Remote Launch Control System

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Description of Purpose

Waterloo Rocketry's Remote Launch Control System (RLCS) is the system that controls all propellant loading and other preflight actuations required to launch our rocket.

Design Constraints

The system was designed to satisfy the following constraints:

1. The system must be operated from a minimum safe distance of 1km Once RLCS takes control of the launch operations, no human intervention should be required (in any possible error state) that requires a human to approach the system. In event of total failure, the system must safe all rocket components so that personnel can approach the rocket without placing themselves in any danger

2. The system should integrate with our preexisting fill system, and control the following actuators

   - A ball valve that connects to the supply cylinder (Remote Fill valve)
   - A ball valve that opens the fill line to atmosphere to vent it (Remote Vent valve)
   - A linear actuator that pulls a pin to disconnect the fill line from the rocket's oxidizer tank
   - Two nichrome coils that are used (in conjunction with the Injector valve) to actuate ignition
   - A ball valve that connects the rocket's oxidizer tank to the combustion chamber, allowing the propellant to ignite (Injector valve)
   - A ball valve that connects the rocket's oxidizer tank to atmosphere, allowing us to vent the tank in event of a launch abort

   The latter two valves are actuated by a separate system (Flight Instrumentation), but they are under the control of RLCS, which is why they are mentioned here

3. The system must use sensors to collect the following data, and report that data back to the operator

   - The current state of all valves (open/closed)
   - The amount of current flowing through the nichrome coils
   - The mass of the rocket, loaded on the rail
   - The pressure of oxidizer in the rocket's oxidizer tank
   - The pressure of oxidizer in the fill lines

   In addition to showing this information to the user, the system should also log all of this data so that it can be used for post-flight analysis

Block Diagrams

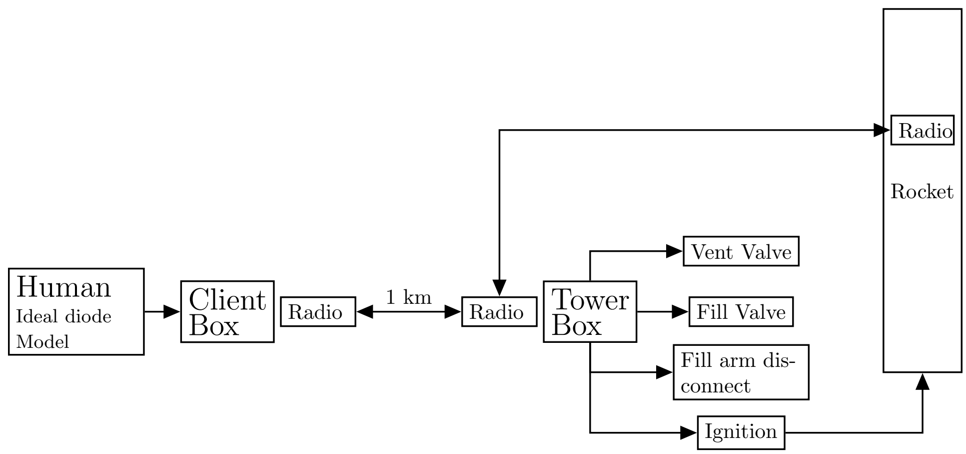

Figure 1: High-level System Overview

RLCS is composed of two parts, the client side box and the tower side box. The client side box interfaces with the operator through a bunch of switches and a big LCD that displays sensor data. The tower side box controls all of the actuators necessary to launch the rocket (2 valves, nichrome coils, and the disconnect linear actuator). In addition to controlling the actuators, the tower box communicates with two other components in the rocket in order to control the two ball valves mounted in the rocket (see documentation of the flight instrumentation system for more details).

The client box and tower box communicate over a pair of XBEE Pro S3B transceivers both using half dipole antennas with a gain of 3dBi each. The tower box communicates with flight instrumentation using XBEE series 1 transceivers all of which have a small whip antenna. The XBEE Pro's operate at 900MHz, while the series 1's communicate at 2.4GHz.

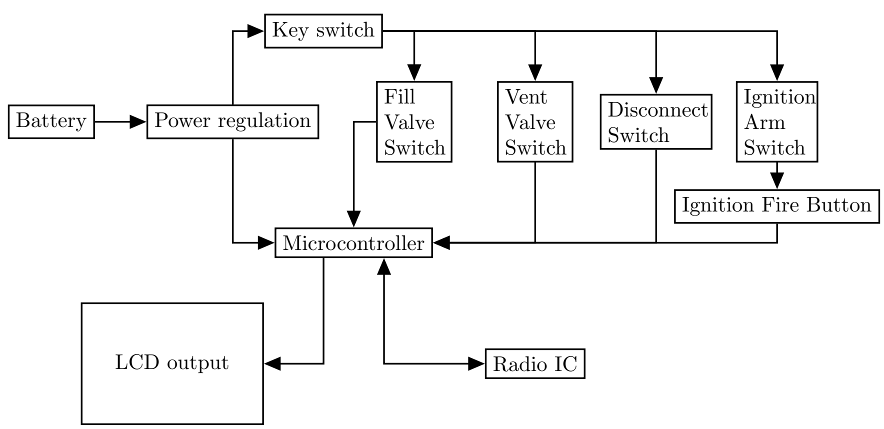

Figure 2: Client side block-level diagram

The client side box is composed of a number of switches connected to a microcontroller (in this case, an Arduino Mega), which is in turn connected to an LCD (to relay information to the user) and the radio transceiver. All switches are connected in series with a keyswitch to allow the system to be disabled whenever personnel are nearby the rocket. The ignition switch is in series with a momentary pushbutton to remove the possibility of a switch being left in the the "fire" position when the system is first started. The "power regulation" board is a switching regulator which drops the 11.1v from the battery to 5v, which can be used by the microcontroller.

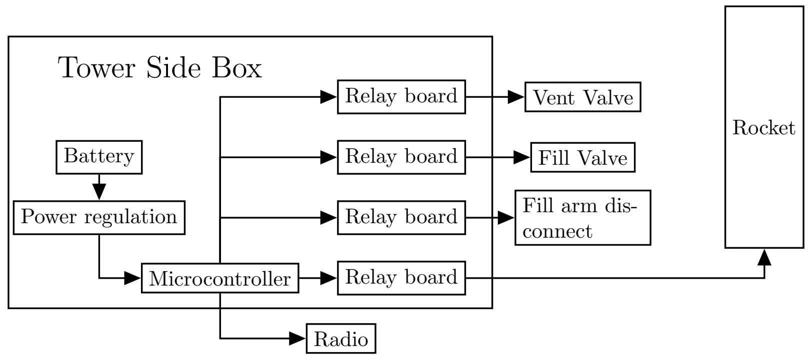

Figure 3: Tower side block-level diagram

The tower side box controls external actuators through relay boards, which are cutomed designed PCBs that feature a DPDT relay, for changing direction of valves or swapping between ignition circuits, and an SPST relay, for interrupting current to the actuator when it is set to off. The boards also feature current sensors on all actuator outputs, and logic level shifting for the limit switch signals coming off of the valve, dropping the signal from 12 volts to 5, which the microcontroller can read. The batteries in this box (as well as all other batteries the system uses) are fused to prevent a fire in the event of power ever being shorted to ground.

Tradeoffs

Analysis/testing

Here's why this doesn't break a bunch of rules.

Design, Test, & Evaluation Guide

Rule 2.2 - PROPULSION SYSTEM SAFING AND ARMING

- **"A propulsion system is considered armed if only one action (eg an ignition signal) must occur for the propellant(s) to ignite"**

  Our propellant is really hard to ignite. We've performed numerous tests to determine if our fuel grain (main propellant) can be ignited without nitrous oxide present. We've never managed to ignite it. Using that as precedent, we can say that our ignition system isn't armed until oxidizer is present in our flight tank. Since oxidizer alone isn't enough to ignite our propellant without extreme heat also present, you could make the argument that our ignition system isn't really armed until the ignition puck is burning *and* there is oxidizer present in our flight tank.

Rule 2.2.1 - GROUND-START IGNITION CIRCUIT ARMING

- **"All ground-started propulsion system ignition circuits/sequences shall not be "armed" until all personnel are at least 50 ft (15 m) away from the launch vehicle."**

  Our operations procedures ensure that there is never oxidizer in our flight tank until we are ready to launch, and all personnel are already at the minimum safe distance away from the rocket. We do not arm our ignition sequences until all personnel are much further than 15m away from the vehicle.

Rule 2.2.3 - PROPELLANT OFFLOADING AFTER LAUNCH ABORT

- **"Hybrid and liquid propulsion systems shall implement a means for remotely controlled venting or offloading of all liquid and gaseous propellants in the event of a launch abort"**

We have a 0.3mm diameter hole in series with an electrically controlled valve in our rocket to facilitate offloading of all liquid propellant in the event of an abort. Before going to the competition, we perform a full systems integration test in which we fill the rocket with CO_2 and then vent all of it to ensure that this system is operational and functions properly. TODO Jacob do we still do this?

Rule 3.4 - SAFETY CRITICAL WIRING

- **"Safety critical wiring is defined as electrical wiring associated with recovery system deployment events and any "air started" rocket motors"**

  This system is in no way associated with either of those things, which is why it does not (in some minor places) comply with the safety critical wiring standard.

Rule 4.1 - ENERGETIC DEVICE SAFING AND ARMING

- **"All energetics shall be safed until the rocket is in the launch position, at which point they may be "armed". An energetic device is considered safed when two separate events are necessary to release the energy"**

  Our ignition system contains two nichrome igniters embedded in a flammable solid fuel puck, which is the only energetic associated with this system. Until the rocket is mounted on the rail, these igniters are shorted and are not connected to the system, and thus they are not armed, since you'd have to un-short them and then plug them in before the energy can be released.

10.1 EQUIPMENT PORTABILITY

- **"Teams should make their launch support equipment man-portable over a short distance (a few hundred feet)"**

  The tower side box component of this system is the heaviest piece, which weighs 12lbs and has a handle on it for ease of portability. The entire system is easily man portable and can be carried by 2 or 3 people well over a few hundred feet.

10.3 OPERATIONAL RANGE

- **"All team provided launch control systems shall be electronically operated and have a maximum operational range of no less than 2,000 ft (610 m) from the launch rail"**

  Our system is electronically operated and uses two XBEE-PRO XSC S3B modules which have an advertised range of 28 miles with line of sight. We used the exact same modules last year and had no issues with loss of communication.

10.4 FAULT TOLLERANCE AND ARMING

- **"All team provided launch control systems shall be at least single fault tolerant by implementing a removable safety interlock (i.e. a jumper or key to be kept in possession of the arming crew during arming) in series with the launch switch"**

  We use a key switch in series with all other control switches on our client side box. The key is held by either an IREC official or the arming crew until the rocket is ready to launch.

10.5 SAFETY CRITICAL SWITCHES

- **"All team provided launch control systems shall implement ignition switches of the momentary, normally open (aka "deadman") type"**

  Our ignition actuation button is momentary and normally open.

APPENDIX C: FIRE CONTROL SYSTEM DESIGN GUIDLINES

- **"The control console should be designed such that two deliberate actions are required to fire the system"**

  Since all switches are in series with the keyswitch, any action taken at the control box really takes 4 deliberate actions (put key in box, turn key, flip up switch cover, actuate switch). Because the ignition fire button is in series with two missile switches, firing the system takes 5 deliberate actions, and 5 is greater than two for all values of 5 (insert key, turn key, flip up switch cover, actuate switch, press button).

- **"The system should include a power interrupt such that firing current cannot be sent to the firing leads while personnel are at the pad and this interrupt should be under the control of personnel at the pad."**

  Does the keyswitch count?

- **"The failure of any single component should not compromise the safety of the firing system."**

  Our ignition system requires at minimum 3 separate actions to occur (open fill valve, send ignition current, open injector valve) before our ignition system actuates. There is no single component that can fail that would cause all three of these actions to occur (unless a microcontroller fails in an impossibly specific and malicious way), and thus our the safety of our system would never be compromised by a single component's failure. All subsystems are designed to fail safe (certain valves close in the event of communications loss, there are inline fuses on all actuator power lines, etc) in the event of component failure.

Glamour shots

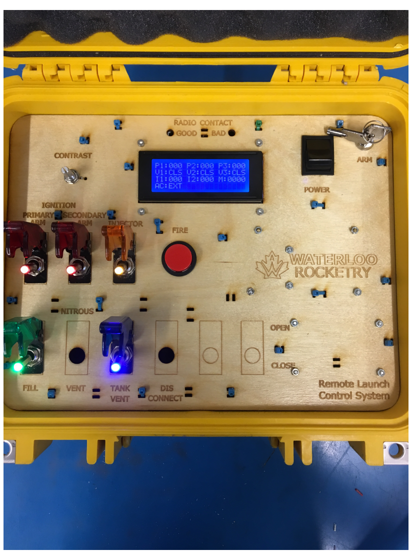

Figure 4: The clientside box

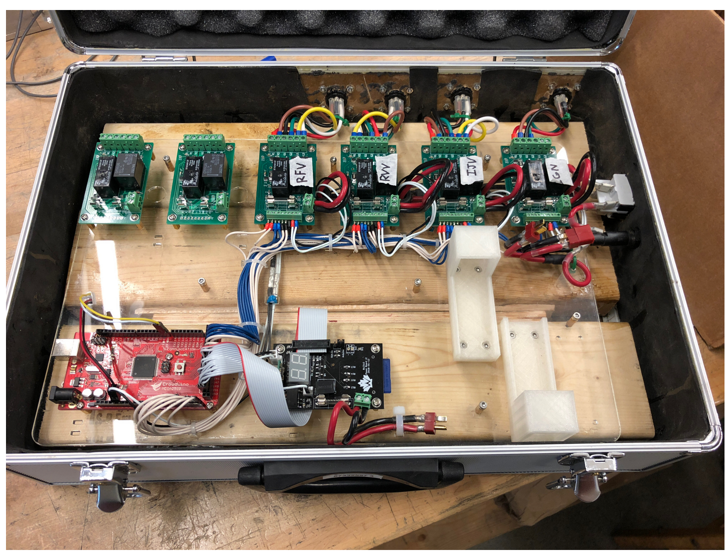

Figure 5: The towerside box

Technical Details and Schematics if you're *really* interested

All technical specifications (from schematics and layouts down to individual component datasheets) can be found in this project's github repository, `https://github.com/waterloo-rocketry/rlcs`. Also present in that repository is all the code that runs on the microcontrollers, all the unit tests that that code is checked against, and also this document.

Assembly and Pre-Launch Checklists

The order of operations:

1 ☐ When RLCS takes over, here's the current state of our fill system:

2 ☐ The NOs K bottle's cylinder valve is open

3 ☐ The plumbing system is set up, all valves are closed (except series fill)

4 ☐ The only pressurized line is the fill line (leads from cylinder to remote fill valve). All other lines are atmospheric.

5 ☐ The primary operator marks the current fill line pressure (reads from SP1)

6 ☐ The primary operator opens the rocket vent valve, which will allow the rocket to be fuelled.

7 ☐ The primary operator opens the remote fill valve, pressurizing the feed line. Oxidizer begins to flow into the run tank, while fumes vent from the top of the run tank through the rocket vent valve. At this moment (oxidizer in the run tank), our ignition system and rocket are considered armed. All personnel must be at the Minimum safe distance before this point.

8 ☐ Once the rocket is fuelled (as indicated be the primary load cell and rocket pressure transducer), the rocket vent valve is closed, sealing the run tank.

9 ☐ The remote fill valve is closed, sealing the supply tank off from the rest of the plumbing assembly.

10 ☐ The remote vent valve is opened, venting the feed line, so that is at atmospheric pressure. The goal of this step is to allow the remote disconnect arm to swing free without spraying the airframe of the rocket with oxidizer.

11 ☐ The remote disconnect pin is pulled, allowing the fill arm to swing free. The rocket is now disconnected from the fill system, and ready to launch. because of the one way check valve in the rocket, the nitrous does not vent through the fill arm adapter)

12 ☐ Once the IREC official says so, we can actuate ignition and launch:

13 ☐ Ignition is fired, igniting the puck in the CC.

14 ☐ Once we have confirmation of flame in the CC (read from ammeter on ignition circuit), we open the injector valve.

15 ☐ Watch the rocket, because this'll be pretty cool.

End of Operations.