2



KhalifaSat
(Used to be DubaiSat-3)



DubaiSat
(Not Officially Announced yet)

CAN-Bus System

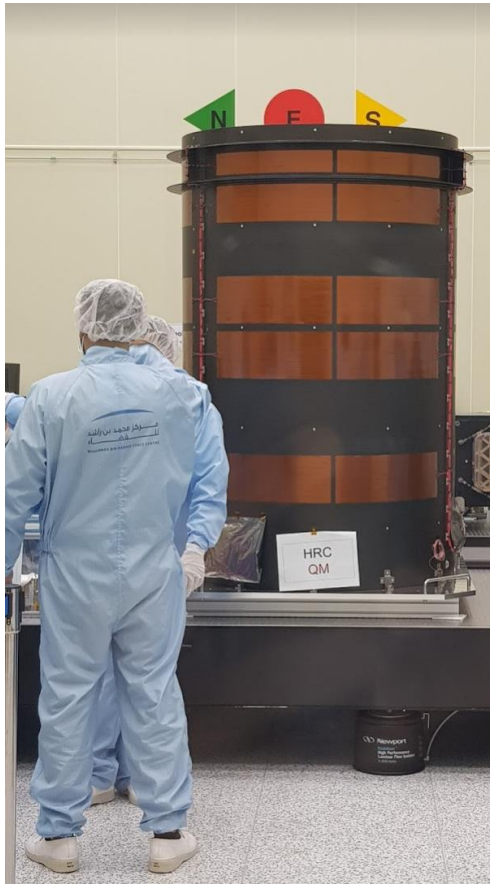
GSD = 2.5m	GSD = 1m	GSD = 0.7m	GSD = <0.3m
32Gbit	256Gbit	512Gbit	8 TBit
X-band 33Mbps	X-band 160Mbps	X-band 320Mbps	X-Band 1.2Gbps
<200kg	<300kg	<330Kg	<700kg
July 2009	Nov 2013	Oct 2018	Q3 2023

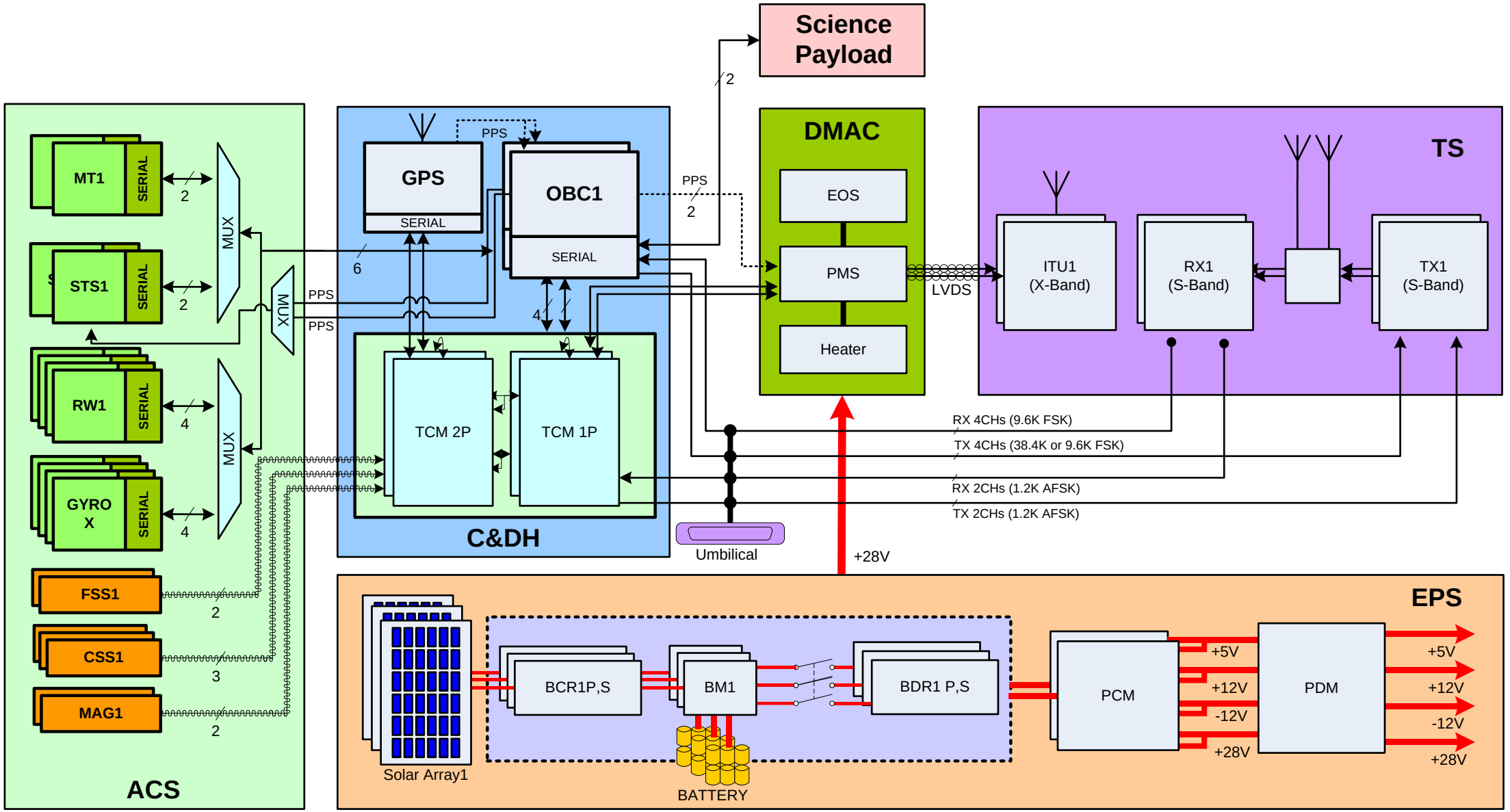
DubaiSat System Architecture

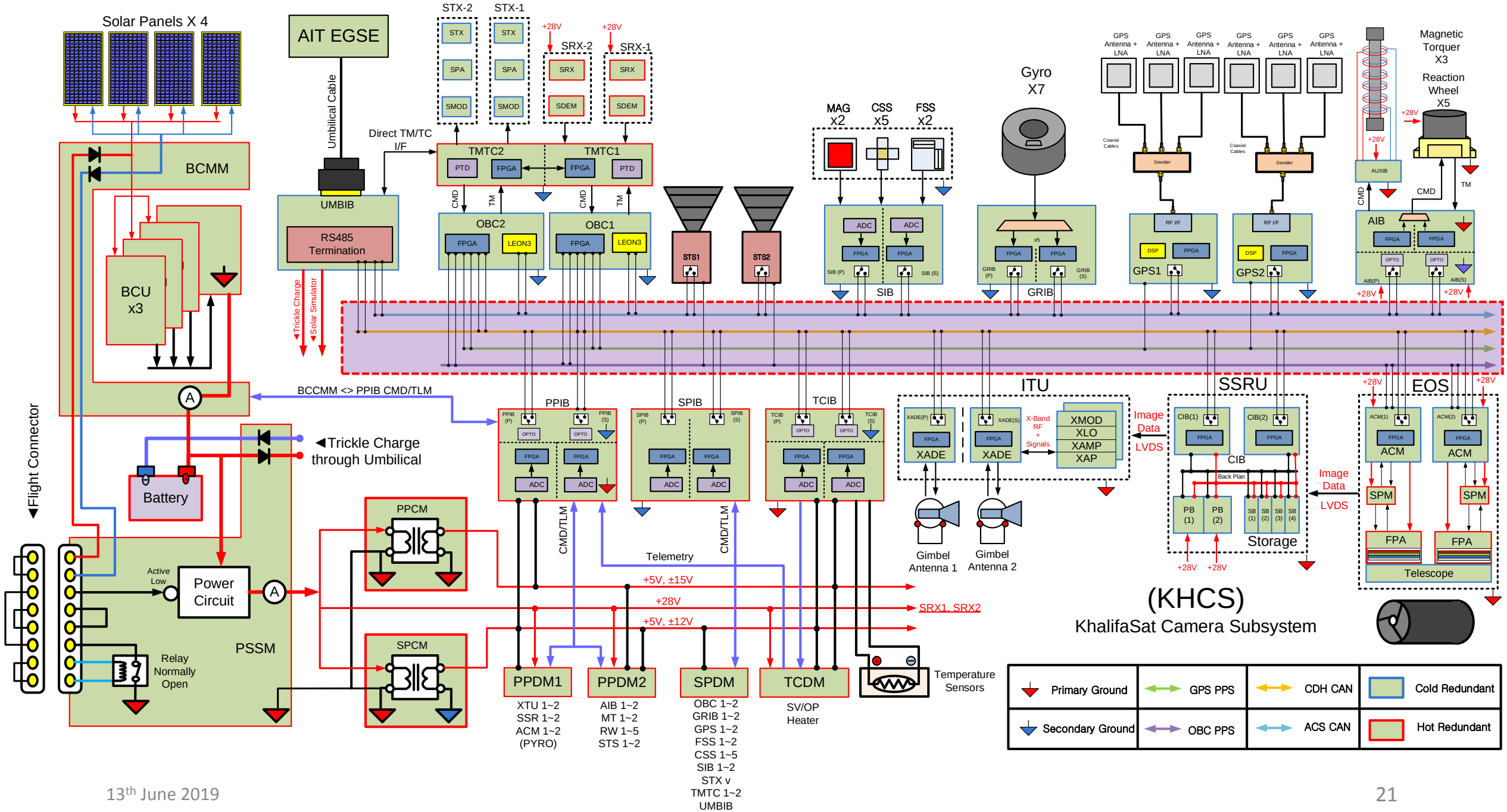
- CAN-Bus (2.0B) was first introduced in DubaiSat-2
- Flexible, reliable and easy to implement
- Two CAN Bus Interfaces for C&DH and ADCS Systems
- Both C&DH and ADCS CAN Bus have cold Redundancy
- 20 CAN-Bus active Nodes.
- Only 3 Type of CAN Bus circuits are made
- Speed of 500kbps (CAN 2.0B)
- Simple Protocol for Telecommand and Telemetry
- Note: These are exact the same system features for DS2, KHS and DS4

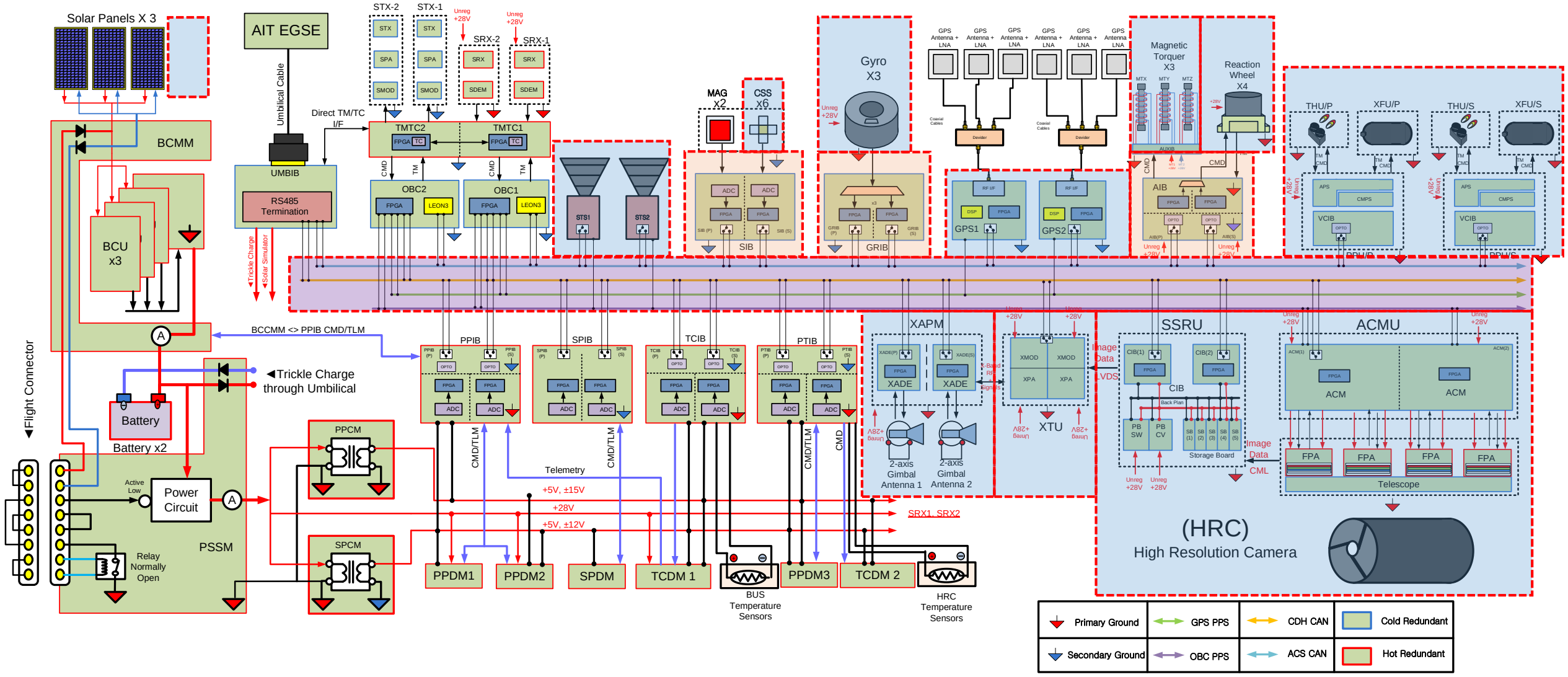
DubaiSat System Architecture

- DubaiSat-2 and Khalifasat and upcoming missions are all based on high resolution payloads
- Bus system evolved in performance to Match and support the specs of the Payload.
- Each system required different Data throughput, command and telemetry. Still the Specs shown before can handle such mission.




Science Payload
DMAC
EOS
PMS
Heater
TS
ITU1 (X-Band)
RX1 (S-Band)
TX1 (S-Band)
LVDS
GPS
SERIAL
OBC1
SERIAL
PPS
C&DH
TCM 2P
TCM 1P
MUX
MT1
STS1
RW1
GYRO X
FSS1
CSS1
MAG1
ACS
RX 4CHs (9.6K FSK)
TX 4CHs (38.4K or 9.6K FSK)
RX 2CHs (1.2K AFSK)
TX 2CHs (1.2K AFSK)
Umbilical
+28V
EPS
Solar Array1
BCR1P,S
BM1
BDR1 P,S
BATTERY
PCM
PDM
+5V
+12V
-12V
+28V

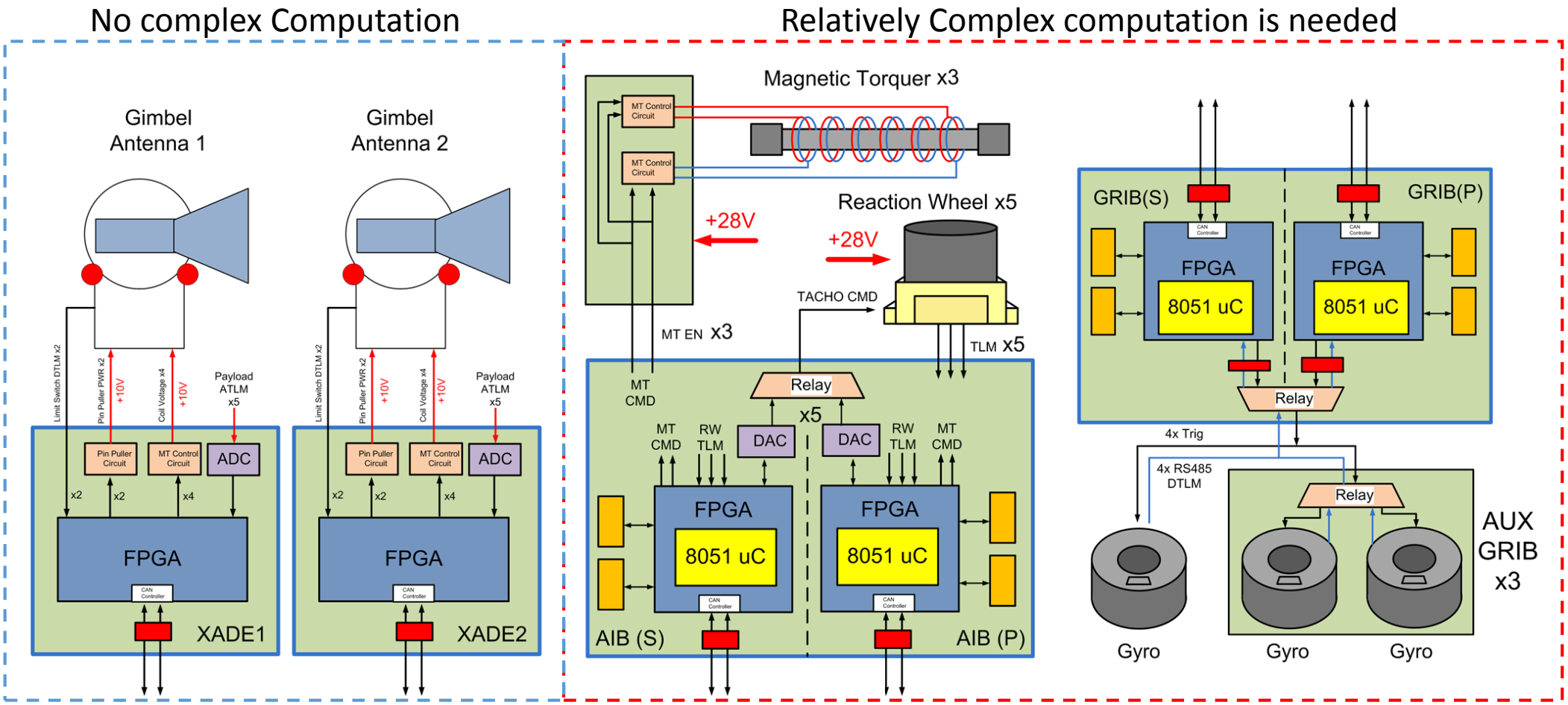

Solar Panels X 4
AIT EGSE
Umbilical Cable
STX-2
STX-1
SRX-2
SRX-1
+28V
Direct TM/TC I/F
BCMM
BCU x3
UMBIB
RS485 Termination
TMTC2
TMTC1
PTD
FPGA
STX
SPA
SMOD
SRX
SDEM
CMD
TM
OBC2
OBC1
LEON3
Trickle Charge
Solar Simulator
STS1
STS2
MAG x2
CSS x5
FSS x2
ADC
SIB
Gyro X7
GRIB
GPS Antenna + LNA
Coaxial Cables
Devider
RF I/F
DSP
GPS1
GPS2
Magnetic Torquer X3
Reaction Wheel X5
AUXIB
AIB
OPTO
AIB(P)
AIB(S)
BCCMM <> PPIB CMD/TLM
PPIB
SPIB
TCIB
◄Trickle Charge through Umbilical
Battery
Flight Connector
Active Low
Power Circuit
Relay Normally Open
PSSM
PPCM
SPCM
CMD/TLM
Telemetry
+5V, ±15V
+28V
+5V, ±12V
SRX1, SRX2
PPDM1
XTU 1~2
SSR 1~2
ACM 1~2
(PYRO)
PPDM2
AIB 1~2
MT 1~2
RW 1~5
STS 1~2
SPDM
OBC 1~2
GRIB 1~2
GPS 1~2
FSS 1~2
CSS 1~5
SIB 1~2
STX v
TMTC 1~2
UMBIB
TCDM
SV/OP Heater
Temperature Sensors
ITU
XADE(P)
XADE(S)
XADE
X-Band RF + Signals
XMOD
XLO
XAMP
XAP
Gimbel Antenna 1
Gimbel Antenna 2
Image Data LVDS
SSRU
CIB(1)
CIB(2)
CIB
Back Plan
PB (1)
PB (2)
SB (1)
SB (2)
SB (3)
SB (4)
Storage
EOS
ACM(1)
ACM(2)
ACM
SPM
FPA
Telescope
(KHCS)
KhalifaSat Camera Subsystem
Primary Ground
Secondary Ground
GPS PPS
OBC PPS
CDH CAN
ACS CAN
Cold Redundant
Hot Redundant


Solar Panels X 3
AIT EGSE
Umbilical Cable
UMBIB
RS485 Termination
Direct TM/TC I/F
STX-2
STX-1
SRX-2
SRX-1
Unreg +28V
STX
SPA
SMOD
SRX
SDEM
TMTC2
TMTC1
FPGA
TC
CMD
TM
OBC2
OBC1
LEON3
STS1
STS2
MAG x2
CSS x6
ADC
SIB
Gyro X3
GRIB
GPS Antenna + LNA
Coaxial Cables
Divider
GPS1
GPS2
RF I/F
DSP
Magnetic Torquer X3
MTX
MTY
MTZ
AUXIB
Reaction Wheel X4
AIB
THU/P
XFU/P
THU/S
XFU/S
APS
CMPS
VCIB
PDHU/P
PDHU/S
BCMM
BCU x3
Trickle Charge
Solar Simulator
BCCMM <> PPIB CMD/TLM
PPIB
SPIB
TCIB
PTIB
CMD/TLM
CMD
Telemetry
+5V, ±15V
+28V
+5V, ±12V
SRX1, SRX2
PPDM1
PPDM2
SPDM
TCDM 1
PPDM3
TCDM 2
BUS Temperature Sensors
HRC Temperature Sensors
XAPM
XADE
2-axis Gimbal Antenna 1
2-axis Gimbal Antenna 2
XMOD
XPA
XTU
SSRU
CIB
Back Plan
PB SW
PB CV
SB
Storage Board
ACMU
ACM
FPA
Telescope
Image Data LVDS
Image Data CML
(HRC)
High Resolution Camera
Flight Connector
Trickle Charge through Umbilical
Battery
Battery x2
Active Low
Power Circuit
Relay Normally Open
PSSM
PPCM
SPCM
Primary Ground
Secondary Ground
GPS PPS
OBC PPS
CDH CAN
ACS CAN
Cold Redundant
Hot Redundant

DubaiSat System Architecture

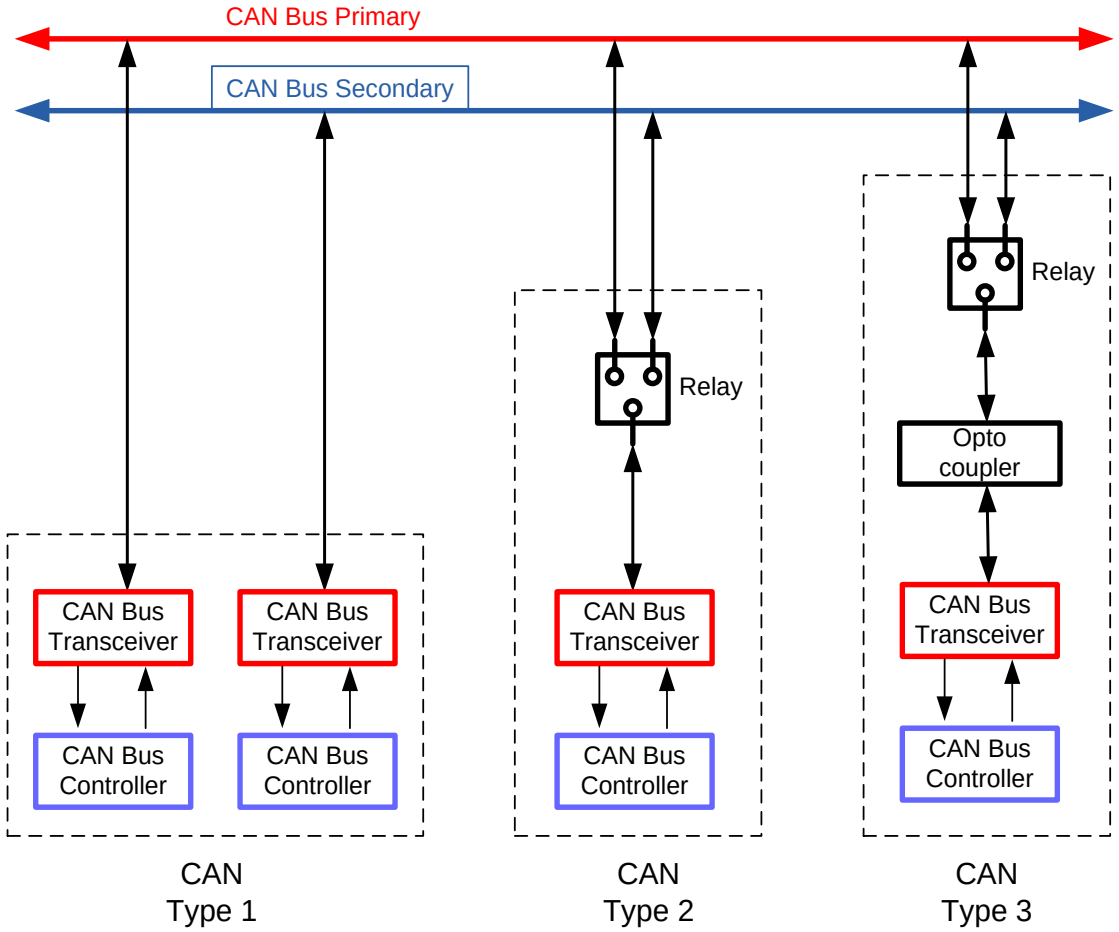
- How we were able to achieve this:
- CAN Bus Interface is a requirement in every mission.
- CAN Bus meets both early Data flow analysis at early design stage and meet the operation during Ground testing.
- CAN Nodes with higher data requirements are moved to Less busy bus.
- Commands/telemetry are used in an efficient way.
- Investment into EGSE, Software development, hours of Establishing robust FMECA all point toward using CAN Bus Again.
- Vendors negotiations always include request to have CAN-Bus Data interface (CAN2.0B).
- We support Vendors implement CAN-Bus (Joint Development)
- For off the shelf components that are not CAN-Bus compatible we develop an interface board. Or if the Price for adaptation is too high.

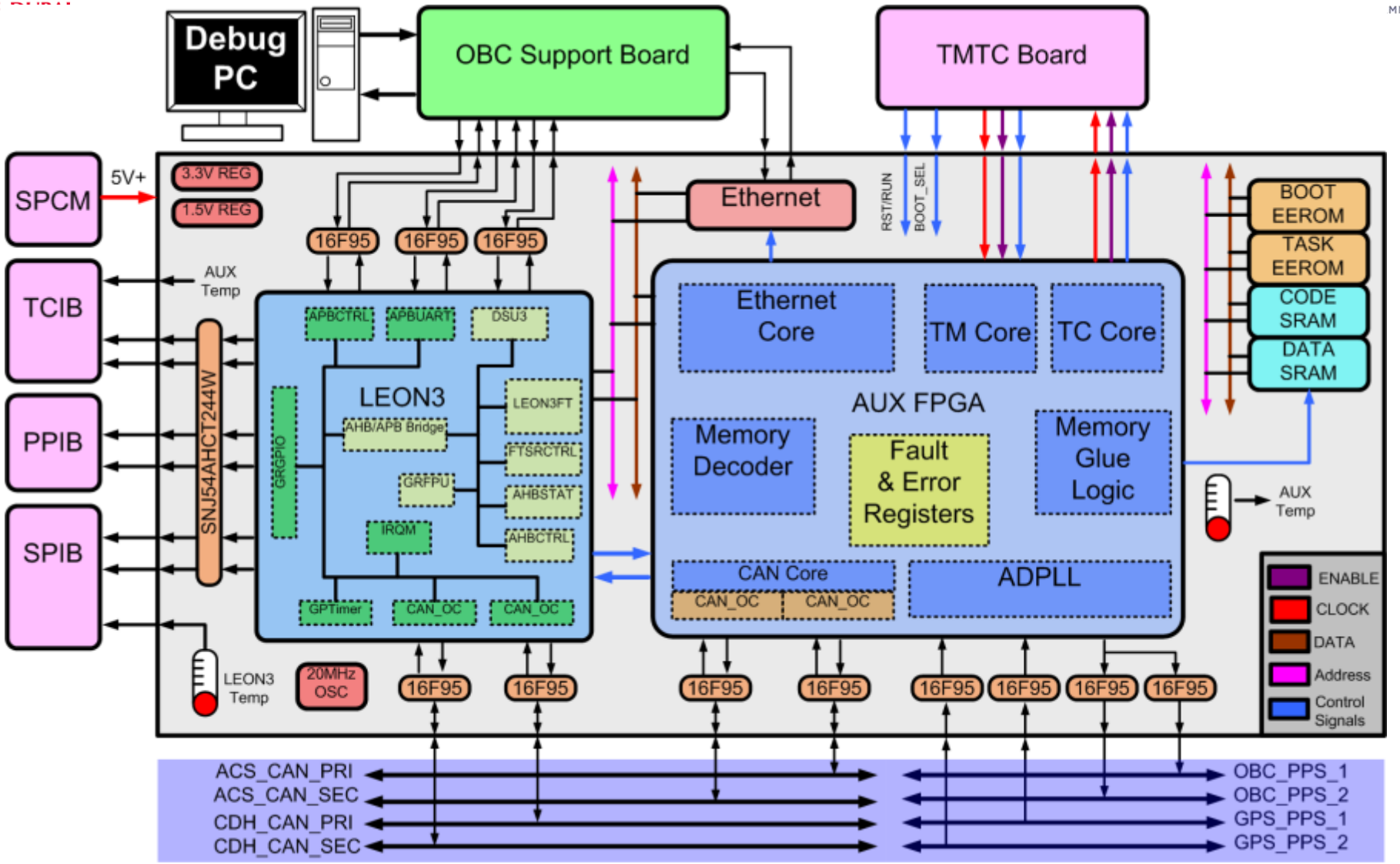
DubaiSat System Architecture



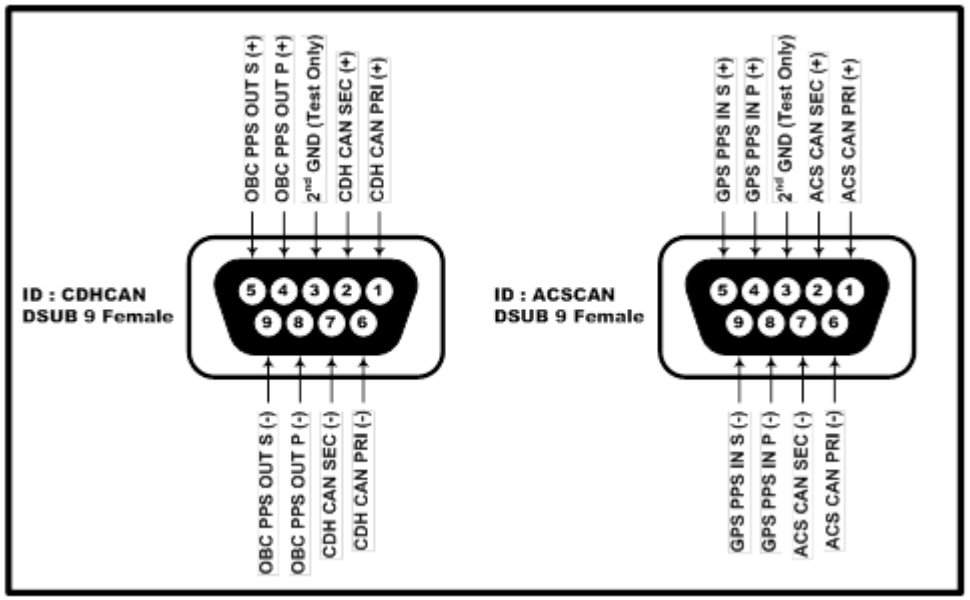
DubaiSat System Architecture

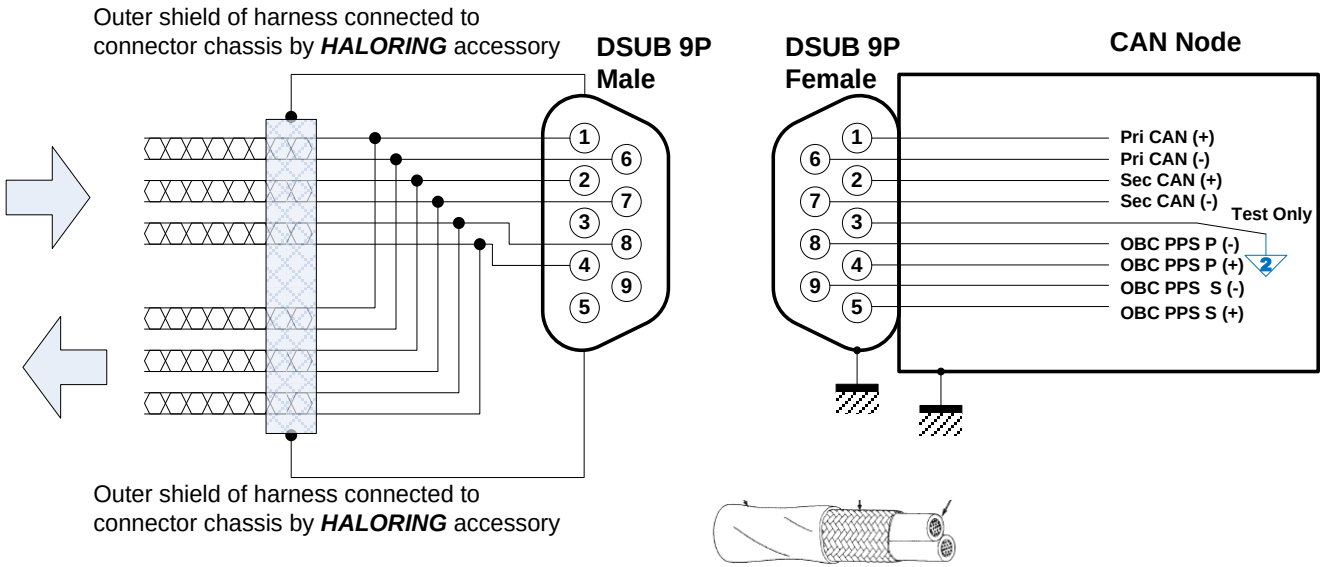
- Limit the Design of CAN Bus circuit to only three to limit issues of compatibility.
- On Board computer (OBC) One Master controlling the Network.
- Each Node can connect to either CAN Bus (Primary or redundant)
- System auto Detect failure in communication and re-configure the system to change from Primary to redundant CAN Bus.



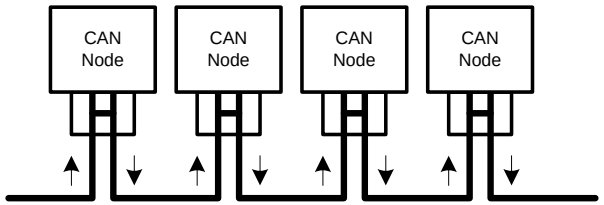

Debug PC
OBC Support Board
TMTC Board
SPCM
5V+
3.3V REG
1.5V REG
TCIB
PPIB
SPIB
AUX Temp
SNJ54AHCT244W
16F95
Ethernet
RST/RUN
BOOT_SEL
BOOT EEROM
TASK EEROM
CODE SRAM
DATA SRAM
APBCTRL
APBUART
DSU3
LEON3
AHB/APB Bridge
GRGPIO
LEON3FT
FTSRCTRL
GRFPU
AHBSTAT
IRQM
AHBCTRL
GPTimer
CAN_OC
Ethernet Core
TM Core
TC Core
AUX FPGA
Memory Decoder
Fault & Error Registers
Memory Glue Logic
CAN Core
ADPLL
LEON3 Temp
20MHz OSC
ENABLE
CLOCK
DATA
Address
Control Signals
ACS_CAN_PRI
ACS_CAN_SEC
CDH_CAN_PRI
CDH_CAN_SEC
OBC_PPS_1
OBC_PPS_2
GPS_PPS_1
GPS_PPS_2

DubaiSat System Architecture



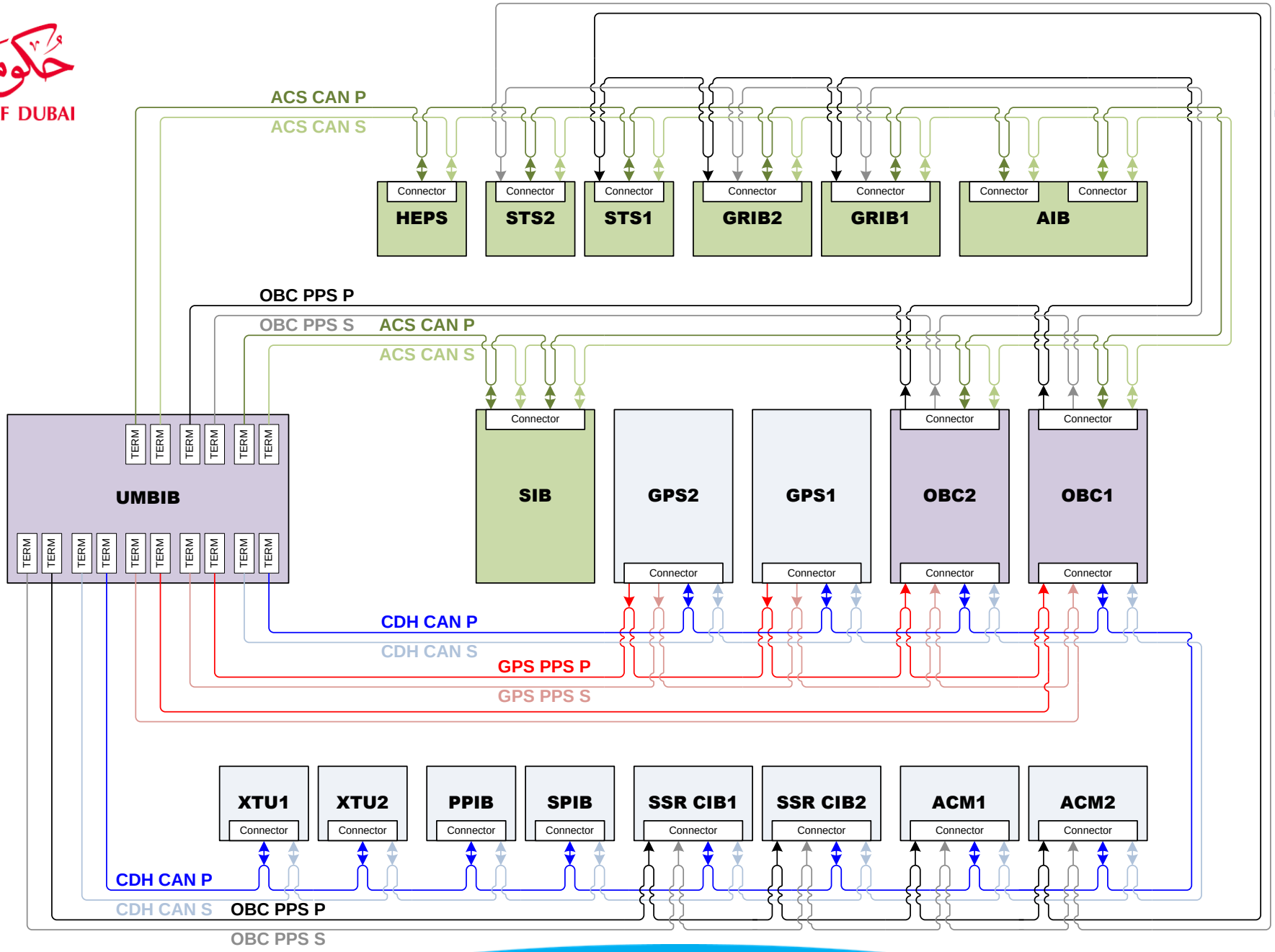


Setting Rules in the Electrical interface document is important



Can Network Configuration

- **Harness** : Use three single pair shielded cables manufactured by RAYCHEM
- Can network must not be disconnected without CAN node.


ACS CAN P
ACS CAN S
Connector
HEPS
STS2
STS1
GRIB2
GRIB1
AIB
OBC PPS P
OBC PPS S
ACS CAN P
ACS CAN S
UMBIB
TERM
SIB
GPS2
GPS1
OBC2
OBC1
CDH CAN P
CDH CAN S
GPS PPS P
GPS PPS S
XTU1
XTU2
PPIB
SPIB
SSR CIB1
SSR CIB2
ACM1
ACM2
CDH CAN P
CDH CAN S
OBC PPS P
OBC PPS S

CAN Bus Protocol

- Protocol is simple to implement
- Implementation of the protocol is left not to the controller but to the logic interfacing with the controller:
  - Processor (example Onboard computer or Solid state Recorder)
  - Micro-controller (example GPS, or Gyro Control or Reaction wheel control)
  - FPGA (example: Power Interface Boards)

Arbitration Field (29 bits)					Control Field	Data Field
DA(7)	SA(7)	Frame Type(5)	Sub Frame Type(7)	Task ID(3)	DLC(4)	Data(Max. 64)

Two Ways to send telecommand and receive telemetry:

- **STSR** (Single transmission Single Reply)
  - Example: turn ON/OFF Module, Set Frequency
- **STMR** (Single Transmission Multi-reply)
  - Example: Gather Telemetry from a Node, Gather Ancillary Data from GPS
-

Arbitration Field (29 bits)					Control Field	Data Field
DA(7)	SA(7)	Frame Type(5)	Sub Frame Type(7)	Task ID(3)	DLC(4)	Data(Max. 64)

Field Name	(bits)	Description
DA	7	It is abbreviation for Destination Address
SA	7	It is abbreviation for Source Address
Frame Type	5	It specifies the type of frame
Sub Frame Type	7	It is used to provide additional information about the frame type. It is only applied some specific frame type like PMC and MDT. (Ex. It is used to contains PMC index for PMC frame type)
Task ID	3	It is used to deliver the received frame to specific task on multi-tasking system. Therefore, this field only applies to the system which has OS.
DLC	4	It is abbreviation for Data Length Count. It is used to indicate the number of valid data in data field.

TRx Type	Frame Type	Frame No.	Description
STSR	NMT Request	0x001	Node Monitoring, Bus Switching
	NMT Reply	0x002	Reply NMT
	B-CMD	0x003	Bi-Level Command
	B-CMD Reply	0x004	Bi-Level Command Reply
	Reserved	0x005	
	Reserved	0x006	
	TLM Request	0x007	Telemetry Request
	TLM Reply	0x008	Telemetry Reply.
	TLM NAK	0x009	To notify invalid PMC index
	G-CMD	0x00A	General Command
	G-CMD Reply	0x00B	General Command Reply
	Bootload CMD	0x00C	Bootload Command
	Bootload CMD Reply	0x00D	Bootload Command Reply
STMR	M-CMD	0x00E	Multiple Packet Request Command
	M-CMD Reply	0x00F	Multiple Packet Command Reply
	Reserved	0x012-0x01F	

CAN Bus Protocol

- CAN Bus is used for all commands in the satellite except for few commands that are executed in Bi-Level (0~5V).
- CAN Bus is used for Payload:
  - Upload the best compression algorithm and compression table to the Video Signal Processers (VSPs)
  - Update the Gain, Offset and other parameters of the Sensors.
  - Update VSP parameters.
  - Imaging command, Image Stopping Command, image Storing…etc
  - Telemetry gathering from Payload (Current, Temperature…etc)
  - Control the Solid state Recorder and re-configure it.
  - Store Attitude Control information into the Captured image for easy

Command

Arbitration Field (29 bits)					Control	Data Field							
DA	SA	FT	Sub FT	Task ID	DLC	D0	D1	D2	D3	D4	D5	D6	D7
ACM_ID	OBC_ID	0x0A	0x10		0x08	0x10	"0000 0" & PAN Pattern [2:0]	"0000 0"& MS1 Pattern [2:0]	"0000 0"& MS2 Pattern [2:0]	"0000 0"& MS3 Pattern [2:0]	"0000 0"& MS4 Pattern [2:0]	"0000 000" & Clk_Sel [0]	"0000 00" & CIB_Sel [1:0]

Reply

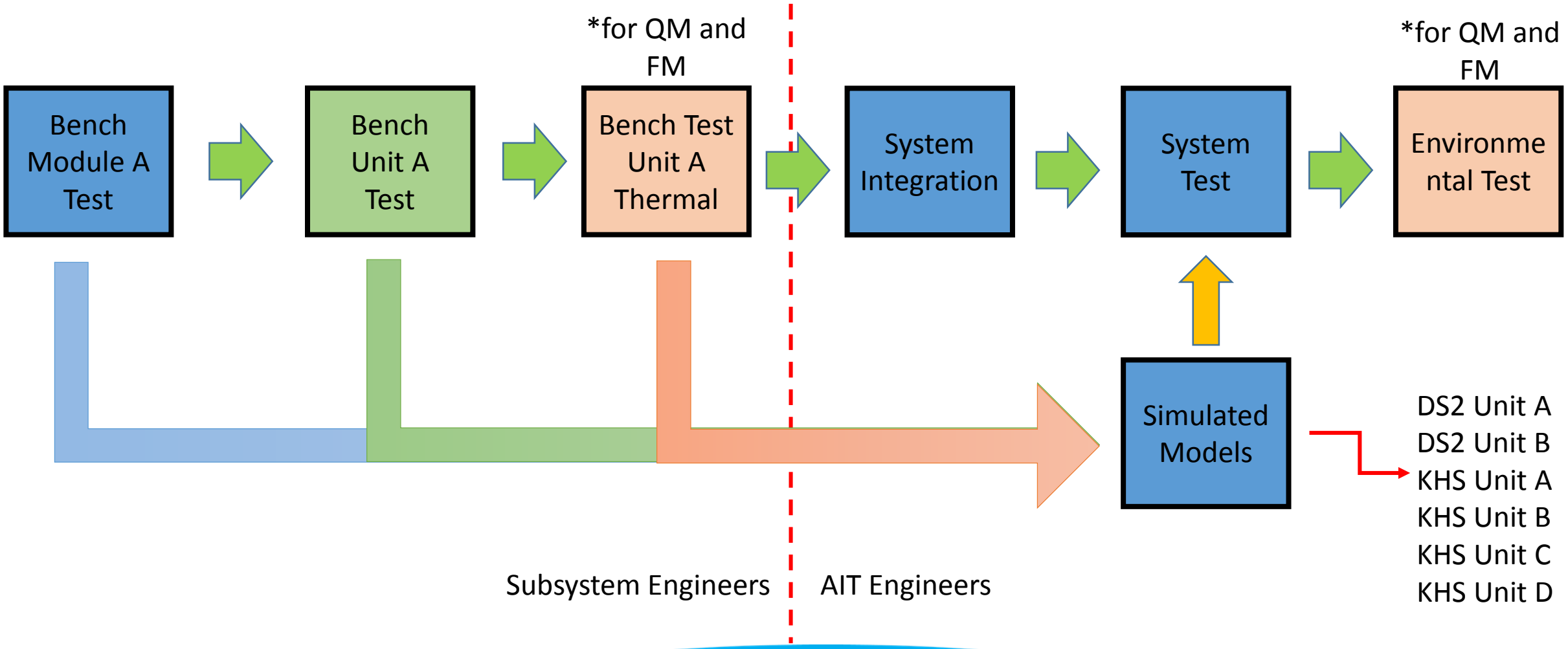
Arbitration Field (29 bits)					Control	Data Field							
OBC_ID	ACM_ID	0x0B	0x10		0x00								

General Command List
Pattern & Select Programmable Clock
Ext Programmable Clock
Reserved
Line Rate Control
VSP #1&3 Gain/Offset – PAN
VSP #5&7 Gain/Offset – PAN
VSP #9&11 Gain/Offset – PAN
VSP #13&15 Gain/Offset – PAN
VSP #17&19 Gain/Offset – PAN
VSP #21&23 Gain/Offset – PAN
VSP Gain/Offset – MS1 & MS2
VSP Gain/Offset – MS3 & MS4
TDI Step
PAN VSP CDS Control
MS VSP CDS Control
Reserved
CCD Operation Start/Stop
Image Save Start/Stop
TIME_DIFF_ACM_GET
TIME_DIFF_OBC_GET

CAN Bus Protocol

- Khalifasat CAN-Bus adaptation:
- All engineers understand the rules, regulations, CAN Controllers features, ways to send telemetry, EGSEs..etc
- We built a good experience of what could go wrong.
- All work went smoothly and we had only 2 Non-Conformance Due to CAN-Bus (Failure in Driver)
- Robust and proven technology to the point of not even considering it during issue resolving or During Non-conformance Meetings.

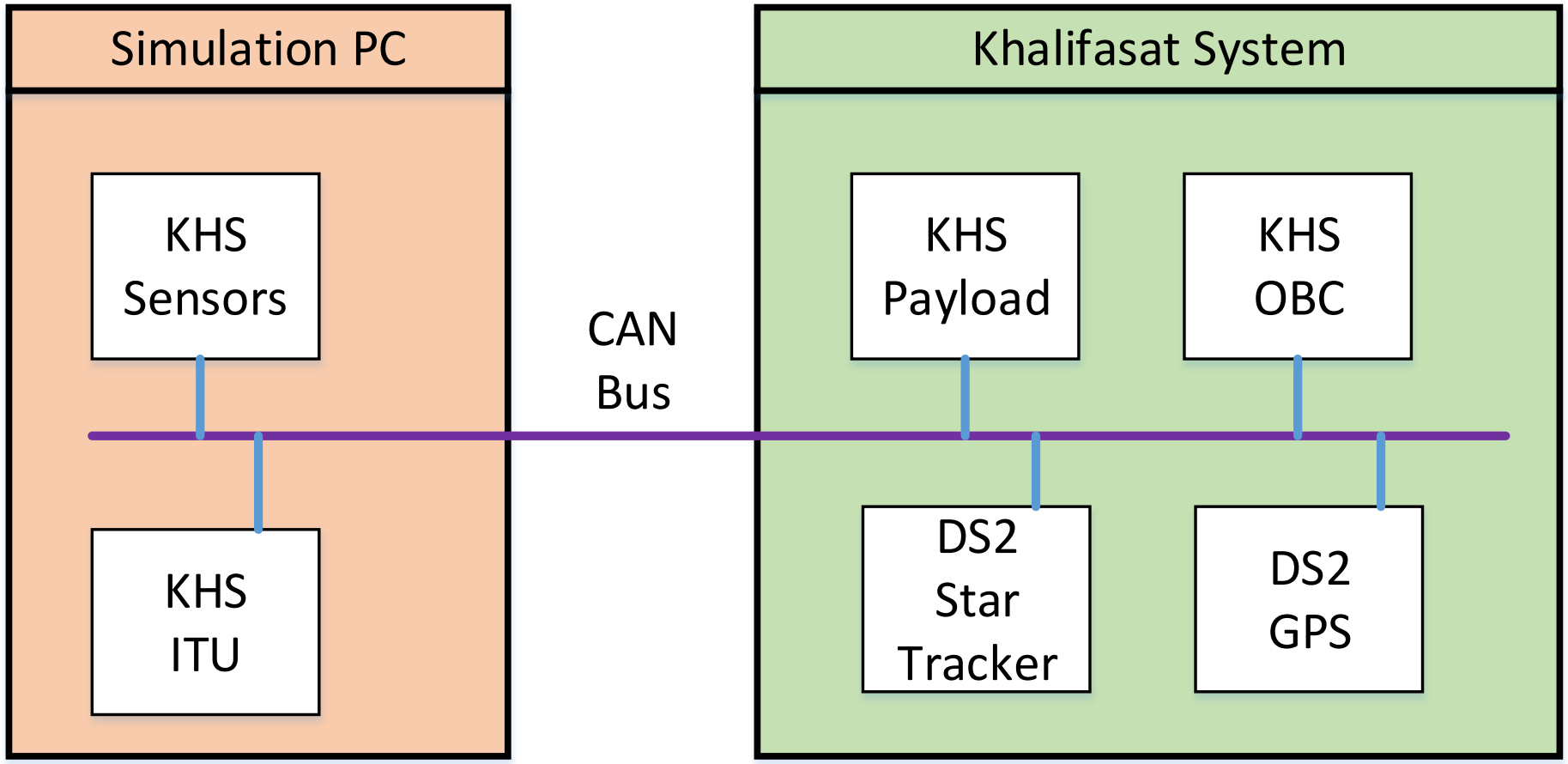
Verification



Focus performance of the Module/Unit

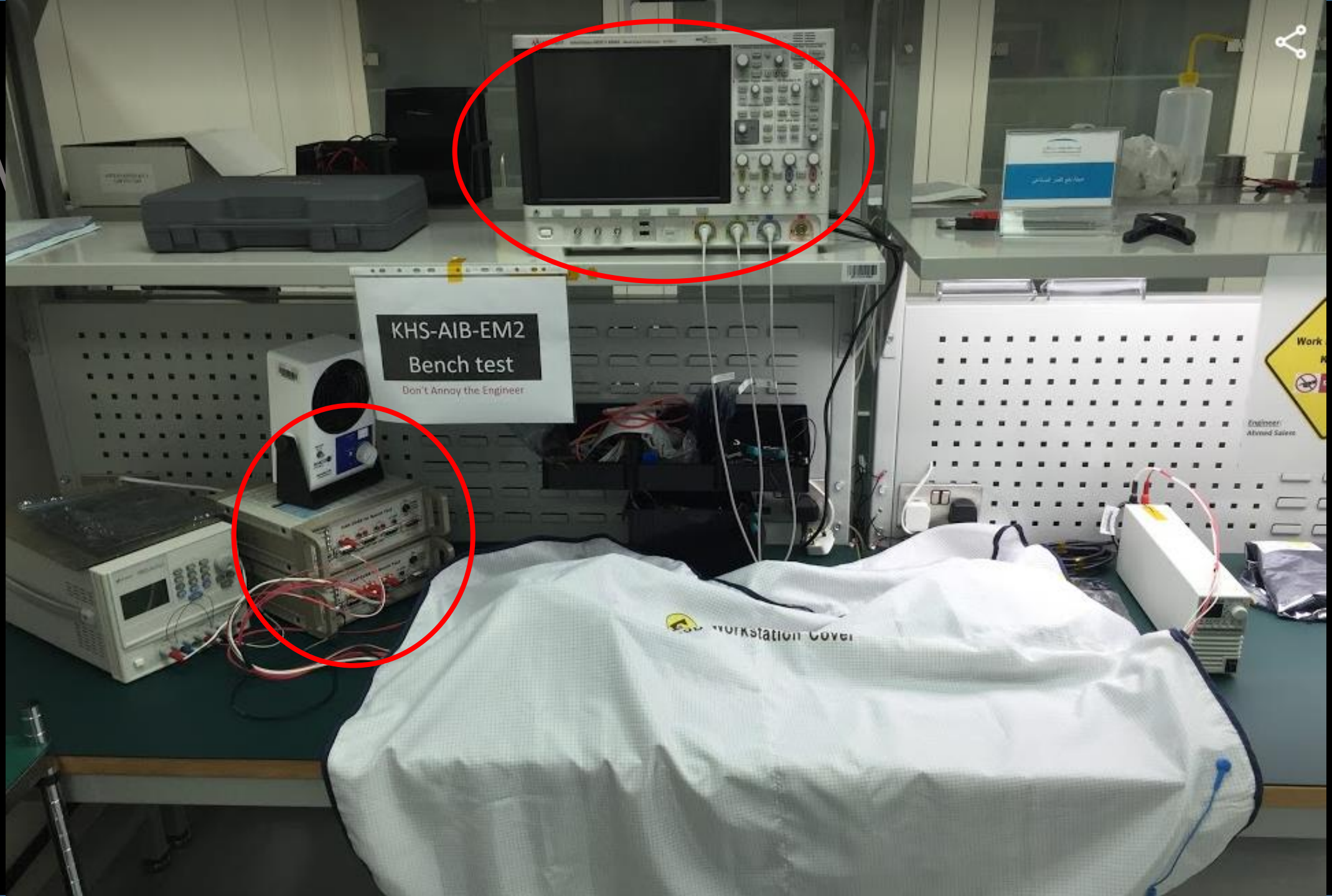
Focus performance of Whole System Verification

Verification



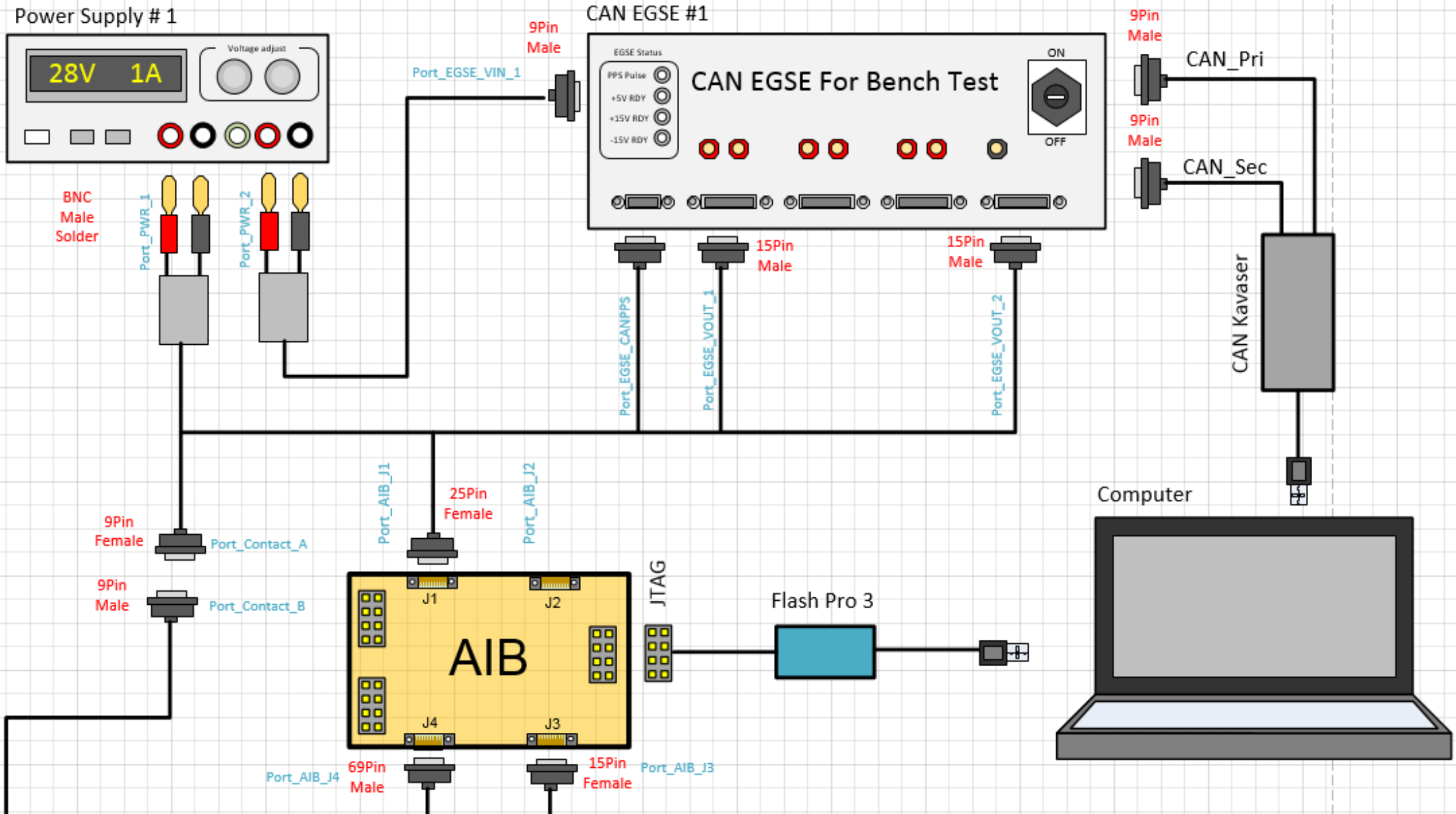
Verification

- CAN-Bus Verification is emphasis on Bench test rather than System
- We make sure that the Module/unit is tested prior to integration with the whole system.
- CAN-Bus commands that are only used during Bench test are not tested on System level. (example: PID controller testing for AIB)
- In case of comprehensive Test is required for the module due to uploading of a new software (example GPS) or due to Uploading new control Coefficients (Example PID controller for AIB) then such test can be made on system.


KHS-AIB-EM2
Bench test
Don't Annoy the Engineer

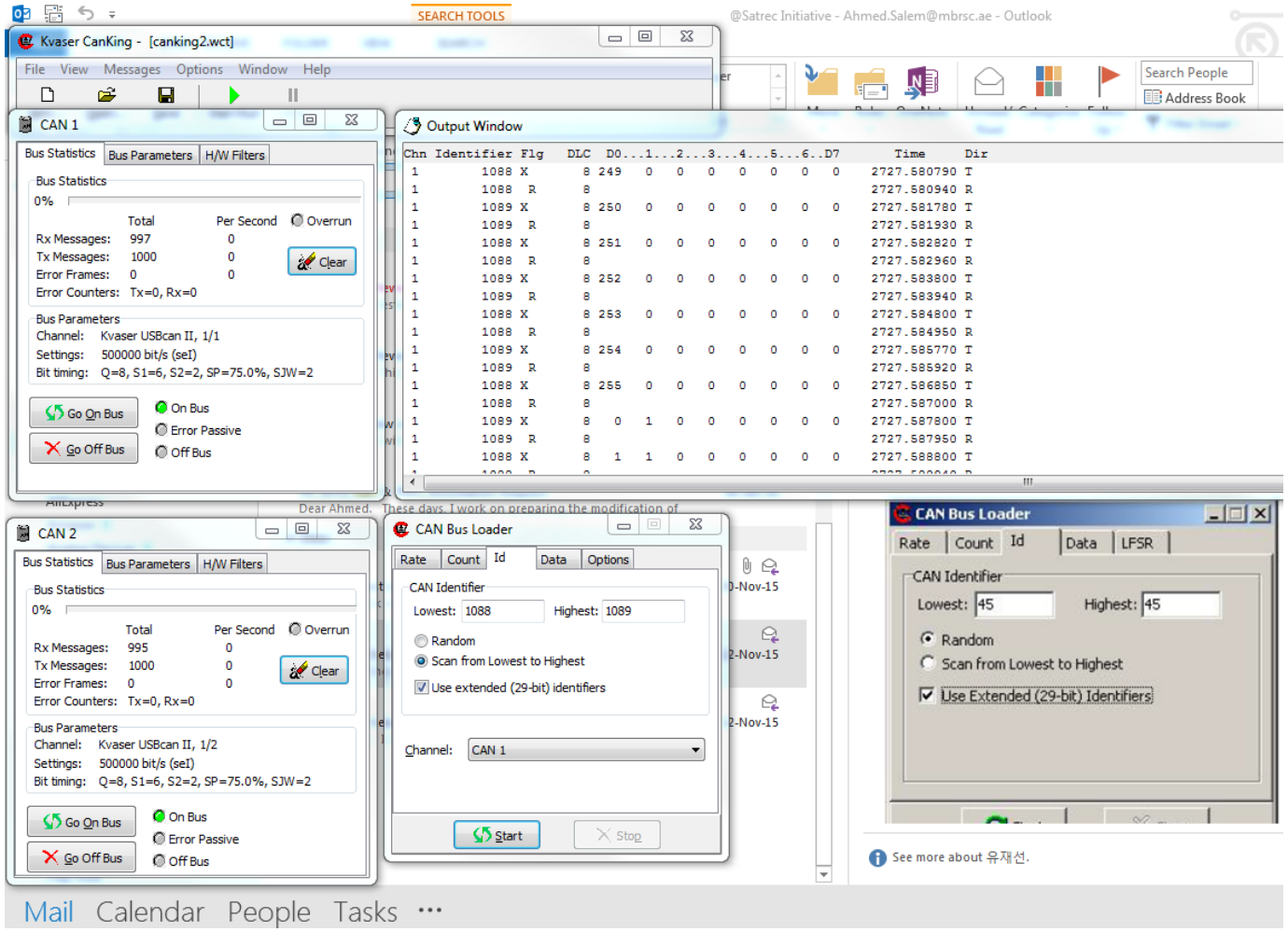
Verification

- **CAN-EGSE**
- Simple EGSE provide CAN interface with the help of CAN-KVASER CAN-to-USB Hardware to connect to PC.
- Provide PPS Signals
- Provide Power Interface +5V, ±12V, ±15V, +28V.


Power Supply # 1
28V 1A
Voltage adjust
BNC
Male
Solder
Port_PWR_1
Port_PWR_2
9Pin
Male
Port_EGSE_VIN_1
CAN EGSE #1
EGSE Status
PPS Pulse
+5V RDY
+15V RDY
-15V RDY
CAN EGSE For Bench Test
ON
OFF
9Pin
Male
CAN_Pri
9Pin
Male
CAN_Sec
CAN Kavaser
15Pin
Male
15Pin
Male
Port_EGSE_CANPPS
Port_EGSE_VOUT_1
Port_EGSE_VOUT_2
Computer
Port_AIB_J1
25Pin
Female
Port_AIB_J2
9Pin
Female
Port_Contact_A
9Pin
Male
Port_Contact_B
J1
J2
AIB
J4
J3
JTAG
Flash Pro 3
Port_AIB_J4
69Pin
Male
15Pin
Female
Port_AIB_J3

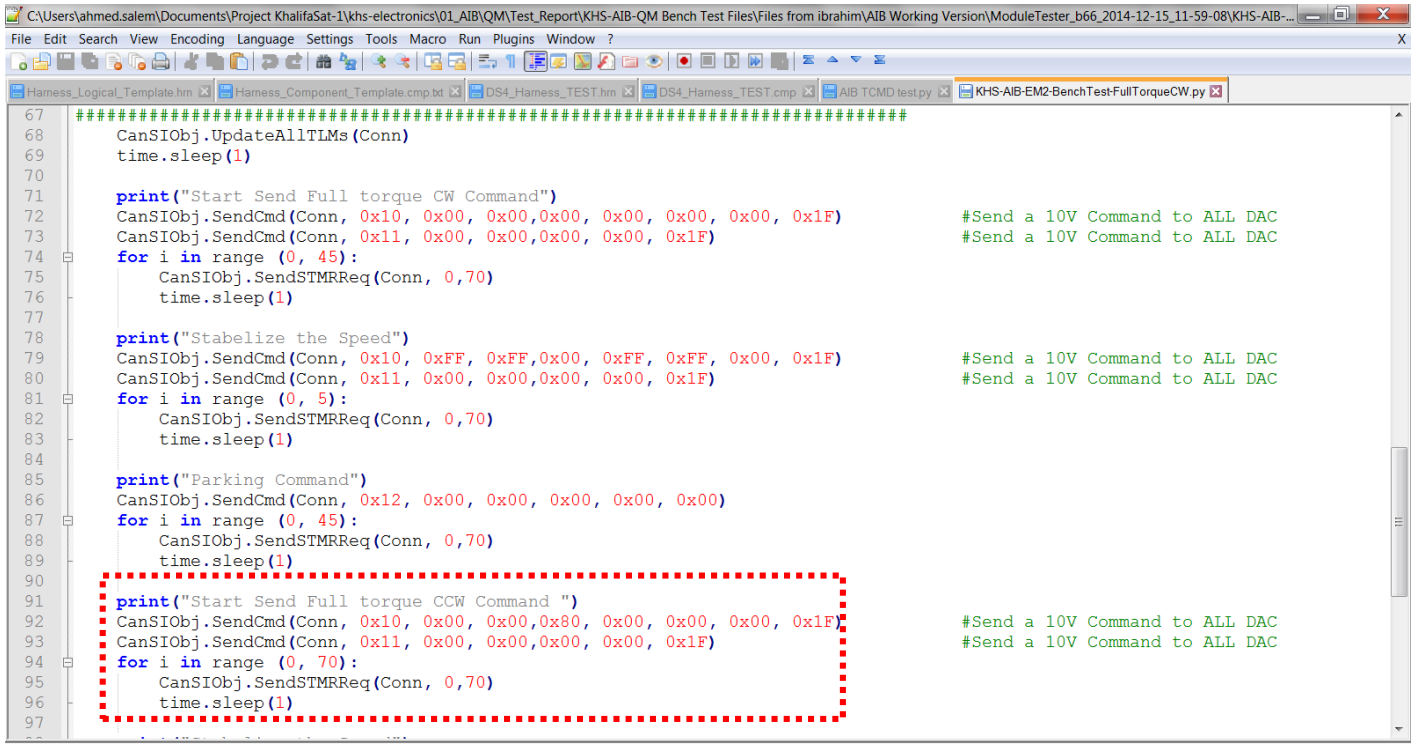
Verification

- **CAN-EGSE**
- Simple EGSE provide CAN interface with the help of CAN-KVASER CAN-to-USB Hardware to connect to PC.
- Provide PPS Signals
- Provide Power Interface +5V, ±12V, ±15V, +28V.



Verification

- **CAN-Script-Library**
- All commands are already defined in the script library and we don't have to create our own commands.
- All engineers share the same Script library however they can




```
print("Start Send Full torque CCW Command ")
CanSIObj.SendCmd(Conn, 0x10, 0x00, 0x00,0x80, 0x00, 0x00, 0x00, 0x1F)
CanSIObj.SendCmd(Conn, 0x11, 0x00, 0x00,0x00, 0x00, 0x1F)
for i in range (0, 70):
    CanSIObj.SendSTMRReq(Conn, 0,70)
    time.sleep(1)
```

Verification

- **CAN-Compatible Oscilloscope**
- Simplest way to make sure that your CAN Bus is working
- Not necessary to Engineers but it does simplify troubleshooting.

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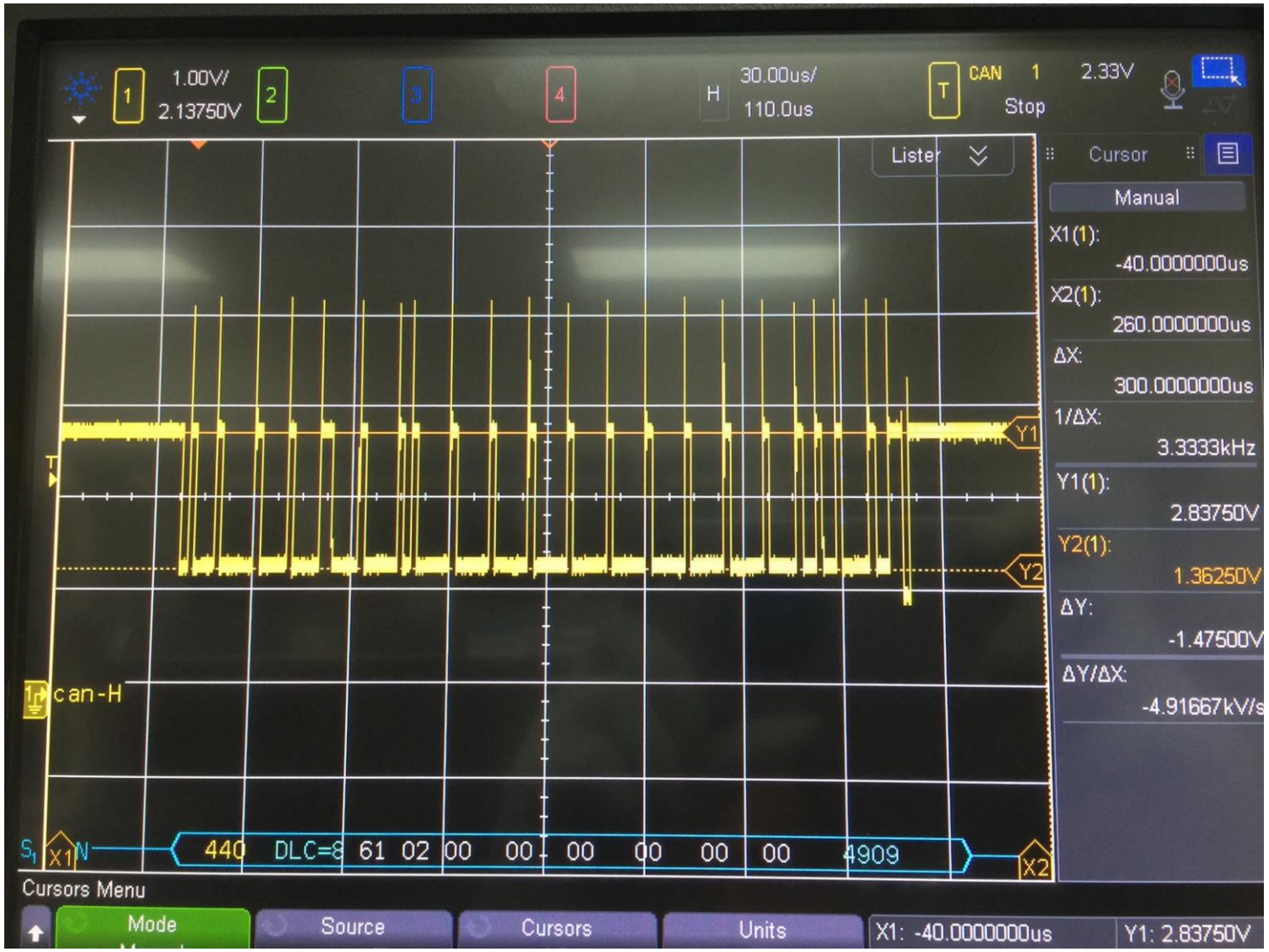
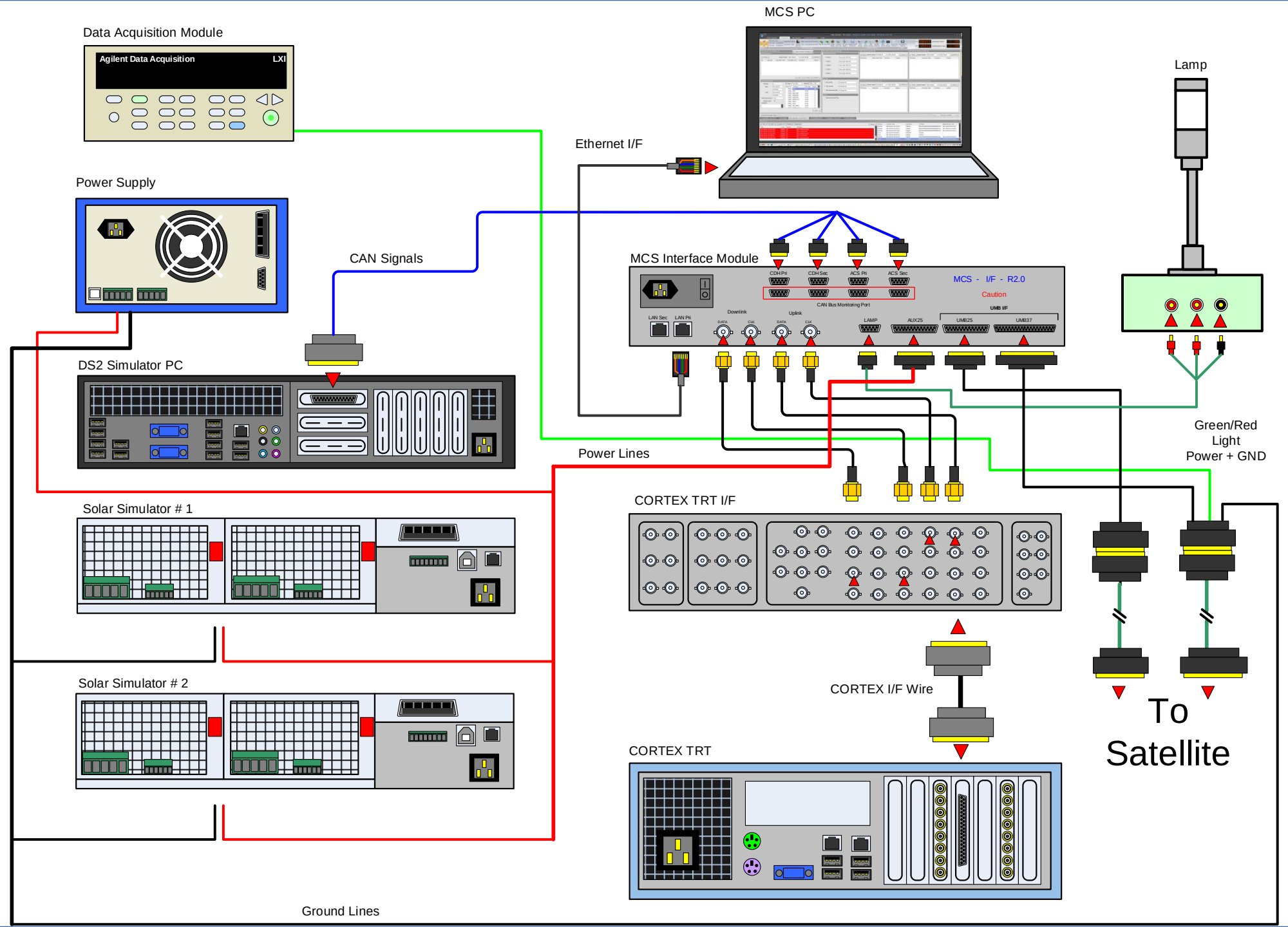
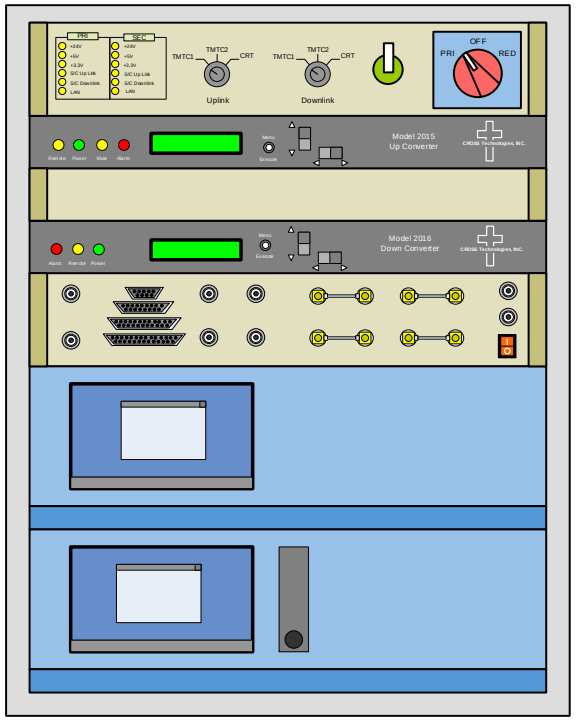


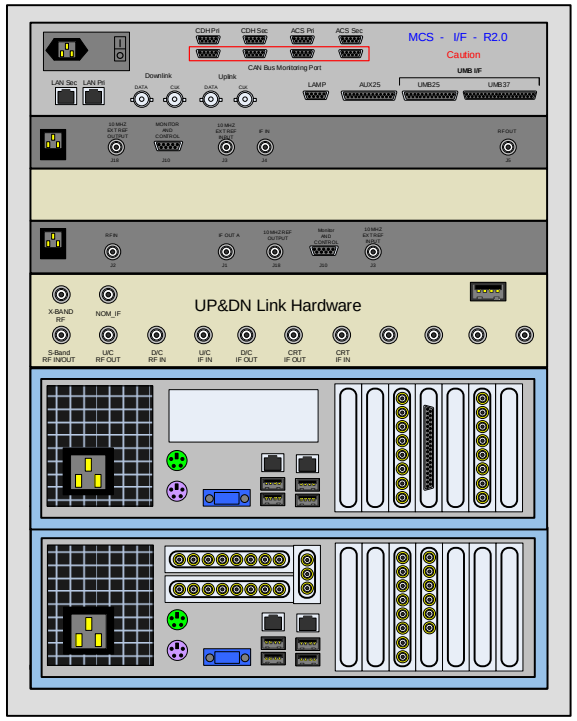

Data Acquisition Module
Agilent Data Acquisition
LXI
MCS PC
Lamp
Ethernet I/F
Power Supply
CAN Signals
MCS Interface Module
MCS - I/F - R2.0
Caution
CDH Pri
CDH Sec
ACS Pri
ACS Sec
CAN Bus Monitoring Port
Downlink
Uplink
LAN Sec
LAN Pri
LAMP
AUX25
UMB25
UMB37
DS2 Simulator PC
Green/Red
Light
Power + GND
Power Lines
Solar Simulator # 1
CORTEX TRT I/F
Solar Simulator # 2
CORTEX I/F Wire
To
Satellite
CORTEX TRT
Ground Lines

Verification

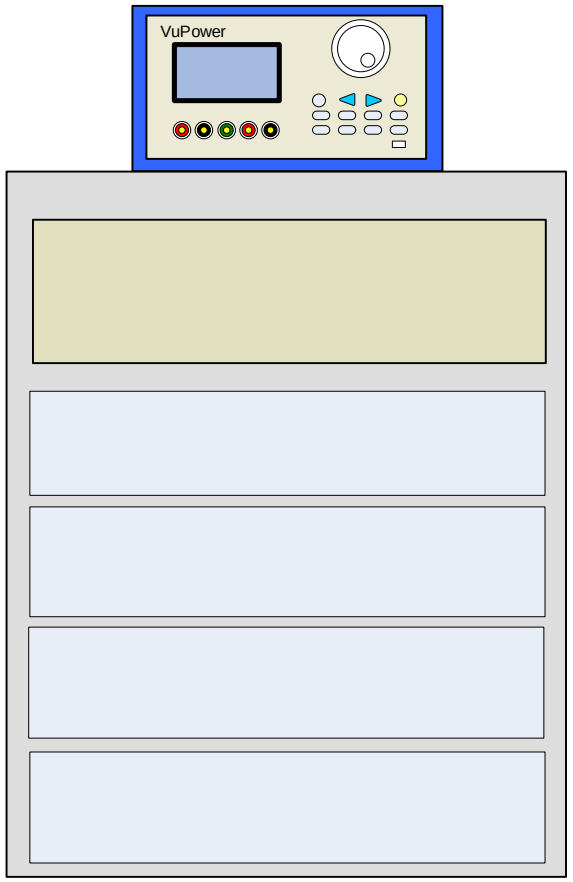
AIT EGSE RACK#1F



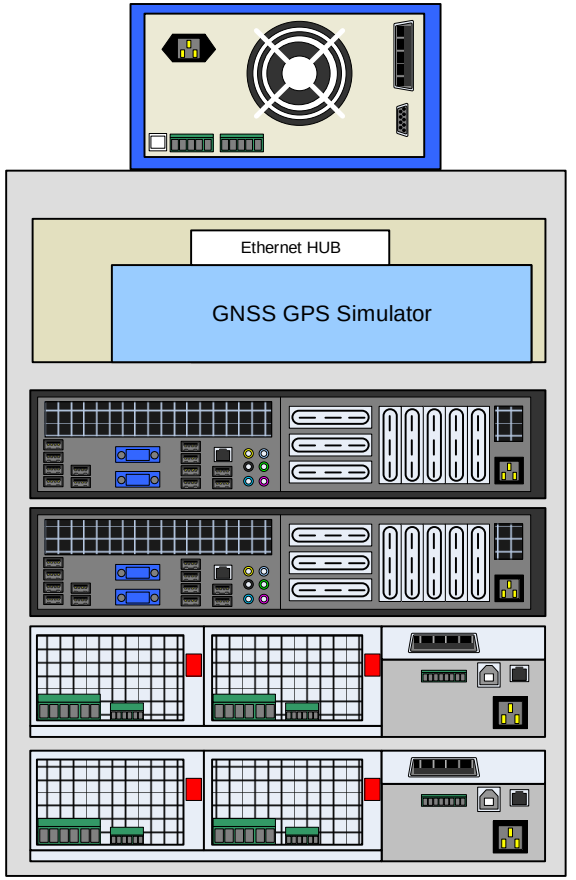
AIT EGSE RACK#1 B



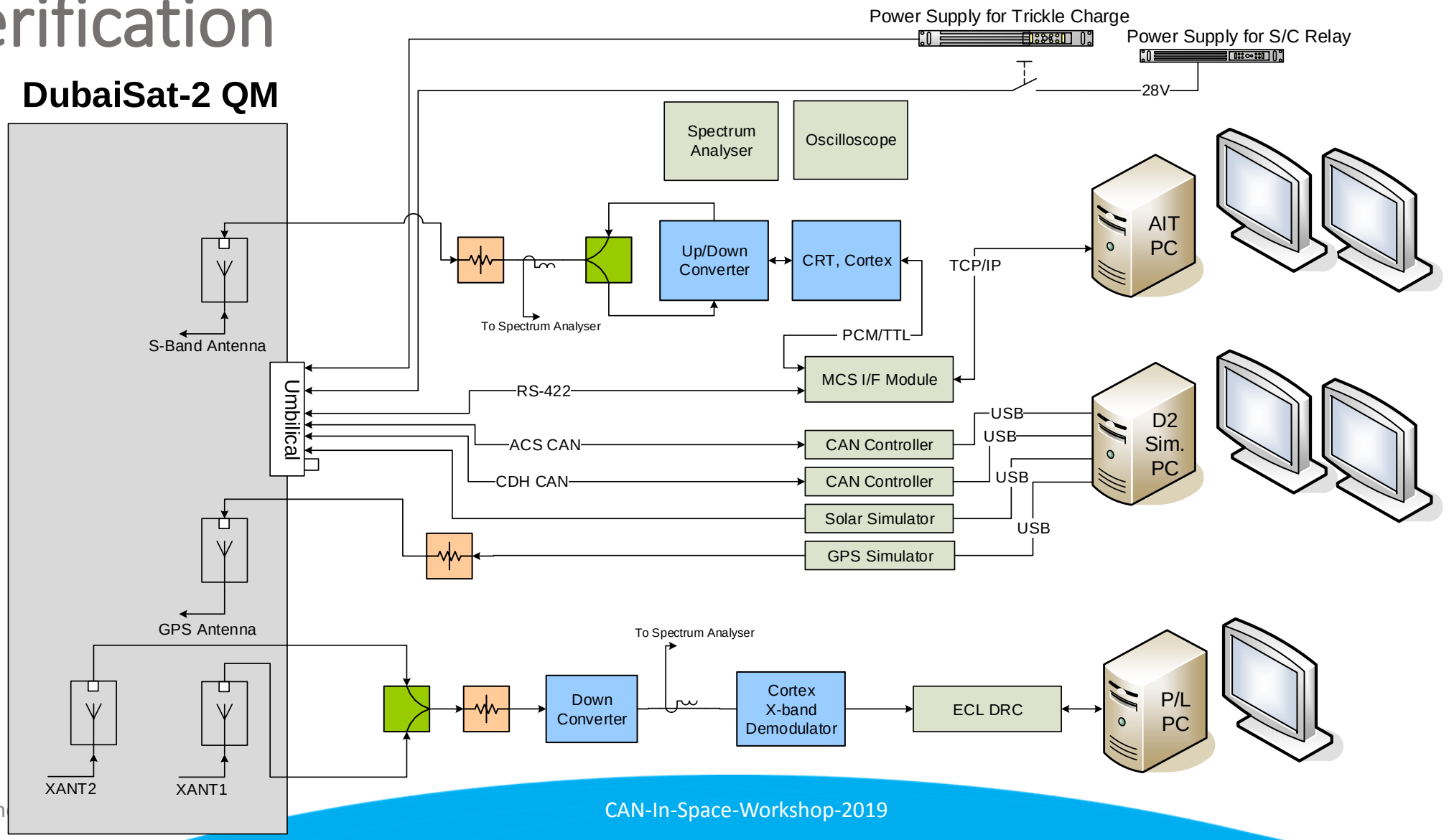
AIT EGSE RACK2F



AIT EGSE RACK2B

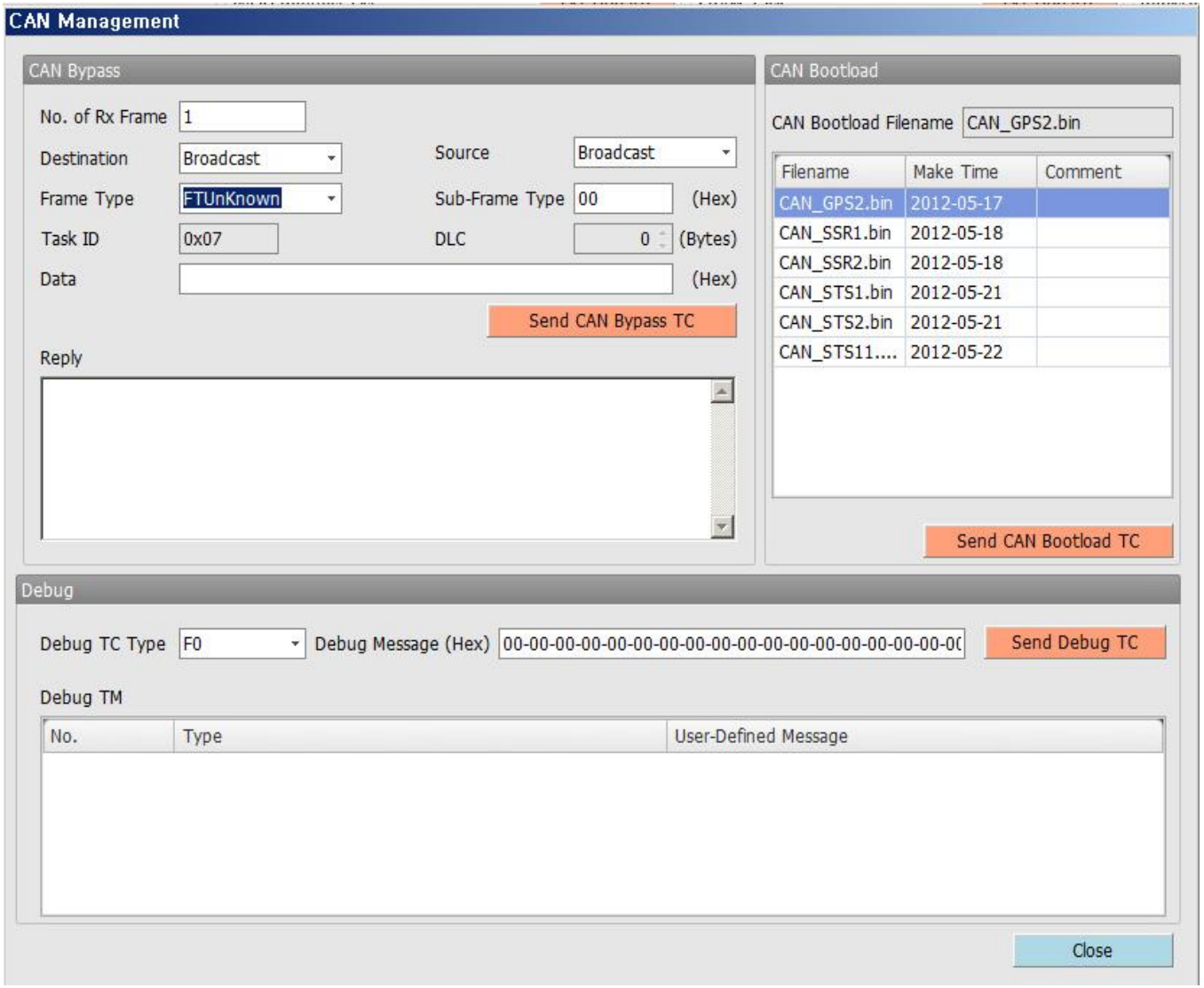


Verification



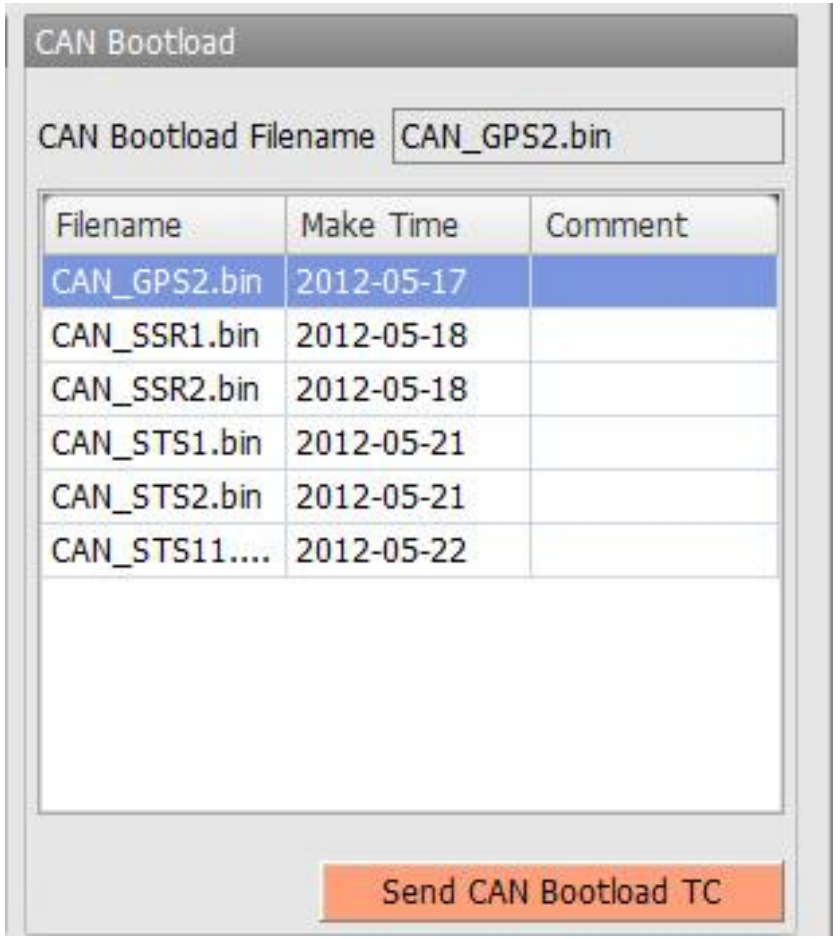
Verification

- **System Level CAN Bus**
- DubaiSat system allows direct injection of CAN Bus packet through Main Communication link (S-Band or Umbilical)
- CAN Bus packet are encapsulated in a CCSDS telecommand format. the OBC sends the commands to the correct bus.



Verification

- **System Level CAN Bus**
- DubaiSat system allows also updating the Software in some modules. This is called CAN Bootloading.
- Usually all modules are updated with the final software Version prior to launch. Still in case of issues or better performing software updates can be made.



Upcoming Work

- Work on next mission CAN Bus System.
- Upgrade from RS485 Drivers to Actual CAN-Bus transceivers (COBHAM)
- Update the Electrical Interface Document to reflect circuit changes.
- Work on Selecting/developing of new EGSE for Bench Level and System.
- Work on Vendors CAN-Bus Adaptation (Command list, telemetry, circuit, FPGA IP, Joint testing…etc).
- Prepare for PDR is in August 2019

Thank You