You're about to hear a series of talks about the work of the HighFire Risk Project. I'd like to start by quickly outlining **why you need to hear these talks**.

SLIDE 1... TITLE

This decade a great many people have espoused their views on the strengths and weaknesses of how we collectively manage fire in and around the high country. As you all know we have had an unprecedented series of catastrophic fires impact on the mainland's high country. These fires have been followed with an air of inevitability by coronial enquiries, legal cases and parliamentary enquiries. In each of these there have been lawyers, witnesses and expert witnesses relating their views on what went wrong and why. The media has jumped on the bandwagon with glee.

SLIDE 2... ABC NEWS ARTICLE

Many of these processes have adopted an adversarial stance. The fundamental foundation of these has been this chain of logic:

1) The industry has a **robust set of tools**, defended by "the industry's" experts, that predicted what was about to happen.

SLIDE 3... CHENEY PHOTO

2) "The experts" confirm that this is indeed what happened.

3) Despite the predictions, a lot of damage happened and processes failed to work as expected.

4) The correlation is taken as proof, and therefore those in charge of the fire are (pick one): [ ] negligent, [ ] incompetent, [ ] the nominated scapegoat.

I have personal experience of the "blow-torch to the belly" that is involved in this process.

SLIDE 4... ABC NEWS PAGE

While these hearings are still going on in various places, and the lawyers and investigators stepped in before the fires were extinguished, the science has, of necessity, been much slower in producing results. The science started almost imediately after the 2003 alpine fires and is still labouring away in the back rooms. However, now we are finally in a position to start rolling-out the science, and this is the reason for this set of four presentations this afternoon.

You must remember that it takes years to carry out research and have it published in a peer-reviewed science journal. Most of the papers we will talk about today have been published in the last couple of years, after the CRC project finished.

As a spoiler it has been found that the robust set of tools used by the "experts" is definitely faulty.

SLIDE 5... TITLE SLIDE

SHORTCOMINGS OF CURRENT BUSHFIRE RISK MANAGEMENT PRACTICES IN AND AROUND THE HIGH COUNTRY

SLIDE 6... FIRE PIK

Now, the focus of this talk is risk management. This includes suppression, hazard reduction, land management, insurance, shrugging your shoulders, public education and much more. But I'd like to start by chastising myself. I have already used the term "RISK" on its own. There is no such thing. What I should say is "risk to something from something over a certain time period".

So I'd like to redefine my talk as being about risk to valuable assets in and around the high country from wildfire over the next, say, twenty years. From now on if I say risk this is what I mean.

But what is a valued asset? The expectation is that this audience will include people who would offer up a range of different things. Some would think of *Gymnobelideus leadbeateri*, a threatened glider possum, some would think of the Upper Yarra Reservoir, others would think about the opportunity to enjoy a walk through the snowgum woodlands of the Dargals Range. In my case I nearly lost my house to the 2003 fires and my neighbourhood has been irreversibly changed.

SLIDE 7... DUFFY WILKES SHOT

WHAT IS A WILDFIRE?

We also need to define the meaning of "wildfire". It's not as simple as you might expect.

We have studied a large number of fires in our work, and we have been forced to categorise fires, as there is clearly a number of different types of behaviour.

SCALE

SLIDE 8... MEDIUM FIRE

Firstly we had to address the fact that fires of different sizes respond differently to external drivers. Whereas a small knoll may be the dominant driver of a small fire, a landscape fire will burn over it with no effect.

And yet we all know that **fires burn faster upslope**. What is going on? For bigger fires the detail of the local relief is effectively blurred-out or lost in a statistical melting pot. This is an example of a “scale-dependency”.

PLUME-DRIVEN FIRES

SLIDE 9... RUN 4 PCA LINESCAN

Should a very-large fire get bigger, there is only one larger category – the plume-driven fire. There has been debate in Australia about the existence of plume-driven fires, as opposed to plume-dominated fires. The latter is a fire that is so intense that its plume starts to feedback on and influence its behaviour on the ground. A plume-driven fire, also known as a coupled fire – atmosphere event, is one where the behaviour of the plume determines the spread of the fire on the ground.

The debate is now over. Plume-driven fires have been recorded by remote-sensing in the ACT, Kosciuskzo National Park, the Sydney Basin, the Pilliga Scrub, the Big Desert, the southwest of Western Australia. There is a large international research effort studying the process in Australia, the US, Canada, Siberia, Mongolia and elsewhere. It is directly linked to the threat to civil aviation from volcanic eruptions, currently causing economic havoc in Europe.

VIOLENT PYRO-CONVECTION

SLIDE 10... PYRO-CB PIK

A key concept from this work is violent pyro-convection. If a plume resists mixing with the surrounding air up to the lifting condensation level – the cloudbase - then the latent heat of condensation released can be up to three times that of the fire. The plume is now the dominant part of the event, but is still reliant on the fire to produce the plume. A fire thunderstorm, or pyro-cumulonimbus, can form.

Clearly this is a process that cannot be found by use of a McArthur Meter.

How important is this? It is clear that over 95% of house losses from wildfire ever recorded in the ACT are due to this. Satellite data makes it clear the losses at Kinglake and Marysville were due to this. These events leave a clear and unmistakable signature in imagery.

On the basis of terrain type and historical records we have been able to identify a number of species of wildfire.

SPECIES OF FIRE

SLIDE 11... GOOROMON PONDS FIRE

Firstly we have wind-driven generally elliptical grass fires on flat countryside. We have long known a lot about how to suppress these and how to predict them and how to plan for them.

SLIDE 12... SEWERAGE FARM FIRE

Secondly we have fires in undulating countryside. Fire controllers have been trained in how to avoid the intense uphill runs and to use the milder downhill runs for suppression opportunities. We have skills in predicting their behaviour and planning for them.

SLIDE 13... TINDERRYS FIRE

Thirdly we have escalated fires in rugged landscapes. We studied a number of these events, where there was detailed mapping of fire spread. In most cases the fires stopped where the prevailling winds took them out of the rugged landscape, and perhaps a few kilometres on from that due to what is colloquially called "momentum". It is tempting to say that it is at the edge of the rugged landscape that we have changes in fuels and a good fire trail network, so we can put them out at that point.

SLIDE 14... VIC ALPS 14 DEC 06 4:33 IR SATPIK

And yet satellite data showed that the Victorian alpine fires of 2006 reached that point as one of the most intense fires ever recorded in Australia. It wasn't the fire trucks that caused this to decay. The evidence makes it clear that something else is going on. Our studies have shown that it is vertical air flow that is behind these events. More detail on this follows, but it is the defining aspect of this species of fire. The movement of air is greatly modified by interactions with rugged landscapes. Fires burning in the proximity are strongly affected. I spoke before about coupled fire – atmosphere events, now we see that the terrain and the atmosphere can be coupled. Is this the new fire triangle?

SLIDE 15... NEW FIRE TRIANGLE?

The big fires, that cause most of the risk, are three-dimensional beasts.

HFR

Now to our research project.

After the 2003 fires there was a significant volume of direct evidence – photos, weather records, linescans, etc. These made it clear that we knew very little about what was going on in the ranges west of Canberra. When the HighFire Risk project was set up the colloquial goal was that we should put on our pith helmets and grab our blunderbusses and go on safari. We believed that almost anything we "bagged" would be of interest. We were right.

OUR SAFARI TROPHIES

SLIDE 16... TINDERRYS CHANNELLING

Channelling is a special form of interaction between wind and terrain. The first confirmation of the ability of channelling to alter fire behaviour was seen in the multispectral linescans taken during the fires in the ACT on 18th January 2003. Subsequent research has identified nearly thirty confirmed or probable events in southeast Australia and in the United States. A number of past fire fatalities may have been partially due to channelling. Highly reliable evidence has allowed development of process models and of a partial predictive model. We identified a new phenomenon – lee-slope channelling – which is now known to be important for fire spread.

SLIDE 17... WXZONE FOEHN MAP

Foehn Winds have been studied for their role in fire development, and Jason will talk about them shortly. In collaboration with the Bureau of Meteorology we have (a) shown that mild Foehn winds are relatively common, (b) studied their development and extent and (c) shown that they have a role in elevating fire danger in the southeast and Tasmania.

SLIDE 18... WAVE GENERATORS MAP

Mountain Wind Waves have also been studied in collaboration with the Bureau of Meteorology. We have shown that they are a reasonably common driver of locally amplified wind speeds which make dangerous conditions for fire controllers.

SLIDE 19... THERMAL BELT MODEL NET

The Thermal Belt is a problem for fire fighters using fire at night to set control lines in rugged landscapes. We have shown how the drainage inversions responsible form and have developed a predictive model that may alert fire controllers when backburning might be too dangerous to implement at night.

SLIDE 20... MT TAYLOR

Wind Regimes in the rugged landscapes have been poorly studied. In part this is due to the practice of setting weather observation equipment on ridgetops or accessible valley floors. We have shown that winds on the slopes may be dominated by lee-slope eddies, which cannot be efficiently modelled at present. Jason will talka bout this shortly. They act to drive fires upslope under most prevailing wind conditions. Many gullies are also affected by dynamic channelling, which causes wind to flow upstream or downstream, depending on the orientation of the terrain with the winds.

SLIDE 21... TIDBINBILLA PLUME

Nocturnal Low-Level Jets are a localised increase in wind speed that occurs at night after the night-time inversion develops. Freed of ground friction, winds blow atop the inversion with higher speeds than would otherwise be the case. High points in the terrain that protrude above the inversion experience these strong winds.

SLIDE 22... BENDORA BACKBURN

Nocturnal Dew Point Depression Events occur in the high country on one night in seven. They result in a peak in Fire Danger between midnight and sunrise. This is counter to the expected diurnal cycle. Like the Thermal Belt, these events act to reduce or remove tactical options for setting control lines at night.

COLLABORATIONS

The study team have also been involved in international collaborations:

SLIDE 23... ESPERANCE PYRO CB

Violent Pyro-convection is the subject of a global research effort. It arose out of impacts of volcanic plumes on civil aviation, but has subsequently shown that intense fires can produce equivalent impacts on the atmosphere. The Canberra Fires were the subject of a major international study, with remarkable results. The Australian climatology of violent pyro-convective events shows alarming evidence for a change in the fire environment around the high country, and perhaps indicates a climate change cause.

SLIDE 24... BARUTA FIRESTORM

Unusual Combustion Processes arise in violent wildfire settings. Professor John Dold has studied key observations from the Canberra fires and other events as they indicate unusual processes dominating the normal combustion expected from the "fire triangle". Many Victorians have reported fire balls and such like in the recent events.

SLIDE 25... WILKES MT FRANKLIN

Eruptive Fire Spread is a research area from Europe. There is strong evidence of exponential fire acceleration under conditions first elucidated from studies of the Kings Cross Railway Station Fire in the UK. There are strong links to a number of historical fatal fires in a number of countries.

WHAT HFR MEANS

The important message to take out of what I have just said is not that we have carried out a series of separate fire weather studies. Some have even called them sudies of local winds. We need to take the scope of the studies and ask ourselves what impact they have on the usefulness of the tools currently in use to model fire behaviour and assess wildfire risk.

VERTICAL AIR MOVEMENT

SLIDE 26... VENN TORNADO

At the very least the significance of vertical air movement must be considered. Vertical air movement is a feature of most of the processes listed, and yet has no explicit appearance in any of the fire management tools available.

KEY ISSUES

Previously in my talk I have raised a fair list of matters of importance. I would now like to summarise these as as et of **Key Issues**.

SLIDE 27... ISSUE 1

1) Fires in and around the high country are from a range of types, each needing different tools to predict their behaviour and analyse risks that arise from them. Fires escalate through a series of size classes. For each, their drivers are different. Our Transition Model is a method for handling all aspect's of a fire's *life cycle*.

SLIDE 28... ISSUE 2

2) Fires fall into three species: flat country fires, undulating country fires and rugged country fires. The drivers of these and the ways to suppress them vary.

SLIDE 29... ISSUE 3

3) Most significantly, records clearly show that escalated fires in a rugged landscape typically are not suppressed until they leave that landscape. Evidence strongly indicates that there is more to this than difficulty of suppression – rather the presence of critical drivers of fire behaviour in that landscape negates suppression effort, no matter how skilfully applied.

SLIDE 30... ISSUE 4

4) Very large fires and rugged landscape fires are prone to being controlled by vertical air movement. Vertical air movement can be due to a number of processes, many brought into the spotlight by our project.

SLIDE 31... ISSUE 5

5) Elevated fire danger and vertical air movement are precursors to the formation of a plume-driven fire. Plume-driven fires need deep flaming, which can arise from strong winds, wind changes and channelling.

SLIDE 32... ISSUE 6

6) Plume-driven fires are responsible for a large proportion of the loss of life, property, land management assets and water management assets from wildfire.

SLIDE 33... LANDSATS

LIFE CYCLE

So, I'd like to explain to you the life-cycle of a catastrophic fire, the cause of most risk.

SLIDE 34... FDI / FMC

We have shown that we can say, with a very high level of certainty, that fire danger is proportional to wind speed divided by fuel moisture content. Its that simple.

TRIGGERS

Now, we have also shown that fuel moisture content is, firstly, directly proportional to drought factor and, secondly, 10 minus a quarter of the difference between temperature and relative humidity. This permits you to list the triggers for bad fire danger: strong winds, extreme drought factor and the difference between temperature and RH approaching 40.

SLIDE 35... FMC AT BIMBERI

If as happened on 2003 and 2009 this latter number does approach 40, then the fire danger index involves dividing by a very small number, giving an almost arbitrarily large result. Errors in the measurement of the inputs – wind speed, temperature and relative humidity - would have a huge influence on the output.

SLIDE 36... DRY SLOTS

On bad fire days there is frequently a band of very dry air above a few kilometres above the ground. Vertical air movement associated with a fire can drag that dry air downwards, rapidly dropping the RH. As listed above there are a number of mechanisms that we have studied that have the ability to cause this. Add to this list the very important studies of Graham Mills in the Bureau of Meteorology on abrupt surface dryings (nicknamed "dry slots" by the media).

A CATASTROPHIC FIRE…

SLIDE 37… GINGERA FIRE

The life cycle of any catastrophic fire begins with a small fire. All fires start small, but some grow bigger. Obviously this requires escalating fire weather, difficult access or involvement of more than just fine surface fuel in the spread of the fire. Escalation reflects a combination of ruggedness and full fuel availability.

When they become large fires they start to come under the influence of the special interactions of the rugged landforms and the weather. This is where vertical air flow becomes important.

SLIDE 38… BENDORA IN NSW

They may persist as large fires for some time until one or more of the discrete weather phenomena comes along. Let's say a subsidence inversion drops below the top of the fire. This means that that night the planned backburns around the fire will get out of control. It also means that the drainage inversion that night will be cool but very dry and will produce a strong thermal belt. This means that other tactics that night may fail. Subsidence inversions happen under high pressure cells and are often followed by troughs or cold fronts. Thus the work that <u>has to</u> succeed before the weather changes <u>cannot</u> succeed. This is a situation now familiar to field crews.

SLIDE 39… RECENT WV

Ahead of the approaching weather change we may see in satellite imagery an abrupt surface drying. Thermal mixing will drag down very dry air. When this happens over the fire a very rapid escalation of conditions may occur. The fire will become a lot more intense, as will its convection. This adds to the vertical movement of air.

We now have a situation where lateral channelling within a lee-slope eddy may take control of part of the fire's perimeter and cause catastrophic escalation. This is where ten to twenty square kilometres may be alight at once and this is where violent pyro-convection begins.

SLIDE 40… PYRO-CB CROSSSECTION

Now there is so much vertically rising air and it is so hot that it is resisting mixing with the surrounding air. At, say, seven kilometers cloud forms in the plume, and a fire thunderstorm begins to form. Under the influence of winds up to ten kilometres above the surface, the storm is pushed away downwind. It takes with it huge quantities of embers which start to light up vast tracts of countryside underneath. It injects smoke at all level of the atmosphere. The fire thunderstorm may produce hail, lightning and tornadoes.

SLIDE 41...   KAZ GORRIE PHOTO

Anyone looking on from nearby or underneath will have their own vision of hell, but will scarcely begin to get a true perspective of an event that now involves well over ten thousand cubic kilometres of air.

Within the footprint there is destruction, death and chaos. It is difficult to imagine just how bad it is and certainly it is impossible to understand without direct experience.

IMPACTS

The landscape is incinerated in one of these events. But is it what we have planned for? Many areas of the high country have had ecological planning done for them. We know that there is a dominant toposequence from dry NW slopes to sheltered SE slopes, reflected in vegetation, fuel and fire behaviour.

SLIDE 42...   DOWNHILL RUN

But this picture has been found wrong in recent years. The downhill runs of fire have been systematically shown to be by far the most intense when caused by channelling-driven fire. Huge changes have happened to stand dominance.

SLIDE 43...   SCOURED LANDSCAPE

Few foresaw, for example, a need for the protection of water supplies where the **sheltered, damp slopes** were burnt to mineral earth and the seed bank fried.

Now we have identified the causes of the catastrophic fires we may start to plan for them. This planning must be based on sound evidence. Jason will now convey some of that to you.