# REDHAWK DUELS

## - Engineers in space…

### Background

In the year 2512 A.D. spaceflight is possible, but science fiction of past got it mostly wrong for the human race, particularly space battles. Sure there are space battles (mostly in the form of sporting events), but the reality is that in the depth of space you hear no explosions and see no enemy, mainly, because it’s space.

The good news, though, is engineers still play a fundamental role in building things in the universe as we know it. And for some strange reason, modern sport is a game of engineer(s) against engineer(s) in an effort to design and control the best ship. Celebrities are no longer the best at using an implement to hit an object through a poll. No, they’re the minds that create tactics such as the infamous double loop evasion and shot to win the duel in the match “RedhawkIV versus Queen’s Liberty” circa 2505 A.D.

### Premise

Version 0.0 of Redhawk Duel puts you in charge of designing, controlling, and maintaining your ship in a battle against an opposing duelist. Each ship is physically configured the same, and consists of an engine on the back, a cannon mounted on the front, a laser finder on top, a power cell, and control. The engineers are responsible for designing the control for the ship.



The above figure shows the conceptual configuration and size of the ship. The engine is the blue square and the arrow coming from these engines show the direction of generated thrust. The purple triangle represents the cannon, and the orange semi-circle represents the laser finder sensor.

The controller is a combination of human control and electrical control. For example, to steer the ship, the human controller could turn on a single switch that would send thrust to the engine resulting in the ship moving in the direction of the current facing. Therefore, the controller needs to be built to allow the user to adjust and modify how they are moving, to display the information from the sensor, to fire the cannon, etc.

The goal of a duel is to render the opponents ship powerless by repeatedly hitting him with your laser cannon until the opponents can’t reroute their power network to supply sufficient power to operate.

The following document describes each piece of the ship, the control functionality of the ship, and the dueling field in more detail to help you understand the game and get started on building your own ship.

### Ship

The ship as shown above has the dimensions 10 meters by 10 meters by 10 meters. This is enough room for all the equipment for the sensors and actuators and a maximum 3 person crew. The ship has a mass of 2,000,000 kilograms.

### Power Cell

Both the cannon and the engines are driven by a power cell. The power cell is a modern power source based on energy amplification through a crystal substance (similar to the concepts of laser amplification). Each time energy passes through a crystal the power beam is increased in strength. However, this affect is not a simple linear concept. Each crystal when initially installed goes through a process in which a crystal is refined (via a magnetic field) to allow for maximum amplification when matched (paired) with similar crystal. The process of adding fields to the crystals (much like silicon manufacturing) does not create uniformly matched crystals. For example, imagine that a power source is passed through crystal one and crystal two such that the original power source 10kW/m (kilo-watt minutes) is amplified to 20kW/m (a +10kW rating). A different pairing might result in an amplification of only (18kW/m).



Therefore, if you have four crystals of various matching properties (with one another) and a power source (as shown above) depending on how you configured how the power source amplifies the signal through each of the crystals, you will get varying power amplification at the end.



For the above diagram, if you configured the crystals with the path A to D to C to B you get 32kW/m (10+8+9+5) versus the path A to B to D to C where you get 33kWm (10+7+7+9). Crystals can only be routed through once, and all crystals in a power cell need to be routed through once.

What’s even worse is that the cannon mounted on each ship does not cause physical damage to an opposing ship, but instead, the cannon is specifically designed to degrade the amplification fields of the crystals.



The diagram above shows a theoretical impact of a cannon on our four crystal network. Now the path A to B to D to C only gets 29kW/m compared to 33kW/m in before being shot.



The power cell within a simple ship consists of 8 crystals as show above. Each crystal can connect to each other cell, but as described earlier, the power source starts at A and each crystal must be routed through only once and at least once or the resulting power generated is 0kW/m. The final connection must be back to the original crystal, A. The maximum power output of the 8 crystal power cell is 90kW/m. This means that during battle at every minute a perfect configuration of crystals will generate 90kW per minute as your power budget for that minute.

The per minute power budget generated by the crystal array is transferred to a reservoir that can be used over the next minute while the next minutes power budget is generated. As long as the ship only uses less than or equal to the reservoirs power budget everything is fine. After a minute, the remaining power in the reservoir is instantaneously lost, meaning it cannot be saved or added to the incoming power generated.

If, however, the power ship goes over the reservoirs budget (asking a engine or laser to use more than what is still available) then the ship will stall for the next minute as the power cell reinitializes itself. During this time the power budget available is 0.

Also, note that basic life support, sensors, control circuitry, and the power cell itself require a minimum of 10kW to run. Therefore, the power budget available to other devices must take this into account.

### Engine

The engine on the ship, in terms of thrust output, accelerates the ship at 1m2/s in the opposite direction of its’ output thrust. The cost of this full power thrust in terms of power is 1kW/s. Therefore, in a minute you can spend 60kW towards thrust if you have a sufficient power budget.

In a non-gravitational environment, such as deep space (roughly 0 gravitational pull), note that acceleration will result in velocity that is maintained since there is nothing to slow down your ship except obstacles or other ships. The dueling field of play has special dampening fields installed. These will stop your ship instantly and teleport your ship back to the starting point stalling your ship. Similarly, hitting an opponent’s ship will result in the same behavior.

### Sensor

The sensor is a simple device that sends out a laser pulse and responds to that pulse if it bounces off an object. The sensor, when it finds something will tell you what it is. In terms of what it is it will tell you if it is another ship, an object, or a boundary. Since the field is enclosed it is guaranteed that there is always a response of what is in front of you, however, it is the ships responsibility for recording it’s location (if the need arises). The sensor result is updated once per second.

The sensor is mounted in the center of the ship and can be rotated 360 degrees in steps of a half degree (.5 degrees). The angle 0 and 360 both point towards the front of the ship defined by the direction the cannon is mounted.

The power cost of the sensor is (essentially) 0kW as it is included in the 10kW/m overhead for the entire ship.

### Cannon

The cannon, as described briefly in the power cell section, is used to degrade the opposing ships power cell. The cannon is mounted on the front of the ship and fires in a straight line at the speed of light, and therefore, a firing of the cannon is considered to be instant (once the command reaches the laser). The fire power of the cannon can be set to anything from 0 to 1000 in steps of 1, where each power level costs the equivalent in kW. Therefore, a single shot with a power of 23 will cost 23kW of the current power budget in the reservoir.

The impact of the weapons power on the opposing ship, in an instance of a hit, is the amount of power allocated to the shot. This value is then randomly subtracted from the amplification paths in the crystal.



The above diagram shows what could happen for a 4-crystal power cell that got hit by a shot of power 18.

### Dueling Field



The dueling field is a 2-dimensional map that is 340m in the x direction and 240m in the y direction. On this map there are the ships, immovable objects, and a boundary. Any collision with objects, ships, or boundaries result in an instantaneous stopping of the ships, teleportation to starting point, and the ship will stall for a minute.

### Conditions of winning

A ship that cannot generate 10kW/min over a 2 minute period at the start of each minute will self-destruct.

* Basic game:
  + Winner: The remaining ship when the other ship self destructs.
  + Draw: Neither ship has power to do anything over the same 2 minutes

### Controller Technical Details:

The previous section described the mechanics behind the various pieces of the machine. In this section we describe how to control the various units of the ship and how the system/game is setup.

The figure below shows the game master board and player 2 board with a crystal array. Note, the red Ethernet cable is a crossover cable that allows the two boards to communicate with each other. In the full game, a hub and Ethernet cables are used to hook up the three boards. Also note that the games master has a VGA cable hooked up to a monitor. This allows spectators to watch the event unfold, and can be used to debug your design. During an actual competition, the teams are not allowed to view the VGA display.



A basic prototype ship has been provided to show how to communicate with the games master and rudimentarily control the ship. The following picture shows how all the switches are used in this prototype. The display of the data for the ship is not shown in this image, but the majority of the information is shown using the seven-segment displays. For more details, you will need to understand the design of the prototype ship by investigating the Verilog design files.



Within the game, the power crystal array is key in providing your ship with power. The following picture shows how the prototype power crystal array is configured through the GPIO ports from the DE2 board and some wires plugged into a breadboard. During battle, this allows a player to reconfigure the crystal array during battle to find more power for the ship. Again, details of this setup will need to be understood



The spectators of the game will see figures similar to the following:



This image shows the beginning of the game where player 1 in the top left corner and player 2 in the bottom right corner have just started the battle and are trying to wire the maximum power budget on their respective crystal arrays.



This image shows player 2’s shot path that hit player 1 and will result in a lower power budget the following minute depending on the power of the shot, and the player 1’s crystal array.

### Project Goal:

The goal of the project in ECE 287 is to take the existing ship prototype and add to it to allow you to control your ship better.

Some examples include:

* Interface the DE2 with a keyboard to control the ship easier than flicking switches
* Interface the DE2 with a VGA monitor to display the power crystal configuration so you can easily rewire it
* Build an algorithm into the FPGA that moves the ship from the top corner to the bottom corner automatically as a macro