Preliminary Project Plan: Design of a Lifesaving Aerial Lifevest Delivery System (LALVDS)

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SYST490-001 Fall 2015
Context Analysis
Context Analysis

● Beach
  ○ Over 300 million people go to the beach every year
  ○ All surf beaches in the US have rip currents
  ○ Rip currents can happen at any beach with breaking waves

● Ocean
  ○ What are rip currents?
    ■ Powerful channels of fast-moving water that flow away from shore
    ■ Rip currents form when waves break near the shoreline
Rip Current Diagram
Rip Currents Measurements [9]

- **Length**
  - Extend out hundreds of feet

- **Width**
  - Very narrow: 10 to 20 feet
  - Very wide: upwards of 150 feet

- **Speed**
  - Average 1 to 2 ft/s
    - Not too dangerous for strong swimmers
  - Up to 8 ft/s
    - Dangerous for even strong swimmers
Beach Incidents (USLA) [2][8]

- Unguarded Drowning Deaths
- Guarded Drowning Deaths
- Rescues
- Some beach agencies only report totals for fatalities and rescues
Unguarded Drowning Deaths

- **Rip Currents**
  - Slightly increasing
  - Past ten years total drowning deaths is 315 only from reported agencies
- **Total (Swift, surf, and scuba)**
  - Stable
Guarded Drowning Deaths

- **Rip Currents**
  - Increasing
  - Past ten years total drowning deaths is 46 only from reported agencies
- **Total (Swift, surf, and scuba)**
  - Increasing
Rescues

- Rip Currents
  - Increasing
- Total (swift, surf, and scuba)
  - Increasing
Primary Cause of Rescue

- Rip current is the primary cause of rescue
- From 2003 to 2012
  - Rescues from rip currents account for 81% (33,418)
- The 10 year average of annual rip current fatalities is 51 [3].
Fatalities [1]

- Rip Currents
  - Fatalities account for 79% in 2014
    - According to NOAA
Stakeholder Analysis
Stakeholders

1. Lifeguarding Associations
   a. Lifeguarding associations are professional lifesaving associations that train dedicated beach lifeguards and open water rescuers.
   b. Certify lifeguards
2. Lifeguards
   a. Lifeguards are strong swimmers who supervise the safety and rescue of swimmers, surfers, and other water sports participants.
3. Beach Goers
   a. Beach goers are the people who go to the beach and use its services. They want the least restrictions and the instructions given by lifeguards are of no concern. However, they want the lifeguards to be 100% effective at their jobs.
4. Manufacturers
   a. Manufacturers are companies that produce equipment for the lifeguards. Some major companies include Swimoutlet and Marine Rescue Products.
5. Municipalities
   a. The municipality is broken down into owner and operator. Either can be the county, city, or state.
Stakeholder Analysis
Explaination of Stakeholder Analysis (preliminary)

- The Life guarding associations train and certify lifeguards and inspect the Beach Operator
  - They provide legal assistance
- The lifeguards protect beach goers and provide rescue services
- The beach goers hold the lifeguard liable if injured, who hold the operator liable, and then the operator holds the owner liable
  - It is a flow (supportive system)
- At the end, the beach owner is always liable
- The catastrophic insurance umbrella protects the beach owner, beach operator, and lifeguards
  - if a lawsuit is unsuccessful
  - if damages are extremely expensive
Process of lifeguard rescuing a victim

- Beach separated into multiple zones with one lifeguard in each zone
- LG running with right hand up in the air means assistance is needed
- LG pointing and tapping on top of their head means assistance is NOT needed
Gap and Problem Statement

- **Gap Statement**
  - There is a gap between the victim survival time and the time needed for a lifeguard to reach the victim.

- **Problem Statement**
  - Rip tides are, on average, 81% of annual beach rescues, 80% of annual beach fatalities, and cause 51 annual deaths [3][2][1]. Lifeguards are very good at their job and can reach victims in an average time of X seconds, however some victims cannot survive that long and have survival times as low as X seconds. By raising the average victim survival time and reducing the variance of the victim's survival time by X, we can reduce drowning deaths by X%.
Need Statement and Win-Win

- **Need Statement**
  - There is a need for a system that can close the gap between a victim's survival time and a lifeguards rescue time. Specially, there is a need for a system that can reach and assist the victim before the lifeguard in order to increase the victim's survival time.

- **Win-Win**
  - This system would decrease the amount of rip current fatalities. Since there is less fatalities, beaches with the system would be considered safer, thus more beach goers would come, which is a win for municipalities and for beach goers. The system can be equipped with any reasonably weighted life ring, so it is unlikely any lifeguarding agencies need to buy equipment from a different manufacturer. Thus, manufacturers should not be affected by the system.
The lifeguard process and the drone system are independent. If the lifeguard for some reason is not able to reach the victim the drone will still continue and drop the ring buoy. If the drone is not able to drop the ring buoy the lifeguard will reach the victim.
Concept of Operations - Operational Scenario

**Precondition:** Lifeguard has detected victim of rip current. Lifeguard is prepared for rescue process. Victim is currently somewhere on the rip current and is currently attempting an escape method. Drone is ready to deploy. Ring buoy is stocked on drone.

**Primary:**
- The system takes off to a height of X meters.
- The system accelerates to X m/s and maintains it towards the victim's location.
- Once the system is within 4m of the victim's location, system shall decelerate to victim's speed and position. At the same time, the system will reduce height until the ring buoy touches the water (confirmed by eye from controller).
- Once victim has a firm grasp on ring buoy, system shall detach/release the tether.
- System will hover over victim until lifeguard has reached the victim.
- Once lifeguard has reached the victim and starts pulling them to shore, system will be driven back to the home point.
- System lands on homepoint.

**Post-Condition:** Lifeguard is enacting the rest of rescue process starting with pulling the victim back to shore. Drone has landed back at the home point and awaits restocking of ring buoy. Victim is being helped by the lifeguard.
Requirements

A. Mission Requirements
   MR.1 The system shall reduce the average annual number of rip current deaths by a minimum of X%.

B. Functional Requirements
   F.1 The system shall hover at a minimum altitude of 2m above the ground.
      F.1.1 The system shall hover at an altitude of 2m with a minimum payload of 2kg.
   F.2 The system shall be operable within Xm of the home point.
   F.3 The system shall reach a victim within X seconds.
      F.3.1 The system shall increase the victim survival time by an average of X seconds, if the system
does reach the victim.
   F.4 The system shall be able to restock its payload within X seconds.

C. Design Requirements
   DR.1 The system shall attach the lifesaving device to the drone through a tether.
      DR.1.1 The system may have a disconnect method to cut or release the tether in order to deliver
the lifesaving device.
   DR.2 The system shall comply with federal and state drone-use regulations and laws.
   DR.3 The system shall work with any life ring that is under 5lbs.

D. Usability Requirements
   U.1 The system shall be usable by a person that has less than 12 hours of training.
Proposed Solution/Alternatives
Proposed Design Solution

● A system that will increase the victim survival time during the rescue process
  ○ This will be done by delivering a lifesaving device to them before the stage where the lifeguard reaches them
    ■ This delivery will be done through the use of a drone
## Drone Alternatives for Simulation Table

Comparison of Expert Drones Available

<table>
<thead>
<tr>
<th>Drones</th>
<th>Cost ($)</th>
<th>Payload Weight (Kg)</th>
<th>Size</th>
<th>Flight Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>3DR X8+</td>
<td>1,350</td>
<td>1</td>
<td>350 x 510 x 200 mm</td>
<td>15 minutes</td>
</tr>
<tr>
<td>DJI Phantom 3</td>
<td></td>
<td></td>
<td>Diagonal size 590mm</td>
<td>23 minutes</td>
</tr>
<tr>
<td>DJI Inspire 1</td>
<td>2,899</td>
<td>0.465</td>
<td>438x451x301 mm</td>
<td>18 minutes</td>
</tr>
<tr>
<td>DJI Spreading Wings S1000+</td>
<td>1,900</td>
<td>6.6</td>
<td>Diagonal Wheelbase 1045mm</td>
<td>15 minutes</td>
</tr>
<tr>
<td>DJI Spreading Wings S900</td>
<td>1,400</td>
<td>4.9</td>
<td>Diagonal Wheelbase 900mm</td>
<td>18 minutes</td>
</tr>
</tbody>
</table>
Drone Alternatives for Simulation

- Comparison of drones of potential drones
  - use as a basis for our design
  - that are sold by our sponsor Expert Drones

  - largest payload capacity
  - Biggest size
  - Middle of the road cost
  - Average flight time.

- We have agreed with our sponsor to use an S900 for testing purposes.
Simulation Design
Simulation Design

● Goal: Verify that the system meets the mission requirement
  ○ MR.1 The system shall reduce the average annual number of rip current deaths by a minimum of X%.
● Must compare results of lifeguard rescue without drone and then rescue with a drone.
Simulation Requirements

A. Functional Requirements

SR.1 The system shall be able to fly towards a waypoint and maintain position within 0.5m of the waypoint.
SR.2 The system shall have one run simulated under 1 minute.
SR.3 The system shall simulate wind and weight interactions with the drone.
SR.4 The system shall model drone rotational and translational dynamics.
SR.5 The system shall model the lifeguard-victim rescue process up til the lifeguard reaches the victim.

SR.5.1 The system shall model the three victim escape methods (swim parallel to neck, swim against the neck, float)
SR.5.2 The system shall model riptides of length 100/200/300/400/500 meters.
SR.5.3 The system shall model the lifeguard speed on land and on water as an average velocity of Xm/s and Ym/s respectively.
Simulation Requirements (Conti.)

A. Input Requirements
   IR.1 The system shall input a victim swimming method. It will pick between floating, swimming parallel against the shore, and swimming parallel to shore.
      IR.1.1 The system shall model the swimming methods as velocities. The choice will be based on a discrete random distribution.
      IR.1.2 The system shall be input a random victim survival time based on the swimming method chosen.
   IR.2 The system shall be input a random rip current speed. The speed will be chosen by a random X distribution with mean X and variance X.

B. Output Requirements
   OR.1 The system shall output the victim position over time.
   OR.2 The system shall output the lifeguard position over time.
   OR.3 The system shall output the drone position over time.
   OR.4 The system shall output 1 or 0 depending if the lifeguard rescue time is under victim survival time.
      OR.4.1 The system shall detect if the drone reached the victim before the lifeguard and increase victim survival time by X seconds.
Simulation Steps

1. Generate victim position over time
2. Based on victim position, generate drone position over time
3. Based on victim position, generate lifeguard position over time
4. Pass judgment
   a. If drone reached victim before survival time ended and before lifeguard, drop life ring
      i. increase survival time by X seconds.
   b. If lifeguard reaches victim before survival time, victim is saved.
   c. If lifeguard does not reach victim before survival time, victim is lost.
   d. Save result
Simulation Design

**Inputs:**
1. Victim Escape Method
2. Rip Current Velocity and Length

**State Variables:**
1. Victim Survival Time
2. Avg. Lifeguard Velocity (land/water)
3. Drone Properties and Coefficients

**Outputs:**
1. Lifeguard Position(t)
2. Victim Position(t)
3. Drone Position(t)
4. Judgement on Victim Survival
Victim Model

- **Inputs**: Escape Method, Rip Velocity, Rip Length
  - Calculates Survival Time based on escape method and rip length
- **Function**: Calculates victim position
  - Victim applies some velocity in the frame of the rip current, which is also moving.
- **Outputs**: Position of victim over time
Lifeguard Model

- **Inputs:** Victim Position(t), Rip Current Velocity
- **Function:** Calculates lifeguard position over time.
  - Lifeguard swims faster than the victim. Toward victim’s direction.
- **Outputs:** Lifeguard position over time
Drone Model - General

- **Inputs**: Waypoint (position of victim over time)
- **Function**: Control drone in order to reach waypoint and match waypoint’s velocity
  - Actuator based on manual flight, some errors and delay will later be added.
- **Output**: Drone position, velocity, and acceleration over time.
Drone Model - Translational

- Inputs: Voltage, Euler Angles
- Function: Convert voltage and angle readings thrust. Then derive acceleration based on thrust, drag forces, and force from the lifevest (weight).
  - Contains properties of air and gravity.
- Outputs: Drone acceleration, velocity, and position
Drone Model - Rotational

Inputs: Voltage

Function: Convert voltage to angular acceleration

Output: Euler angles (roll, pitch, yaw)
Scope of Work

● The scope of the work we will do includes:
  ○ Testing the feasibility (physical and economical) of lifesaving-device-delivery drones with varying drone and lifesaving-device properties.
    ■ We will analyze current stakeholder and current rescue processes.
    ■ We will simulate drone delivery and other drone mechanics.
    ■ We will design a drone that can help lifeguards with the rescue process.
      ● May build the drone and tether system to experiment with.
  ○ Estimating life-cycle costs of such a system if it was employed.

● The scope of work will NOT include:
  ○ Designed systems that help lifeguards but do not employ a drone. There is too many possibilities of modifying training, equipment, beach rules, submersibles, etc that can be done or are being researched currently.
  ○ Telling lifeguard agencies where to put the drone (each beach is different).
# Milestones

<table>
<thead>
<tr>
<th>Milestones</th>
<th>Dates</th>
</tr>
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<tbody>
<tr>
<td>Fall Brief 1</td>
<td>9/21/2015</td>
</tr>
<tr>
<td>Fall Brief 2</td>
<td>10/5/2015</td>
</tr>
<tr>
<td>Preliminary Project Plan</td>
<td>10/21/2015</td>
</tr>
<tr>
<td>Fall Brief 3</td>
<td>10/26/2015</td>
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<td>Fall Brief 4</td>
<td>11/09/2015</td>
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<tr>
<td>Faculty Presentation</td>
<td>11/20/2015</td>
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<tr>
<td>Proposal Final Reports</td>
<td>12/09/2015</td>
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<tr>
<td>Proposal Final Report Slides</td>
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</tr>
<tr>
<td>Draft Conference Paper</td>
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</tr>
<tr>
<td>Draft Poster</td>
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<table>
<thead>
<tr>
<th>Milestones (SYST 495 Spring 2016)</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring Brief 1</td>
<td>2/2016</td>
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<tr>
<td>Spring Brief 2</td>
<td>2/2016</td>
</tr>
<tr>
<td>Spring Brief 3</td>
<td>3/2016</td>
</tr>
<tr>
<td>SIEDS Abstract Due</td>
<td>2/2016</td>
</tr>
<tr>
<td>SIEDS Notification</td>
<td>3/2016</td>
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<tr>
<td>SIEDS Manuscript Due</td>
<td>4/2016</td>
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<tr>
<td>SIEDS Conference</td>
<td>4/2016</td>
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<tr>
<td>Registration for Keith Memorial Capstone Conference</td>
<td>Before 4/2016</td>
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<tr>
<td>GDRKMC Conference</td>
<td>5/2016</td>
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Salary Estimation

- According to Indeed.com the average salary of a Entry-Level Systems Engineer in Fairfax County is 63,000 per year [16].
- Assuming 50 work weeks and 40 hours a week, this is 27.50/hour.
  - We will round this up to $30 for simplicity.
- Overhead will be a 2.0 multiplier (accord to Dr. Sherry)
- Total charge is $60.00 per hour per person
Work Breakdown
Work Breakdown Structure

Top level WBS

The project’s major tasks and subtasks

Stakeholder analysis, DOE, and especially the simulation are the most important of the work.
Critical Tasks

1. Project File
2. Tension and sequence diagrams
3. Functional Requirements
4. Evaluate Life Saving Device Alternatives
5. Stakeholder: Lifeguard Research and Analysis
6. Stakeholder Liability Research and Analysis
7. Sensitivity Analysis
8. Project Risk Analysis
9. Simulation Risk Analysis
10. Motor Experiment
11. Program PID Control
12. Create Rip Current Model
13. Create GUI
14. Simulation Testing
15. Faculty Presentation
16. Final Reports and Stuff.
## Critical Path

<table>
<thead>
<tr>
<th>WBS</th>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
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<tbody>
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<td>11.1</td>
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<td>8/31/2015</td>
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<td>8.1.4</td>
<td>Program PID Control</td>
<td>30.75 days</td>
<td>9/23/2015</td>
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<td>4.2</td>
<td>Functional Requirements</td>
<td>8.88 days?</td>
<td>10/22/2015</td>
<td>12/25/2015</td>
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<td>9.2.1</td>
<td>Faculty Presentation Creation</td>
<td>5.13 days</td>
<td>11/14/2015</td>
<td>11/19/2015</td>
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<td>Faculty Presentation</td>
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<td>11/20/2015</td>
<td>11/20/2015</td>
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<td>10.2.3</td>
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<td>11/23/2015</td>
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<td>6.4.3</td>
<td>Simulation Risk Analysis</td>
<td>8.5 days</td>
<td>12/7/2015</td>
<td>12/16/2015</td>
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<td>10.1.2</td>
<td>Proposal Final Report</td>
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<td>12/9/2015</td>
<td>12/9/2015</td>
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<tr>
<td>8.1.7</td>
<td>Create Rip Current Model</td>
<td>7 days?</td>
<td>2/17/2016</td>
<td>3/2/2016</td>
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<td>9.4.3</td>
<td>Spring Brief 3</td>
<td>0 days</td>
<td>3/14/2016</td>
<td>3/14/2016</td>
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<tr>
<td>3.2.3</td>
<td>Sequence Diagrams</td>
<td>6.21 days?</td>
<td>3/29/2016</td>
<td>4/12/2016</td>
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<tr>
<td>3.2.2</td>
<td>Tension Diagrams</td>
<td>6.67 days?</td>
<td>4/2/2016</td>
<td>5/7/2016</td>
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<tr>
<td>11.3</td>
<td>Finish</td>
<td>0 days</td>
<td>5/14/2016</td>
<td>5/14/2016</td>
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Schedule

Stakeholders and building the simulation happen throughout 490 and first half of 495

DOE happens in 490 with some in early 495

Context and con-ops take place in in 490.

Those tasks that are pink are critical.
Schedule cont.
Cost and Schedule Variance

For the first 2 months

Cost variance (CV) is negative

Schedule variance (SV) are both negative.
SPI and CPI

Between Aug 31 and Oct 17

Our indices are hovering between 0.8 and 1.
Earned Value

Actual cost (ACWP) has been consistently above our Earned Value (BCWP).

BCWP was not that much different from our planned value (BCWS) but has been increasing.
Current State of Project

We have been consistently over budget

As of October 18th

ACWP is $36,642.68

BCWP is $28,631.91.

Estimated cost at completion is $146,937.25
# Project Risk Mitigation

<table>
<thead>
<tr>
<th>Risk</th>
<th>Severity</th>
<th>Likelihood</th>
<th>Detectability</th>
<th>Score</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation Control Structure is not done by Nov. 15th (2 weeks behind schedule)</td>
<td>8</td>
<td>10</td>
<td>1</td>
<td>80</td>
<td>Revert to old model with no control. Manually adjust voltages in order to get the right distance and other values needed.</td>
</tr>
<tr>
<td>Simulation Testing is Delayed by X days beyond scheduled due date</td>
<td>10</td>
<td>3</td>
<td>5</td>
<td>150</td>
<td>Do primary analysis of the drone’s effectiveness in reducing fatalities. Forgo all other simulation tests until we find time again.</td>
</tr>
<tr>
<td>Evaluate life saving device alternatives is not done, ring buoy information is wrong</td>
<td>9</td>
<td>3</td>
<td>5</td>
<td>135</td>
<td>Find other life saving devices with accurate information about them and evaluate them/</td>
</tr>
<tr>
<td>Gather accurate information about force, pitch, roll, yaw, velocity, height and wind speed</td>
<td>7</td>
<td>4</td>
<td>4</td>
<td>112</td>
<td>Perform the flight experiment again until we get accurate data. Use pocket money to get program and tablet that can watch the instruments.</td>
</tr>
<tr>
<td>Unable to acquire tools to perform experiments</td>
<td>10</td>
<td>6</td>
<td>1</td>
<td>60</td>
<td>Use the University’s lab experiments to get the tools.</td>
</tr>
</tbody>
</table>
Bibliography


