



## Designing, Implementing and Testing a Low-Power GPS Rx Subsystem for LEO Satellites



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# Agenda

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- Navigation Systems and Segments.
- Project RoadMap.
- GPS Rx Subsystem - Prototype.
- GPS Rx Subsystem - Engineering Model.
- MisrSat Constellation - GPS Rx Subsystem EM.
- Conclusion and Future Work.

# Navigation Systems

Global Navigation Satellite System (GNSS) is the **standard generic term** for satellite navigation systems:

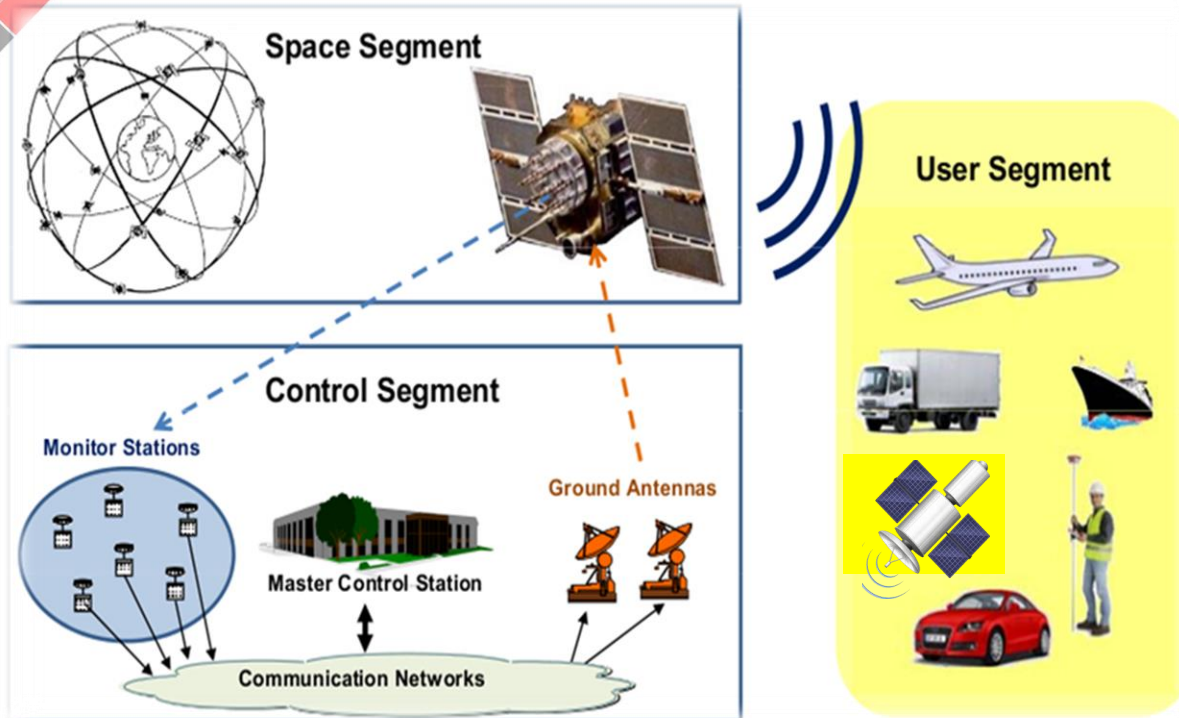
- Beidou (China),
- Galileo (Europe),
- GLONASS (Russia)
- QZASS (Japan)
- GPS(USA).

A GNSS allows small electronic receivers to determine their location (longitude, latitude and altitude).



Satellite navigation using a laptop and a GPS receiver

# Navigation Segments



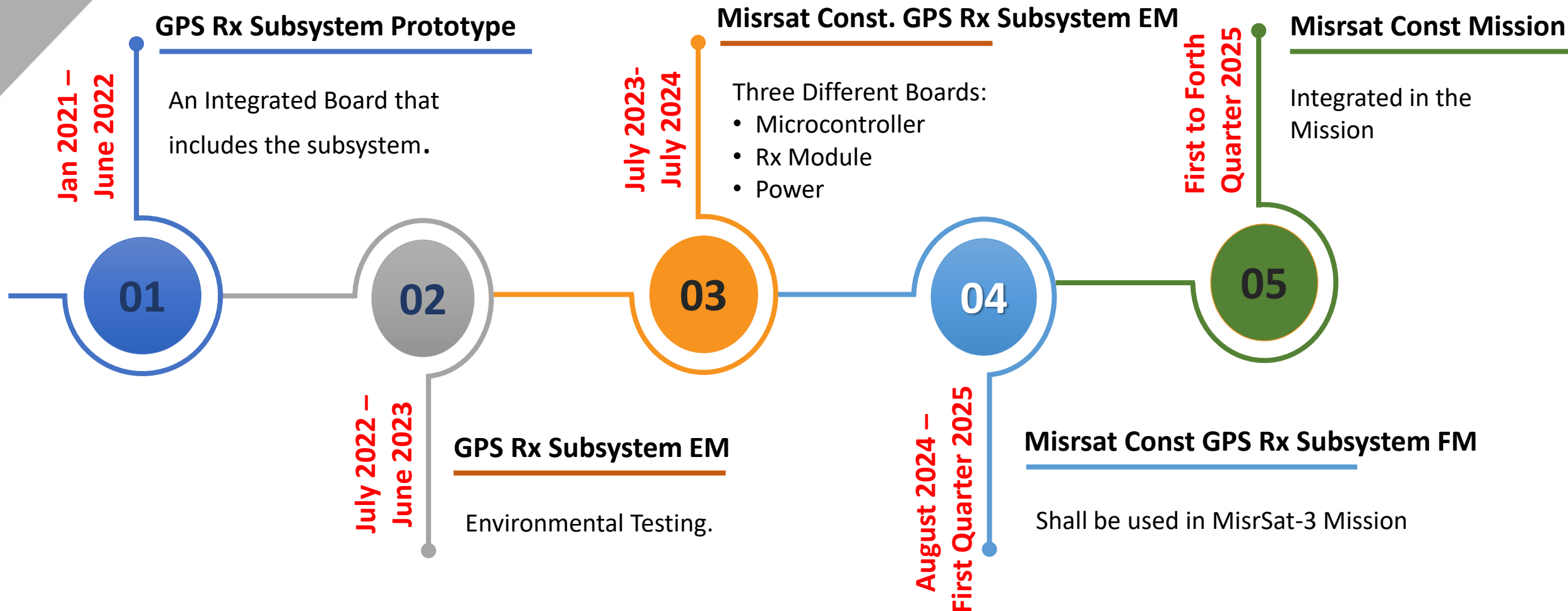
## GPS Receivers Subsystems

- Output position and velocity determination messages.
- Broadcast UTC.
- Broadcast the 1PPS signal which synchronizes satellite time.

All three parts of a GPS system work in such a manner to provide the information regarding time and location.



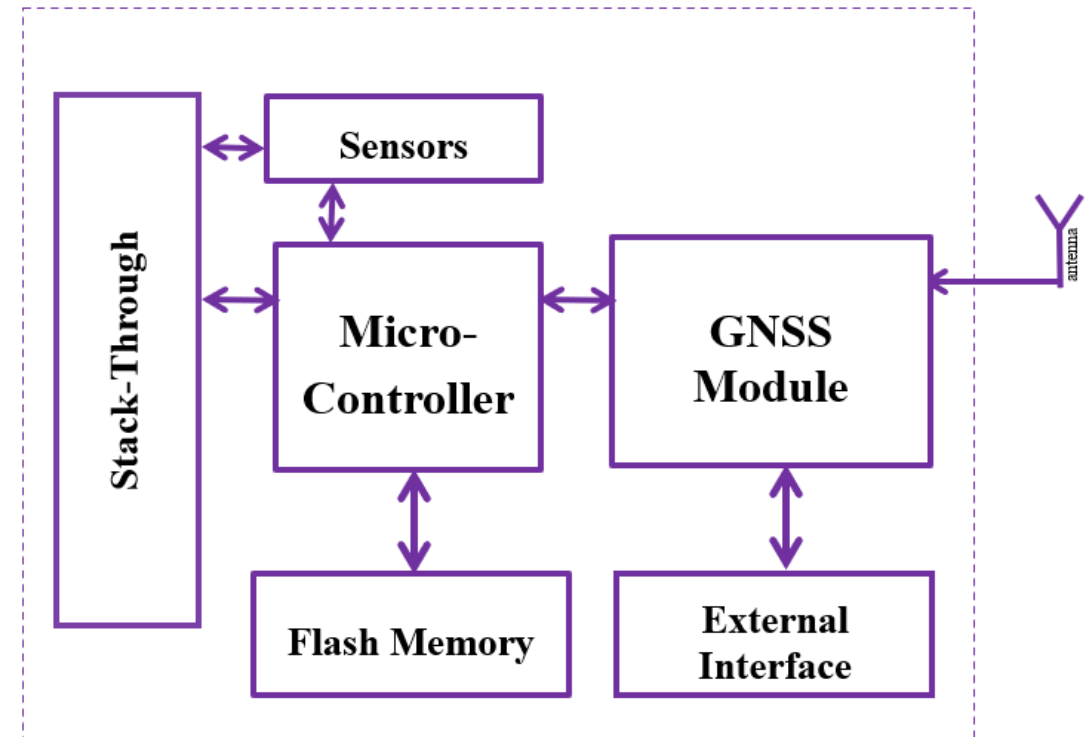
# Project RoadMap



# Main Block Diagram of the Proposed GPS Rx Subsystem

In developing a satellite Subsystem, three primary units shall be involved:

- The Hardware Unit.
- The Software Unit.
- Check and Test Equipment Unit.



Block Diagram for Proposed GPS Receiver



# GPS Rx Subsystem Designing and Implementation

## 1. HW Designing and Manufacturing

**Components Selection and  
Trade-OFF**

- Space Certified/ Space Heritage.
- Tolerance.
- Temperature Range of Operation.
- Price.

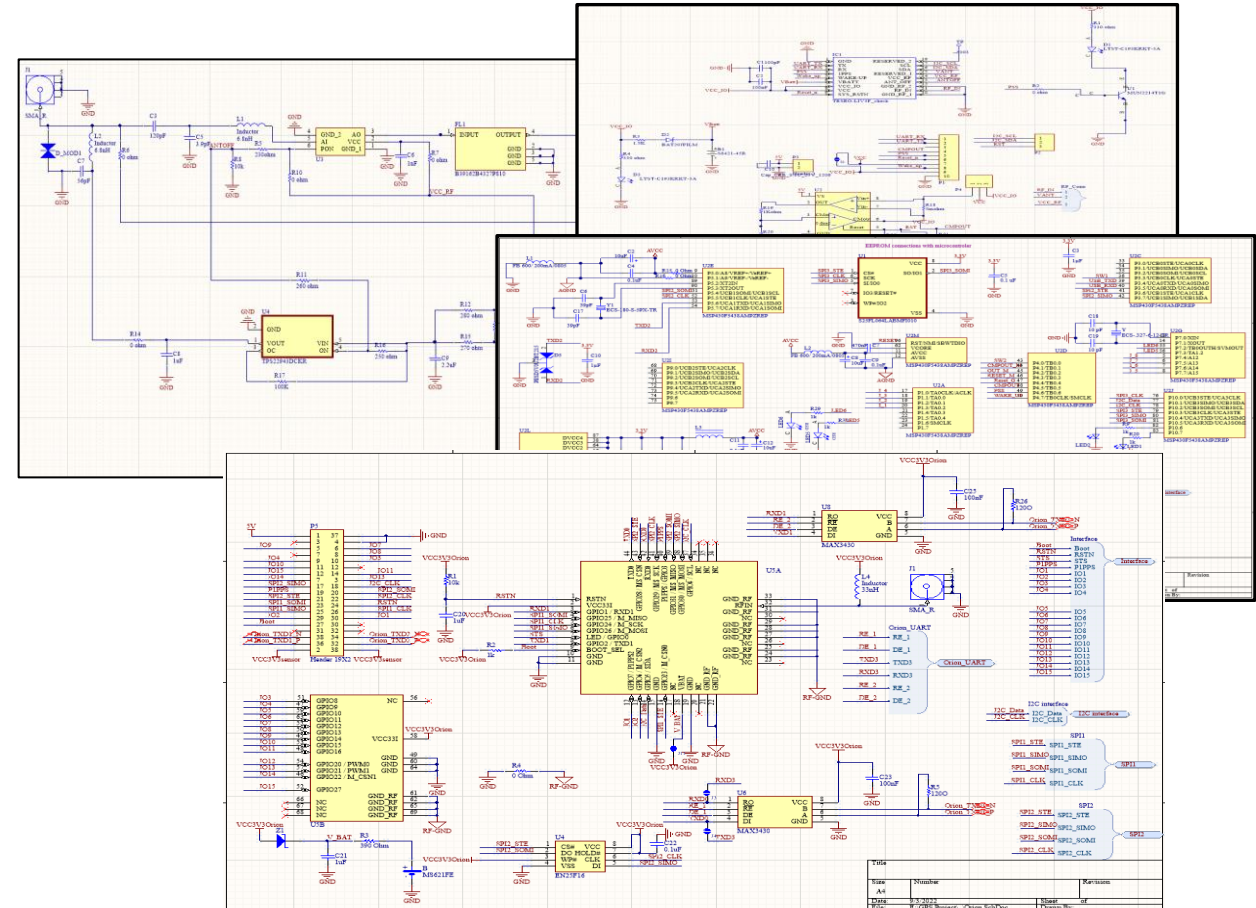


# GPS Rx Subsystem Designing and Implementation

## 1. HW Designing and Manufacturing

Components Selection and Trade-OFF

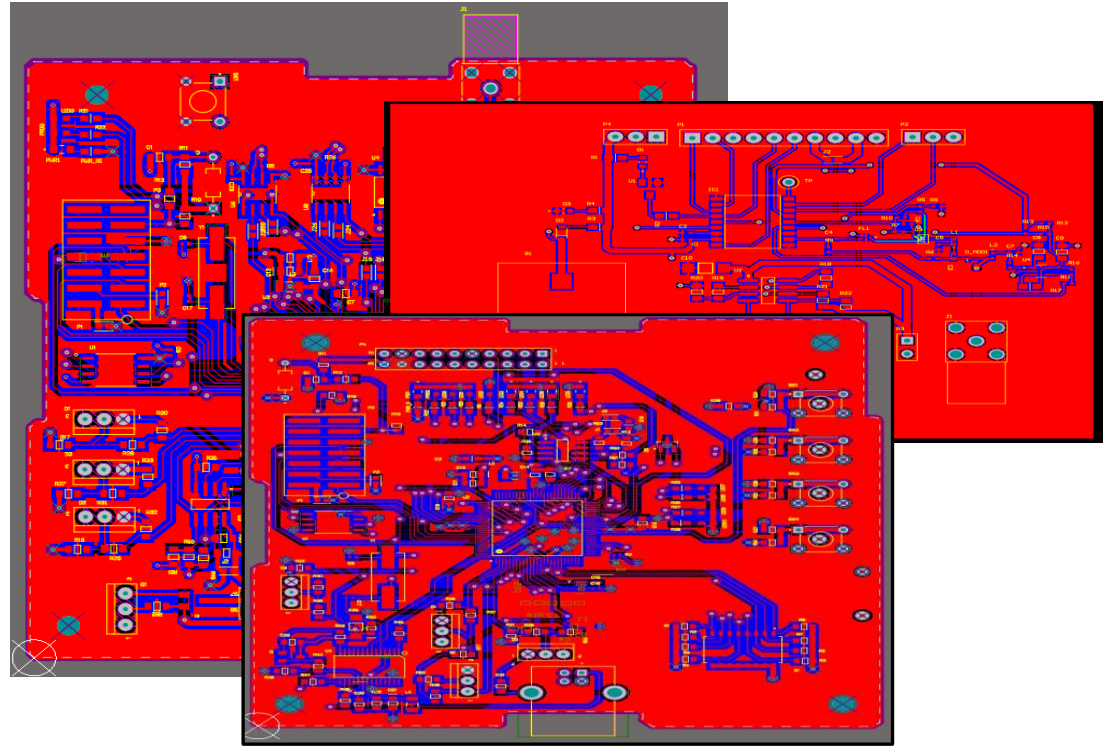
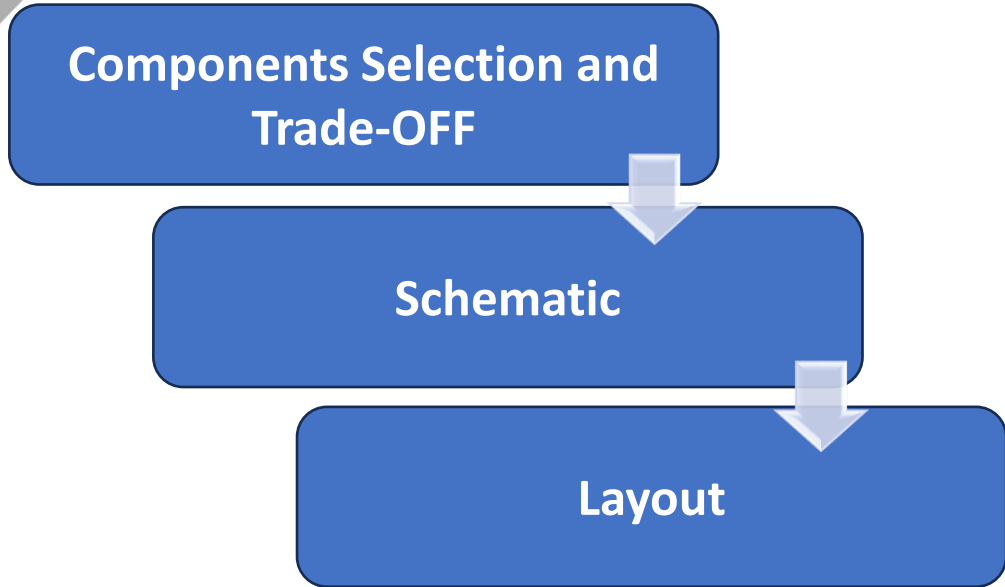
Schematic



Samples of Schematic Design

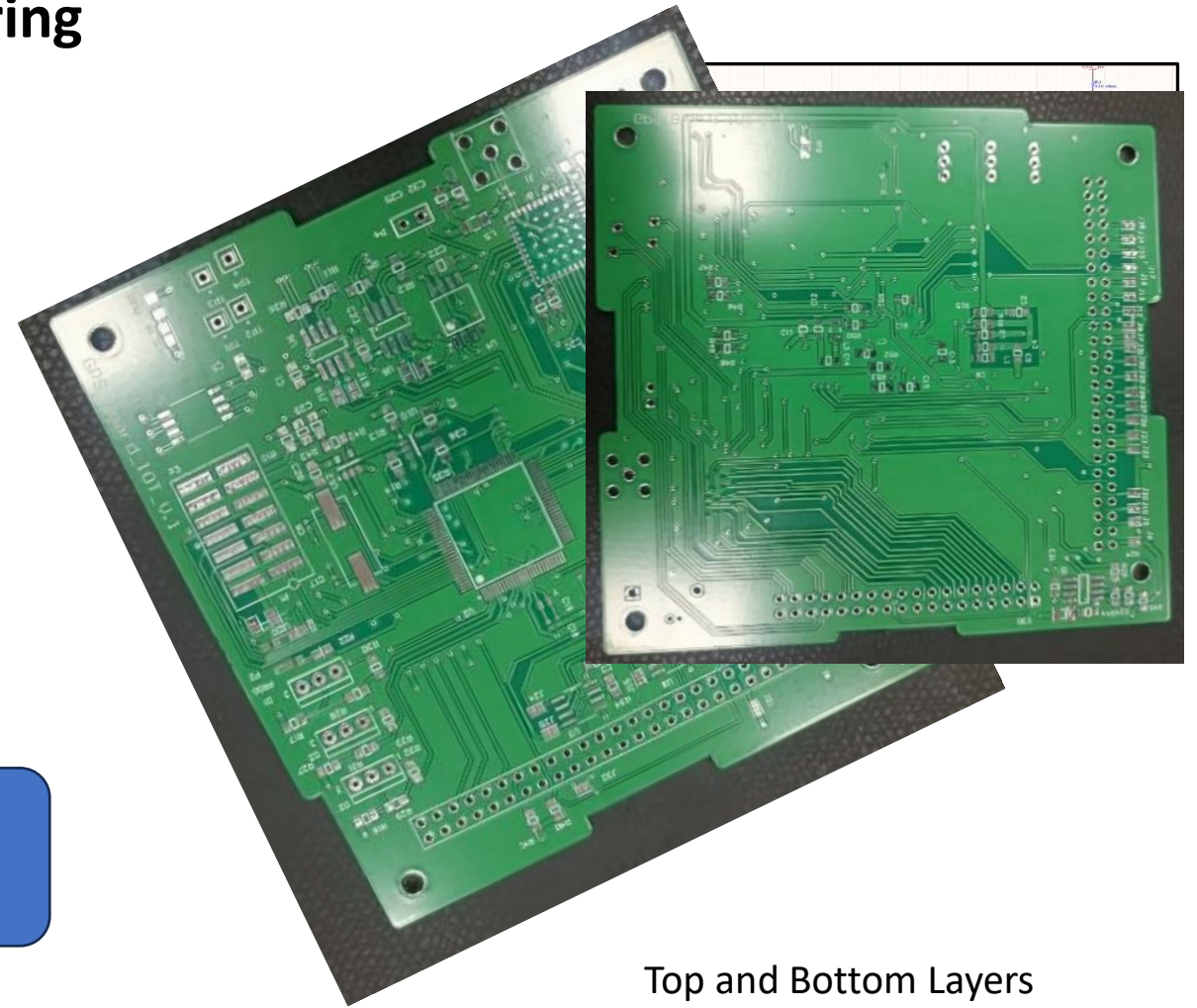
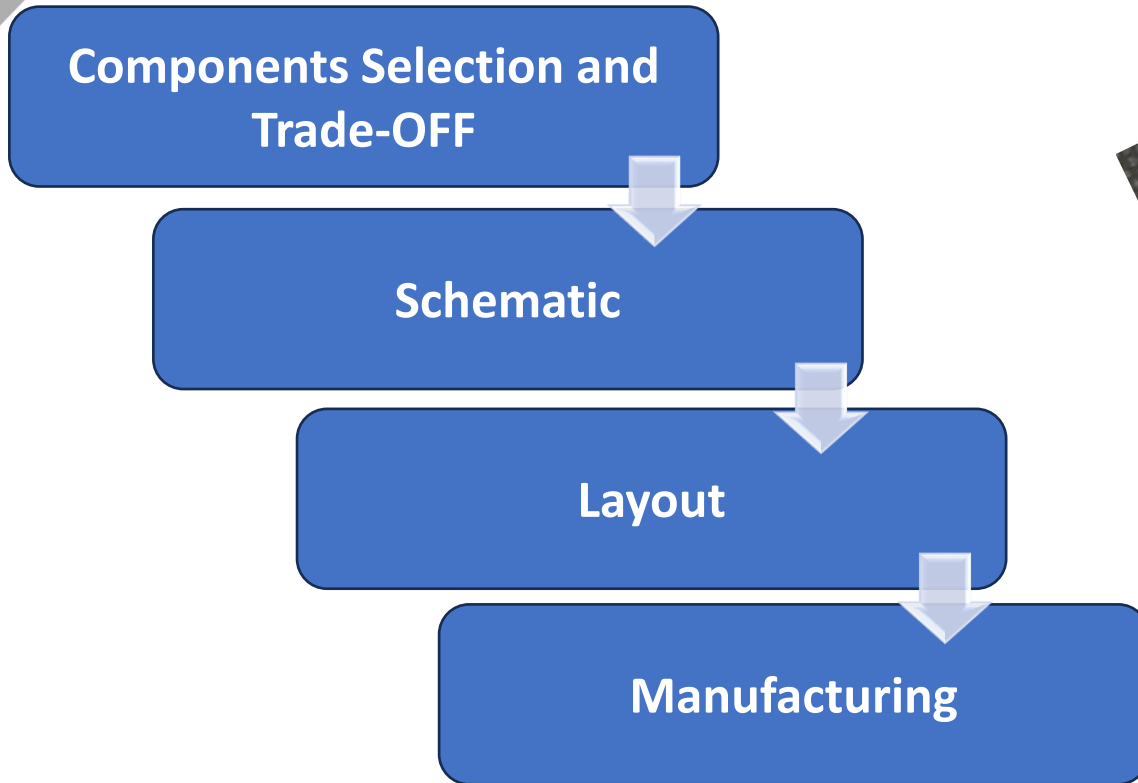


## 1. HW Designing and Manufacturing



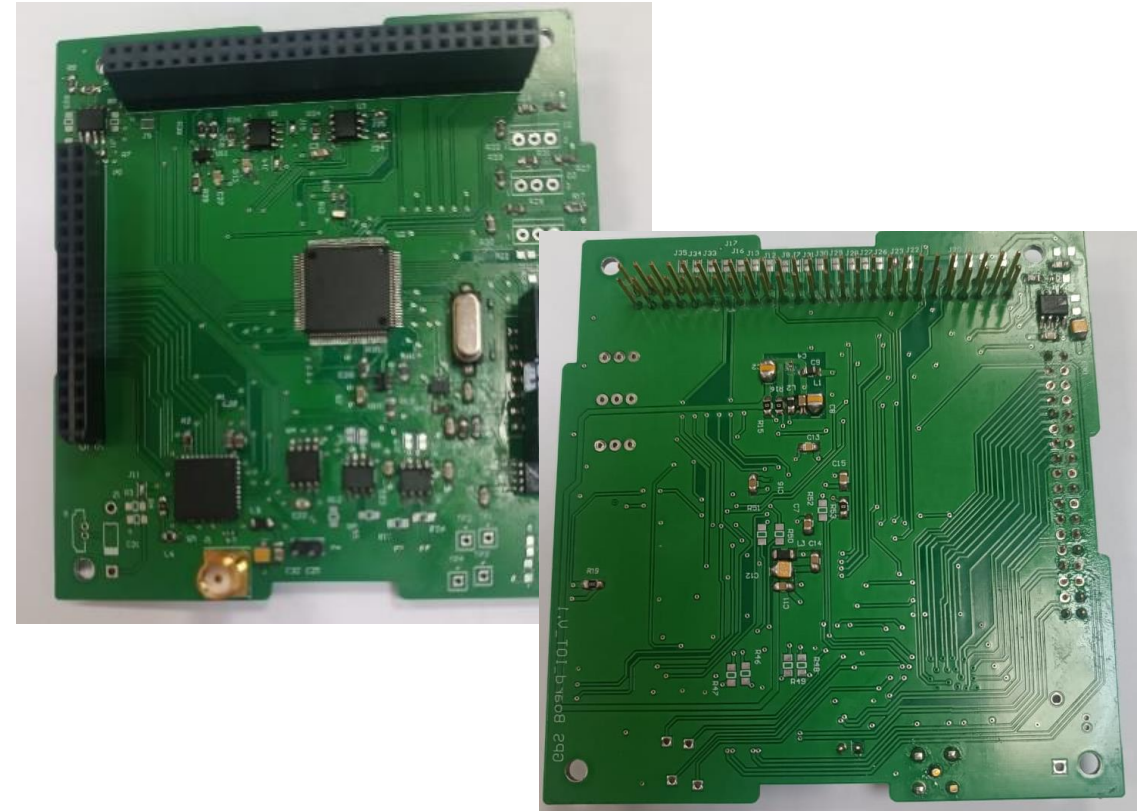
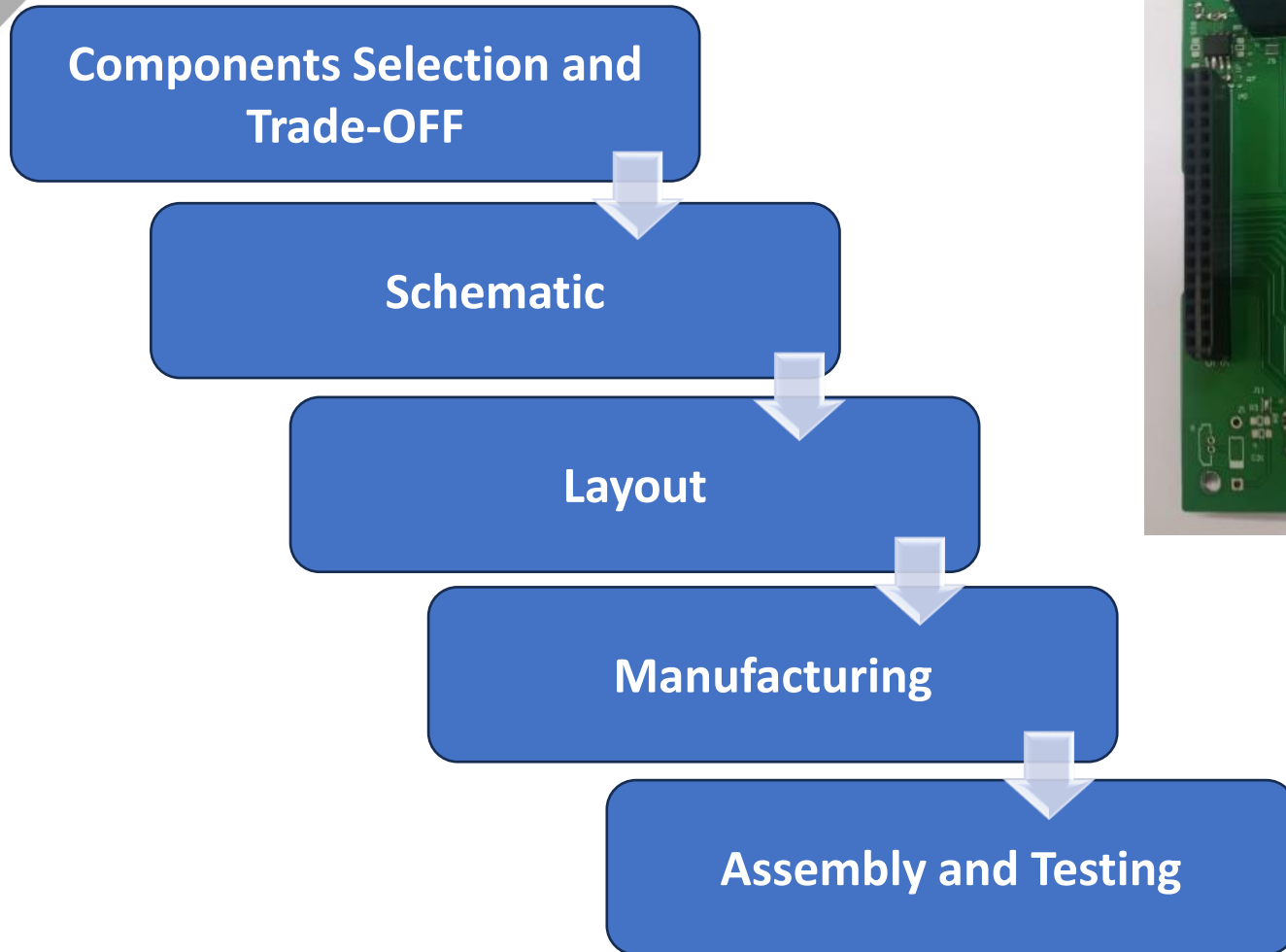
Samples of Layout Design

## 1. HW Designing and Manufacturing



Top and Bottom Layers

## 1. HW Designing and Manufacturing



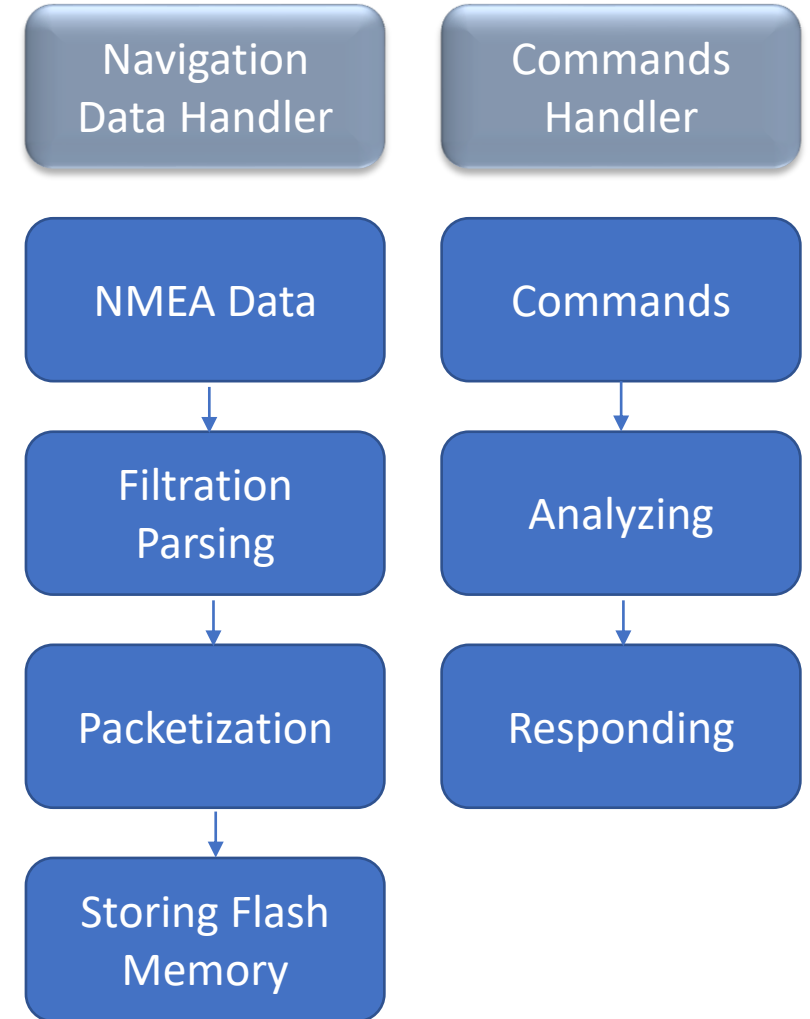
Top and Bottom Layers after Assembly



## 2. SW Implementation

### Software Specifications and Functionalities

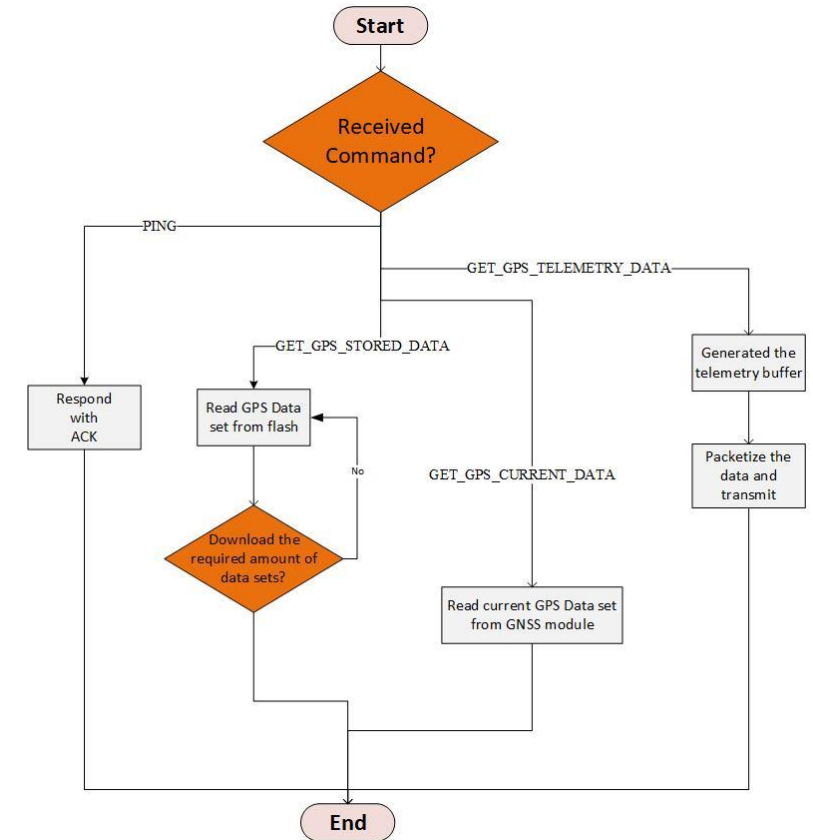
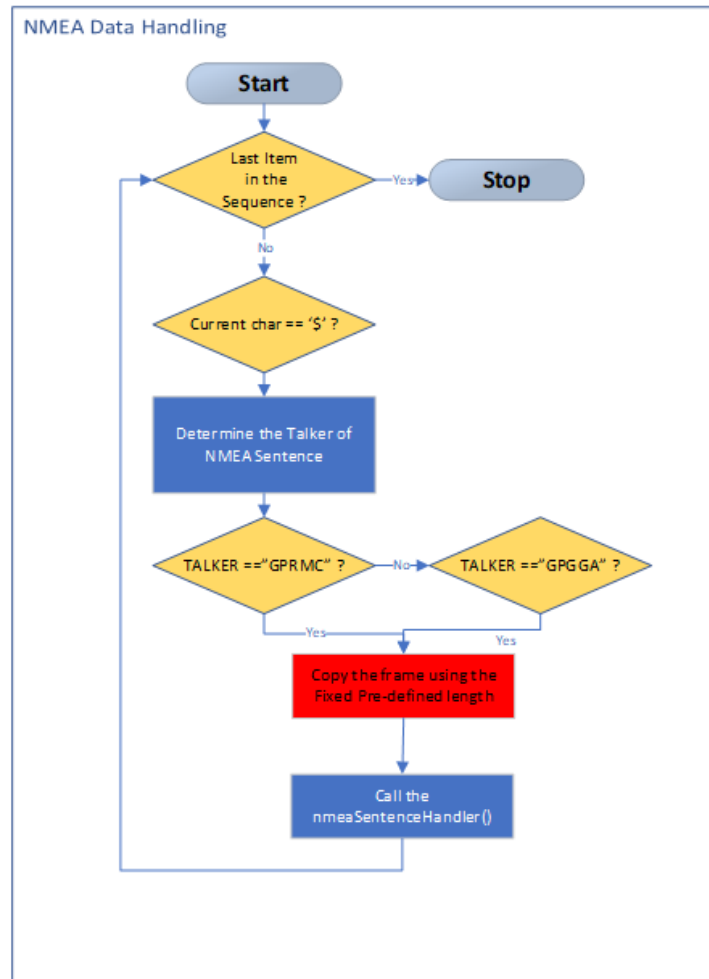
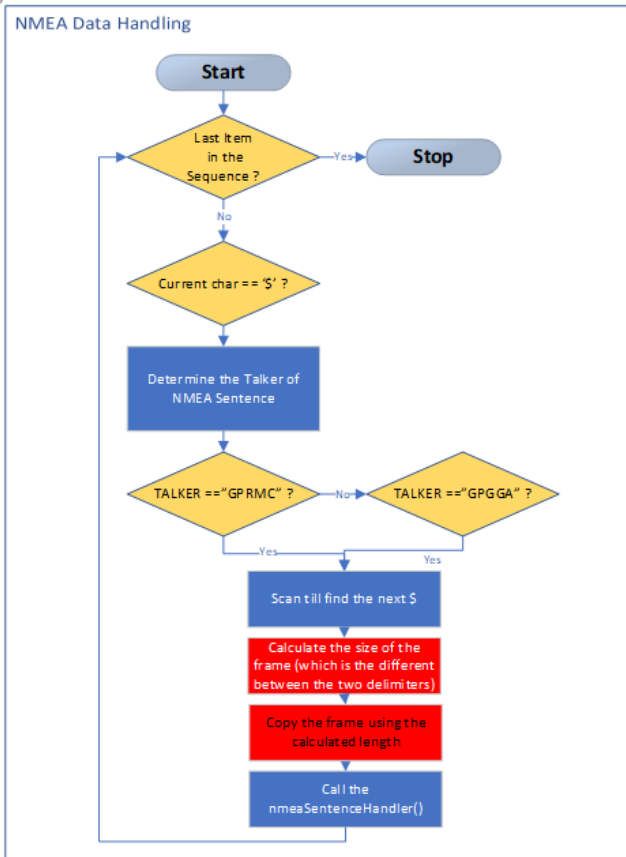
- Serial Communication Protocol and Drivers.
- Interfacing the Microcontroller with the GPS Module and the Flash memory.
- Ground Station Commands Handling and Execution.
- NMEA Data Analysis; Filtering, Parsing and Storing.





# GPS Rx Subsystem Designing and Implementation-Cont.

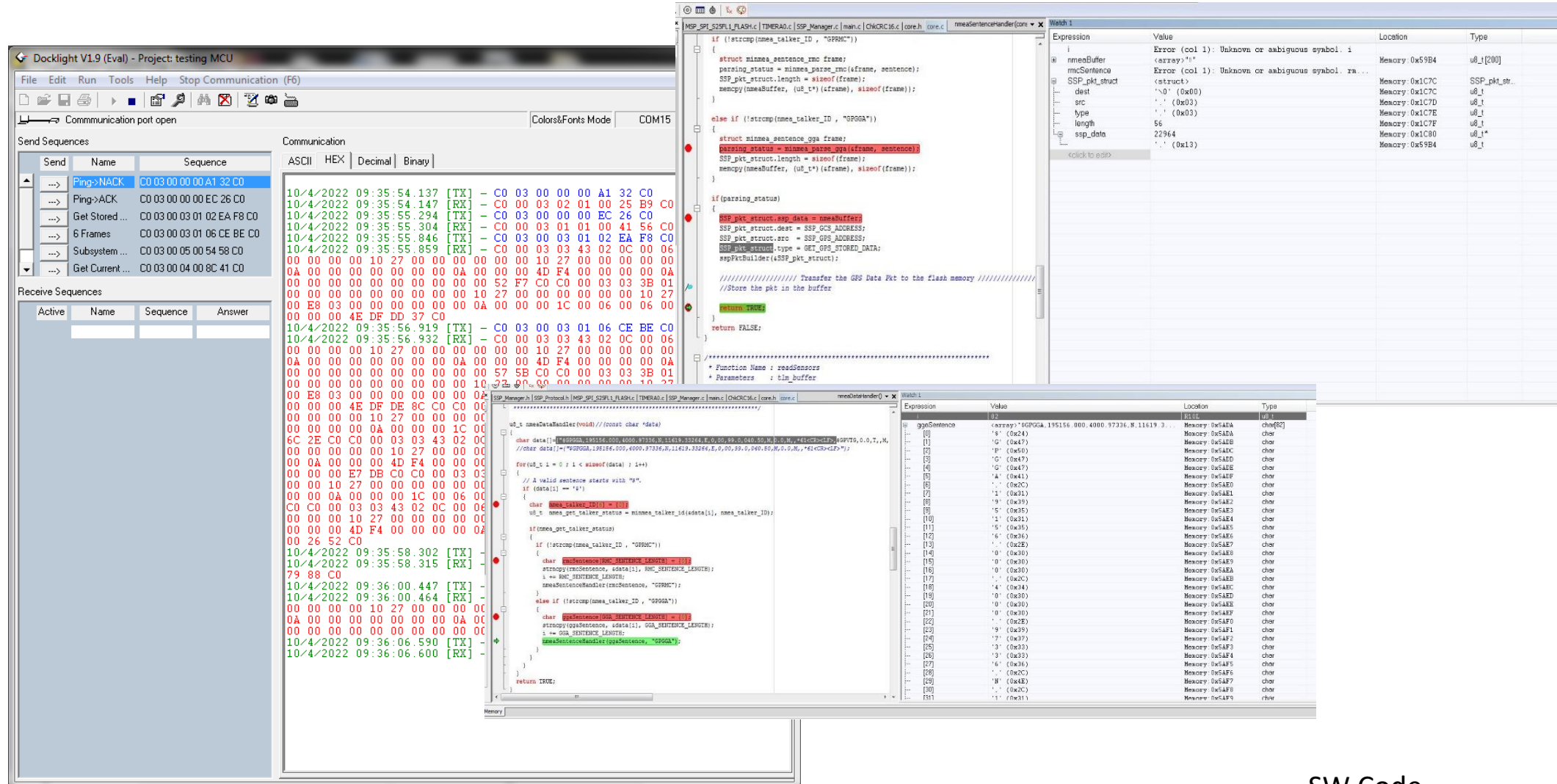
## 2. SW Implementation



SW Flowcharts



## 2. SW Implementation



The screenshot displays a development environment with three main windows:

- Left Window (Docklight V1.9):** Shows communication sequences. The 'Send Sequences' table includes:
 

Send	Name	Sequence
...	Ping->NACK	CO 03 00 00 00 A1 32 CO
...	Ping->ACK	CO 03 00 00 00 EC 26 CO
...	Get Stored...	CO 03 00 03 01 02 EA F8 CO
...	6 Frames	CO 03 00 03 01 06 CE BE CO
...	Subsystem...	CO 03 00 05 00 54 58 CO
...	Get Current...	CO 03 00 04 00 8C 41 CO
- Middle Window (Communication Log):** Shows a log of TX and RX data. Key entries include:
 

```

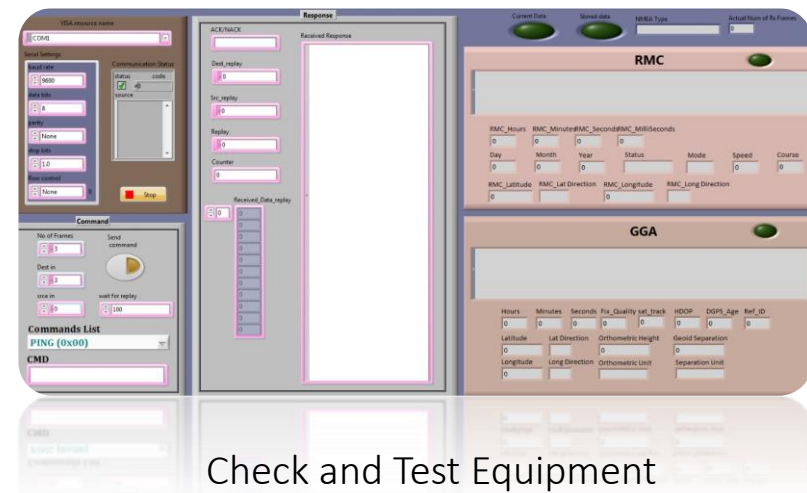
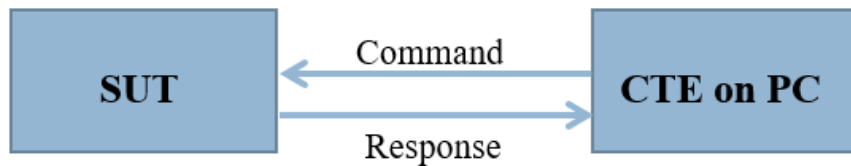
      10/4/2022 09:35:54.137 [TX] - CO 03 00 00 00 A1 32 CO
      10/4/2022 09:35:54.147 [RX] - CO 00 03 02 01 00 25 B9 CO
      10/4/2022 09:35:55.294 [TX] - CO 03 00 00 00 EC 26 CO
      10/4/2022 09:35:55.304 [RX] - CO 00 03 01 01 00 41 56 CO
      10/4/2022 09:35:55.846 [TX] - CO 03 00 03 01 02 EA F8 CO
      10/4/2022 09:35:55.859 [RX] - CO 00 03 03 43 02 0C 00 06
      0A 00 00 00 10 27 00 00 0A 00 00 00 10 27 00 00 00 00 00
      0A 00 00 00 00 00 00 00 0A 00 00 00 4D F4 00 00 00 0A
      00 00 00 00 00 00 00 00 00 52 F7 CD C0 00 03 03 3B 01
      00 00 00 00 00 00 00 00 10 27 00 00 00 00 00 10 27
      00 E8 03 00 00 00 00 00 0A 0A 00 00 00 1C 00 06 00 06
      00 00 00 4E DF DD 37 CO
      10/4/2022 09:35:56.919 [TX] - CO 03 00 03 01 06 CE BE CO
      10/4/2022 09:35:56.932 [RX] - CO 00 03 03 43 02 0C 00 06
      00 00 00 10 27 00 00 00 00 00 10 27 00 00 00 00 00
      0A 00 00 00 00 00 00 0A 00 00 00 4D F4 00 00 00 0A
      00 00 00 00 00 00 00 00 00 57 5B C0 C0 00 03 03 3B 01
      00 00 00 00 00 00 00 10 27 00 00 00 00 00 00 00 00
      00 E8 03 00 00 00 00 00 0A 0A 00 00 00 1C 00 06 00 06
      00 00 00 4E DF DD 8C CO CO CO
      00 00 00 10 27 00 00 00 00 00 1C 00 06 00 06
      00 00 00 0A 00 00 00 00 00 1C 00 06 00 06
      00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
      00 0A 00 00 00 4D F4 00 00 00 00 00
      00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
      00 26 52 CD
      10/4/2022 09:35:58.302 [TX] -
      10/4/2022 09:35:58.315 [RX] -
      79 88 CO
      10/4/2022 09:36:00.447 [TX] -
      10/4/2022 09:36:00.464 [RX] -
      00 00 00 00 10 27 00 00 00 00
      0A 00 00 00 00 00 00 00 0A 00 00 00 4D F4 00 00 00 0A
      00 00 00 00 00 00 00 00 00 52 F7 CD C0 00 03 03 3B 01
      00 00 00 00 00 00 00 00 10 27 00 00 00 00 00 00 00
      10/4/2022 09:36:06.590 [TX] -
      10/4/2022 09:36:06.600 [RX] -
      
```
- Right Window (Code Editor):** Shows C code for `readSensors` and `mcSentence`. The `readSensors` function processes received data, checks for valid sentences, and transfers GPS data to flash memory. The `mcSentence` function handles sentence parsing and status updates. A Watch window on the right shows variable values like `mcSentence` (array), `SSP_pkt_struct` (struct), and `ssp_data` (int).





## 3. Check and Test Equipment Implementation

- The CTE is used to simulate the behavior of other subsystems/ Ground Control Station.
- The Software and Hardware are tested Using the CTE.

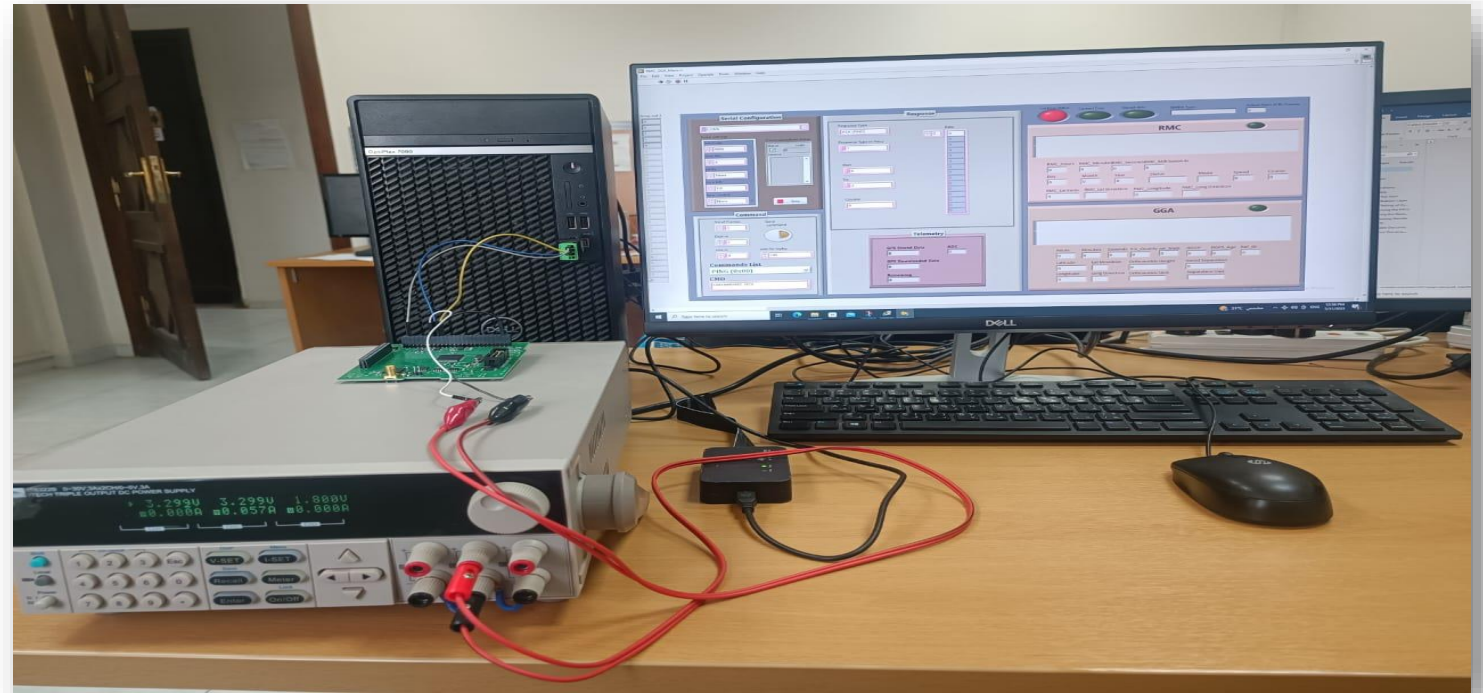




# GPS Rx Subsystem Integrated Testing

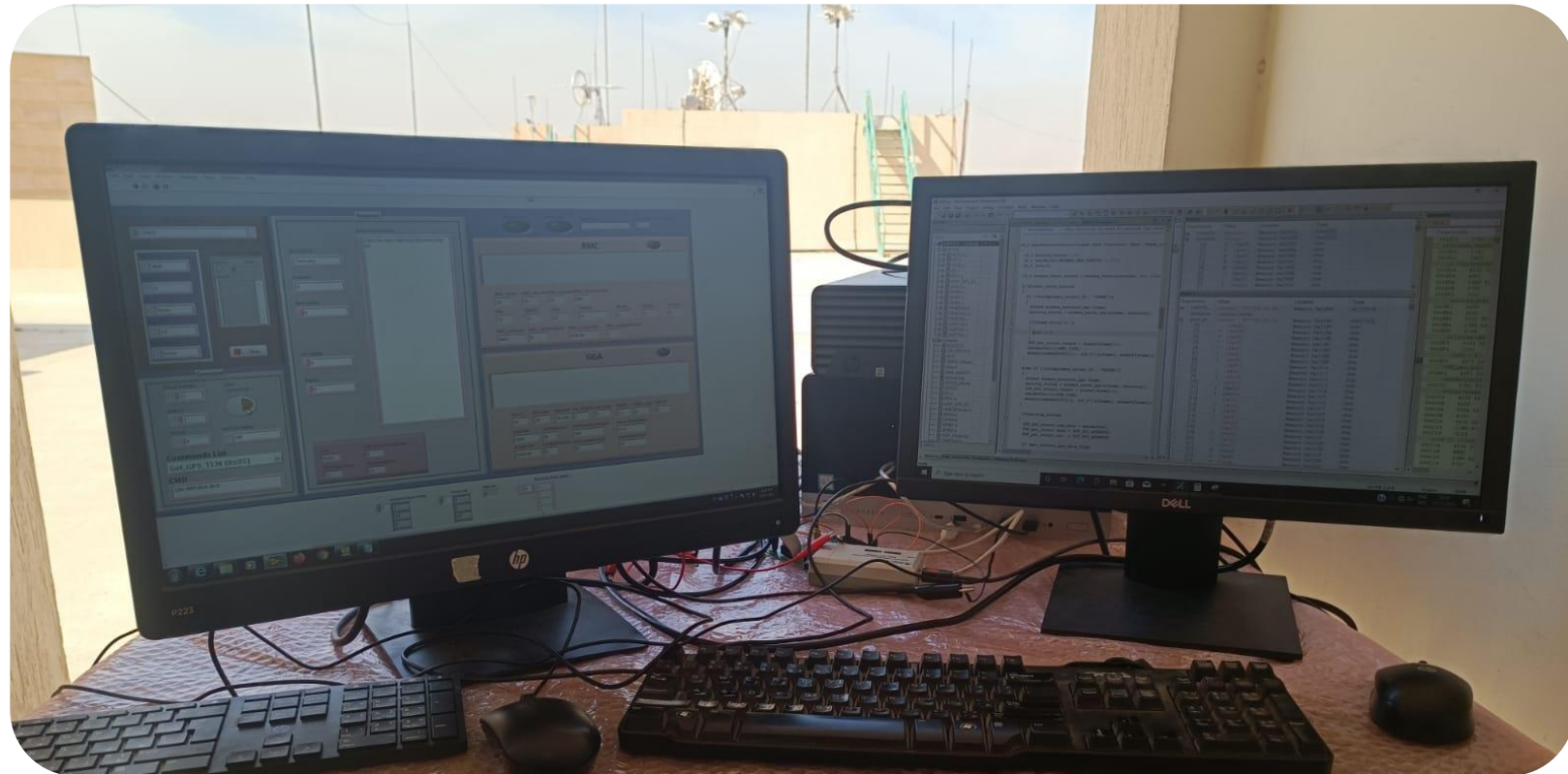
GPS Data																			
UTC_No	UTC_Mi	UTC_Sc	RMC_St	Latitude	Longitude	RMC_S	RMC_C	RMC_U	RMC_V	RMC_N	GGA_Fr	GGA_Sl	GGA_Hc	GGA_Or	GGA_Gr	GGA_Gr	GGA_Ap	GGA_Ref_ID	
13	23	23	NA	0	N	0	NA	NA	NA	NA	0	0	0	0	M	0	M	0	0
13	23	23	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	26	37	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	26	37	V	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	26	38	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	26	40	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	26	41	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	26	43	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	26	43	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	26	46	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	26	46	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	26	43	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	26	43	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	26	52	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	26	52	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	26	55	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	26	55	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	26	58	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	26	58	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	27	1	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	27	1	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	27	4	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	27	4	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	27	7	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	27	7	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	27	10	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	27	10	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	27	13	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	27	13	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	27	16	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	27	16	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	27	19	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	27	19	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	27	22	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	27	22	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	27	24	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	27	25	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	27	27	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	27	28	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	27	30	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	27	31	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	27	33	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	27	33	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	27	34	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	27	36	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	27	36	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	27	33	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	27	33	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA
13	27	42	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	M	0	M	0
13	27	42	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA

Navigation Data



Testing Setup

# GPS Rx Subsystem Functionality Testing



1PPS signal from GNSS Rx Subsystem after locking

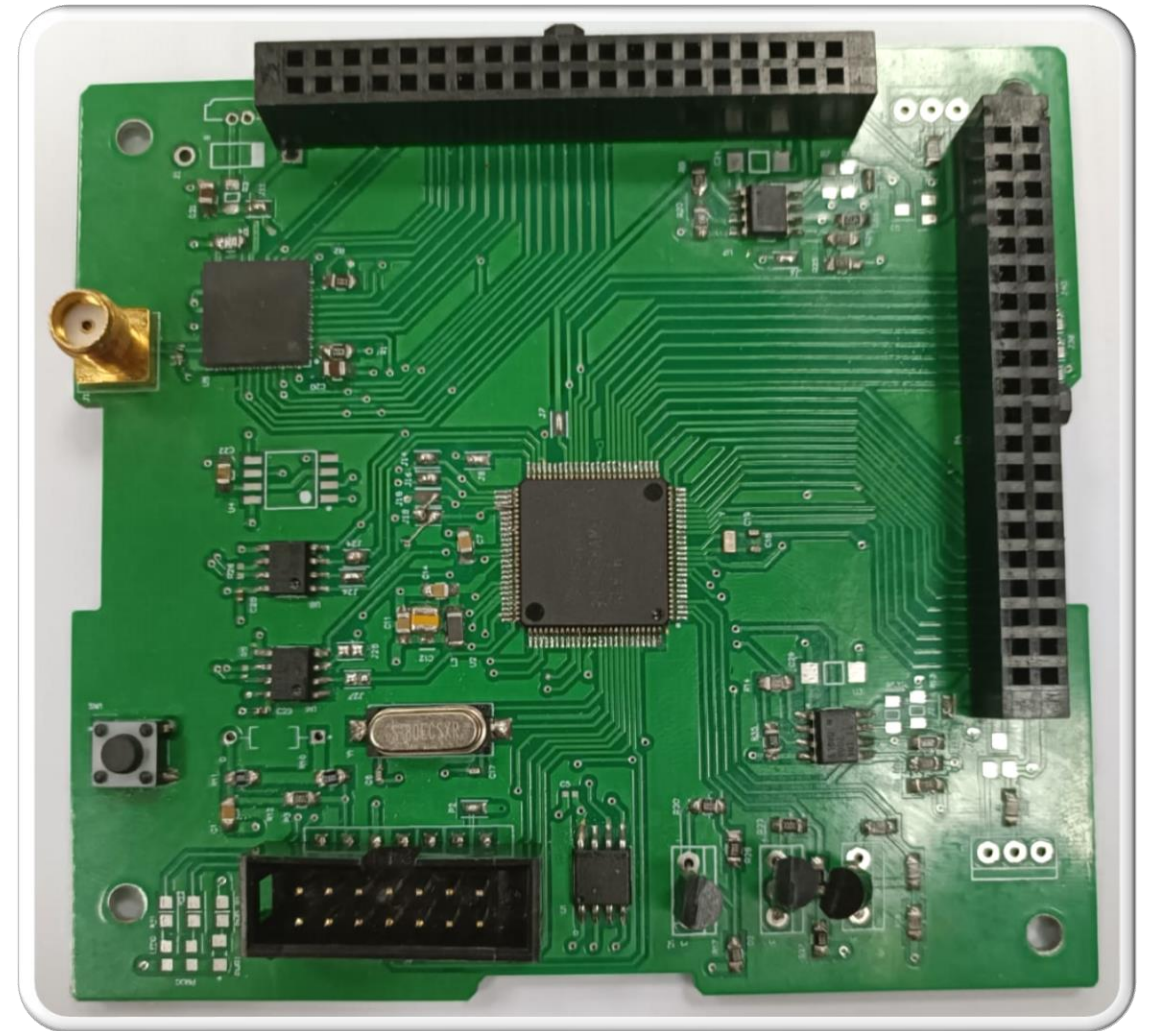
# GPS Rx Subsystem Functionality Testing



1PPS signal from GNSS Rx Subsystem after locking

## Prototype Specifications

- Power Consumption: 3.3 Watt.
- Accuracies
  - Position 2.5m.
  - Velocity 0.1m/sec.
  - Timing 10ns.
- Customized for Low Earth Orbit missions.





# GPS Rx Subsystem Environmental Testing

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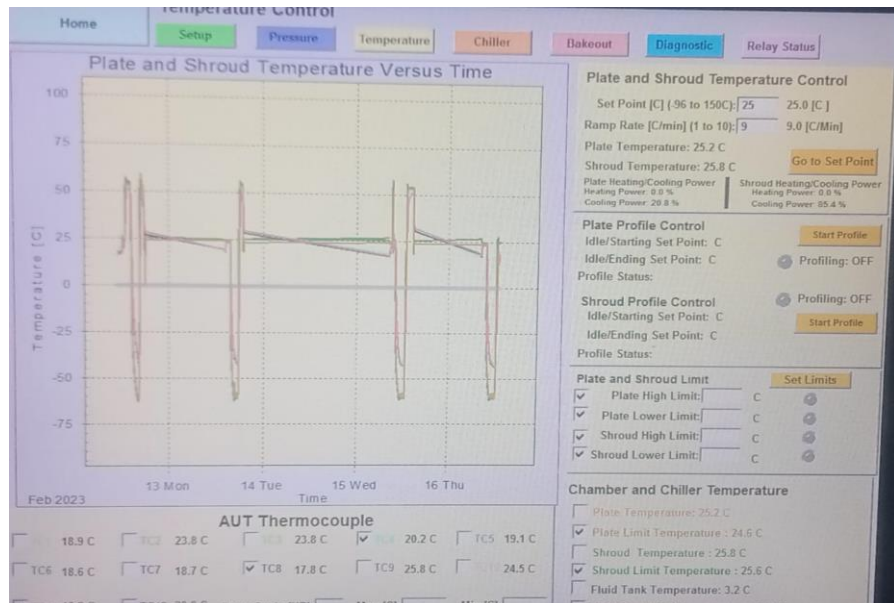
To ensure the system's capability to withstand the harsh conditions of space, rigorous **environmental testing** was conducted.

**1. Thermal Testing**

**2. Mechanical Testing**

## 1. Thermal Vacuum Testing Results

The DUT was installed into a thermal vacuum (TVAC) chamber to perform a thermal cycling test at vacuum.



Different Cycles for Subsystem Qualification

Part of the Test Setup



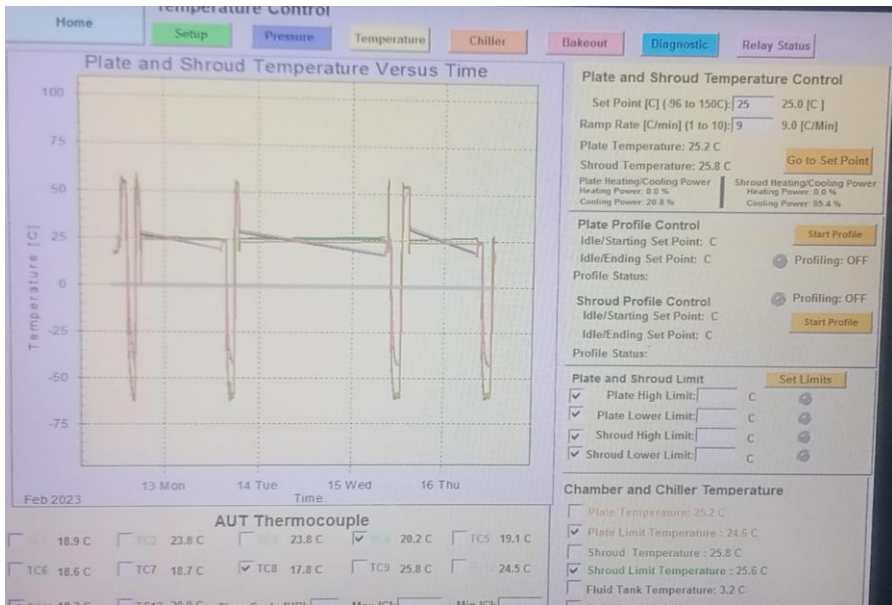
# GPS Rx Subsystem Environmental Testing-Cont.

## 1. Thermal Vacuum Testing Results

### Test Conditions

The DUT was installed into a thermal vacuum (TVAC) chamber to perform a thermal cycling test at vacuum.

Maximum Operational Temperature	50 deg.
Minimum Operational Temperature	-40 deg.
Temperature at the start and end of the test	23 deg.
Pressure set point	1.0E+001 Torr
Total number of cycles	4



Different Cycles for Subsystem Qualification

### Test Log

Day (Date)	Temperature	Pressure	Functional Test
Day1 (12/2/2023)	High	Vacuum	FT1
	Low	Vacuum	FT2
	High	Vacuum	FT3
Day2 (13/2/2023)	Low (Cold Restart)	Vacuum	FT4
	High	Vacuum	FT5
Day3 (15/2/2023)	Low	Vacuum	FT6
	High	Vacuum	FT7
Day4 (16/2/2023)	Low	Vacuum	FT8

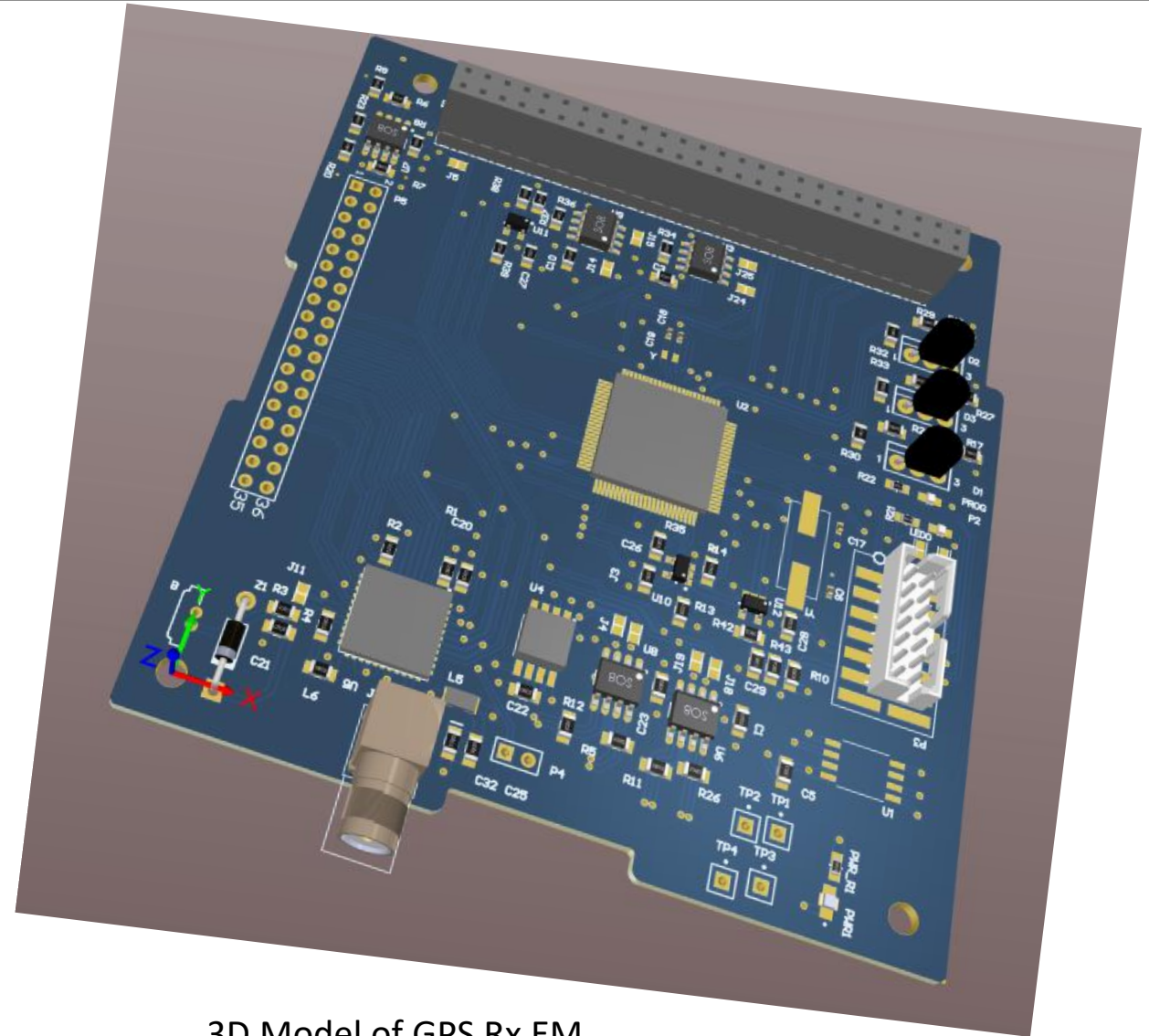


## 2. Mechanical Vibration Testing Results



# GPS Rx Subsystem EM

By June 2023, the initial In-Home GPS-RX Subsystem had been developed, implemented, and thoroughly tested, demonstrating successful and reliable functionality through various functional and environmental tests.



3D Model of GPS Rx EM

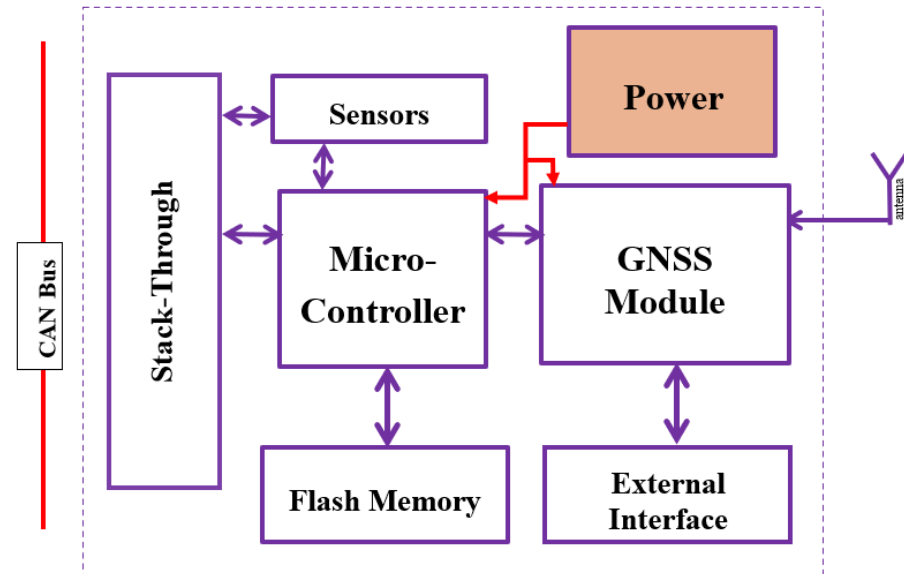
# Mirsat Constellation GPS Rx Subsystem EM

Due to the constellation platform, New Specifications are added:

- External and Internal Interfaces.
- Internal Communication Protocol: CAN.
- Voltage Supply: 29 volt.

Thus, the three main units shall be modified.

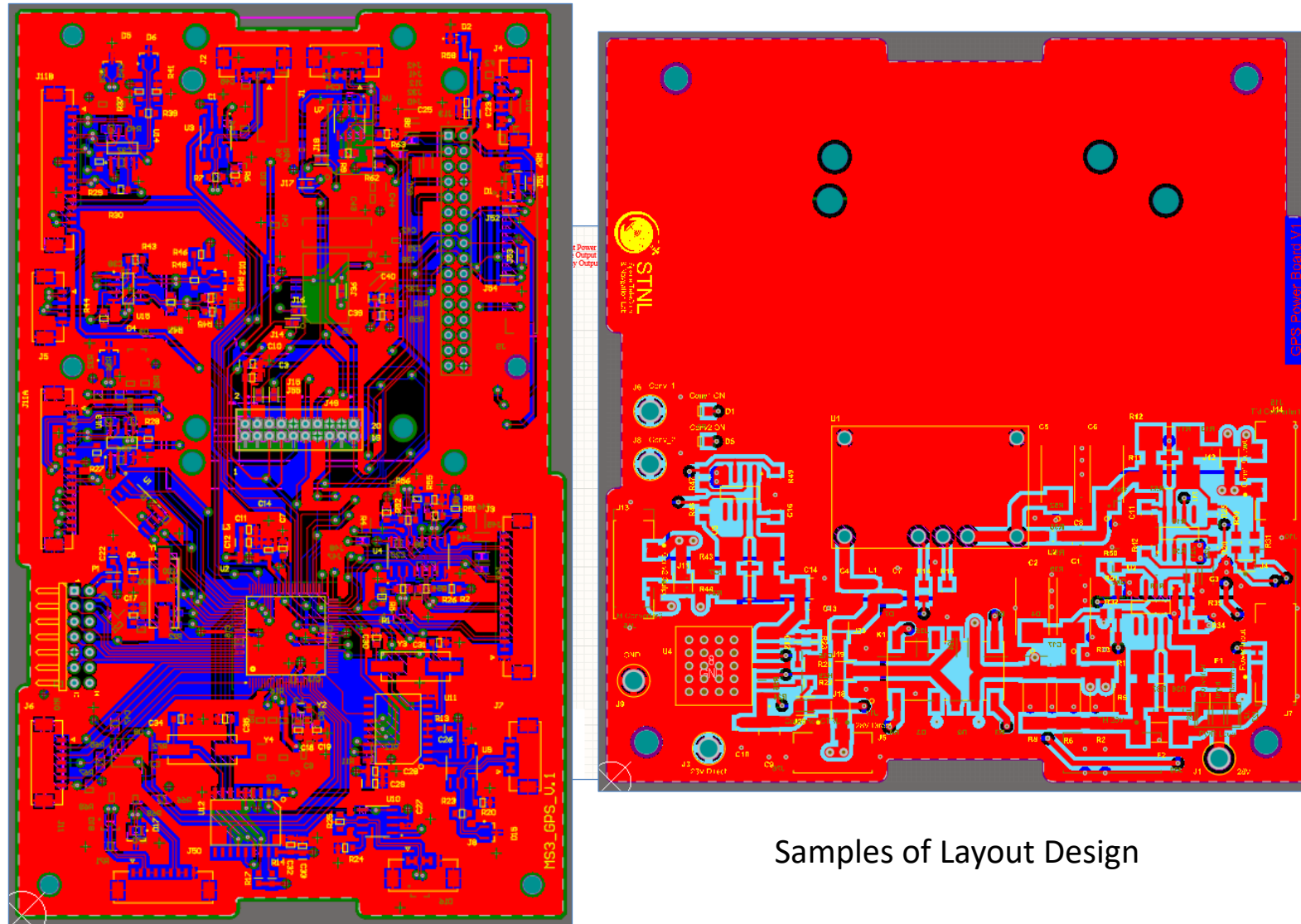
- ❖ The GPS Rx subsystem is designed for utilization in the upcoming Mirsat constellation. Nonetheless, in the first satellite of the constellation, it will be the auxiliary subsystem rather than the primary one.



Block Diagram for Proposed GPS Receiver



## 1. HW Design and Manufacturing



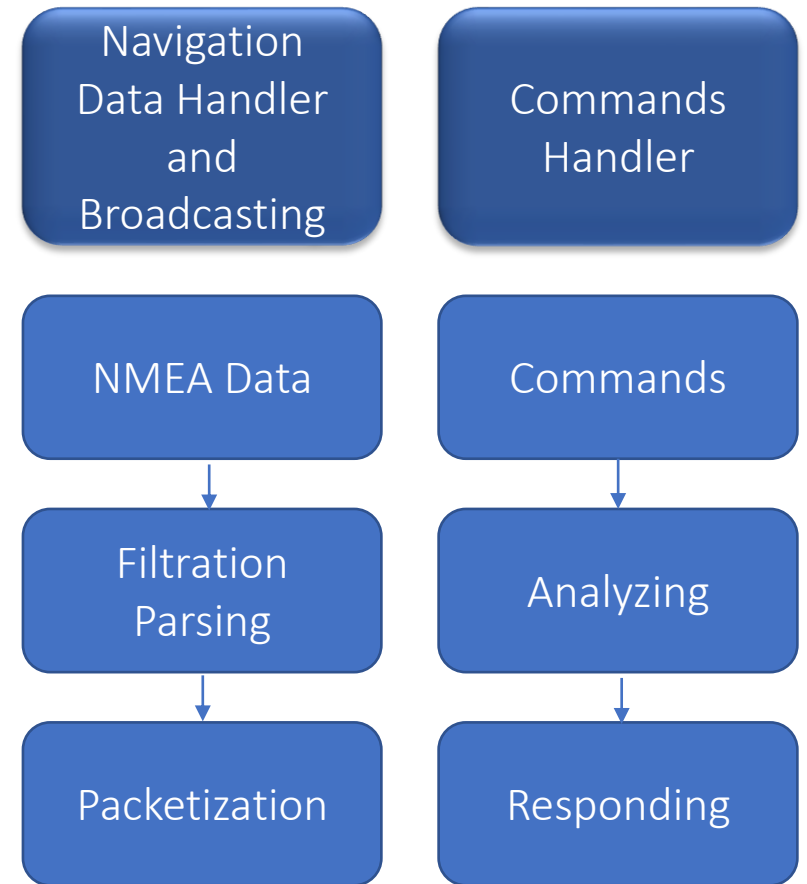
Samples of Layout Design



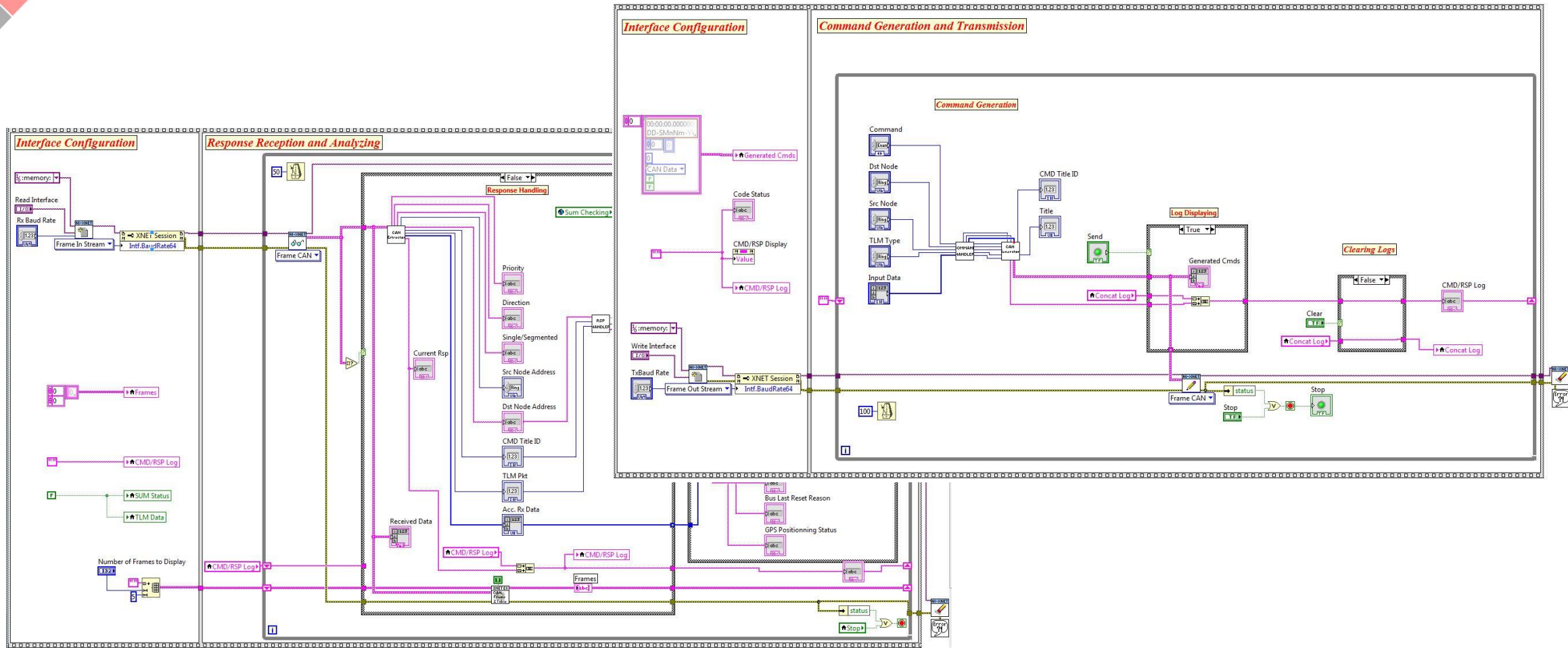
## 2. SW Implementation

### Software Modifications:

- Board Drivers.
- Communication Protocol.
- Ground Station Commands Handling and Execution.



## 3. Check and Test Equipment Implementation



Check and Test Equipment



## 3. Check and Test Equipment Implementation

**MirSat-3 GPS CTE**

**Commands Generation and Transmission**

**CAN Interface**

Write Interface: % CAN2

TxBaud Rate: 125000

**Send**

**Tx Command Parameters**

Command: Customized    Input Data: 22

Dst Node: <C>

Src Node: <C>

TLM Type: Fast Tlm

Generated Cmds

identifier	extended?	echo?	type	timestamp
x0	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	CAN Data	00:00:00.000000C DD-SMnNm-YY
payload: 0 0 0 0 0 0 0 0				
x0	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	CAN Data	00:00:00.000000C DD-SMnNm-YY
payload: 0 0 0 0 0 0 0 0				
x0	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	CAN Data	00:00:00.000000C DD-SMnNm-YY
payload: 0 0 0 0 0 0 0 0				

**Response Handling and Analyzing**

**CAN Interface**

Read Interface: % CAN1

Rx Baud Rate: 125000

**Rx Data Parameters**

Priority: 0    CMD Title: x0    Acc. Rx Data: 0

Direction: 0    TLM Pkt: 0

Single/Segmented: 0    Data Size: 0

Src Node Address: <C>

Dst Node Address:

Rsp Status:

SUM Status:     TLM Data:

Received Data

identifier	extended?	echo?	type	timestamp
x0	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	CAN Data	00:00:00.000000C DD-SMnNm-YY
payload: 0 0 0 0 0 0 0 0				

TimeStamp	Data	ID	Extended?	Echo?

**LOG and TLM**

CMD/RSP    TLM

**CLEAR**    **STOP**

RSP/CMD Control

Check and Test Equipment





# Conclusion and Future Work

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## Conclusion

In 2021, our project started with the objective of designing, implementing, and testing an In-Home GPS Receiver Subsystem characterized by high accuracy, and low power consumption compared to existing subsystems in the market. The initial prototype was developed in 2022, while the engineering model (EM) was generated by the end of June 2023.

## Future Work

- By the end of July 2024, we shall have MisrSat Const. GPS Rx EM.
- Within the first quarter of 2025 the FM will be ready to be used in constellation mission.

# Remark



Thermal Vacuum Chamber

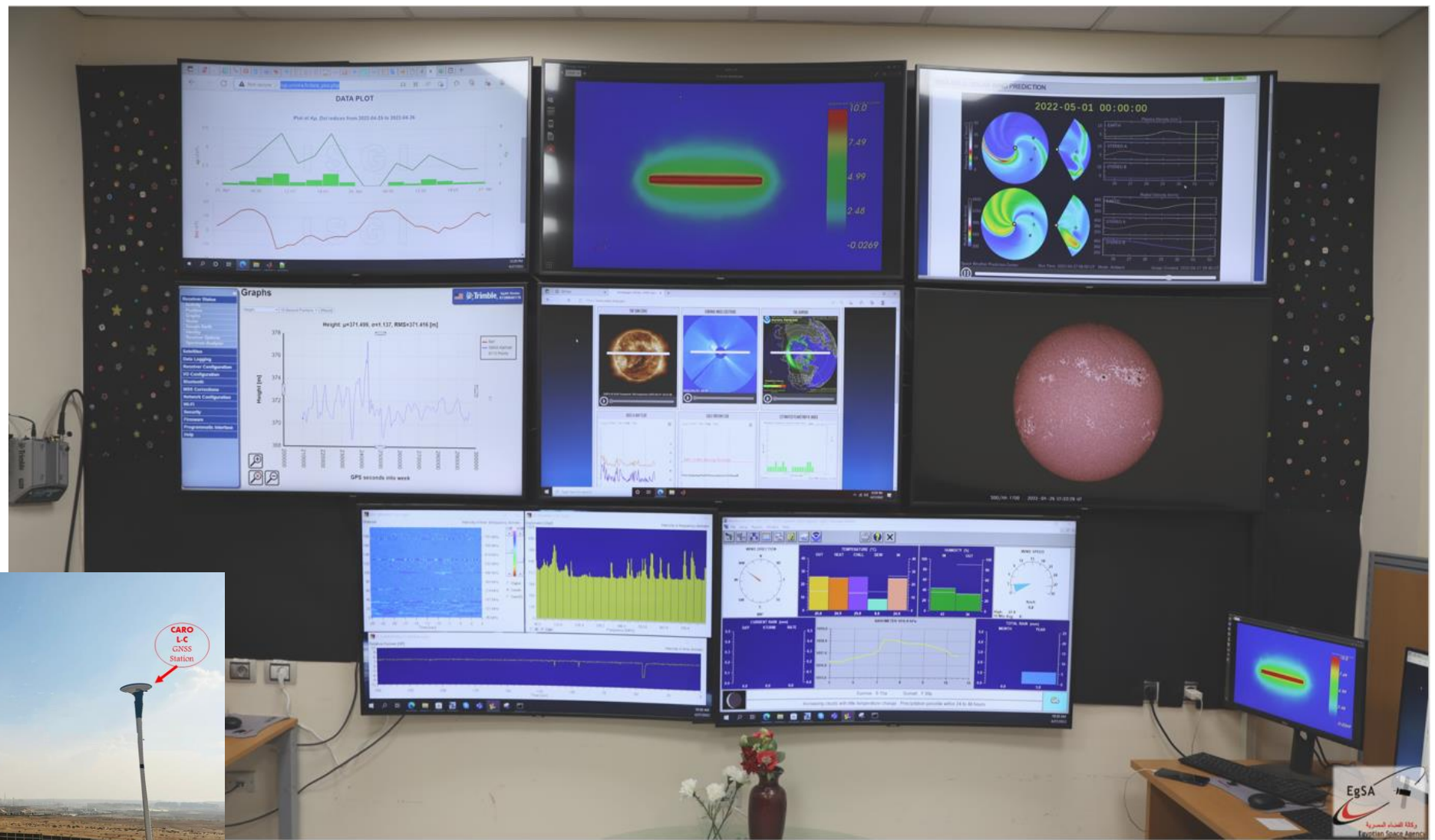


Satellite Communication Lab



AIT Station

# Remark



The Space Weather Monitoring Center



# Thanks

Eng. Ranya Salah Elagooz

Email: [Ranya.elagooz@egsa.gov.eg](mailto:Ranya.elagooz@egsa.gov.eg)