BIRDS-5 OBC

Open-Source Webinar Presentation

10-Aug-2022

On-Board Computer (OBC)

- Transmit the Continuous Wave (CW) Beacon
- Collect, store and transmit Housekeeping Data
- Analyze the Uplink commands received from Ground Station
- Execute mission commands and store mission data
- Monitor the general status of the satellite and survive space environment.

Requirements Analysis Sheet (RAS)

ID	System Requirement	ID	Design Requirement	ID	Verification Requirement	Verification Method
SR1	Send the CW data	DR1.1	Collect CW data from each Sub System	VR1.1.1	C&DH and Other Sub System is connected by UART	Check the data between OBC and other Sub Systems
		DR1.2	Save the data	VR1.2.1	OBC PIC save the data on memory	Check the saved the data on Flash memory
		DR1.3	Count the time	VR1.3.1	OBC PIC count the time	Check the count data on OBC PIC
		DR1.4	Send these data to COM PIC	VR1.4.1	Received the data on COM PIC	Check the data on COM PIC

RAS

ID	System Requirement	ID	Design Requirement	ID	Verification Requirement	Verification Method
SR2	Collect and store HK data	SR2.1	Collect HK data from each system	VR2.1.1	C&DH and Other Sub System is connected by UART	Check the data between OBC and other Sub Systems
		SR2.2	Save the data	VR2.2.1	OBC PIC save the data on memory	Check the saved the data on Flash memory
		SR2.3	Send these data to COM PIC	VR2.3.1	Received the data on COM PIC	Check the data on COM PIC

RAS

ID	System Requirement	ID	Design Requirement	ID	Verification Requirement	Verification Method
SR3	Analyze Uplink Commands	SR3.1	Get the uplink command from COM	VR3.1.1	Received the data on OBC PIC	Check the data on OBC PIC
		SR3.2	Analyze the command	VR3.2.1	Verify command data is accurate	Compare the uplink details and tested data during EM testing

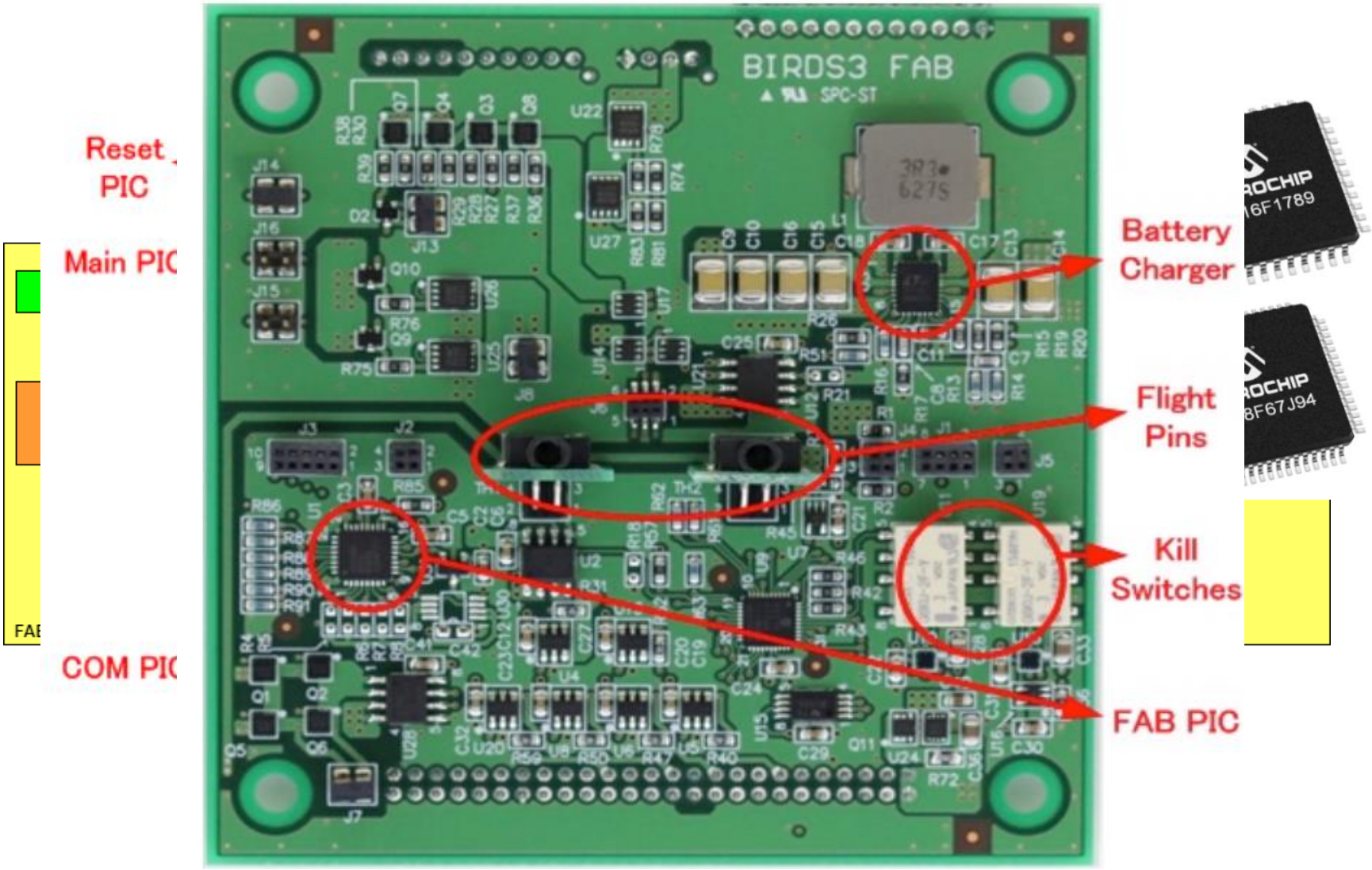
RAS

ID	System Requirement	ID	Design Requirement	ID	Verification Requirement	Verification Method
SR4	Execute Mission Commands	DR4.1	Send mission command to Mission	VR4.1.1	OBC and Mission is connected by UART	Check the command data on Mission PIC
		DR4.2	Get the mission data	VR4.2.1	Received the data on OBC PIC	Check the data on OBC PIC
		DR4.3	Save the mission data	VR4.3.1	OBC PIC save the data on memory	Check the saved the data on Flash memory
		SR4.4	Send these data to COM PIC	VR4.4.1	Received the data on COM PIC	Check the data on COM PIC

RAS

ID	System Requirement	ID	Design Requirement	ID	Verification Requirement	Verification Method
SR5	Monitor the satellite status	DR5.1	Get the information on each Sub System	DR5.1.1	C&DH and Other Sub System is connected by UART	Check the data between OBC and other Sub Systems
		DR5.2	Detect the abnormal	DR5.2.1	Collected data show the config	Check whether they are right or not
		DR5.3	Reset the satellite	DR5.3.1	Send the command to FAB	Check the data on FAB PIC

OBC Block Diagram



Software/Hardware Environment

- CCS Compiler
  - IDE for developing C code
  - Used with previous BIRDs

- MPLAB IPE
  - Used to program OBC via hex file
  - Used with previous BIRDs

- Acer Predator Helios
  - Development Laptop

Uplink Command Format

Header	Sat ID	Command Format	Command ID	Reservation Time	Mission Command Data							CRC	
00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D

- **Header (1 byte)** - Leading byte for the command signal. Set by the GS Software.
- **Satellite ID (1 byte)** - Designated for each BIRDS-5 satellite. It can be chosen as any unique value for each satellite.
- **Command Format (1 byte)** - Determines which PIC the command is designated (0xA0 - MAIN PIC, any - COMM PIC, 0x33 - RESET PIC, etc.).
- **Command ID (1 byte)** - Determines which command to execute. The upper 4 bits describe which mission MCU the command is for the lower 4 bits describe what command to execute.
- **Reservation Time (1 byte)** - Designates the reservation time for specific mission. Delays command execution by the specified time.
- **Command Data (7 bytes)** - Describes the command data to be included in the command.
- **CRC (2 bytes)** - Cyclic Redundancy Check for error checking. Set by the GS Software.

An example camera capture command to the Multispectral Camera 1 on ZIMSAT-1: ABA0290000000000000000

Header	Sat ID	Command Format	Command ID	Reservation Time	Mission Command Data							CRC	
-	0xAB	0xA0	0x29	0x00	0x00	0x00	0x00	0x00	0x00	0x00	0x00	-	-

Flash Memory Management

- OBC handles Main Flash (MF), Shared COM Flash (SCF) and Shared Mission Flash (SMF)

System	Address from	Address to	Sector from	Sector to	(1Sector =	Storage Size[kByte]	1 Data[Bytes]
Address Data location	0000 0000	-	0	0	1	64	4
Address Data	0000 1000	-	1	3	3	192	37
Flag Data	0004 0000	0004 FFFF	4	4	1	64	15
RSV Data	0005 0000	-	5	5	1	64	-
SAT LOG	0006 0000	0007 FFFF	6	7	2	128	11
I-C	0008 0000	006B FFFF	8	107	100	6400	-
MCAM-1_thmb	006C 0000	009D FFFF	108	157	50	3200	-
MCAM-1_img	009E 0000	00CF FFFF	158	207	50	3200	-
MCAM-2_thmb	00D0 0000	0101 FFFF	208	257	50	3200	-
MCAM-2_img	0102 0000	0133 FFFF	258	307	50	3200	-
FAB_HK	0134 0000	025F FFFF	308	607	300	19200	76
FAB_CW	0260 0000	0291 FFFF	608	657	50	3200	5
HSSC	0292 0000	038F FFFF	658	911	254	16256	76
DC STATUS	0390 0000	0390 FFFF	912	912	1	64	-
S&F/APRS	0391 0000	0399 FFFF	913	921	9	576	-
ADCS	039A 0000	03FE FFFF	922	1022	100	6400	-
PINO	03FF 0000	07FF FFFF	1023	2047	1025	65600	-

Satellite Log

- Satellite Log is 11 bytes long:

0xDA	0xDA	Sec	Min	Hr	Day_h	Day_l	data1	data2	data3	0xEF

- Data bytes record the code for what was logged

- SATLOG is recorded after events with specific codes:
  1) Satellite RESET – 0x25, 0x25, 0x25
  2) Burner Circuit Activation – 0xBB, 0x30, 0x30
  3) Kill SAT Command – 0xEE, 0x04, Kill Count
  4) Mission Command Uplink to Main – 0xCC, CMD0, CMD2
  5) Reservation Command – 0xDD, CMD0, RSV Time
  6) Data Erase – 0xE0, D1, D2
  7) Data Transfer - 0xAB, D1, D2
  8) Mission Time Elapse - 0x99,0x99,0x99

Satellite Log

- Satellite Log is 11 bytes long:

0xDA	0xDA	Sec	Min	Hr	Day_h	Day_l	data1	data2	data3	0xEF

1st log – SAT RESET

2nd log – Antenna Deploy 30mins after

Address	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F
00000000	DA	DA	00	00	00	FF	FF	25	25	25	EF	DA	DA	3B	1F	00
00000010	FF	FF	BB	30	30	EF	FF	FF	FF	FF	FF	FF	FF	FF	FF	FF

CW Beacon

- CW Beacon shows critical status data in concise format:
  - 5 bytes long
  - Two Types: Type 1 and Type 2
  - Saved to SCF, MF, SMF from address: 0260 0000

D1	D2	D3	D4	D5

Type1			Type2		
Cell Number	Data	bit	Cell Number	Data	bit
1	Battery Voltage (mV)	8bit	1	Gyro X axis (deg/s)	8bit
2	Battery Current (mA)	8bit	2	Gyro Y axis (deg/s)	8bit
3	Battery Temperature (℃)	8bit	3	Gyro Z axis (deg/s)	8bit
4	Format identifier “0” (Data Type 1)	1bit	4	Format identifier “1” (data type 2)	1bit
	Operation Modes --> 11: Normal	2bit		HSSC Automatical Trial ----> 1: done 0: not done	1bit
	Kill Switch Main -----> Nomal:0 Kill:1	1bit		COM to MAIN Flag----> 1: comm 0: no comm	1bit
	Kill Switch FAB -----> Nomal:0 Kill:1	1bit		RESET to MAIN Flag ----> 1: comm 0: no comm	1bit
	Antenna deploy status------> Success:1 Unsuccess:0	1bit		FAB to MAIN Flag ----> 1: comm 0: no comm	1bit
	Solar cell +Y----------> Sunshine:1 Shadow:0	1bit		Battery Heater -------> ON:1 OFF:0	1bit
	Solar cell +X----------> Sunshine:1 Shadow:0	1bit		Reservation command ----> Reserve:1 Nothing:0	1bit
5	Solar cell -Z----------> Sunshine:1 Shadow:0	1bit		Uplink Success ----> Success:1 Not Success:0	1bit
	Solar cell -X----------> Sunshine:1 Shadow:0	1bit	5	Mission status (ON/OFF)	4bit
	Solar cell +Z----------> Sunshine:1 Shadow:0	1bit			
	Time after last reset (number of hours)	5bit		Mission Operating Status (Operating/Not Operating)	4bit

Housekeeping Data

- Housekeeping Data shows critical satellite status information:
  - Time Data
  - Voltage Data (Panel, Battery, etc.)
  - Current Data (Panel, Battery, etc.)
  - Temperature Data (Panel, Battery, BPB)
  - ADCS Data (Gyro and Magnetometer)

from	to	size(byte)	HK DATA	
0	1	2	header(0x33)	OBC
2	2	1	sec	RESET
3	3	1	min	RESET
4	4	1	hour	RESET
5	6	2	day_H&L	RESET
7	9	3	for confirmation(0xAA)	OBC
10	11	2	+Y_Temp_HIGH&LOW	FAB
12	13	2	+X_Temp_H&L	FAB
14	15	2	-Z_Temp_H&L	FAB
16	17	2	-X_Temp_H&L	FAB
18	19	2	-Y_Temp_H&L	FAB
20	21	2	+Z Temp_H&L	FAB
22	23	2	+Y Voltage_H&L	FAB
24	25	2	-Y Voltage_H&L	FAB
26	27	2	-Z Voltage_H&L	FAB
28	29	2	-X Voltage_H&L	FAB
30	31	2	+Z Voltage_H&L	FAB
32	33	2	-X Current_H&L	FAB
34	35	2	+Y Current_H&L	FAB
36	37	2	-Z Current_H&L	FAB
38	39	2	-Y Current_H&L	FAB
40	41	2	+Z Current_H&L	FAB
42	43	2	Raw Current_H&L	FAB
44	44	1	SRC Voltage	FAB
45	45	1	RAW Voltage	FAB
46	47	2	SRC Current_H&L	FAB
48	48	1	Battery Voltage	FAB
49	50	2	Battery Current_H&L	FAB
51	51	1	Battery Temp	FAB
52	52	1	Heater FLAG	FAB
53	53	1	Kill Status	FAB
54	56	3	for confirmation(0xBB)	OBC
57	58	2	Magnetometer_X	ADCS
59	60	2	Magnetometer_Y	ADCS
61	62	2	Magnetometer_Z	ADCS
63	64	2	GYRO_X	ADCS
65	66	2	GYRO_Y	ADCS
67	68	2	GYRO_Z	ADCS
69	71	3	for confirmation(0xCC)	OBC
72	72	1	Voltage_RAW	RESET
73	73	1	CURRENT_3V3#1	RESET
74	74	1	CURRENT_3V3#2	RESET
75	75	1	CURRENT_5V	RESET
76	76	1	CURRENT_UNREG#1	RESET
77	77	1	Time since last reset (hrs)	RESET
78	79	2	footer(0x44)	OBC

Housekeeping Data

- Housekeeping Data shows critical satellite status information:

Address	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F
00000000	33	33	03	00	00	FF	FF	AA	AA	AA	05	DB	04	6A	05	D4
00000010	05	D5	05	D7	05	D8	03	FE	04	24	03	66	04	00	07	13
00000020	00	0E	00	18	00	10	00	23	00	0D	02	43	AC	9A	01	D1
00000030	9B	08	D2	82	00	00	BB	BB	BB	00	00	00	00	00	00	00
00000040	00	00	00	00	00	CC	CC	CC	97	07	01	00	00	00	44	44
00000050	33	33	20	01	00	FF	FF	AA	AA	AA	05	DB	04	84	05	D4
00000060	05	D5	05	DA	05	D6	03	F3	04	29	03	68	04	02	07	16
00000070	00	0F	00	17	00	10	00	24	00	0C	02	4B	AC	9B	01	D4
00000080	9C	08	D6	81	00	00	BB	BB	BB	00	00	00	00	00	00	00
00000090	00	00	00	00	00	CC	CC	CC	98	06	01	01	00	00	44	44

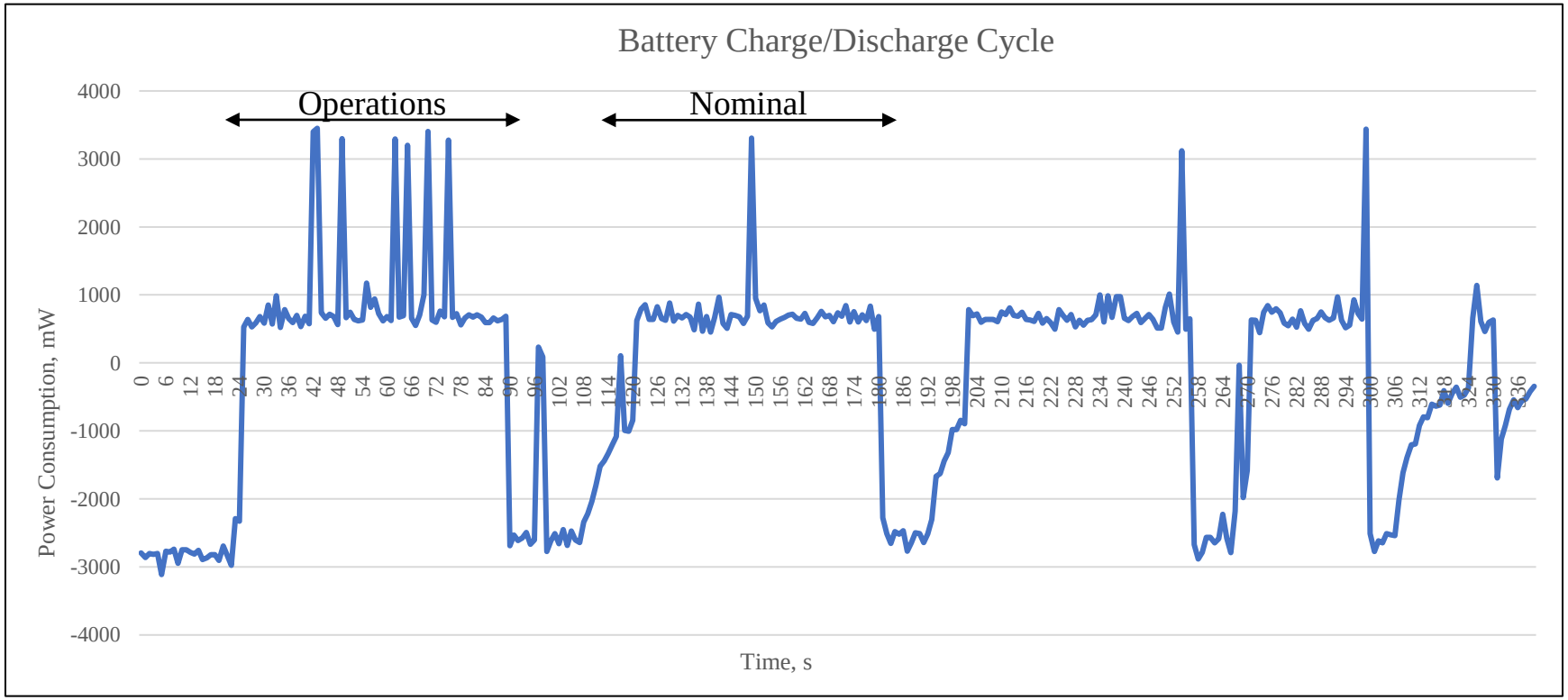
1st HK collection

2nd HK collection

BIRDS-5 HSSC and HK Analyzer																		
Start byte		5	7	9	11	21	25	29	33	37	41	45	49	53	57	61		
Number of bytes long		2	2	2	4	4	4	4	4	4	4	4	4	4	4	4		
Type of Data		Time Data				Solar Panel Temperatures						Solar Panel Voltages						
Insert HSSC/HK Data:	33 33 03 00 00 FF FF AA AA AA 05 DB	03	00	00	FFFF	05DB	046A	05D4	05D5	05D7	05D8	03FE	0424	0366	0400	0713	00	
		sec	min	hour	day	Tpy (°C)	Tpx (°C)	Tmz (°C)	Tmx (°C)	Tmy (°C)	Tpz (°C)	Vpy (mV)	Vmy (mV)	Vmz (mV)	Vmx (mV)	Vpz (mV)	Imx	
1	3333030000FFFFAAAAAA05DB046A05D	3	0	0	0	21.83	62.78	22.61	22.5	22.28	22.17	1,559.83	1,617.83	1,327.84	1,562.88	2,764.04		

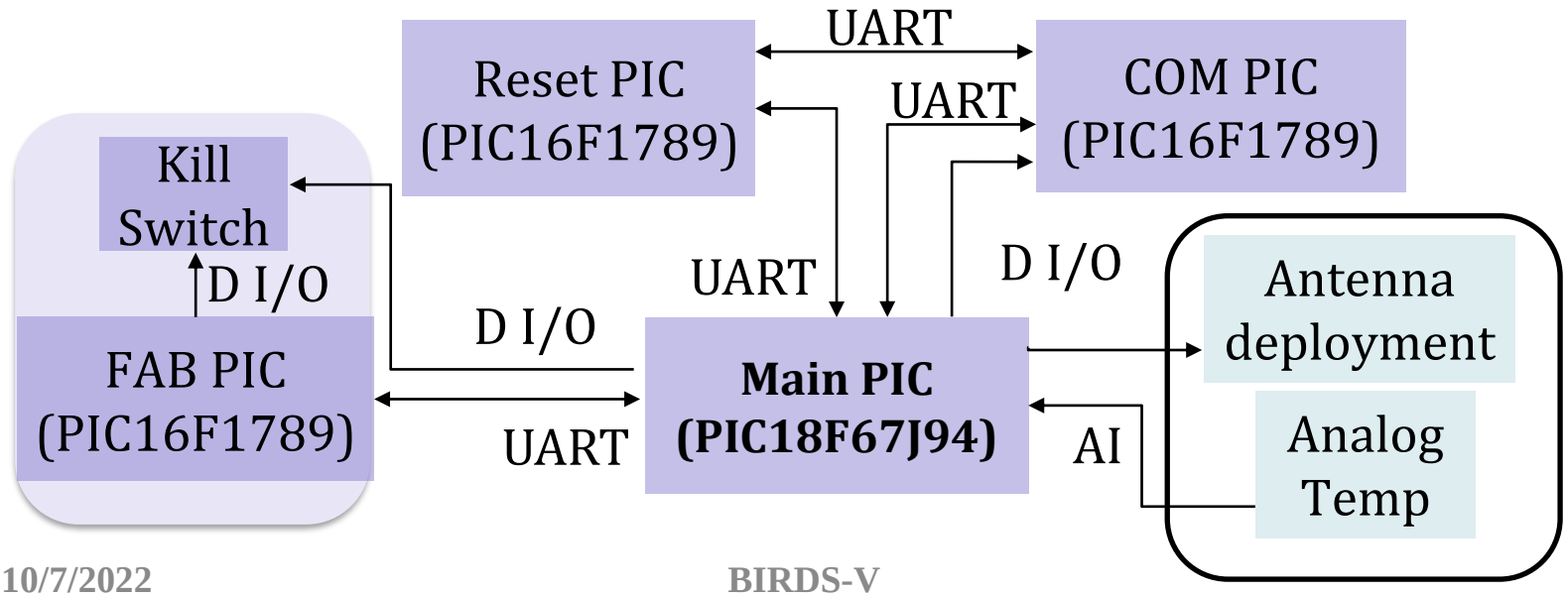
HK data collection

- Power consumption during Long Duration Testing:
  - Collected 612kB of HK data over 7 days
  - Nominal Average: 680mW over 90 minutes



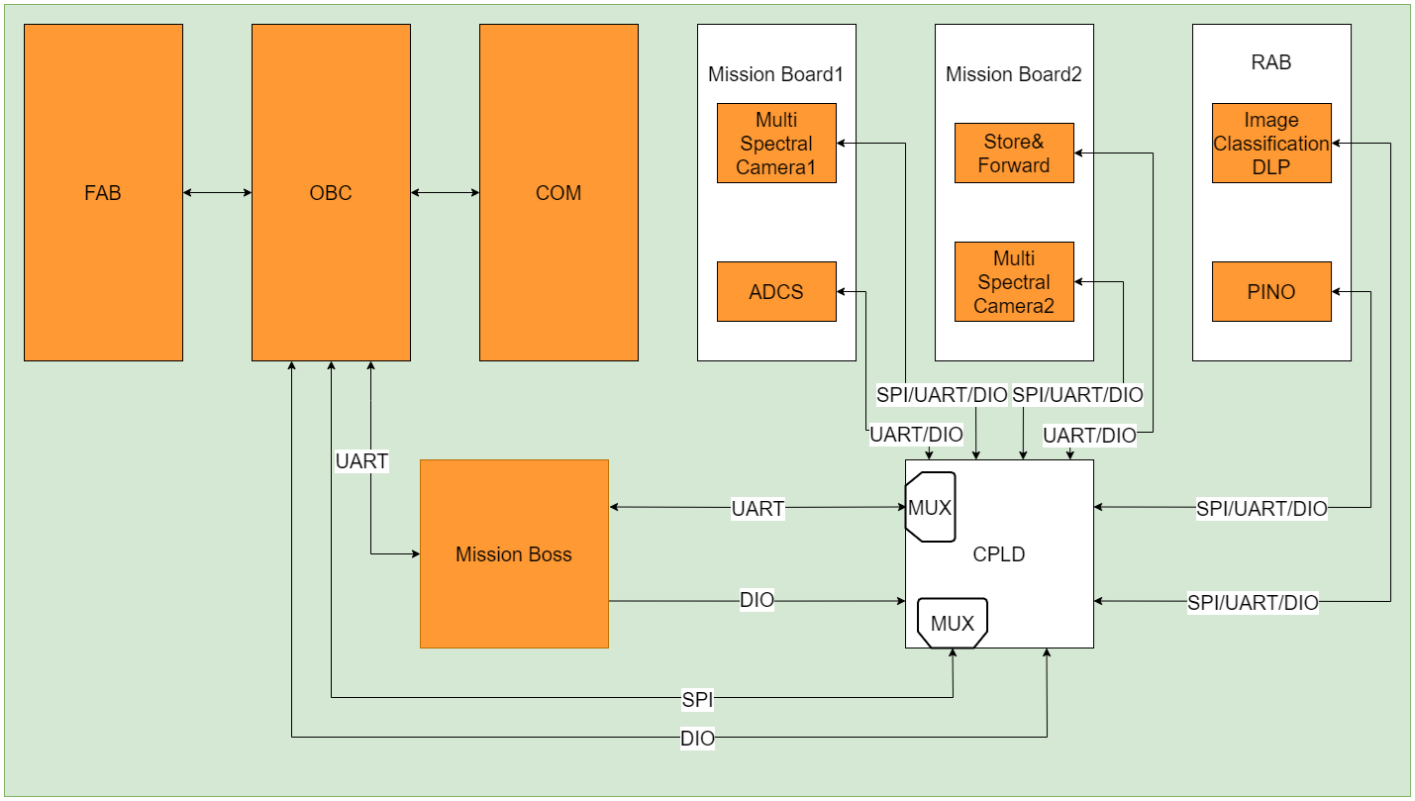
OBC Functional Tests

Part	Work	Hardware
Communication with COM	✓	UART
Communication with RESET	✓	UART
Communication with FAB	✓	UART
Communication with MB	✓	UART
Kill Switch	✓	Digital In/Out
Antenna deployment switch	✓	Digital In/Out
Analog sensors reading	✓	Analog In



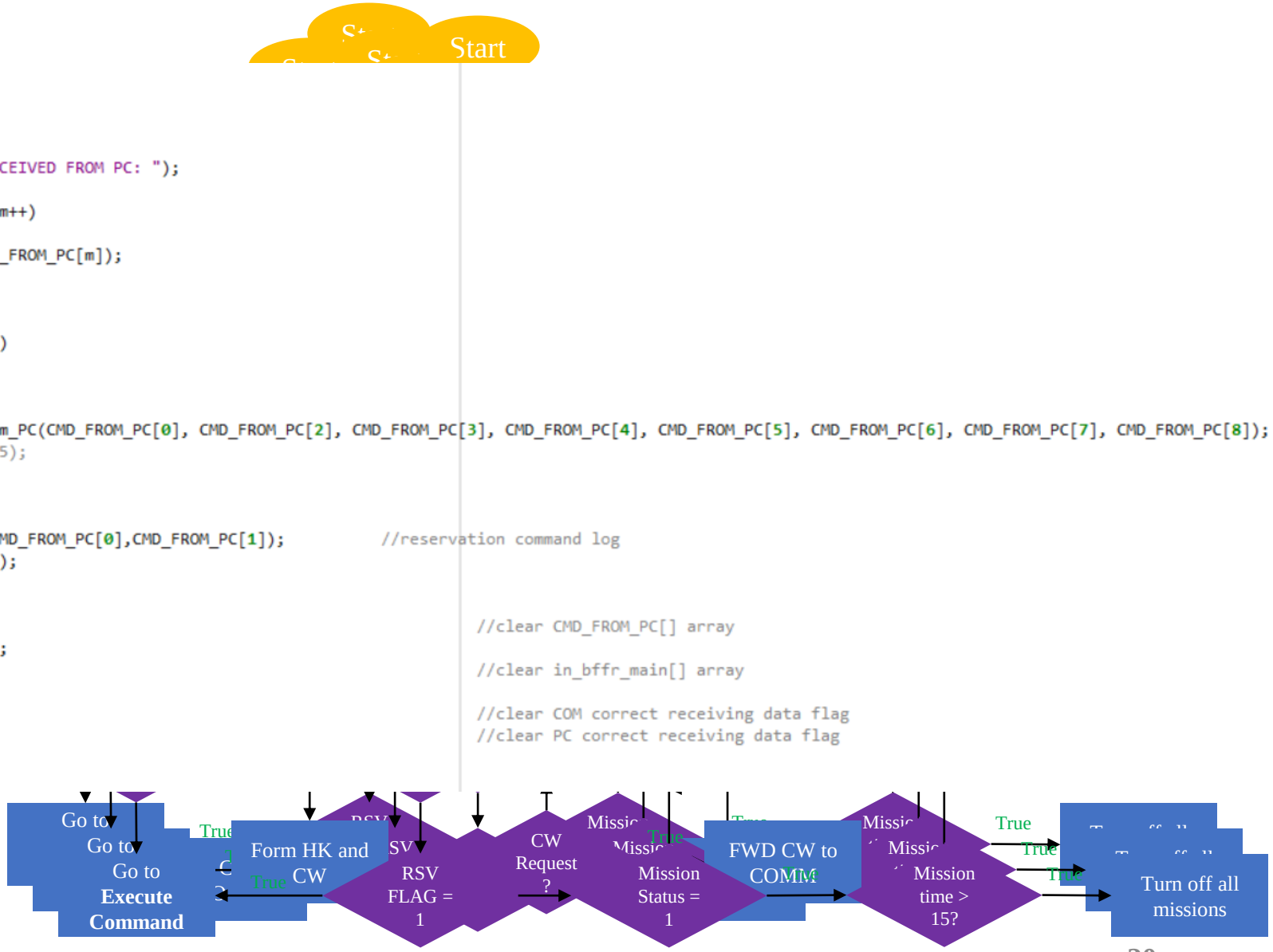
Functional Tests – UART & D I/O

Part	Work	Hardware
Control of mission's switches	✓	Digital In/Out
Communication with Mission(ADCS, MCAM, MBP)	✓	UART

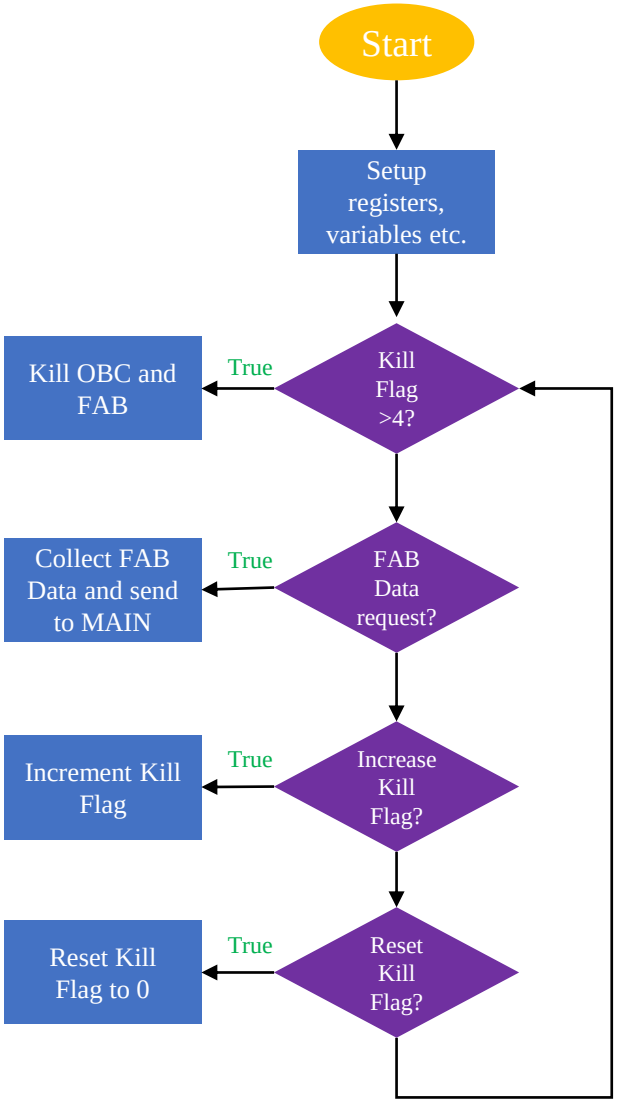


Satellite Operation - MAIN PIC

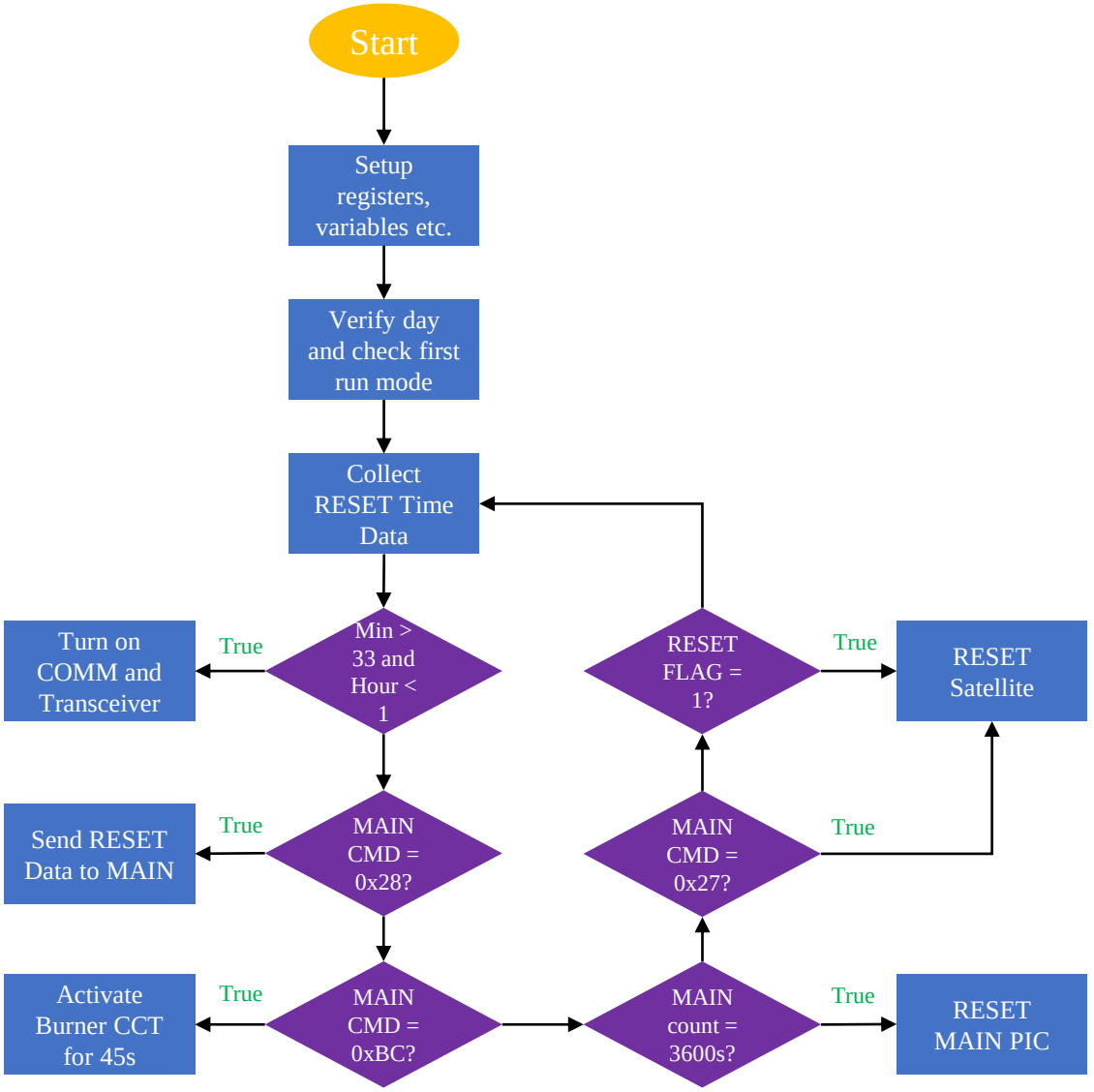
```
if(CMD_FROM_PC[0])
{

   fprintf(PC,"\r\n");
   fprintf(PC,"COMMAND RECEIVED FROM PC: ");

   for(int m = 0; m < 9; m++)
   {
      fprintf(PC,"%x",CMD_FROM_PC[m]);
   }
   fprintf(PC,"\r\n");

   if(CMD_FROM_PC[1] == 0)
   {
      Turn_On_MBP();
      delay_ms(1000);
      EXECUTE_COMMAND_from_PC(CMD_FROM_PC[0], CMD_FROM_PC[2], CMD_FROM_PC[3], CMD_FROM_PC[4], CMD_FROM_PC[5], CMD_FROM_PC[6], CMD_FROM_PC[7], CMD_FROM_PC[8]);
      //output_high(PIN_A5);
   }
   else
   {
      SAVE_SAT_LOG(0xDD,CMD_FROM_PC[0],CMD_FROM_PC[1]);          //reservation command log
      Reserve_command_PC();
   }

   DELETE_CMD_FROM_PC();                                        //clear CMD_FROM_PC[] array
   DELETE_CMD_FROM_COMM();
   Delete_Buffer();                                             //clear in_bffr_main[] array
   CMD_FROM_PC[1] = 0;
   COM_DATA = 0;                                                //clear COM correct receiving data flag
   PC_DATA = 0;                                                 //clear PC correct receiving data flag

}
```



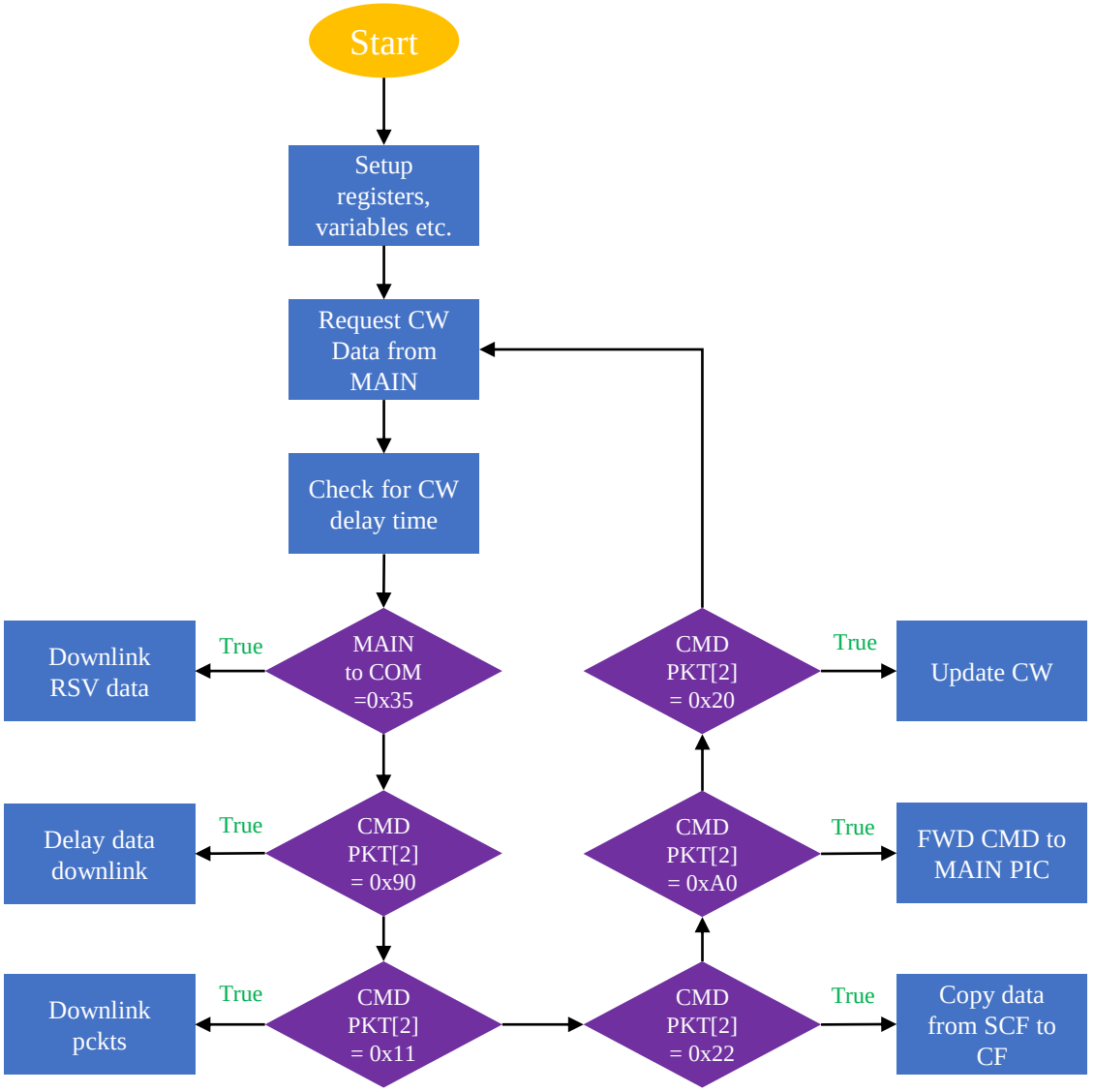
FAB PIC


Start
Setup registers, variables etc.
Kill Flag >4?
True
Kill OBC and FAB
FAB Data request?
True
Collect FAB Data and send to MAIN
Increase Kill Flag?
True
Increment Kill Flag
Reset Kill Flag?
True
Reset Kill Flag to 0

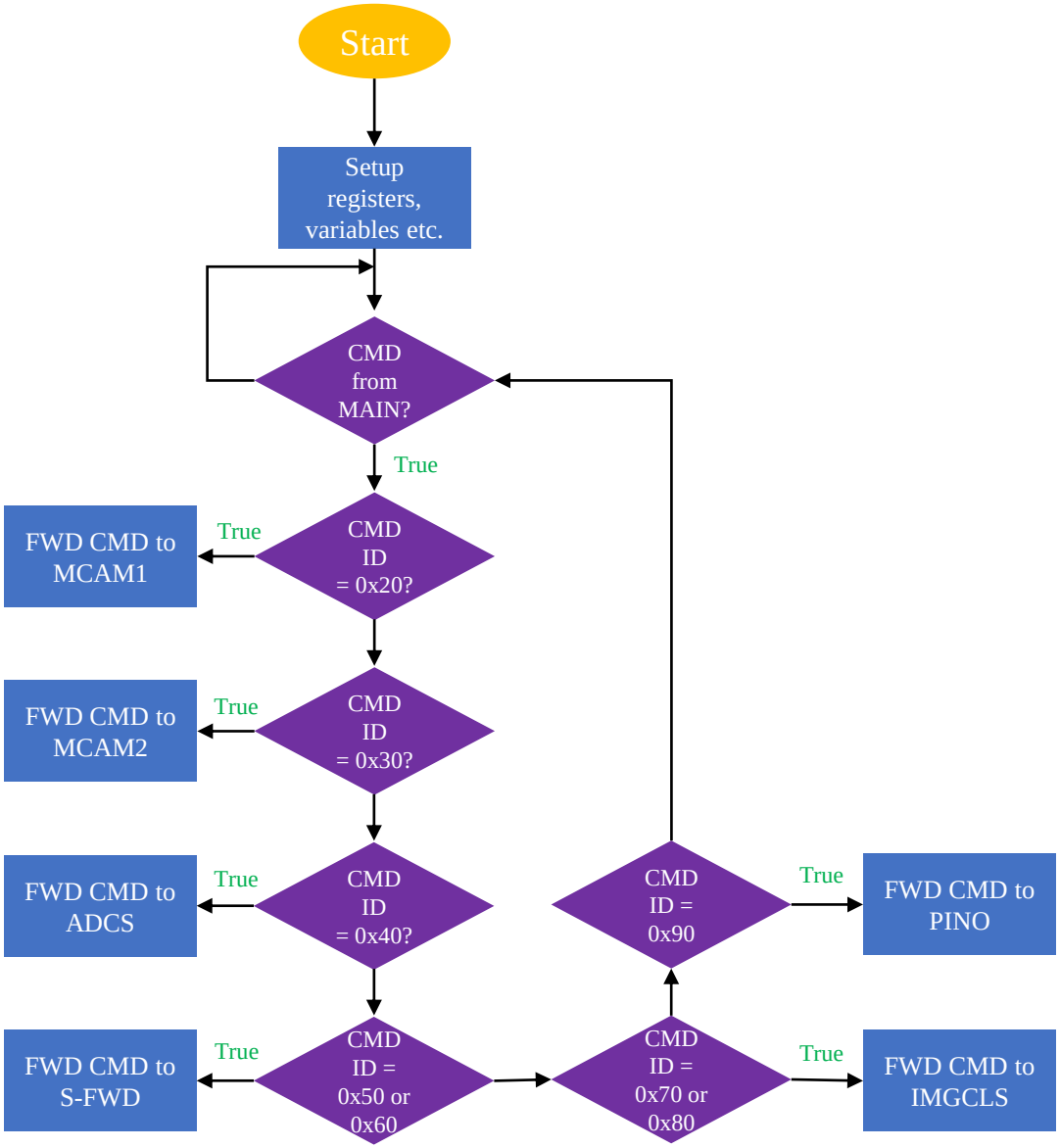
RESET PIC


Start
Setup registers, variables etc.
Verify day and check first run mode
Collect RESET Time Data
Min > 33 and Hour < 1
True
Turn on COMM and Transceiver
MAIN CMD = 0x28?
True
Send RESET Data to MAIN
MAIN CMD = 0xBC?
True
Activate Burner CCT for 45s
MAIN count = 3600s?
True
RESET MAIN PIC
RESET FLAG = 1?
True
RESET Satellite
MAIN CMD = 0x27?
True

COMM PIC


Start
Setup registers, variables etc.
Request CW Data from MAIN
Check for CW delay time
MAIN to COM =0x35
True
Downlink RSV data
CMD PKT[2] = 0x90
True
Delay data downlink
CMD PKT[2] = 0x11
True
Downlink pckts
CMD PKT[2] = 0x22
True
Copy data from SCF to CF
CMD PKT[2] = 0xA0
True
FWD CMD to MAIN PIC
CMD PKT[2] = 0x20
True
Update CW

Mission Boss PIC



Conclusion

- OBC is used in every aspect of the satellite:
  - COMM, EPS, FAB, Mission Management, Memory Management
- Main Tests using OBC:
  - Antenna Deployment
  - TVT Testing
  - Long Duration Testing
- Mainly embedded system (Electrical/Computer Engineering)
  - Program in C
  - Heritage system with lots of support

Thank you