Hydra Framework Design Notebook

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| Rocket: | Gee-Force One |
| File Name: | DN-2022-AV-Hydra-Framework |
| Sub Team: | Avionics |
| Point of Contact: | Liam, Serban, Noah |
| Purpose: | Document Hydra-level decisions that affect all Hydra boards to develop a general framework for supplemental hardware. |

Revision History:

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| --- | --- | --- |
| Revision | Description | Date |
| 0 | Baseline updated (Hydra V1) | Jan 18, 2023 |
| 1 | Updated design following first design review | Feb 11, 2023 |

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# Introduction

This document contains an overview of the macroscopic design requirements and considerations for the first version of uORocketry’s new avionics system, Hydra. The goal of this system is to develop a modular avionics stack in which boards can be stacked in no particular orders and swapped/upgraded over time. The first version of Hydra contains a power board, a logic board, a communication board, and a recovery board. A functional diagram detailing inter-board interaction is pictured below.

Diagram

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Figure 1 – Functional Diagram of Hydra V1

# System Behaviour

## Arming

The power board includes a switch that is actuated by a rod protruding from the rocket and serves to disable power delivery to the avionics stack. No further arming procedures are included since no custom hardware is in control of any controllable mechanisms/elements.

The recovery electronics are controlled by two redundant COTS RRC3 boards with individual batteries which have a similar safety mechanism. Two switches are included on the ejection board, one for each RRC3 battery, to disable power flow to the recovery systems.

## Recovery

The recovery portion of the first version of Hydra is composed of two RRC3s with separate power sources that control the dual event recovery. The presence of the second RRC3 is due to the competition redundancy requirement. The two altimeters function completely independent from one another, and in case of failure of the primary system, the backup system guarantees a safe recovery of the rocket.

# Hardware Design

## Board Layout

All Hydra boards intended for mounting within the avionics bay will follow a circular shape, 140mm in diameter, with three 5.3mm mounting holes spread equally along a pattern of radius of 60mm. The mounting holes are specifically located at (0, 2362.2mil), (-2045.729mil, -1181.1mil) and (2045.729mil, -1181.1mil) on the circuit board. Each stackable board in the avionics bay has two 2x15-pin headers mounted with the following Altium settings, assuming the center is at the true center of the board (Figure 2). The right header uses the same values however the X value is positive (+50mm). IMPORTANT: the location is set by selecting the header component itself, not a pin within the header.

Graphical user interface, text, application, chat or text message

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Figure 2. Left header Location in Altium

Finally, a pass through cutout is included at the rear section of the board as a 15mm circular cutout, tangent to the board’s outline, and along the vertical axis in Figure 3.

Graphical user interface

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Figure 3. Hydra Board General Dimensions (all in mm)

## Inter-board Connections

### General Framework

The goal of Hydra is to improve the avionics stack’s malleability and modularity thereby simplifying the process of upgrading the stack over time. As such, all Hydra boards intended to be placed in the avionics bay will have an identical connector pattern with identical pinouts such that various combinations of boards can be stacked in any order. All Hydra boards will have two sets of 2x15-pin 2.54mm pitch headers on opposing sides of the circular PCB with standardized pinouts across all boards as tabulated below:

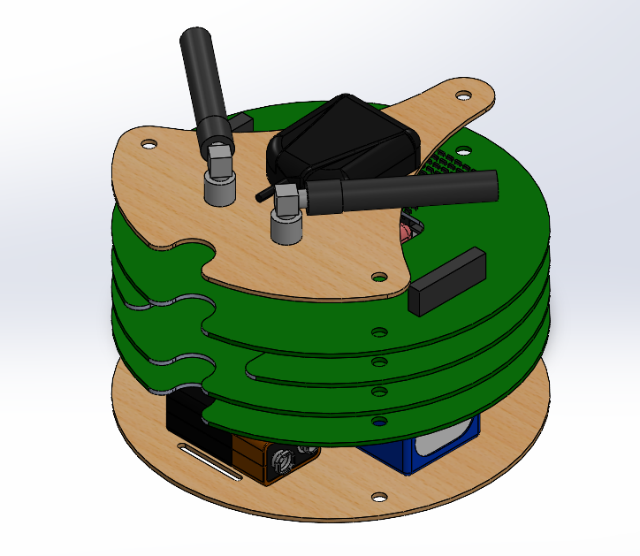
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| |  |  |  | | --- | --- | --- | | POWER | V\_BATT | V\_BATT | | V\_BATT | V\_BATT | | +5V | +5V | | +5V | +5V | | +3V3 | +3V3 | | +3V3 | +3V3 | | I2C | GND | GND | | SDA | SCL | | SPI | GND | GND | | MOSI | MISO | | SCK | CS | | UART | GND | GND | | UART\_TX | UART\_RX | | CAN | GND | GND | | CAN\_HI | CAN\_LO | | |  |  | | --- | --- | | PYRO\_PWR | PYRO\_PWR | |  |  | |  |  | |  |  | |  |  | |  |  | |  |  | |  |  | |  |  | |  |  | |  |  | |  |  | |  |  | |  |  | | GND | GND | |

The left header transmits all power and data signals for the avionics stack whereas the right header is mostly free for future upgradeability. The data buses on the left header are segregated by ground rails to prevent crosstalk due to the proximity of these data lines.

### Hydra V1 Considerations

The power, logic, and communication boards stack closely in this design to enable the use of inter-board connectors and minimize free wires within the avionics bay. No additional inter-board connections should be required seeing as the ejection board runs independently of Hydra and utilizes separate power supplies. The only clearance issue lies with the SBG as its 24mm height will require a hole in the communication board to maintain the close stacking of the circuit boards.

## Hydra V1 Boards

A picture containing diagram

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Figure 4. Hydra V1 Preliminary Render

The flight computer is currently split into four circuit boards each having a specific role, as depicted in Figure 4 above. The two beige plates above and below the stack only serve structural purposes and are not part of the computer itself. The top beige plate serves as a mounting point for the GPS antenna and the RFD900’s antennas whereas the bottom beige board serves as a mounting point for the lithium polymer battery as well as the two 9V batteries used by the RRC3s. The material for the beige plates is not determined, however we will likely use excess unpopulated PCBs since we must order a minimum of 5 for each PCB of this flight computer. The functional flight computer PCBs, depicted in green, from bottom to top are as follows: the power board, the logic board, the communication board, and the recovery board. Their specific functionality is listed below:

### Recovery Board

Hydra V1 does not contain any flight-critical functionality. Therefore, this board functions independently and serves solely to house two RRC3s alongside individual power sources (9V batteries) for each and the SBG’s GPS antenna. The Rocktopus airframe stores the main chute in the nose cone of the rocket (immediately above the avionics bay) and the drogue chute immediately below the avionics bay. This means that two separate sets of wires are required on either end of the avionics bay to interact with both recovery systems. Furthermore, each recovery device is actuated by a set of redundant CD3s (CO2-based deployment charges) so four independent sets of wires are required (8 total).

Beyond providing mounting locations for the components this board serves to replace the wire-to-board connectors on the RRC3s with more reliable connectors. This eliminates the risk of electrical failure due to vibration while maintaining some level of maintainability in that the avionics stack can be conveniently connected and disconnected from the airframe’s hardware.

### Communication Board

The Hydra V1 communication board serves to provide a mounting point for the RFD900 radio as well as the Featherlight backup GPS tracker. The RFD900 radio receives power and UART from the header with no additional hardware whereas the featherlight functions independently from the avionics stack. As a result, the featherlight uses a separate LiPo battery and does not communicate with the avionics stack.

### Logic Board

Hydra V1 contains no flight-critical logic and therefore this board serves solely as a telemetry gathering system to log rocket attitude/location data from the SBG to an SD card and transmit it using the RFD900 radio. This is the only board containing an MCU in this version of Hydra. Data is gathered from the SBG using a CMOS-TTL to RS-232 converter linked to a UART port of the MCU and data is logged onto an SD card using an SPI port of the MCU.

In addition to the electrical hardware, this board provides a mounting point for the SBG that must be at its center to ensure accurate attitude data is collected.

### Power Board

This board contains two switching regulators providing the other boards with a 5V and 3.3V rail from the integrated avionics battery. Current version includes reverse polarity protection as well as thermal and overcurrent protection.

## Board Hardware Requirements

### Recovery Board

Used for redundant two-stage recovery system deployment and GPS antenna mounting.

* 2 RRC3 footprints to transfer I/O from RRC3 wire-to-board connectors to locking connectors on the recovery board
* Safety disconnect switches
* Cutout in center to provide clearance for SBG
* Passthrough for RF cables throughout stack
* Two 2x15-pin headers

### Communication Board

Used to mount RFD900 and Featherlight GPS tracker.

* RFD900 footprint
  + UART and power traces
* Featherlight tracker footprint
  + Independent battery so no traces needed whatsoever
* Passthrough for RF cables throughout stack
* Two 2x15-pin headers

### Logic Board

Used for data logging and ground station communication.

* Micro SD card holder
* 1 external crystal 32KHz
* 1 external crystal 8MHz
* Microcontroller ATSAME51J18A
* SBG mounting point
* UART link to SBG
  + CMOS-TTL to UART adapter
* LEDs:
  + Green: connected to power
  + Red: connected to chip, error
  + Yellow: connected to chip, communication
* SWD debugging port (<https://www.segger.com/products/debug-probes/j-link/models/j-link-edu-mini/>)
* Two 2x15-pin headers
  + UART link for RFD900
  + CAN link for future avionics boards
  + I2C link for future avionics boards
  + SPI link for future avionics boards?

### Power Board

Used to step down battery voltage to 5V and 3.3V rails.

* 5V regulator
* 3.3V regulator
* LEDs to indicate operational state of each power rail
* Battery connector
* Safety power-disconnect switch
* Two 2x15-pin headers

# Software Design

Enjoy, cutie

# EMI/RF Considerations

Four antennas are used for the avionics stack’s various RF components: two quarter-wave 900MHz dipoles for the RFD900, one 900MHz dipole for the Featherweight tracker, and a GPS antenna for the SBG. The avionics stack may be surrounded with non-conductive RF isolating material depending on future testing which will be done once the boards are manufactured. A potential concern is the proximity of the RFD900’s antennas to the ejection circuitry though the RRC3s are likely perfectly capable of withstanding the radiation induced by the RFD900’s relatively low 1W transmission power.

The RFD900’s two dipoles will be placed orthogonally and perpendicular to the rocket’s axis above the avionics stack alongside the GPS antenna. The Featherweight’s antenna is placed at the top of the payload bay to limit interference since it transmits on the same band as the RFD900. As previously mentioned, the entire Featherweight unit may be transferred to the top of the payload bay pending testing.

# Arming and Safety Considerations

The power board has a cutoff switch that interacts with a rod protruding from the rocket’s fuselage which must be removed to allow power to flow from the battery to the voltage regulators. Furthermore, the ejection board has two separate switches, one for each RRC3, that utilize a similar mechanism to disconnect the 9V batteries from their accompanying RRC3 prior to flight. Both of these rods will protrude out of both sides of the rocket through holes drilled along a centerline of the fuselage. Additionally, each rod intended to be removed before flight will have a Clevis pin to ensure it cannot be removed accidentally. A sample photo of the proposed locking pin design is included below in Figure 5.

Text, whiteboard

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Figure 5. Clevis Pin

3D-printed rod guides will be attached to any PCB containing safety cutoff switches such that a dummy rod can be inserted during assembly to maintain the switches in an open position. Once the rocket has been fully assembled, the real rod will be inserted into the fuselage hole consequently pushing out the dummy rod without ever closing any safety cutoff switches. These 3D-printed rod guides will also contain O-rings to provide additional friction for maintaining the safety rods in place.

# Battery and SBG Considerations

As depicted in Figure 4, the battery is placed horizontally below the PCB stack. The avionics battery will be a 3S 2200mAh lithium polymer pack as we found this to be lighter than using lithium-ion cells of a similar capacity while also providing plenty of battery life. Two additional 9V batteries are included for each RRC3. All batteries are attached using a combination of double-sided adhesive and straps going through slits in the battery mounting plate.

The SBG was included in this section as it lies on the second board from the bottom of the stack and is relatively large. As a result, the communication and ejection boards will have cutouts in the middle to allow the SBG’s body to protrude through their center thereby providing the required clearance. Due to the relative simplicity of the hardware, this cutout does not deprive us of any required PCB space. A few additional cutouts are included on the rear of the stack to allow RF and power cables to pass through the boards since clearance around the avionics stack is limited. These cutouts allow RF cables to pass from the RFD900 to the two antennas above the stack and the GPS antenna’s cable to connect with the SBG. Additionally, they allow power cables from the two 9V batteries on the bottom plate to pass through to the RRC3s on the recovery board.