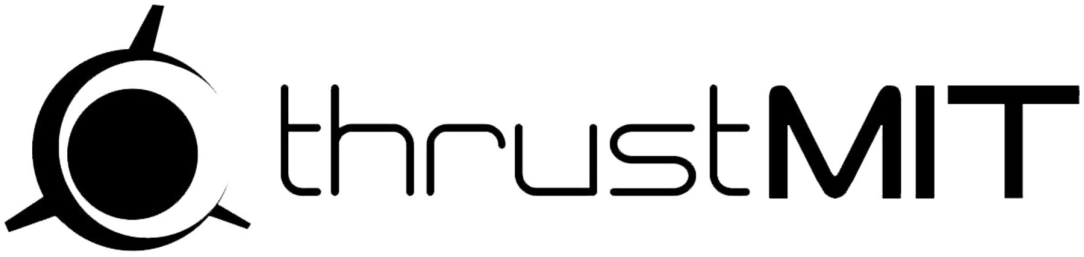
GUIDELINES AND DOCUMENTATION

Motor Test November 6, 2023



I. NOMENCLATURE

RF – Radio Frequency

PDB – Power Distribution Board

LiPo – Lithium Polymer Battery

FSM – Finite State Machine

II. INTRODUCTION

The Motor Test Project undertaken by team ThrustMIT 2023-24 aims to test and analyze the working and response of a Commercial M-Class Solid Rocket Motor. This document will integrate both the Concept of Operations Overview, and the Operating Procedures Checklist for the Avionics Subsystems reference for the Motor Test scheduled for 6th November 2023.

III. BACKGROUND

The Motor will be situated on a testbed, where it will be placed upon a Load Cell. Additionally, there will be a Strain Gauge module that will be attached to the nozzle. The Motor is fired via an ignitor device. For the purpose of operations and reference, we shall divide the Avionics Systems into two: *Motor* and *Ground*. The microcontroller used for both systems is a Teensy 4.1, and the RF Module required for wireless communication between the two systems in an XBee S2C.

The Ground System employs a switch-controlled Ignition System with three states, SAFE, ARMED, and LAUNCHED. These are coordinated between the two systems via a Finite State Machine on both sides to ensure safe transition between phases. The Motor Side also employs logging of peripheral data in the built-in SD Card via the peripheral modules.

The Strain Gauge Module (BF350) is powered via a Power Distribution Board (PDB), providing approx. 5V voltage to the module, converting the 7.4V it receives from a LiPo Battery. The Load Cell is powered by an Arduino Uno R3 to provide stable 5V input; Both the Arduino and Teensy on Motor Side are powered via a Power Bank through respective USB Cables.

Additionally, a live video telemetry system is employed via a Runcam Split 3 Lite and associated transceiver module.

Module	Motor Side	Ground Side
Teensy 4.1	✓	✓
XBee S2C	✓	✓
RS232/TTL Converter	✓	✗
BF350 Strain Gauge	✓	✗
Built-in SD Card	✓	✗
Load Cell Indicator	✓	✗
Ignition Control	✗	✓
TPT Color Monitor	✗	✓
RD945 Transceiver	✗	✓
RunCam Split 3 Lite	✓	✗

a. Checklist for Modules on both systems

IV. CONCEPT OF OPERATIONS

The execution of the project is divided into four phases: Final Assembly, Initial Arming, Final Arming and Launch. Each phase involves the integration of implementing practical safeguards, ensuring reliability, and finalizing safe and secure ignition.

PRE-LAUNCH: Both Systems apparatuses, required tools and backup materials are required to be packed safely. LiPos shall be kept in LiPo Guards when not in use. The Materials Checklist must be referenced the morning of the test i.e., by 10AM. All Materials shall be brought to the test site immediately post-securing both systems and materials checklist, after coordinating with the other involved subsystems.

Upon reaching the test site, the testbed must be confirmed to be secure/stable for arming. Power Sources for the Load Cell Indicator and Video Telemetry Module must be secured. All Connections (Jumpers & Terminal Blocks) must be rechecked upon reaching the test site. The working of Peripherals (PDB and Load Cell) must be confirmed by providing LiPo power. Test codes may be run on the motor side to ensure both modules are providing data. SD Card datalogging must be tested at least once.

Ranging is necessary to ensure smooth working of ignition system during final arming and launch phases. This involves broadening the range of the RF Modules by testing transmission and reception at regularly increasing intervals. The Motor Side's RF System will carry a Dipole Antenna, and Ground system via a Yagi. Ranging shall begin at 2-5m, with ground apparatus moving back in Line of Sight (LoS) in intervals of 5-10m (depending upon increasing reliability of modules). Once a range of 150m has been secured, range can be confirmed, and may be checked up to 200m. Additionally, Range shall be confirmed from the motor's end through the testbed cage. If Interference is found, the RF Module must be placed outside the cage. Finally, D4184 Latching must be confirmed at the maximum distance. Both Systems must be reset after ranging.

The Transmission testing sequence is as follows: KEY shall remain switched on at ground side, and ARM_ON and ARM_OFF sequences must be sent at each increasing distance for testing. Reception of data may be checked either via Serial Monitor (if using Laptops) or via the associated LED.

FINAL ARMING & LAUNCH: Once Prelaunch Operations have been carried out successfully, the Motor Side's connections shall be confirmed. Load connections shall be made at motor side from the D4184 terminal block and confirmed via DMM. There should be no continuity between the Load Power terminal and load pinouts. The key shall be placed in the key switch. Video Telemetry shall begin and a live feed of motor side with clear view of the LEDs must be confirmed. Upon confirmation, the system shall be armed. Once safety provisions are confirmed and everyone is confirmed to be a safe distance from the testbed, System is ready to Launch.

V. PHASE TRANSITIONS

The phase transitions are initiated via the switches on the Ground system and handled via the FSM installed onto the Teensy 4.1 Microcontroller. The FSM defines three states involved on either side: SAFE, ARMED, and LAUNCHED. The motor side includes an additional FAILURE state provided to add fail-safes or additional safety provisional programs. These states are structured as such:

SAFE: At Ground side, the KEY is inserted into the key switch, allowing power from the LiPo to reach the Peripherals. This operation is purely mechanical and does not initiate any transition or hold any connection to the microcontroller. At both Motor side and Ground side, the key-LED will be shown as ON, showing that the Motor Side is in SAFE state. In this state, no peripherals are called i.e., datalogging does not occur, and the D4184 firing pin is pulled LOW to ensure load remains unpowered in this state.

ARMED: The ARM switch is switched ON at the ground side, sending a transmission string "ARMON" to the motor side. These causes a state transition at the motor end from SAFE to ARMED. Both sides should now show both YELLOW and GREEN LEDs as ON. This shall be confirmed via the Live Video Feed. The system being *armed* is defined as it having only one control operation separating it from ignition. In this case, that is the LAUNCH switch at the Ground system.

LAUNCHED: The LAUNCH switch is turned on, causing a transmission string "LAUNCH" to reach the motor side, causing the D4184 to 'latch' or pull HIGH, completing the load circuit and allowing power to reach the load connection. The Ground system will enter an infinite loop, where it will log data from the Strain Gauge module and Load Cell in intervals of approximately 100ms (processing time between each loop). The data is logged onto the SD Card as a CSV file.

```
case LAUNCHED:
  digitalWrite(key, HIGH);
  digitalWrite(arm, HIGH);
  digitalWrite(launch, HIGH);
  digitalWrite(D1,  HIGH);    //D4184 is pulled HIGH
  while (true) {
    Peripherals();
  }
  break;
```

b. Code Snippet of the D4184 'Latching' operation

VI. OPERATIONS AND MATERIALS CHECKLIST

PRELAUNCH:

- Check Motor Mount Teensy connections
- Check Ground Station Teensy connections
- Keep two 7.4V LiPos, one 11.1V LiPo in LiPo Guard
- Charge LiPos
- Charge Motor System Power Bank
- Check Load Cell connections
- Secure Load Cell adapter and Indicator
- Secure Strain Gauge Module and PDB
- Carry plastic bags to carry apparatus in case of rain
- Yagi and Dipole Antennas secured
- Walkie-Talkies ready for Comms.

Pack:

- Jumpers (Male-Male, Male-Female, Female-Female)
- Screwdrivers
- Stripper
- Scissors
- Double Sided Tape, Insulation Tape
- DMM
- Breadboard, 9V Battery
- Glue for Strain Gauge
- Extra wiring
- Backup Arduino Uno R3
- Micro USBs (Two reqd., one extra for backup), MIDI Cable for Arduino (two)
- Ignitor Wire
- Markers
- Zipties
- Pliers

INITIAL ARMING:

- Testbed Secure
- Load connections secure
- Peripherals (load cell and strain gauge) connected
- Ranging Done
- D4184 Latched
- LiPo connections secure
- FINAL CHECK jumper connections

FINAL ARMING:

- KEY in key switch
- ARM operations working
- LAUNCH

VII. PROCEDURAL CHECKLIST

☐ ALL MATERIALS PACKED

☐ CONNECTIONS CONFIRMED

☐ BATTERY VOLTAGES OPTIMAL

PREREQUISITES READY ☐

☐ STRAIN GAUGE CONNECTED + RESPONDING

☐ LOAD CELL CONNECTED + RESPONDING

☐ MOTOR MOUNT + CAMERA READY

☐ D4184 LATCH CONFIRMED

☐ MOTOR SYSTEM LEDs RESPONDING

MOTOR SYSTEM READY ☐

☐ GROUND STATION + SWITCHES RESPONDING

☐ COMMS. WORKING

☐ RANGE CONFIRMED

GROUND SYSTEM READY ☐

☐ SAFETY PROVISIONS APPLIED

SYSTEMS ALL CLEAR ☐

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Signature of Attendee