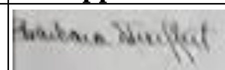
Department of Aerospace Engineering Sciences
University of Colorado
ASEN 4018

Project Definition Document (PDD)

INFERNO

INtegrated **F**light **E**nabled **R**over for **N**atural disaster **O**bservation

Approvals

	Name	Affiliation	Approved	Date
Customer	Barbara Streiffert	Jet Propulsion Laboratory (JPL)		09/14/2015
Course Coordinator	James Nabity	CU/AES		

Project Customers

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1 Problem/Need

Wildfires are a highly prevalent, costly, and dangerous natural disaster in the United States, particularly in mountainous, difficult-to-access locations. Fire prevention and suppression efforts by the United States Forest Service currently total $320 million, and are projected to reach $1.8 billion by 2025.[1] Not only is wildfire mitigation and containment expensive, but it requires personnel to enter hostile conditions to obtain information about the fire, which often results in casualties. In order to reduce the expense and human risk associated with wildfires, the FireTracker project seeks to develop and implement an aerial drone-based data collection system for use in hazardous environments and areas impassible by ground-based methods.

The FireTracker project is composed of four unique systems: a remote ground station (GS), a mother rover (MR), a flying child drone (CD), and a sensor package (SP). The remote ground station will serve as a deployment base for the mother rover, which will carry the child drone to a specified location. The child drone will then take off and fly to a GPS location designated by an operator, where it will deliver a sensor package. The sensor package will take and record temperature data to transmit back to the ground station. The child drone will also transmit video and/or photos of the area of interest to the ground station. Our project, INFERNO, includes the design and fabrication of the sensor package and child drone. These will, in turn, be designed so that they can interface with a mother rover and ground station that are to be built by a separate, future project.

2 Previous Work

NASA’s Jet Propulsion Laboratory (JPL) has been sponsoring rover projects since 2008. These projects have ranged in purpose from deployable child rovers that can take and transmit photos back to a mother rover to rovers that can repel down the side of a cave. The last mother rover built, called TREADS, supported two child rovers and had the capability to store collected samples.

Interest in autonomous delivery of packages has become a popular area of modern research. Autonomous delivery of packages to precise GPS coordinates up to 10 miles has been achieved while reaching speeds of 40mph, at a height of 50 meters. The electric power unit used enables flight time up to 45 minutes and carrying a load of up to 1.2 kg.[2][3][4]

GPS technology has become essential when piloting a UAS. Such technology can be used to instruct a drone where to fly at a given height and speed and can even give hover instructions at each point. These “waypoint maps” can be transferred between a computer’s digital mapping software and a drone.[5] If wireless communication is put in place, these instructions can be sent to the drone from anywhere in the world. There are dozens of companies that use and produce this software, such as DJI, Service Drone, Aerialtronics, Ardupilot, 3DRobotics, and MicroPilot.[4][5]

3 Specific Objectives

Table 3-1 INFERNO Levels of Success

Level	Child Drone	Imaging	Sensor Package
1	- Wired comm with MR/GS Simulator - Simulated deployment of Sensor Package - Flight testing with simulated payload	- Burst 8MP photos - Time stamping - Wired comm with CD	- Temperature data taken at 1 Hz with 8-bit resolution - Time stamping - Wired data transmission
2	- Deploy Sensor Package on command - Flight Testing with Sensor package in deployment mechanism	- Time stamped video wired to CD	- Flight capable mass and volume (TBD) - Wireless transmission of 1 hour of data

	- 20 minute flight duration - Wireless communications link - Piloted landing	- TBD resolution less than 1080p @ 30fps	
3	- Flight with video-tracked piloting - 200 m wireless data/imagery transmission - GPS signal transmission		- Store 1 hour of data on-board - Transmit 200 m - Survive flight and deployment
4	- Semi-Autonomous flight via GPS waypoints, and landing within 5 m radius - Integrated systems testing	- Full 1080p, 30fps transmitted to CD	- Retransmission of data in case of signal loss

The INFERNO team is designing the child drone and sensor package for JPL. Additionally, proper interface control documents will be created to allow future teams to interface with the child drone and sensor package. These deliverables will be ultimately tested with a full system test. This test will simulate the entire expected mission of the child drone and sensor package.

4 Functional Requirements

4.1 Concept of Operations (CONOPS)

The CONOPS diagram in Figure 4.1-1 below shows a high level concept of the design for the entire FireTracker system. Futhermore, Figure 4.1-1 illustrates how the INFERNO project fits within the larger scope.

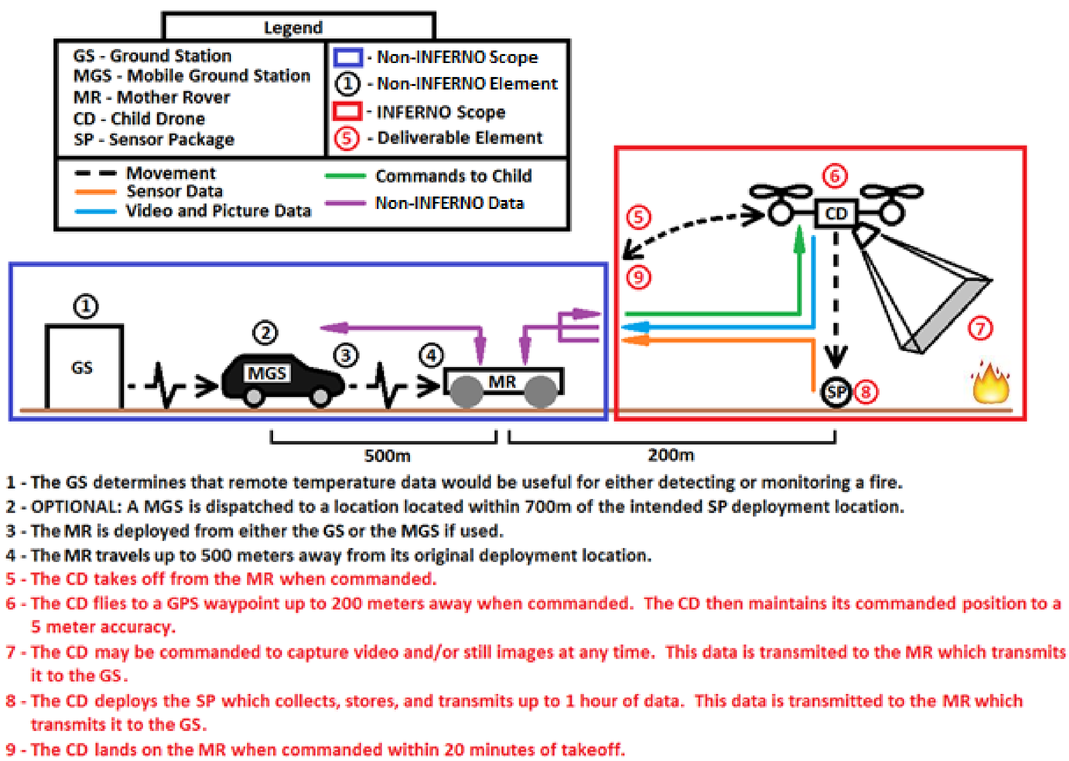

Figure 4.1-1 Project Concept of Operations (CONOPS)

The specific elements the overall system are differentiated by their relevance to the defined scope of the INFERNO project. Elements of the CONOPS which fall outside of the project scope, such as the MR and GS components, will need to be simulated during system tests. The remaining deliverable elements shown in Figure 4.1-1 will be implemented and tested as functioning systems through both small-scale tests for individual design goals and as a full systems test scenario, as shown in the CONOPS diagram, to validate the full system.

4.2 Functional Block Diagram (FBD)

As previously noted, the INFERNO project will be designing, building, and testing the child drone and sensor package components of FireTracker. Trade studies will be performed to determine whether the CD will need to be custom-built to meet mission requirements, or if it may be acquired as a commercial off-the-shelf (COTS) vehicle and modified as necessary. The SP will be built to meet mission requirements, using COTS components where possible in order to reduce project cost. Sensor data may be relayed through the CD and/or sent directly to the MR, as determined by the results of future trade studies and prototyping.

In order to enable system-level testing of the CD and SP, as well as to verify that they will be able to operate as part of the overall FireTracker system, a single Ground Station & Mother Rover Simulator (GSMRS) will be built in order to provide an electrical and mechanical analog for the command, telemetry, and docking capabilities provided by the future ground station and mother rover. Figure 4.2-1 below shows the Functional Block Diagram for INFERNO, outlining internal and external connections between the CD, SP, and GSMRS.

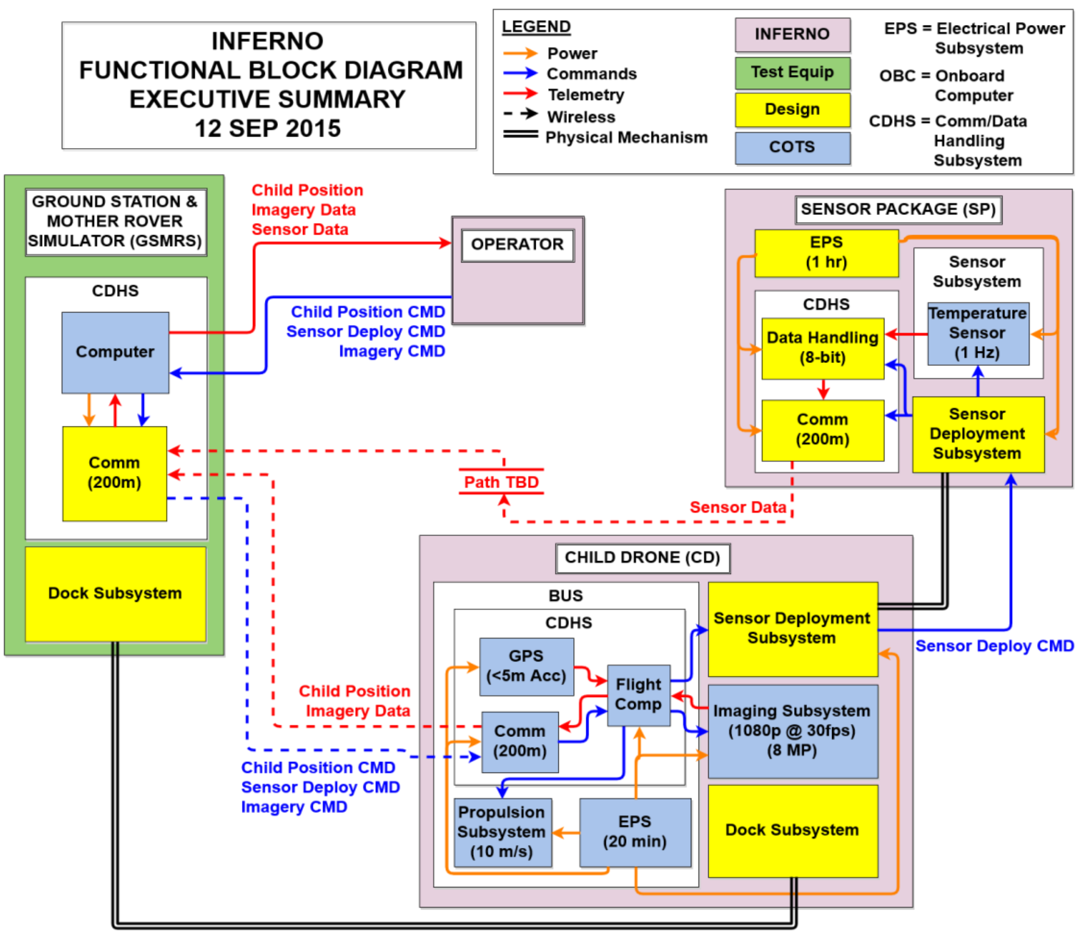

Figure 4.2-1 INFERNO Functional Block Diagram

5 Critical Project Elements

5.1 Communications

The CD must communicate wirelessly with the MR and the GPS system. This may present a problem due to the demanding nature of photo/video transmission. Trade studies must done to determine how to best address connection losses. Additionally, a great deal of RF communication understanding will be required of the team which, at present, is largely unfamiliar with RF communication. This system will also be very demanding of the onboard power system, thus perpetuating the critical aspect of power consumption. This will likely consume a significant portion of the project budget.

5.2 Power System

The CD requires sufficient power to operate in flight while receiving/transmitting information, as well as carrying a deployable payload, a photo and/or video device, a GPS receiver, and long-range communication systems. The ability of the CD to carry the added weight of batteries to support these power needs is of critical importance. The power system will consume moderate funding and time.

5.3 Software Interfacing

Intensive software development will be required for project success. Each project element will require significant software algorithms to function at any level. In addition to the individual project element software, there will be a great deal of interfacing and testing software needed for full system integration and testing, which will require perhaps the greatest amount of time and effort for the project.

5.4 FAA Certificate of Authorization (COA)

Due to the fact that the CD will be an airborne system, the team will need to acquire sufficient FAA permission to fly outdoors in the form of a COA. This process may be very time intensive and will be critical to enabling full system-level testing of the CD and SP.

5.5 System Integration

All of the mission systems/subsystems must be properly integrated. This may prove difficult to achieve with such a wide variety of mission components. Even if the team purchases a COTS UAS, all components must be able to interface with this device seamlessly, which will require significant modification of the base design. This will require multiple trade studies to weigh various options and will prove very time intensive but will require minimal funding.

6 Team Skills and Interests

Table 6-1 INFERNO Team Skills and Interests

Name	Major	Skills / Interests	CPEs
K. Pinover	ASEN	Communications planning and software package design for complex system modeling. Experience in systems engineering, mission design, trade studies, and financial management. Interest in communications and embedded systems.	5.1, 5.2, 5.3, 5.5
N. Peper	ASEN	Experience with systems engineering and communication subsystem design. Software experience with C, Python, bash and Matlab. Interest in electronics and embedded systems.	5.1, 5.2, 5.3, 5.5
A. Archuleta	ASEN	CAD experience, mechanical design, machine shop certified. Interested in robotics and 3D printing. Minor in Astroplanetary Sciences. Software experience with Perl, UNIX, MATLAB, Python, and C. Leadership experience.	5.3, 5.5

T. Geiger	ECE	Experience in electronic system design and embedded systems. Software proficiency in C and Assembly.	5.1, 5.2, 5.3, 5.4, 5.5
D. Campbell	ASEN	Experience in embedded systems and microcontroller design. Software experience in LabView, C, Assembly, and Matlab. Interest in electronic systems.	5.1, 5.2, 5.3, 5.5
J. Thompson	ASEN	Extensive experience in wireless communication and swarm robotics, microcontroller design, and machining. Experience in embedded systems and autonomous robotics. Extensive coding experience in C++, Java and python.	5.1, 5.2, 5.3, 5.5
K. Mulcair	ASEN	Complex system modeling and software development in C, C++, and Matlab. Electrical and mechanical test engineering experience. Interest in systems engineering.	5.1, 5.2, 5.3, 5.5
E. Rodriguez	ASEN	Experience in structural design and analysis, including Finite Element Method and manufacturing. Leadership experience; interest in systems design.	5.2, 5.3, 5.5
T. Jeffries	ASEN	Extensive leadership and management experience. Prior customer experience; minoring in Applied Mathematics with an interest in systems engineering, software, and electronics. Experience with algorithm development in C and MatLab.	5.2, 5.3, 5.4, 5.5

7 Resources

Table 7-1 INFERNO Project Resources

Project Elements (PEs)	**Resources**	**Explanation**
Technical PEs		
Operations Concept	Barbara Streiffert (Customer)	Necessary to define CONOPS
	Senior Projects Advisor	Resource to help define obtainable project goals
Component Design and Testing	Bobby Hodgkinson	Resource for technical help with machining, manufacturing, and electronic component design
	Trudy Schwartz	Resource for technical help with electronic component design
	Matt Rhode	Resource for technical help with machining and manufacturing
	Aerospace Lab	Location to perform circuit board fabrication and component manufacturing
Logistical PEs		
FAA Certificate of Authorization (COA)	Eric Frew & James Mack	Knowledge of COA regulations
Testing	James Mack	Pilot
	Eric Frew	Knowledge of possible test locations
	Nick Peper's House	Possible test location
Financial	Engineering Excellence Fund (EEF) *if necessary	Additional funding

8 References

[1] *The Rising Costs of Wildfire Operations: Effects on the Forest Service's Non-Fire Work*. U.S. Forest Service, 4 Aug. 2015. Web. Accessed 29 Aug. 2015. <http://www.fs.fed.us/sites/default/files/2015-Rising-Cost-Wildfire-Operations.pdf>.

[2] "DHL PARCELCOPTER 2.0." *Jebiga Design Lifestyle*. Web. 3 Sept. 2015.

[3] Kuhlmann, Dunja. "DHL Parcelcopter Launches Initial Operation for Research Purposes." *Deutsche Post DHL Group*. DHL, 24 Sept. 2014. Web. 29 Aug. 2015.

[4] Rui, He. *Mechatronics and Mechanical Engineering Selected, Peer Reviewed Papers from the 2014 International Conference on Mechatronics and Mechanical Engineering (ICMME 2014), September 6-8, 2014, Chengdu, China.* 2014 ed. 2014. Print.

[5] Corrigan, Fintan. "Drone Waypoint GPS Navigation Technology and Uses Explained." *DroneZone.com*. 30 Nov. 2014. Web. 29 Aug. 2015.