PRATHAM
IIT BOMBAY STUDENT SATELLITE

Thermovac Test Handbbok

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Contents

How should you use this handbook?

I would recommend that you read the chapter on terminologies and important information first. Remember by-heart the **Important Precautions** given before entering the chamber. Refer to the **All about Programming** chapter while programming. Go through the **External Connections to be Done** and **Functionality Check Sequence** chapter before thermovac and refer to them during thermovac, if necessary. Go through the **Expected/Common Questions** chapter before entering the chamber. You should atleast know which questions have been covered in this section, so that you don't waste time when the ISRO scientists actually ask these questions. The other chapters can be read directly during thermovac if needed, but I would recommend that you read them once before the actual test, though not in detail.

"Your intuition is always alive and active. Go with your gut. It's an awesome conductor."

Terminologies and Important Information

1. **GUI:** GUI stands for ‘Graphical User Interface’. All our GUIs have a ‘Start’ button. The button should be pressed within one minute of expecting data, or else, time out will occur. Please set the COM port properly in the GUI. Then go to the corresponding .fig file, right click and select ‘Open in Guide’. When you are about to expect data, click ‘Start’. If for some reason, you need to stop the GUI, then you got to close MATLAB, store the data somewhere and then start it again. For some reason, Stop button doesn’t work.

2. **Master GUI:** The GUI on which data received from the Master OBC will be displayed. This data is also known as **house-keeping telemetry**. The data consists of HM Data, Sunsensor ADC Data, GPS Data (one byte), Magnetometer data (x,y,and z separately). This GUI also has buttons that enable us to Start and Stop Downlink on command, and Start Torquers.

3. **Slave GUI:** The GUI on which data received from the Slave GUI will be displayed. This data consists of the temperature of the four critical components of the satellite, namely, Battery, Beacon Power Amplifier, Downlink Power Amplifier and Uplink Low Noise Amplifier.

4. **Wireless GUI:** The GUI on which data received transmitted by the Downlink and received by the Uplink on the groundstation (i.e. outside the TVAC chamber) is displayed. This data consists of HM Data, Latitude, Longitude and Attitude data (for TVAC purposes, Lat-Long-Att data is fixed: “IamUndefined”. This translates to some very long but fixed numbers for each of the Lat, Long and Attitude sections). The wireless GUI also consists of two fields for CRC. One of them indicates the CRC received and the other is the CRC calculated on the ground station uplink. The data received from the Ground Station Uplink is known as **payload telemetry**.

5. **House-keeping telemetry:** Data received on the Master GUI.

6. **Payload Telemetry:** Data received on the Wireless GUI.

“Let me tell you something you already know. The world ain’t all sunshine and rainbows. It’s a very mean and nasty place, and I don’t care how tough you are, it will beat you to your knees and keep you there permanently if you let it. You, me, or nobody is gonna hit as hard as life. But it ain’t about how hard you hit. It’s about how hard you can get hit and keep moving forward; how much you can take and keep moving forward. That’s how winning is done! Now, if you know what you’re worth, then go out and get what you’re worth. But you gotta be willing to take the hits, and not pointing fingers saying you ain’t where you wanna be because of him, or her, or anybody. Cowards do that and that ain’t you. You’re better than that!”

All about Programming

0.1 Codes to be burnt in different Boards

- **Boards inside Satellite:**
  1. Master OBC - *MasterOBC(1)*
  2. Slave OBC - *SlaveToDownLink_OBC_Atmega128*
  3. Power - *Power_Code_Board_v4*
  4. ADC - *Slave_ADC*
  5. Downlink - *Downlink*
  6. Uplink - *Uplink_Reset*
  7. Beacon - *hBeacon_OOKtest*
- **Boards Outside Satellite:**
  1. Receiver Uplink(for receiving payload telemetry sent by Downlink): *Uplink*
  2. Downlink sending Reset Command: *Downlink_Reset*

0.2 Programming Connectors

1. **Power:** 1-1; Program Using Power Connector on Preflight Board
2. **Comm (Beacon, Downlink, Uplink):** 1-1; Program using Comm Connector on the Preflight Board
3. **ADC:** Special **Polar Connector**; Program using Power Connector on the Preflight board. Make sure that you connect the correct side of the connector to the Preflight board.
4. **OBC:** 1-1 DB 25 to DB 15. If programming from inside chamber, remove the 10 pin DB 15 connector and instead, connect the 11 pin DB 15 connector. To program the Slave, erase Master first, program the slave and then re-program the Master. If only Master needs to be program, you can program it directly.

"And once the storm is over, you won't remember how you made it through, how you managed to survive. You won't even be sure, whether the storm is really over. But one thing is certain. When you come out of the storm, you won't be the same person who walked in. That's what the storm's all about."

Chapter 1

Functionality Check Sequence

1. Keep the battery switch **disconnected** and connect the SNAP connectors.

2. Now connect the battery switch and remove the SNAP connectors. SNAP occurs and the micro-controller goes in a 50 min. sleep.

3. Post these 50 minutes, the Power Board turns on the OBC and in the immediately next loop, OBC asks the Power to turn ON GPS, Magnetometer, Magnetorquer, and Beacon.

4. After about 10 seconds, the first house-keeping telemetry should be received on the Master-GUI. All loads except Uplink and Downlink should be shown as ON. There should ideally be no over-current. This telemetry will repeat after every 5 loops (approx. 10 seconds).

5. On the slave GUI, the calibrated temperatures of the four critical components should be showing.

6. Once during the test, press the 'Start Torquer' Button on the Master GUI. This will turn ON the x, y and z torquers sequentially for a period of 15 cycles (30 seconds) each, i.e. x-torquer will be ON for 15 cycles and then it will be turned OFF and y-torquer will be turned ON and so on. After 45 cycles, all the torquers will be turned OFF. It is recommended that the 'Start Torquer' button is pressed immediately after a reading is received on the Master GUI and not midway between two readings, as the prediction of start time of the torquers will become difficult in the latter case.

7. Note down the reading number when the Start Torquer Button was pressed. The changes in magnetometer data should be noted from hereon.

8. When needed, turn ON the downlink by pressing the 'Start Downlink' Button on the Master GUI. Simultaneously, press 'Start' on the wireless GUI.

9. Data should start showing up in the wireless GUI in a couple of seconds. While the Downlink transmits data very quickly (at about 4 packets per second), the data is displayed at a comparatively slow rate on the Wireless GUI, perhaps due to the processing time on MATLAB. The data will be displayed at approximately 1 set per second.

10. The Downlink will stay ON for 300 cycles (approx. 10 minutes). This will be followed by a period of 150 cycles(approx. 5 minutes) for which Uplink stays ON.

"Obstacles don't have to stop you. If you run into a wall, don't turn around and give up. Figure out how to climb it, go through it, or work around it."

11. During the time for which the Uplink stays ON, if resetting the satellite is required, then it should be done by providing power to the Downlink-Reset board via pre-flight. This board will send "resetpratham" command every 1 second.

12. If the command is successfully received by the satellite, the HM Data set after receiving the command will consist of zeroes. This means that on the Master GUI, all loads will be shown as OFF, solar panel current, load consumption current, downlink voltage, OBC voltage will be zero, while battery voltage will be 0.3 V.

13. The reception of all zeroes in HM Data will be followed by a 5 second period for which all loads will be OFF and then the satellite will start afresh.

14. Note that the write and read pointer of the EEPROM will again return to the initial location. The satellite will behave as if it has just woken up from the 50 minute sleep following SNAP, i.e., operation starts from point no. 3 above.

"In order to succeed, your desire for success should be greater than fear for failure"

Chapter 2

External Connections to be Done

1. Pre-flight connector coming out from the chamber should be connected to the OBC connector on the pre-flight board. Use the 10 pin preflight connector and not the 11 pin connector. 11 pin connector should be used only in the case when OBC needs to be programmed.

2. On the pre-flight board, one USB cable will be connected on the Master OBC connector. This cable should be connected to the PC on which the Wired-Master GUI is running.

3. Another USB cable should be connected to the Slave connector on the preflight board and this should be connected to the PC on which Slave GUI is running.

4. The COMM connector on the preflight board should be connected to the Receiver Uplink. The COMM USB port on the pre-flight should be connected to the PC on which Wireless GUI is running.

5. On another preflight board, Reset Downlink board should be connected when Reset is desired. Don't connect the board if Reset is not desired.

"Forget past mistakes, forget failures, forget everything except what you're going to do now and do it"

Chapter 3

Some Important Precautions

1. Set the COM ports properly in the GUI before starting the GUI.

2. In case the GUI hangs in between, copy paste the log files in a different location before re-starting the GUI. The log files will get re-written on starting it again.

3. If it is required to program the OBC in the closed satellite, follow the following steps:

   (a) Change the connector connected to the preflight board from 10 pins to 11 pins. If possible, disconnect the Power, ADC, Downlink and Beacon boards from the OBC board while programming. This can be done in the testing before integration.

   (b) Erase the Master. (This and the next step can be skipped if Slave need not be programmed)

   (c) Program the Slave

   (d) Program the Master.

4. The GUIs have a timeout of 10 mins. So try to start the GUI only if you are expecting data within 10 mins.

5. For the olden COMM boards (which will mostly be placed outside the chamber), for programming, 1-1 connector can be used. However, for UART communication WITH THE PREFLIGHT board, 10 of comm board should be connected to 11 of Pre-flight and vice versa. For UART communication with other boards (like Uplink-Power or Downlink-OBC), 1-1 connector should be used.

"Difficult roads often lead to beautiful destinations"

Chapter 4

What all can go wrong

General Instructions: Don't panic. Things can go wrong for the silliest of reasons and most of the solutions are trivial and panic will make it all the more difficult to debug. In order to find the solution of a problem, you first got to convince yourself that a solution exists. An there has been hardly any problem we haven't been able to debug. So face every problem with confidence.

4.1 No data is received in the Master GUI more than 51 minutes after SNAP

Possible Reasons:

1. The battery switch was connected before the SNAP connectors were connected. See the first point in the previous chapter.
2. The power board micro-controller has got stuck (Never observed till now, but then 50 min. SNAP wasn't tested much)
3. COM port incorrect in GUI.

Solutions: First and foremost, check the COM port in the GUI. Once this is done, try to observe the data on the terminal instead of GUI. If the data is not coming in the terminal as well, do the following:

1. Remove the Battery Switch
2. Connect the SNAP connectors
3. Connect the battery switch
4. Remove the SNAP connectors

This should work. If the data is coming in the terminal and not in MATLAB GUI, there is a possible error in the data. Please note that if the GUI has worked correctly atleast once in the same configuration, then this case is very unlikely and you should consider the other solutions suggested. If the data wasn't received correctly on the GUI even once, try debugging using the Terminal. If everything works correctly, the following should be observed on the terminal:
PRA+ 7 bytes of HM + PRC + 12 bytes of Sunsensor ADC + PRB + 1 byte of GPS + PRD + 7 bytes of Magnetometer data
It would be useful to observe the data in HEX, rather than ASCII. There should be total 39 bytes of data in each set. How to debug using the terminal data is explained in one of the later chapters.

"There is no secret ingredient. To make something special, you just have to believe it's special"

4.2 No Data received on Wireless GUI for more than 15 seconds after clicking the 'Start Downlink' button

Possible Reasons:

1. It often happens that the command doesn't trigger the desired response(the UART interrupt is disabled when the one byte from the GPS has to be received). In this case the housekeeping telemetry doesn't show the Downlink to be ON either.
2. If the Downlink is ON in the housekeeping telemetry and the data is not coming in the Wireless GUI, then there is a possibility of an error due to noises during transmission.
3. Loose connection on the receiving side Uplink, or improper mounting of CC on the receiving side Uplink
4. Incorrect code in the receiving side Uplink
5. Saturation of CC

Solutions:

- If Downlink is not ON in the housekeeping telemetry for maximum of two readings after the 'Start Downlink' command was sent, re-send the command
- Check the connections and the CC mounting on the receiving side Uplink
- Make sure that the Receive_cc code is burnt in the receiving side Uplink and not Uplink_Reset code
- To check if the CC is getting saturated or not, remove the black antenna from the receiving Uplink outside the chamber. If the data gets received properly, it means that CC saturation was the problem.
- If the Downlink is ON but data is not coming in the GUI:
    1. Send the 'Stop Downlink' command and wait for the Downlink to be turned OFF in the house-keeping telemetry
    2. Re-send the 'Start Downlink' command

"Calmness is the cradle of power. Find some place to experience quiet, clear your mind, contemplate."

4.3 The Reset is not happening

Possible Reasons:

1. The ATmega on the Downlink board sending the reset command has stuck/ hanged during operation; loose connections
2. The ATmega on the Uplink board on the satellite has stuck/hanged (this is very less probable as the Uplink board was just turned ON)
3. CC saturation

Solutions:

1. To make sure that saturation isn't the problem, remove the black antenna from the Transmitting Downlink outside the chamber and see if Reset happens within the next 15 seconds.
2. Disconnect and re-connect the external downlink board and also check for loose connections
3. If the above doesn't work, do the following:
   (a) Send 'Stop Downlink' command
   (b) Wait for Downlink to be shown as OFF in Housekeeping telemetry
   (c) Turn ON Downlink again by sending the 'Start Downlink' command

You'll have to wait for the downlink to stay ON for 10 minutes.

4.4 The data in Wireless GUI is completely unexpected

Well, this is not an error if all the data is HIGH (0xFF). On the GUI this manifests itself as all loads ON, and extremely high values for all the HM data variables (Battery voltage: 10.2 V, OBC voltage: 6.6V, Downlink voltage: 6.6V, Solar Panel Incoming Current = 2.64 A, Load Consumption Current = 2.64 A and all loads ON). But this data is bound to cause confusion and anxiety if you don't know it's origin. The EEPROM starts reading data backwards when the 'Start Downlink' command is given. After a certain time, it reaches the first byte written and then, it sort of overflows and reaches the end of the memory. Now, the default memory of the EEPROM consists of 0xFF. So, the end of the memory, on which nothing is written, when read, will output 0xFF and this is the source of the supposedly unexpected data.

"A problem is a chance for you to do your best"

If there is some other sort of unexpectedness, then it might be due to some errors introduced during transmission. Most of these errors are temporary and disappear after one or two readings. If the error persists, do the following:

1. Send 'Stop Downlink' command

2. Wait for Downlink to be shown as OFF in Housekeeping telemetry

3. Turn ON Downlink again by sending the 'Start Downlink' command

"Happiness can be found even in the darkest of times, if only one remembers to turn on the light"

Chapter 5

Expected/Common Questions

In this chapter, some of the questions asked or expected to be asked by ISRO scientists are covered.

Q: What is the memory of the EEPROM and what are the number of read-write cycle?
A: 128kB, or 131072 bytes (1kB = 1024 bytes = 2^{10} bytes in digital world) and it has 1 million read-write cycles

Q: How many hours of data can be stored in the EEPROM?
A: About 66.19 hours, since that one data set consisting of 11 bytes is stored every 20 seconds

Q: How many hours of data can be transmitted in one downlink pass?
A: Assuming the pass to be 2 minutes long, about 5.33 hours of data can be transmitted.

Q: What are the specifications of the battery?
A: 6.6 Ah capacity, 8.4 V is the maximum voltage, and 6 V is the minimum voltage on discharge, 2S-3P configuration (specs may be slightly different in the battery they provide. Check this once)

Q: What is the charging current?
A: Approx. 1 A. Can change. Usually about 0.8A and above. Check it once

Q: What is the maximum power consumed during operation?
A: Current accepted value is 11.64 W

Q: What is the maximum power that will be produced by the solar panels?
A: Need to ask Vishal. Don't know yet

Q: What is the mechanism of Kill?

"If you encounter a problem, tell yourself repeatedly that a solution exists. The solution may not be in sight, may seem to be impossible. But still, tell yourself that it exists, is out there somewhere, and you just got to find it out. That's when your mind will focus on the solution."

A: A fixed string, packeted using the AX.25 protocol is transmitted via the groundstation at the Uplink frequency. Every time a correct string is received, the Uplink notifies the Power board. The power board keeps a track of the number of correct strings received and when the number becomes equal to 3, the Power board disables interrupts, shuts down all the loads and goes into an infinite while loop doing nothing.

Q: What is the mechanism of Reset?
A: A fixed string, packeted using the AX.25 protocol is transmitted via the groundstation (we have a downlink board which acts as a groundstation outside the chamber) at the Uplink frequency. On receiving the reset command, Uplink notifies the Power board and, as a check, the Power board waits for the next poll for HM by the OBC, and sends the HM data bytes as 0. This can be seen on the GUI. Post this, the power shuts down the loads, counts to 5 and starts the OBC again. Things resume as if the satellite has just woken up from the sleep after SNAP.

Q: Why are we transmitting only one byte from the GPS during TVAC?
A: GPS puck antenna doesn't give correct data indoors. There are two parts to verify GPS functionality - transmission and accuracy. Transmission gets verified by sending the one byte. As for accuracy, it was verified by taking the GPS, mounted on the integrated satellite, on the rooftop after the QM Thermovac and was discussed in CDR. Data was received correctly.

Q: How are magnetorquers getting verified?
A: On clicking the 'Start Torquer' button, all the three magnetorquers, x,y and z are turned on sequentially (see point 6 in Functionality Check sequence). The corresponding change in magnetometer readings is noted.

Q: Details of SNAP?
A: As long as the SNAP connectors are connected, the Power Board micro-controller is in Power Down Sleep Mode. When the connectors are removed, the voltage at the INT0 pin falls from approx. 3.3 V to 0 V and an interrupt is generated. Inside the interrupt, the power board microcontroller counts to 3000 seconds (50 mins), then comes out of the interrupt and starts the OBC and then the OBC takes charge and instructs the Power as to which loads have to be turned ON/OFF etc.

"Push yourself, because no one else is going to do it for you"

Chapter 6

Interpreting the House-keeping Telemetry on the Terminal

If at all a time comes when the GUI is not receiving the data properly and you have to rely on the terminal to get the data, here's how you should interpret it.:
The entire set consists of 39 bytes as discussed previously. If 39 bytes are not getting received in one set, either the Power-OBC communication isn't working, or one of the sensors is not giving correct data. Try to identify which data is missing using the sequence shown earlier, which I am writing here again for completion:
PRA+ 7 bytes of HM + PRC + 12 bytes of Sunsensor ADC + PRB + 1 byte of GPS + PRD + 7 bytes of Magnetometer data

Now, I'll give a brief description of all the bytes that may aid in debugging.

1. The first three bytes are 'PRA' and they serve as identifiers for HM data to the GUI.
2. The **4th byte** is the Load Status. Each bit of this byte, except the least significant bit, is reserved for one of the loads. A high on that bit indicates that the load is ON. The following is the convention used:
   (a) Most Significant Bit: 7th Bit = Beacon
   (b) Sixth Bit: Torquers (A high doesn't necessarily mean Torquers are ON. PWM may be zero)
   (c) Fifth Bit: GPS
   (d) Fourth Bit: Downlink
   (e) Third Bit: OBC
   (f) Second Bit: Magnetometer
   (g) First Bit: Uplink
   (h) Least Significant Bit = Zeroth Bit: Unused
3. The **5th byte** indicates scaled Battery voltage
4. The **6th byte** indicates scaled OBC voltage
5. The **7th byte** indicates scaled Downlink voltage
6. The **8th byte** indicates scaled Solar Panel Incoming Current. It should be zero if we are not charging the battery using the external Power Source

"Be in the moment. It's going to be one of your most cherished memories"

7. The **9th byte** indicates scaled Load Consumption Current

8. The **10th byte** indicates the Over Current Status. Each bit of this byte, except the last three bits, is reserved for one of the loads. A high on that bit indicates that there is **NO** over current on that particular load. The following is the convention used:

   (a) Most Significant Bit: 7th Bit = Beacon

   (b) Sixth Bit: Torquers (A high doesn't necessarily mean Torquers are ON. PWM may be zero)

   (c) Fifth Bit: GPS

   (d) Fourth Bit: Downlink

   (e) Third Bit: OBC

   (f) Second Bit: Unused

   (g) First Bit: Unused

   (h) Least Significant Bit = Zeroth Bit: Unused

9. The next three bytes are 'PRC' and they serve as identifiers for the sunsensor ADC data to the GUI.

10. The following twelve bytes should be splitted into six groups of two bytes each. The two bytes contain the readings of one sunsensor. The first byte is the LSB which is followed by the MSB. The following is the meaning of the twelve bytes:

    (a) Leading SS LSB

    (b) Leading SS MSB

    (c) Lagging SS LSB

    (d) Lagging SS MSB

    (e) Anti-sun side SS LSB

    (f) Anti-sun side SS MSB

    (g) Sun side SS LSB

    (h) Sun side SS MSB

    (i) Nadir SS LSB

    (j) Nadir SS MSB

    (k) Zenith SS LSB

    (l) Zenith SS MSB

11. The next three bytes are 'PRB' and they serve as identifiers for the GPS data to the GUI

12. The next byte is any random byte transmitted by the GPS
13. The next three bytes are "'PRD' and they serve as identifiers for the Magnetometer data to the GUI.
14. The next seven bytes are magnetometer data. Here is the detail of each byte:
    (a) X MSB
    (b) X LSB
    (c) Y MSB
    (d) Y LSB
    (e) Z MSB
    (f) Z LSB
    (g) 0x0D in hex, or a carriage return in ASCII which will appear as a time stamp and a new line.

This is basically the detailed description of whatever the master sends via the house-keeping telemetry. Now, if the data is not getting received on the GUI properly, but the LED on the preflight board is blinking every 10 seconds, indicating that the data is being transmitted properly, then observing the data on the terminal and interpreting it and drawing conclusions is recommended.

"You will be surprised to know that you always have it in you to try just one more time"

Chapter 7

General Problem Solving Guidelines

Apart from the cases discussed earlier, there might arise some random problems. In that case, the following guidelines might prove beneficial. These are not fool-proof, and may not exactly give any solutions, but these might give a direction when you are stuck. Also, I am not qualified enough to give any guidelines, nor have I solved enough problems. So please use these only for reference. Each problem comes with its own uniqueness and no algorithm can solve all the problems that we can encounter.

7.1 Think with a clear mind

Many solutions are much easily found if the mind is not clouded with tension, anxiety or doubt. Have confidence on your work and efforts. They will bear fruit.

7.2 Gather Data

If you can't solve the problem, get to know as much about the problem as you can. The purpose of the housekeeping telemetry is to provide data. Observe all the variables, and note down the obvious data. For instance, during the beacon problem in the QM thermovac, the house-keeping telemetry and the spectrum analyzer provided the following data:

- The beacon was not getting turned off by the Power Board. It was shown ON in the HM data
- The load consumption current fell when the beacon gain fell.
- The beacon gain revived for a few seconds on re-powering the beacon and then subsequently fell

7.3 Perform as many experiments as possible

Experiments help gather more data. The more the experiments you perform, the more the data you will have. The thermovac chamber does not leave much scope for experimentation, but some can still be performed. Some examples are:

- Turn off the satellite and start again and observe the behaviour. (This will be tedious though, with the 50 min. SNAP)

"If I had 60 minutes to solve a problem, I'd spend 55 minutes to define it, and 5 minutes to solve it"

- Observe the behaviour at different temperatures and try to get a rough qualitative plot of behaviour vs. Temp.
- Switching charging of battery ON/OFF and observing the behaviour (only for specific cases)

7.4 Make the immediate conclusions from the gathered data

This helps a lot in eliminating the different possibilities that show up. For instance, the fact that the beacon was ON in the HM data eliminated the possibilities of failure of TPS, or PTH in the power board, to a great extent. Also, the falling of the current, and the short revival on re-powering indicated that the PA on the beacon was not damaged, but something was turning it OFF. Had it been damaged, the current wouldn't have recovered.

7.5 Try to theorize and find a model that fits the observations

Now, with the fact established that something was turning off the PA, the immediate focus shifted to the IC responsible for controlling the power to the PA. Now, another observation was the somewhat hysteresis behaviour and that's how the Schmidt Trigger model was developed.

7.6 Substantiate your model with more facts

Once a model is developed, you need to ask yourself, "If this model is correct, what else should be true?". You will get some answers definitely. For the Schmidt Trigger case, one of the conclusions was that if we keep the beacon OFF while increasing the temperature and start it when it's temperature is already in the negative, then it should work fine. We tried this experiment. It consumed one full thermal cycle and did not work.

7.7 Don't fall in love with your own theory

This is one thing thermovac has taught me. After the Schmidt trigger model failed, we proposed the faulty crystal capacitor model, and I was very very confident about it as all the facts were fitting well. But the actual reason came out to be quite different. And that's when I realised not to defend my theories ferociously before conducting proper experiments.

"When a problem comes along, study it till you are completely knowledgeable. Then find the weak spot and break the problem apart. The rest will be easy."