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Mine Rescue Team Unmanned Rescue Craft (MRTURC) Design Development

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Mine Rescue Team Unmanned Rescue Craft (MRTURC) Design Development

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Introduction

A mine is a rich place of minerals and metals such as, gold, silver, diamonds, Manganese, Coal, cassiterite, tin, copper, nickel, bauxite (aluminum ore), iron ore, and tantalum. Miners who extract those important minerals could face a lot of hazards during working in mines. Some of the hazards that might occur are dangerous and might even cause death. There are a lot of tragic stories that happened in some of the mines in the United States. According to National Institute for Occupational Safety and Health (NIOSH), a frightful accident happened to two miners who worked for Tri-Star Mining Inc., in Washington DC. They got buried under 93,000 tons of rock due to a massive high wall collapse. The company’s ground control did not adequately address high wall conditions and obvious hazards were allowed to exist. Another accident occurred in National Coal Straight Creek Mine in Kentucky when the highball collapsed in late afternoon or early evening. Two pieces of equipment, a high wall miner and a front-end loader, were damaged in the collapse. [1]

Gases can make working in the mines dangerous even if it has not collapsed or exploded. For example, Coal mines are confined spaces, and abnormal gases don’t always have the chance to disperse in the same way. Some gases may build up in the mine, and can cause danger to people working either underground or on surface. Some of the common gasses in mines are, Carbon Dioxide (CO2), Methane (CH4), Carbon Monoxide (CO), Hydrogen Sulphide and Nitrogen Oxides.

Unmanned Aerial Vehicles (UAVs) or commonly known as “Drones”, remotely controlled, can be used in a mine and it would be helpful for miners. There are several functions that a drone can do in a mine operation. For instance, a drone can be used for communication of daily/weekly mining plans. It also could go checking on haul route surface optimization as well as checking on storm damage assessment and control. Besides, a drone can go for inspection on pre and post blasts and provides the reports were needed. A drone can be sent anywhere in a mine to detect gasses, erosion and thermal hazards or water flooding incidents.

There are many benefits of using a drone in a mine. First, for safety and time management purposes; anyone involved in mining knows that the worker safety is paramount importance. By using a drone to collect accurate spatial data from above can vastly reduce risk also minimizing the time the worker would spends on site. Secondly, using a drone is more reliable. In fact, mining UAVs use the latest in 3D mapping technology to generate accurate overviews of any conceivable terrain. High-resolution images can be instantly generated and that would extremely help operators to get to work instantly. Last, one of the strongest cases for using Drones in mining is that it’s simply a more cost effective method than traditional approaches. Drones are cheaper to operate than manned aircraft, which entail a number of running and maintenance cost. Although there are associated ongoing costs, the bulk of the expenses involved with owning and operating a drone lies in the initial procurement.
A Mine Rescue Team Unmanned Rescue Craft (MRTURC) would be exposed to difficult environmental conditions including low air temperatures, that could reach down to 20°F in the winter and quite warm temperatures within the mine. For that reason, materials and supporting equipment will have to undergo careful selection. A beneficial factor is a low humidity of the area that would alleviate some of the otherwise harsh working conditions.

Figure 1. The daily average low (blue) and high (red) temperature with percentile bands (inner band from 25th to 75th percentile, outer band from 10th to 90th percentile). [2]
Statistic of accidents in the U.S mines

We don’t usually hear about tragedies at surface mines, but they happen. Slope stability accidents and high wall failures are one of the leading causes of fatalities at U.S. surface mining operations, according to National Institute for Occupational Safety and Health (NIOSH).

- In April 17th, 2007: In Tri-Star Mining Inc., in Washington DC: There was an accident occurred. 2 miners got buried under 93,000 tons of rock resulting from a massive high wall collapse. The company’s ground control plan did not adequately address high wall conditions, and obvious hazards were allowed to exist

- In March 17th, 2006: in National Coal Straight Creek Mine, in Kentucky: The high wall at the mine collapsed in the late afternoon or early evening. Two pieces of equipment, a high wall miner and a front-end loader, were damaged in the collapse.
Figure 3. This chart showing the statistic for injuries people by National Institute for Occupational Safety and Health (NIOSH).

This chart showing the lost-time nonfatal injuries recorded for the coal industry for the time period of 10 years from 2004 to 2013. The data excludes the office employees. Highest number of injuries being reported for the year 2004 of 3601. Then declining to 2399 to as reported in the year 2013. [4]

Figure 4. This chart showing the statistics for fatalities people by National Institute for Occupational Safety and Health (NIOSH).

This chart showing the number of fatalities for a 10 year period for people working in coal mining sector excluding the office employees. The highest number of deaths being recorded for the year 2006 and 2010, being 47 and 48 respectively. Least number of the deaths were observed for the year 2009, being 18 fatalities. [5]
Using Drones to mitigate risks in mines

Slope stability accidents are one of the leading causes of fatalities at U.S. surface mining operations. The Spokane Research Laboratory of the National Institute for Occupational Safety and Health (NIOSH) is currently conducting research to reduce the fatalities associated with slope failures and other unexpected failures of ground. The goal here is to get warning signs of slope instability so miners are better able to recognize hazards. How the drone is going to help prevent these accidents will be elaborated as well. [6]

Avoiding mine collapses:

There is a common system for this job and it is the digital detection systems. The system function dependent on the sensors that are attached on the mine’s walls. Those sensors are connected to the monitoring room. Instead, for the sectors that don’t have the system, the drone goes in mine to take snap-shots of the mine’s walls weekly, daily or even multiple times a day. Those photos are to be compared to see if any changes are noticed that can be a symptom to a collapse. Thus the data to be collected in this process is the photos taken by drone

Explosion and suffocation:

Methane explosions occur in mines when a buildup of methane gas, a byproduct of coal, comes into contact with a heat source, and there is not enough air to dilute the gas to levels below its explosion point, said Yi Luo, an associate professor of mining engineering at West Virginia University.

Other gases such as, carbon monoxide and carbon dioxide, also pose a dangerous atmosphere for workers as well. Having a specific detector attached to the drone, drone will be reporting multiple gasses once it accesses inside the mine. A MX6 iBrid Gas Detector is a sensor chosen for the drone as the biggest component in the gas detection process.

Process would go like this: Drone gets sent in a mine with the detector attached, once the drone is at the spot where the gases need to be measured and write down the time. When the drone is back to base, monitoring room will be able to unattached the detector and see measurements for the time when drone was located in the hot spot. Remind you that drone will collect measurements any spot chosen as long as the time is known to when drone was flying by the spots. Therefore, the only data to be collected for this process is time when drone is flying by areas targeted. Sensors would be constantly conveying data like gas temperatures as well as warning operators if any gas is out of limit. Miners would be more up to date and can send the drone to measure gases before people go in.
Project priorities

The project initiated when a meeting was held between our Mine Rescue Team Unmanned Rescue Craft (MRTURC) team and Colorado School of Mine’s Rescue team, in July 2015, stating the requirement for design ideas for an unmanned craft capable of search and rescue reconnaissance into hazardous mines and collapsed buildings. The constraints that were discussed were as follows: Limited Budget, Size Constraint (2ft X 2ft X 2ft) and the availability of only a single radio frequency in those areas, corresponding to 2.4 GHz. The features that were required by the team was: ability to self-stabilize, an infrared sensor for distance measurements, around 45 mins of operation on a single battery charge, ease of control of craft for the operator, ability to operate in severe environment condition of -20°C to 50°C, durability and easy availability of spare child parts if broken during operation. Thus the project started with keeping in mind the above requirement of an unmanned craft for search and rescue of trapped people in collapsed mines and buildings. Computer design soft-wares like Solid-works were used for the design and analysis of the same.

The first step into the project was deciding between an unmanned ground vehicle (UGV) and an unmanned aerial vehicle (UAV). Because of the problems of unpredictable terrains in case of an unmanned ground vehicle (UGV), it was discarded. The next step was to decide on the base quadcopter on which the UAV will be built. Considering the limited budget available, a multi rotor air craft was chosen, with enough rotor and propeller strength to be able to carry a camera and an infrared sensor. The size of quadcopter was designed to allow for the UAV to be self-stabilizing and maneuver with smooth control operations. It was kept in mind for the aircraft to easily operate in severe conditions of -20°C to 50°C, along-with the ease of availability of its child parts which could be replaced if broken.

Second priority was to choose a camera which could transmit live feed from the UAV to the operator. The camera had to such that it could easily rotate on its axis and get the full view of its surroundings, for which 3 axis gimbal was opted. Given the constraint of the only radio frequency available to be of 2.4 GHZ, a radio antenna operating on the same frequency was thus installed on the drone. Further, an infrared sensor had to be selected which could measure the distance and path ahead of the drone.

The final step was to choose the power source for the drone. The battery had to be such that it could allow for the drone a flight time of around 20-25 minutes. Later, the controller for the drone had to be designed permitting the operator an easy and simple control over the drone’s movement, for which various controls and a mobile holder was provided which could hold the mobile on which the live feed from the drone is played.

Why do we think drones should be used in a mine?

Because of the ability of Drones to send live pictures and videos, there are many benefits of using Drones over the mines. For example:

1. Mining operators can use Drones to communicate daily and weekly mining plans, miners can use drone while planning to head somewhere in the mine.
2. Miners can use Drones to control haul route/ surface optimization, and heavy equipment traffic control to avoid potential accidents.
3. Miners can use Drones for mine blast conditions (Pre and blast conditions).
4. Miners can use Drones to evaluate flood condones after storms or major water flood incidents (like break of a storing dams).
5. Inspect slurry pipeline stability and leakage (can be spotted and pin pointed by cameras).
6. Detect misfires.
7. Inspect wall damages.
8. Check surface stability.
9. The same goes for erosion detection.
10. Monitor training and execution of evacuation plans in case of emergency.

➤ The Mine Rescue Team’s Unmanned Rescue Craft’s (MRTURC) Solution & Design

▪ Drone overview

For mines operation safety our project team have chosen the unmanned aerial vehicle (UAV) over the alternative unmanned ground vehicle (UGV). The UGV was rejected because UAV is much easier than UGV to navigate unpredictable site terrains, buildings, and other obstacles like construction debris. Second, the UAV is easier to control and lighter in weight. The UAV provides a much wider view to during monitor and survey operations. In addition, UAVs saves time and money because it is much faster and covers a much larger areas in a shorter time compared to UGVs.

The hardware components of the MRTURC proposed are described in this section and presented:
- **Smart Battery**

  Team agreed on choosing the drone’s battery to be one of the main components in drone. This particular battery was made for drone because it lasts longer with weight vs any other batteries we searched. With Lithium polymer, 5200 (mAh) capacity and 14.8 (Vdc). The smart battery for Solo quadcopter allows the drone to fly up to 25 minutes unladen and up to 20 minutes with Solo gimbal and camera attached. LED indicators allow you to see remaining battery life or check the charge status. Being able to do that work and the time it can keep the drone working, Team thought it was the fittest choice.

![Figure 6. Dimensions of the Smart battery](image_url)
- **Motors and Propellers**

880Kv Brushless Motor should be used for the drone since it’s very reliable and delivers a very high level of thrust with the matched 10in x 4.5in propellers.

![Figure 7. Dimensions of the propeller housing](image)

![Figure 8. Dimensions of the propeller](image)
### Orientation LED’s

Each arm contains an LED for ground-to-air directional awareness; when armed for flight, the two front arms display white, and the two rear arms display red. This LED scheme mimics the headlight and taillight style of a car.

![Figure 9. Light housing](image)

![Figure 10. Light](image)
- **Camera & Gimbal**

The 3-axis gimbal carries the GoPro camera and helps the camera to be stable while taking shots or streaming a live video. There is a HDMI cable connects to the GoPro® to output video during

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Figure 11. Camera

Figure 12. Gimbal
- **Fixed Camera Mount and HDMI Cable**

Drone design includes a GoPro® the Frame fixed mount to mount a GoPro® HERO camera. The HDMI Cable connects to the GoPro® to output video during flight. “HDMI (High-Definition Multimedia Interface) is a proprietary audio/video interface for transferring uncompressed video data and compressed or uncompressed digital audio data from an HDMI-compliant source device” [7]

![Camera Mount Diagram]

Figure 13. Camera mount
- **Sensors**

A sensor is a device that detects to some type of input from the physical environment. These inputs could be pressure, motion, heat, light. While output is the signal that is changed the man-readable display at the sensor location. The sensor may provide various types that use electrical signal or optical signals. We use sensors day in day out, i.e., every day like touch-sensitive elevator buttons. Sensor sensitivity shows how much sensor's output changes when the input quality being measured changes (Lai 105). A good sensor should consider the following rules: It is sensitive to measure properly; it does not influence the measured property and is insensitive to any other encountered in its application. Thus, sensor's sensitivity is the ratio between the output signal and measured property. They are various type of sensor: analog sensor and digital signal. To process, integrate or implement analog sensor in digital equipment, it first should be converted to a digital signal using an analog-to-digital converter.

Adding these sensors would be necessary in providing these readings while also keeping the drone safe. While the drone is flying and approaching areas /landscapes or, a small entrance to a coal mine, for example, it is quite risky. Although, Base/Monitoring Room will have a clear vision of where the drone is heading, a distance sensor will prevent drone from crashing/physically touching objects by measuring them and reporting a sign to system control to pause the drone. Searching for a sensor that suits our mission the team chose one from “LedderTech”. This sensor was considered to be the right one because of its reliability and its ability to work in harsh environments as well as a multi gas detector (MX6 iBrid Gas Detector) that can detect five of the most concerning gases simultaneously and more other.

There are two sensors attached for (measuring the distance between the drone and an object, without physical contact with the object). (Sensor – LeddarTech). It decades that it is fast, give accurate distance measurements, and it is better cost and highly reliable in harsh environments which is a feature we desired for the sensor. Range is set to0m to 15m on natural targets. Leddar sensor has wide field-of-view and rich spatial awareness as a feature too which will be potential as the drone would be put to work in areas like mines. Attaching it: Using the same means cellphones use to detect when the caller is holding their phone to their ear” programmed. [7]
Figure 14. LeddarTech for distance sensing

Technical specification multi gas detector (MX6 iBrid Gas Detector) was picked after searching for sensors that can fit our design idea; a sensor that can get attached to a drone easily and collect data. MX6 can detect 5 gases of the ones we care about and matter most in the processes (oxygen O2, carbon monoxide CO, hydrogen sulfide H2S, lower explosive limit PID, photoionization detector LEL, Methane CH4). Sensor range is set: O2 30%, CO 0 to 999 ppm, H2S 0 to 200 ppm. Its Operation temperature range is -20 to 50 degrees C which is also a great fact due to mines’ atmosphere. It is adjustable. Manually can be set, for example, low O2 19.5% high O2 23.5% or CO 35 ppm warning or 100 ppm danger. MX6’s battery life last about 13 hours. Detector will be attached in gimbal under GoPro’s holder the same way you hang a pager to your jeans. [8]

Figure 15. MX6 iBrid Gas Detector
Figure 16. drone in solidworks

Figure 17. drone in solidworks
Controller’s Hardware:

Mobile-Device Holder: Attached on top of controller to hold any cell phone as well as an IPad.

Joysticks: The controller’s left and right joysticks provide direct manual control of drone and physical control mechanisms for use with Smart Shots.

Screen: The controller’s full-color screen provides live in-flight data and prompts for certain Solo functions
Power Button: to start controller the power button is to be held until the controller startup screen appears to power the controller.

Fly Button: The Fly button allows the control of Solo’s main flight functions: starting motors, takeoff, land, and activating GPS flight.

Return Home: allows to end flight automatically at any point by returning Solo to its Original launch point and landing.

Pause Button: emergency air brake. Press Pause to stop Solo and hover in place at any time.

Option Buttons (A&B): You can program A and B to specific functions using the App. By default, the A button is assigned to Cable Cam and the B button is assigned to Orbit.

Antennas: The controller’s long-range dipole antennas communicate with Drone’s system during flight.

Gimbal Controls: used to control the Solo Gimbal. They can also be used in some Smart Shots. [9]

➢ 3DR SOLO Drone Experiment
  o This is SOLO 3DR the team bought following a constrain (using an existing solution)

3DR Solo is a small unmanned aerial vehicle (UAV) powered by four motors and four propellers. Solo’s onboard computers control navigation, attitude, and communications in flight while sending real-time telemetry and video output and receiving control inputs over the 3DR Link secure Wi-Fi network. Solo is optimized for capturing aerial video using a GoPro® HERO camera.

➢ Report:

The main purpose of this report is to use the drone over the mine for several purposes and understand the working principle and procedure of the use of drone having a camera fitted on it. The main purpose of the camera is delivering the video from the top of the mine. One of the main objectives of this report is to understand the drone control and it practical application of flying over the mine.

Drone is an unmanned aircraft. There is no person who is driving the drone. Drones are controlled and flown by the humans who control them through the remote and use it for several purposes.

On April 26th, we had set up an appointment/meeting with the Montana resources rescue team and inform them about our project. They told us that drones can be used for different purposes so first you have to show the permit from the college and then you have to take the permission from the government to do the experiment relating the drone. These are compulsory
things and they also told us that you must have all the tools for the experiment as well as leader who will guide them to do the experiment.

For this purpose, we, as planned, bought a drone to do the experiment. We complete all the set ups that have to be done before operating the drone and went to the mine supervisor to allow us to do the experiment. They told us that doing experiment for the first time using the drones can be risky as far as the regulations for the mine, workers as well as for the students, so first of all, you have to see the safety video and our safety will tell you about the hazards of the mine and how can we reduce the risk of any loss from it. So, they take us to the safety team room where safety team representatives guide us about the mine working safety procedure as well as reviewing the rules and regulations to do the experiment. The rules and regulations mentioned by them are as follows:

- Fly the aircraft below the 400 m and keep it away from all the obstacles.
- Keep it in the sight all the time.
- Remain clear and do not interface with manned aircraft operations.
- Stay away from people and stadiums.
- Don’t fly overweight aircrafts.
- Don’t be careless or reckless about your drone. You can be fined for endangering people and other aircrafts. [10]

After watching the safety video and understand the rules and regulations, we went and set our equipment to fly the drone over the mine. Because of high wind conditions, the Drone air speed sensors continued to send non-calibrating signals to the Drone controller. The Drone was not capable to fly because of high wind conditions. We had to make another attempt to fly the Drone on another day, but outside the mine area. There was a problem with We fly our drone over the mine and they did not allow us to take the picture or the video of it as it is illegal. We tried talking to them to take me the photo of the flying drone but they did not allow us. We checked the surfaces of the mine and did not able to collect the data and they did not allow us to take the photos. Yet. They told us that if we would like to take photos/collect any sort of data from the mine, we would have to set another appointment to prove that it is going to be for a senior design project and the data will not be leaked whatsoever. If we had the time, we would set another appointment with them and request them again to allow me to take the pictures as it is part of my project.
Figure 19. Solo’s Drone [10]

Figure 20. Solo [10]
Autopilot

Solo would use a Pixhawk 2 autopilot running ArduPilot Copter software. ArduPilot is open-source flight control based on the MAVlink communication protocol. Pixhawk 2 runs an ARM Cortex-M4 STM32F427 processor with 2 MB of flash memory and 256 KB of RAM. Combined with an array of CAN, I2C, SPI, PWM, and UART interfaces, Pixhawk 2 uses a suite of onboard sensors to calculate solo’s orientation and motion in flight. This data is input into ArduPilot’s inertial navigation and position-estimation algorithms and combined with control inputs to send commands to solo’s propulsion system. [11]

Architectural Overview for 3DR

Solo is a Linux system (iMX.6 running Yocto Linux) connected to a Pixhawk autopilot. The Pixhawk controls flight modes, stabilization, and recovery in the case of an RTL event (return to-launch). Pixhawk communicates over the MAVLink telemetry protocol to both the on-board Linux computer and downstream devices like the Controller and mobile phone Solo apps. The Linux system controls high-level operation of the copter: smart shots, camera and gimbal control, mobile app communication, and accessory interaction are all implemented in this layer. [11]
Smart shots are used to pre-program complicated flight paths. The Smart Shot framework build upon DroneKit, and adds support to pause and resume shots (storing the flight state) and re-map controller buttons and sticks during a shot.

The functions in the solo Smartshot are:

- Handling RC input. Remapping the control sticks to perform alternate functions. For example, this is used in Cable Cam to allow the right stick to control Solo’s position along the virtual cable instead of its position relative to earth.
- Buttons. A and B can be mapped to provide shortcuts like setting fixed waypoints or recording a position.
- Resume from brake. When the pause button is pressed, the drone goes into BRAKE mode and the flight state is lost. This function is called after five seconds to restore...
the flight mode state and prepare the shot to continue once the user resumes controlling Solo.

- **Accessing Software**

Solo can be accessed via Wi-Fi. When Solo and its Controller are booted, the Controller creates a private network between the two devices. Any computer or smartphone can connect to this network and access these devices via their IP addresses. The network assigns particular addresses to the Controller and to Solo.

All other devices are assigned within a particular range:

- 10.1.1.1 — Controller
- 10.1.1.10 — Solo
- 10.1.1.100–10.1.1.255 — Computers, phones, or other devices on the network SSH is a mechanism to access the shell of another device securely. SSH is the primary mechanism by which you can access Solo's internals. You can SSH into either Solo or the Controller. To SSH into Solo, an SSH client is required. On Windows Putty or Cygwin with OpenSSH can be used while on Linux or OS X OpenSSH is already installed. [12]

- **Video Pipeline**

The GoPro video device (/dev/video0) is acquired exclusively by Solo's video encoder (sndast).

The following video pipeline is applied:

- GoPro.
- HDMI cable.
- HDMI encoder.
- iMX6 (h.264 encode/gstreamer).
- Wi-Fi (UDP).
- Controller (h.264 decode/hdmi output/UDP relay to phone).
- Wi-Fi (UDP).
- App. [13]

- **Solo Software and Hardware Interface**

The Solo system presented on Figure 22 includes: Solo, the Controller, and the Solo App. The operator interacts with the controller and app on the ground, and the controller communicates with Solo during flight. [14]

- **Specifications and Operating Parameters**

Solo is a quad-rotor aerial vehicle powered by the 3DR Pixhawk 2 autopilot system and APM:Copter flight control software. Solo communicates with the controller and Solo app over the 3DR Link secure Wi-Fi connection.
Autopilot: 3DR Pixhawk 2
Flight code: ArduPilot Copter
Control: 3DR Solo Controller
Wireless communication: 3DR Link 1.0
Frequency: 2.4 GHz
Height: 10 in. (25 cm)
Motor-to-motor dimension: 18 in. (26 cm)
Propulsion: 880 KV motors, two clockwise rotating motors and two counterclockwise rotating motors
Propeller: 10 in. x 4.5 in. (25 cm x 11.4 cm)
Weight with battery: 3.3 lbs. (1.5 kg)
Controller battery life: 3 hours
Extended controller battery life: 6 hours
Controller battery: Li-ion 2600 mAh 7.2 Vdc (5200 mAh for extended battery)
Power: Electric (rechargeable lithium polymer battery)
Battery: Lithium polymer, 5200 mAh, 14.8 Vdc
Battery weight: 1 lb. (.5 kg)
Estimated flight time: 25 minutes*
Maximum altitude: 328 ft. (100 m)
Range: .5 miles** (.8 km)
Payload capacity: 1.1 lbs. (500 g)
Cruise speed: 5.7 mph (2.5 m/s)
Maximum speed: 55 mph (25.5 m/s)
Maximum climb rate: 11 mph (5.0 m/s)
Maximum descent rate: 5.5 mph (2.5 m/s)
Headwind limitation: 25 mph (11 m/s)
Crosswind limitation: 25 mph (11 m/s)
Camera: Streaming video compatible with GoPro® HERO 3, 3+ or 4
Full compatibility with GoPro® HERO 4
Solo app compatibility: iOS 8.0 or later / Android 4.3 or later
Operating temperature: 32° F - 113° F (0° C - 45° C)
Operating relative humidity: 0-85% RH. [15]
- SoloLink Manager — Proprietary (3DR)
- DroneKit (solo version) — BSD (The BSD license is a class of extremely simple and very liberal licenses for computer software that was originally developed at the University of California at Berkeley (UCB). Apr 19, 2004)
- pymavlink (solo version) — LGPL (Lesser General public Licenses)
- MAVProxy (solo version) — GPL (General Public license)
- Ardupilot (solo version) — GPL (General Public license)
- STM32 Loader — GPL (General Public license). [15]

## Conclusion

The mining industry has recorded various unfortunate incidents in which many mine workers have lost their lives due to high-wall collapse, fire explosions due to gas accumulation, etc. Many of these accidents occurred due to the workers not able to reach some of the inaccessible areas in the mines, making them skip the safety assessment. This leads to the miners working in area with existing potential hazards. Mining Unmanned Aerial Vehicles (UAVs) - also known as Drones - prove to be of great help to collect accurate spatial data from above reducing the involved risk by minimizing the involvement of human worker. It can carry out the 3d mapping of the mine with ease and hence help in damage assessment and control for pre and post blast inspections. Drones equipped with gas sensors can detect the presence of harmful and combustible gases and thus prevent explosions. For the same purpose a UAV quadcopter was designed with the following main characteristics: Self-stabilizing, attached camera for live feed pictures, Infrared Sensor (for measuring distances), good battery life, simple to operate, and operating temperatures of -20°C to 50°C.

The mine rescue team has selected an existing UAV to test the usage of Drones in mine rescue/safety operations. Due to cost and time constrains, the team chose to test an existing Drone (Model) to make preliminary exploration and testing. The Drone overall cost was $1200 (One thousand and two hundred USD) including mounted camera and batteries.

For this Drone, the camera attached to the done provides live feed from open areas or enclosed spaces (tunnels), reaching out to the areas which are no possible to reach manually. The drone was designed to be durable and feasible (not expensive to make). The controller of the Drone is easy to operate, equipped with a mobile holder to easily watch and control the drone’s movement via the live feed. The controller has the following buttons for easy control of the Drone. The human constraint of not being able to operate under -20°C was rectified as the drone is able to operate in those conditions.

An attempt was made by the team to fly the Drone over the open mining area in Montana Resources Mining operation in Butte, MT on April 22nd, 2016. Due to severe windy conditions, the Drone was not capable to fly on that day, the sensitive navigation system was not functioning accurately due to strong winds. A second attempt was made later in an open area near the mining operation. In summary, the testing of this Drone proved that Drones are cost effective in mentoring operations, easy to assemble, easy to obtain from the open market, and do not need much of training and experience to operate.
However, the team found that under some severe weather conditions – high winds – the Drones may encounter some technical problems due to its navigation system that may limit their use under such conditions.
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