NIST Special Publication 1263

Large Outdoor Fires and the Built Environment (LOF&BE): Summary of Virtual Workshop

Sponsored by the International Association for Fire Safety Science (IAFSS)

Sayaka Suzuki
Sara McAllister
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THE INTERNATIONAL ASSOCIATION FOR FIRE SAFETY SCIENCE

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Large Outdoor Fires and the Built Environment (LOF&BE): Summary of Virtual Workshop

Sayaka Suzuki
National Research Institute of Fire and Disaster, Chofu, Tokyo, Japan

Sara McAllister
U.S. Forest Service, U.S. Department of Agriculture, Missoula, MT USA

Samuel L. Manzello
Fire Research Division, Engineering Laboratory

Alex Filkov
University of Melbourne, Melbourne, Australia

Daniel Gorham
Insurance Institute for Business and Home Safety, South Carolina, USA

Xinyan Huang
Hong Kong Polytechnic University, Honk Kong, China

Brian Lattimer
Virginia Tech, Blacksburg, VA, USA

Maria Theodori
Reax Engineering Inc., Berkeley, CA, USA

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U.S. Department of Commerce
Wilbur L. Ross, Jr., Secretary

National Institute of Standards and Technology
Walter Copan, NIST Director and Under Secretary of Commerce for Standards and Technology

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Abstract

Two virtual workshops of the permanent working group, sponsored by the International Association for Fire Safety Science (IAFSS), entitled *Large Outdoor Fires and the Built Environment* (LOF&BE), were held this past August (2020). The first session was held on August 4, 2020 with times selected to suit those in Africa, Europe, and Asia/Oceania. The second session was held on August 6, 2020 with times to suit those in North and South America. The Ignition Resistant Communities (IRC) subgroup is focused on developing the scientific basis for new standard testing methodologies indicative of large outdoor fire exposures, including the development of necessary testing methodologies to characterize wildland fuel treatments adjacent to communities. IRC subgroup progress was presented by Alex Filkov (U Melbourne) and Daniel Gorham (IBHS). The Emergency Management and Evacuation (EME) subgroup is focused on developing the scientific basis for effective emergency management strategies for communities exposed to large outdoor fires. EME subgroup progress was presented by Maria Theodori (Reax Engineering Inc.) and Sayaka Suzuki (NRIFD). The Large Outdoor Fire Fighting (LOFF) subgroup is providing a review of various tactics that are used, as well as the various personal protective equipment (PPE), and suggests pathways for research community engagement, including environmental issues in suppressing these fires. LOFF subgroup progress was presented by Xinyan Huang (Hong Kong Poly U) and Brian Lattimer (Va Tech). An extended session was held for open discussion so that participants could provide feedback on current progress and offer suggestions for the upcoming LOF&BE workshop being organized as part of 13th IAFSS, now being held in April (2021). A total of 60 participants joined from Australia, Brazil, Canada, China, India, Israel, Italy, Japan, Malaysia, Nigeria, Norway, Russia, South Africa, Zambia, UK, USA.

Key words

Large Outdoor Fires; Urban Fires; Wildland-Urban Interface (WUI) Fires; Informal Settlement Fires; Wildland Fires

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1. Introduction

1.1. Workshop Objectives

The International Association for Fire Safety Science (IAFSS) has approved the formation of the permanent working group entitled *Large Outdoor Fires and the Built Environment* or (LOF&BE) [1-2]. This report details the *third* official workshop of this permanent working group. Due to the COVID-19 pandemic, the 13th IAFSS has been postponed and the opportunity was seized to hold two virtual workshops during August 2020.

1.2. Program of the Workshop

Time (Aug. 4th BST)	Time (Aug. 6th PDT)	Title	Speaker
9:00-9:10	4:00-4:10	Introduction to Virtual LOF&BE 2020	S. Manzello, S. McAllister, S. Suzuki
9:10-9:30	4:10-4:30	IRC Presentation	A. Filkov, D. Gorham
9:30-9:50	4:30-4:50	EME Presentation	S. Suzuki, M. Theodori
9:50-10:10	4:50-5:10	LOFF Presentation	X. Huang, B. Lattimer
10:10-10:30	5:10-5:30	Open Discussion	All participants

1.3. List of Registered Participants (Alphabetical Order by First Name)

Alex Filkov (University of Melbourne, Australia)
Anene Basil Oguaka (ABC, Nigeria)
Babak Bahrani (Oregon State University, USA)
Brian Lattimer (Virginia Tech, USA)
Calisa Katiuscia Lemmertz (Federal University of Rio Grande do Sul – UFRGS, Brazil)
Cecilia Lam (National Research Council Canada, Canada)
Charles Kahanji (University of Zambia, Zambia)
Chris Lautenberger (Reax Engineering Inc., USA)
Daniel Gorham (Insurance Institute for Business & Home Safety, USA)
Danielle G Antonellis (Kindling, USA)
David Blunck (Oregon State University, USA)
Davood Zeinali (The University of Lorraine, France)
Ekaterina Markus (Peter the Great St. Petersburg Polytechnic University, Russia)
Emanuele Gissi (CNVVF Italian Fire and Rescue Service, Italy)
Faraz Hedayati (Insurance Institute for Business & Home Safety, USA)
Felipe Roman Centeno (Federal University of Rio Grande do Sul, Brazil)
Felix Wiesner (The University of Queensland, Australia)
Franz Richter (UC Berkeley, USA)
Geir Jensen (FSS AS, Norway)
Hari Krishnan Mohana Krishnan (Ulster university, UK)
Harry Mitchell (Imperial College London, UK)
Hideki Yoshioka (Building Research Institute, Japan)
Ido Marom (Technion - Israel Institute of Technology, Israel)
Jacques De Beer (University of Maryland, Department of Fire Protection Engineering, USA)
John Cloney (Ulster University, UK)
John Hewson (Sandia National Laboratories, USA)

Jonathan Hodges (Jensen Hughes, USA)
Joshua Costello (Los Angeles County Fire Department, USA)
Julian Mendez (The University of Queensland, Australia)
Kathryn Butler (NIST, USA)
Maria Theodori (Reax Engineering Inc., USA)
Martin Kristoffersen (COWI, Norway)
Matthew Kury (Sandia National Labs, USA)
Michael Currie (Fire Underwriters Survey, Canada)
Michael Gollner (University of California, Berkeley, USA)
Mohamad El Houssami (Efectis, France)
Mohamed Beshir (University of Edinburgh, UK)
Mohd Zahirasri Mohd Tohir (Universiti Putra Malaysia, Malaysia)
Muhammad Asim Ibrahim (Linnaeus University, Sweden)
Nan Hua (University at Buffalo, USA)
Nima Masoudvaziri (University at Buffalo, USA)
Praveen Kumar B (Indian Institute of Technology, Madras, India)
Richard Walls (Stellenbosch University, South Africa)
Samuel L. Manzello (NIST, USA, Japan)
Sara McAllister (USDA Forest Service, USA)
Sayaka Suzuki (National Research Institute of Fire and Disaster, Japan)
Shaorun Lin (The Hong Kong Polytechnic University, China)
Stephen Wong (University of California, Berkeley, USA)
Supan Wang (The Hong Kong Polytechnic University, China)
Vinny Gupta (The University of Queensland, Australia)
Wai Cheong Tam (NIST, USA)
Wu Xiqiang (The Hong Kong Polytechnic University, China)
Xinyan Huang (The Hong Kong Polytechnic University, China)
Yu Wang (University of Science and Technology of China, China)

2. Summary and Next Steps

A total of 60 participants joined from Australia, Brazil, Canada, China, India, Israel, Italy, Japan, Malaysia, Nigeria, Norway, Russia, South Africa, Zambia, UK, USA. The LOF&BE work process is divided into three main approaches. Specifically, Phase 1 is the data collection aspect where each of the three subgroups are collecting all available information on codes and standards, best practices, and current research for their respective topic areas. In Phase 2, each subgroup will attempt to identify the gaps amongst codes and standards, between codes and standards and current research, and within current research. In the final Phase, called Phase 3, each subgroup will work on products to address the identified gaps.

At present, all three subgroups are still working in Phase 1, so the audience was queried as to the progress that each subgroup is achieving to this end. During the two workshops, a free-flowing discussion developed where participants were able to ask a diverse set of questions. These questions, as well as key discussion points that ensued, are parsed to the various subgroups as follows:

- What hand calculation would you recommend for heat flux?
    - IRC subgroup: Thank you for the question. As we are not sure if the question is referring to vegetative or structural fuel exposures, please refer to AS3959 for a discussion on simulated exposure levels in these standards.

- Are there any international codes for WUI fires?
    - IRC subgroup: There is an International Code Council (ICC) WUI Code. The ICC WUI code is also in the IRC slides in this workshop. Please see the following papers that describe a global overview.
      https://link.springer.com/article/10.1007/s10694-020-00962-6
      https://link.springer.com/article/10.1007%2Fs10694-019-00902-z

- What is fire resistant gardening?
    - IRC subgroup: it is an ornamental vegetation which has fire resistance properties to create a fire buffer zone

- Where can we view these collated templates for the EME case studies? For example, Cadiz, 2016, Spain?
    - EME subgroup: Currently we are only sharing them with our WG members.

- Among your 4 objectives none deals with firefighting efficiency in reducing fire loss? Is the aim to protect firefighters and environment only, not structures?
    - LOFF subgroup: This area overlaps with the IRC subgroup, as the best way to protect the structure is to prevent the ignition in the first place.

- Is there much work out there focused on using existing sensor networks (for detection) and data gathered from drones/satellites for data assimilation to help forecast fire spread in the wildland? I think fire science has a distinct role and advantage here.
    - LOFF subgroup: For any AI application, establishing a database is the first step. Not many activities have been ongoing to date. There is not yet a standard data format or metadata for wildfire data, and this part needs work. It is expected that the AI tools have a great potential for wildfire forecast and decision making that will be applied soon.

- A question on liaison between ISO/TC92/WG14 and LOF&BE. Nice collaboration would be most expected, hopefully thanks to your coordination.
    - LOF&BE co-leaders: Thanks for your good point. The question is related to the process to explore having IAFSS become a full liaison organization to ISO TC92. As this involves many complex procedures, we plan to have one member of our LOF&BE management team present to ISO TC92/WG14 at our next meeting. Manzello, as convener of ISO TC92/WG14 is arranging this and depending on the discussions at that meeting, we will decide to develop a more formal tie up. Recent ISO TC92/WG14 activities are part of special issue in Fire Technology, Volume 56, Issue 6, September 2020: https://link.springer.com/journal/10694/56/5

- There does not seem to be a significant focus on outdoor fire dynamics or establishing a clear path of experimental and numerical research and major gaps in the existing literature.
    - IRC subgroup: Fire behavior and fire dynamics are included in our Topic 2 (IRC sub-group). We will analyze fire exposures and provide recommendations how to improve standards to reduce likelihood of ignition of structures and house loss.

- Thank you for organizing the workshop. May we have access to these presentations?
    - LOF&BE co-leaders: Slides will be published and available to everyone. We will contact everyone and ask permission to share notes.

- I am glad to see a nice African presence today.
    - LOF&BE co-leaders: We need more members from Africa, please join us!

- How does anyone join LOF&BE?
    - LOF&BE co-leaders: Anyone may join. It is free. Please see our website on IAFSS page. https://iafss.org/committees/large-outdoor-fires-the-built-environment-working-group/

- What are the IRC subgroup timelines?
    - IRC subgroup: Current timeline for topic 2 (fire exposure) paper [end of 2020]. Need to revisit topic 1. Topic 3 needs some pushing from subgroup participants.

- Comment about lack of research on human behavior studies in informal settlement fires.
    - LOF&BE management team: We agree.

- What data is available and collected in EME subgroup case studies?
    - EME subgroup: Please join the EME subgroup. We are using these case studies in various literature review papers.

- Who is typically involved in the vehicular accidents? For example, are the vehicle accidents civilians colliding with responders?
    - LOFF subgroup: This is something the group is looking into.

- How many countries have different training for structural and wildland fire fighting (similar to the states)?
    - LOFF subgroup: China, Canada, and Australia are examples of different structural and wildland firefighting training.
    - LOF&BE previously conducted a survey to the Working Group. Will send survey results to the members.

- Does the workgroup also review and have any recommendations to revise the tenability criteria for firefighters in various incident situations (e.g. structural, wildfire, etc.)?
    - LOFF subgroup: Thanks for the interesting question. It has not been focused on to date in the LOFF subgroup.

- For wildland firefighting (in the US) an additional piece of emergency PPE is a fire shelter. Was this included in the literature survey?
    - LOFF subgroup: Not included in review to date but plans to add.

- Has there been any progress on using UAVs on wildland fires in the US? Historically they have been banned because of airspace issues (hard to control where the UAVs are relative to air suppression resources).
    - LOFF subgroup: Operationally on WUI seems like there are still too many hurdles (both technically and procedurally). There are NFPA standards for UAVs (http://www.nfpa.org/2400). These technologies are covered in the encyclopedia from Springer Nature. https://link.springer.com/referencework/10.1007/978-3-319-51727-8

- Might be a little off topic, what is the time between detection by the cameras and fire fighters response?
    - LOFF subgroup: Alert Wildfire cameras are not monitored but are used for confirmation. There are other companies that take camera video and have detection algorithms.

- Related to this question, is the firefighter tenability point above in relation to long term exposure? Is there tenability criteria for people evacuating from any types of large outdoor fires? This is a gap in informal settlements.
    - LOFF subgroup: An interesting point worth considering. We are not aware of any information presently.

- With respect to EME and community evacuation tracking when at risk of WUI fires, may be interesting to survey insurers for claims related to "Additional Living Expenses (ALE)".
    - EME subgroup: Thank you.

The LOF&BE management team plan to use these valuable suggestions going forward. In particular, these will be most helpful as the next workshop is prepared as part of the IAFSS 2021 meeting to be held in Waterloo, Canada.

3. Acknowledgments

The LOF&BE team would like to personally thank Professor Patrick Van Hees of Lund University, IAFSS President for his constant support. The authors would like to thank Dr. David Rush of University of Edinburgh and Mr. Len Garis of University of the Fraser Valley for their input.

References

[1] Manzello, S.L., McAllister, S., Suzuki, S., Blanchi, R., Pastor, E., and Ronchi, E., (2019) Large Outdoor Fires and the Built Environment: Summary of Kick-off Workshop, NIST Special Publication 1236 https://doi.org/10.6028/NIST.SP.1236.

[2] Manzello, S.L., McAllister, S., Suzuki, S., Blanchi, R., Pastor, E., and Ronchi, E., (2019) Large Outdoor Fires and the Built Environment: Summary of Workshop at Interflam 2019, NIST Special Publication 1241 https://doi.org/10.6028/NIST.SP.1241.

Appendix A: Presentations Delivered at the Workshop

THE INTERNATIONAL ASSOCIATION FOR FIRE SAFETY SCIENCE

VIRTUAL LOF&BE 2020 WORKSHOP

Sayaka Suzuki[1], Sara McAllister[2] & Samuel L. Manzello[3]
Alex Filkov[4], Len Garis[5], Dan Gorham[6], Xinyan Huang[7],
Brian Lattimer[8] David Rush[9], Maria Theodori[10],

1 NRIFD 2 USFS 3 NIST
4 U of Melbourne 5 UFV 6 IBHS 7 HKPolyU
8 Virginia Tech 9 U of Edinburgh, 10 Reax Engineering

What LOF&BE means?

Large Outdoor Fires and the Built Environment (LOF&BE)

Wildland fires (or forest fires)*, wildland-urban interface (WUI) fires, urban fires**, and informal settlement fires, which pose a threat to people

Discussed in Lund workshop

*Wildland fires also include (but not limited to) Wildfires, Bushfires, Mountain fires, Grassland fires, Veld fires; depending on location
** Urban fires include post-earthquake fires

Introduction

- Over the past several decades, fire safety science research has spent a great deal of effort to understand fire dynamics within buildings
- Research into large outdoor fires, and how to potentially mitigate the loss of structures in such fires, lags behind other areas of fire safety science research
- Large outdoor fires affect many people in the world directly and indirectly, both short term and long term (e.g. evacuation, losing property, losing loved ones, breathing products of combustion)

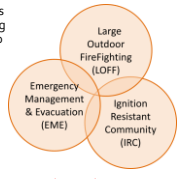
Some Important Problems?

- Fire spread in Large Outdoor fires
  - Very complex - interaction of topography, weather, vegetation, and structures
  - Structure-structure fire spread can occur under similar mechanisms as in urban fire spread as well as WUI fire spread
- Impact on fire and smoke on climate and health
  - Long term and short term effect
- Large outdoor firefighting
  - Structure/Urban firefighting PPE and tactics different than wildland fire firefighting PPE and tactics; what needs to be done for WUI fire fighting?
- Emergency management strategies
  - How or when or whether to evacuate

IAFSS Permanent Working Group

- IRC develop scientific basis for new standard testing methodologies indicative of large outdoor fire exposures, develop necessary testing methodologies to characterize wildland fuel treatments adjacent to communities
- EME develop scientific basis for effective emergency management strategies for communities exposed to large outdoor fires
- LOFF review various tactics used, as well as various personal protective equipment (PPE), and suggest pathways for research community engagement, including environmental issues in suppressing these fires

The overall objectives are to bring full depth of knowledge of the community to work on these priority topics



Those subgroups are related to each other

General Approach

- Phase 1 Collect information
  - Codes and standards
  - Best practices
  - Current research
- Phase 2 Identify the 'Gaps'
  - Among codes and standards
  - Among codes and standards and current research
  - Among current research
- Phase 3 Work on 'Products' solving the Gaps

THE INTERNATIONAL ASSOCIATION FOR FIRE SAFETY SCIENCE

THE UNIVERSITY of EDINBURGH School of Engineering

IAFSS Permanent Working Group

More than 140 members from 25 countries *and growing…!*

From University, Research Institute, Fire service, Industry

Leaders: Samuel L. Manzello (NIST) Sara McAllister (USFS) Sayaka Suzuki (NRIFD)

SubGLs :

IRC: Alex Filkov (U Melbourne), Dan Gorham (IBHS), Dave Rush (U Edinburgh)

LOFF: Len Garis (UFV), Xinyan Huang (HKPolyU), Brian Lattimer (VirginaTech)

EME: Sayaka Suzuki (NRIFD), Maria Theodori (Reax Engineering)

Thank you for former subGLs
Raphaele Blanchi (CSIRO), Elsa Pastor (UPC), Enrico Ronchi (Lund U)

Workshop & Summary Paper

- 2017 IAFSS workshop – look at problem from global perspective (Asia view, Oceania view, European view, North American view, South American view)
- Overview of the large outdoor fire risk to the built environment from each region presented
- Critical research needs for this problem in the context of fire safety science are provided
- Workshop Summary paper published in *Fire Safety Journal* (adding Africa view)

Mini workshops at 11th AOSFST (2018) & Interflam (2019)
Full workshop (1.5 days) planned for 2020/2021 13th IAFSS Symposium

13th IAFSS Workshop program

- *Subgroups' progress report*
- *Interesting view from WG members*

Hope you will join this too!

Acknowledgement

- All the WG members

THE INTERNATIONAL ASSOCIATION FOR FIRE SAFETY SCIENCE

If you would like to join WG, please sign up from the link below or QR codes;

https://goo.gl/forms/oTMW2SbWi7mmHYIv1

Ignition Resistant Communities (IRC)

•••

Session 1: August 4
Session 2: August 6

Status of the subgroup

New co-leaders

Members: 82 [as of 23-July-2020]

Interested parties (keep me informed)*: 31 [as of 28-July-2020]

*This option is being removed and individuals will be contacted to change their status.

Objectives and methodology

Aim

To develop the scientific basis for new standard testing methodologies indicative of large outdoor fire exposures, including the development of necessary testing methodologies to characterize wildland fuel treatments adjacent to communities

Topics

IRC-1. Regulatory Framework and Standards Survey

IRC-2. Fire exposure characterization

IRC-3. Effectiveness of fuel treatments at the WUI

Work Progress - Topic 1 - Standards survey

Questions to address in analysis

1. **Document objectives**
2. Scope of implementation
3. Fire exposure analysis
4. Other comments

Is it a standard explaining a method for fire testing?
Is it a standard providing construction requirements?
Is it a guideline providing construction advices? Etc.

Work Progress - Topic 1 - Standards survey

Questions to address in analysis

1. Document objectives
2. **Scope of implementation**
3. Fire exposure analysis
4. Other comments

Who has developed the document? Where is this document being used? Is it mandatory by law in any region/country)?

Work Progress - Topic 1 - Standards survey

Questions to address in analysis

1. Document objectives
2. Scope of implementation
3. **Fire exposure analysis**
4. Other comments

What are the types of large outdoor fire exposures considered in this document (flame contact, flame radiation, firebrands)?

What are they representing (wildfire main front exposure, post-frontal combustion of residential fuels, structure-to-structure fire exposure)?

In case of a method for fire testing, how is the fire represented (type of fuel used, flame characteristics - i.e. dimensions, heat flux, duration-, ember shower characteristics – flux and duration-, etc.)?

What is the element receiving the fire exposure (residential/industrial/commercial properties, external construction elements –windows, walls, decks, etc.-)?

Work Progress - Topic 1 - Standards survey

Questions to address in analysis

1. Document objectives
2. Scope of implementation
3. Fire exposure analysis
4. Other comments

County	Documents
Australia	AS 1530.8 Parts 1 & 2 AS 3959 NASH 2014
United States	CBC Chapter 7A SFM Testing Standard 7A ASTM standard on external fire exposure
Japan	Building Standard Law Roof testing standard
International	FM Global NFPA 1144 ICC Wildland-Urban Interface Code

Work progress - Topic 2 - Fire exposures

Aim of the work

To collect data on the different phases/modes of fire exposures and their impact on the built environment. Fire sources to explore will be the main wildfire front and the residential fuels, either natural (ornamental vegetation) or non natural (fences, sheds, stored material, structures, etc.).

Work progress - Topic 2 - Fire exposures

A review paper on LOF&BE interaction:

- to improve our understanding of LOF&BE fires and to provide recommendations for future research and standards development.

The Knysna Fires of 2017. Technical Report. 2019

AS 3959:2018

Work progress - Topic 2 - Fire exposures

Questions:

- What data are available?
- What data collection methods are used?
- Compatibility and consistency of data?

Discussion:

- What kind of data we don't have but we need?
- How can we obtain better data for standardization purposes?
- How to improve existing standards?

Work progress - Topic 2 - Fire exposures

1. Introduction
2. Wildland fire exposures
    - 2.1 Flame contact and convection
    - 2.2 Radiation
    - 2.3 Embers and firebrands
3. Built environment response
    - 3.1 Flame contact and convection
    - 3.2 Radiation
    - 3.3 Embers and firebrands
4. Discussion (gaps and future directions)

Work progress - Topic 3 - Fuel treatments

Documentation gathering and classification

1. Guidelines/recommendations on wildland treatments around WUI areas issued by land-management agencies
2. Empirical investigations of wildland treatments effectiveness around WUI areas in wildfire conditions
3. Guidelines/recommendations on WUI-fuel treatments in WUI perimeters issued by agencies
4. Empirical investigations of WUI-fuel treatments effectiveness in WUI perimeters
5. Fire resistant gardening guidelines
6. Evidences of efficiency

Thank you!

If you would like to join a WG, please sign up from the link below or using a QR code:

https://goo.gl/forms/0TMW2SbWi7mmHYlv1

EMERGENCY MANAGEMENT & EVACUATION SUBGROUP

Virtual Workshop
August 2020

Large Outdoor Fires and the Built Environment | International Association for Fire Safety Science

OUTLINE

- EME subgroup, vision & goals
- Work completed to date
- Work in progress & planned
- Open floor

VISION & GOALS

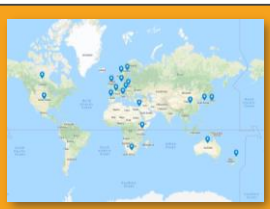
The **main aim** of this subgroup is to develop the scientific basis for effective emergency management strategies for communities exposed to large outdoor fires (informal settlement fires, WUI/wildfires, urban fires, etc.)

Main objectives:

1. Inventory of strategies and regulatory frameworks
2. Inventory of tools
3. Gaps, research roadmap and strategy/tool assessment

Achievement of these aims and objectives requires a **global collaborative effort**.

EME SUBGROUP MEMBERS



59 members from 23 countries

UNDERSTANDING EMERGENCY MANAGEMENT

- Estimate damage
- Debris management
- Provide necessary support – Economic, Health, Social Services
- Assess emergency protocol

etc.

Our current focus

- Preparedness + Mitigation
- Establish emergency response protocol
- Perform risk assessment
- Education & training to residents/ emergency service

etc.

- Notification to public
- Dispatch emergency service
- Incident stabilization
- Evacuation & mass care

etc.

WORK COMPLETED TO DATE

- Literature collection
- Case studies collection
- EME regulatory frameworks survey

CASE STUDIES COLLECTION

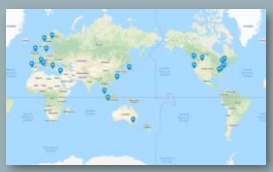
- Case studies collected based on template
- Around 40 case studies including WUI/wildland fires, urban fires and informal settlement fires
- Analysis will start soon

Sakata	1976	Japan	Urban	Sayaka Suzuki
Okanagan	2003	Canada	Wildfire/WUI	Ronchi et al
San Diego	2007	USA	Wildfire/WUI	Ronchi et al
Victoria	2009	Australia	Wildfire/WUI	Ronchi et al
Swinley	2011	UK	Wildfire/WUI	Harry Mitchell
La Gomera	2012	Spain	Wildfire/WUI	Ronchi et al
Colorado Springs	2012	USA	Wildfire/WUI	Maria Theodori
Black Forest	2013	USA	Wildfire/WUI	Maria Theodori
Laerdalsoyri	2014	Norway	Urban	Martin Kristoffersen
Västmanland	2014	Sweden	Wildfire/WUI	Ronchi et al
Fort McMurray	2016	Canada	Wildfire/WUI	Ronchi et al
Madeira	2016	Portugal	Wildfire/WUI	Ronchi et al
Cadiz	2016	Spain	Wildfire/WUI	Sandra Vaiciulyte
Gatlinburg	2016	USA	Wildfire/WUI	Maria Theodori
Haifa	2016	USA	Wildfire/WUI	Ronchi et al
Atlas	2017	USA	Wildfire/WUI	Stephen Wong
Nuns	2017	USA	Wildfire/WUI	Stephen Wong
Tubbs	2017	USA	Wildfire/WUI	Stephen Wong
Creek	2017	USA	Wildfire/WUI	Stephen Wong
Rye	2017	USA	Wildfire/WUI	Stephen Wong
Skirball	2017	USA	Wildfire/WUI	Stephen Wong
Thomas	2017	USA	Wildfire/WUI	Stephen Wong
British Columbia	2017	Canada	Wildfire/WUI	Chunyun Ma
Imizamo Yethu	2017	South Africa	Informal settlement	Sayaka Suzuki
Camp	2018	USA	Wildfire/WUI	Stephen Wong
Carr	2018	USA	Wildfire/WUI	Stephen Wong
Hill	2018	USA	Wildfire/WUI	Stephen Wong
Ranch	2018	USA	Wildfire/WUI	Stephen Wong
River	2018	USA	Wildfire/WUI	Stephen Wong
Woolsey	2018	USA	Wildfire/WUI	Stephen Wong
Jämtland	2018	Sweden	Wildfire/WUI	Johanna Fransson
Calci/Vicopisano	2018	Italy	Wildfire/WUI	Sandra Vaiciulyte
Nelson	2019	New Zealand	Wildfire/WUI	Ruggiero Lovreglio

And more

REGULATORY FRAMEWORK SURVEY

- Survey as a first step



Big thanks to Audrey Roy-Poirier, Peter Sunderlad, Virginie Felicelli-Tihay, Luis Mario Ribeiro, Ido Marom, Alex Filkov, Martin Kristoffersen, Julie Dugdale, Jean-Paul Monet, Daniel Gorham, Hubert Biteau, Charles Scawthorn, Sue Su, Mohd Zahirasri Mohd Tohir, Dionysis Kolaitis, Asim Ibrahim, Yu Wang, Margaret McNamee, Michael Currie, LingChu Su and Anonymous members!

WORK IN PROGRESS & PLANNED

- Literature review report
- Case studies analysis
- EME regulatory frameworks collection & analysis

REVIEWS FOR LARGE OUTDOOR FIRE EVACUATION

Contributors:
Negar Elhami Khorasani[1], Max Kinateder[2], Vincent Lemiale[3], Samuel L. Manzello[4], Ido Marom[5], Leorey Marquez[3], Darlene Rini[6], Sayaka Suzuki[7], Maria Theodori[8], Yu Wang[9], Stephen Wong[10]

1 University at Buffalo, State University of New York
2 NRC Canada
3 CSIRO
4 NIST
5 Technion – Israel Institute of Technology
6 Jensen Hughes
7 NRIFD
8 Reax Engineering
9 University of Edinburgh
10 UC Berkeley

Key report sections:
- Data collection for large outdoor fire evacuation
- Human Behavior in Large Outdoor Fires
- Evacuation Modelling for Large Outdoor Fires
- Lesson learned from evacuation in other disasters
- Challenges for large outdoor fire evacuation

REVIEWS FOR LARGE OUTDOOR FIRE EVACUATION

Data collection for large outdoor fire evacuation

Investigative focus
- Methods of data collection and analysis
- Which data is being collected
- Where/when data is collected
- What questions the data answers
- What areas might more focus be placed

Preliminary key findings of the studies reviewed
- Survey is the most common data collection method, including semi-structured, online, mail-in, mixed-mode, pre-fire, post-fire, qualitative and quantitative findings.
- Most studies were conducted to understand factors that influence human behavior and evacuation or sheltering decision-making during wildland-urban interface fire. Few available studies specifically examined the influence of available transportation modes on evacuation.
- Most studies were conducted in the US and Australia, perhaps leaving a gap in understanding of potential cultural differences in attitude toward evacuation.

REVIEWS FOR LARGE OUTDOOR FIRE EVACUATION

Human behavior in large outdoor fires

Investigative focus
- Methods of assessing human behavior
- Behavior across all disaster temporal points
- What factors influence evacuation choices
- How transferable is behavior between geographies
- What are lessons learned from previous large outdoor fires

Preliminary key findings of the studies reviewed
- Few quantitative analyses of human behavior related to evacuation and no consensus on factors influencing behavior
- Most research focuses on mitigation/preparedness and the decision to evacuate or stay/defend, not on key transportation and sheltering choices that can impact outcomes
- Minimal work understanding human behavior of vulnerable populations beyond research on Indigenous populations such as First Nations
- Unclear generalizability of behavior across geographies, urban forms, and cultures

REVIEWS FOR LARGE OUTDOOR FIRE EVACUATION

Evacuation modelling for large outdoor fires

Investigative focus

- Computational methods available
- Aims and applications of models
- Current computing challenges and emerging trends
- The growing role of data
- Notable systems currently in use – case studies
- Open questions

Preliminary key findings of the studies reviewed

- Growing trend towards developing Decision Support Systems
- A key focus is to couple and combine multiple methods (traffic/pedestrian/disaster modelling) into unified frameworks
- Data analytics and AI play an increasingly important role

REVIEWS FOR LARGE OUTDOOR FIRE EVACUATION

Lesson learned from evacuation in other disasters: Tsunami

Investigative focus

- Factors that influence the number of the deaths from tsunami events
- Knowledge from Indigenous communities

Preliminary key findings of the studies reviewed

- Four main factors that influence the numbers of deaths from tsunami events
  - Overall nature of the tsunami
  - Overall geographical area where it occurs
  - Types of mitigation strategies implemented in an at risk area
  - Social or human behavior aspects
- Another consideration seen in situations where there exist a large indigenous population is that the rate of deaths from tsunami events tend to much less for these communities owing to their experience
  - Inherent knowledge that an indigenous community holds has also been subject of research in wildland and wildland-urban interface (WUI) fires as well.

REVIEWS FOR LARGE OUTDOOR FIRE EVACUATION

Lesson learned from evacuation in other disasters: Earthquake

Investigative focus

- Factors for earthquake evacuation models at an urban scale
- Evacuation analysis and modelling

Preliminary key findings of the studies reviewed

- Site hazard, buildings vulnerability, and the exposed elements are main factors
  - Additional to these three factors, interactions between people and the environment are key issues that significantly affect human behaviour during earthquake evacuation
- The evacuation analysis and modelling are presented in two ways:
  1) timeline of an earthquake 2) mechanism of models

REVIEWS FOR LARGE OUTDOOR FIRE EVACUATION

Lesson learned from evacuation in other disasters: Hurricanes

Investigative focus

- What factors influence decision to evacuate
- How do people evacuate / where do they go
- Do hypothetical studies provide realistic data
- What ideas can be applied to large outdoor fire research

Preliminary key findings of the studies reviewed

- Perceived risk significantly influences the decision to evacuate or not.
- Social and demographic factors, and prior experience with hurricanes, also influence evacuation behavior.
- Majority of those evacuated use personal vehicles and prefer shelter with family or friend.
- Hypothetical hurricane scenario studies seem to provide similar results to actual evacuation studies, and thus could be used to further study people's response.
- Discrete choice analysis and traffic simulations could be extended to wildfire application

WORK IN PROGRESS & PLANNED

- Literature review report
- Case studies analysis
- EME regulatory frameworks collection & analysis

Please join us! Let's work together.

THANK YOU!

IAFSS LOF&BE Working Group

Large Outdoor Firefighting (LOFF)

Workshop A: August 4th (Tue) 9:00–10:30 AM (BST)
Workshop B: August 6th (Thu) 4:00–5:30 PM (PDT)

LOFF Vision and Goals

- **Main Aim: Large Outdoor Firefighting (LOFF)** subgroup will provide a review of firefighting injuries and challenges, new firefighting technologies, and protection measures, suggest pathways for research community to engage and support firefighting tactics.
- Please join us if you are interested (see IAFSS website).

Focus of LOFF

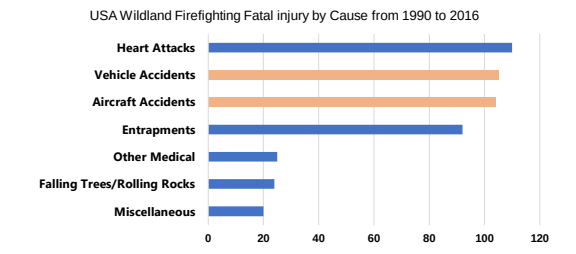
1. **Firefighter injury and health issues**
   - Use statistics to understand how to improve the firefighter safety
2. **Firefighter personal protection equipment (PPE)**
   - Standards to test PPE and potential areas for improvement
3. **Technologies to support firefighting**
   - Improve response and planning
   - Reduce firefighter exposure / injury
4. **Environmental impacts**
   - Effects of firefighting / large outdoor fires on environment

1. Fatality of Wildfire Fighting (Statistics)

Country	Years	Number	Main reasons
USA	1990-2018	3,031 (all fires)	overexertion, struck by and vehicle collision
		495 (wildfire)	heart attacks, vehicle accidents, aircraft, and entrapments
Canada	2006-2018	920	traumatic injury and circulatory system, cancer*
China#	1980-2008	1.4 per fire	collapse, vehicle accidents, explosion, asphyxia, electric shock, and burn
Australia*	1976-2011	6,249	malignancies, circulatory disease, respiratory disease, injury and trauma

#data from 161 major wildfire and firefighting actions
*Data of Australia are gathered from different databases

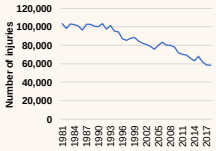
Causes of Firefighting Fatal Injury (Statistics)



National Wildfire Coordinating Group, NWCG Report on Wildland Firefighter Fatalities in the USA, 2017.

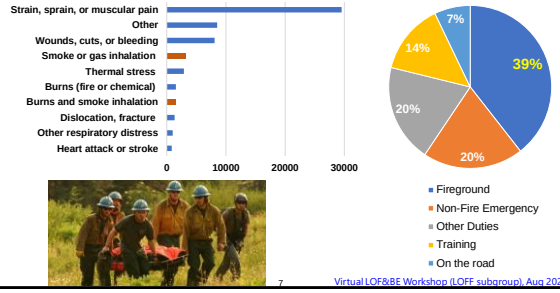
Non-lethal Injuries of Firefighters (Statistics)

Country	Years	Number	Main Causes
USA	1990-2016	3,243,320 (all fires)	overexertion or strain, falls or slips, exposure to fire products, contact with an object
	2003-2007	1,301 (wildfire)	slips/trips/falls, wounds by equipment, tools or machinery, fire, smoke, flash or burnt
Canada	2006-2018	20,081 (all fires)	traumatic injuries to muscles, tendons, bones, nerves, spinal cord, etc.
China#	1980-2008	3.6 per fire	explosion, poisoning, hit by objects, and entrapments



#data from 161 major wildfire and firefighting actions

Firefighting Injury Types and Ratio



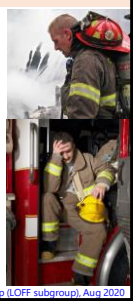
Risks and Health Issues during Wildland Firefighting

Risks	Composition
Smoke & Toxic gases	CO Toxic nitrides, toxic sulfides, formaldehyde, ozone particulate matter (PM2.5/3.5/4) Benzenes, benzene compounds, PAHs
Others	High-intensity work
	Lacking sleep
	Mental health hazards
	Noise

Adetona et al. (2016) Inhal. Toxicol.
Aurell et al. (2013) Environ. Sci. Technol.

Long-term Health Problems of Wildfire Fighters

Type of illnesses	Related Research
Respiratory disease	Relationship between exposures and respiratory related illnesses
Post-traumatic stress disorder (PTSD)	Exposed to wildfires may suffer from PTSD
Sleep disorder	High-intensity physical work and changeable environments result in sleep disorder.
Mental disorder	High risk of suffering mental disorders:
Suicide	Higher suicide rate than other occupational groups
Oxidative stress	increased risk of oxidative stress, may cause other disease, such as cause damage to DNA
Other disease	Heat stress, systemic inflammation and hearing loss



Adetona *et al.* (2016) Inhal. Toxicol.
Groot et al. (2019) Int. J. Occup. Med. Environ. Health.

2. Firefighter PPE

- **Literature review on PPE** in different countries on the LOFF drive
  - Structural for urban / informal settlements
  - Wildland/WUI
- **Standards for PPE in different countries** (ASTM, NFPA, ISO, EN, etc.)
  - Mostly clothing thermal protection performance
- **Survivability of firefighter equipment**
  - Vehicle operation following burn-over

Protection Measures & Training

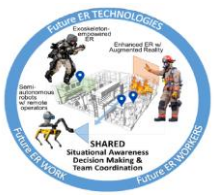
	Measures
Firefighters	Exercise and take medical examination regularly to keep healthy
	Maintain good work and rest habits
	Know common heat-related or respiratory related illnesses
	Report all work-related injury and illness
	Wear standard-compliant PPE
Supervisors	Promote a safe work environment
	Manage work/rest periods of WFFs
	Provide enough and credible PPE
	Arrange reasonable work schedule and shift hours

National Institute for Occupational Safety and Health, CDC
https://www.cdc.gov/niosh/docs/2013-158/default.html

3. LOFF Technologies

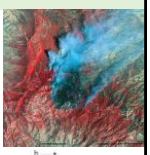
LOFF requires unique technology since the scale is very large

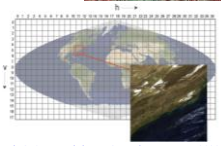
- Detection & Communication
- Response Planning & Decision Making
- Search and Rescue
- Operations (management, suppression)



LOFF Technologies – Detection / Response

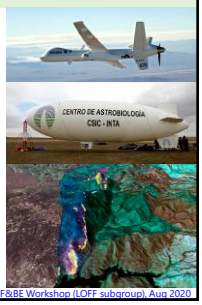
- **Satellite imaging**
  - Multi-spectral imaging / weather
  - Lower resolution and more frequent (days to hours)
- **Manned aircrafts**
  - Multi-spectral and hyperspectral imaging (fire location / burned mapping / vegetation)
  - Higher resolution
  - Infrequent (months) or only on select fires





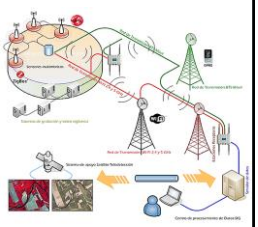
LOFF Technologies – Detection / Response

- **UAVs (Drones)**
  - More global view than possible from ground
  - Possible use in entering spaces to dangerous for firefighters (unstable structures, identify hazard, etc.)
  - New NFPA 2400 standard on use of drones by emergency responders



LOFF Technologies – Detection / Response

- **Camera & Sensor Networks**
  - Systems being used to provide in-situ data on fire events
    - Early detection
    - Monitoring
    - Mostly urban and wildland
    - possible for informal settlements?



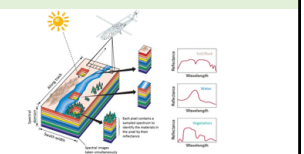
LOFF Technologies – Detection / Response

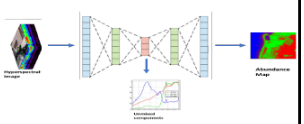
- **Camera & Sensor Networks**
  - ALERTWildfire system of cameras setup in Western U.S.
    - Early detection and monitoring wildfires
    - Over 1,000 cameras
  - Combined with communication system and energy storage system (PV + battery etc.)
  - Several commercial companies of camera & sensor network are available today

Alkhatib (2014) *Int. J. Distributed Sensor Networks*

LOFF Technologies – Decision Making

- **Large amount of data being produced**
  - Historic data from satellites for fire tracking, vegetation, weather
  - Newer systems (drones, manned aircraft, camera/sensors)
  - Needs to be interpreted to support making decisions
- **Machine learning to interpret**
  - Classification of objects (fire, vegetation type, person, etc.)
  - Predict phenomena (fire spread)
  - Fast so can be used for forecasting





LOFF Technologies – Search & Rescue / Operations

- **Exoskeletons**
  - Assist with lifting
  - Reduce fatigue by supporting load
- **Track / wheeled ground robots**
  - Suppression
  - Land management
  - Equipment movement

Sniderman, D. "Robotic Firefighting Vehicles", ASME Magazine, 2011.

Upcoming Opportunity: LOFF Review Paper

Advances in Outdoor Firefighting

- ❖ Outdoor firefighting has different challenges compared with structure firefighting
- ❖ Focus of paper on technology advances for outdoor firefighting
  - reduce firefighter injury (PPE, robotics, etc.)
  - improve planning and decision making
  - Increase efficiency in operations (management, search/rescue, suppression, etc.)
- ❖ Include all types of outdoor fires (urban, wildland/WUI, informal settlements)
- ❖ Challenges and Future Needs

- Outline being distributed to subgroup within the next week

LET US KNOW IF YOU WANT TO BE INVOLVED !!

LOFF Subgroup Leaders:

Xinyan Huang (HK PolyU, China)

Brian Lattimer (Virginia Tech, USA)

Len Garis (UFV, Canada)

THANK YOU!