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Egyptian Space Agency

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

Ranya Salah Elagooz

Communication Designer Engineer

Egyptian Space Agency

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Agenda

- 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

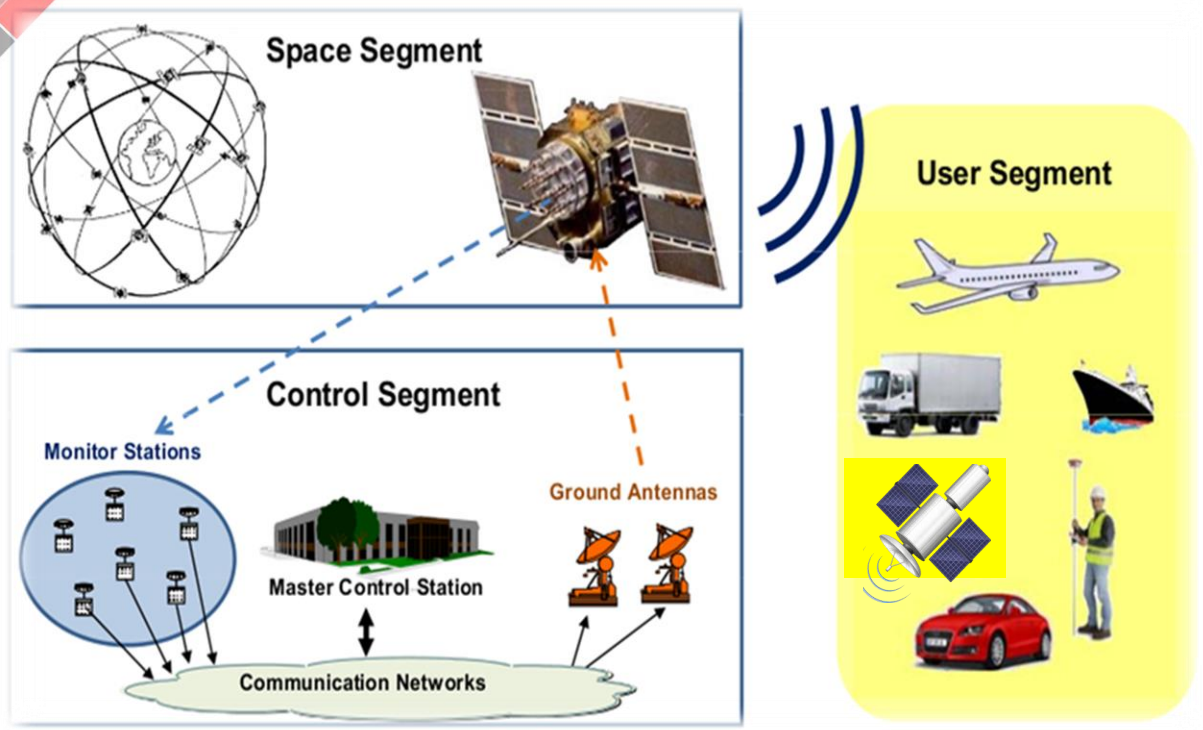
Global Navigation Satellite System (GNSS) is the standard generic term for satellite navigation systems:

- 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



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

GPS Receivers Subsystems

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

Project RoadMap

01

Jan 2021 – June 2022

GPS Rx Subsystem Prototype

An Integrated Board that includes the subsystem.

02

July 2022 – June 2023

GPS Rx Subsystem EM

Environmental Testing.

03

July 2023- July 2024

Misrsat Const. GPS Rx Subsystem EM

Three Different Boards:

- Microcontroller
- Rx Module
- Power

04

August 2024 – First Quarter 2025

Misrsat Const GPS Rx Subsystem FM

Shall be used in MisrSat-3 Mission

05

First to Forth Quarter 2025

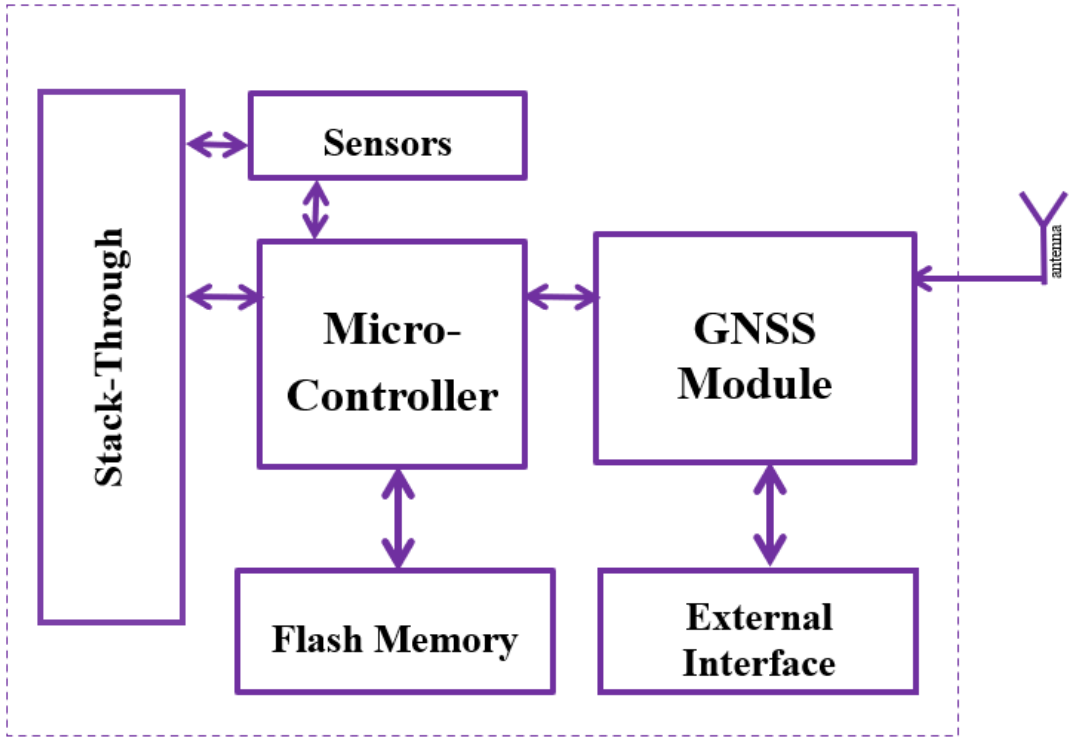
Misrsat Const Mission

Integrated in the Mission

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

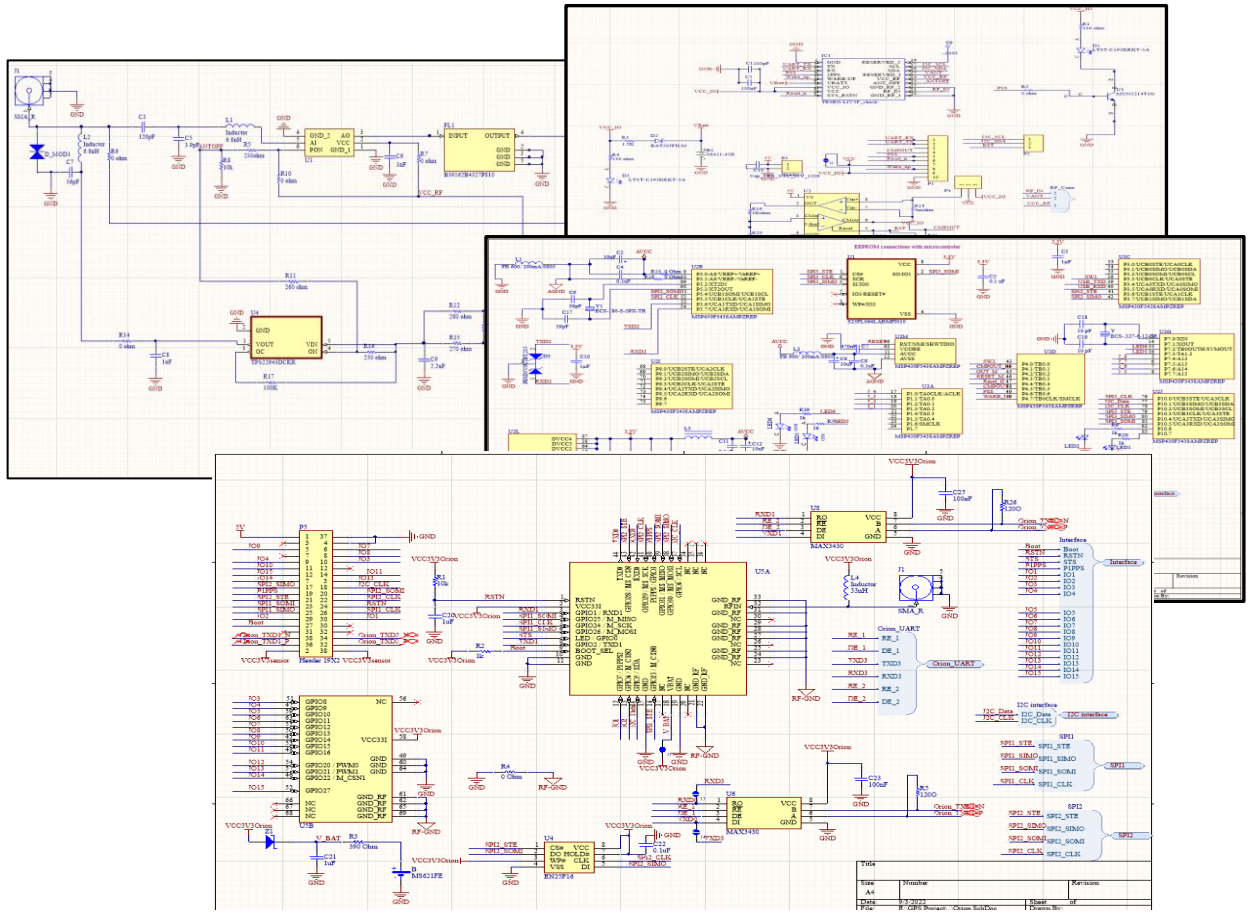
- Space Certified/ Space Heritage.
- Tolerance.
- Temperature Range of Operation.
- Price.

GPS Rx Subsystem Designing and Implementation

1. HW Designing and Manufacturing

Components Selection and Trade-OFF

Schematic

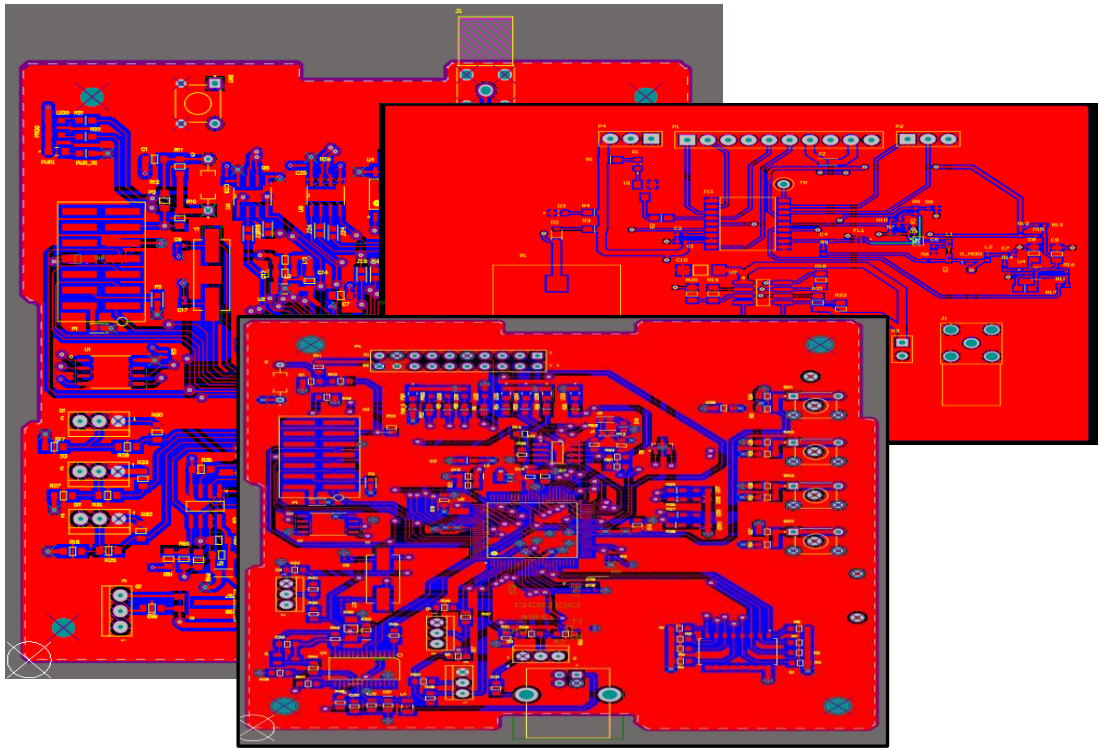


Samples of Schematic Design

GPS Rx Subsystem Designing and Implementation

1. HW Designing and Manufacturing

- Components Selection and Trade-OFF
- Schematic
- Layout

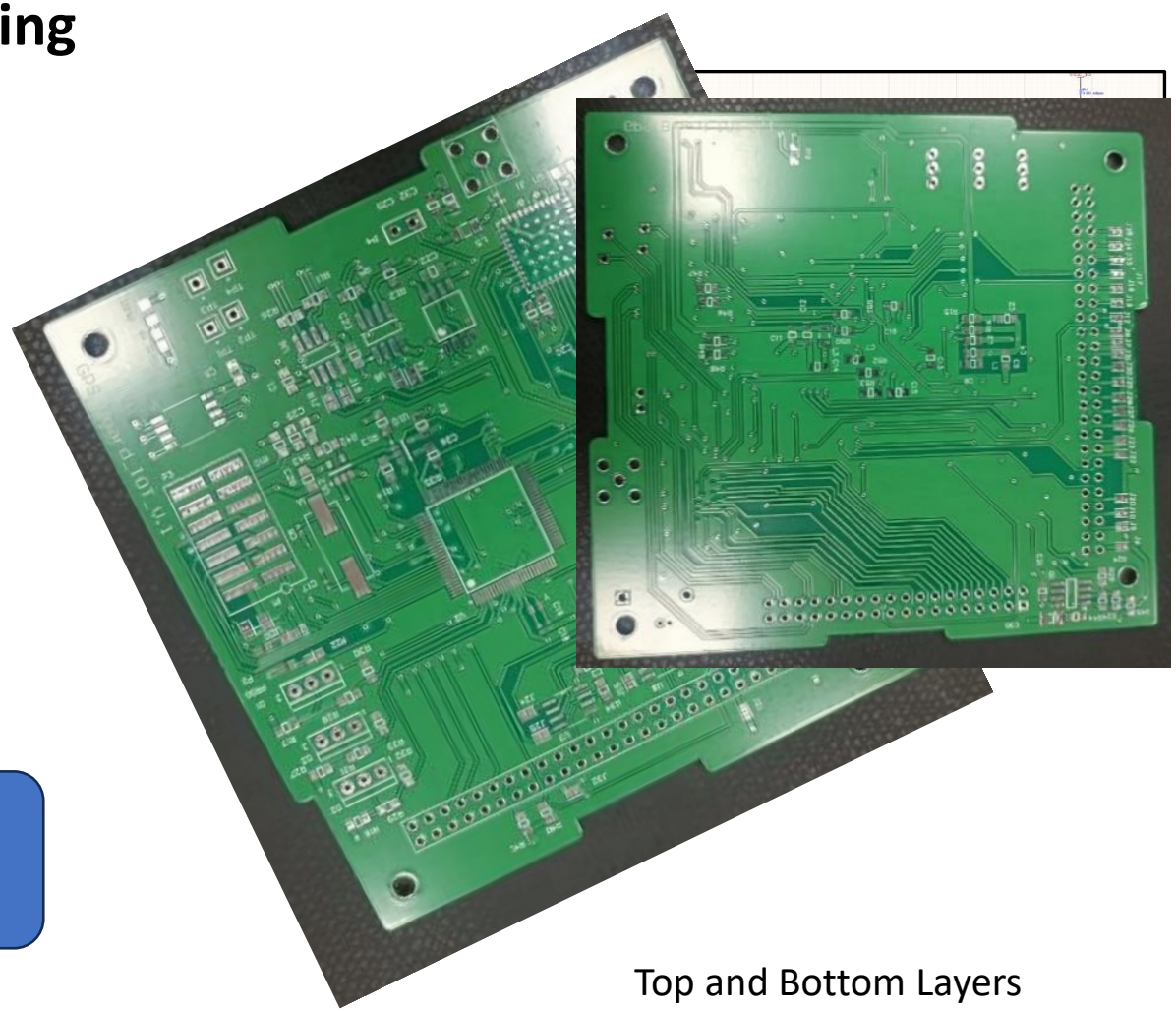


Samples of Layout Design

GPS Rx Subsystem Designing and Implementation

1. HW Designing and Manufacturing

- Components Selection and Trade-OFF
- Schematic
- Layout
- Manufacturing

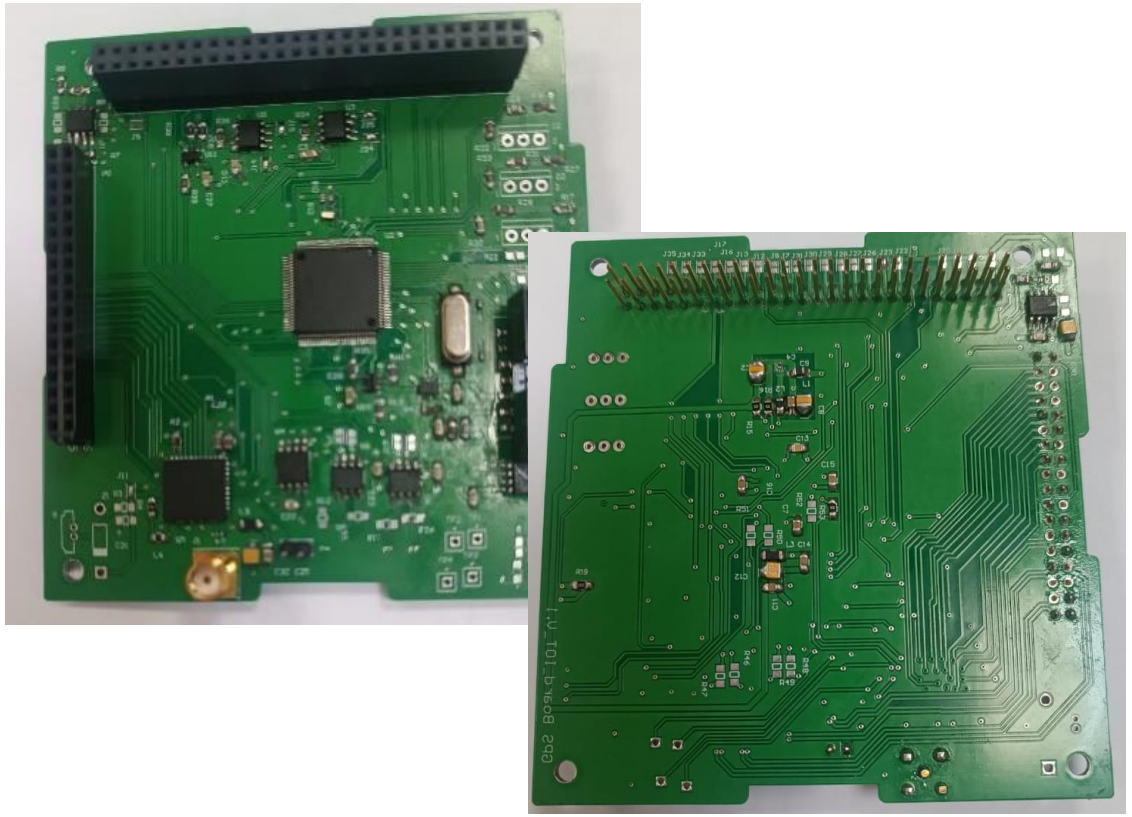


Top and Bottom Layers

GPS Rx Subsystem Designing and Implementation

1. HW Designing and Manufacturing

- Components Selection and Trade-OFF
- Schematic
- Layout
- Manufacturing
- Assembly and Testing



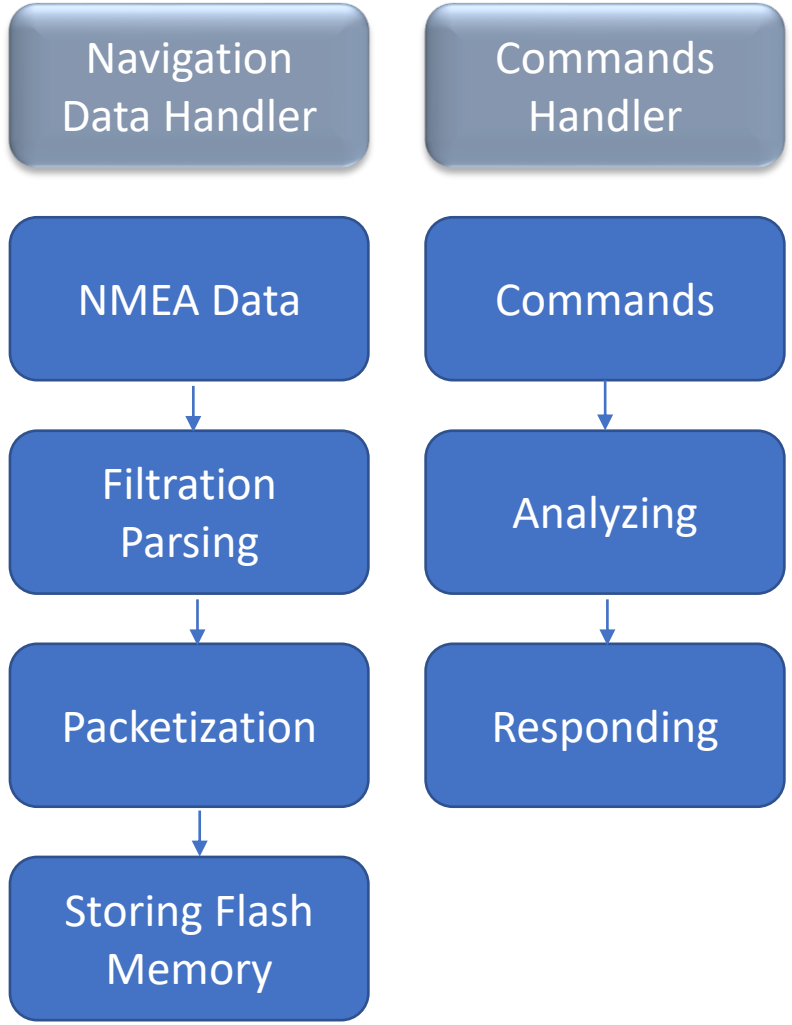
Top and Bottom Layers after Assembly

GPS Rx Subsystem Designing and Implementation-Cont.

2. SW Implementation

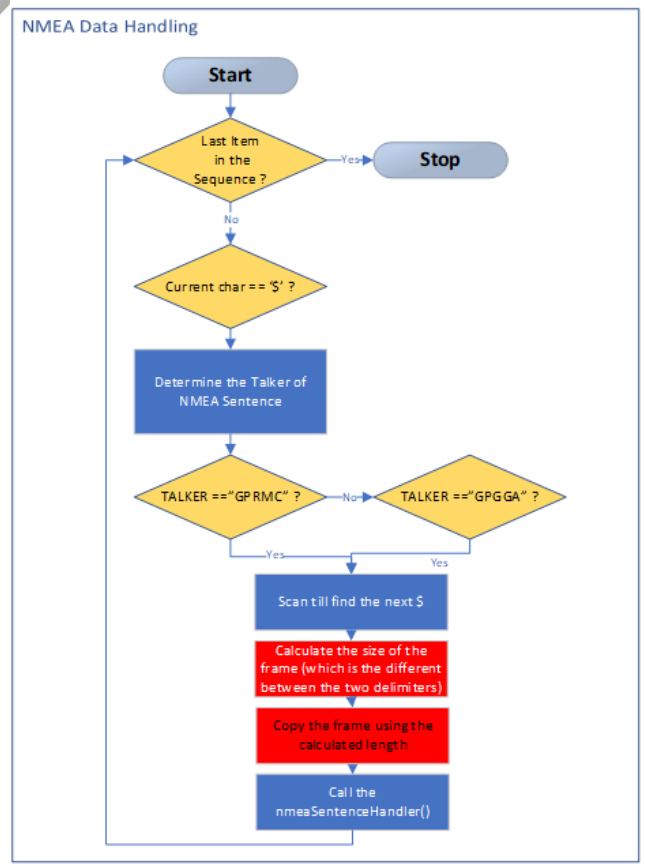
Software Specifications and Functionalities

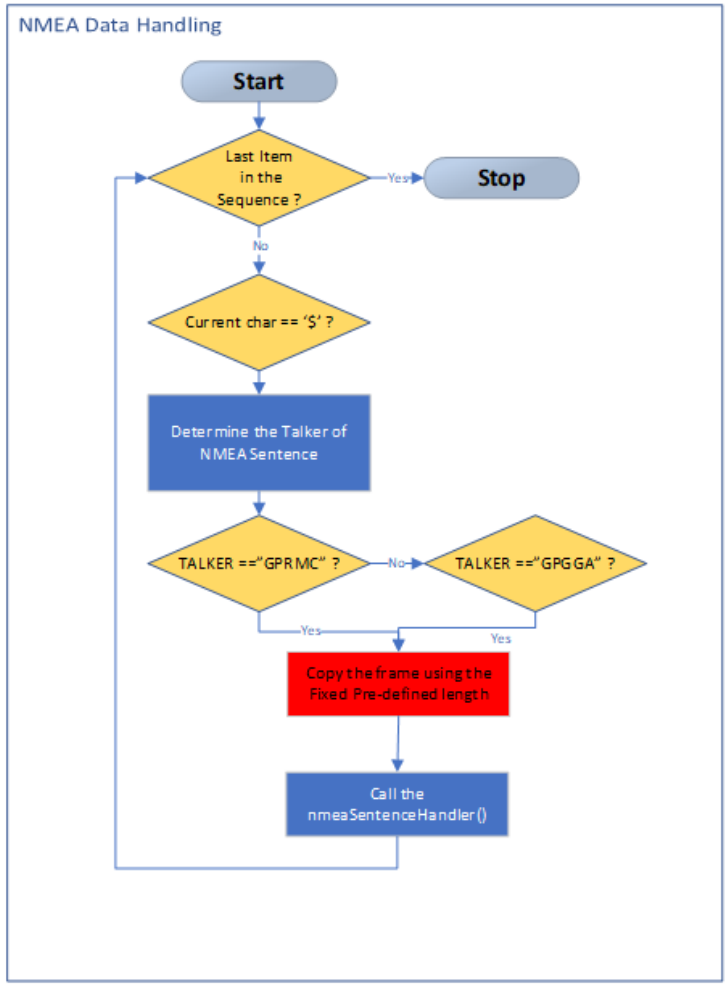
- Serial Communication Protocol and Drivers.
- Interfacing the Microcontroller with the GPS Module and the Flash memory.
- Ground Station Commands Handling and Execution.
- NMEA Data Analysis; Filtering, Parsing and Storing.

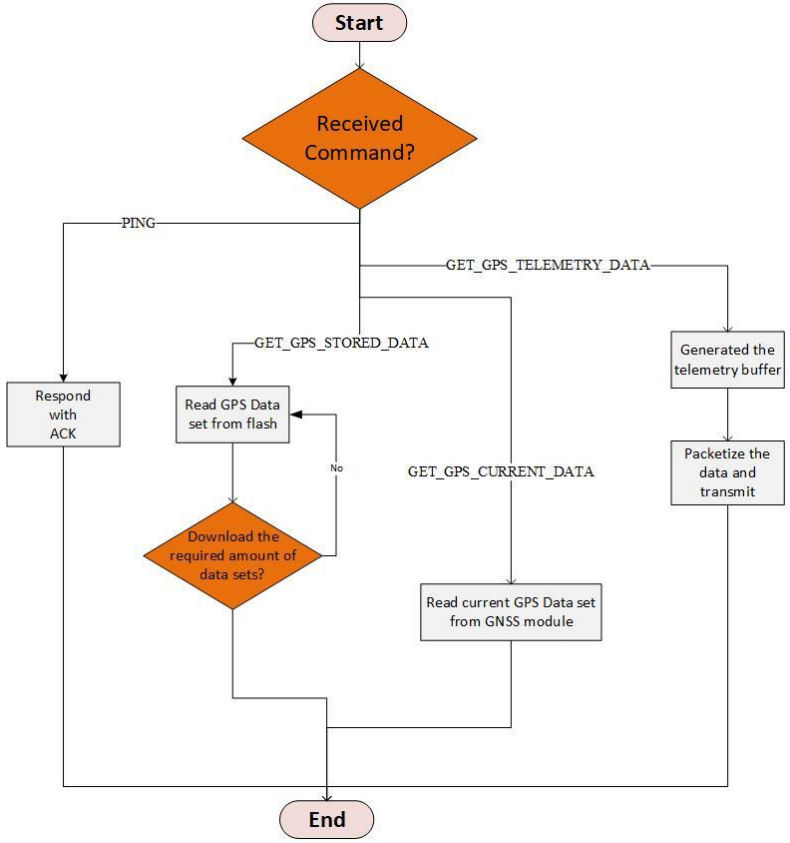


GPS Rx Subsystem Designing and Implementation-Cont.

2. SW Implementation



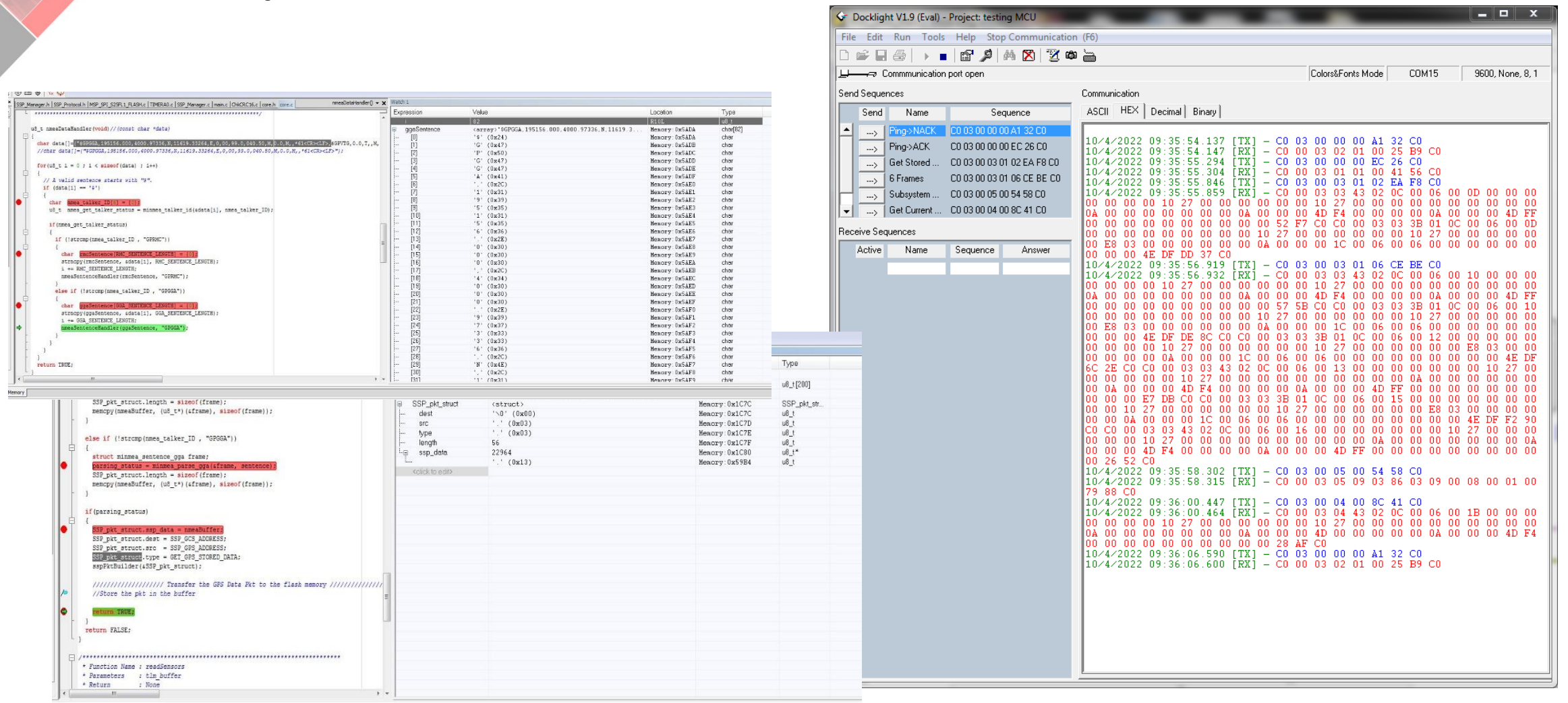




SW Flowcharts

GPS Rx Subsystem Designing and Implementation-Cont.

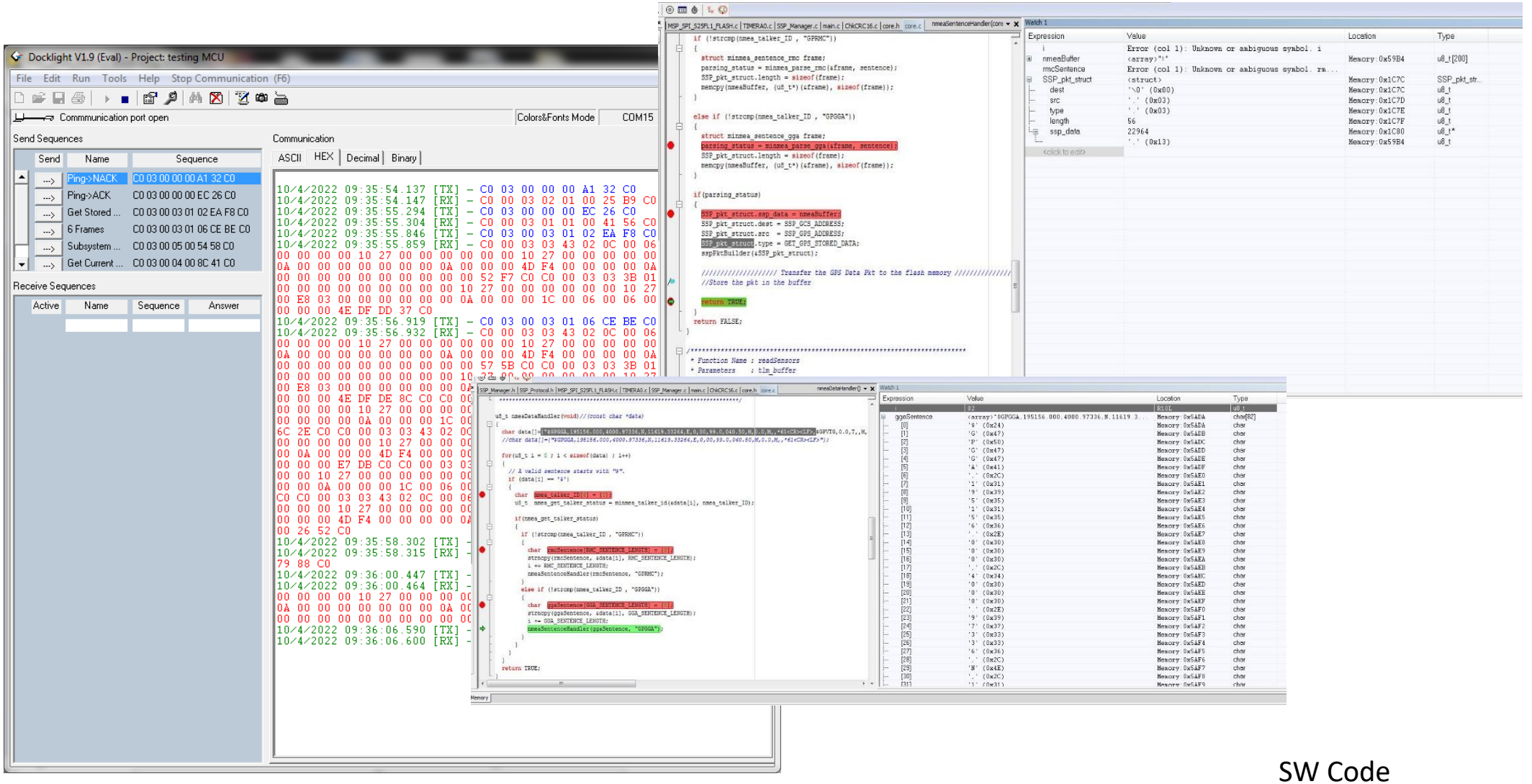
2. SW Implementation



SW Code

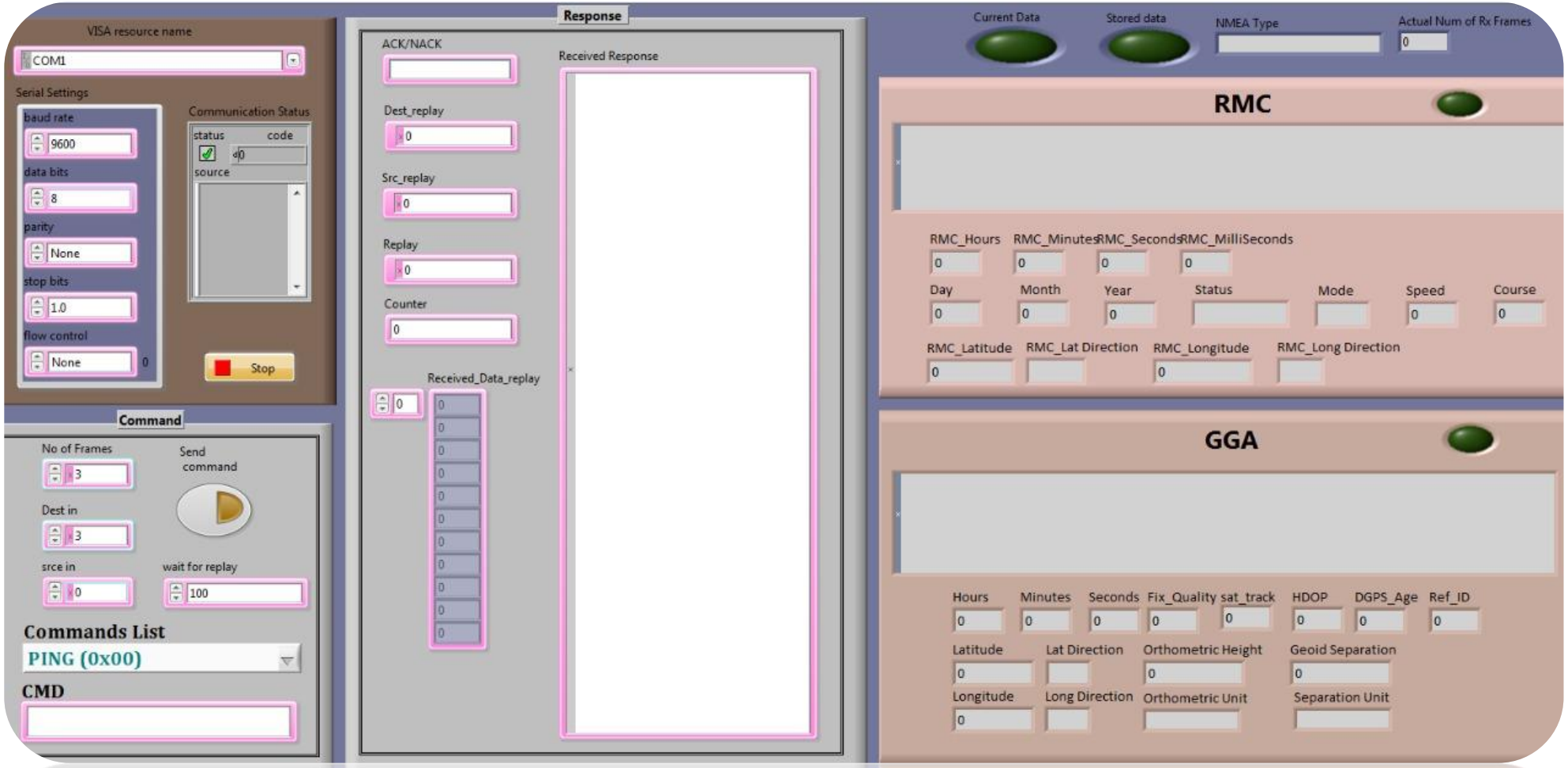
GPS Rx Subsystem Designing and Implementation-Cont.

2. SW Implementation



SW Code

GPS Rx Subsystem Designing and Implementation-Cont.

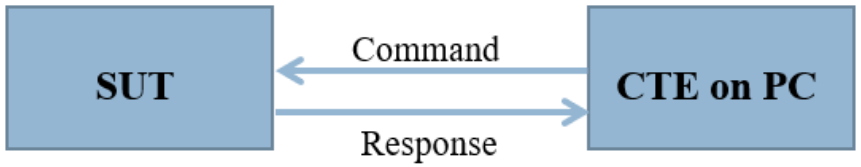


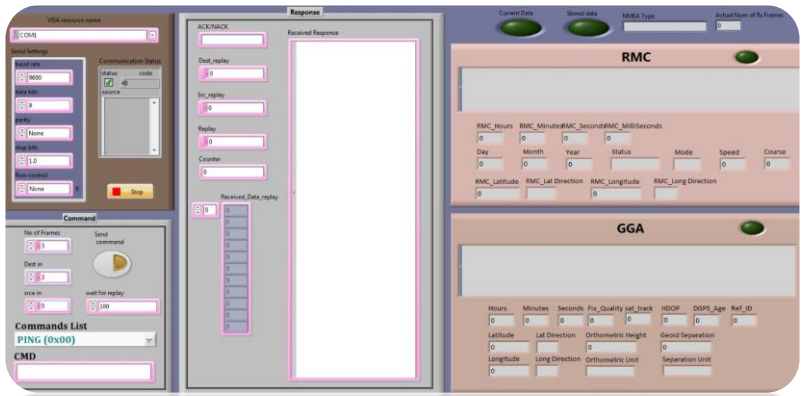
Check and Test Equipment

GPS Rx Subsystem Designing and Implementation-Cont.

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.





Check and Test Equipment

GPS Rx Subsystem Integrated Testing

GPS Data

UTC_Ho	UTC_Mi	UTC_Sc	RMC_St	Latitude	Latitude_	Longitud	Longitud	RMC_Sp	RMC_C	RMC_U	RMC_U	RMC_M	GGA_Fi	GGA_Qu	GGA_SV	GGA_HD	GGA_Or	GGA_Or	GGA_Ge	GGA_Ge	GGA_Ag	GGA_Ref_ID
13	29	23	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	0	M	0	M	0	0	
13	29	23	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA	NA	NA	
13	36	37	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	0	M	0	M	0	0	
13	36	37	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA	NA	NA	
13	36	38	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	0	M	0	M	0	0	
13	36	40	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA	NA	NA	
13	36	41	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	0	M	0	M	0	0	
13	36	43	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	0	M	0	M	0	0	
13	36	43	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA	NA	NA	
13	36	46	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	0	M	0	M	0	0	
13	36	46	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA	NA	NA	
13	36	49	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	0	M	0	M	0	0	
13	36	49	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA	NA	NA	
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13	36	55	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA	NA	NA	
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13	36	58	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA	NA	NA	
13	37	1	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	0	M	0	M	0	0	
13	37	1	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA	NA	NA	
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13	37	10	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA	NA	NA	
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13	37	25	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	0	M	0	M	0	0	
13	37	27	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA	NA	NA	
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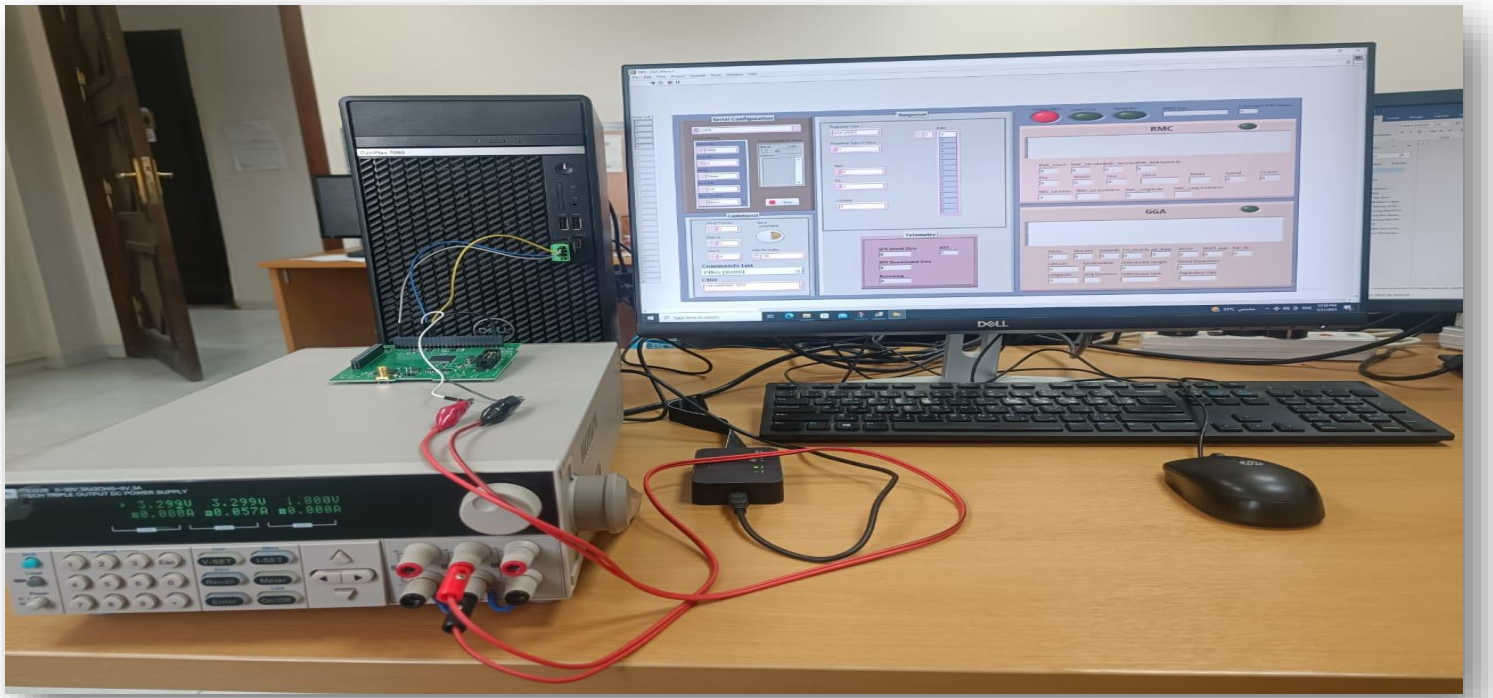
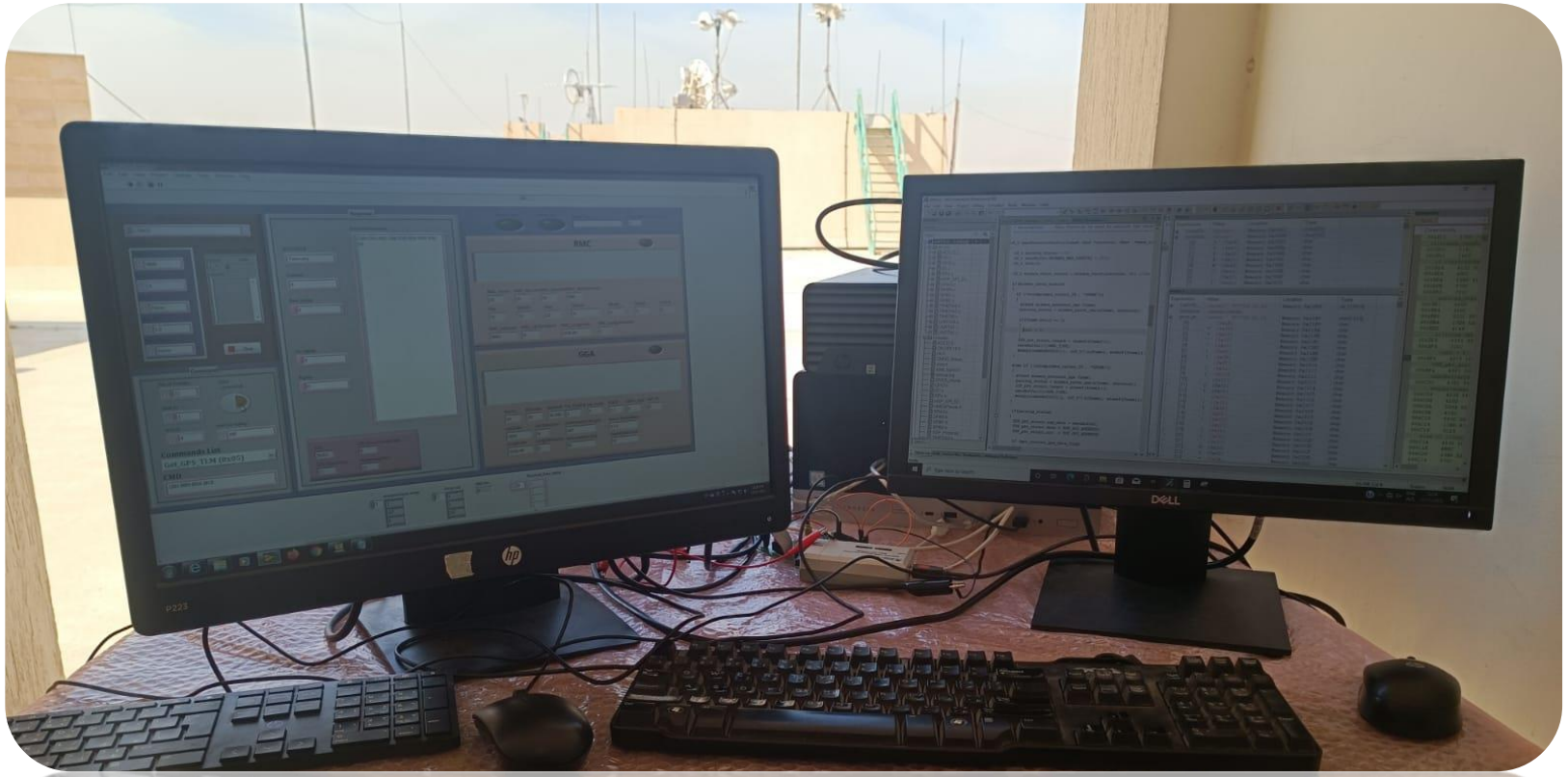
13	37	30	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA	NA	NA	
13	37	31	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	0	M	0	M	0	0	
13	37	33	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	0	M	0	M	0	0	
13	37	33	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA	NA	NA	
13	37	34	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	0	M	0	M	0	0	
13	37	36	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	0	M	0	M	0	0	
13	37	36	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA	NA	NA	
13	37	39	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	0	M	0	M	0	0	
13	37	39	V	0	N	0	E	0	0	28	6	6	N	NA	NA	NA	NA	NA	NA	NA	NA	
13	37	42	NA	0	N	0	E	NA	NA	NA	NA	NA	NA	0	0	0	M	0	M	0	0	

Navigation Data



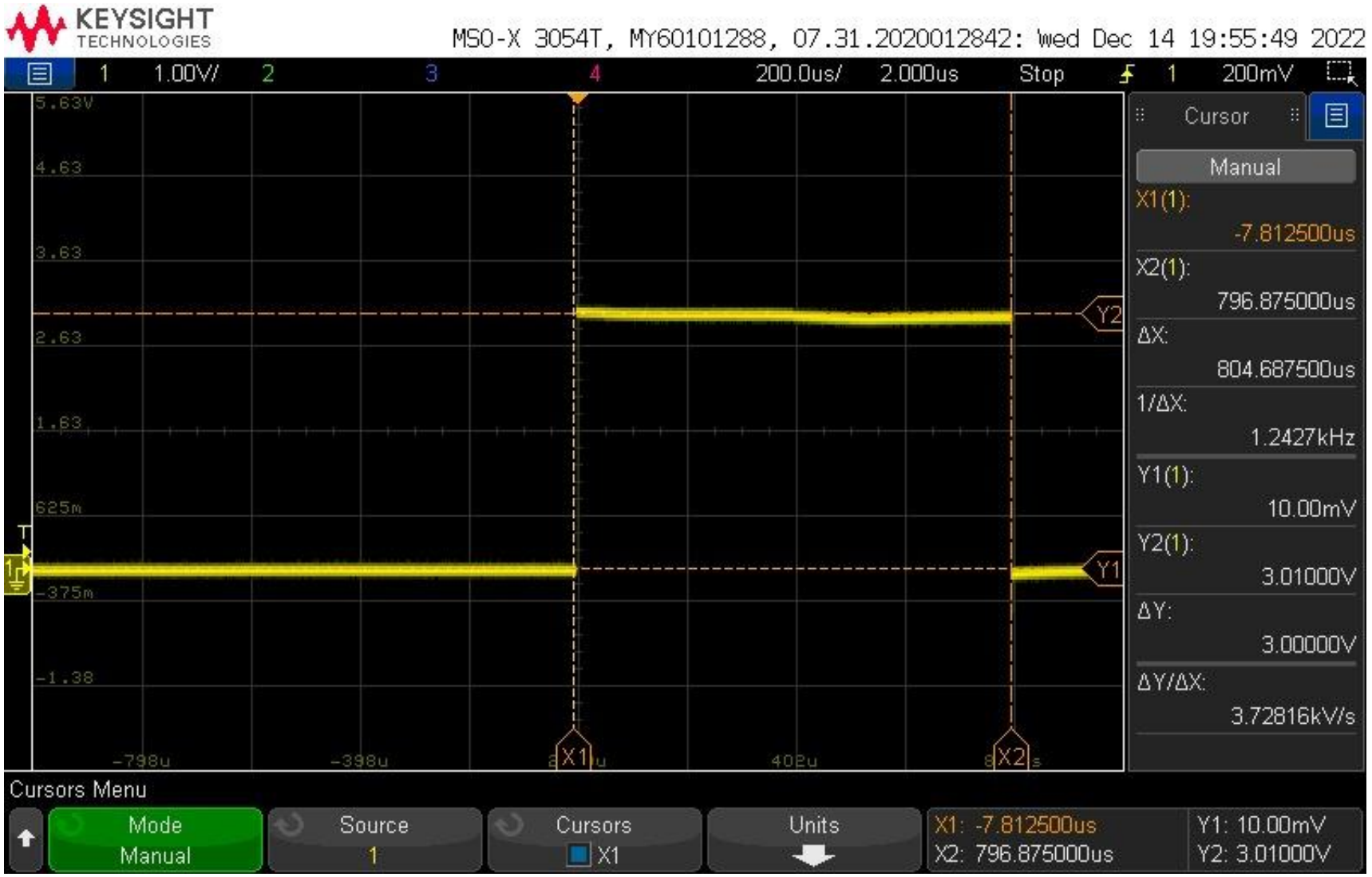
Testing Setup

GPS Rx Subsystem Functionality Testing



1PPS signal from GNSS Rx Subsystem after locking

GPS Rx Subsystem Functionality Testing

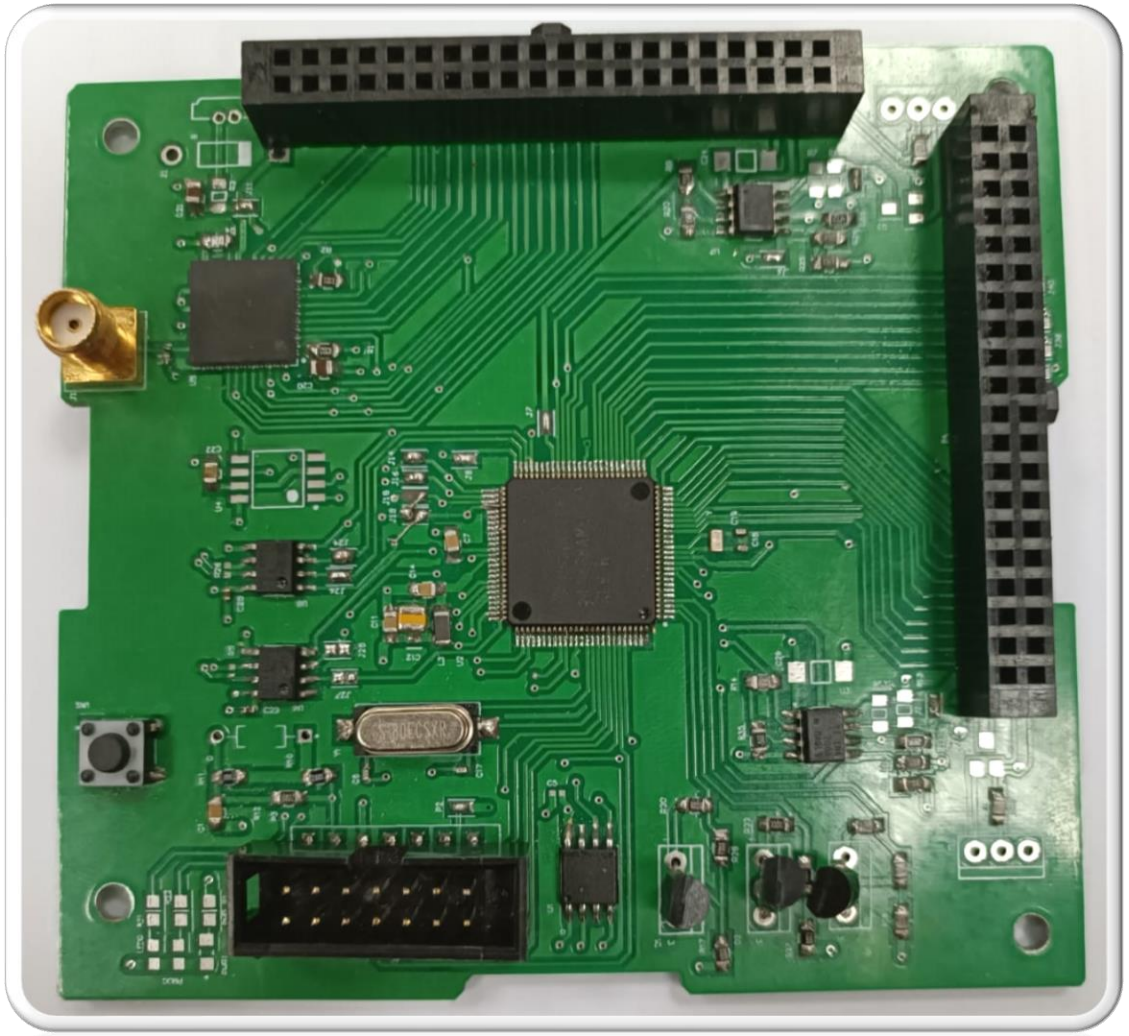


1PPS signal from GNSS Rx Subsystem after locking

GPS Prototype

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

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

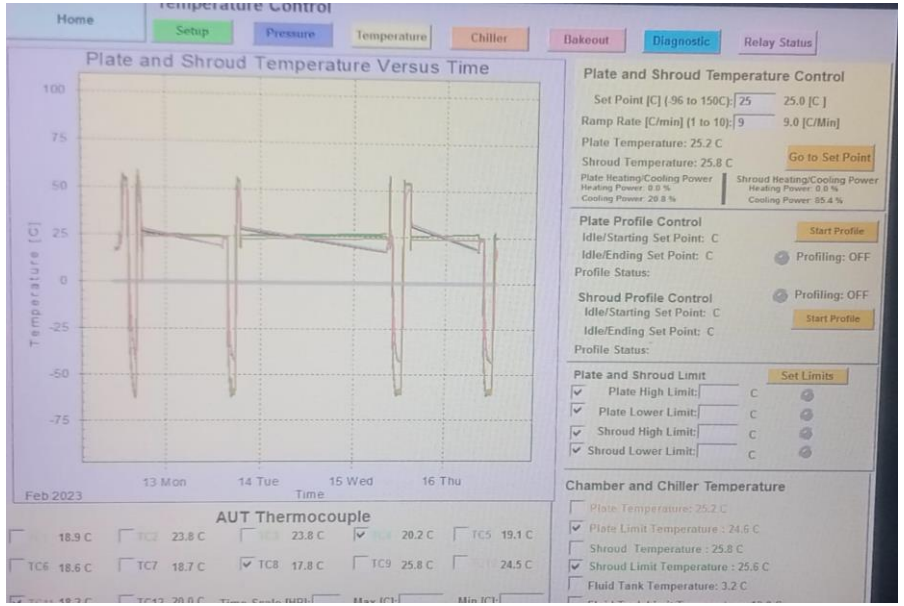
1. Thermal Testing

2. Mechanical Testing

GPS Rx Subsystem Environmental Testing-Cont.

1. Thermal Vacuum Testing Results

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



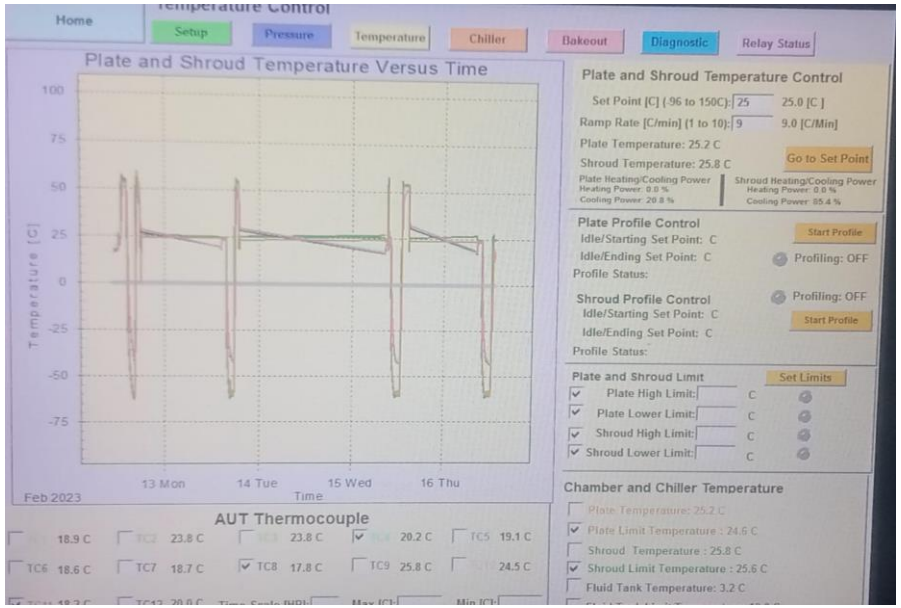
Different Cycles for Subsystem Qualification

Part of the Test Setup

GPS Rx Subsystem Environmental Testing-Cont.

1. Thermal Vacuum Testing Results

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



Different Cycles for Subsystem Qualification

Test Conditions

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

Test Log

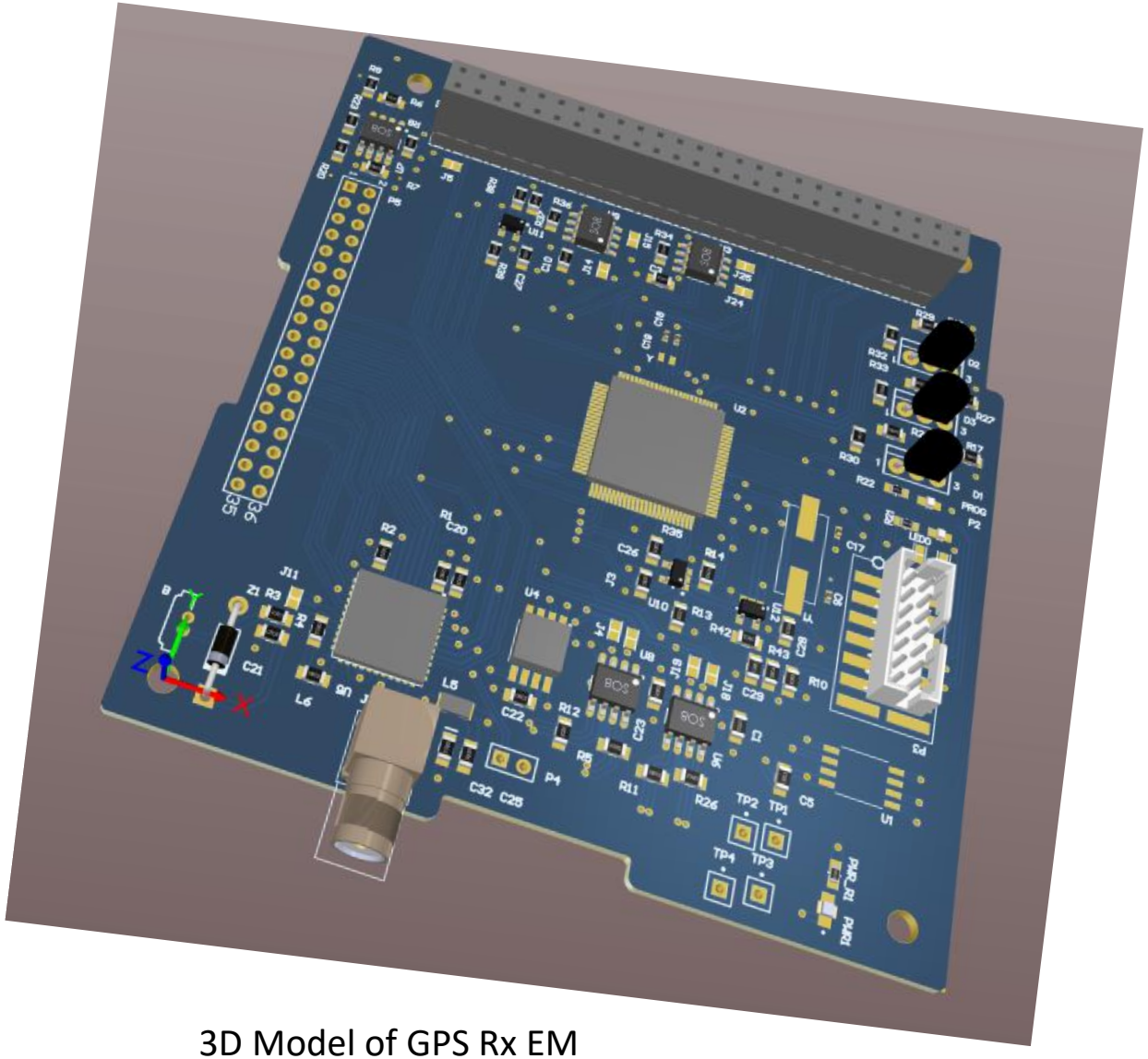
Day (Date)	Temperature	Pressure	Functional Test
Day1 (12/2/2023)	High	Vacuum	FT1
	Low	Vacuum	FT2
	High	Vacuum	FT3
Day2 (13/2/2023)	Low (Cold Restart)	Vacuum	FT4
	High	Vacuum	FT5
Day3 (15/2/2023)	Low	Vacuum	FT6
	High	Vacuum	FT7
Day4 (16/2/2023)	Low	Vacuum	FT8

GPS Rx Subsystem Environmental Testing-Cont.

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

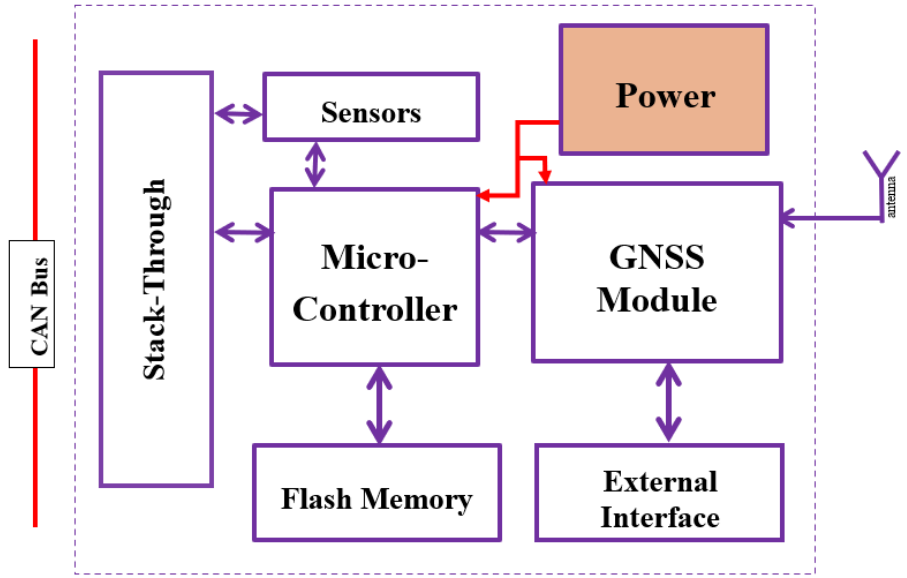
Misrsat Constellation GPS Rx Subsystem EM

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.

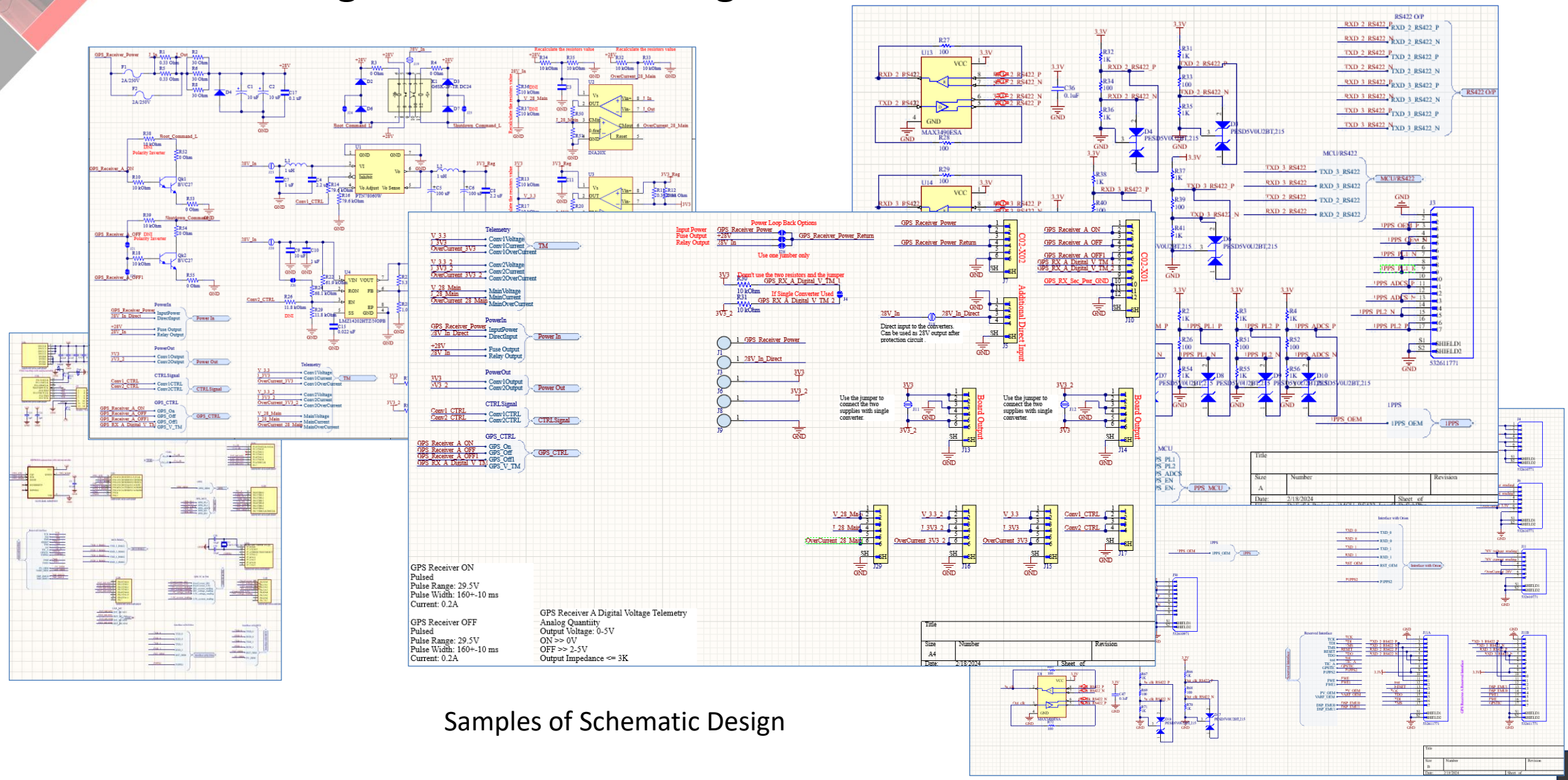
❖ The GPS Rx subsystem is designed for utilization in the upcoming Misrsat constellation. Nonetheless, in the first satellite of the constellation, it will be the auxiliary subsystem rather than the primary one.



Block Diagram for Proposed GPS Receiver

Misrsat Constellation GPS Rx Subsystem Designing and Implementation

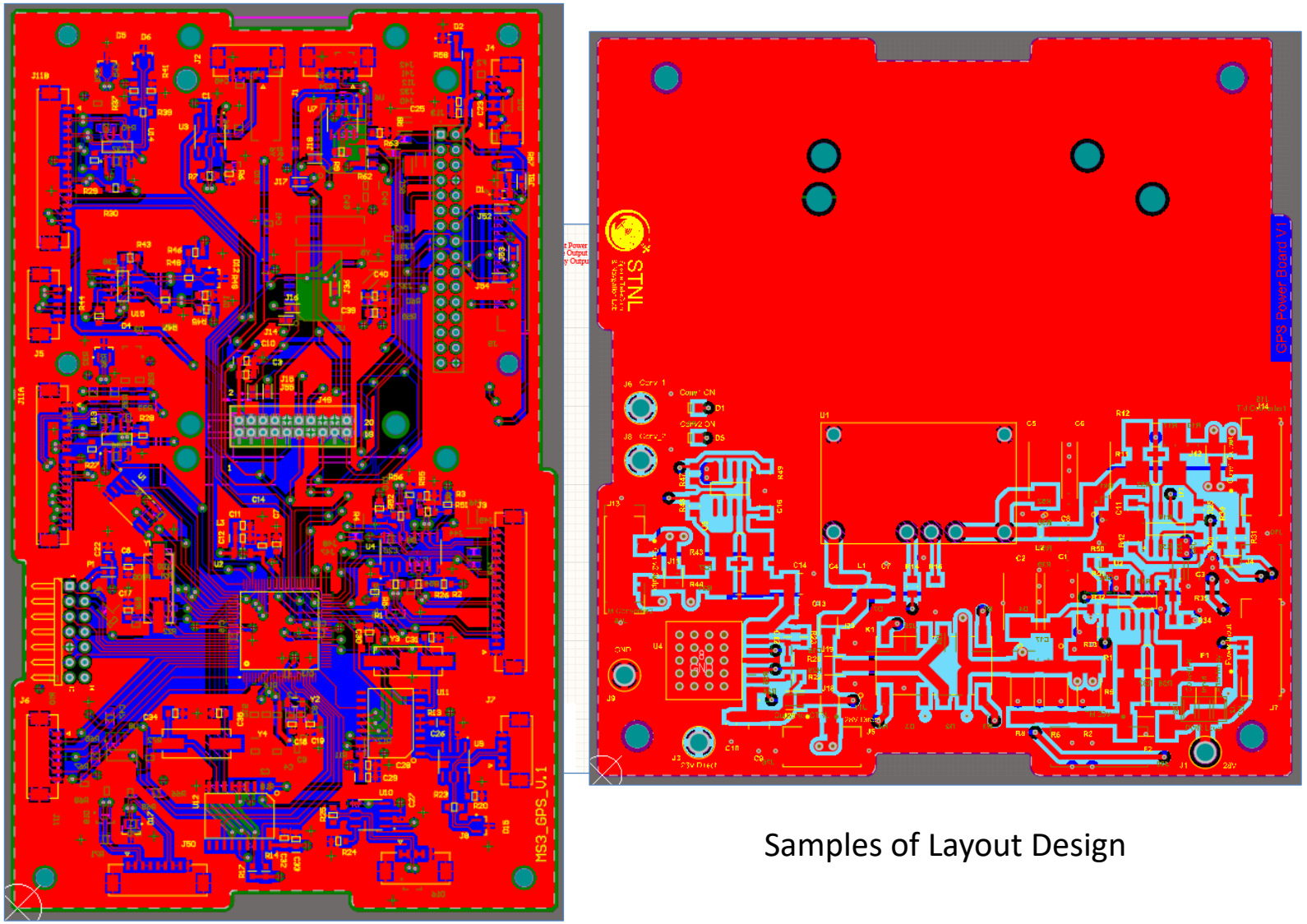
1. HW Design and Manufacturing



Samples of Schematic Design

Misrsat Constellation GPS Rx Subsystem Designing and Implementation

1. HW Design and Manufacturing

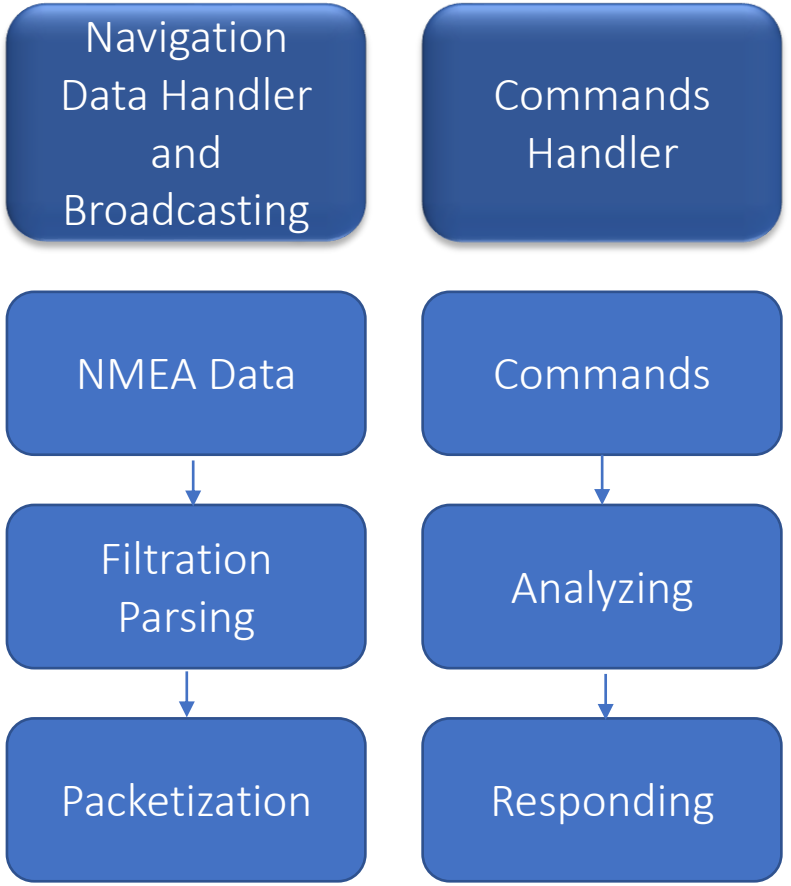


Samples of Layout Design

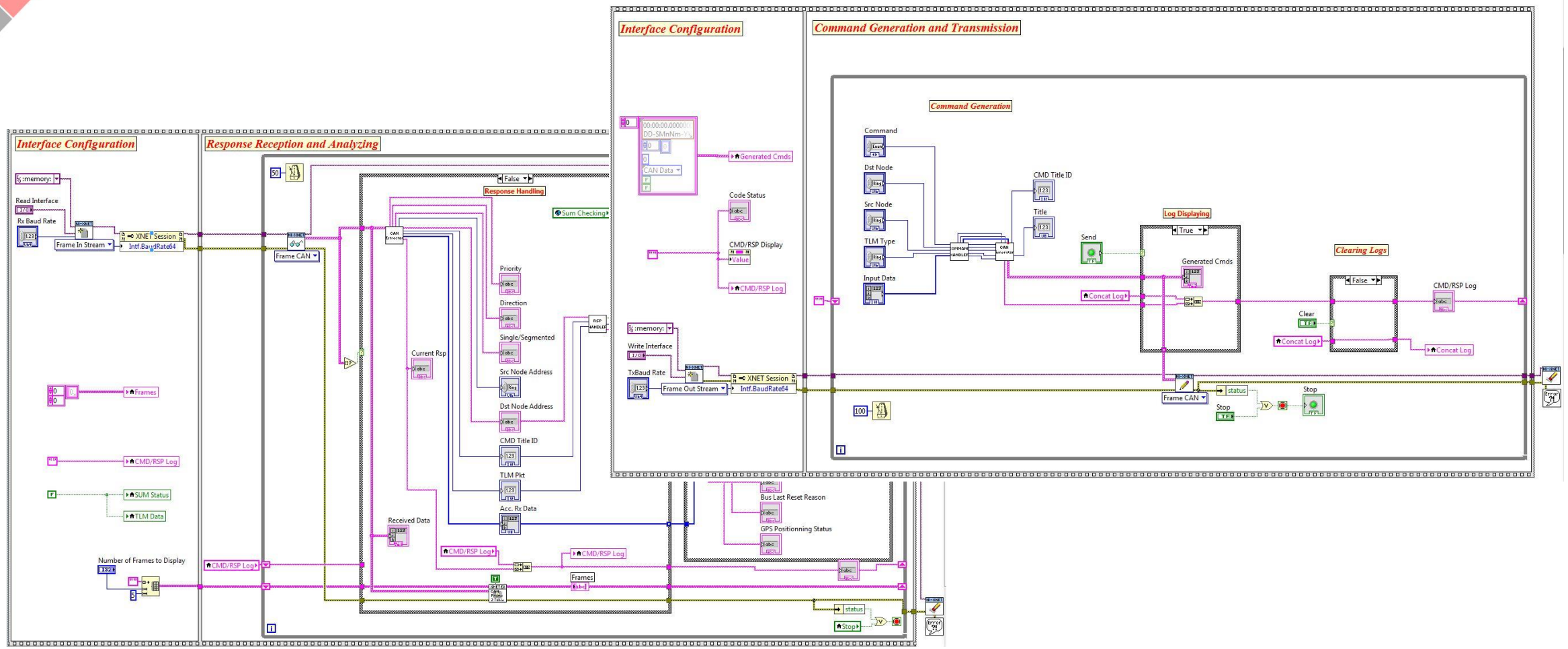
2. SW Implementation

Software Modifications:

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

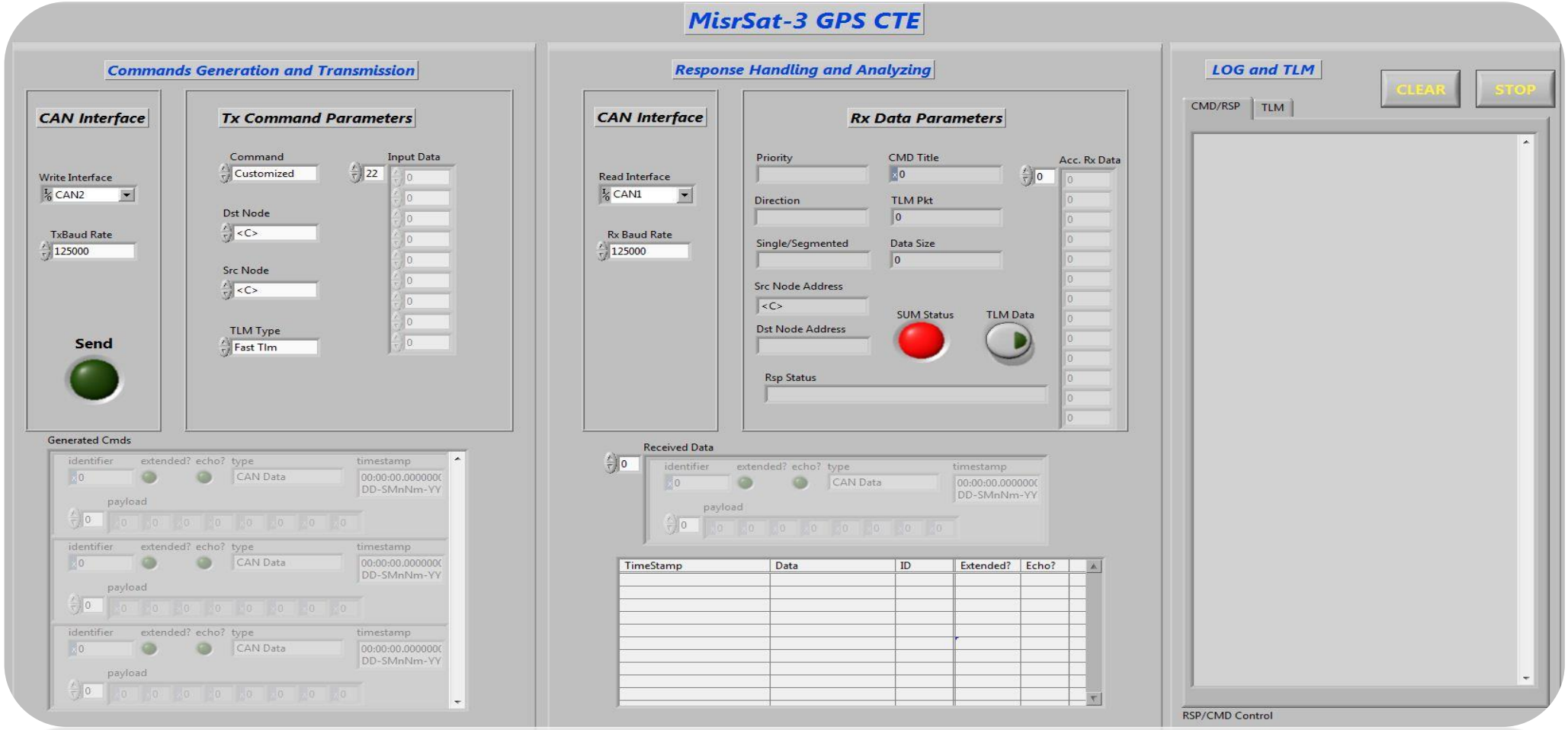


3. Check and Test Equipment Implementation



Check and Test Equipment

3. Check and Test Equipment Implementation



Check and Test Equipment

Conclusion and Future Work

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.

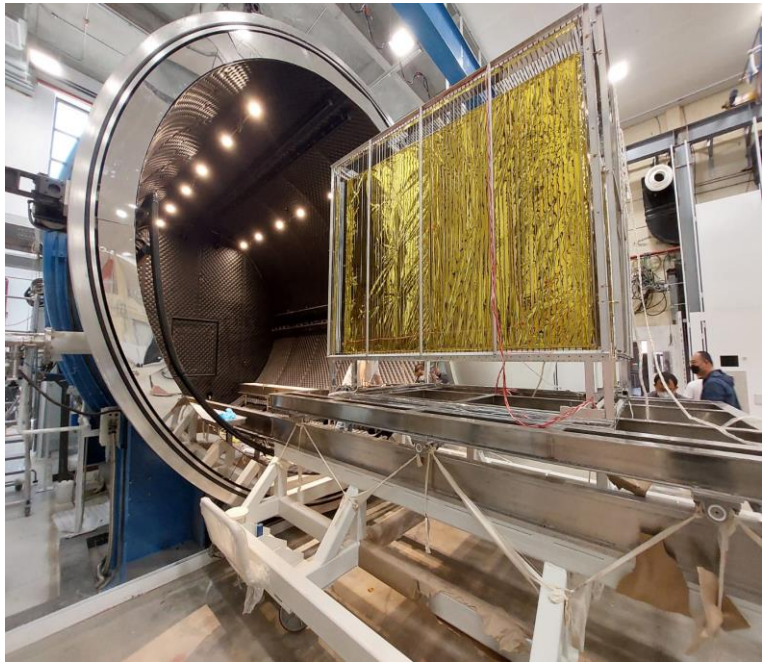
Future Work

- 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

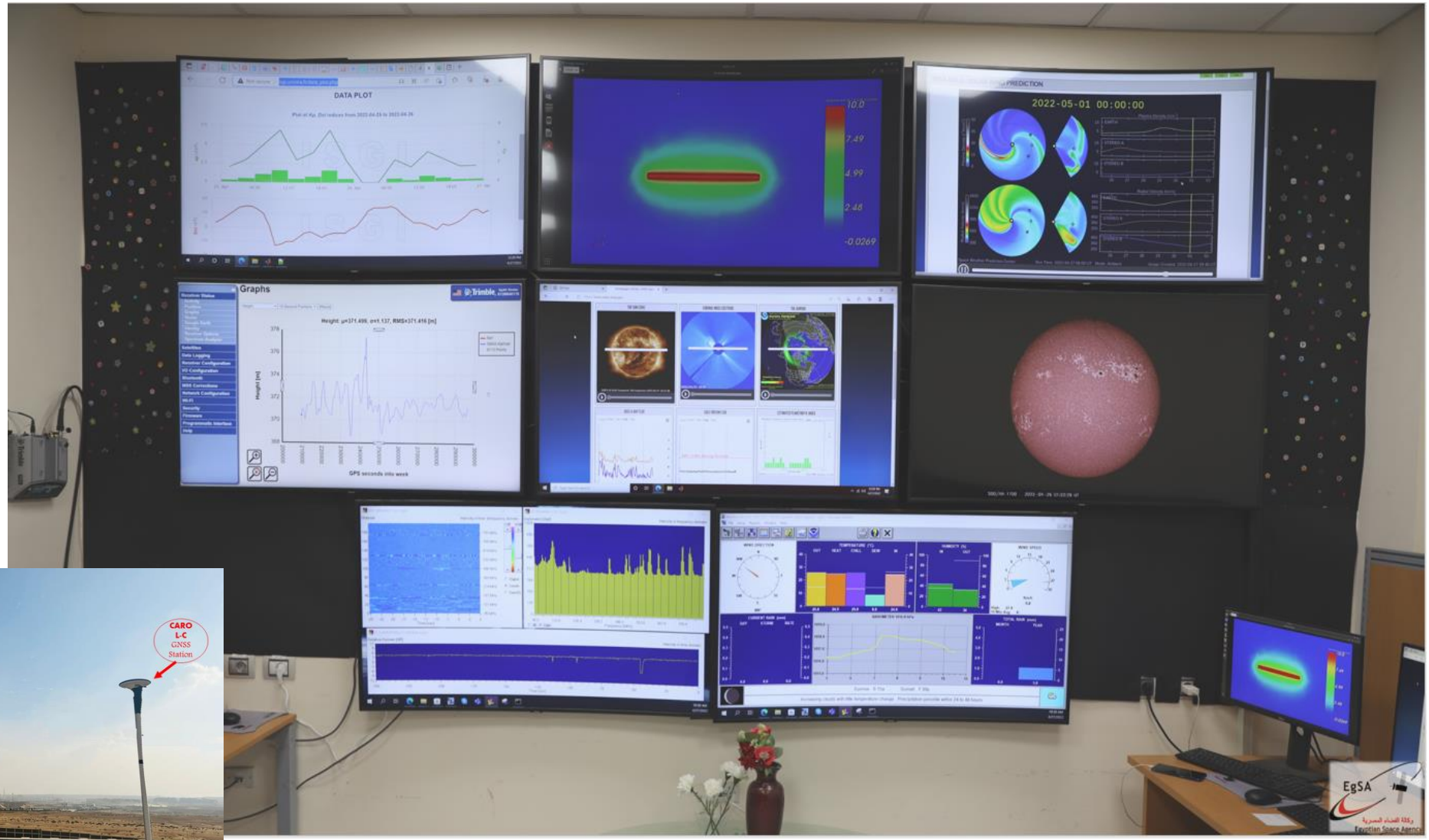
Thermal Vacuum Chamber

Satellite Communication Lab



AIT Station

Remark



The Space Weather Monitoring Center

Amira.salloumah@egsa.gov.eg

Thanks

Eng. Ranya Salah Elagooz
Email: Ranya.elagooz@egsa.gov.eg