DRIFT: Drone-Rover Integrated Fire Tracker System

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Wildfire reconnaissance and mitigation efforts are a primary concern for the United States Department of the Interior and National Forest Service. The critical consequences of climate change are becoming more prevalent with longer fire seasons throughout the Western United States [1]. The fire seasons are characterized by hotter and drier conditions, allowing for a wildfire to easily start and rapidly spread with the potential to burn millions of acres and cause billions of dollars in property loss. The National Forest Service (NFS) predicts that it will spend over half of its budget in the fight against wildfires within the next decade [2]. Wildfires can have devastating impacts on communities, ecosystems and wildlife, but also pose a dangerous threat to the fire fighters responsible for their mitigation and containment. A Mother Rover-Child Drone Firetracker System will assist firefighters by traveling to locations at risk of wildfire and gather environmental data which it then transmits back to the designated ground station. This provides information on a fire's intensity, severity, and extent while firefighters remain a safe distance away from the threat. Team DRIFT is a group of eleven undergraduate Aerospace Engineering Sciences students at the University of Colorado Boulder currently developing the Mother-Rover for the Firetracker System with the purpose to secure and carry the Child Drone (Unmanned Aerial Vehicle) to a desired location of interest. The development of this Mother-Rover involves integrating the hardware and software of the already completed Child Drone and Landing Platform. The Mother Rover, approximately 46.3 by 58.9 inches, weighing 450 lbs and driven by a remote operator, is capable of traversing rough terrain, defined by small gravel, fine dirt, and slopes up to 20 degrees. Due to the image recognition system utilized on the landing platform for the autonomous landing of the Child Drone, the landing platform must be level to within 3.5 degrees in order for the child drone to safely take off and land. Therefore, the Mother Rover utilizes an internal leveling jack system to level in the landing platform to within 3.5 degrees if the child drone is to be deployed on a slope. The considerable weight of the Mother Rover presents a unique engineering challenge as it must be capable of traversing over the defined rough terrain while also maintaining the security of the onboard Child Drone. The design solution for this Mother Rover and associated leveling system will be discussed in this paper.

Nomenclature

COM	=	Common Ground Pin
CS	=	Chip Select
DIR	=	Direction Pin
EN	=	Enable Pin
GND	=	Ground
$I2C$	=	Inter-Integrated Circuit
LP	=	Landing Platform
$MOSI$	=	Master Out Slave In
PWM	=	Pulse-Width Modulated
SCK	=	Serial Clock
SP	=	Sensor Package
SPI	=	Serial Peripheral Interface
STP	=	Stop Pin

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I. Introduction

The purpose of the Drone-Rover Integrated Flight Tracker (DRIFT) project is to design, manufacture and test a mother rover (MR) capable of securing, carrying, and leveling an Unmanned Aerial Vehicle (UAV) to a desired location of interest as a crucial portion of the natural disaster observation Fire Tracker System. The Fire Tracker System consists of the mother rover, child drone, landing platform, and ground station. The full Fire Tracker concept of operations is shown in Figure 1 with DRIFT's mission outlined in red dashed lines. Numbers located next to the following mission description correspond this CONOPS figure. The mother rover is deployed at a specified location (1) where it then navigates through rough terrain while carrying the child drone to a specified location of interest as commanded by the ground station (2). Once the mother rover arrives at the location of interest it levels the landing platform (3), the ground station commands the child drone to deploy, navigate to a specified location, and deploy a sensor package to gather scientific data pertaining to the surrounding area (4-6). Once the sensor package has been released, the child drone then returns to the mother rover where it autonomously lands on the landing platform where it is secured (7). The mother rover returns to the ground station (8).

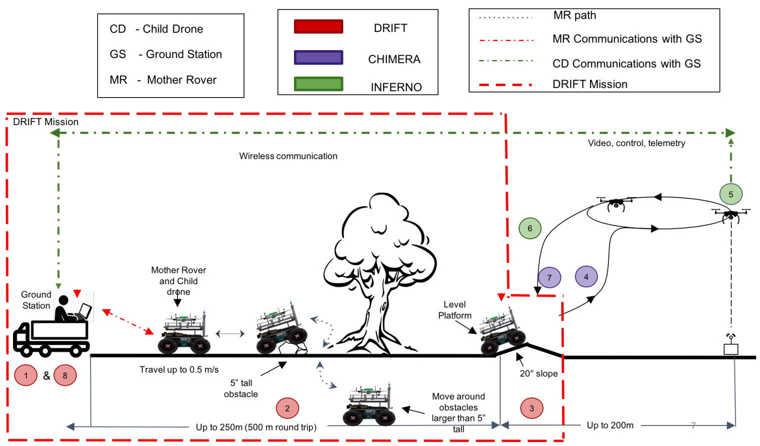

Fig. 1 DRIFT Concept of Operations

A. Field of Application

The critical consequences of climate change are becoming more prevalent with longer fire seasons throughout the Western United States [1]. These fire seasons are characterized by hotter and drier conditions, allowing for wildfires to easily start and rapidly spread. The National Forest Service (NFS) predicts that it will spend over half of its budget in the fight against wildfires within the next decade[2]. This, in turn, leaves a limited budget for the NFS's other responsibilities including research, restoration, and conservation. Therefore, the purpose of the Fire Tracker System is to provide a low cost means to remotely identify areas susceptible to wildfires. Should a wildfire occur, the Fire Tracker System may be used by the emergency response team to monitor conditions in the surrounding regions and alert the operator to danger.

B. Rationale of Design Choices

The mother rover's translational system is the key component in its ability to maneuver over rough terrain consisting of loose dirt, gravel, and grass as well as obstacles up to 5 inches tall and up 20° slopes. This translational system consists of all components ranging from the chassis structure to wheel and motor types as well as other associated components. This system must to be sturdy enough to hold the weight of the drone, platform, and it's own chassis as well as be robust enough such that the mother rover can scale the defined rough terrain. The translational system must be able to travel safely such that the rover itself does not tip over or cause any damage to the child drone, as well as must be able to level the landing platform once it reaches its desired GPS location. A 4-wheel fixed-chassis design was chosen due to its simplistic design while also allowing mechanical and electrical integration with other components, stability, allowing for requirements to be met. This design has shown great success in the automobile industry, therefore giving Team DRIFT confidence in its success for the Fire Tracker System. Figure 2 is a CAD rendering of the 4-wheel fixed-chassis design.

A method of leveling the landing platform is critical to mission success as the CD (Child Drone) is only capable of taking off and landing at inclinations less than 3.5°, because the rover will experience slopes up to 20°. Without a successfully integrated leveling system, the CD will not be able to land on the platform while the rover is stationary on any non-leveled ground which limits the Fire Tracker System performance capabilities. An internal leveling jack system was chosen due to its lightweight, little or no custom components, ability to meet all leveling requirements and its ability to be easily mechanically and electrically integrated with other portions of the rover. Figure 5 (located in Section IV B) is a CAD rendering of the internal leveling jack system.

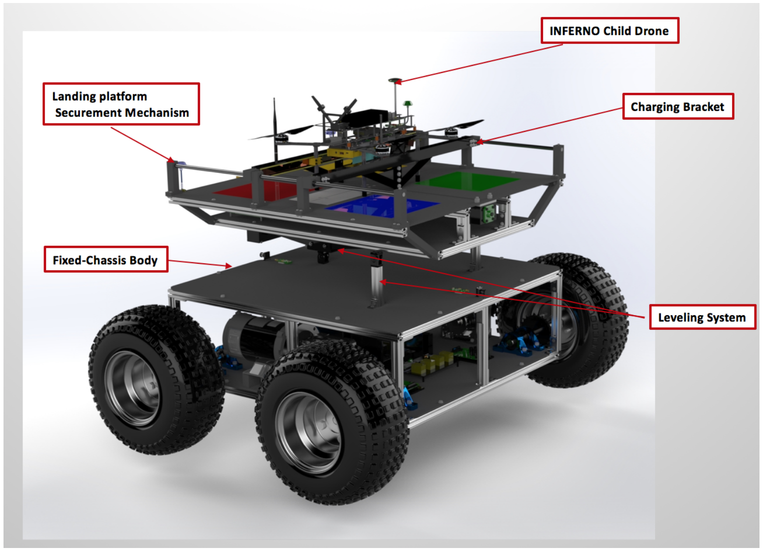

Fig. 2 4 Wheeled Fixed-Chassis Translational System

II. Design Objectives

As stated previously, the primary objective of the DRIFT project is to design, manufacture and test a mother rover capable of securing, carrying, and leveling an Unmanned Aerial Vehicle (UAV) to a desired location of interest in remote and hazardous areas. The rover will be mechanically and electrically integrated with the already completed landing platform and child drone. The translational system must be able to secure and carry the landing platform and child drone as it traverses up to 250 m away from the ground station to a desired location of interest. Once it arrives at this location of interest, the mother rover must be able to level the landing platform within 3.5°of gravity 0 such that the child drone is able to autonomously takeoff and land.

A. Primary Design Criteria and Functional Requirements

Functionally, the mother rover must be capable of traversing up to 250 meters away from the ground station over the defined rough terrain while securing the landing platform and completes the Fire Tracker System following the two heritage projects CHIMERA and INFERNO which developed the Landing Platform and Child Drone respectively. DRIFT's primary design criteria will focus on the mother rover's translational system as well as its associated leveling system for the landing platform. There are 5 functional requirements that are necessary to be completed in order to verify DRIFT's success. Table 1 lists all the functional requirements which will be used to measure the success of the critical project elements.

Table 1 DRIFT's Functional Requirement

Functional Requirement	Description
FR 1.0	The MR shall integrate with the attached landing platform such that it is permanently fixed and securely carries the CD without tipping while traversing the defined rough terrain
FR 2.0	The MR shall receive commands from the GS at a rate of 5 Hz
FR 3.0	The MR shall transmit data to the GS at a rate of 30 Hz
FR 4.0	The MR shall traverse 250 m away from the GS to a specified GPS location over rough terrain defined by varying slopes and obstacles. The MR shall navigate over and around the obstacles. The MR shall return to the GS after the mission is complete
FR 5.0	The MR shall position itself for the CD to take-off and land safely such that it is able to be secured by the MR's securement mechanism.

FR 1.0 requires the integration of the MR with the associated heritage projects to complete Fire Tracker System. DRIFT's project will securely fix the LP to the MR so that the CD can perform its mission in the specified environment. FR 2.0 and FR 3.0 is an expansion of the software requirements from the heritage projects. The MR will have a separate communication line from the LP and CD to the GS. The MR will receive commands from the GS and transmit required data back to the GS. These commands include for the MR to level the LP, to traverse forward/backwards, turn, and to turn the video feed on and off. The MR will transmit its GPS location, live video feed, and leveling status back to the GS. FR 4.0 defines the translational capabilities needed of the rover as it traverses the defined rough terrain. FR 5.0 is a continuation from CHIMERA's platform requirement for the CD to take off and land safely. The platform must be leveled within ± 3.5° from 0° in order for the CD to recognize the AR tags on the LP needed for autonomous landing.

B. Leveling System Derived Requirements

The MR's leveling system deigned for the LP is critical to mission success as the CD is only capable of taking off and landing at inclinations of less than 3.5°, while the rover will experience slopes of up to 20°. Without a successfully integrated leveling system, the CD will not be able to land on the platform while the rover sits on any non-leveled ground. Table 2 is a detailed requirement for FR 5.0.

Table 2 FR 5.0 Derived Requirements

Functional Requirement	Description
FR 5.0	The MR shall position itself for the CD to take-off and land safely such that it is able to be secured by the MR's securement mechanism.
Design Requirement	**Description**
DR 5.1	The MR must level itself within 3.5° after coming to a complete stop.
DR 5.1.1	The MR will use an accelerometer to measure the angle of the LP with respect to level ground.

C. Translational System Derived Requirements

The translational system has two functional requirements that must to be achieved to satisfy the objectives of the project and to meet the customer's requirements. Table 3 and Table 4 shows the associated breakdown for FR 1.0 and FR 4.0.

Table 3 FR 1.0 Derived Requirements

Functional Requirement	Description
FR 1.0	The MR shall integrate with the attached landing platform such that it is permanently fixed and securely carries the CD without tipping while traversing the defined rough terrain.
Design Requirement	**Description**
DR 1.1	The MR shall support the structural size and weight of both the LP and CD.
DR 1.1.1	The MR shall support the 0.9 m by 0.9 m LP frame such that it is securely fastened for translational motion.
DR 1.1.2	The MR shall support the combined weight, 24.95 kg (55 lbs) of the LP frame and CD.
DR 1.2	The MR shall incorporate the preexisting software/hardware of the LP.
DR 1.2.1	The MR and LP shall communicate to the GS through two separate lines of communication.
DR 1.3	The LP shall be fixed permanently to the MR.

Table 4 FR 4.0 Derived Requirement

Functional Requirement	Description
FR 4.0	The MR shall traverse 250 meters away from the GS to a specified GPS location over rough terrain defined by varying slopes and obstacles which require the MR to navigate over and around them. The MR shall return to the GS after the mission is complete.
Design Requirement	**Description**
DR 4.1	The MR shall travel at a speed within the range of 0 - 0.5 m/s in forward and reverse.
DR 4.2	The MR shall have enough on board power to travel a total distance of 500 m without needing recharging.
DR 4.2.1	The MR batteries shall have enough power available to provide to the motors in order to traverse the defined rough terrain.
DR 4.3	The MR shall turn 90° in 3.05 m (10 ft) radius.
DR 4.4	The MR shall execute received commands.
DR 4.5	The MR shall traverse up and down a 20° slope.
DR 4.5.1	The MR motors shall provide enough torque to traverse up and down a 20° sloe with a speed up to 0.5 m/s.
DR 4.6	The mother rover shall traverse over a maximum of 12.7 cm (5 inch) tall obstacles.
DR 4.6.1	The mother rover shall maneuver around obstacles greater than 12.7 cm (5 inches) tall in height.

D. Levels of Success

Project DRIFT's success will be measured by how each individual subsystem can contribute in achieving project's outlined objectives and requirements. Using the previously developed CD (INFERNO) and LP (CHIMERA), the MR will integrate with the Landing Platform (LP) in order to extend the range that the CD will be able to cover during its mission. Currently, as received from the previous project, the CD can be commanded to take off and land autonomously, while the LP has the capability of securing and recharging the CD. The CD mission includes taking off, deployment of the SP, an observational flight, and landing. In this mission, the CD transmits video and data the GS and the SP transmits data to the GS separately.

DRIFT will increase the Fire Tracker System's competence by building a MR that can traverse through specified rough terrain, level the landing platform on a slope up to 20°, and relay live video feed and other pertinent data back to the GS. In order to define the capabilities of the MR, various levels of success have been developed. Level 1 represents the minimum goals that must be accomplished by the team for the project to be considered successful, whereas Level 3 represents the highest level of success that the team plans on accomplishing.

1. Translational System Levels of Success

There are three levels of success for the translational system, which includes navigation and structural securement. The first level of success is satisfied when the MR can traverse over a flat, dirt path while supporting the attached LP and CD. The LP and CD weigh 25 kg and is 0.914 m x 0.914 m (36 in x 36 in) wide. The second level is achieved when the MR can traverse rough terrain that contains obstacles less than or equal to 0.127 m (5 in) and can overcome slopes less than or equal to 10^o. These need to be achieved while securing the CD and LP that is attached to the MR. The third level of success is satisfied when the MR can maneuver around obstacles over 0.127m (0.5 in) tall and can overcome slopes less than or equal to 20^o. The maximum speed of the MR is 0.5 m/s for all three levels.

2. Leveling System Levels of Success

The leveling system is a subsystem that is formed to satisfy the LP's requirement from project CHIMERA, which is to level the platform to $0^o \pm 3.5^o$ for the drone to take off and land. Since the MR will travel on a flat path for the first level of success of the translational system, there is not a first level of success for the leveling system. This is because on a flat path leveling would not be needed. To achieve the second level of success, the MR needs to level the platform to $0^o \pm 3.5^o$ on a 10^o of slope. The third level of success is satisfied when the MR can level the platform on a slope up to 20^o. The MR needs to be in a stationary position to level the platform.

E. Critical Project Elements

The translational system has three primary critical project elements: mass, power and ease of integration. The MR weighs about 450 lbs which consists of both the LP and CD, two motors, two batteries and four 9-inch diameter wheels. These parts need to be integrated to the fixed body chassis frame to build the MR and need to be powered for the entire round trip mission. The critical elements for the leveling system is the accuracy of the leveling indicator. This accuracy explained in Table 2 is decided based on the accuracy from CHIMERA's platform that need to be achieved for the CD to take-off and land safely. All the elements for both the systems are crucial in order to complete level 3 of success and therefore are critical for this project.

III. Design Methodology

A. Driving Requirements and Design Choice

As stated in Section II, the driving requirements behind the translational system and leveling system are that the mother rover must be able to traverse the desired rough terrain while securely carrying the LP and CD, and the mother rover must be able to level the landing platform to within 3.5° such that the child drone is able to safely takeoff and land. To meet these requirements, several types of translational and leveling systems were considered in the design phase. For the leveling system, three design choices were initially considered: external leveling jacks, ball and cap, and internal leveling jacks. A trade study was then conducted to determine which method would be most effective, based on metrics of time, accuracy, cost, mechanical complexity, and manufacturability. The results can be seen in Figure 3. For the translational system, three design choices were initially considered: rocker-bogie, continuous tread, and four wheeled fixed-chassis. A trade study was then conducted to determine which method would be most effective, based on metrics of time, mechanical complexity, cost, power consumption, terrain capability, and platform safety. The results can be seen in Figure 4.

Metric	Weight	External Jacks	Ball and Cap	Internal Jacks
Time Required	15%	2	2	4
Accuracy	15%	4	5	4
Cost	25%	4	3	4
Mechanical Complexity	25%	3	4	4
Manufacturability	20%	3	2	4
Total	**100%**	**3.25**	**3.2**	**4**

Fig. 3 Trade Study of Leveling System Design Solutions

Metric	Weight	Rocker Bogie	Continuous Tread	4 Wheel Fixed Chassis
Time Required	10%	2	1	4
Mechanical Complexity	10%	3	2	5
Cost	10%	2	2	4
Power Consumption	15%	2	1	4
Terrain Capability	30%	5	4	3
Platform Safety	25%	5	2	4
Total	**100%**	**3.75**	**2.35**	**3.80**

Fig. 4 Trade Study of Translational System Design Solutions

From the the trade study, it was determined the internal leveling jacks system to be the best design for DRIFT's mission. The internal leveling jacks system offers reliable accuracy at an unsubstantial cost, but with the potential for more time required for meodeling and integration than the other design options. This system consists of almost entirely consumer off-the shelf parts and therefore eliminates the need for complex manufacturing. This system was chosen due to its reliability, minimized manufacturing, and ability to meet all set requirements.

Again, from the trade study, it was determined that the four wheeled-fixed chassis translational system would be the best design for DRIFT's mission. This fixed chassis system is simplistic compared to all other design solutions, and has been used in many other applications such as ATVs. It has proven to be a highly reliable design and capable over rough terrain. This design minimizes the number of moving parts, reducing risk and increases the chances of mission success. Its simplisitic design also allows for simple manufacturability.

B. Feasability Analysis and Preliminary Testing

It was necessary to validate the feasibility of the leveling and translational system before moving forward with the design. Feasability analysis with the internal leveling jacks design began with analyzing its rated lift force and height which are 2000lb and 18.75 inches respectively. The leveling jacks must only lift approximately 50lbs and clear approximately 14.8 inches. Therefore, this design is well within budget and weight constraints, and the scissor jack used provide the necessary lifting force and height for leveling the landing platform. A tipping analysis of the entire mother rover was then conducted if the leveling jack was to be completely exteneded. It was proven that under these conditions and on a 20 degree slope, the center of mass will not be located downhill from the rear wheel of the rover, meaning that the mother river is unlikely to tip.

Feasability analysis of the 4 wheel fixed-chassis design began by analyzing a torque and traction model. This model defines the required coefficient of friction between the wheels and ground for the mother rover to not slip at a designated torque provided by the motors and motor drivers. It was proven that even while traversing a 20° slope over a 5 in obstacle, the rover will not slip. Again a tipping analysis was then performed on this translational system, proving that it has a low center of mass and the rover will not tip when the leveling jacks are extended. This preliminary analaysis was used to prove that both translational and leveling design choices are feasbile for the DRIFT mission.

IV. Hardware Design Results

A. Translational System

The translational system is pertinent to the MR because it not only adds mobility to the system, but also support for the MR and LP. To fulfill the requirements for the translational system, the system begins with two 24V DC brushed motors that are mated with reducers, which are both bolted to the MR chassis. Gear sprockets are integrated with chains to transfer the torque generated by the motors to the wheels. The wheel gear sprockets are integrated with keyed steel rotary drive shafts through the use of a keyway. Each drive shaft is connected to two bearings that are bolted to the MR chassis. The drive shafts interface with the wheels through a custom machined flange to function as a wheel hub. The flange is bolted to the wheels and connected to the drive shaft through a press-fitted dowel pin.

Using a torque model built in MATLAB, the torque required to traverse a 20° slope with a rover weight of 449.42 lbs is 842 in-lbs per motor. Two 24V motors that can provide a maximum of about 1070 in-lbs (after an additional 2:1 gear reduction after the output from the motor) are utilized within the translational system to ensure some margin of provided torque. This shall also provide the rover with enough torque to maintain the speed requirement. Since the rover must be able to overcome obstacles less than or equal to 5 inches, the radii of each wheel is 9 inches. The connection of the wheels to the MR chassis through the drive shafts leaves a clearance of 4 inches underneath the rover to ensure that the rover will not bottom out when traversing obstacles less than or equal to 5 inches.

Using the large torque requirements along with a large mass for the rover, appropriate structural components were chosen such that these forces could be transferred safely while holding the rover structure up. First, the drive shaft was chosen as a keyed rotary steel shaft to provide sufficient structural capabilities to hold the entire structure and transfer the torque. Gear sprockets and roller chains were chosen to the ANSI 50 standard ratings to safely transfer the loads. The gears were also chosen at different dimensions as a method to apply the large torque loads needed to power the wheels up the defined rough terrain. The gears diameters were sized as a 2:1 ratio to do this while still providing enough RPM. Next, mounted pillow block, radial ball bearings were chosen to simplify the integration of the drive shafts with the chassis as well as provide the structural strength to hold the weight of the rover. Two bearings will be used to distribute the loading as well as eliminate the torque loading from the weight of the rover if only a single one were to be used, therefore preventing the bearings from realigning. All pillow block bearings are rated to hold thousands of pounds of loading in the radial direction, therefore providing the MR with a large factor of safety. Shaft collars will be placed in between the bearings to provide an extra level of securement for the drive shaft to the bearings since set screws have been known to be unreliable. Next, a custom flange was manufactured out of Al-6061 to act as a wheel hub for simple integration of the drive shaft with the wheel itself. Finally, the rover chassis was constructed using Al-6061 base plates that are 0.25 inches thick to ensure the chassis contains plenty of structural integrity for holding many heavy components. Also, 80-20 T-slotted aluminum beams were chosen to act the skeleton for the chassis for additional structure as well as simpler manufacturability.

B. Leveling System

To allow the CD to autonomously take-off and land, the MR must be able to level the 55-lb LP to within 3.5^o of 0^o on a slope of up to 20^o. This is actuated using a motorized scissor jack rated for 2,000 lbs of lift force, mounted towards the rear of the MR, underneath the LP.The jack is connected to the top of the rover chassis with a T-slotted pivot joint, and integrated to the LP through a ball joint bolted to the LP base, with a custom fixture to the top of the jack. The LP is also connected to the MR chassis at the front through two support points topped with pivot joints, which interface directly with the T-slotted framing of the LP. These assemblies are depicted in Figure 5.

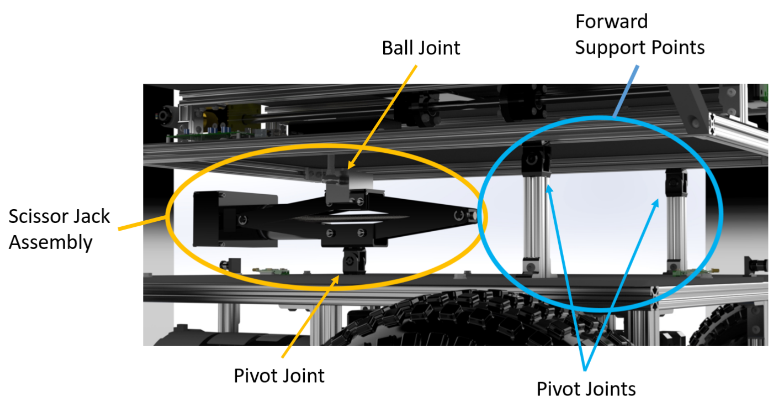

Fig. 5 Schematic of the Translational System

The forward support points are placed 8.5 in from the front, and 19 in ahead of the scissor jack along the rover centerline. This results in a required lift height of approximately 6.5 in on a slope of 20^o. The support points are separated from each other by 20 inches. In its unactuated configuration, the LP rests at a height of 7.5 inches above the top of the rover chassis.

V. Electrical Design Results

A. Translational System

In order to construct a capable translational system, two 12V DC60-4Q Series motor drivers, two MCP 4131 digital potentiometers, and two 24V DC brushed motors capable of supplying 900 in-lb each were purchased. Figure 6 shows the schematic of the translational system. Translational motor #1, motor driver #1, and digital potentiometer #1 all correspond to the left side of the rover. Similarly, translational motor #2, motor driver #2, and digital potentiometer #2 all correspond to the right side of the rover.

At the left of Figure 6, two 12V 100Ah batteries will be placed in series to provide the motors 24V through the motor drivers. With an estimated current draw of 40A/h. After accounting for a 20% battery inefficiency, the provided mission duration is 1.82 hours. According to the mission requirements, if the rover is traveling at approximately 0.25 m/s on average due to changes in direction and motion at 0.5 m/s for 500 m, the calculated required mission duration is 0.56 hours. Therefore, with the two 12V 100Ah batteries, the mission has a duration safety factor of 3.25.

The two resistors serve as a voltage divider circuit to calculate the instantaneous voltage across the combined 12V batteries. This small component of the circuit serves as the system's battery monitor. It is likely that a second battery monitor will be put in place to measure the voltage of each battery to ensure that one battery is not depleting faster than the other to prevent unwanted charging of the second battery.

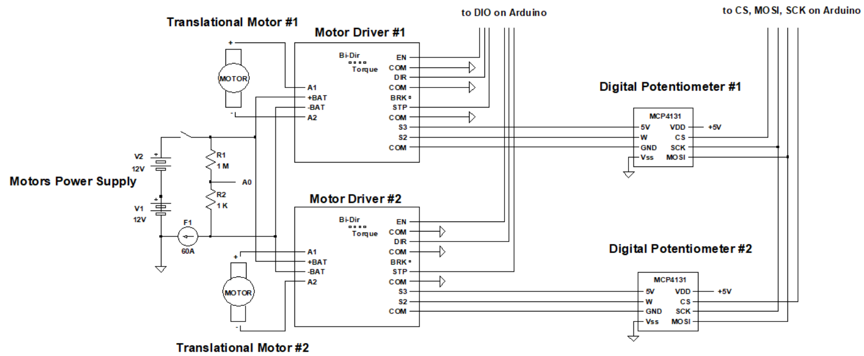

Fig. 6 Schematic of the Translational System

Moving right, the two 24V DC brushed motors draw 20A continuously while outputting approximately 900 in-lb each. Figure 7 shows the speed-current-torque curve for each of the motors. Using a model to compute the maximum torque necessary to traverse a 20° slope with our rover weighing 449.42 lbs results in a required torque of 842 in-lbs per motor. Therefore, the expected current draw from the motors is approximately 40A/h.

Two DC60-4Q Series motor drivers capable of outputting 20A continuously with a one-minute peak current output of 60A were chosen due to their capability with the motors. The EN (enable), STP (stop), and DIR (direction) pins are controlled via DIO (digital input output) pins on the Arduino Mega utilizing 5V logic high and 0V logic low. Additionally, two digital potentiometers were required to be implemented into the system in order to utilize speed control of the motors. These digital potentiometers communicate with the Arduino Mega via SPI (serial peripheral interface) using the SCK (serial clock), CS (chip select) and MOSI (master out slave in) data pins. Although speed control will not be used for constant varying speed, it was observed that slowly increasing the speed of the motors decreases the transient peak current when first turning on. This will prevent high current draws through the motor driver which would cause damage when above 60A. Therefore, the only time for which the variable speed will be used is when the motor are starting from a stop. In order to prevent a current above 60A to be drawn through the motor driver, a 60A slow-blow fuse will be placed between the battery and motor driver.

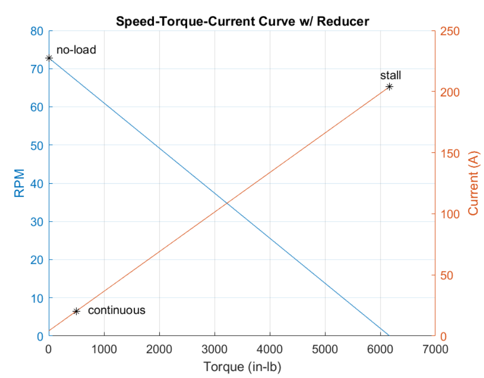

Fig. 7 Speed Torque Current Curve with Reducer

B. Leveling System

The electrical schematic for the leveling system can be seen in Figure 8 and is comprised of a scissor jack motor, a motor driver, two limit switches, and a 12V 100Ah battery.

The scissor jack motor is capable of lifting 2,000 lbs. Although this weight exceeds our requirement of lifting approximately 55 lbs enormously, the scissor jack motor was chosen due to its low cost and ability to be redesigned electrically. After testing the current draw of the scissor jack when lifting 55 lbs, the continuous current draw at 12V was approximately 2.5A. The transient peak current when starting to lift 55 lbs is 13A. Therefore, we only expect to draw approximately 0.03A in total during the mission. This is assuming that the total time the motor is running is two minutes. This approximation was found by timing the scissor jack to fully extend and providing a safety factor of 2.

Furthermore, because the transient peak current draw of the motors is 13A, we had to choose a motor driver that could withstand a current draw of that magnitude. The IRF7862PBF motor driver produced by Pololu is capable of handling 15A, and 21A with the addition of a heat sink. However, the heat sink is not necessary due to the maximum transient current draw of only 13A. The motor driver is controlled via two pins. The DIR pin controls the direction of the motion of the scissor jack. A DIO pin from the Arduino Mega control the DIR pin by reversing the polarity of the voltage to the motors by utilizing 5V logic high and 0V logic low. The PWM (pulse width modulated) pin controls the speed of the motor according to the duty cycle of the signal provided by the Arduino Mega analog output pins.

Two limit switches are included in the system in order to prevent the scissor jack from moving too high or too low and damaging the motor. In order to implement them into the electrical system, they will act as a switch between the PWM output from the Arduino Mega to the PWM input to the motor driver. Two separate PWM signals will be generated by the Arduino Mega; each to control the upwards and downwards motion of the scissor jack motor. However, only one PWM signal will be output at a time because the scissor jack will only move either upwards or downwards. Therefore, for example, if the up limit switch is triggered, the down PWM signal can still be sent but the motor can only move downwards. The same goes for the opposite direction and corresponding limit switch. The GND (ground) pin is connected to the Arduino Mega's common ground. +V is the positive voltage input from the 12V battery to the motor driver and GND is the negative battery input to the motor driver. OUTA represents the output signal to one end of the motor and OUTB is the second output signal to the opposite connection of the motor. The two diodes protect the Arduino Mega from reverse current from one PWM back into the second PWM pin.

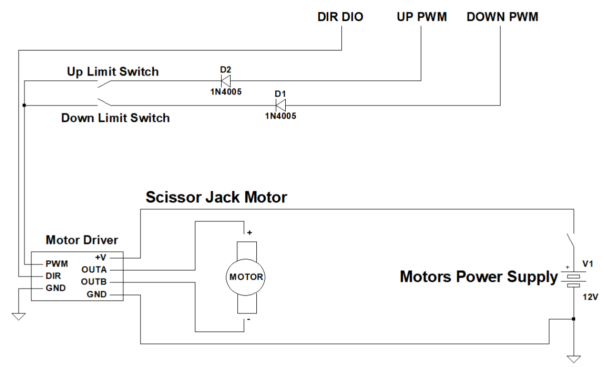

Fig. 8 Schematic of the Leveling System

Additionally, only one of the two 12V batteries is shown in Figure 8 for simplicity. The power for the scissor jack motor will branch from the two 12V batteries in series to provide the motor driver and motor the required 12V.

VI. Software and Communications Design Results

A. Translational System

In order to control the rover translational motion, two DC60-4Q Series motor drivers, and digital potentiometer are connected to Arduino Mega pins and controlled via DIO (digital input output) pins. The rover will utilize skid steering for it's turning and in order to archive this the left and right motor has to move in different directions. This is done by having the DIR (direction) pins to be in different state of HIGH and LOW for each driver. The flowchart in Figure 9 shows the complete logic of the motor control. The user will be sending input that is an alphabet F-forward,B-backward,L-left,R-right or S-stop to control the rover and based the input sent, the motor driver will send the command to the motor to make the rover move.

B. Leveling System

In order for the CD to initiate flight, the platform from which it takes off must be level to within 3.5 degrees of the horizontal. In order to do this, a simple control loop is implemented into the system. The Arduino first reads the pitch and roll from the Inertial Measurement Unit (IMU), then checks whether or not the rover has been positioned so that the roll is in the allowable tolerance of uphill positioning such that the leveling system is able to level the platform within 3.5^{deg}. If the rover has not been positioned correctly, the rover will send a message to the user requesting adjustment to the positioning. Once the roll requirement has been satisfied, the Arduino will check if the pitch is leveled, if not the Arduino will send a high or low input to the direction control of the jacks, and raise or lower the jack as required. This method is shown in Figure 10. Once the platform has been leveled, the rover will notify the ground station.

After leveling, the rover can also reset back to its original position. At the beginning of the leveling process, the

Arduino saves the beginning value of the pitch. This pitch is then used to have the platform level back to its original state. Both the leveling and resetting functions have been tested by hooking up the Arduino and monitoring the responses to different given angles. A full scale test is the next step.

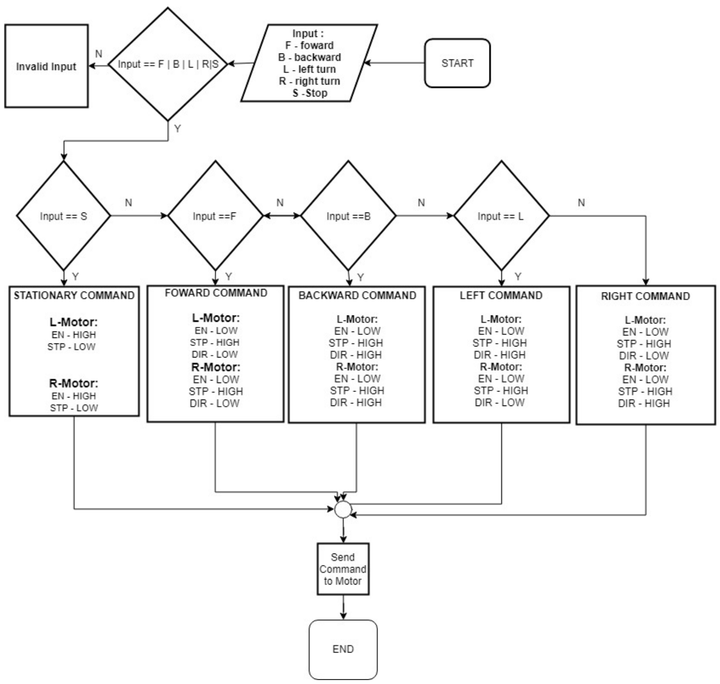

Fig. 9 Motor Control Flowchart

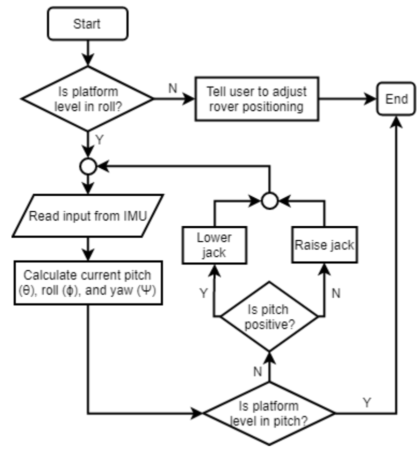

Fig. 10 Leveling Subsystem Flowchart

VII. Conclusion

The combination of the massive translational system and leveling system is critical to complete the functional requirements for the mission of the MR. The task of creating the translational system becomes difficult since it is created around a 55 pound LP and due to the functional requirements that it must traverse over obstacles that are 5 inches tall and up 20° slopes. These challenges would continually increase the weight, which increases the torque required to complete the mission. The creation of a leveling systems seems simplistic on the surface, but it is challenging due to the full integration of hardware, software, and electronics. These successes of the translational system and the leveling system are necessary in order to complete the full concept of operations for the entire Fire Tracker System. The next task is to fully integrate the electronics with the constructed Mother Rover. This is a crucial step as it will deliver power to all components, including the motors and the leveling jack. With the previous successes INFERNO Child Drone and the CHIMERA Landing Platform, the completion of the DRIFT Mother Rover will mark the completion of the Fire Tracker System. The Fire Tracker System will be used to reduce the risk of life and assets when investigating areas that are susceptible or currently experiencing wildfires.

References

[1] "Global Warming and Wildfires," National Wildlife Federation, `www.nwf.org/Wildlife/Threats-to-Wildlife/Global-Warming/Global-Warming-is-Causing-Extreme-Weather/Wildfires.aspx`.

[2] "The Rising Cost of Wildfire Operations: Effects on the Forest Service's Non-Fire Work." United States Department of Agriculture: Forest Service, 4 Aug. 2015.