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## Project Summary

In November 2005, a group of Sixth-Form Students from New Mills School were given the task of designing and producing a solution that would allow rapid response to moorland fires in the Peak District National Park by use of a helicopter.
The group undertook a survey of the surrounding moorland and interested parties in order to decide on factors to be considered during the design stage.
These design factors were brought together duing a 3-day workshop at Sheffield Hallam University, where a proposed design for a hose dispensing unit was formed, along with initial construction of a framework for a prototype test unit.
The team have presently formalised a design for a prototype test unit, and are now in the stages of finishing construction of the unit with a view towards testing in the early summer of 2006.
This project details the engineering process of the project in full up to March 2006.

## Acknowledgements

Shaun, Lucy, Michael and Jack appreciate and acknowledge the help, advice and assistance in the project (up to the time of writing) of the following people:

Peter Arnfield, John Bailey and the staff from Derbyshire Fire & Rescue, Sean Prendergast and the staff from the Peak District National Park Ranger Service – their help at Sheffield Hallam and beyond has been greatly appreciated, and long may our working links continue;

Peter Tattersall from the Engineering Education Scheme – for arranging the project in the first place and his tips and advice;

The staff at Sheffield Hallam University for their time and valuable assistance during the workshop there, and for helping with materials and assembly advice;

The teachers and staff at New Mills School: Mr Arezoo for his engineering and project expertise; Mr Leake for his engineering and construction genius; and Mrs Crowton for her financial guidance.

Chris Ruddy at Pennine for creating the opportunity to test the finalised prototype in the coming months;

Finally, to all of those who have assisted in this project in some way shape or form, their help has been very welcome.

## Introduction to the project

New Mills Helibourne Solutions consists of 4 members and an engineering advisor.

We are:

Shaun Davies: Concept co-ordinator and Structural engineer

Lucy Harris:  Administrator and Creative engineer.

Michael Mansour: Creative interpreter and Administrator.

Jack Mayo: Mathematician and Physicist.

Mr Amir Arezoo: Engineering Advisor.

We are assisted by the Derbyshire Fire & Rescue Service and the Peak Ranger Service, specifically:

Peter Arnfield: Derbyshire Fire & Rescue, Engineering consultant.

John Bailey: Derbyshire Fire & Rescue, an Engineering consultant.

Sean Prendergast: Peak District National Park Ranger and Engineering consultant.

## Introduction

Helibourne solutions were approached in October 2005 by the Derbyshire Fire and Rescue Service to work in conjunction with the Peak District National Park Ranger Service and F.O.G (Fire Operations Group) in order to solve a problem they were encountering.

### *The Problem*

How do you lay fire hose over vast distances of sparse moorland (more specifically, the Peak District National Park) in an efficient and cost effective manner?

### *Why Does A Solution Need To Be Found?*

#### From An Environmental Point Of View

The peak district moorland is habitat to many wild animals. When a fire strikes it spreads quickly through the peat in the soil, in tandem with the notorious wind common to these moors, killing many animals and destroying the habitats for those animals remaining.
As these fires are relatively common, it is important for a quick method of extinguishing them to be found.

See Appendix for potential risk areas in the Peak District National Park.

### *From A Fire Services Point Of View*

In the summer of 2003, moorland fires struck simultaneously on Bleaklow Moor and Kinder Scout, two of the largest peaks in the National Park, and two of the most treacherous in terms of terrain and climate.

With the local fire brigade only having the capability to tackle the fire on Bleaklow, colleagues from county fire services other than Derbyshire were required to assist so that both blazes could be tackled.

The impact on the moorland and wildlife in particular was devastating, as evidenced by the image below:

Despite having resources to tackle the blazes, the key problem was the time to set up equipment – pumps, hoses, tanks, FOG equipment, etc. The longer the equipment takes to set up, the greater potential for serious environmental damage on the moorland.

As a result, the Fire Service were on the search for a solution that would allow the fire teams to respond to blazes quickly and efficiently.

### *The Terrain*

Before considering a design, the first major obstacle to consider is the terrain we are dealing with. Below is an example of the topography of Peak District moorland, in this case at Bleaklow.

As one can see from the picture, there are great distances and changes in height to be overcome, which makes manual Fire Hose lying nearly impossible.

In order to fully understand the scale of the terrain in the Peak District moorland, we went out with the ranger service to Bleaklow, where, in 2003, a severe fire put a large area of moorland at risk.

One of the most apparent features of the land was the peat, which as a fuel, is a major factor effecting the spread and intensity of moorland fires. Peat is prevalent in much of the Peak District ground, and as a result, much of the land is a potential fire risk. In addition, if a fire is left on peat for any length of time it starts to burn deep into the peat, making the fire incredibly hard to extinguish.

### *Current Moorland Fire-Fighting Techniques*

Currently the Fire Service use helicopters to drop large container-fuls of water onto the areas of fire. This is a very expensive operation: a helicopter dropping blankets of water over the fire can cost £1000 for one hour’s work.

Once the fire has started burning into the peat, water has to be manually injected into the ground in order to extinguish the fire that lies in the seams of peat under the terrain surface, as shown by the image above.

Though these are effective methods, they are time-consuming and costly in terms of man-power and equipment costs, so in tandem with the need to respond to fires quickly, cost is a major factor. A solution that was relatively cheap and effective in the short term would also save thousands of pounds in the long term, and would help preserve the countryside for generations to come, something one which a price cannot be placed.

## *Interested Parties*

Interest in a solution has been shown by many different parties, along with the Fire and Rescue Service and FOG, the Peak Park Rangers, United Utilities, Landowners and Gamekeepers all have an interest.

- The Peak Park Rangers help restore the land after fires: the smaller the fire, the less restoration needed.
- United Utilities supply the water used for fighting fire, and in addition, when rain filters through the more damaged land pollutants and sediments end up in reservoirs and have to be removed later, at great cost.
- Landowners have to pay for the restoration of the moorland in their possession: less restoration needed means less long term expense.
- Gamekeepers lose game in the fires (as evidenced in the picture in the previous section) and as such as large moorland fire can greatly affect a person's livelihood.

**Anticapted Outcomes of the Project**

- Rapid response to moorland fires, and as a result…
- …the moorland fires will cause less damage to the moorland habitat.
- The fire service will have less trouble tackling more than one fire in different locations, as large amounts of hose can be laid in a shorter time frame.
- The project could help to raise awareness about moorland fires are started, possibly meaning the human causes are reduced.
- Other industries that need to lay cable or rope in similar environments may be able to adapt the design to fit their needs.

## *What are the Preferred Systems?*

The best solution would be to have an "on call" retained moorland helicopter fire service to tackle any reported fire. However, these services are time-consuming and expensive. And so this is the aim of this project, to make this process quicker and less costly both financially and physically, although the issue has been raised at the House of Commons in order to seek government funding. Previously there were a number of helicopter companies to assist in the fighting of the moorland fires, but these are not always available so a proposed design should be made to be available to All Terrain Vehicle's for easy transport at ground level.

## *Areas at Risk*

When researching the fire fighting process, we also looked at the areas where fire incidents frequently occurred, and it was observed that these areas were well away from main roads (see figure 1&2 in Appendix) in the hilly areas of the High Peak.
It also revealed that there are certain areas that have a high concentration of fires (see figure 3 &4) and these areas stay fairly constant over time.
On further inspection of these sites, a possible reason for this was revealed.

The fires tended to occur at sites with the most flammable vegetation in the region (see figure 5) and also, many of the sites were fairly close to the Pennine way (see figure 1 & 6).
With this information it is easy to see our solution needs to include a form of transport to remote areas quickly as the fire will soon spread throughout these highly flammable vegetated areas.

## How to Solve the Problem

To extinguish fires on remote moorland, there are many different possibilities within the restraints of moorland fire fighting involving manual labour and mechanical solutions.
For this problem in particular there are many options to consider:

- Manually laying hose – this is time consuming and physically demanding. By the time the hose has been lay the fire could well be out of control and have spread a great distance.
- Laying fire hose from centaur – although the physical demands on people are removed with this method, the vehicle is still fairly slow and cannot carry vast amounts of hose. Also some terrain is too extreme for it to navigate.
- Dropping water from a helicopter – this method is already in use and proves to be a great help, however does not allow constant supply of water to fire site and what water is transported does not penetrate the fire deep enough to extinguish the fire fully.
- Laying fire hose from a helicopter – this method appears to be the best solution as the helicopter is not affected by the terrain and travels fairly fast. In order for this solution to work, a mechanism must be designed for this purpose that follows the safety guidelines for under slung objects on helicopter.

The most effective of these would easily be the hose-laying helicopter. This would cover the dry season fires highlighted above as high-pressure water could be released onto deeply penetrating fires, quickly stemming their development, and also could be used as an extra measure in the damper seasons.
The solution also covers the fast transport problem, the helicopter will be able to transport fire hose quickly to the sites of highly flammable vegetation.

### *A Previous Effort*

In 2001 Highlands and Islands Fire Service created a working prototype of a device that could be lifted by helicopter to dispense fire hose.
They worked with a drum shaped design that can be seen in the image below:

The fire hose was pre coiled around the device and was let out by the end of the hose being tethered in place and the drum rotating to release the fire hose.

Safety Issues

This design was rejected after health and safety concerns were voiced about the drum over rotating and possibly causing the fire hose to jam, putting a dangerous amount of stress on the helicopter.

In addition because the design was a rotating barrel with the hose coiled around it, the drum would gather momentum and feed too much hose at an uncontrollable speed and jammed the feeder. As a result, design points for the safety to be considered were:

- Weight
- Jamming
- Aerodynamics
- Having the dispenser pulled into the Helicopter Tailfin

### *What Are The Requirements For Moorland Fire Fighting?*

This question is dependant on a number of factors:

- Time of year
- Size of fire
- Location
- Vegetation type

During spring there is often fairly high moisture below the surface of the peat and damage is restricted to surface burns. At this time of year beaters can be used to put out small fires. However, during summer/autumn the peat is dry and deep-seated burns can occur, therefore water is fundamental to extinguishing these fires.
The requirements are also dependant on where the fire is; those on difficult or remote terrain may be inaccessible using particular equipment etc.
Successful partnerships with the peak district national park have been undertaken, however they have to be maintained and built upon to really make a difference.

## Sheffield Hallam Residential Workshop

At this workshop, the main objective was to develop a suitable design for the under slung mechanism.

As with any design process this could easily have occupied the majority of our three days at Sheffield, however after a swift brainstorming session, and a rough ideas sketching session, a design appeared which stood out as the start of our solution, quite simply, a mesh covered framework that held hose in place underslung from a helicopter, with a taped front-end which the hose would be reeled from.

### *How to Control the Hose*

This solution had only one specification missing, the control system in order to maintain a safe unreeling of hose from the proposed container unit.

After further analysis and brainstorming the group decided that this problem had two practical solutions (see attached sketches).

- Using rubber flaps as a brake
- Using brush heads as a brake

Reclaimed materials from the university stores were fixed to an old table (including a set of wheels for easy manoeuvrability) and both rubber and brush heads were attached to the front of the device.

The atrium area of the Engineering block was used as a test area providing enough space to run several lengths of hose out. With Jack as our test pilot we soon discovered pros and cons of both ideas.

### *Braking System Development*

**Brushes**

Advantages:

- Cheap – reducing cost of the overall unit.
- Easily replaceable – mounted on a backboard would make removing and fitting brush heads easy when they wore out.
- Most effective – a layer of thick brushes provided enough resistance without having too much frictional force.

Disadvantages:

- Catching edges – any edges could cause the bulky coupling to get caught, stopping hose being released and as a result exerting undue force on the helicopter.
- Bristle wear – over time these will be worn down, so brushes will need to be replaced.
- Brushes made of wood, fixture made of metal – this could cause the wood to come under pressure and fail.

**Rubber**

Advantages:

- Provided friction – the main mechanism in our braking system
- Robust material – will wear away slowly and is much less likely to break due to excessive force

Disadvantages:

- Provides too much friction – this caused a great effort to be exerted in order for the hose to move even slightly through the flap. Even when larger slits and gaps were tested the balance between friction and movement could not be met.
- Tears – as such a force is put into moving the hose through the rubber; this force could easily tear the flap, reducing the friction caused by the device to a point where it would no longer be effective.

From these comparisons it was evident that, although the brushes had as many disadvantages as advantages, the advantages greatly outweighed the disadvantages, which could be easily overcome, whereas the rubbers cons outweighed its pros.

Our final decision was to go with using brush heads.

A 3D-sketch of the chosen design is on the next page.

## *Why Choose This Design?*

### The Advantages Of The Chosen Design

- Simple design – an efficient, and hopefully effective design.
- No moving parts – nothing to fail.
- Cheap – economical to produce.
- Good Hose to weight ratio – large amounts of hose can be transported at once without exceeding the load limit of the helicopter
- Fireman proof – our prototype is to be made from steel, it is a simple robust design, which can withstand being stood on, sat on, or lay in
- Requires little maintenance – with a good finish the only maintenance needed should be checking the brush heads and refilling with fire hose

### The Disadvantages Of The Chosen Design

- Transporting a full box – this will weigh a great deal, too much to be lifted by one person, and too much to lift at all without help from a wheel and handles.
- Swinging – once the box is secured under the helicopter and is in mid air, air resistance could cause swinging which could make the helicopter difficult to handle.

Next on the list was the building of a prototype. However before this could happen, dimensions and calculations needed to be done to make sure we got the maximum efficiency from our final product. We also needed to decide on a material for the construction. In order to do so, we researched two of the metals renowned for good weight/strength ratios for their price, steel and aluminium.

## *Material Comparison*

The group decided that the two materials that should be considered to produce the unit from were mild steel and aluminum, two freely available materials that are easy to manufacture from, especially in a school workshop environment.

The tensile strength of pure aluminium is not high, but depending upon the alloy or temper the strength can be significantly increased. Steel however is very strong and resistant to fractures, and hence is used in building frames, security doors, trains, ships, etc.

The yield strength of steel is 400 Mpa whereas that of aluminium is 180 Mpa which means that steel has about twice as much yield strength and so is twice as more likely to flex under certain forces. The ultimate strength of structural steel 650Mpa yet that of aluminium is 200Mpa, this indicates that the ultimate strength of steel is practically three times greater than that of aluminium. It is obvious that steel is more suitable and more appropriate for both the required job as well as its environment.

**Material Calculations**

The Civil Aviation Authority decree that the maximum mass of a unit that can be carried by the standard of helicopter used in moorland fire fighting is 500kg.

It was also agreed by the Fire Service officials that the maximum distance that hose could be reeled in one event would be approximately 500meters.

In addition, it was stated that under a working situation of 4 firefighters carrying the unit empty for storage, the unit should be of a mass no greater that 100kg.

Hose mass:

One standard fire hose weighs approximately 15 kilograms.

Weight, (W, in Newtons) = Mass (kg) x Acceleration Due To Gravity (N/kg)
W = 15 kg x 9.8 N/kg
W = 147 Newtons

This would imply that if we were to use 20 length of hose, the maximum weight will be equivalent to:

W = 147 Newtons x 20 lengths
W = 2940 Newtons (this value is approximately the same as 300kg)

Hose length:

Individual hose length = 25m
Number of hose lengths to be carried = 20 hose lengths = 500meters

As a result the total sum of masses of both the hose and the unit would be 400kg, which is well within the acceptable and allowed range of 500kg for the total underslung weight carried by the helicopter.

Another possibilty is to increase the number of hose length to 24, thereby increasing the total length that can be carried. Since it will only increase the mass of the structure by an additional 60kg it might prove to be beneficial and quite doable considering the calculations and assumptions are vaild: all these variations will naturally increase the total mass (460kg), but it will still be maintained in the specified range.

This would imply a total length of 500 metres to be carried, with a 100m additional capacity if required.

After making rigorous comparisons, we decided that, for our prototype at least we would use steel, as it was more cost effective, more easily available at the time of construction and more robust – an important consideration for storage and transportation of the unit.

From there we made estimated calculations, allowing excess weight for our materials to ensure we did not exceed the load limit of a helicopter that is in frequent use when fighting fires in this area. (See figure …)

## Construction of the Prototype

Whilst still at the Sheffield Hallam Workshop, it was decided that rather than constructing a complete unit for testing, a 1/3 scale unit would be built to test the ideas that were thought through in the development stage. In addtion the decision was taken to carry out all construction of the prototype in house.

The main outer frame of the unit was built at Sheffield Hallam, with assistance from the Workshop staff at the University.

In addition, the team acquired steel mesh which would contain the hose within the unit during operation. Using the mesh would also save weight, an important consideration in terms of transportation and operation.

Once back at New Mills School, the team set out completing the main framework of the unit and adding additional supports.

### *Assembly Of Prototype*

The box-section steel tubing for the outer frame was cut with the aid of a mechanical hacksaw at the Sheffield Hallam Workshop.

The additional supports were cut to size using equipment in-house.

With steel as the main construction material, the chosen method to join the steel supports was welding. To make this possible, a portion of the project budget was spent on a new MIG welder.

**How does MIG-welding work?**

The desired material is attached to a negative connection. This allows electricity to flow through the material.
The electricity melts the steel rod being passed down the connecting cable to the handle, as carbon dioxide is blown around the rod to stop oxidisation taking place on the steel.
The rod melts the steel together, forming an almost unbreakable connection.

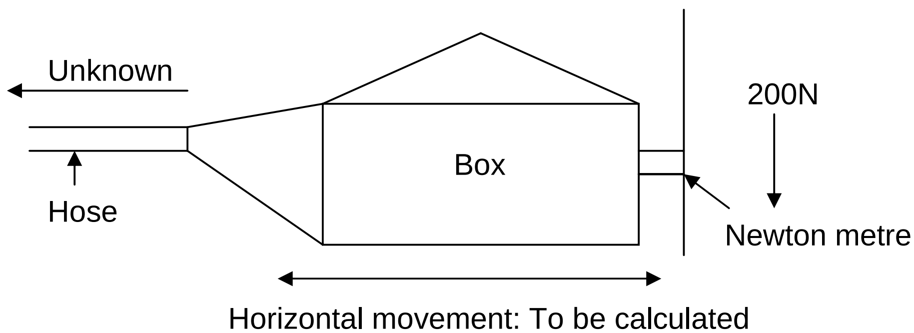
# Further Design Considerations

## *Overcoming Safety Issues In The Air*

The weight specification for the helicopter is 500kg. Should the helicopter jam there is an electro magnetic hook with in cab controls, which can be used as a quick release for the hose unit should the occasion arise.

To overcome the aerodynamic issues the side casing will not be made from plate but from mesh to allow some airflow around through the box. This will hopefully assist in high-wind situations.

We will have to test the force of the coupling through the braking device to decide whether the box has enough mass to allow a coupling through the friction device without pulling the box into the tail fin of the helicopter.




Testing is to be carried out through hanging up the box with a Newton metre attached to the back and pulling a length of coupled hose through whilst measuring the forward force it exerted.

There are plans in place to test the prototype unit (upon it's completion) with the use of a helicopter from Pennine Helicopters, a local helicopter operations company, who presently assist with moorland firefighting. The helicopter will carry the prototype up and down the field with the hose being lay out on a local field, with assistance from Derbyshire Fire & Rescue.

## *Attaching The Braking System*

Despite the braking system and the taped front already decided upon – there is still scope for further development for attaching the braking system.

At present, the braking system is to be fixed on to the front of the taped front, however, there are plans for an adjustable front braking system to allow for variances in friction and drag from the hose in operational conditions.

## Further Work

The prototype is yet to be complete, with the tapered front currently in construction from steel plate. It is hoped that this will be complete by early May, ready for testing.

From there, detailed engineering work and testing will take place from which a final design for the actual hose unit will be completed, ready for production and testing.

It is hoped (and partly planned) that a second engineering team from New Mills School will take this project on, with assistance from the Fire Service, with a view to putting the completed Hose Dispenser System into production and usage.