Lab 3 - Taylor Cowley and Andrew Okazaki

Chapter 1: Space Invaders Overview

Section 1.1: Space Invaders History

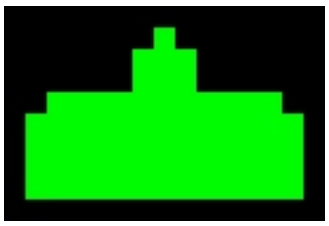
Two good-sized paragraphs are required for full credit.

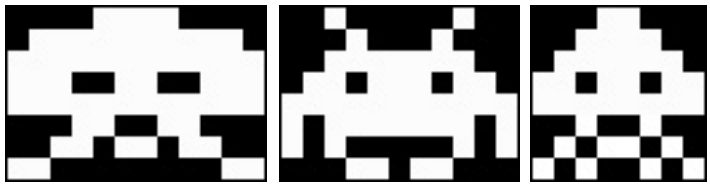
Space Invaders is a video game, developed by Tomohiro Nishikado, released in 1978 by Taito. Development was hindered by lack of technology at the time- Nishikado was required to design his own arcade board hardware capable of running it. Using an Intel 8080 CPU and a Texas Instruments sound chip, he was still reportedly disappointed in the limitations.

Released as an arcade machine in Japan and the United States, Space Invaders became the best-selling video game at the time, and is still the second best-selling arcade game of all time, bested only by Pac-Man. Space Invaders is credited with expanding video games into a real industry, and inspiring future video-game legends, such as Shigeru

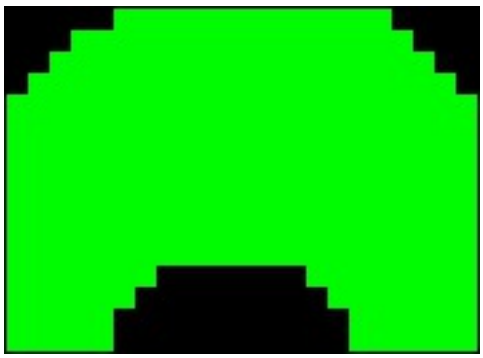
Miyamoto (Nintendo, Mario) and Hideo Kojima (Castlevania, Metal Gear).

Section 1.2: Game Play

The player's tank 

The aliens 

The UFO 

The bunkers 

The objective of space invaders is earn the most points by destroying aliens.

To destroy the aliens the user will control a tank which can move left and right as well as shoot. There is only one tank bullet aloud on the screen at one time. If the bullet hits an alien the alien and the bullet from the tank will be destroyed. The tank only has three lives, if the

user spends all three lives the game will be over.

The tank will lose a life if it is hit with a bullet from the aliens. There are three different types of aliens with a total of fifty five aliens on screen. However there is only allowed to be a maximum of four alien bullets on screen at one time. The bullets will fire at random from random aliens. The tank Needs to destroy all of the aliens in a allotted time period becasue as the aliens move on screen and reach the ends of the screen the aliens will shift forward towards the tank. If the tank fails to destroy the aliens it will become over run and the usser will lose the game.

The tank has the option of hidding from the aliens behind bunkers. There are 4 bunkers on screen. These bunker will degrade if they are hit by a bullet or come into contact with an alien.

To add another level of complexity there is an alien saucer that will cross the screen at random intervals behind the aliens. If the user is able to hit the saucer they will be able to earn bonus point.

If you are able to destroy all of the alien the aliens, a new wave of aliens will be generated. However the bunkers that the tank hid behind will not be regenerated and will continue to degrade as they are hit.

Section 1.3: Game Details and Specifications

Tank Movement:

The tank can move left and right but will not exit the playing field which is bound by the ends of the screen. To move the tank left pixels outlining the left outside of the tank are drawn and pixels on the right inside of the tank are blacked out. This maneuver will shift the tank one pixel to the left. To shift the tank right the same operation occurs however the right outside pixels are drawn and the left inside pixels are blacked out. We decided to execute the code in this manor because it is much faster changing a few pixels than blacking the image out and re-drawing the image. This is faster because the program no longer has to loop through each pixel as well as limiting the amount of times it needs to read and write to memory. Storing this data of the tank in a struct makes it organized and easy to access. The data stored includes tank position, which is a column and row number and an integer that keeps track of how many lives the tank has left.

Alien Movement:

There are fifty-five aliens located in five rows of eleven on the screen. There are three different type of aliens the first type of alien is located on the first row, the second type of alien is located on rows two and three, The third and final type of alien is located on rows four and five. As the aliens move left or right the alien will cycle between two different frames adding some animation to the aliens. As the far left or far right column of aliens reach the end of the screen all aliens will shift one row down towards the tank then continue to move in the opposite direction. Each alien type is stored as a struct which contains a Boolean telling if the alien is alive or dead as well as an alien row and column number. These Struct’s are built into an array, so that each

individual alien is represented. Knowing the position of each alien allows the program to over write the aliens with black pixels and re draw the next frame of alien to the left or right when the aliens are moving. As the aliens become hit by the tank the Boolean with in each alien struct will move to dead. When an alien is dead the program will no longer continue to draw the alien leaving a blank spot. If the far left or right column becomes obliterated and no aliens exist then the alive aliens still travel to the far end of the screen. To execute this we loop through the columns until an alive alien is found and return its location to push the alien hoard to the end of the screen.

Bunker:

As the bunkers begin to be hit with the alien bullets or the tanks shells they will begin to degrade. There are four bunkers and each bunker is split into ten different sections. These sections will degrade at different rates depending on how many times they have been hit. Each section will only be able to take four hits, each time showing the degradation. There are four degradation templates that will overwrite the bunker section every time a hit is registered. Once a bunker section is gone bullets will travel through uninterrupted.

Bullet movement:

Both Tank and Aliens will be able to fire bullets. However there is only one tank bullet aloud to be on screen where aliens are allowed to have four bullets on screen. The tank built is a single column of pixels that move linearly. The aliens have two different types of bullets that are chosen at random using the random number generator. The first type is a cross which will oscillate the arms of the cross between front

middle and back. The second type will flip between a less than operator and a greater than operator as it travels. To move the bullets the program stores each built as a struct keeping track of if it is alive and its location. With the location we are able to erase the trailing pixels and draw the incremented pixel causing the bullet to move. The variable keeping track will of its alive status, will be continuously checked before a bullet is fired to confirm there would not be too many bullets on the screen.

Game interface:

The game will end when the tank has been hit three different times and all of the lives have been used. As the tank destroys the aliens it will earn points which will accumulate and display at the top left of the screen.

Bug Report

The first error that we ran into was when trying to input a character we would run out of memory. To fix this error we ran our program from the DDR. However we forgot to update the starting location in DDR and outputted many random pixels at the top inch of the screen. To fix the error we needed to change the starting location.

The error that was most common was changing the in-correct bits. This happened many times from the erosion of the bunkers to the moving of the aliens. The fix for this was simply correcting the value to represent the correct bit location. This was easily accomplished with trial and error techniques. By first changing the pixel color then

updating the value of the location until it was located in the correct position.

The final error that plagued us was getting stuck in infinite loops. A few of our functions when we erode the bunker are recursive. So in some case we would get stuck in an infinite loop. To fix this error we simply needed to add a base case that would exit before entering the infinite loop.

```c
/*
 * helloworld.c: simple test application
 * Currently used to test lab 3 for Space Invaders.
 * Taylor Cowley and Andrew Okazaki
 */

#include <stdio.h>
#include <stdint.h>
#include "platform.h"
#include "xparameters.h"
#include "xaxivdma.h"
#include "xio.h"
#include "time.h"
#include "unistd.h"
#include "bunkers.h"
#include "tank.h"
#include "interface.h"
#include "aliens.h"
#define DEBUG

#define SCREEN_RES_X 640    // Our screen resolution is 640 * 480
#define SCREEN_RES_Y 480    // Our screen resolution is 640 * 480
#define BLACK 0x00000000    // Hex value for black

void print(char *str);



#define FRAME_BUFFER_0_ADDR 0xC1000000  // Starting location in DDR where we will store the images that we display.

int main() {
    init_platform();                    // Necessary for all programs.
    int Status;                         // Keep track of success/failure of system function calls.
    XAxiVdma videoDMAController;
    // There are 3 steps to initializing the vdma driver and IP.
    // Step 1: lookup the memory structure that is used to access the vdma driver.
    XAxiVdma_Config * VideoDMAConfig = XAxiVdma_LookupConfig(XPAR_AXI_VDMA_0_DEVICE_ID);
    // Step 2: Initialize the memory structure and the hardware.
    if(XST_FAILURE == XAxiVdma_CfgInitialize(&videoDMAController, VideoDMAConfig, XPAR_AXI_VDMA_0_BASEADDR)) {
        xil_printf("VideoDMA Did not initialize.\r\n");
    }
    // Step 3: (optional) set the frame store number.
    if(XST_FAILURE ==  XAxiVdma_SetFrmStore(&videoDMAController, 2, XAXIVDMA_READ)) {
        xil_printf("Set Frame Store Failed.");
    }
    // Initialization is complete at this point.

    // Setup the frame counter. We want two read frames. We don't need any write frames but the
    // function generates an error if you set the write frame count to 0. We set it to 2
    // but ignore it because we don't need a write channel at all.
    XAxiVdma_FrameCounter myFrameConfig;
    myFrameConfig.ReadFrameCount = 2;
```

```
53     myFrameConfig.ReadDelayTimerCount = 10;
54     myFrameConfig.WriteFrameCount =2;
55     myFrameConfig.WriteDelayTimerCount = 10;
56     Status = XAxiVdma_SetFrameCounter(&videoDMAController, &myFrameConfig);
57     if (Status != XST_SUCCESS) {
58        xil_printf("Set frame counter failed %d\r\n", Status);
59        if(Status == XST_VDMA_MISMATCH_ERROR)
60            xil_printf("DMA Mismatch Error\r\n");
61     }
62     // Now we tell the driver about the geometry of our frame buffer and a few other
   things.
63     // Our image is 480 x 640.
64     XAxiVdma_DmaSetup myFrameBuffer;
65     myFrameBuffer.VertSizeInput = 480;    // 480 vertical pixels.
66     myFrameBuffer.HoriSizeInput = 640*4;  // 640 horizontal (32-bit pixels).
67     myFrameBuffer.Stride = 640*4;         // Dont' worry about the rest of the values.
68     myFrameBuffer.FrameDelay = 0;
69     myFrameBuffer.EnableCircularBuf=1;
70     myFrameBuffer.EnableSync = 0;
71     myFrameBuffer.PointNum = 0;
72     myFrameBuffer.EnableFrameCounter = 0;
73     myFrameBuffer.FixedFrameStoreAddr = 0;
74     if(XST_FAILURE == XAxiVdma_DmaConfig(&videoDMAController, XAXIVDMA_READ,
   &myFrameBuffer)) {
75         xil_printf("DMA Config Failed\r\n");
76      }
77     // We need to give the frame buffer pointers to the memory that it will use. This
   memory
78     // is where you will write your video data. The vdma IP/driver then streams it to
   the HDMI
79     // IP.
80      myFrameBuffer.FrameStoreStartAddr[0] = FRAME_BUFFER_0_ADDR;
81      myFrameBuffer.FrameStoreStartAddr[1] = FRAME_BUFFER_0_ADDR + 4*640*480;
82
83      if(XST_FAILURE == XAxiVdma_DmaSetBufferAddr(&videoDMAController, XAXIVDMA_READ,
84                            myFrameBuffer.FrameStoreStartAddr)) {
85          xil_printf("DMA Set Address Failed Failed\r\n");
86      }
87      // Print a sanity message if you get this far.
88      xil_printf("Woohoo! I made it through initialization.\n\r");
89      // Now, let's get ready to start displaying some stuff on the screen.
90      // The variables framePointer and framePointer1 are just pointers to the base
   address
91      // of frame 0 and frame 1.
92      uint32_t* framePointer0 = (uint32_t*) FRAME_BUFFER_0_ADDR;
93      // Just paint some large red, green, blue, and white squares in different
94      // positions of the image for each frame in the buffer (framePointer0 and
   framePointer1).
95      int row=0, col=0;
96           for( row=0; row<SCREEN_RES_Y; row++) {
97              for(col=0; col<SCREEN_RES_X; col++) {
98                 framePointer0[row*SCREEN_RES_X + col] = BLACK;
99              }
100          }
101
102     bunkers_init(framePointer0);       // initialize the bunkers
103     tank_init();                       // initialize the tank
104     tank_draw(framePointer0, false);   // draw the tank
```

```
105
106     interface_draw_line(framePointer0);            // draw the line at the bottom
107     interface_draw_tanks(framePointer0);           // draw the tanks at the top
108     aliens_init(framePointer0);            // initialize aliens
109
110
111
112     // This tells the HDMI controller the resolution of your display (there must be a
    better way to do this).
113     XIo_Out32(XPAR_AXI_HDMI_0_BASEADDR, 640*480);
114
115     // Start the DMA for the read channel only.
116     if(XST_FAILURE == XAxiVdma_DmaStart(&videoDMAController, XAXIVDMA_READ)){
117         xil_printf("DMA START FAILED\r\n");
118     }
119     int frameIndex = 0;
120     // We have two frames, let's park on frame 0. Use frameIndex to index them.
121     // Note that you have to start the DMA process before parking on a frame.
122
123     if (XST_FAILURE == XAxiVdma_StartParking(&videoDMAController, frameIndex,
    XAXIVDMA_READ)) {
124         xil_printf("vdma parking failed\n\r");
125     }
126     char input;
127     srand((unsigned)time( NULL ));
128     while(1){
129     input = getchar();
130     switch(input){
131     case '4':
132         tank_move_left(framePointer0);     // move the tank left
133         break;
134     case '6':
135         tank_move_right(framePointer0);        // move the tank right
136         break;
137     case '8':
138         aliens_move(framePointer0);    // move the aliens
139         break;
140     case '2':
141         aliens_kill(framePointer0);    // Kill an alien
142         break;
143     case '5':
144         tank_fire(framePointer0);      // Make the tank fire
145         break;
146     case '3':
147         alien_missle(framePointer0);   // Make the aliens fire
148         break;
149     case'9':
150         tank_update_bullet(framePointer0); // update all bullets
151         aliens_update_bullets(framePointer0);  // update all bullets
152         break;
153     case '7':
154         bunkers_hit_rand_bunker(framePointer0);    //Erode bunker
155         break;
156     }
157     }
158
159
160    cleanup_platform();
```

```
161
162     return 0;
163 }
164
```

```c
/*
 * aliens.h
 *  Taylor Cowley and Andrew Okazaki
 */

#include <stdbool.h>
#include <stdint.h>
#ifndef ALIENS_H_
#define ALIENS_H_


#endif /* ALIENS_H_ */

void aliens_init(uint32_t * framePointer);  // Initializes the aliens
void aliens_move(uint32_t * framePointer);  // Moves the aliens
void aliens_left(uint32_t * framePointer);  // Moves aliens left
void aliens_right(uint32_t * framePointer); // Move aliens right
void aliens_kill(uint32_t * framePointer);  // Kills a random alien
void alien_missle(uint32_t * framePointer); // Shoots an alien bullet
void aliens_update_bullets(uint32_t * framePointer);    // Updates the bullets

```

```c
/*
 * aliens.c
 * Taylor Cowley and Andrew Okazaki
 */

#include <stdio.h>
#include "platform.h"
#include "xparameters.h"
#include "xaxivdma.h"
#include "xio.h"
#include "time.h"
#include "unistd.h"
#include <stdbool.h>
#include <stdint.h>
#define ALIEN_HEIGHT 8      // Aliens are 8 pixels tall
#define ALIEN_COLUMNS 11    // 11 columns of aliens
#define TOP_TOTAL 11        // 11 aliens in top group
#define LOC_ALIEN_ONE 50    // Pixel where the first alien is
#define MIDDLE_TOTAL 22     // There are 22 total middle aliens
#define BOTTOM_TOTAL 22     // There are 22 total bottom aliens
#define ALIEN_NUM_BULLETS 4 // Aliens can have up to 4 bullets at a time
#define ALIEN_NUM_BULLET_TYPES 2// Aliens have 2 types of bullets to choose from
#define BAD_ADDRESS -1      // Nothing exists at screen address -1
#define MOVE_DOWN_PIXELS 15 // When the aliens move down, they do so 15 pixels
#define LEFT_BOUNDRY    11  // Aliens cannot go more left than this
#define RIGHT_BOUNDRY   307 // Aliens cannot go more right than this
#define BULLET_COL_OFFSET 6 // Bullets appear 11 more right than their alien
#define BULLET_ROW_OFFSET 11// Bullets appear more down than their alien
#define SCREEN_LENGTH   320 // Our screen is 320 pixels wide
#define SCREEN_HEIGHT   240 // Our screen is 240 pixels tall
#define SCREEN_RES_X    640 // Our screen RESOLUTION is 640 pixels wide
#define SCREEN_RES_Y    480 // Our screen RESOLUTION is 480 pixels tall
#define WHITE 0xFFFFFFF     // These
#define BLACK 0x0000000     // are colors
#define WORD_WIDTH 12

// Packs each horizontal line of the figures into a single 32 bit word.
#define packword12(b11,b10,b9,b8,b7,b6,b5,b4,b3,b2,b1,b0) \
        ((b11 << 11) | (b10 << 10) | (b9  << 9 ) | (b8  << 8 ) | (b7  << 7 ) | (b6  << 6 ) \
                | (b5  << 5 ) | (b4  << 4 ) | (b3  << 3 ) | (b2  << 2 ) | (b1  << 1 ) | (b0  << 0 ) )

// -------------------------------------------------
// The following static const ints define the aliens
// We have 3 types of aliens with 2 poses each
static const int32_t alien_top_in_12x8[ALIEN_HEIGHT] = {
        packword12(0,0,0,0,0,1,1,0,0,0,0,0),
        packword12(0,0,0,0,1,1,1,1,0,0,0,0),
        packword12(0,0,0,1,1,1,1,1,1,0,0,0),
        packword12(0,0,1,1,0,1,1,0,1,1,0,0),
        packword12(0,0,1,1,1,1,1,1,1,1,0,0),
        packword12(0,0,0,1,0,1,1,0,1,0,0,0),
        packword12(0,0,1,0,0,0,0,0,0,1,0,0),
        packword12(0,0,0,1,0,0,0,0,0,1,0,0,0) };
static const int32_t alien_top_out_12x8[ALIEN_HEIGHT] = {
        packword12(0,0,0,0,0,1,1,0,0,0,0,0),
        packword12(0,0,0,0,1,1,1,1,0,0,0,0),
```

```
 57         packword12(0,0,0,1,1,1,1,1,1,0,0,0),
 58         packword12(0,0,1,1,0,1,1,0,1,1,0,0),
 59         packword12(0,0,1,1,1,1,1,1,1,1,0,0),
 60         packword12(0,0,0,0,1,0,0,1,0,0,0,0),
 61         packword12(0,0,0,1,0,1,1,0,1,0,0,0),
 62         packword12(0,0,1,0,1,0,0,1,0,1,0,0) };
 63 static const int32_t alien_middle_in_12x8[ALIEN_HEIGHT] = {
 64         packword12(0,0,0,1,0,0,0,0,0,1,0,0),
 65         packword12(0,0,0,0,1,0,0,0,1,0,0,0),
 66         packword12(0,0,0,1,1,1,1,1,1,1,0,0),
 67         packword12(0,0,1,1,0,1,1,1,0,1,1,0),
 68         packword12(0,1,1,1,1,1,1,1,1,1,1,1),
 69         packword12(0,1,1,1,1,1,1,1,1,1,1,1),
 70         packword12(0,1,0,1,0,0,0,0,0,1,0,1),
 71         packword12(0,0,0,0,1,1,0,1,1,0,0,0) };
 72 static const int32_t alien_middle_out_12x8[] = {
 73         packword12(0,0,0,1,0,0,0,0,0,1,0,0),
 74         packword12(0,1,0,0,1,0,0,0,1,0,0,1),
 75         packword12(0,1,0,1,1,1,1,1,1,1,0,1),
 76         packword12(0,1,1,1,0,1,1,1,0,1,1,1),
 77         packword12(0,1,1,1,1,1,1,1,1,1,1,1),
 78         packword12(0,0,1,1,1,1,1,1,1,1,1,0),
 79         packword12(0,0,0,1,0,0,0,0,0,1,0,0),
 80         packword12(0,0,1,0,0,0,0,0,0,0,1,0) };
 81 static const int32_t alien_bottom_in_12x8[ALIEN_HEIGHT] = {
 82         packword12(0,0,0,0,1,1,1,1,0,0,0,0),
 83         packword12(0,1,1,1,1,1,1,1,1,1,1,0),
 84         packword12(1,1,1,1,1,1,1,1,1,1,1,1),
 85         packword12(1,1,1,0,0,1,1,0,0,1,1,1),
 86         packword12(1,1,1,1,1,1,1,1,1,1,1,1),
 87         packword12(0,0,1,1,1,0,0,1,1,1,0,0),
 88         packword12(0,1,1,0,0,1,1,0,0,1,1,0),
 89         packword12(0,0,1,1,0,0,0,0,1,1,0,0) };
 90 static const int32_t alien_bottom_out_12x8[] = {
 91         packword12(0,0,0,0,1,1,1,1,0,0,0,0),
 92         packword12(0,1,1,1,1,1,1,1,1,1,1,0),
 93         packword12(1,1,1,1,1,1,1,1,1,1,1,1),
 94         packword12(1,1,1,0,0,1,1,0,0,1,1,1),
 95         packword12(1,1,1,1,1,1,1,1,1,1,1,1),
 96         packword12(0,0,0,1,1,0,0,1,1,0,0,0),
 97         packword12(0,0,1,1,0,1,1,0,1,1,0,0),
 98         packword12(1,1,0,0,0,0,0,0,0,0,1,1) };
 99 // End of the const ints that define the alien pixels
100 // ---------------------------------------------------
101
102 // ------------------------------------------------------------
103 // These are our internal methods, used only by ourselves
104 // Draws the aliens on the screen - top, middle, and bottom aliens
105 void build_tops(uint32_t * framePointer, const int32_t alien_top[]);
106 void build_middle(uint32_t * framePointer, const int32_t alien_middle[]);
107 void build_bottom(uint32_t * framePointer, const int32_t alien_bottom[]);
108 // Fire a bullet from either a top, middle, or bottom alien
109 int32_t fire_bottom(uint32_t * framePointer, int32_t r);
110 int32_t fire_middle(uint32_t * framePointer, int32_t r);
111 int32_t fire_top(uint32_t * framePointer, int32_t r);
112 // Checks to see whether our aliens are currently capable of shooting
113 bool can_aliens_shoot();
114 // Draws a bullet on the screen
```

```
115 void draw_bullet(uint32_t * framePointer, int32_t bullet, uint32_t color);
116 // Draws a pixel on the screen.
117 void aliens_draw_pixel(uint32_t *framePointer, uint32_t row, uint32_t col,
118         uint32_t color);
119 // End internal method declarations
120 // -------------------------------------------------------------
121
122 // These structs hold all of our aliens.
123 struct top { // Struct for our top aliens
124     int32_t row;
125     int32_t col;bool alive; // alien has row, column, and alive?
126 } top[TOP_TOTAL];
127
128 struct middleAlien { // Struct for our middle aliens
129     int32_t row;
130     int32_t col;bool alive; // alien has row, column, and alive?
131 } middleAlien[MIDDLE_TOTAL];
132
133 struct bottomAlien { // Struct for our bottom aliens
134     int32_t row;
135     int32_t col;bool alive; // alien has row, column, and alive?
136 } bottomAlien[MIDDLE_TOTAL];
137
138 // aliens can have two types of bullet: cross and lightning
139 // cross 0 and 3 are identical
140 typedef enum {
141     cross0, cross1, cross2, cross3, lightning0, lightning1
142 } bullet_type;
143 struct alien_bullet { // Struct that holds our aliens' bullets
144     int32_t row;
145     int32_t col;bool alive; // Bullets have coordinates and alive?
146     bullet_type bullet_type; // Bullets also have a type.
147 } alien_bullet[ALIEN_NUM_BULLETS];
148
149 int32_t alien_count; // a count of how many aliens are alive
150
151 /*
152  * Draws a pixel on the screen. To compensate for our double-resolution screen,
153  * it must draw 4 real pixels for every in-came pixel.
154  */
155 void aliens_draw_pixel(uint32_t *framePointer, uint32_t row, uint32_t col,
156         uint32_t color) {
157 #define DRAW_PIXEL_ROW_MULTIPLIER 1280  // 640 * 2 for screen doubling
158 #define DRAW_PIXEL_ROW 640              // one row offset
159 #define DRAW_PIXEL_DOUBLE 2             // for doubling
160     // We draw 4 pixels for every 1 small-screen pixel
161     framePointer[row * DRAW_PIXEL_ROW_MULTIPLIER + col * DRAW_PIXEL_DOUBLE]
162             = color;
163     framePointer[row * DRAW_PIXEL_ROW_MULTIPLIER + col * DRAW_PIXEL_DOUBLE + 1]
164             = color;
165     framePointer[row * DRAW_PIXEL_ROW_MULTIPLIER + DRAW_PIXEL_ROW + col
166             * DRAW_PIXEL_DOUBLE] = color;
167     framePointer[row * DRAW_PIXEL_ROW_MULTIPLIER + DRAW_PIXEL_ROW + col
168             * DRAW_PIXEL_DOUBLE + 1] = color;
169 }
170
171 //initialize all of the aliens by setting values contained in struct's and printing
    aliens to the screen
```

```c
void aliens_init(uint32_t * framePointer) {
#define ALIEN_TOP_ROW_INIT 30               // Where
#define ALIEN_MIDDLE_ROW_INIT 45            // the
#define ALIEN_MIDDLE2_ROW_INIT 60           // aliens
#define ALIEN_BOTTOM_ROW_INIT 75            // are
#define ALIEN_BOTTOM2_ROW_INIT 90           // initialized to
#define ALIEN_SPACING 15                    // Spacing between aliens
    //local variables, loc is the starting location of alien one on the screen
    int32_t i, loc = LOC_ALIEN_ONE;

    //loops through one row of aliens
    for (i = 0; i < ALIEN_COLUMNS; i++) {
        top[i].row = ALIEN_TOP_ROW_INIT; //set the row of alien tops to 30
        top[i].col = loc;//sets the column of alien tops
        top[i].alive = true;//sets the alien is alive flag

        middleAlien[i].row = ALIEN_MIDDLE_ROW_INIT; //middle aliens
        middleAlien[i].col = loc;//sets column of first row of middle aliens
        middleAlien[i].alive = true;//sets first row of middle aliens to alive
        middleAlien[i + ALIEN_COLUMNS].row = ALIEN_MIDDLE2_ROW_INIT;//sets middle
        middleAlien[i + ALIEN_COLUMNS].col = loc;//sets column second row middle
        middleAlien[i + ALIEN_COLUMNS].alive = true;//sets second row middle alive

        bottomAlien[i].row = ALIEN_BOTTOM_ROW_INIT;//sets bottom aliens
        bottomAlien[i].col = loc;//sets column of first row of bottom aliens
        bottomAlien[i].alive = true;//sets first row of bottom aliens to alive
        bottomAlien[i + ALIEN_COLUMNS].row = ALIEN_BOTTOM2_ROW_INIT;//bottom
        bottomAlien[i + ALIEN_COLUMNS].col = loc;//sets column second row bottom
        bottomAlien[i + ALIEN_COLUMNS].alive = true;//sets second row bottom alive
        loc += ALIEN_SPACING; //controls the column spacing in-between alien
    }

    //now that structs are built draw top, middle, and bottom aliens to screen
    build_tops(framePointer, alien_top_in_12x8); // Top
    build_middle(framePointer, alien_middle_in_12x8); // Middle
    build_bottom(framePointer, alien_bottom_in_12x8); // Bottom
}

// Draws the top aliens on the screen
void build_tops(uint32_t * framePointer, const int32_t alien_top[]) {
    int32_t row, col, i; // initialize variables
    for (i = 0; i < TOP_TOTAL; i++) { //loop through top column of aliens
        for (row = 0; row < ALIEN_HEIGHT; row++) { //loop top aliens' pixels row
            int32_t currentRow = row + top[i].row;// current pixel row of alien
            for (col = 0; col < WORD_WIDTH; col++) { //loop alien's pixel col
                int32_t currentCol = col + top[i].col; //current col of alien
                if ((alien_top[row] & (1 << (WORD_WIDTH - col - 1)))
                        && top[i].alive) {
                    // If our alien is alive and has a pixel there, draw it
                    aliens_draw_pixel(framePointer, currentRow, currentCol,
                            WHITE);
                } else { // If not, erase it.
                    aliens_draw_pixel(framePointer, currentRow, currentCol,
                            BLACK);
                }
            }
        }
    }
```

```
230 }
231
232 // Draws the middle aliens to the screen
233 void build_middle(uint32_t * framePointer, const int32_t alien_middle[]) {
234     int32_t row, col, i; // declare our variables
235     for (i = 0; i < MIDDLE_TOTAL; i++) { // Looping through all the middle aliens
236         for (row = 0; row < ALIEN_HEIGHT; row++) { // Pixel y
237             int32_t currentRow = row + middleAlien[i].row;//current pixel row
238             for (col = 0; col < WORD_WIDTH; col++) {// Pixel x
239                 int32_t currentCol = col + middleAlien[i].col;// current col alien
240                 if ((alien_middle[row] & (1 << (WORD_WIDTH - col - 1)))
241                         && middleAlien[i].alive) {
242                     // If our alien is alive and has a pixel there, draw it
243                     aliens_draw_pixel(framePointer, currentRow, currentCol,
244                             WHITE);
245                 } else { // Otherwise, erase it.
246                     aliens_draw_pixel(framePointer, currentRow, currentCol,
247                             BLACK);
248                 }
249             }
250         }
251     }
252 }
253
254 // Draws the bottom aliens to the screen
255 void build_bottom(uint32_t * framePointer, const int32_t alien_bottom[]) {
256     int32_t row, col, i; // Declare vars
257     for (i = 0; i < BOTTOM_TOTAL; i++) { // Looping through all the bottom aliens
258         for (row = 0; row < ALIEN_HEIGHT; row++) { // looping through y pixels
259             int32_t currentRow = row + bottomAlien[i].row; // current row
260             for (col = 0; col < WORD_WIDTH; col++) { // looping through x pixels
261                 int32_t currentCol = col + bottomAlien[i].col; // current col
262                 if ((alien_bottom[row] & (1 << (WORD_WIDTH - col - 1)))
263                         && bottomAlien[i].alive) {
264                     // If our alien is alive and has a pixel here, draw it
265                     aliens_draw_pixel(framePointer, currentRow, currentCol,
266                             WHITE);
267                 } else { // otherwise, erase it.
268                     aliens_draw_pixel(framePointer, currentRow, currentCol,
269                             BLACK);
270                 }
271             }
272         }
273     }
274 }
275
276 // Does the needful to move the aliens left
277 void aliens_left(uint32_t * framePointer) {
278     int32_t i, row; // Declare loop vars
279     for (i = 0; i < MIDDLE_TOTAL; i++) { // Move every single alien LEFT
280         if (i < TOP_TOTAL) {
281             top[i].col--;
282         } // Move the top aliens LEFT
283         middleAlien[i].col--; // Move the middle aliens LEFT
284         bottomAlien[i].col--; // Move the bottom aliens LEFT
285     }
286     if (alien_count == 0) { // If aliens are out, make them in
287         alien_count = 1;
```

```
288         build_tops(framePointer, alien_top_in_12x8); // Draw top aliens
289         build_middle(framePointer, alien_middle_in_12x8); // Draw mid aliens
290         build_bottom(framePointer, alien_bottom_in_12x8); // Draw bot aliens
291     } else { // And vice versa
292         alien_count = 0;
293         build_tops(framePointer, alien_top_out_12x8); // Draw top aliens
294         build_middle(framePointer, alien_middle_out_12x8); // Draw mid aliens
295         build_bottom(framePointer, alien_bottom_out_12x8); // Draw bot aliens
296     }
297 
298     for (row = 0; row < ALIEN_HEIGHT; row++) { // For all the alien Y pixels
299         for (i = 0; i < MIDDLE_TOTAL; i++) { // For every alien
300             // Erase them for the middle and bottom aliens - top is skinnier
301             aliens_draw_pixel(framePointer, row + bottomAlien[i].row,
302                     WORD_WIDTH + bottomAlien[i].col, BLACK);
303             aliens_draw_pixel(framePointer, row + middleAlien[i].row,
304                     WORD_WIDTH + middleAlien[i].col, BLACK);
305         }
306 
307     }
308 }
309 
310 // Does the needful to move the aliens right
311 void aliens_right(uint32_t * framePointer) {
312     int32_t i, row; // Declare loop vars
313     for (i = 0; i < MIDDLE_TOTAL; i++) { // Move every single alien RIGHT
314         if (i < 11) {
315             top[i].col += 1;
316         } // Move top aliens RIGHT
317         middleAlien[i].col += 1; // Move middle aliens RIGHT
318         bottomAlien[i].col += 1; // Move bottom aliens RIGHT
319     }
320 
321     if (alien_count == 0) { // If aliens are out, make them in
322         alien_count = 1;
323         build_tops(framePointer, alien_top_in_12x8); // Draw top aliens
324         build_middle(framePointer, alien_middle_in_12x8); // Draw mid aliens
325         build_bottom(framePointer, alien_bottom_in_12x8); // Draw bot aliens
326     } else { // And vice versa
327         alien_count = 0;
328         build_tops(framePointer, alien_top_out_12x8); // Draw top aliens
329         build_middle(framePointer, alien_middle_out_12x8); // Draw mid aliens
330         build_bottom(framePointer, alien_bottom_out_12x8); // Draw bot aliens
331     }
332 
333     for (row = 0; row < ALIEN_HEIGHT; row++) { // For all the alien Y pixels
334         for (i = 0; i < MIDDLE_TOTAL; i++) { // For every alien
335             // Erase that column of pixels for mid and bottom. Top not necessary
336             aliens_draw_pixel(framePointer, row + bottomAlien[i].row,
337                     bottomAlien[i].col - 1, BLACK); // Notice it's col-1 bottom
338             aliens_draw_pixel(framePointer, row + middleAlien[i].row,
339                     middleAlien[i].col, BLACK);
340         }
341     }
342 }
343 
344 // Does the needful when aliens hit the left rail
345 void hit_left_rail(uint32_t * framePointer) {
```

```
346     // First we erase the entire top row of alien pixels for moving down.
347     int32_t col, row, i; // declare loop vars
348     for (row = 0; row < ALIEN_HEIGHT; row++) { // Go through alien pixels Y
349         for (col = 0; col < WORD_WIDTH; col++) { // Go through alien pixels X
350             if (((alien_top_out_12x8[row] | alien_top_in_12x8[row]) & (1
351                     << (WORD_WIDTH - col - 1)))) {// if pixel exists here
352                 for (i = 0; i < TOP_TOTAL; i++) { // ERASE IT!
353                     aliens_draw_pixel(framePointer, row + top[i].row,
354                             col + top[i].col, BLACK);
355                 }
356             }
357         }
358     }
359     for (i = 0; i < MIDDLE_TOTAL; i++) { // For all the aliens, move them down
360         if (i < TOP_TOTAL) {
361             top[i].row += MOVE_DOWN_PIXELS;
362         } // Move top aliens down
363         middleAlien[i].row += MOVE_DOWN_PIXELS; // Move mid aliens down
364         bottomAlien[i].row += MOVE_DOWN_PIXELS; // Move bot aliens down
365     }
366     for (row = 0; row < ALIEN_HEIGHT; row++) { // Now to erase pixels on left side
367         for (i = 0; i < MIDDLE_TOTAL; i++) { // For all the middle aliens
368             aliens_draw_pixel(framePointer, row + middleAlien[i].row,
369                     middleAlien[i].col, BLACK);// Erase the pixels on the left
370         }
371     }
372 }
373
374 // Does the needful when aliens hit the right rail
375 void hit_right_rail(uint32_t * framePointer) {
376     // First we erase the entire top row of alien pixels for moving down
377     int32_t col, row, i; // Declare loop vars
378     for (row = 0; row < ALIEN_HEIGHT; row++) { // Go through alien pixels Y
379         for (col = 0; col < WORD_WIDTH; col++) { // Go through alien pixels X
380             if (((alien_top_out_12x8[row] | alien_top_in_12x8[row]) & (1
381                     << (WORD_WIDTH - col - 1)))) {// if pixel exists here
382                 for (i = 0; i < TOP_TOTAL; i++) { // Erase it!
383                     aliens_draw_pixel(framePointer, row + top[i].row,
384                             col + top[i].col, BLACK);
385                 }
386             }
387         }
388     }
389     for (i = 0; i < MIDDLE_TOTAL; i++) { // For all the aliens, move them down
390         if (i < TOP_TOTAL) {
391             top[i].row += MOVE_DOWN_PIXELS;
392         }// Move top aliens down
393         middleAlien[i].row += MOVE_DOWN_PIXELS; // Move mid aliens down
394         bottomAlien[i].row += MOVE_DOWN_PIXELS; // Move bot aliens down
395     }
396     for (row = 0; row < ALIEN_HEIGHT; row++) { // Now to erase pixels on the right
    side
397         for (i = 0; i < TOP_TOTAL; i++) { // Erase the pixels on the right
398             aliens_draw_pixel(framePointer, row + top[i].row,
399                     WORD_WIDTH - 1 + top[i].col, BLACK);
400         }
401     }
402 }
```

```
403
404 // moves the aliens and detects wall boundries and direction changes too!
405 void aliens_move(uint32_t * framePointer) {
406     static int32_t flag;
407     int32_t i, j;
408     for (i = 0; i < ALIEN_COLUMNS; i++) { // Go through every alien column
409         // And see if any alien in that column is alive and has hit left
410         if (top[i].alive || middleAlien[i].alive || middleAlien[i
411                 + ALIEN_COLUMNS].alive || bottomAlien[i].alive || bottomAlien[i
412                 + ALIEN_COLUMNS].alive) {
413             if (top[i].col == LEFT_BOUNDRY) { // If an alien has hit side
414                 flag = 1; // Set the flag that we've hit the side
415                 hit_left_rail(framePointer); // Call hit_rail.
416             }
417         }
418     }
419     for (j = ALIEN_COLUMNS - 1; j >= 0; j--) { // Now to check to see
420         if (top[j].alive || middleAlien[j].alive || middleAlien[j
421                 + ALIEN_COLUMNS].alive || bottomAlien[j].alive || bottomAlien[j
422                 + ALIEN_COLUMNS].alive) {
423             if (top[j].col == RIGHT_BOUNDRY) {// if an alien has hit right.
424                 flag = 0; // false
425                 hit_right_rail(framePointer); // we have hit the right rail
426             }
427         }
428     }
429     if (flag == 1) { // if we are moving right
430         aliens_right(framePointer); // go right
431     } else { // we are actually going left
432         aliens_left(framePointer); // so go left
433     }
434 }
435
436 // Kills a random alien
437 // Currently has a bug that if the last alien dies, infinite loop
438 void aliens_kill(uint32_t * framePointer) {
439     int32_t r = rand() % 55; // Get a random number
440
441     if (r < TOP_TOTAL) { // If we have killed a top
442         if (!top[r].alive) { // Already dead!
443             aliens_kill(framePointer); // Try again
444         } else {
445             top[r].alive = false; // kill the alien
446             build_tops(framePointer, alien_top_in_12x8); // redraw aliens
447         }
448     } else if (r < (TOP_TOTAL + MIDDLE_TOTAL)) { // if we have killed a mid
449         if (!middleAlien[r - TOP_TOTAL].alive) { // Already dead!
450             aliens_kill(framePointer); // try again
451         } else {
452             middleAlien[r - TOP_TOTAL].alive = false; // kill alien
453             build_middle(framePointer, alien_middle_in_12x8);// redraw aliens
454         }
455     } else { // we have killed a bot
456         if (!bottomAlien[r - (TOP_TOTAL + MIDDLE_TOTAL)].alive) { // Already dead!
457             aliens_kill(framePointer); // Try again
458         } else {
459             bottomAlien[r - (TOP_TOTAL + MIDDLE_TOTAL)].alive = false;// Kill alien
460             build_bottom(framePointer, alien_bottom_in_12x8);// redraw aliens
```

```
461         }
462     }
463 }
464 
465 // Returns true if aliens can shoot- that is, if there exists a top alive alien
466 bool can_aliens_shoot() {
467     int32_t i; // Declare loop variable
468     for (i = 0; i < TOP_TOTAL; i++) { // Look at all the top aliense
469         if (top[i].alive) { // If there exists a single alive top alien
470             return true; // We have an alive alien!
471         }
472     }
473     return false; // All the top aliens are dead; we cannot shoot
474 }
475 
476 // Fires a bullet from a random alien
477 void alien_missle(uint32_t * framePointer) {
478     if (!can_aliens_shoot()) { // The aliens can't even shoot! Don't even try.
479         return;
480     }
481 
482     int32_t r = rand() % ALIEN_COLUMNS; // Get a random column
483     int32_t bullet_address = BAD_ADDRESS; // Initialize the address
484     do { // Keep trying to shoot
485         bullet_address = fire_bottom(framePointer, r);
486     } while (bullet_address == BAD_ADDRESS); // until we get a good address
487 
488     // We have a bullet address! now to make it alive and draw it.
489     int32_t i;
490     for (i = 0; i < ALIEN_NUM_BULLETS; i++) {
491         if (alien_bullet[i].alive) { // If we already have a living bullet
492             continue; // Go on to the next one
493         } else { // We have a dead bullet spot- let's alive a bullet here!
494             alien_bullet[i].alive = true;
495             // Randomly choose a bullet type
496             alien_bullet[i].bullet_type
497                     = rand() % ALIEN_NUM_BULLET_TYPES ? cross0 : lightning0;
498             // TODO: This math can be simplified
499             alien_bullet[i].col = bullet_address % SCREEN_RES_X;// Set address
500             alien_bullet[i].row = bullet_address / SCREEN_RES_X;// of bullet
501             draw_bullet(framePointer, i, WHITE); // And draw it!
502             return;
503         }
504     }
505 }
506 
507 // Draws the selected bullet to the screen
508 void draw_bullet(uint32_t * framePointer, int32_t bullet, uint32_t color) {
509 #define PIXEL_LINE_1 1      // These
510 #define PIXEL_LINE_2 2      // defines
511 #define PIXEL_LINE_3 3      // only
512 #define PIXEL_LINE_4 4      // have
513 #define PIXEL_LEFT -1       // meaning
514 #define PIXEL_RIGHT 1       // in this function, so I put them here
515     uint32_t row = alien_bullet[bullet].row; // Current row
516     uint32_t col = alien_bullet[bullet].col; // and column where to draw
517     switch (alien_bullet[bullet].bullet_type) {
518     case cross0: // Cross0 and cross 3 are identically drawn
```

```
519     case cross3: // The only difference is in the state machine where they go
520         // 5 pixels down in a line
521         aliens_draw_pixel(framePointer, row, col, color);
522         aliens_draw_pixel(framePointer, row + PIXEL_LINE_1, col, color);
523         aliens_draw_pixel(framePointer, row + PIXEL_LINE_2, col, color);
524         aliens_draw_pixel(framePointer, row + PIXEL_LINE_3, col, color);
525         aliens_draw_pixel(framePointer, row + PIXEL_LINE_4, col, color);
526 
527         // Crossbar on the cross - right in the middle
528         aliens_draw_pixel(framePointer, row + PIXEL_LINE_2, col + PIXEL_RIGHT,
529                 color);
530         aliens_draw_pixel(framePointer, row + PIXEL_LINE_2, col + PIXEL_LEFT,
531                 color);
532         break;
533     case cross1:
534         // 5 pixels down in a line
535         aliens_draw_pixel(framePointer, row, col, color);
536         aliens_draw_pixel(framePointer, row + PIXEL_LINE_1, col, color);
537         aliens_draw_pixel(framePointer, row + PIXEL_LINE_2, col, color);
538         aliens_draw_pixel(framePointer, row + PIXEL_LINE_3, col, color);
539         aliens_draw_pixel(framePointer, row + PIXEL_LINE_4, col, color);
540 
541         // Crossbar on the cross- on the lower one
542         aliens_draw_pixel(framePointer, row + PIXEL_LINE_3, col + PIXEL_RIGHT,
543                 color);
544         aliens_draw_pixel(framePointer, row + PIXEL_LINE_3, col + PIXEL_LEFT,
545                 color);
546         break;
547     case cross2:
548         // 5 pixels down in a line
549         aliens_draw_pixel(framePointer, row, col, color);
550         aliens_draw_pixel(framePointer, row + PIXEL_LINE_1, col, color);
551         aliens_draw_pixel(framePointer, row + PIXEL_LINE_2, col, color);
552         aliens_draw_pixel(framePointer, row + PIXEL_LINE_3, col, color);
553         aliens_draw_pixel(framePointer, row + PIXEL_LINE_4, col, color);
554 
555         // Crossbar on the cross- on the upper one
556         aliens_draw_pixel(framePointer, row + PIXEL_LINE_1, col + PIXEL_RIGHT,
557                 color);
558         aliens_draw_pixel(framePointer, row + PIXEL_LINE_1, col + PIXEL_LEFT,
559                 color);
560         break;
561     case lightning0:
562         // 5 pixels down - starting left then right, then going back left
563         aliens_draw_pixel(framePointer, row, col + PIXEL_LEFT, color);
564         aliens_draw_pixel(framePointer, row + PIXEL_LINE_1, col, color);
565         aliens_draw_pixel(framePointer, row + PIXEL_LINE_2, col + PIXEL_RIGHT,
566                 color);
567         aliens_draw_pixel(framePointer, row + PIXEL_LINE_3, col, color);
568         aliens_draw_pixel(framePointer, row + PIXEL_LINE_4, col + PIXEL_LEFT,
569                 color);
570         break;
571     case lightning1:
572         // 5 pixels down - starting right then left, then back right
573         aliens_draw_pixel(framePointer, row, col + PIXEL_RIGHT, color);
574         aliens_draw_pixel(framePointer, row + PIXEL_LINE_1, col, color);
575         aliens_draw_pixel(framePointer, row + PIXEL_LINE_2, col + PIXEL_LEFT,
576                 color);
```

```
577         aliens_draw_pixel(framePointer, row + PIXEL_LINE_3, col, color);
578         aliens_draw_pixel(framePointer, row + PIXEL_LINE_4, col + PIXEL_RIGHT,
579                 color);
580         break;
581     }
582
583 }
584
585 // This sees if our bottom alien at index r is alive to shoot
586 int32_t fire_bottom(uint32_t * framePointer, int32_t r) {
587     if (!bottomAlien[r + ALIEN_COLUMNS].alive) { // If the very bottom alien is dead
588         if (!bottomAlien[r].alive) {// AND the second row alien is also dead
589             return fire_middle(framePointer, r); // Try to make a higher alien shoot
    it
590         } else { // the bottom alien is dead, but the second-row one is alive
591             // This is the starting coordinate of the bullet.
592             return (bottomAlien[r].row + BULLET_COL_OFFSET + 1) * SCREEN_RES_X
593                     + (BULLET_COL_OFFSET + bottomAlien[r].col);
594         }
595     } else { // The very bottom alien is alive and needs to shoot
596         // Time to return the starting position of the bullet!
597         return (bottomAlien[r + ALIEN_COLUMNS].row + BULLET_COL_OFFSET + 1)
598                 * SCREEN_RES_X + (BULLET_COL_OFFSET + bottomAlien[r
599                 + ALIEN_COLUMNS].col);
600     }
601 }
602
603 // This sees if either middle alien at index r is alive to shoot
604 int32_t fire_middle(uint32_t * framePointer, int32_t r) {
605     if (!middleAlien[r + ALIEN_COLUMNS].alive) { // If the very bottom (middle) alien
    is dead
606         if (!middleAlien[r].alive) {// AND the second row (middle) alien is dead
607             return fire_top(framePointer, r); // Top row alien has to fire
608         } else { // the bottom alien is dead, but the second-row one is alive
609             // This is the starting coordinate of the bullet
610             return (middleAlien[r].row + BULLET_COL_OFFSET) * SCREEN_RES_X
611                     + (BULLET_COL_OFFSET + middleAlien[r].col);
612         }
613     } else { // The bottom alien is alive and needs to fire
614         // This is the starting coordinate of the bullet
615         return (middleAlien[r + ALIEN_COLUMNS].row + BULLET_COL_OFFSET)
616                 * SCREEN_RES_X + (BULLET_COL_OFFSET + middleAlien[r
617                 + ALIEN_COLUMNS].col);
618     }
619 }
620
621 // This sees to see if our top alien at index r is alive to shoot
622 int32_t fire_top(uint32_t * framePointer, int32_t r) {
623     if (!top[r].alive) { // Our top alien is dead.
624         return BAD_ADDRESS; // We failed to fire a missle! return -1
625     } else { // Our alien is alive!
626         return (top[r].row + BULLET_COL_OFFSET) * SCREEN_RES_X
627                 + (BULLET_COL_OFFSET + top[r].col); // Return good address
628     }
629 }
630
631 // Updates alien bullets. erases previous one, increments type, and redraws.
632 void aliens_update_bullets(uint32_t * framePointer) {
```

```
633     int32_t i; // Declare loop var
634     for (i = 0; i < ALIEN_NUM_BULLETS; i++) { // Cycle through all bullets
635         if (alien_bullet[i].row > SCREEN_HEIGHT) { // If bullet off screen
636             alien_bullet[i].alive = false; // kill it
637         } else if (alien_bullet[i].alive) { // If bullet is alive
638             draw_bullet(framePointer, i, BLACK); // erase to prep redraw
639 
640             switch (alien_bullet[i].bullet_type) { // Increment bullet type
641             case cross0: // mid, going down
642                 alien_bullet[i].bullet_type = cross1; // bar go down
643                 break;
644             case cross1: // down
645                 alien_bullet[i].bullet_type = cross3; // bar go mid
646                 break;
647             case cross2: // up
648                 alien_bullet[i].bullet_type = cross0; // bar go down
649                 break;
650             case cross3: // mid, going up
651                 alien_bullet[i].bullet_type = cross2; // bar go up
652                 break;
653             case lightning0:// left lightning
654                 alien_bullet[i].bullet_type = lightning1; // go right
655                 break;
656             case lightning1:// right lightning
657                 alien_bullet[i].bullet_type = lightning0; // go left
658                 break;
659             }
660             alien_bullet[i].row++; // Move bullet down
661             draw_bullet(framePointer, i, WHITE); // redraw bullet
662         }
663     }
664 }
665 
```

```c
/*
 * bunkers.h
 * Taylor Cowley and Andrew Okazaki
 */

#ifndef BUNKERS_H_
#define BUNKERS_H_

#include <stdint.h>


// Initializes the bunkers - draws them to the screen
void bunkers_init(uint32_t * framePointer);

// Draws the bunkers to the screen
void bunkers_build(uint32_t * framePointer);

// Hits a random bunker in a random place
void bunkers_hit_rand_bunker(uint32_t * framePointer);

#endif /* BUNKERS_H_ */

```

```c
/*
 * bunkers.c
 * Taylor Cowley and Andrew Okazaki
 */
#include <stdio.h>
#include <stdint.h>
#include <stdbool.h>
#include "platform.h"
#include "xparameters.h"
#include "xaxivdma.h"
#include "xio.h"
#include "time.h"
#include "unistd.h"

#include "bunkers.h"

#define BUNKER_HEIGHT 18        // Bunkers are 18 pixels high
#define BUNKER_DAMAGE_HEIGHT 6  // Each bunnker square is size 6
#define BUNKER_ROW 175          // All bunkers are at row 175
#define BUNKER_SIZE 10          // All bunkers have 10 sections
#define BUNKER_0 0              // Gotta have
#define BUNKER_1 1              // constants to
#define BUNKER_2 2              // represent
#define BUNKER_3 3              // each bunker
#define BUNKER_DAMAGE_0 0       // Gotta have
#define BUNKER_DAMAGE_1 1       // different
#define BUNKER_DAMAGE_2 2       // damage
#define BUNKER_DAMAGE_3 3       // values
#define BUNKER_DEAD     4       // Damage bunker has when it is dead
#define BUNKER_ROWS     18      // How many rows each bunker has
#define BUNKER_COLS     24      // How many columns each bunker has

#define GREEN 0x0000FF00        // Hex value for green
#define BLACK 0x00000000        // Hex value for black

#define DAMAGE_WORD_WIDTH 6
#define WORD_WIDTH 24
#define NUM_OF_BUNKERS 4
#define LOC_BUNKER_ONE 60   // Divided this by 2 because screen is half

// ------------------------------------------
//  hardcoded static const stuff

// Necessary for storing bunker damage data
#define packword6(b5,b4,b3,b2,b1,b0) \
        ((b5  << 5 ) | (b4  << 4 ) | (b3  << 3 ) | (b2  << 2 ) | (b1  << 1 ) | (b0  << 0 ) )

// Necessary for storing the bunker data
#define packword24(b23,b22,b21,b20,b19,b18,b17,b16,b15,b14,b13,b12,b11,b10,b9,b8,b7,b6,b5,b4,b3,b2,b1,b0) \
        ((b23 << 23) | (b22 << 22) | (b21 << 21) | (b20 << 20) | (b19 << 19) | (b18 << 18) | (b17 << 17) | (b16 << 16) | \
                (b15 << 15) | (b14 << 14) | (b13 << 13) | (b12 << 12) | (b11 << 11) | (b10 << 10) | (b9  << 9 ) | (b8  << 8 ) | \
                (b7  << 7 ) | (b6  << 6 ) | (b5  << 5 ) | (b4  << 4 ) | (b3  << 3 ) | (b2  << 2 ) | (b1  << 1 ) | (b0  << 0 ) )
```

```
53 // Shape of the entire bunker.
54 static const int32_t bunker_24x18[BUNKER_HEIGHT] = {
55         packword24(0,0,0,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,0,0,0),
56         packword24(0,0,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,0,0),
57         packword24(0,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,0),
58         packword24(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1),
59         packword24(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1),
60         packword24(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1),
61         packword24(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1),
62         packword24(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1),
63         packword24(1,1,1,1,1,1,1,1,1,1,0,0,0,0,1,1,1,1,1,1,1,1,1),
64         packword24(1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,1,1,1,1,1,1,1,1),
65         packword24(1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,1,1,1,1,1,1,1),
66         packword24(1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1,1),
67         packword24(1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1),
68         packword24(1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1),
69         packword24(1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1),
70         packword24(1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1),
71         packword24(1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1),
72         packword24(1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1)};
73
74 // First time a bunker is hit, the first damage that happens
75 static const int32_t bunkerDamage0_6x6[BUNKER_DAMAGE_HEIGHT] = {
76         packword6(0,1,1,0,0,0), packword6(0,0,0,0,0,1), packword6(1,1,0,1,0,0),
77         packword6(1,0,0,0,0,0), packword6(0,0,1,1,0,0), packword6(0,0,0,0,1,0)};
78
79 // Second time a bunker is hit, this is its damage
80 static const int32_t bunkerDamage1_6x6[BUNKER_DAMAGE_HEIGHT] = {
81         packword6(1,1,1,0,1,0), packword6(1,0,1,0,0,1), packword6(1,1,0,1,1,1),
82         packword6(1,0,0,0,0,0), packword6(0,1,1,1,0,1), packword6(0,1,1,0,1,0)};
83
84 // Third time a bunker is hit, this is its damage
85 static const int32_t bunkerDamage2_6x6[BUNKER_DAMAGE_HEIGHT] = {
86         packword6(1,1,1,1,1,1), packword6(1,0,1,1,0,1), packword6(1,1,0,1,1,1),
87         packword6(1,1,0,1,1,0), packword6(0,1,1,1,0,1), packword6(1,1,1,1,1,1)};
88
89 // Fourth time a bunker is hit, this is its damage
90 static const int32_t bunkerDamage3_6x6[BUNKER_DAMAGE_HEIGHT] = {
91         packword6(1,1,1,1,1,1), packword6(1,1,1,1,1,1), packword6(1,1,1,1,1,1),
92         packword6(1,1,1,1,1,1), packword6(1,1,1,1,1,1), packword6(1,1,1,1,1,1)};
93
94 //  End hardcoded static const stuff
95 // ------------------------------------------------------
96
97 struct bunker{      // Holds the data for each bunker
98     int32_t row;        // Where it is
99     int32_t col;        // on the screen
100    int32_t damage;     // What damage level the bunker is at
101    int32_t pixel[];    // A bunker is made out of squares- whether it's alive/dead
102 }bunker[3];
103
104
105 // These arrays show how decayed each part of the bunker is.
106 int32_t bunker_zero[BUNKER_SIZE] = { 0, 0, 0, 0, 0, 0, 0, 0, 0, 0};
107 int32_t bunker_one[BUNKER_SIZE] = { 0, 0, 0, 0, 0, 0, 0, 0, 0, 0};
108 int32_t bunker_two[BUNKER_SIZE] = { 0, 0, 0, 0, 0, 0, 0, 0, 0, 0};
109 int32_t bunker_three[BUNKER_SIZE] = { 0, 0, 0, 0, 0, 0, 0, 0, 0, 0};
110
```

```
111 // -----------------------------------------------------
112 // Declaration for internal functions
113 void bunkers_draw_pixel(uint32_t *framePointer,uint32_t row,uint32_t col,uint32_t
    color);
114 void bunker0(int32_t r, uint32_t * framePointer);
115 void bunker1(int32_t r, uint32_t * framePointer);
116 void bunker2(int32_t r, uint32_t * framePointer);
117 void bunker3(int32_t r, uint32_t * framePointer);
118 void degrigation_patern(int32_t row, int32_t col, int32_t bunker_number, int32_t
    damage, uint32_t * framePointer);
119 void bunker_hit(uint32_t * framePointer, int32_t location, int32_t bunker_num);
120 // End internal function declaration
121 // -----------------------------------------------------
122
123 /*
124  * Draws a pixel on the screen. To compensate for our double-resolution screen,
125  * it must draw 4 real pixels for every in-came pixel.
126  */
127 void bunkers_draw_pixel(uint32_t *framePointer,uint32_t row,uint32_t col,uint32_t
    color){
128 #define DRAW_PIXEL_ROW_MULTIPLIER 1280  // 640 * 2 for screen doubling
129 #define DRAW_PIXEL_ROW 640              // one row offset
130 #define DRAW_PIXEL_DOUBLE 2             // for doubling
131
132     // We draw 4 pixels for every 1 small-screen pixel
133     framePointer[row*DRAW_PIXEL_ROW_MULTIPLIER + col*DRAW_PIXEL_DOUBLE] = color;
134     framePointer[row*DRAW_PIXEL_ROW_MULTIPLIER + col*DRAW_PIXEL_DOUBLE+1] = color;
135     framePointer[row*DRAW_PIXEL_ROW_MULTIPLIER+DRAW_PIXEL_ROW+ col*DRAW_PIXEL_DOUBLE]
    = color;
136     framePointer[row*DRAW_PIXEL_ROW_MULTIPLIER+DRAW_PIXEL_ROW+ col*DRAW_PIXEL_DOUBLE +
    1] = color;
137 }
138
139 // Initializes the bunkers
140 void bunkers_init(uint32_t * framePointer){
141     int32_t i, loc = LOC_BUNKER_ONE;    //
142     for(i = 0; i < NUM_OF_BUNKERS ; i++){
143         bunker[i].row = BUNKER_ROW; // Divided by 2 because screen is half
144         bunker[i].col = loc;        // which column it is at
145         bunker[i].damage = 0;       // Start undamaged
146         loc += LOC_BUNKER_ONE;      // Add by the offset
147     }
148     bunkers_build(framePointer);    // Draw the bunkers on the screen
149 }
150
151
152 void bunkers_build(uint32_t * framePointer){
153     int32_t row, col, b;                            // Declare loop vars
154     for(row=0;row<BUNKER_ROWS;row++){                   // Go through rows
155         for(col=0;col<BUNKER_COLS;col++){               // Go through cols
156             if ((bunker_24x18[row] & (1<<(WORD_WIDTH-col-1)))) {// if pixel
157                 for(b = 0; b <NUM_OF_BUNKERS; b++){// draw that pixel every time
158                     bunkers_draw_pixel(framePointer,row+bunker[b].row,col+bunker[b].co
    l,GREEN);
159                 }
160             }
161         }
162     }
```

```
163 }
164
165 // This randomly selects a bunker and randomly destroys part of it
166 void bunkers_hit_rand_bunker(uint32_t * framePointer){
167     int32_t r = rand()%NUM_OF_BUNKERS;  // Randomly pick a bunker
168
169     switch (r){
170     case BUNKER_0:              // Depending on the bunker number, destroy one in
    that.
171         bunker0(rand()%BUNKER_SIZE, framePointer);
172         break;
173     case BUNKER_1:              // bunker 1
174         bunker1(rand()%BUNKER_SIZE, framePointer);
175         break;
176     case BUNKER_2:              // bunker 2
177         bunker2(rand()%BUNKER_SIZE, framePointer);
178         break;
179     case BUNKER_3:              // bunker 3
180         bunker3(rand()%BUNKER_SIZE, framePointer);
181         break;
182     }
183 }
184
185
186 #define HIT_ROW_LOC_0 0     // For
187 #define HIT_ROW_LOC_1 0     // every
188 #define HIT_ROW_LOC_2 0     // location
189 #define HIT_ROW_LOC_3 0     // it has
190 #define HIT_ROW_LOC_4 6     // a specific
191 #define HIT_ROW_LOC_5 6     // row
192 #define HIT_ROW_LOC_6 6     // associated
193 #define HIT_ROW_LOC_7 6     // with
194 #define HIT_ROW_LOC_8 12    // each
195 #define HIT_ROW_LOC_9 12    // location
196
197 #define HIT_COL_LOC_0 0     // for
198 #define HIT_COL_LOC_1 6     // every
199 #define HIT_COL_LOC_2 12    // location
200 #define HIT_COL_LOC_3 18    // it has
201 #define HIT_COL_LOC_4 0     // a specific
202 #define HIT_COL_LOC_5 6     // column
203 #define HIT_COL_LOC_6 12    // associated
204 #define HIT_COL_LOC_7 18    // with
205 #define HIT_COL_LOC_8 0     // each
206 #define HIT_COL_LOC_9 18    // location
207
208 #define HIT_0 0             // There
209 #define HIT_1 1             // isn't
210 #define HIT_2 2             // an easy
211 #define HIT_3 3             // way to
212 #define HIT_4 4             // loop through
213 #define HIT_5 5             // all these
214 #define HIT_6 6             // yet,
215 #define HIT_7 7             // so we have
216 #define HIT_8 8             // every location
217 #define HIT_9 9             // hard-coded in.
218
219 // Put a hit on bunker 0 at a certain location
```

```
220 void bunker0(int32_t r, uint32_t * framePointer){
221     if(bunker_zero[r]== BUNKER_DEAD){   // If our bunker is already dead here
222         bunkers_hit_rand_bunker(framePointer);      // call rand kill bunker again
223         return;
224     }
225     switch(r){                          // Based on where the hit is
226     case HIT_0:     // Hit in location 0. Row 0 and column 0
227         degrigation_patern(HIT_ROW_LOC_0, HIT_COL_LOC_0, BUNKER_0, bunker_zero[r],
    framePointer);
228         break;
229     case HIT_1:     // Hit in location 1. Row 1 and column 1
230         degrigation_patern(HIT_ROW_LOC_1, HIT_COL_LOC_1, BUNKER_0, bunker_zero[r],
    framePointer);
231         break;
232     case HIT_2:     // Hit in location 2. Row 2 and column 2
233         degrigation_patern(HIT_ROW_LOC_2, HIT_COL_LOC_2, BUNKER_0, bunker_zero[r],
    framePointer);
234         break;
235     case HIT_3:     // Hit in location 3. Row 3 and column 3
236         degrigation_patern(HIT_ROW_LOC_3, HIT_COL_LOC_3, BUNKER_0, bunker_zero[r],
    framePointer);
237         break;
238     case HIT_4:     // Hit in location 4. Row 4 and column 4
239         degrigation_patern(HIT_ROW_LOC_4, HIT_COL_LOC_4, BUNKER_0, bunker_zero[r],
    framePointer);
240         break;
241     case HIT_5:     // Hit in location 5. Row 5 and column 5
242         degrigation_patern(HIT_ROW_LOC_5, HIT_COL_LOC_5, BUNKER_0, bunker_zero[r],
    framePointer);
243         break;
244     case HIT_6:     // Hit in location 6. Row 6 and column 6
245         degrigation_patern(HIT_ROW_LOC_6, HIT_COL_LOC_6, BUNKER_0, bunker_zero[r],
    framePointer);
246         break;
247     case HIT_7:     // Hit in location 7. Row 7 and column 7
248         degrigation_patern(HIT_ROW_LOC_7, HIT_COL_LOC_7, BUNKER_0, bunker_zero[r],
    framePointer);
249         break;
250     case HIT_8:     // Hit in location 8. Row 8 and column 8
251         degrigation_patern(HIT_ROW_LOC_8, HIT_COL_LOC_8, BUNKER_0, bunker_zero[r],
    framePointer);
252         break;
253     case HIT_9:     // Hit in location 9. Row 9 and column 9
254         degrigation_patern(HIT_ROW_LOC_9, HIT_COL_LOC_9, BUNKER_0, bunker_zero[r],
    framePointer);
255         break;
256     }
257     bunker_zero[r]++;
258 }
259
260 // Put a hit on bunker 1 at a certain location
261 void bunker1(int32_t r, uint32_t * framePointer){
262     if(bunker_one[r]== BUNKER_DEAD){    // If our bunker is already dead here
263         bunkers_hit_rand_bunker(framePointer);      // call rand kill bunker again
264         return;
265     }
266     switch(r){                          // Based on where the hit is
267     case HIT_0:     // Hit in location 0. Row 0 and column 0
```

```
268         degrigation_patern(HIT_ROW_LOC_0, HIT_COL_LOC_0, BUNKER_1, bunker_one[r],
    framePointer);
269         break;
270     case HIT_1:     // Hit in location 1. Row 1 and column 1
271         degrigation_patern(HIT_ROW_LOC_1, HIT_COL_LOC_1, BUNKER_1, bunker_one[r],
    framePointer);
272         break;
273     case HIT_2:     // Hit in location 2. Row 2 and column 2
274         degrigation_patern(HIT_ROW_LOC_2, HIT_COL_LOC_2, BUNKER_1, bunker_one[r],
    framePointer);
275         break;
276     case HIT_3:     // Hit in location 3. Row 3 and column 3
277         degrigation_patern(HIT_ROW_LOC_3, HIT_COL_LOC_3, BUNKER_1, bunker_one[r],
    framePointer);
278         break;
279     case HIT_4:     // Hit in location 4. Row 4 and column 4
280         degrigation_patern(HIT_ROW_LOC_4, HIT_COL_LOC_4, BUNKER_1, bunker_one[r],
    framePointer);
281         break;
282     case HIT_5:     // Hit in location 5. Row 5 and column 5
283         degrigation_patern(HIT_ROW_LOC_5, HIT_COL_LOC_5, BUNKER_1, bunker_one[r],
    framePointer);
284         break;
285     case HIT_6:     // Hit in location 6. Row 6 and column 6
286         degrigation_patern(HIT_ROW_LOC_6, HIT_COL_LOC_6, BUNKER_1, bunker_one[r],
    framePointer);
287         break;
288     case HIT_7:     // Hit in location 7. Row 7 and column 7
289         degrigation_patern(HIT_ROW_LOC_7, HIT_COL_LOC_7, BUNKER_1, bunker_one[r],
    framePointer);
290         break;
291     case HIT_8:     // Hit in location 8. Row 8 and column 8
292         degrigation_patern(HIT_ROW_LOC_8, HIT_COL_LOC_8, BUNKER_1, bunker_one[r],
    framePointer);
293         break;
294     case HIT_9:     // Hit in location 9. Row 9 and column 9
295         degrigation_patern(HIT_ROW_LOC_9, HIT_COL_LOC_9, BUNKER_1, bunker_one[r],
    framePointer);
296         break;
297     }
298     bunker_one[r]++;
299 }
300
301 // Put a hit on bunker 2 at a certain location
302 void bunker2(int32_t r, uint32_t * framePointer){
303     if(bunker_two[r]== BUNKER_DEAD){    // If our bunker is already dead here
304         bunkers_hit_rand_bunker(framePointer);      // call rand kill bunker again
305         return;
306     }
307     switch(r){                          // Based on where the hit is
308     case HIT_0:     // Hit in location 0. Row 0 and column 0
309         degrigation_patern(HIT_ROW_LOC_0, HIT_COL_LOC_0, BUNKER_2, bunker_two[r],
    framePointer);
310         break;
311     case HIT_1:     // Hit in location 1. Row 1 and column 1
312         degrigation_patern(HIT_ROW_LOC_1, HIT_COL_LOC_1, BUNKER_2, bunker_two[r],
    framePointer);
313         break;
```

```
314     case HIT_2:     // Hit in location 2. Row 2 and column 2
315         degrigation_patern(HIT_ROW_LOC_2, HIT_COL_LOC_2, BUNKER_2, bunker_two[r],
    framePointer);
316         break;
317     case HIT_3:     // Hit in location 3. Row 3 and column 3
318         degrigation_patern(HIT_ROW_LOC_3, HIT_COL_LOC_3, BUNKER_2, bunker_two[r],
    framePointer);
319         break;
320     case HIT_4:     // Hit in location 4. Row 4 and column 4
321         degrigation_patern(HIT_ROW_LOC_4, HIT_COL_LOC_4, BUNKER_2, bunker_two[r],
    framePointer);
322         break;
323     case HIT_5:     // Hit in location 5. Row 5 and column 5
324         degrigation_patern(HIT_ROW_LOC_5, HIT_COL_LOC_5, BUNKER_2, bunker_two[r],
    framePointer);
325         break;
326     case HIT_6:     // Hit in location 6. Row 6 and column 6
327         degrigation_patern(HIT_ROW_LOC_6, HIT_COL_LOC_6, BUNKER_2, bunker_two[r],
    framePointer);
328         break;
329     case HIT_7:     // Hit in location 7. Row 7 and column 7
330         degrigation_patern(HIT_ROW_LOC_7, HIT_COL_LOC_7, BUNKER_2, bunker_two[r],
    framePointer);
331         break;
332     case HIT_8:     // Hit in location 8. Row 8 and column 8
333         degrigation_patern(HIT_ROW_LOC_8, HIT_COL_LOC_8, BUNKER_2, bunker_two[r],
    framePointer);
334         break;
335     case HIT_9:     // Hit in location 9. Row 9 and column 9
336         degrigation_patern(HIT_ROW_LOC_9, HIT_COL_LOC_9, BUNKER_2, bunker_two[r],
    framePointer);
337         break;
338     }
339     bunker_two[r]++;
340 }
341
342 // Put a hit on bunker 3 at a certain location
343 void bunker3(int32_t r, uint32_t * framePointer){
344     if(bunker_three[r]== BUNKER_DEAD){  // If our bunker is already dead here
345         bunkers_hit_rand_bunker(framePointer);      // call rand kill bunker again
346         return;
347     }
348     switch(r){                          // Based on where the hit is
349     case HIT_0:     // Hit in location 0. Row 0 and column 0
350         degrigation_patern(HIT_ROW_LOC_0, HIT_COL_LOC_0, BUNKER_3, bunker_three[r],
    framePointer);
351         break;
352     case HIT_1:     // Hit in location 1. Row 1 and column 1
353         degrigation_patern(HIT_ROW_LOC_1, HIT_COL_LOC_1, BUNKER_3, bunker_three[r],
    framePointer);
354         break;
355     case HIT_2:     // Hit in location 2. Row 2 and column 2
356         degrigation_patern(HIT_ROW_LOC_2, HIT_COL_LOC_2, BUNKER_3, bunker_three[r],
    framePointer);
357         break;
358     case HIT_3:     // Hit in location 3. Row 3 and column 3
359         degrigation_patern(HIT_ROW_LOC_3, HIT_COL_LOC_3, BUNKER_3, bunker_three[r],
    framePointer);
```

```
360         break;
361     case HIT_4:     // Hit in location 4. Row 4 and column 4
362         degrigation_patern(HIT_ROW_LOC_4, HIT_COL_LOC_4, BUNKER_3, bunker_three[r],
    framePointer);
363         break;
364     case HIT_5:     // Hit in location 5. Row 5 and column 5
365         degrigation_patern(HIT_ROW_LOC_5, HIT_COL_LOC_5, BUNKER_3, bunker_three[r],
    framePointer);
366         break;
367     case HIT_6:     // Hit in location 6. Row 6 and column 6
368         degrigation_patern(HIT_ROW_LOC_6, HIT_COL_LOC_6, BUNKER_3, bunker_three[r],
    framePointer);
369         break;
370     case HIT_7:     // Hit in location 7. Row 7 and column 7
371         degrigation_patern(HIT_ROW_LOC_7, HIT_COL_LOC_7, BUNKER_3, bunker_three[r],
    framePointer);
372         break;
373     case HIT_8:     // Hit in location 8. Row 8 and column 8
374         degrigation_patern(HIT_ROW_LOC_8, HIT_COL_LOC_8, BUNKER_3, bunker_three[r],
    framePointer);
375         break;
376     case HIT_9:     // Hit in location 9. Row 9 and column 9
377         degrigation_patern(HIT_ROW_LOC_9, HIT_COL_LOC_9, BUNKER_3, bunker_three[r],
    framePointer);
378         break;
379     }
380     bunker_three[r]++;
381 }
382
383 // This goes through all the bunkers and destroys them according to our pattern
384 void degrigation_patern(int32_t row, int32_t col, int32_t bunker_num, int32_t damage,
    uint32_t * framePointer){
385     int32_t r,c;
386     for(r=0;r<BUNKER_DAMAGE_HEIGHT;r++){        // Go through rows
387         for(c=0;c<DAMAGE_WORD_WIDTH;c++){       // and columns
388             if (damage == BUNKER_DAMAGE_0       // 0 damage level
389                     && (bunkerDamage0_6x6[r] & (1<<(DAMAGE_WORD_WIDTH-c-1)))){
390                 // If we need to erase a pixel here, do so.
391                 bunkers_draw_pixel(framePointer,r+row+bunker[bunker_num].row
392                         ,c+col+bunker[bunker_num].col, BLACK);
393
394             }else if(damage == BUNKER_DAMAGE_1  // 1 damage level
395                     && (bunkerDamage1_6x6[r] & (1<<(DAMAGE_WORD_WIDTH-c-1)))){
396                 // If we need to erase a pixel here, do so.
397                 bunkers_draw_pixel(framePointer,r+row+bunker[bunker_num].row
398                         ,c+col+bunker[bunker_num].col, BLACK);
399
400             }else if(damage == BUNKER_DAMAGE_2  // 2 damage level
401                     && (bunkerDamage2_6x6[r] & (1<<(DAMAGE_WORD_WIDTH-c-1)))){
402                 // If we need to erase a pixel here, do so.
403                 bunkers_draw_pixel(framePointer,r+row+bunker[bunker_num].row
404                         ,c+col+bunker[bunker_num].col, BLACK);
405
406             }else if(damage == BUNKER_DAMAGE_3  // 3 damage level
407                     && (bunkerDamage3_6x6[r] & (1<<(DAMAGE_WORD_WIDTH-c-1)))){
408                 // If we need to erase a pixel here, do so.
409                 bunkers_draw_pixel(framePointer,r+row+bunker[bunker_num].row
410                         ,c+col+bunker[bunker_num].col, BLACK);
```

```
411             }
412         }
413     }
414 }
415
416
417
```

```c
/*
 * interface.h
 * Taylor Cowley and Andrew Okazaki
 */

#ifndef INTERFACE_H_
#define INTERFACE_H_


#endif /* INTERFACE_H_ */

// Draws the line at the bottom of the screen
void interface_draw_line(uint32_t * framePointer);

// Draws the "extra life" tanks
void interface_draw_tanks(uint32_t * framePointer);

```

```c
/*
 * interface.c
 * Taylor Cowley and Andrew Okazaki
 */

#include <stdio.h>
#include <stdint.h>
#include "platform.h"
#include "xparameters.h"
#include "xaxivdma.h"
#include "xio.h"
#include "time.h"
#include "unistd.h"
#define TANK_HEIGHT 8
#define GREEN 0x0000FF00
#define GAME_X 320          // How wide our game screen is
#define LINE_Y 225          // Where the line at the bottom goes

#define EXTRA_TANK_0 250    // X coordinate of extra tanks
#define EXTRA_TANK_1 270    // X coordinate of extra tanks
#define EXTRA_TANK_2 290    // X coordinate of extra tanks
#define EXTRA_TANK_Y_OFFSET 5   // How far down the extra tanks are

// Packs each horizontal line of the figures into a single 32 bit word.
#define packword15(b14,b13,b12,b11,b10,b9,b8,b7,b6,b5,b4,b3,b2,b1,b0)  \
((b14 << 14) | (b13 << 13) | (b12 << 12) | (b11 << 11) | (b10 << 10) | \
 (b9  << 9 ) | (b8  << 8 ) | (b7  << 7 ) | (b6  << 6 ) | (b5  << 5 ) | \
 (b4  << 4 ) | (b3  << 3 ) | (b2  << 2 ) | (b1  << 1 ) | (b0  << 0 ) )

 // This seems like a *very bad* way to store the tank data, but this is what
 // we are doing for the moment.
static const int tank_15x8[TANK_HEIGHT] =
{
packword15(0,0,0,0,0,0,0,1,0,0,0,0,0,0,0),
packword15(0,0,0,0,0,0,1,1,1,0,0,0,0,0,0),
packword15(0,0,0,0,0,0,1,1,1,0,0,0,0,0,0),
packword15(0,1,1,1,1,1,1,1,1,1,1,1,1,1,0),
packword15(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1),
packword15(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1),
packword15(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1),
packword15(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1)
};

#define WORD_WIDTH 15

// ----------------------------------------
// Our declaration of functions to be used
void interface_draw_pixel(uint32_t * framePointer,uint32_t row,uint32_t col,uint32_t color);
// Ending declaration of internal functions
// ----------------------------------------

// This is 100% copied from aliens.c. Eventually it needs to move to its own global file
void interface_draw_pixel(uint32_t * framePointer,uint32_t row,uint32_t col,uint32_t color){
    #define DRAW_PIXEL_ROW_MULTIPLIER 1280  // 640 * 2 for screen doubling
    #define DRAW_PIXEL_ROW 640              // one row offset
```

```
56    #define DRAW_PIXEL_DOUBLE 2             // for doubling
57
58    // We draw 4 pixels for every 1 small-screen pixel
59    framePointer[row*DRAW_PIXEL_ROW_MULTIPLIER + col*DRAW_PIXEL_DOUBLE] = color;
60    framePointer[row*DRAW_PIXEL_ROW_MULTIPLIER + col*DRAW_PIXEL_DOUBLE+1] = color;
61    framePointer[row*DRAW_PIXEL_ROW_MULTIPLIER+DRAW_PIXEL_ROW+ col*DRAW_PIXEL_DOUBLE] =
  color;
62    framePointer[row*DRAW_PIXEL_ROW_MULTIPLIER+DRAW_PIXEL_ROW+ col*DRAW_PIXEL_DOUBLE +
  1] = color;
63
64}
65
66// This draws the green line at the bottom of the screen
67void interface_draw_line(uint32_t * framePointer){
68    int row, col;                           // Initialize
69    row = LINE_Y;                           // variables
70    for(col=0;col<GAME_X;col++){            // Go along the screen and draw
71        interface_draw_pixel(framePointer, row, col, GREEN);
72    }
73}
74
75// This draws the extra tanks to the screen
76void interface_draw_tanks(uint32_t * framePointer){
77     int row, col;                          // Init loop vars
78     for(row=0;row<TANK_HEIGHT;row++){      // Go through width
79         for(col=0;col<WORD_WIDTH;col++){   // and height
80             if((tank_15x8[row] & (1<<(WORD_WIDTH-col-1)))) {   // and draw 3 tanks
81                 interface_draw_pixel(framePointer, row+EXTRA_TANK_Y_OFFSET,
  col+EXTRA_TANK_0, GREEN);
82                 interface_draw_pixel(framePointer, row+EXTRA_TANK_Y_OFFSET,
  col+EXTRA_TANK_1, GREEN);
83                 interface_draw_pixel(framePointer, row+EXTRA_TANK_Y_OFFSET,
  col+EXTRA_TANK_2, GREEN);
84             }
85         }
86     }
87}
88
```

```c
/*
 * tank.h
 * Taylor Cowley and Andrew Okazaki
 */

#ifndef TANK_H_
#define TANK_H_

#include <stdint.h>
#include <stdbool.h>

void tank_init();
// moves our tank left by a certain number of pixels
void tank_move_left(uint32_t * framePointer);
// moves our tank right by a certain number of pixels
void tank_move_right(uint32_t * framePointer);

// This simply draws the tank on the screen, where it is at now.
void tank_draw(uint32_t * framePointer, bool erase);

// Alives a shell and draws it to the screen
void tank_fire(uint32_t * framePointer);

// Moves the shell up on the screen
void tank_update_bullet(uint32_t * framePointer);

#endif /* TANK_H_ */

```

```c
/*
 * tank.c
 * Taylor Cowley and Andrew Okazaki
 */


#include <stdint.h>
#include "platform.h"
#include "xparameters.h"
#include "xaxivdma.h"
#include "xio.h"
#include "time.h"
#include "unistd.h"

#include "tank.h"   // Do we normally have to include our own h function?
#define TANK_HEIGHT     8       // Tank is 8 pixels high
#define TANK_INIT_ROW   210     // Tank starts at row 210
#define TANK_INIT_COL   160     // Tank starts at col 160
#define SHELL_LENGTH 3          // Shell is 3 pixels long
#define SHELL_COL_OFFSET 7      // Shell is 7 pixels offset from the tank

#define GREEN 0x0000FF00        // Hex value for green
#define BLACK 0x00000000        // Hex value for black
#define WHITE 0xFFFFFFFF        // Hex value for white

// Packs each horizontal line of the figures into a single 32 bit word.
#define packword15(b14,b13,b12,b11,b10,b9,b8,b7,b6,b5,b4,b3,b2,b1,b0)  \
((b14 << 14) | (b13 << 13) | (b12 << 12) | (b11 << 11) | (b10 << 10) | \
 (b9  << 9 ) | (b8  << 8 ) | (b7  << 7 ) | (b6  << 6 ) | (b5  << 5 ) | \
 (b4  << 4 ) | (b3  << 3 ) | (b2  << 2 ) | (b1  << 1 ) | (b0  << 0 ) )

static const int tank_15x8[TANK_HEIGHT] = {     // This is how we
    packword15(0,0,0,0,0,0,0,1,0,0,0,0,0,0,0),  // Store the tank
    packword15(0,0,0,0,0,0,1,1,1,0,0,0,0,0,0),  // drawing data
    packword15(0,0,0,0,0,0,1,1,1,0,0,0,0,0,0),
    packword15(0,1,1,1,1,1,1,1,1,1,1,1,1,1,0),
    packword15(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1),
    packword15(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1),
    packword15(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1),
    packword15(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1)
};

#define WORD_WIDTH 15

struct tank{        // The struct for our tank
    int row;        // Tank's row
    int col;        // Tank's column
}tank;

struct tank_shell{  // The struct that stores the tank's bullet data
    int row;        // Shell's row
    int col;        // Shell's column
    bool alive;     // Whether it is alive
}tank_shell;


// -----------------------------------------
// Our declaration of functions to be used
```

```
 59 void tank_draw_pixel(uint32_t *framePointer,uint32_t row,uint32_t col,uint32_t color);
 60 // Ending declaration of internal functions
 61 // ----------------------------------------
 62
 63 // This is 100% copied from aliens.c. Eventually it needs to move to its own global
    file
 64 void tank_draw_pixel(uint32_t *framePointer,uint32_t row,uint32_t col,uint32_t color){
 65     #define DRAW_PIXEL_ROW_MULTIPLIER 1280  // 640 * 2 for screen doubling
 66     #define DRAW_PIXEL_ROW 640              // one row offset
 67     #define DRAW_PIXEL_DOUBLE 2             // for doubling
 68
 69     // We draw 4 pixels for every 1 small-screen pixel
 70     framePointer[row*DRAW_PIXEL_ROW_MULTIPLIER + col*DRAW_PIXEL_DOUBLE] = color;
 71     framePointer[row*DRAW_PIXEL_ROW_MULTIPLIER + col*DRAW_PIXEL_DOUBLE+1] = color;
 72     framePointer[row*DRAW_PIXEL_ROW_MULTIPLIER+DRAW_PIXEL_ROW+ col*DRAW_PIXEL_DOUBLE]
    = color;
 73     framePointer[row*DRAW_PIXEL_ROW_MULTIPLIER+DRAW_PIXEL_ROW+ col*DRAW_PIXEL_DOUBLE +
    1] = color;
 74
 75 }
 76
 77 // This initializes our tank at its proper location
 78 void tank_init(){
 79     tank.row = 210;     // Tank starts at this row
 80     tank.col = 160;     // and column
 81 }
 82
 83 // This draws (or erases, via the erase bool) an entire tank.
 84 void tank_draw(uint32_t * framePointer, bool erase){
 85     int color = erase ? BLACK : GREEN ;     // green or black depending on erase
 86     int row, col;                           // init loop vars
 87     for(row=0;row<TANK_HEIGHT;row++){       // Go through tank x pixels
 88         for(col=0;col<WORD_WIDTH;col++){    // and tank y pixels
 89             if ((tank_15x8[row] & (1<<(WORD_WIDTH-col-1)))) {   // If a pixel
 90                 //  Draw the pixel
 91                 tank_draw_pixel(framePointer, row+tank.row,col+tank.col,color);
 92             }
 93         }
 94     }
 95 }
 96
 97 // moves our tank left by a certain number of pixels
 98 void tank_move_left(uint32_t * framePointer){
 99 #define L_0_GREEN   7   // When moving left,
100 #define L_2_GREEN   6   // where to
101 #define L_3_GREEN   1   // draw green
102 #define L_7_GREEN   0   // pixels based on row
103
104 #define L_0_BLACK   8   // When moving left,
105 #define L_2_BLACK   9   // where to
106 #define L_3_BLACK   14  // erase pixels
107 #define L_7_BLACK   15  // based on row
108     tank.col --;        // Move our tank left by a pixel
109     int row;            // Declare loop var
110     for(row = 0; row < TANK_HEIGHT; row++){
111         switch (row){   // Depending on the row
112         case 0:         // Draw/erase proper pixels
113             tank_draw_pixel(framePointer,row+tank.row,L_0_GREEN+tank.col,GREEN);
```

```
114             tank_draw_pixel(framePointer,row+tank.row,L_0_BLACK+tank.col,BLACK);
115             break;
116         case 1: // Cases 1 and 2 are identical
117         case 2:         // Keep drawing/erasing pixels
118             tank_draw_pixel(framePointer,row+tank.row,L_2_GREEN+tank.col,GREEN);
119             tank_draw_pixel(framePointer,row+tank.row,L_2_BLACK+tank.col,BLACK);
120             break;
121         case 3:         // Keep drawing/erasing pixels
122             tank_draw_pixel(framePointer,row+tank.row,L_3_GREEN+tank.col,GREEN);
123             tank_draw_pixel(framePointer,row+tank.row,L_3_BLACK+tank.col,BLACK);
124             break;
125         case 4: // Cases 4, 5, 6, and 7 are all identical.
126         case 5:
127         case 6:
128         case 7:         // Keep drawing/erasing pixels
129             tank_draw_pixel(framePointer,row+tank.row,L_7_GREEN+tank.col,GREEN);
130             tank_draw_pixel(framePointer,row+tank.row,L_7_BLACK+tank.col,BLACK);
131             break;
132         }
133     }
134 }
135
136 //moves our tank right by a certain number of pixels
137 void tank_move_right(uint32_t * framePointer){
138 #define R_0_GREEN 7     // When moving
139 #define R_1_GREEN 8     // right,
140 #define R_2_GREEN 8     // which pixels
141 #define R_3_GREEN 13    // are
142 #define R_4_GREEN 14    // to
143 #define R_5_GREEN 14    // be drawn
144 #define R_6_GREEN 14    // green
145 #define R_7_GREEN 14    // based on the row
146
147 #define R_0_BLACK 6     // When moving
148 #define R_1_BLACK 5     // right,
149 #define R_2_BLACK 5     // which pixels
150 #define R_3_BLACK 0     // are
151 #define R_4_BLACK -1    // to
152 #define R_5_BLACK -1    // be ERASED
153 #define R_6_BLACK -1    // with black
154 #define R_7_BLACK -1    // based on the row
155
156         tank.col ++;    // Move our tank right by a single pixel
157         int r = 0;      // Start our count pointer
158         // Draw and erase the proper pixels for row 0
159         tank_draw_pixel(framePointer, r+tank.row, R_0_GREEN+tank.col, GREEN);
160         tank_draw_pixel(framePointer, r+tank.row, R_0_BLACK+tank.col, BLACK);
161         r++;            // increment row counter
162         // Draw and erase the proper pixels for row 1
163         tank_draw_pixel(framePointer, r+tank.row, R_1_GREEN+tank.col, GREEN);
164         tank_draw_pixel(framePointer, r+tank.row, R_1_BLACK+tank.col, BLACK);
165         r++;            // increment row counter
166         // Draw and erase the proper pixels for row 2
167         tank_draw_pixel(framePointer, r+tank.row, R_2_GREEN+tank.col, GREEN);
168         tank_draw_pixel(framePointer, r+tank.row, R_2_BLACK+tank.col, BLACK);
169         r++;            // increment row counter
170         // Draw and erase the proper pixels for row 3
171         tank_draw_pixel(framePointer, r+tank.row, R_3_GREEN+tank.col, GREEN);
```

```
172         tank_draw_pixel(framePointer, r+tank.row, R_3_BLACK+tank.col, BLACK);
173         r++;            // increment row counter
174         // Draw and erase the proper pixels for row 4
175         tank_draw_pixel(framePointer, r+tank.row, R_4_GREEN+tank.col, GREEN);
176         tank_draw_pixel(framePointer, r+tank.row, R_4_BLACK+tank.col, BLACK);
177         r++;            // increment row counter
178         // Draw and erase the proper pixels for row 5
179         tank_draw_pixel(framePointer, r+tank.row, R_5_GREEN+tank.col, GREEN);
180         tank_draw_pixel(framePointer, r+tank.row, R_5_BLACK+tank.col, BLACK);
181         r++;            // increment row counter
182         // Draw and erase the proper pixels for row 6
183         tank_draw_pixel(framePointer, r+tank.row, R_6_GREEN+tank.col, GREEN);
184         tank_draw_pixel(framePointer, r+tank.row, R_6_BLACK+tank.col, BLACK);
185         r++;            // increment row counter
186         // Draw and erase the proper pixels for row 07
187         tank_draw_pixel(framePointer, r+tank.row, R_7_GREEN+tank.col, GREEN);
188         tank_draw_pixel(framePointer, r+tank.row, R_7_BLACK+tank.col, BLACK);
189 }
190
191 // This creates a shell and initially draws it to the screen
192 void tank_fire(uint32_t * framePointer){
193     if(!tank_shell.alive){          // Only go on if our shell is dead
194         tank_shell.col = tank.col;  // give it
195         tank_shell.row = tank.row;  // a location
196         tank_shell.alive = true;    // make it alive!
197
198         // Tank bullet is 3 pixels long.
199         int row;
200         // So go through all 3 pixels and draw them to the screen!
201         for(row = tank_shell.row-1;row>tank_shell.row-SHELL_LENGTH;row--){
202             tank_draw_pixel(framePointer,row,SHELL_COL_OFFSET+tank_shell.col,WHITE);
203         }
204     }
205 }
206
207 // This moves the shell up the screen
208 void tank_update_bullet(uint32_t * framePointer){
209     if(tank_shell.row<0){           // If shell is off the screen
210         tank_shell.alive = false;   // Kill it
211     }
212     else if(tank_shell.alive){      // Don't do anything if it's dead
213         tank_shell.row -= 1;            // move it up
214         // Erase the lowest pixel, and draw one higher up.
215         tank_draw_pixel(framePointer,tank_shell.row-SHELL_LENGTH,SHELL_COL_OFFSET+tank_
    shell.col, WHITE);
216         tank_draw_pixel(framePointer,tank_shell.row,SHELL_COL_OFFSET+tank_shell.col,
    BLACK);
217     }
218 }
219
220
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```

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