1. Problem Statement

The increasingly critical consequences of climate change are becoming prevalent in the longer fire seasons throughout the western United States\(^2\). These fire seasons are characterized by hotter and drier conditions, allowing for a wildfire to easily start and rapidly spread, leaving a path of destruction in its
It is projected that the National Forest Service will spend 67% of its budget in the fight against wildfires by the year 2025. This is an extreme increase from the already considerable 50% of its budget dedicated to wildfires in 2015. Therefore, this Fire Tracker project seeks to develop a low cost means to identify and monitor areas especially susceptible to wildfires. If these areas are able to be identified and monitored, lives and property may be saved.

This project consists of a mother rover (MR) and child drone (CD) who travel together to a designated location of interest (up to 1000 meters roundtrip up to a rate of 0.5 m/s) where the CD is then deployed. The MR must have the capability to navigate over rough terrain (defined in a later section) through woods and grasslands to achieve these mission objectives. Once deployed, the CD then carries and deploys a sensor package (SP) that collects and transmits (to a ground station) temperature data of the surrounding area. Once the SP has been deployed, the CD returns to the MR where it is captured and secured. The MR then returns to the ground station and is then retrieved by its operations team. The SP, CD, and landing platform (LP), have been developed in previous years projects. This year’s DRIFT (Drone-Rover Integrated Fire Tracker) team focuses on the development and integration of the MR to achieve established mission objectives. Developing and implementing the MR will allow for greater mobility of the CD and longer mission range for the CD. With the entirety of the MR and CD system complete, the DRIFT team as well as legacy teams will provide a low cost means to keep firefighters safe while investigating locations at extreme risk of wildfire.

2. Previous Work

The Jet Propulsion Laboratory has sponsored a series of legacy projects since 2008, culminating in the INFERNO and CHIMERA projects of the last two years. INFERNO created an autonomous CD that was able to launch, fly along a prescribed flight path, drop a SP containing a temperature sensor, and fly back to the launch zone. CHIMERA developed a landing platform capable of securing and charging the CD. The CHIMERA project also attempted to integrate autonomous landing onto the landing platform (LP), however they could not consistently land the CD. The recharging process was considered dangerous and therefore will not be used in this year’s project. CHIMERA’s securement mechanism was shown last year to be able to secure the CD through significant impacts and complete inversion of the LP. Additionally, the LP was shown by CHIMERA to be capable of commanding the drone to land/deploy and provide live video feed from the CD. DRIFT will inherit INFERNO and CHIMERA and focus on attaching the LP to the MR with an ultimate goal of providing means of for the rover, as well as integrating communications for control, science data, and video feed between the ground station (GS), MR, and CD.

To achieve these goals, the MR must draw from previous project work in remote sensing, autonomous navigation, and wireless data transfer. Similar methods can be seen in both commercial and military applications: everything from self driving cars and UAVs to bomb squad vehicles. Previous work can also extend to NASA’s autonomous rovers currently exploring other planets.

3. Specific Objectives

Using the previously developed CD (INFERNO) and LP (CHIMERA), the MR will attach to the LP in order to extend the range that the CD will be able to cover during its mission. In order to define the capabilities of the MR, various levels of success have been developed. Level 1 represents the minimum that must be accomplished by the MR for the project to be considered successful, whereas level 3 represents the highest level of success that the project plans on accomplishing. The levels of success are broken into five categories that define the MR’s mission profile: operational terrain, the structural capabilities of the MR, how the MR navigates through the terrain, distance the MR can traverse as a function of power and the ability of the MR to communicate with the ground station and CD. The levels of success for DRIFT are shown below.

The various levels of success will be tested physically or through simulation based on testing environment restrictions. For example environments will be constructed to test if the MR is capable of traversing a 20° slope or able to overcome obstacles 5 inches tall. Multiple field tests will be conducted in
order to quantify confidence in the success of the tests. Project deliverables to the course include the Project Definition Document (PDD), Conceptual Design Document (CDD), Preliminary Design Review (PDR), Critical Design Review (CDR), Fall Final Report (FFR), Manufacturing Status Review (MSR), Test Readiness Review (TRR), Spring Final Review (SFR) and Project Final Report (PFR). Weekly status reports, PDD, CDD, PDR, CDR, FFR, FFR, PFR, and the Drone-Rover Integrated Fire Tracker system are all project deliverables to the customer.

4. Functional Requirements

4.1. Functional Block Diagram (FBD)

The DRIFT project is the third portion of the Fire Tracker System, which is also composed of the INFERNO and CHIMERA projects from previous years. The main focus of the DRIFT project is to design and construct a MR that is integrated with the CHIMERA platform and can communicate with the INFERNO CD and sensor package. The functional block diagram (FBD) in Figure 2 below outlines the connectivity of the Fire Tracker System as a whole, with the main design focus on the mother rover.
4.2. Concepts of Operations (CONOPS)

The concept of operations (CONOPS) in Figure 3 below shows the main sequence of events for the entire Fire Tracker mission. DRIFT’s portion of the Fire Tracker system is boxed in red in the image below. The critical elements of DRIFT’s mission are to drop off the MR/CD system, establish wireless communication between the MR and the GS, navigate to a specified location via way-points while detecting obstacles via live video feed and blind-spot detection sensors and avoid them through operator control, ensure the MR platform is level within 3.5 degrees for CD deployment, deploy and recapture the CD, and return to the GS. Besides transporting and deploying the CD, the MR serves as a communication link between the GS and CD. Throughout the duration of the mission, the MR transmits a live video feed, sensor data, and GPS telemetry to the GS and receives commands from the GS when necessary. While the CD is completing its mission, the CD receives commands from the MR and subsequently transmits a live video feed, sensor data, and GPS telemetry to the MR to be sent to the GS. It should be noted that the final test for this project will be conducted in the same manner as the mission shown in the CONOPS below.

It must be noted that the testing and mission CONOPS were joined because the two are nearly identical. The main distinction between the testing and mission CONOPS is that instead of flying the drone off of the LP once it receives the command to deploy, a person will remove the CD from the LP by hand after an LED notification on the CD verifies the receipt of the command to deploy. Shortly after, the CD will be placed back onto the LP once the command to return to the MR is verified via a second LED. This is because flying the CD is out of the scope of the DRIFT mission and would require an unnecessary amount of operator time.
of logistics to fly the drone. It must also be noted that the propellers on the CD will not be attached when verifying the commands.

![Diagram of logistics](image)

**Figure 3. Concept of Operation for the DRIFT Mission**

### 5. Critical Project Elements

#### 5.1. Navigating Rough Terrain

The team is tasked with designing and implementing a rover with the ability to navigate in woods and grassland-like environments. This would mean that the rover should be able to navigate around obstacles such as trees and bushes, and should also be able to handle a range of rough terrain (defined in the levels of success). To achieve these while keeping the rover safe and stable, it will require much of the design to be constrained.

#### 5.2. Capability of Carrying Hierarchical Elements

The platform and child drone made in previous projects weighs approximately 55 lbs and is approximately 1.1 meter by 1.1 meter in dimensions. This will be a large load for a rover to carry in size and weight. The rover will need to support these loads and dimensions without compromising maneuverability and terrain capability. The MR must also securely carry the CD while traversing the rough terrain defined previously, while also implementing a braking system. The total range of the mission will be 1000 meters, so it must also have the power capability to navigate over the specified range.
5.3. Integration of Software

The platform and the drone have programs that were previously wrote to control their operations. The team will need to have an advanced understanding of these programs in order to assess the feasibility and success of the coding. The team will then need to integrate control of the rover with this predefined code. This can restrict options as compatibility with the previous projects will have to be a consideration when choosing how to address the software of the rover.

5.4. Communications Between Machines

The system, which includes the mother rover, platform, and child drone, must be able to transmit and receive commands between each other in order for the system to function properly. The mother rover shall be able to command the child to takeoff, land, navigate to specific GPS coordinates and turn the video feed on and off. Simultaneously, the child drone should be able to receive the commands and send a live video feed to the mother rover. The ground station and mother rover shall be able to communicate with each other by sending and receiving telemetry in order to allow for communication between the systems.

5.5. Leveling

When the drone returns to the mother rover, the drone requires that the base be at an angle of approximately 3.5 degrees or less. Considering the terrain required, this could pose a problem if the desired location is on a considerable slope. Leveling a 55 lb platform/drone system mechanically would involve significant force and design considerations. Other methods could require similarly complex solutions. Before the leveling process can occur, the rover must find the angle of the platform, which is another consideration in the design process.

6. Team Skills and Interests

In order to characterize the variety of skills, specialties, experiences, and interests on the DRIFT team, the table below displays this information for each team member. To ensure the team has all critical aspects of the project covered, each team mates skills are mapped to a Critical Project Element (CPE) in the right-most column of the table below.
<table>
<thead>
<tr>
<th>Name</th>
<th>Major</th>
<th>Skills/Interests</th>
<th>CPE</th>
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<tbody>
<tr>
<td>S. Growley</td>
<td>Aerospace Engineering</td>
<td>Experience in executing and writing procedures for thermal vacuum, random vibration, inspection, performance, and shock testing. Software experience includes MATLAB, R, and Python. Developed and implemented a procedure using MATLAB toolboxes for image undistortion at Deep Space Systems Inc. Internship. Experience with camera calibration and MTF analysis. Interests include project management, testing, and data analysis.</td>
<td>5.1, 5.2, 5.5</td>
</tr>
<tr>
<td>N. Wiemelt</td>
<td>Aerospace Engineering</td>
<td>Software experience with MATLAB, C++, Arduino, and SolidWorks. Designed, manufactured, and tested inner/outer drives with Neodymium Iron Boron magnets for pumps at Sundyne LLC. Wrote programs for full spectrum laser to execute vector cutting operations and designed/assembled cooling subsystem for thermoforming machine at Skydex Technologies. Interested in mechanical, electrical, and systems design as well as machining and manufacturing.</td>
<td>5.1, 5.2, 5.4, 5.5</td>
</tr>
<tr>
<td>A. Bishop</td>
<td>Aerospace Engineering</td>
<td>Engineered an autonomous robot with obstacle avoidance and a beacon locating system with the Colorado Space Grant Consortium (COSGC). Experience in systems engineering for deep space satellites at Lockheed Martin. Proficient in MATLAB, Unix, Python, Perl, Arduino, and C. Interested in mechanical and electrical design, integration, and test.</td>
<td>5.1, 5.4, 5.5</td>
</tr>
<tr>
<td>D. Collins</td>
<td>Aerospace Engineering</td>
<td>Software experience with MATLAB, Simulink, C, Linux, Python, and SQL. Worked with car electronic systems and big data analytics at Ford Motor Company. Interested in systems engineering and integration between software and electrical components.</td>
<td>5.1, 5.3, 5.4</td>
</tr>
<tr>
<td>B. Cott</td>
<td>Aerospace Engineering</td>
<td>Programmed an Android app that can sort NMEA messages and send them to a database and the program that sorted and visualized the data with the GNSS lab at the University of Colorado at Boulder. Software experience with MATLAB, C, C++, Bash, SQL, Python, Arduino, and Java. Interested in software design, specifically in autonomy.</td>
<td>5.1, 5.3, 5.4</td>
</tr>
<tr>
<td>K. Owens</td>
<td>Aerospace Engineering</td>
<td>Software Experience with Arduino, C, Java, Python,Bash, and Matlab. Leadership experience as a team leader for a Balloon Satellite project, a Team Leader for Younglife, and a Counselor and Unit Coordinator for Kanakuk Summer Camps. Has general design, construction, and electronics experience. Has an interest in mechanical, systems, testing, leadership, and safety work.</td>
<td>5.1, 5.2, 5.5</td>
</tr>
<tr>
<td>A. Stanco:</td>
<td>Aerospace Engineering</td>
<td>Engineered, tested, and manufactured motors and gear boxes at Bison Gear and Engineering. Lead structural design and manufacture for balloon satellite project. Leadership experience with TEAMS engineering along with camp counselor/coach. Proficient with designing and manufacturing structural components. Interest in mechanical, electrical, and testing.</td>
<td>5.1, 5.2, 5.5</td>
</tr>
<tr>
<td>S. Deen</td>
<td>Aerospace Engineering</td>
<td>Experience with MATLAB and Solidworks. Knowledge in manufacturing and electronics. Worked as a Technical lead and System lead in a Sun tracking project. Leadership experience with on campus club as a Program Manager and financial management. Interested primarily in system engineering as well as in technicals.</td>
<td>5.1, 5.2, 5.5</td>
</tr>
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</table>
P. Lieberman  Aerospace Engineering  Experience with MATLAB, Arduino, Lua, and SQL. Built data mapping applications for Chegg, Inc., and analyzed motion capture data at the biomechanical engineering lab at Arizona State University. Interested in mechanical and test systems design and fabrication. 5.1, 5.2, 5.4, 5.5

N. Rashid  Aerospace Engineering  Experience with MATLAB, Arduino, R, C, and Visual Basic Application. Has experience in management, modeling and designing applications using VBA and MATLAB. Interested in mechanical design and data transmission and communication. 5.1, 5.3, 5.4

M. Stoffle  Aerospace Engineering  Software experience with MATLAB, C, Linux/Unix, and Arduino. Proficient with Solidworks and AutoCAD as well as experienced in construction, manufacturing, and maintenance. Interested in mechanical design and manufacturing, systems integration and testing, and software. 5.1, 5.2, 5.3, 5.5

7. Resources

Testing Environment with obstacles and slopes capable of simulating environment as described in requirements CAD experience Machining experience Hierarchy missions components Software with capability of controlling rover and receiving data and live video.

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