# Emberometer

Burgers Program and Combustion Institute Summer School on Fire Safety Science — Wildland/WUI Fire Behavior

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NIST NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
U.S. DEPARTMENT OF COMMERCE

**Acknowledgement and thanks to:** Nicolas Bouvet, Stephen Fink, Savannah Wessies

# Firebrands and Embers

**Ember –** a glowing fragment from a fire; hot carbonaceous particle

**Firebrand –** specifically an airborne, lofted ember

Size: mm to cm+ scale

Energy: smoldering to flaming

Source: detached from vegetative or structural fuels

Babrauskas V. (2018) Firebrands and Embers. *Encyclopedia of Wildfires and Wildland-Urban Interface (WUI) Fires*, ed Manzello SL (Springer). https://doi.org/10.1007/978-3-319-51727-8_3-1

# View Inside a Prescribed Fire

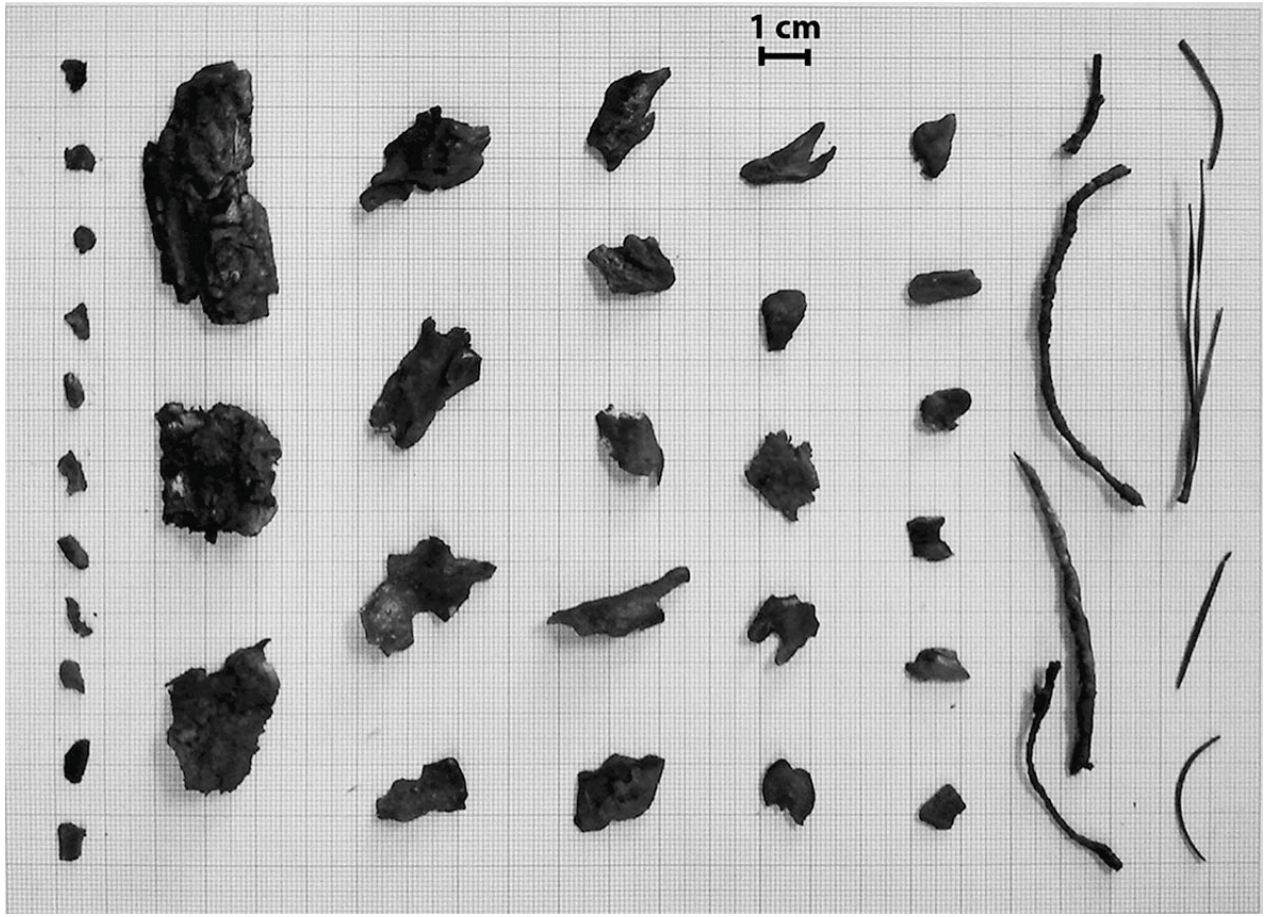
# WUI Firebrands

**Santa Rosa, CA (2017 Tubbs Fire)** *Source: Luis Hernandez via Los Angeles Times*


**Paradise, CA (2018 Camp Fire)** *Source: Paradise Police Department*

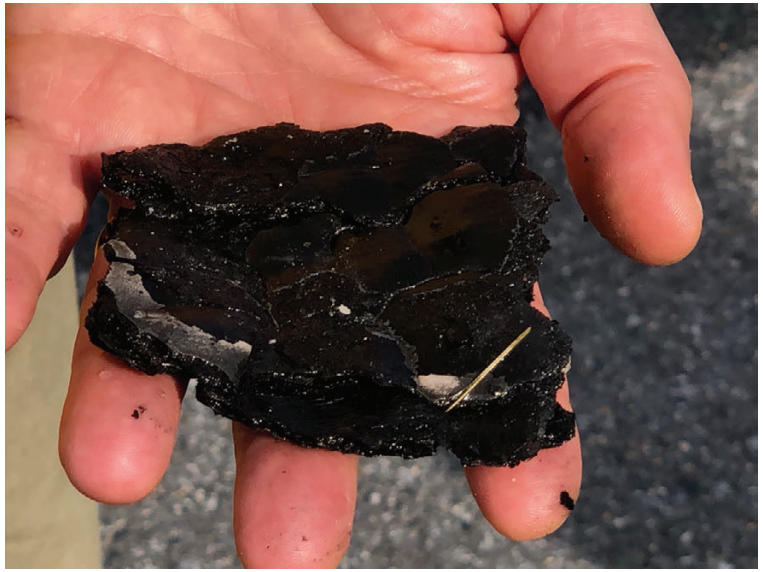
**Paradise, CA (2018 Camp Fire)** *Source: CAL FIRE*

# Firebrands and Embers



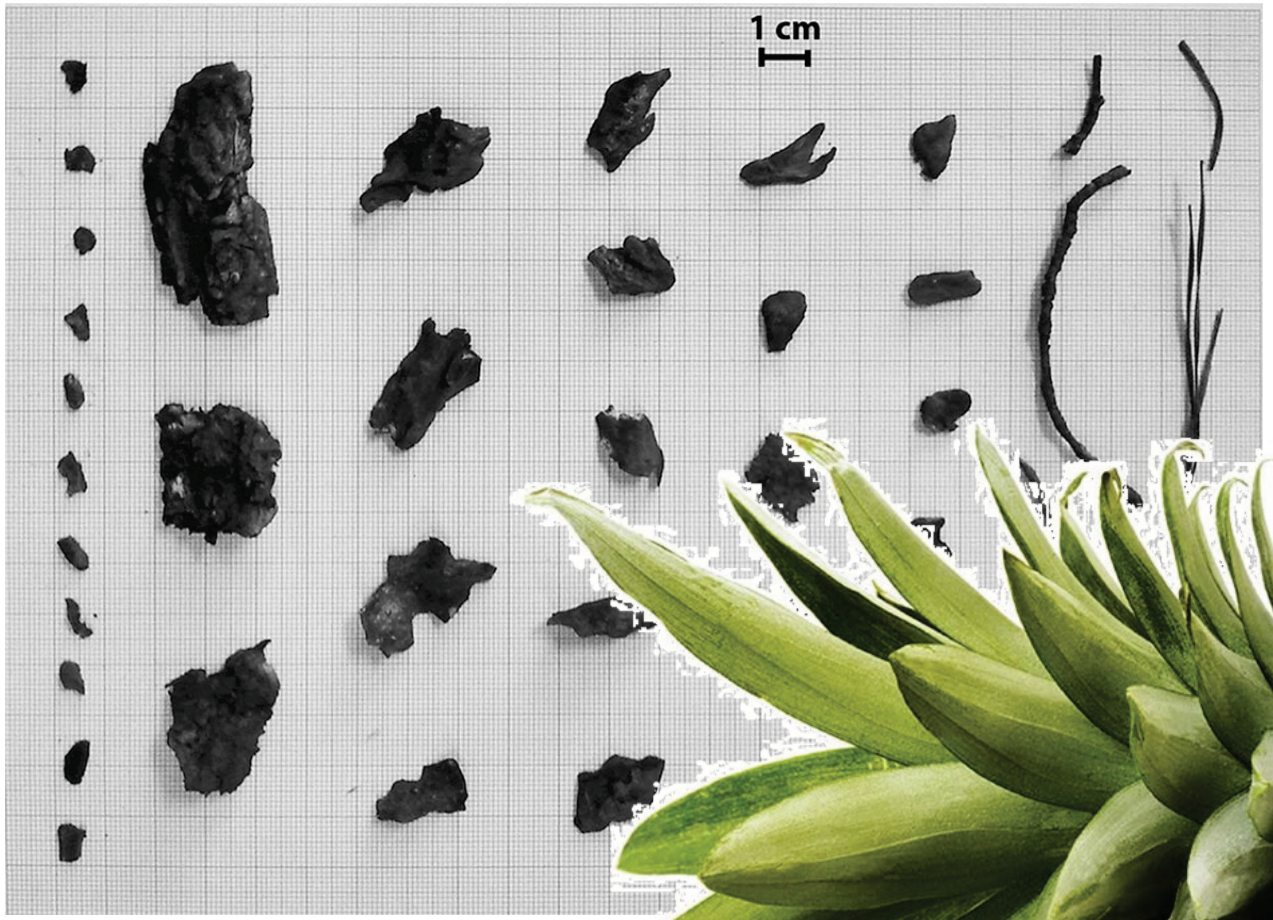

El Houssami M., *et al.* (2016) Experimental Procedures Characterising Firebrand Generation in Wildland Fires. *Fire Technology* 52(3):731-751. https://doi.org/10.1007/s10694-015-0492-z


Suzuki S. , Manzello S.L. (2018) Characteristics of Firebrands Collected from Actual Urban Fires. *Fire Technology*. https://doi.org/10.1007/s10694-018-0751-x



NIST Outdoor SSE Shed Burns

# Firebrands and Embers




El Houssami M., *et al.* (2016) Experimental Procedures C
*Fire Technology* 52(3):731-751. https://doi.org/10.1


Suzuki S. , Manzello S.
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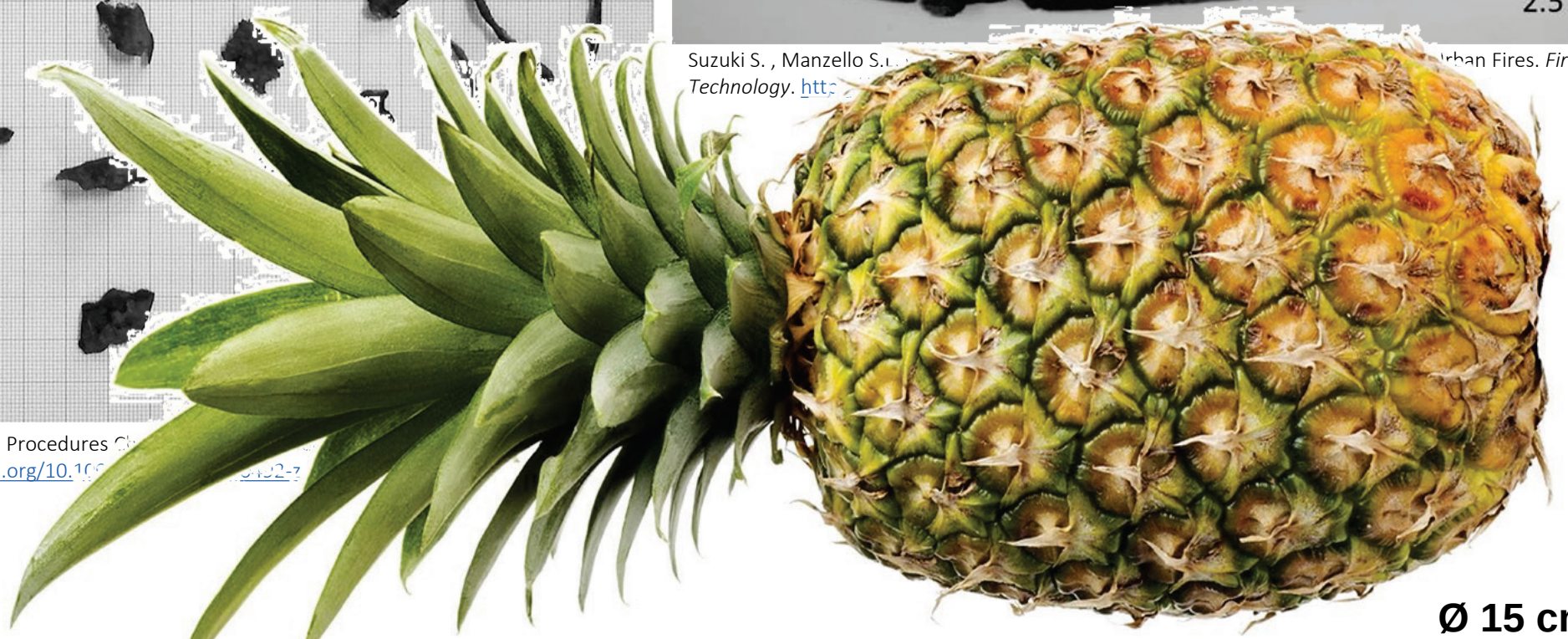
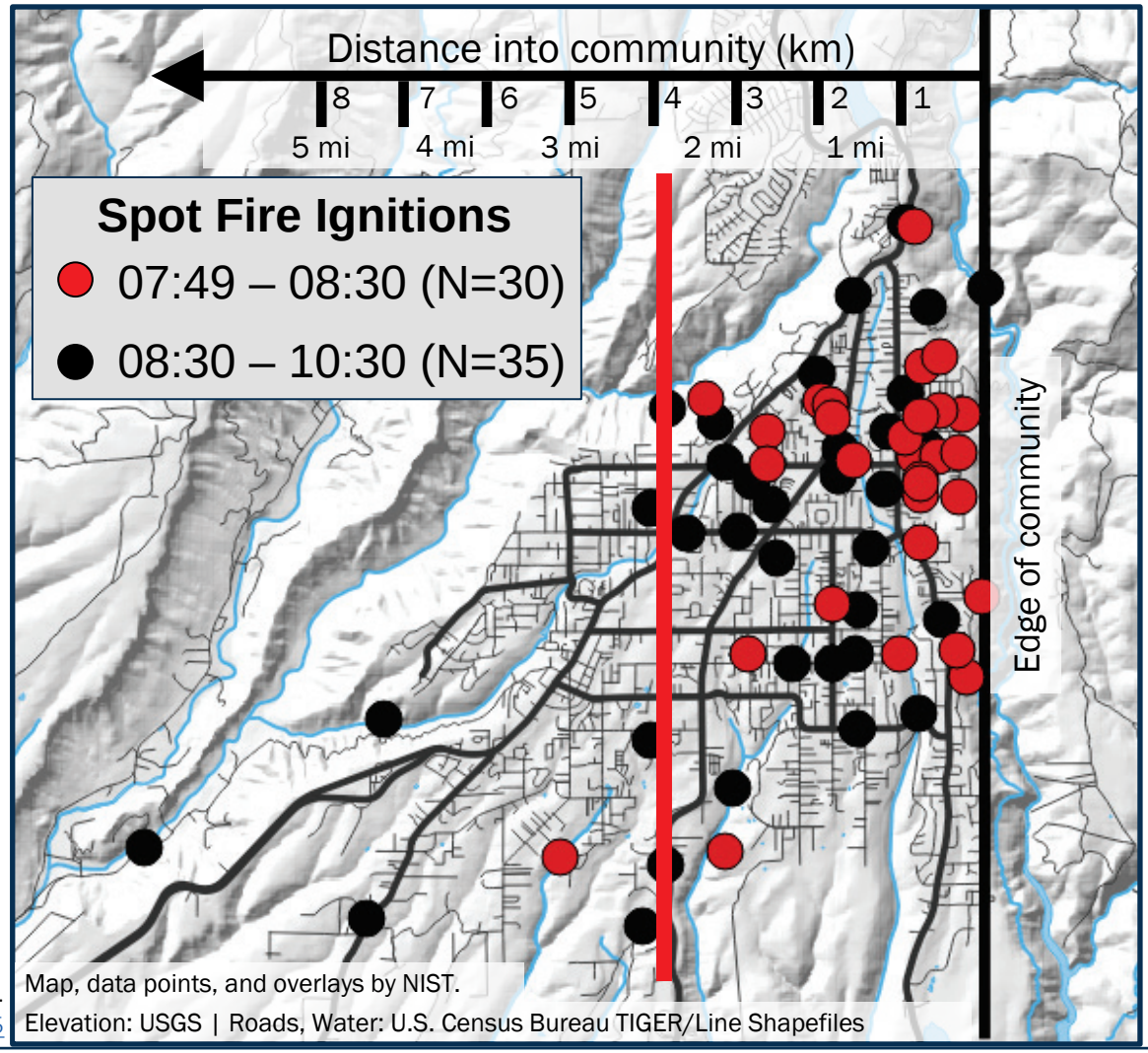


# Threats of Firebrand Ignitions

- Approx. 2/3 structure ignitions, 2007 Witch Fire
  (Maranghides and Mell, NIST TN 1635; 2009)
- At least 50% of structure ignitions from embers only, 2003 ACT bushfires
  (Blanchi and Leonard, CSIRO; 2005)
- Spot fire ignition and fire spread enhancement
  (e.g., Maranghides, et al, NIST TN 2135; 2021)

Dependent on:
geometry, temperature, rate of deposition, fuel properties, environmental conditions

**Camp Fire; Paradise, CA**
30 identified spot fires in first 40 minutes, reaching 4 km (2.5 mi) into community




Maranghides A., *et al.* (2021) A Case Study of the Camp Fire — Fire Progression Timeline. *NIST Technical Note 2135*. National Institute of Standards and Technology, Gaithersburg, MD. https://doi.org/10.6028/NIST.TN.2135

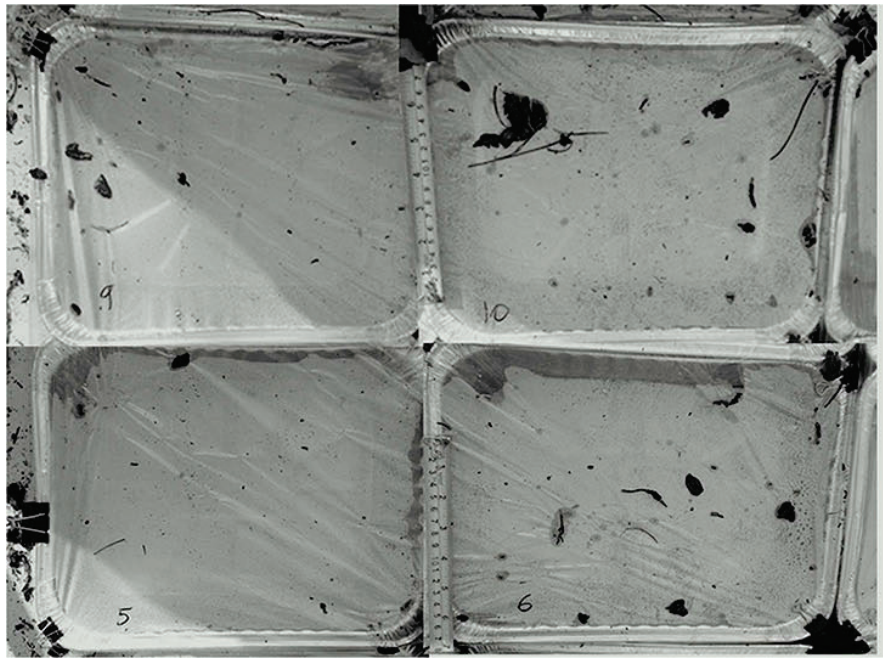
# Technical Needs of Firebrand Measurements

- Source/generation characteristics
- Aerodynamic characteristics
- Deposition characteristics
- Exposure/severity metrics

# “Standard” Methods of Firebrand Quantification

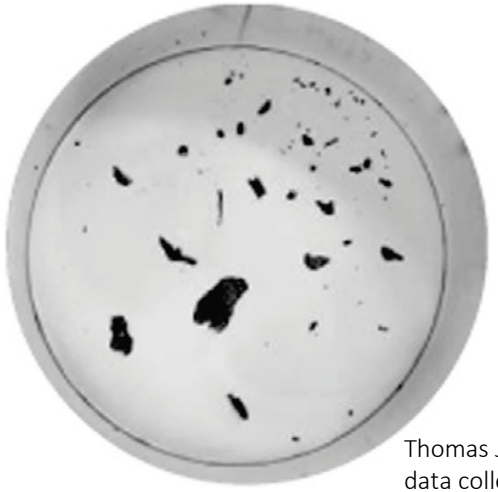
- Water pan collection
- Projected surface area
- Caliper measurements
- Cloth sheets
- Tarps

# Water Pan Collection



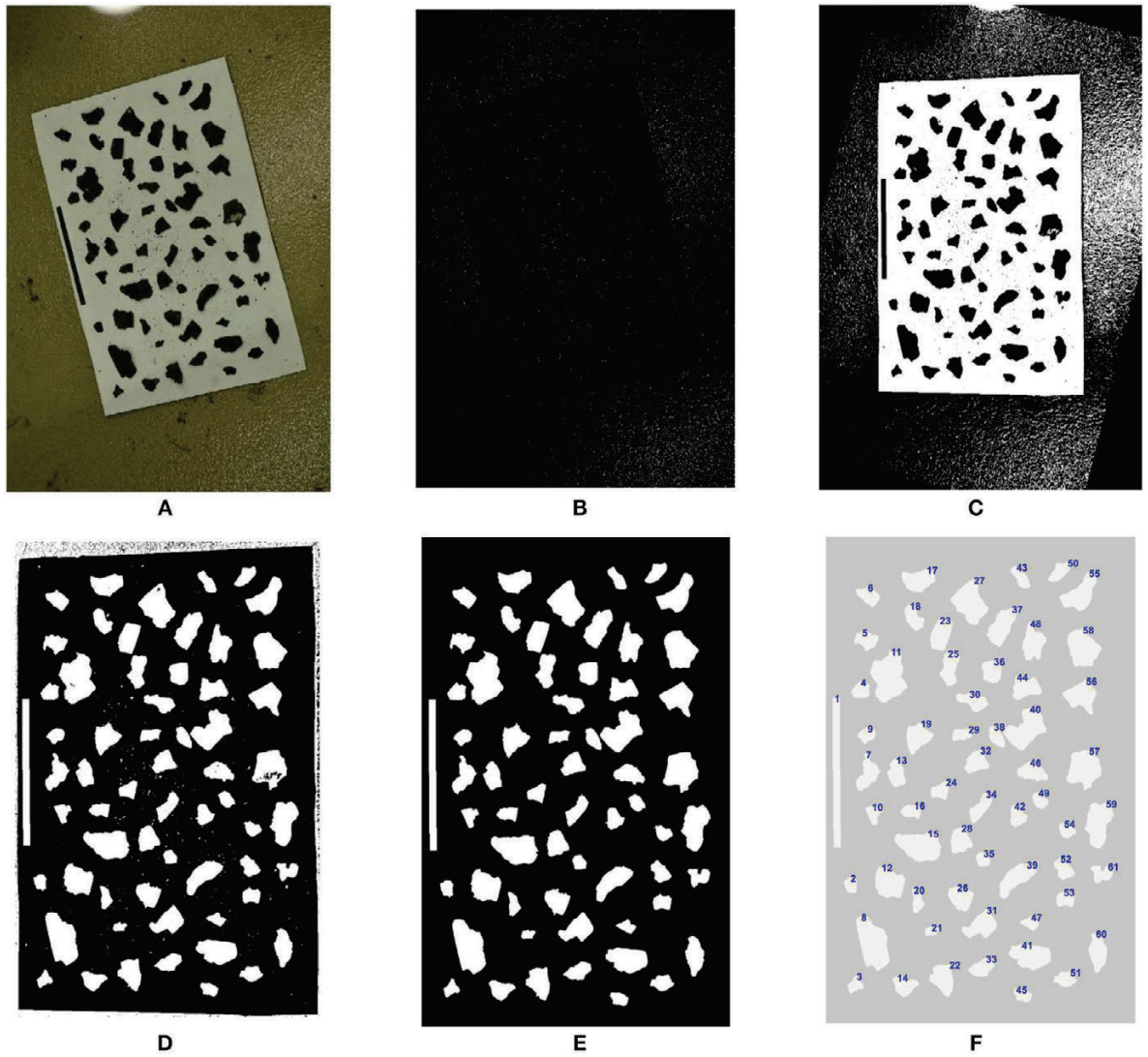

El Houssami M., *et al.* (2016) Experimental Procedures Characterising Firebrand Generation in Wildland Fires. *Fire Technology* 52(3):731-751. https://doi.org/10.1007/s10694-015-0492-z

Bouvet N., *et al.* (2019) On the use of time-resolved three-dimensional diagnostics to characterize firebrand showers in the WUI. *Advances in Forest Fire Research 2018*, ed Viegas DX (Coimbra University Press), pp 826-836. https://doi.org/10.14195/978-989-26-16-506_91

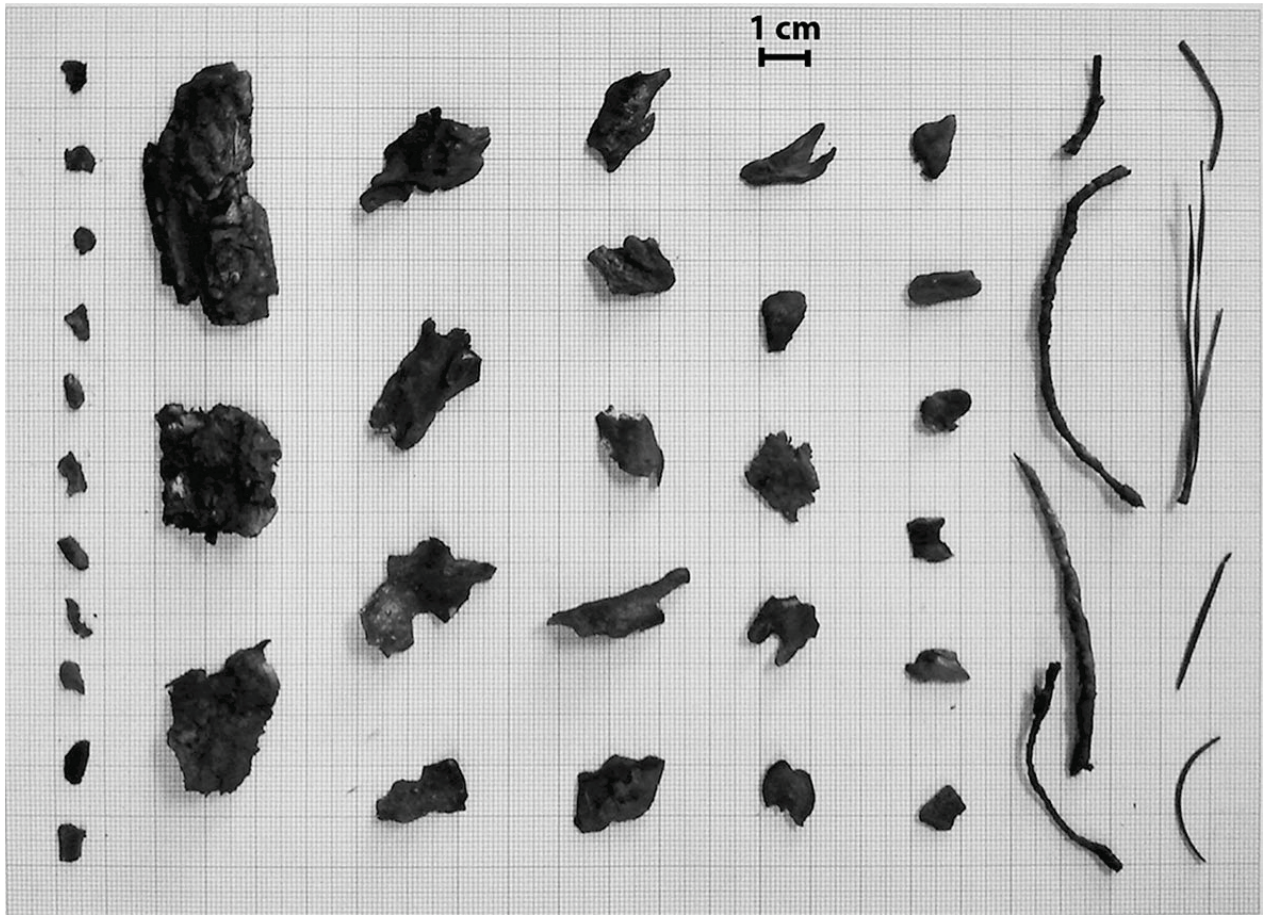


Thomas J.C., *et al.* (2017) Investigation of firebrand generation from an experimental fire: Development of a reliable data collection methodology. *Fire Safety Journal* 91:864-871. https://doi.org/10.1016/j.firesaf.2017.04.002

# Projected Area Analysis

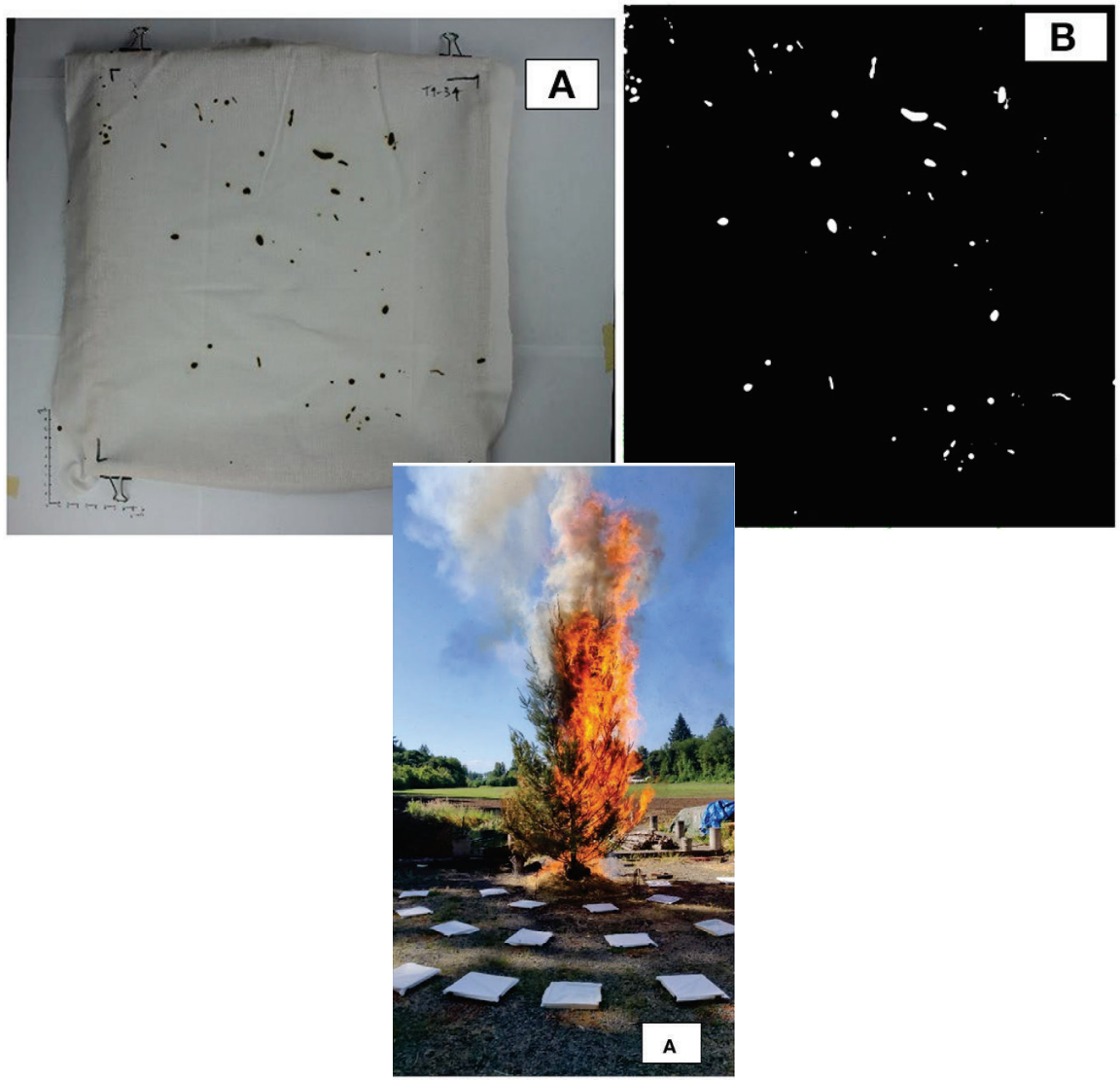



Hedayati F., *et al.* (2019) A Framework to Facilitate Firebrand Characterization. *Frontiers in Mechanical Engineering* 5:43. https://doi.org/10.3389/fmech.2019.00043

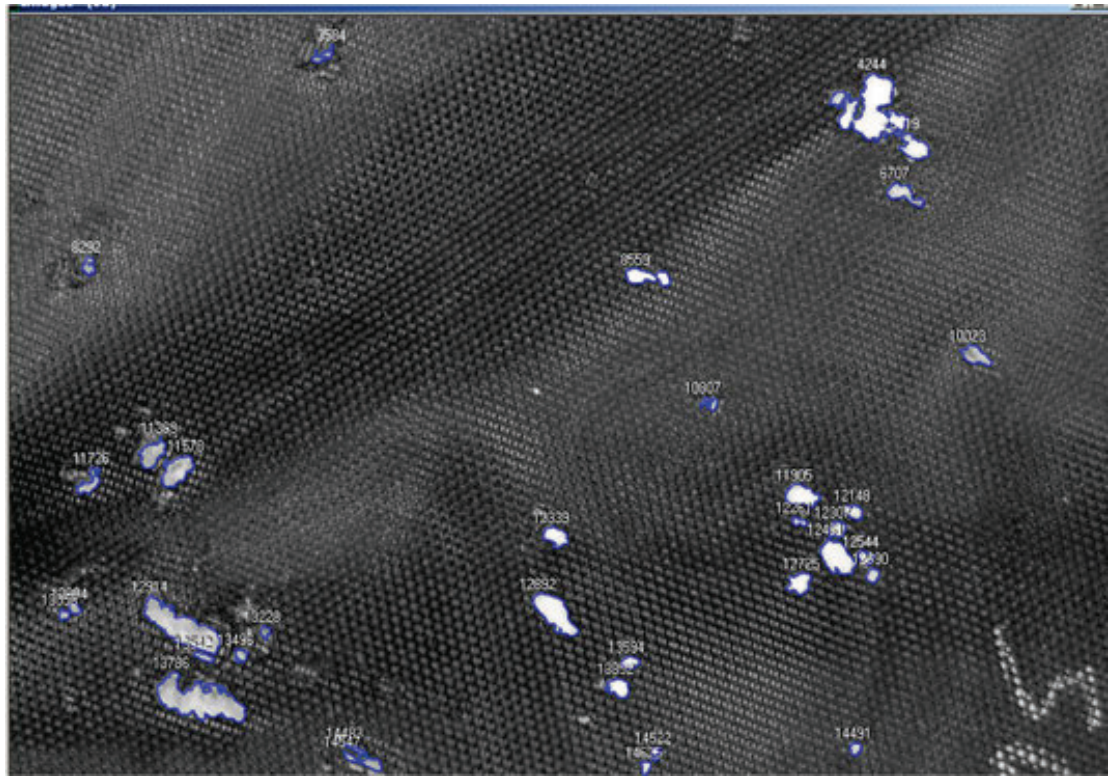



El Houssami M., *et al.* (2016) Experimental Procedures Characterising Firebrand Generation in Wildland Fires. *Fire Technology* 52(3):731-751. https://doi.org/10.1007/s10694-015-0492-z

# Cloth/Trampoline Scorching




Adusumilli S., Chaplen J.E., Blunck D.L. (2021) Firebrand Generation Rates at the Source for Trees and a Shrub. *Frontiers in Mechanical Engineering* 7:655593. https://doi.org/10.3389/fmech.2021.655593



Manzello S.L. , Foote E.I.D. (2014) Characterizing Firebrand Exposure from Wildland–Urban Interface (WUI) Fires: Results from the 2007 Angora Fire. *Fire Technology* 50:105-124. https://doi.org/10.1007/s10694-012-0295-4

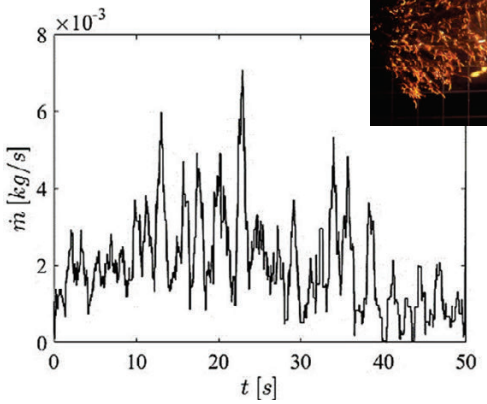
See also:
Rissel S. , Ridenour K. (2013) Ember Production During the Bastrop Complex Fire. *Fire Management Today* 72(4):7-13. https://www.fs.usda.gov/sites/default/files/fire-management-today/72-4.pdf

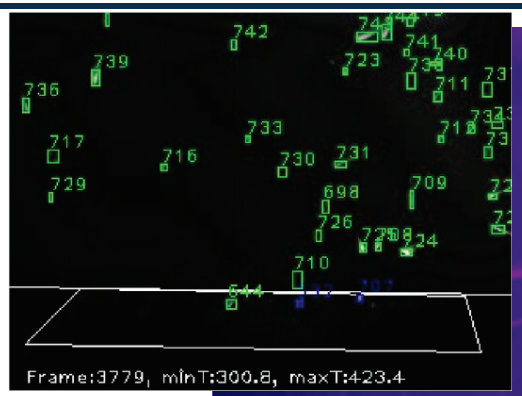
# Limitations

- Passive/non-temporal cumulative collection
- Hot or cold?
- “Deployability”
- Two-dimensional
- Fragile
- Painstaking

# Image Tracking

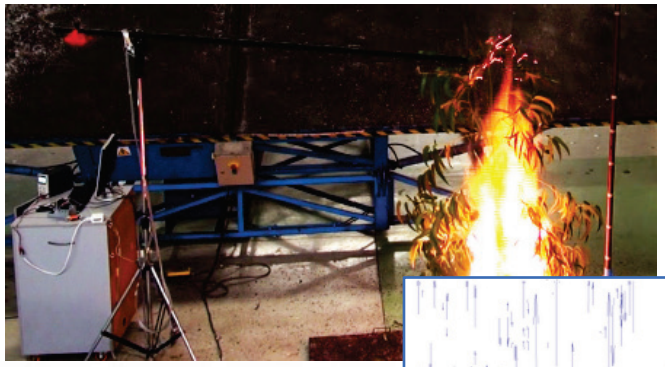
Tohidi A. , Gollner M. (2017) Computer Vision Techniques for Firebrand Detection and Characterization. *SUPDET 2017*.

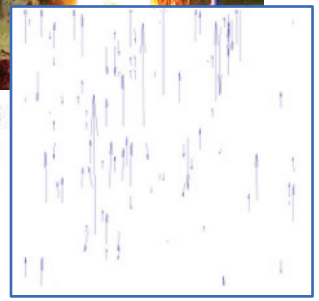


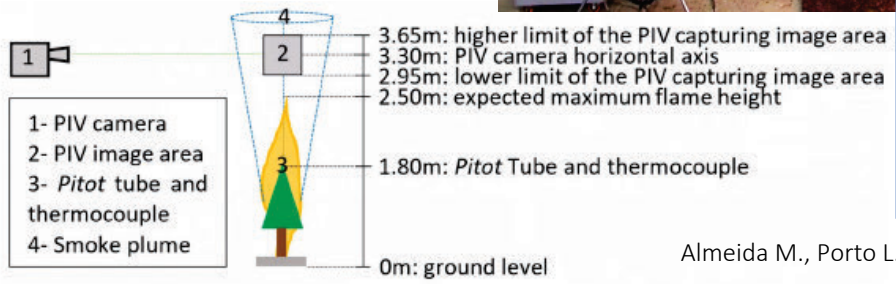





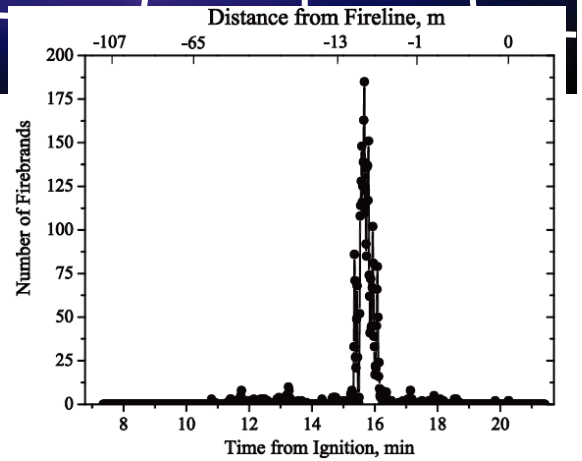









Almeida M., Porto L., Viegas D. (2021) *Front. Mech. Eng.* 7:651135.




Filkov A., *et al.* (2017) *Proc. Comb. Inst.* 36(2):3263-3270.
Filkov A, Prohanov S (2018) *Fire Tech.* 55(3):817-836.
Prohanov S., *et al.* (2020) *Fire* 3(4):68.

# Emberometer

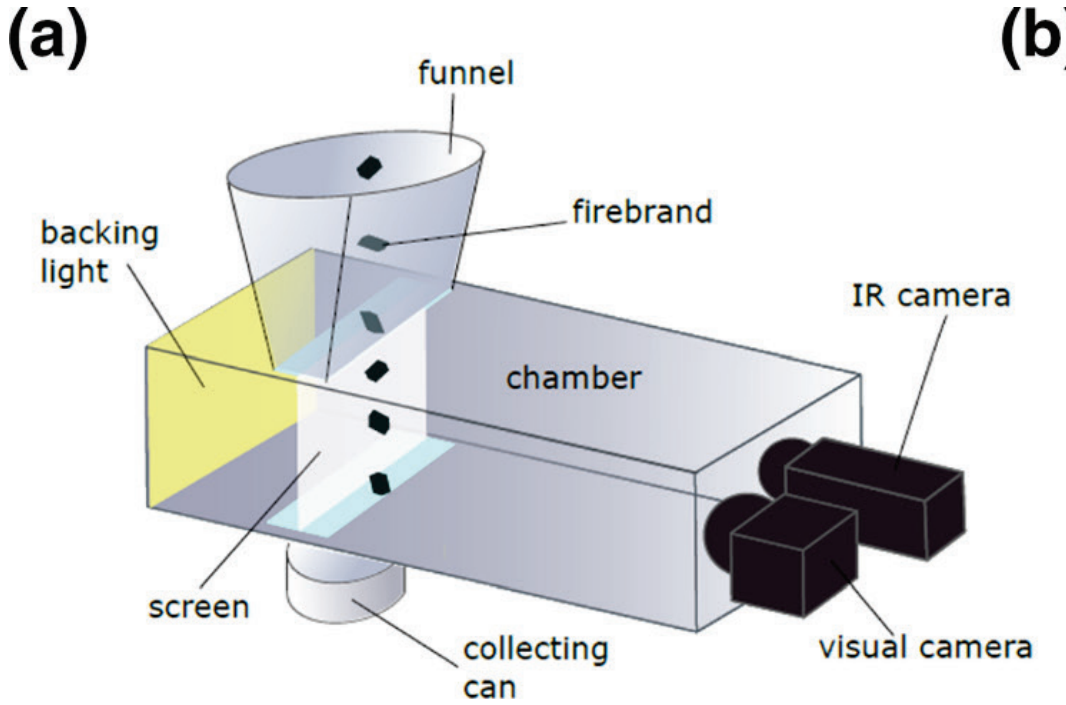
## Where does an emberometer fit in?

Emberometer: device for time-resolved, live, measurement of firebrand characteristics including size, shape, thermal state, flux

- Source/generation characteristics ←
- Aerodynamic characteristics ←
- Deposition characteristics ←
- Exposure/severity metrics ←

Develop the measurement science to **quantify** the threat of **firebrand exposure** from **WUI fires** on structures and structural materials

# Edinburgh Emberometer





**Physical System**

- 25 cm x 35 cm aluminum box
- 55 cm collection funnel
- Backlit screen behind falling firebrands
- Collection can

**Video Recording**

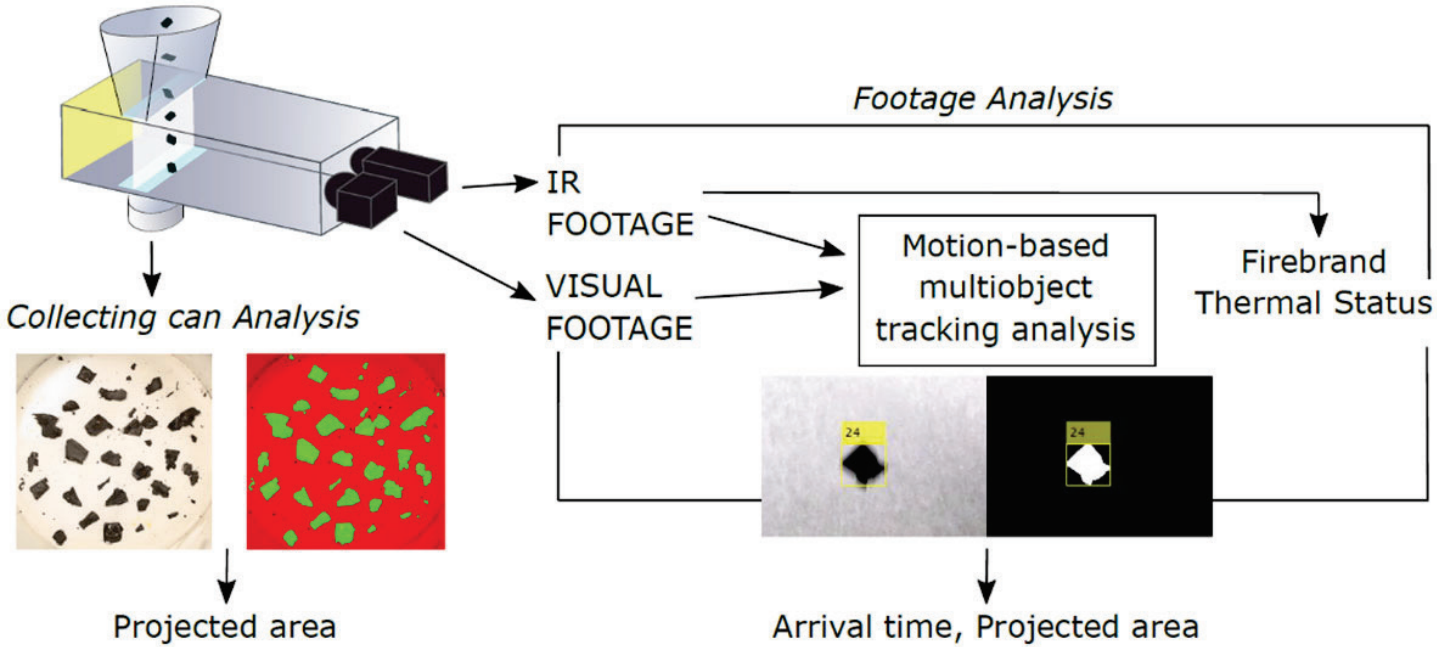
- Visible spectrum camera (50 fps)
- Longwave infrared (IR) camera (7.5–14 um) (FLIR A615)
- ~0.2 s residence time

Zen S., *et al.* (2021) Development of a Field Deployable Firebrand Flux and Condition Measurement System. *Fire Technology* 57:1401–1424. https://doi.org/10.1007/s10694-020-01074-x

# Methodology

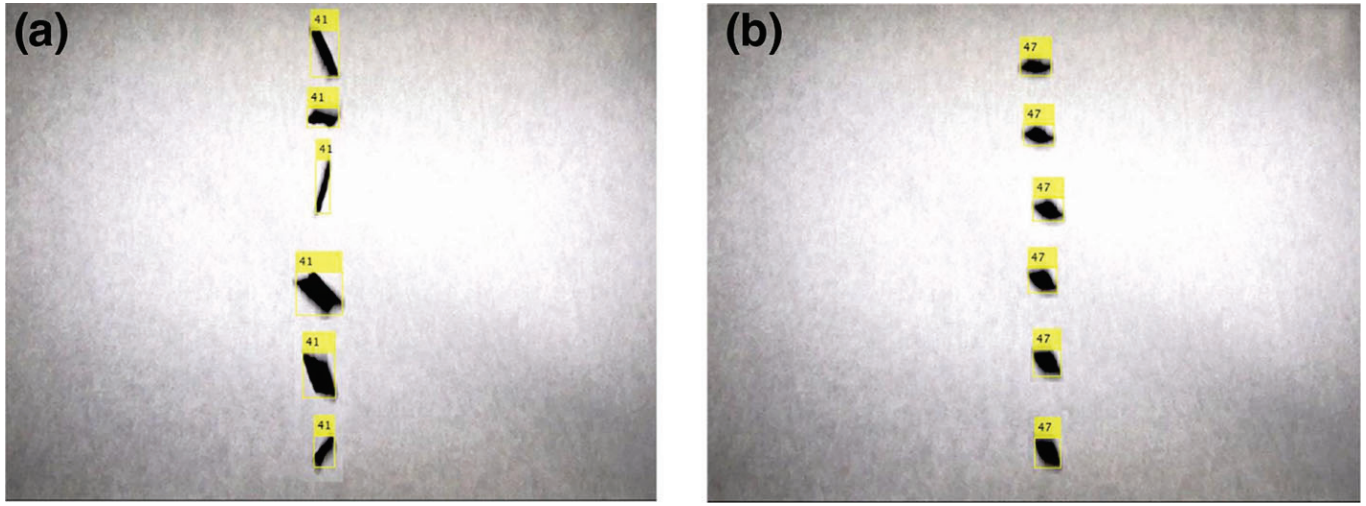
- Geometric and thermal characteristics at deposition
- Detailed time history of deposition (i.e., flux) with respect to fire progression

- IR → tracking and thermal status
- Vis → tracking
- Tracking → arrival time and projected area




Zen S., *et al.* (2021)

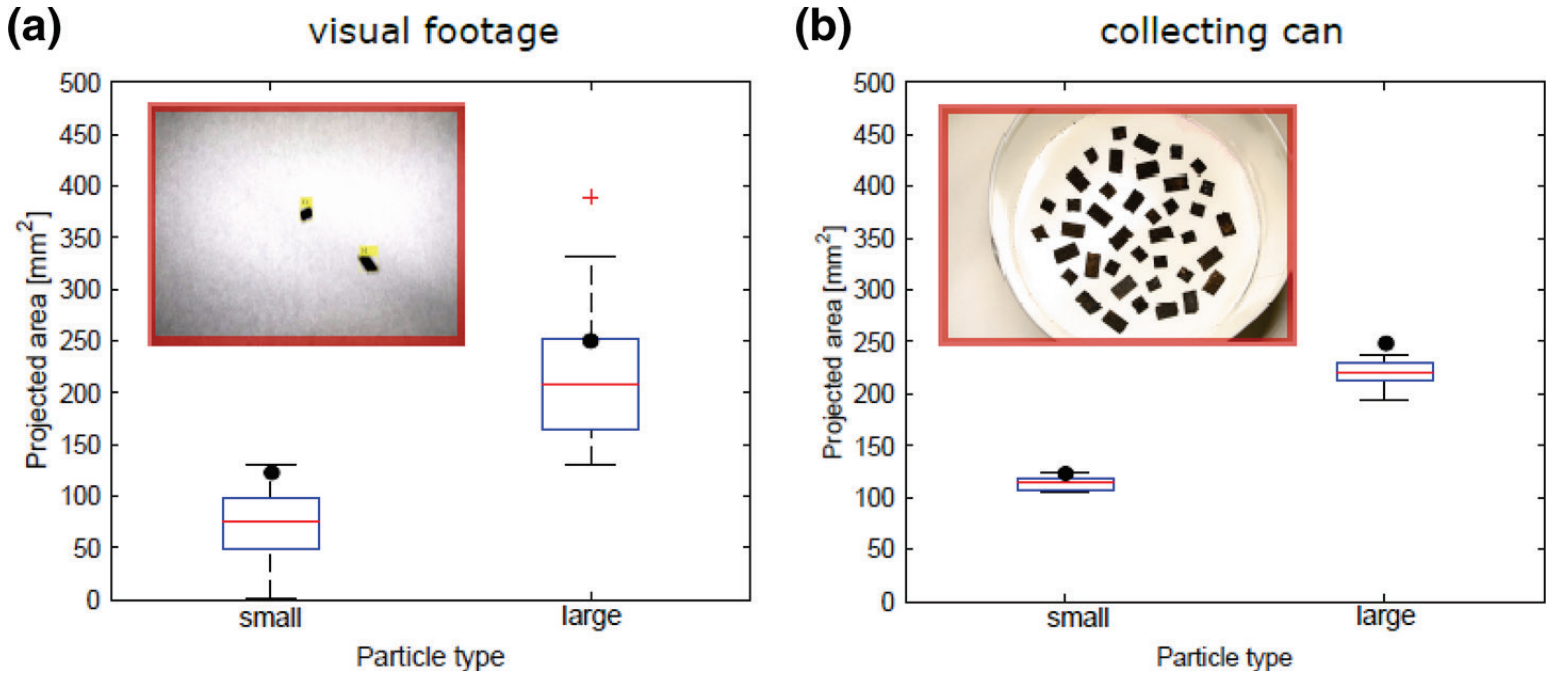
# Particle Size Measurement




- Calibration ~0.16 $mm^2$ per pixel
- Max. projected area observed
- Max. temperature

Area under-predicted in emberometer:

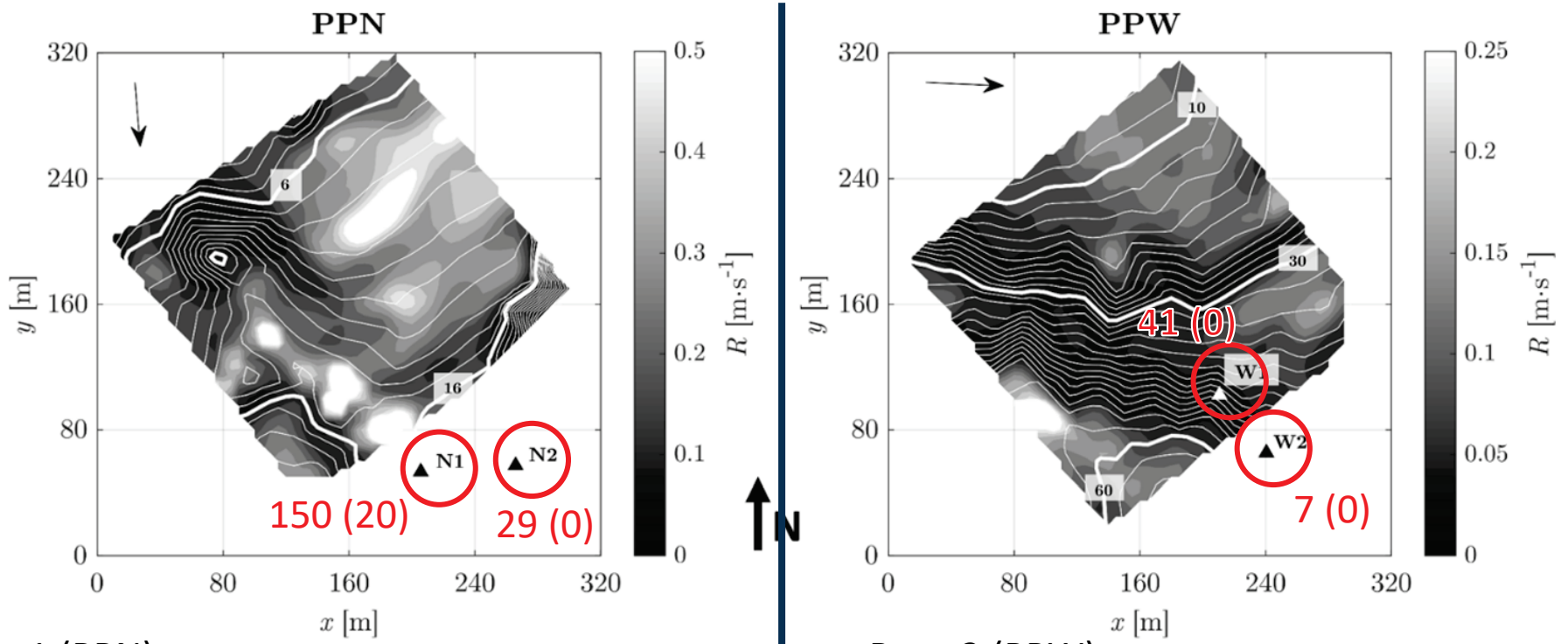
- Rotation and tumbling
- Overlapping
- Motion blur
- Lighting




Zen S., *et al.* (2021)

# Field Deployment

- 2 prescribed burns in NJ Pine Barrens (6.25 ha [15 ac], pitch pine and oak overstory; oak, blueberry, huckleberry understory)
- 2 emberometers deployed in each burn




Burn 1 (PPN)

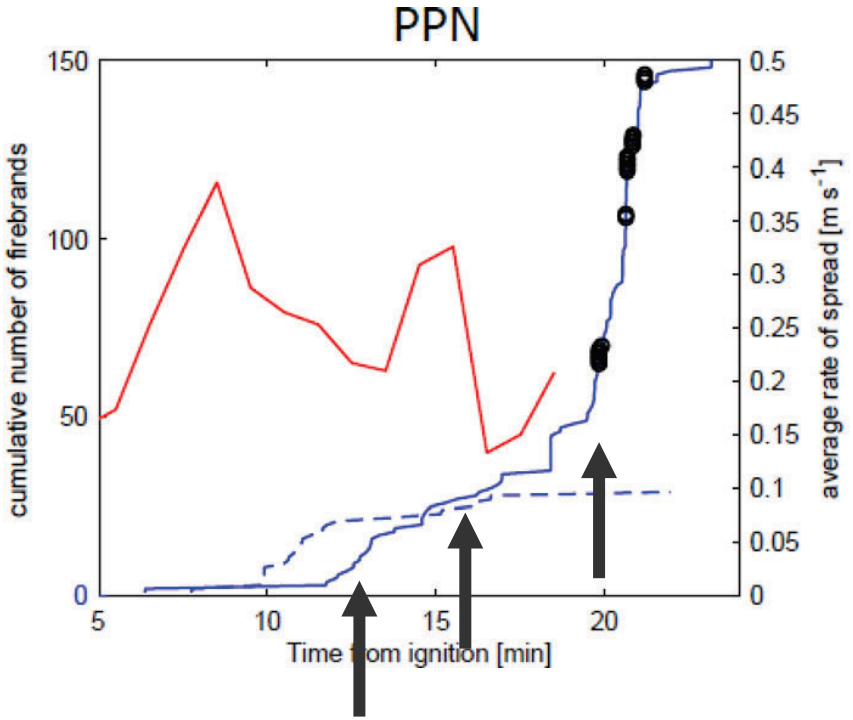
- Avg. fire spread rate: 0.26 m/s
- Outside burn plot (25, 50 m) T to burn
- ~0.05 mm2/px

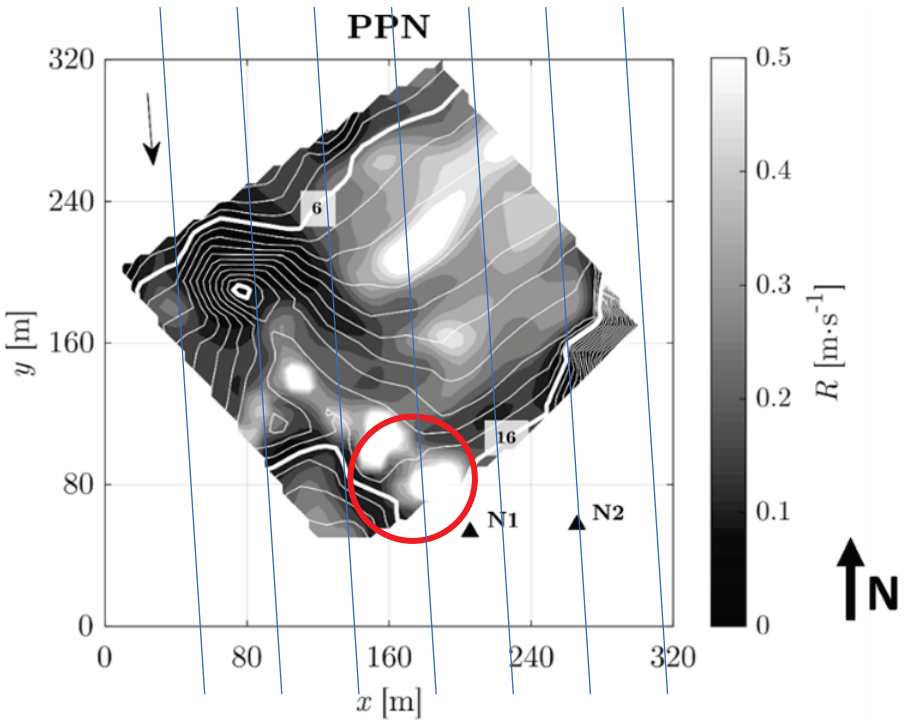
Burn 2 (PPW)

- Avg. fire spread rate: 0.09 m/s
- 1 inside (buried), 1 at 25 m outside
- ~0.15 mm2/px

Zen S., *et al.* (2021)

# Firebrand Showers and Fire Intensity



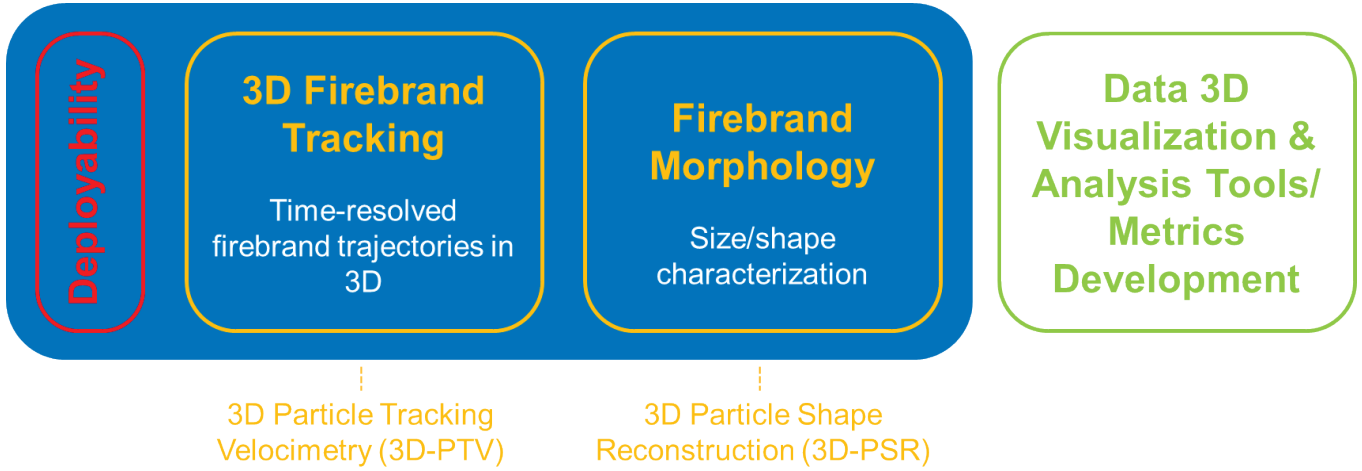




- Increased fire intensity led to more brands
- Major shower at ~20 minutes (station N1) with hot brands
- Increased fire intensity upwind
- Travel time up to 5 minutes

Zen S., *et al.* (2021)

# NIST Emberometer

- Measurement device geared towards **field measurements**
- Two **imaging techniques**: 3D Particle Image Velocimetry (3D-PTV) and 3D Particle Shape Reconstruction (3D-PSR)
- **Quantitative** characterization of an artificially generated firebrand flow in **outdoor settings** (tracking/numbers)
- **Framework** for systematic **comparison** of firebrand exposures (3D)



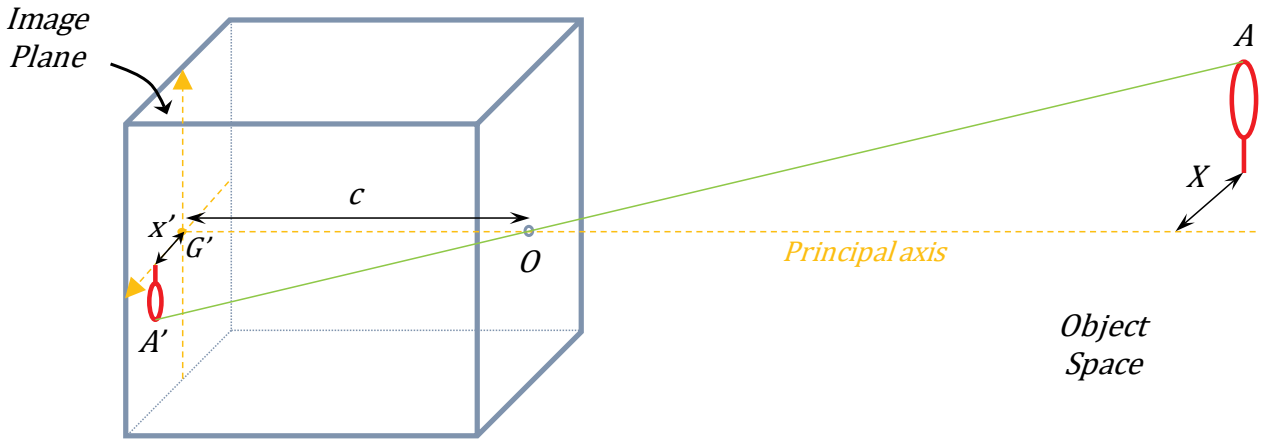


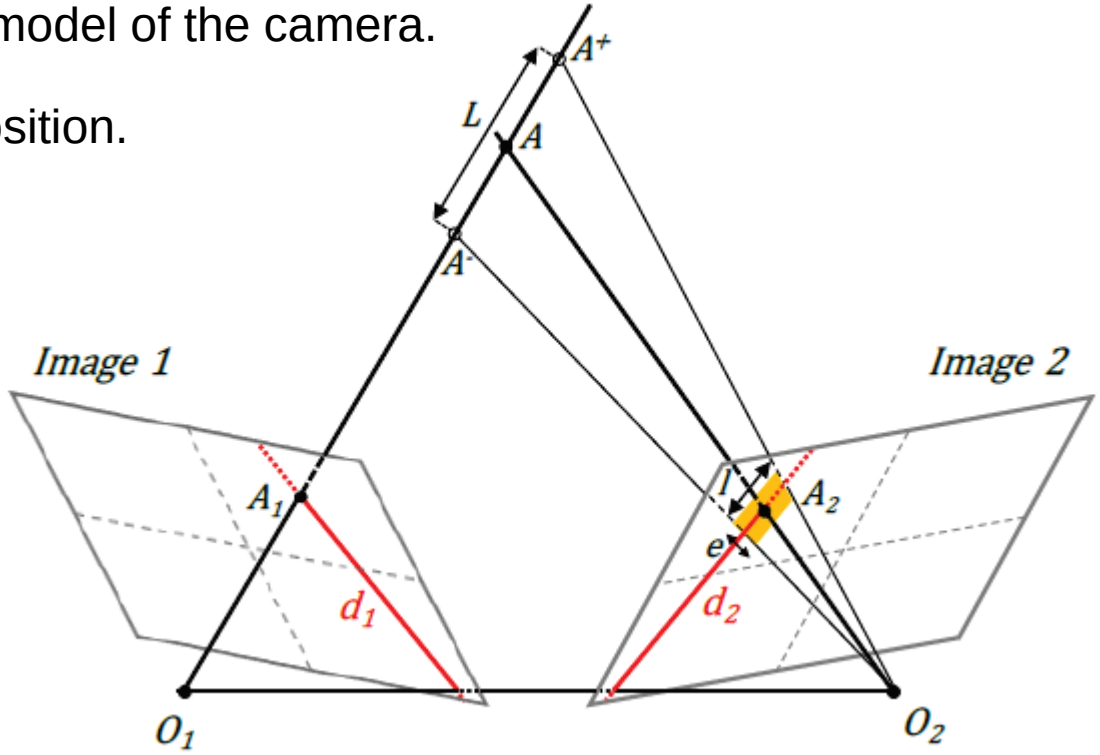
Bouvet N., Link E.D., Fink S.A. (2020) Development of a New Approach to Characterize Firebrand Showers During Wildland-Urban Interface (WUI) Fires: a Step Towards High-Fidelity Measurements in Three Dimensions. *NIST Technical Note 2093*. National Institute of Standards and Technology, Gaithersburg, MD. https://doi.org/10.6028/NIST.TN.2093

Bouvet N., Link E.D., Fink S.A. (2021) A new approach to characterize firebrand showers using advanced 3D imaging techniques. *Experiments in Fluids* 62:181. https://doi.org/10.1007/s00348-021-03277-6

# Operating Principles

- **Photogrammetry** = 3D measurement technique using **central projection imaging**
- Makes possible the **location of an object in 3D** using the intersection of **at least** two homologous image rays (i.e. from the same object point) using two images or more (e.g. cameras with different location/view angles).
- **Interior** (intrinsic) **orientation** = internal geometric model of the camera.
- **Exterior** (extrinsic) **orientation** = camera angles/position.




Bouvet N., Link E.D., Fink S.A. (2020) Development of a New Approach to Characterize Firebrand Showers During Wildland-Urban Interface (WUI) Fires: a Step Towards High-Fidelity Measurements in Three Dimensions. *NIST Technical Note 2093*. National Institute of Standards and Technology, Gaithersburg, MD. https://doi.org/10.6028/NIST.TN.2093

# Operating Principles

3D particle sizing performed using the **Visual Hull Concept** at each time step (in-house code):

1. Back projection of **particle silhouette** (2D image) towards the measurement space using calibration information (spatial + sizing).
2. Process repeated for **all viewpoints.**
3. Intersection of all projection cones defines the **3D particle shape** = largest possible volumetric domain giving identical silhouettes in all image planes.
4. Re-orientation of particle and edge extraction (orthogonal directions).

⇩

Average size characteristics using cumulative plots of particle edges using all available timesteps

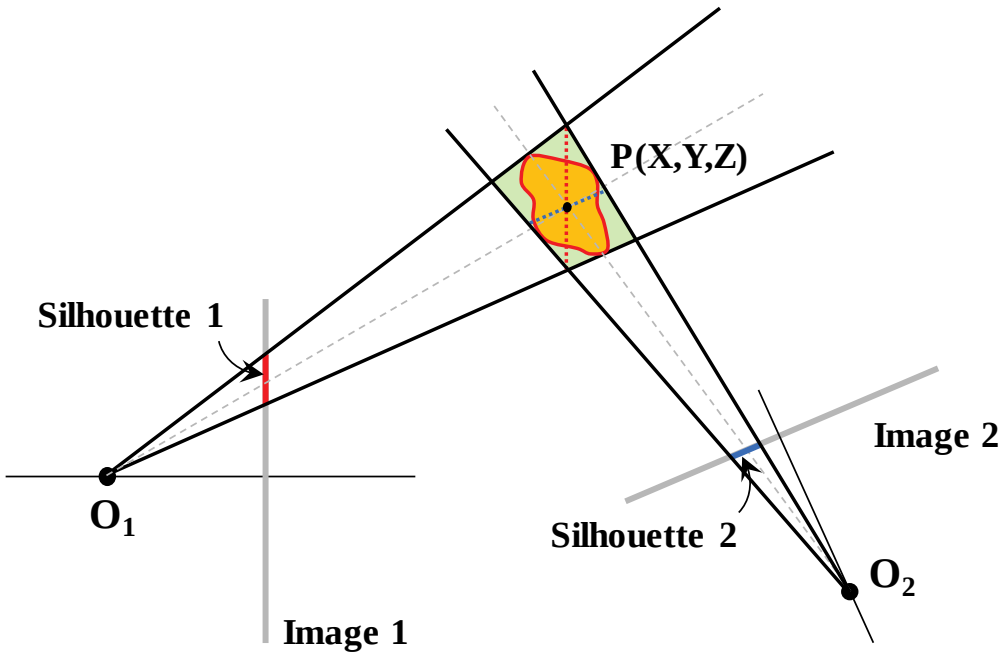
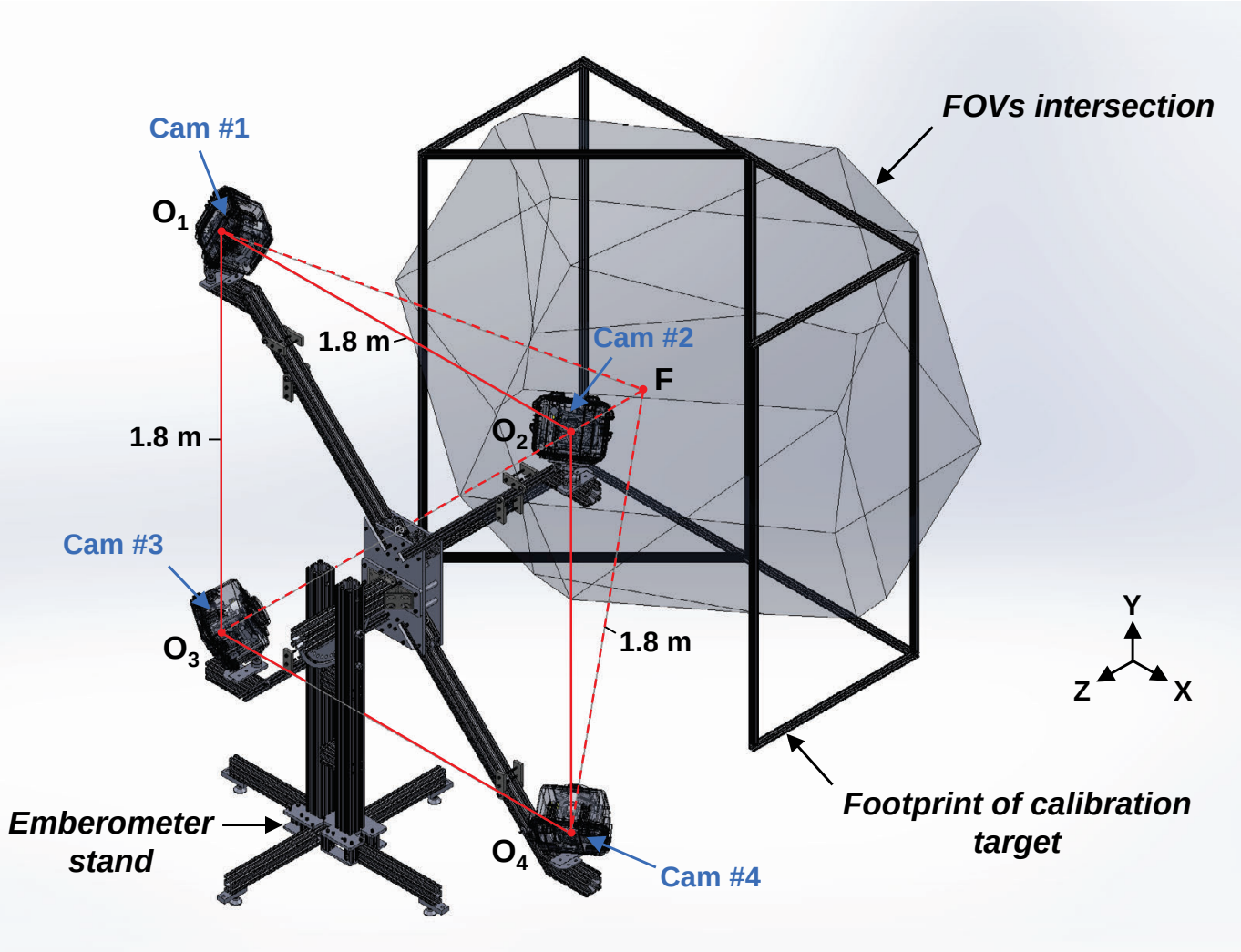



*Illustration of the Visual Hull method*

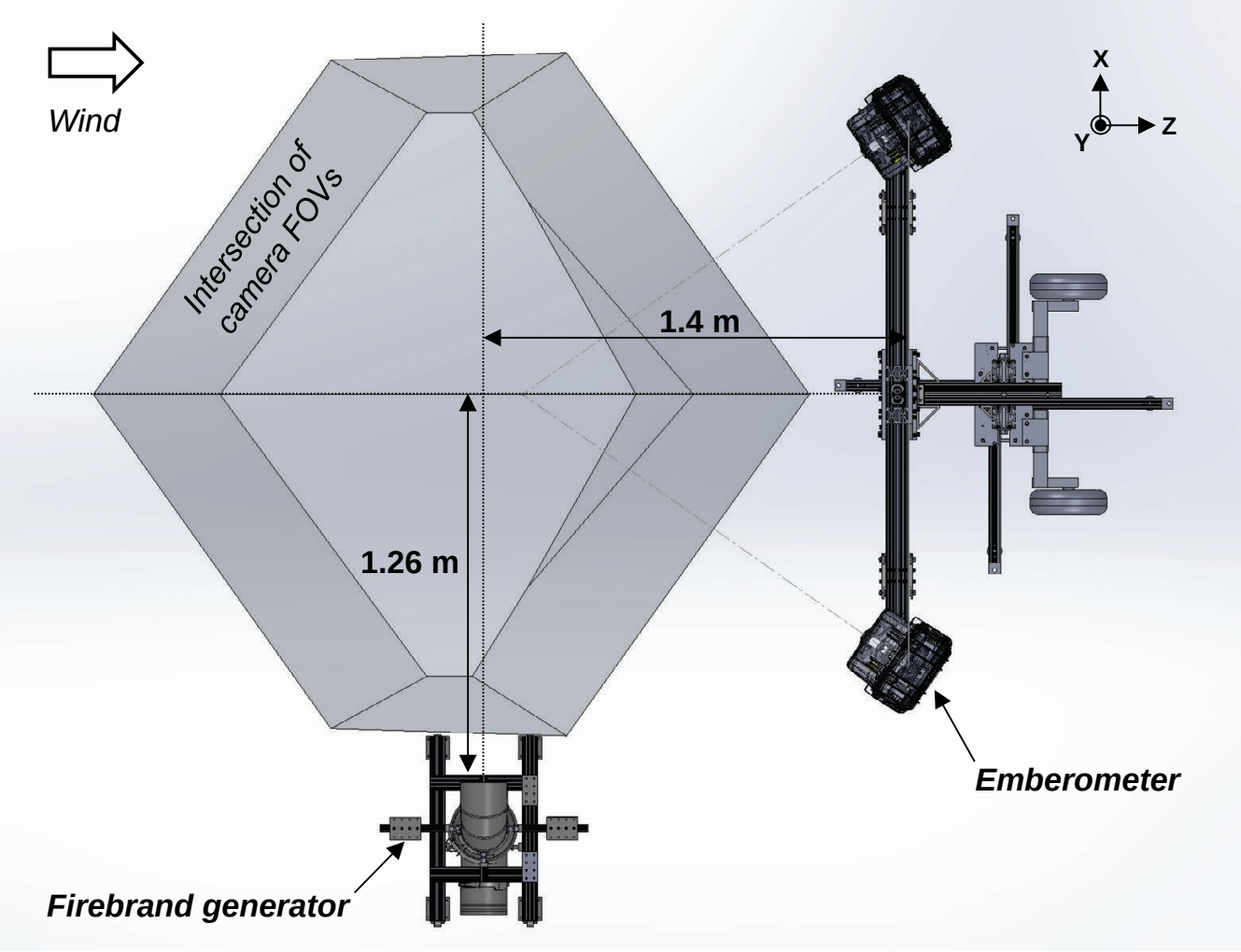
# Emberometer System Configuration




*Emberometer schematic and optical layout*

- Four compact **consumer-grade** cameras operated at min. focal length ($f$ = 8.8 mm) and largest aperture ($f$/2.4)
- **Modified** cameras (**full spectrum conversion**) fitted with infrared filters ($\tau$ = 95 % above 760 nm) → **Enhanced** airborne firebrand **visualization**
- Video mode, nominal frame rate **120 fps** at **1080p**
- **Optical layout**: camera perspective centers forming the base vertices of an equilateral square pyramid (1.8 m edge length)
- FOVs intersection **volume ≈ 3.18 m$^3$** (tri- and stereoscopic tracking allowed)
- **Field-deployable** package with **remote control** capabilities

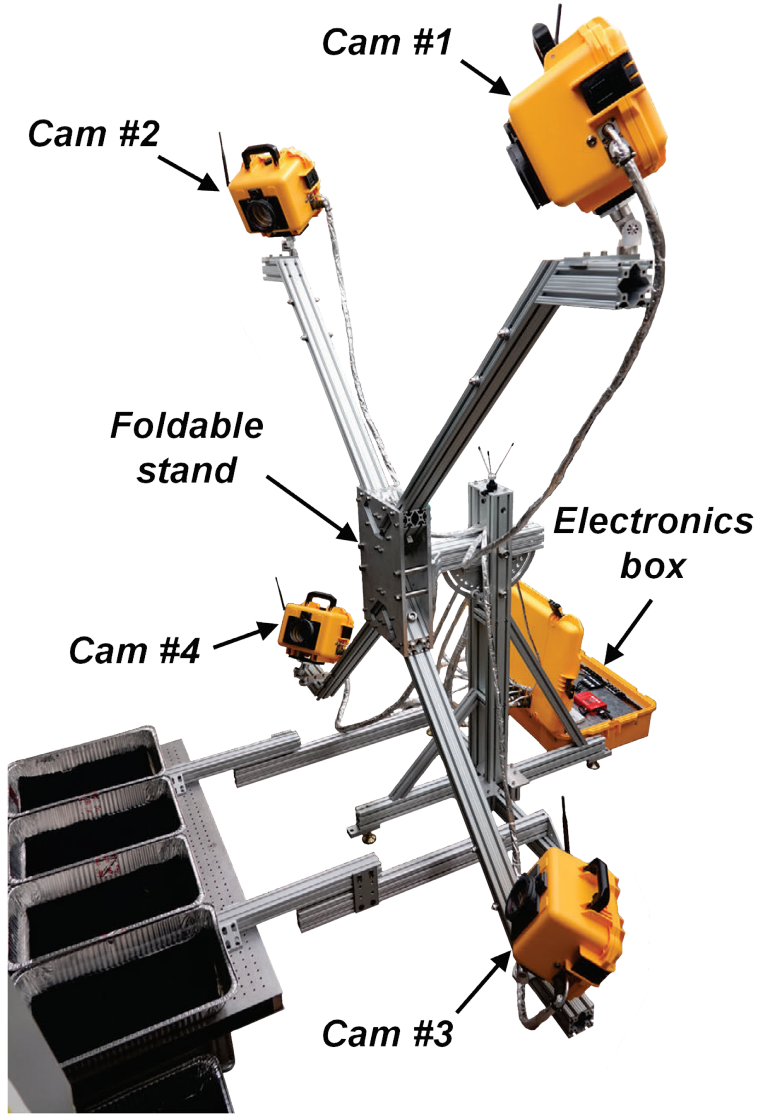
# Emberometer System Configuration




*Experimental layout top view*

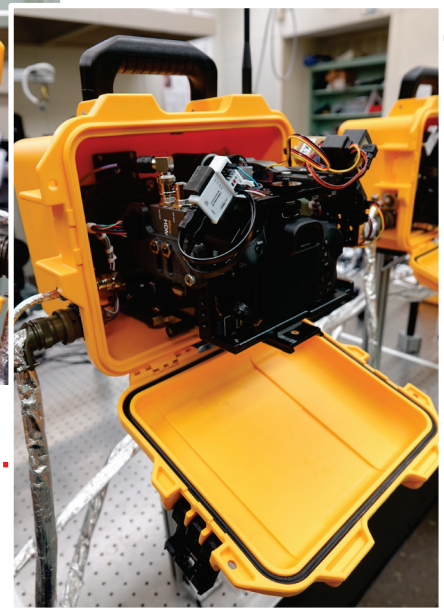
- Emberometer set downstream of **firebrand generator** (centrifugal blower + SS duct elements)
- **Fuel**: 350 g ± 1 g of dry (MC < 6 %) **birch/maple dowels** (diam. 6.4 mm ± 0.1 mm, length 51 mm ± 0.4 mm)
- No specific orientation with respect to **background environment** (mix of asphalt, forested areas and clear sky)
- Mixed production of **smoldering** and **flaming** firebrands

# Emberometer System Configuration



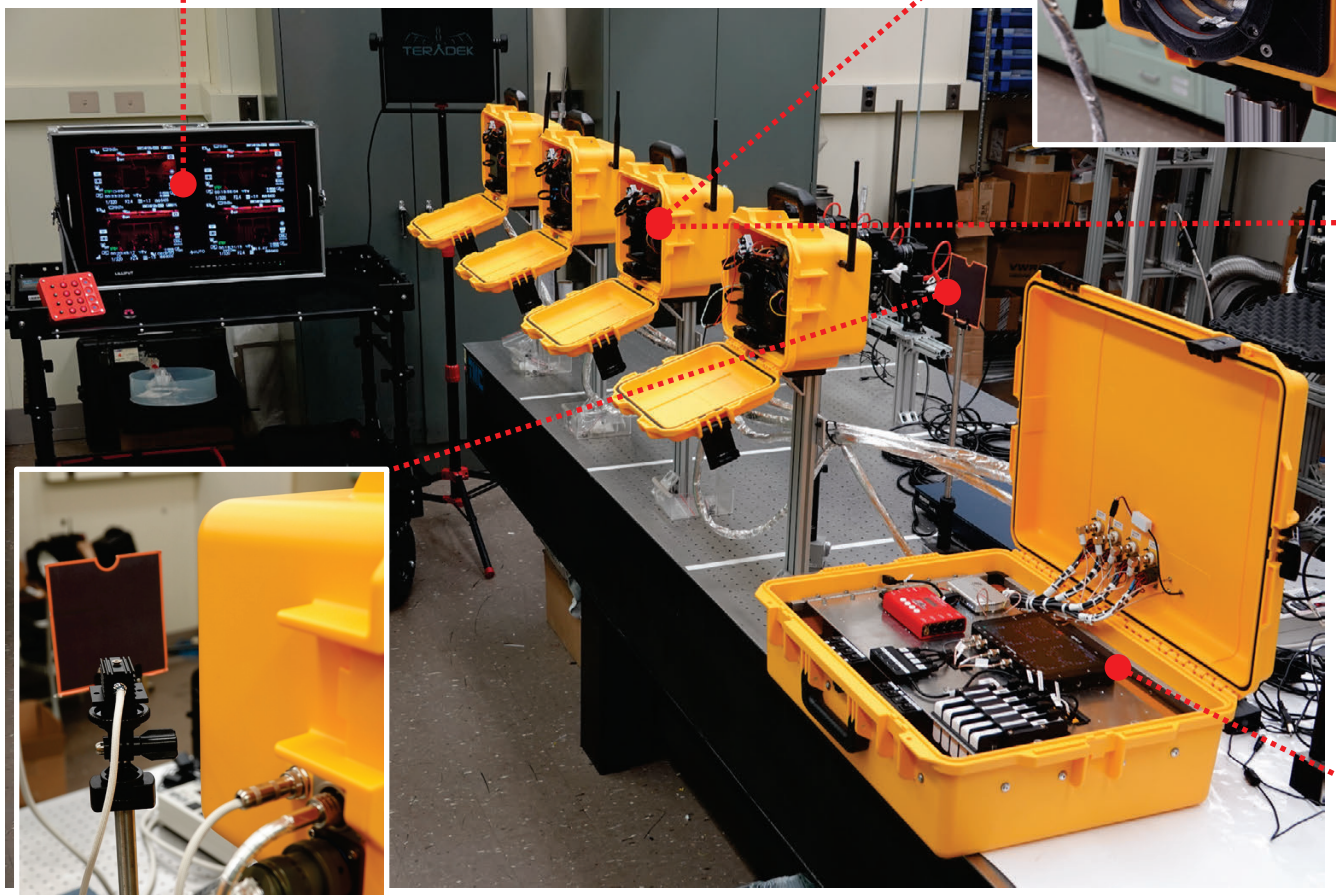
# Electronics

*Camera box front face*



*Retracted camera*

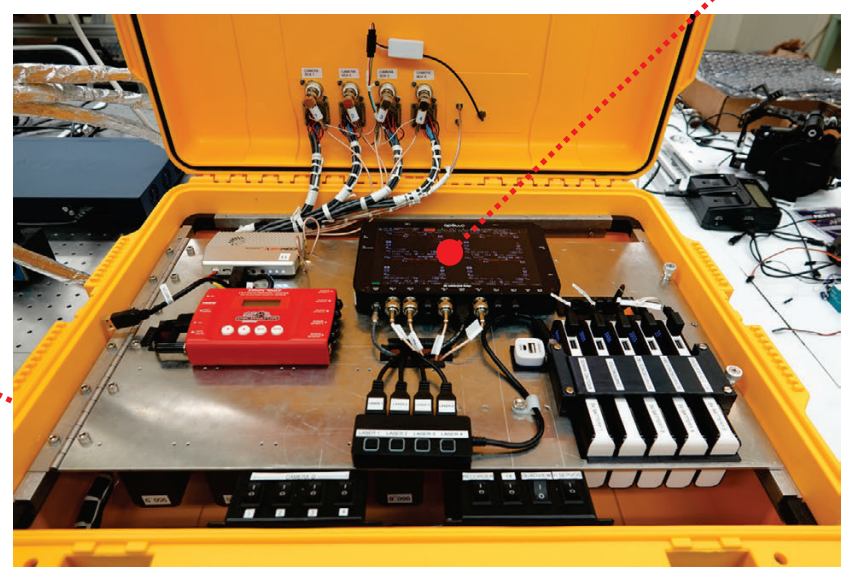
*Remote viewing screen*





*Sync. laser*

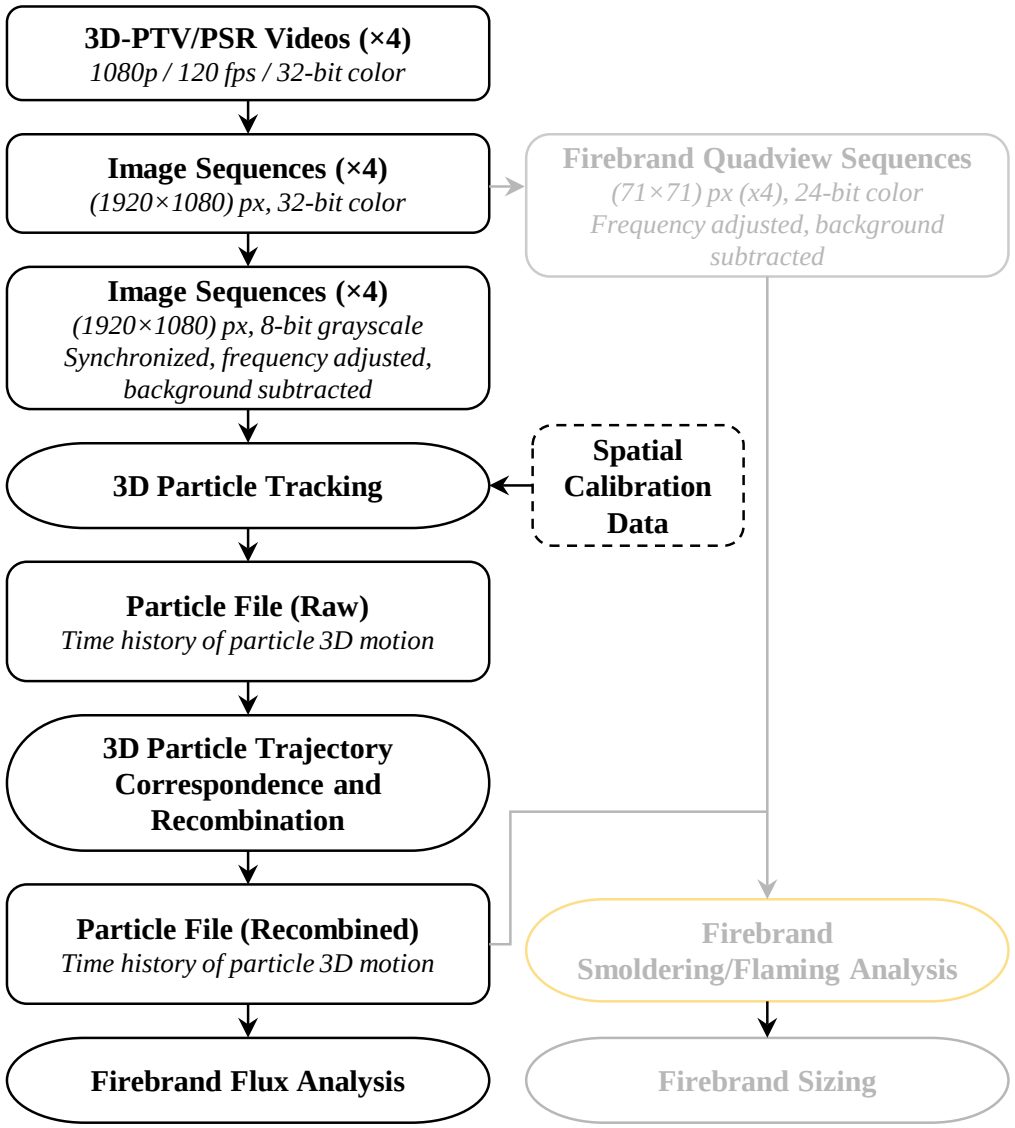
*Batteries*
*Radio transmitters*
*Camera controllers*
*Multi-viewer*



*Main electronics control box*

# Analysis Process

## Processing Flowchart




## Tracking

- **3D tracking** via open-source software OpenPTV

Standard set of operations including:

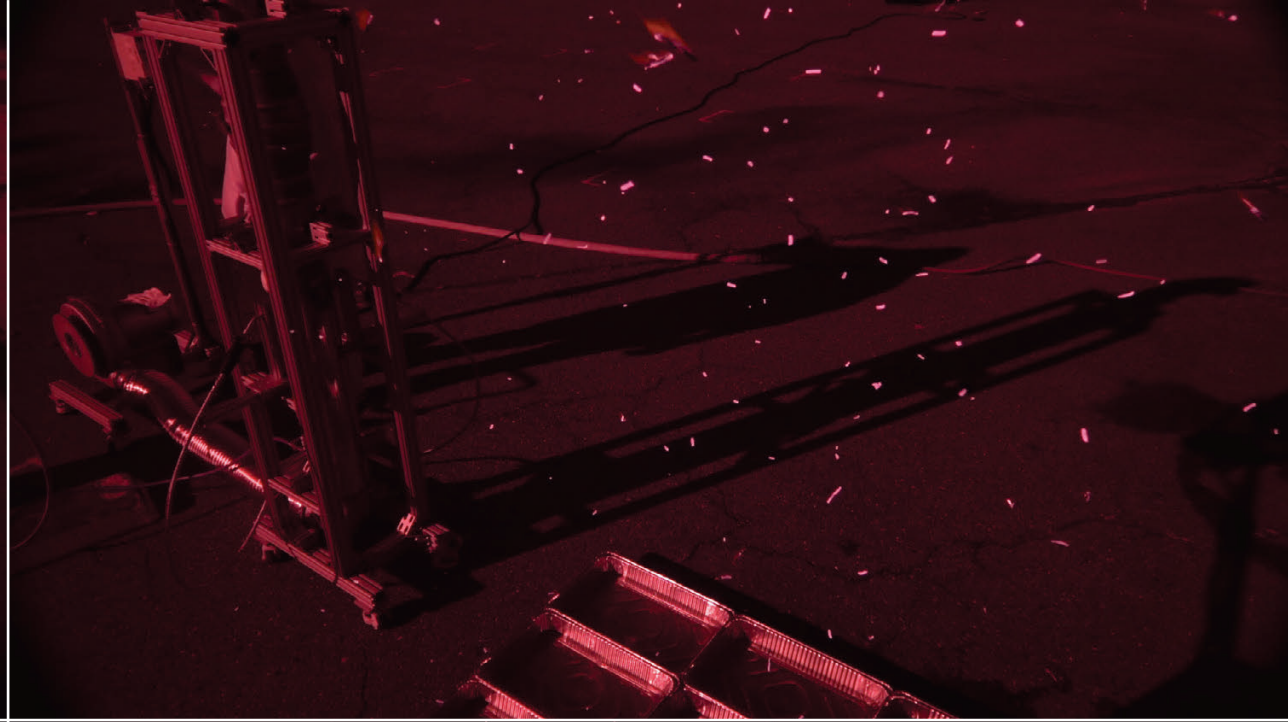
1. Multi-camera system **spatial calibration**
2. Particle **detection** in each image plane
3. Particle **correspondences** across all views
4. Computation of particle **3D coordinates**
5. **Tracking**

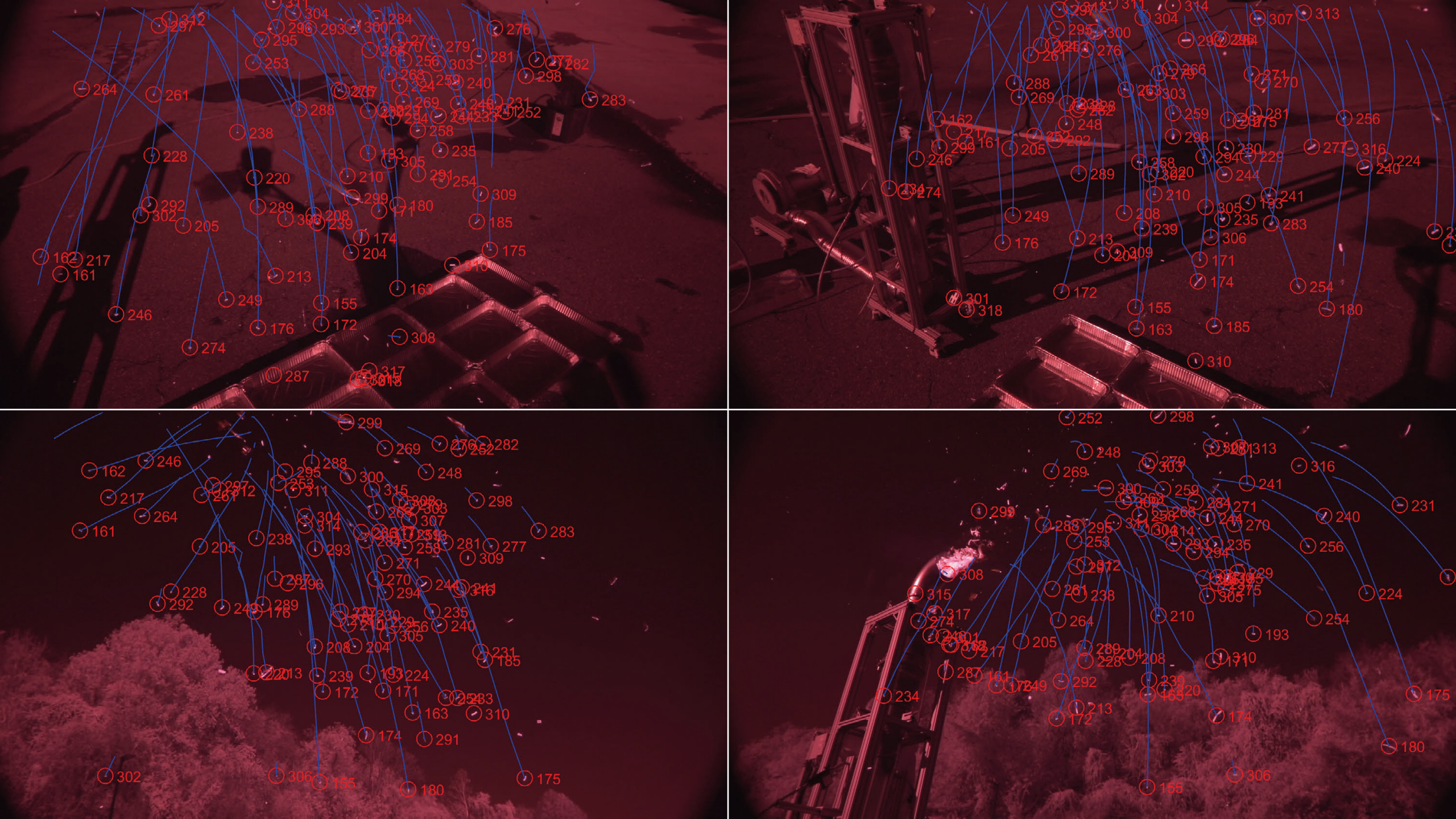
- Max. Particle Image Density (PID) ≈ $1.6 \times 10^{-4}$ particle-per-pixel (ppp):

1 order of magnitude less than PIDs known to promote triangulation errors [1]

3 orders of magnitude less than PIDs requiring advanced tracking procedure [2]

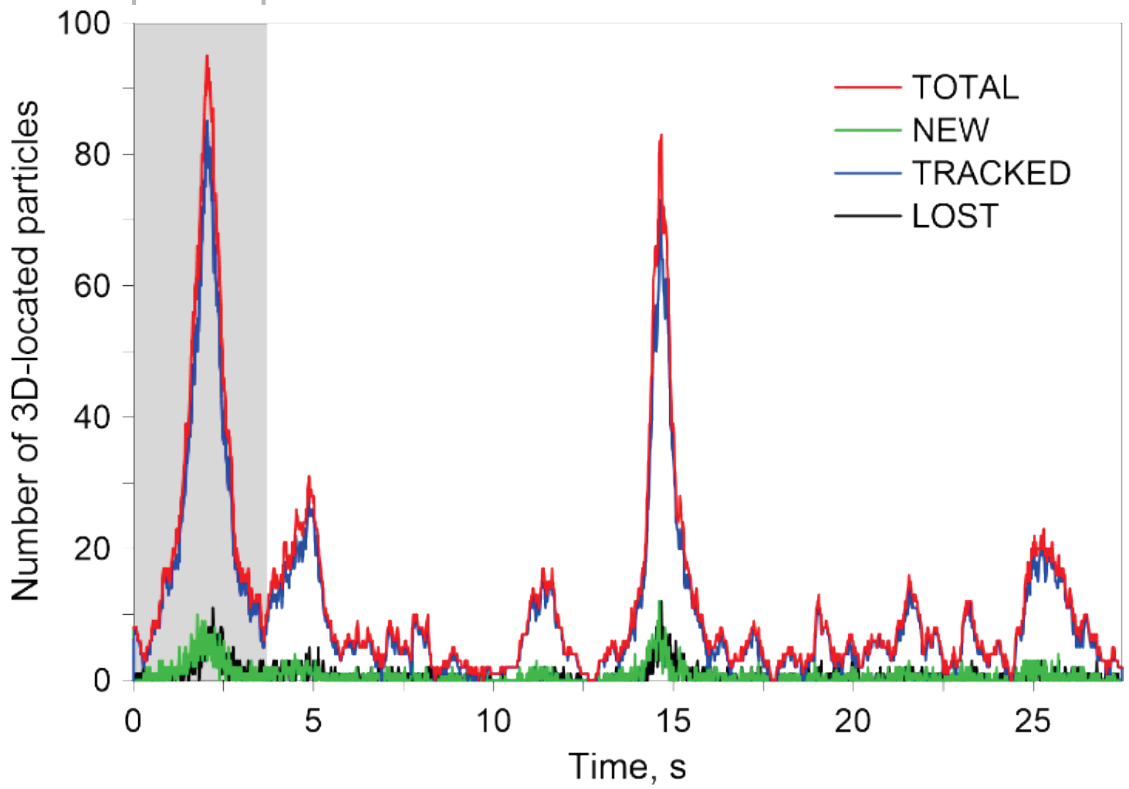

[1] Mass et al., *Exp. Fluids* 15(2): 133-146
[2] Schanz et al., *Exp. Fluids* 57(5): 70



# Particle Tracking Performance

*430 trajectories = over 23,800 individual firebrand images*




*Analysis volume: X = (-2000 to 2000) mm,*
*Y = (-200 to 2000) mm, and Z = (-1100 to 1100) mm*

| Trajectory type | % (# of trajectories) |
|---|---|
| **Single** | 63.3 (272) |
| **Broken** | |
| Successfully recombined | 25.8 (111) |
| Not successfully recombined | |
| *Overlap* | 3.5 (15) |
| *Other* | 1.6 (7) |
| **Spurious** | |
| Successfully removed | 0.9 (4) |
| Not successfully removed | |
| *Duplicate* | 2.3 (10) |
| *Other* | 2.6 (11) |
| **Total** | 100 (430) |

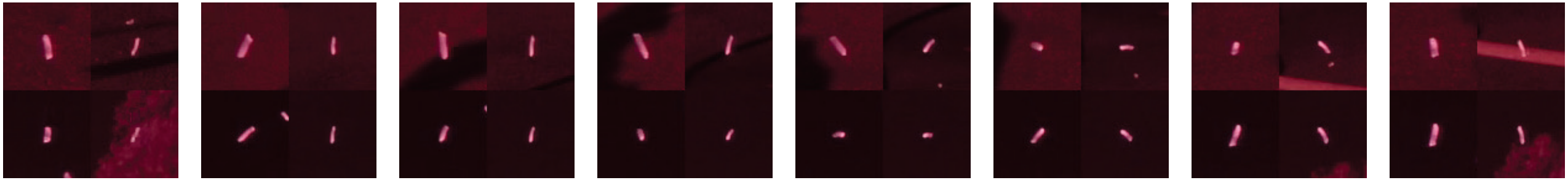
**90 %** of the raw trajectories accurately processed by the tracking/recombination algorithms

Up to **96 %** if dual centroid detection cases (see *Overlap*/*Duplicate*) recouped during the later particle sizing step

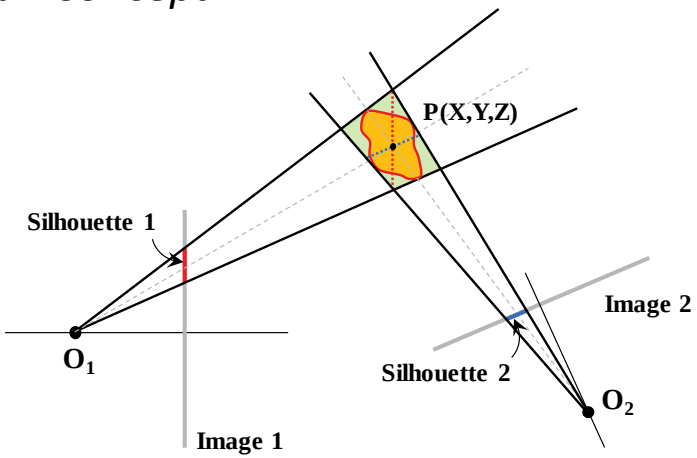
Bouvet N., *et al.* (2023) Enabling exposure comparison for firebrand showers generated during wildland-urban interface (WUI) fires. *13th US National Combustion Meeting* (March 19–22, 2023; College Station, TX).

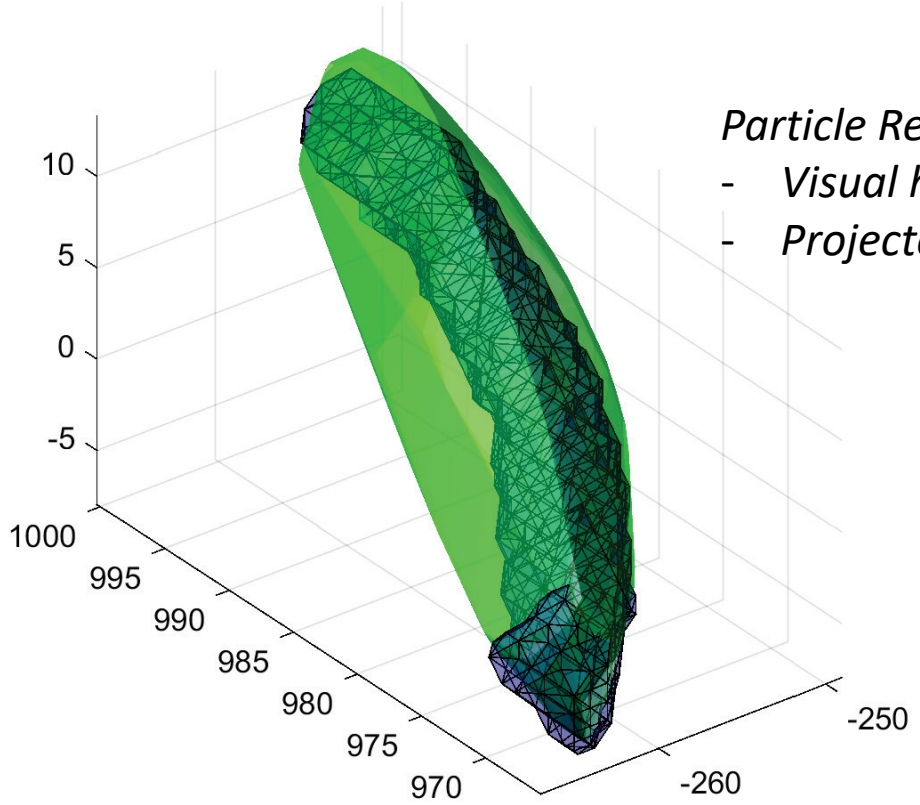
# Particle Shape Reconstruction

*Single Particle Quadview – Particle Lifetime*



*Visual Hull Concept*

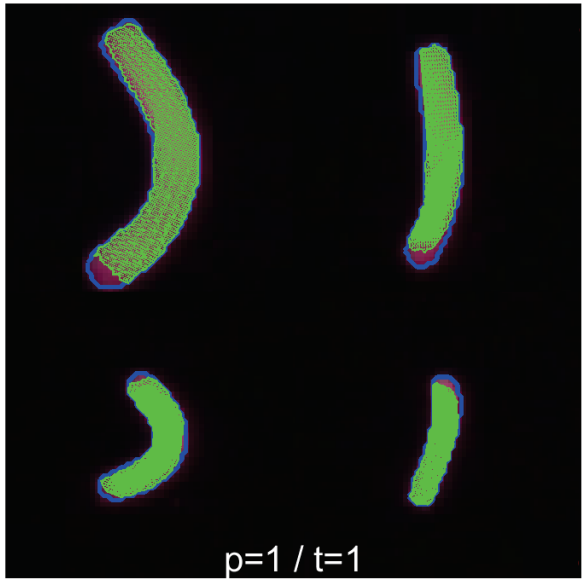



*Particle Reconstruction*

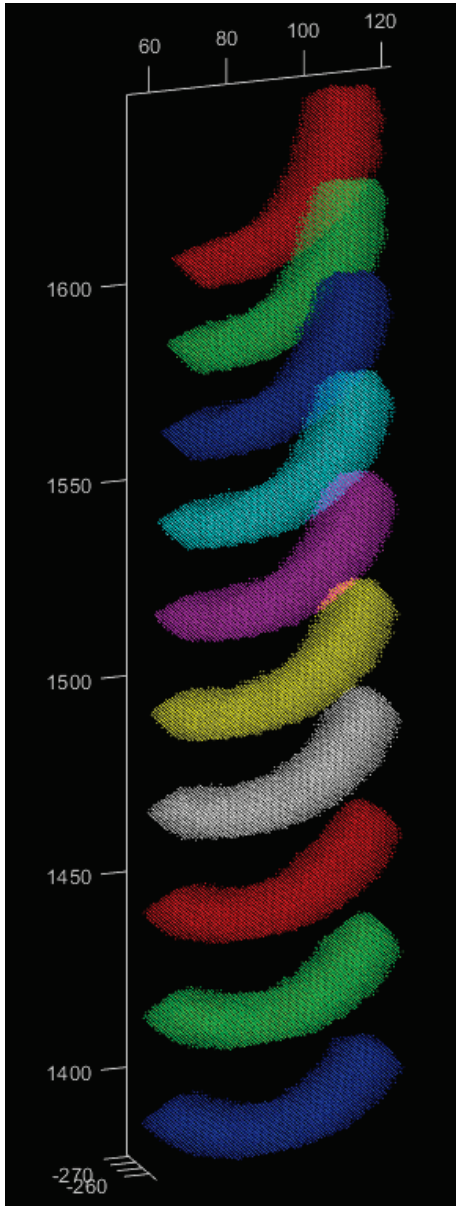
- *Visual hull (green)*
- *Projected voxels (blue)*

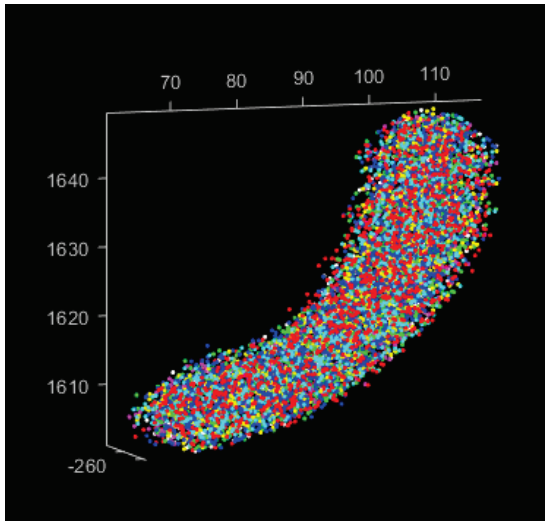
# Particle Shape Reconstruction




*Projected Voxels*

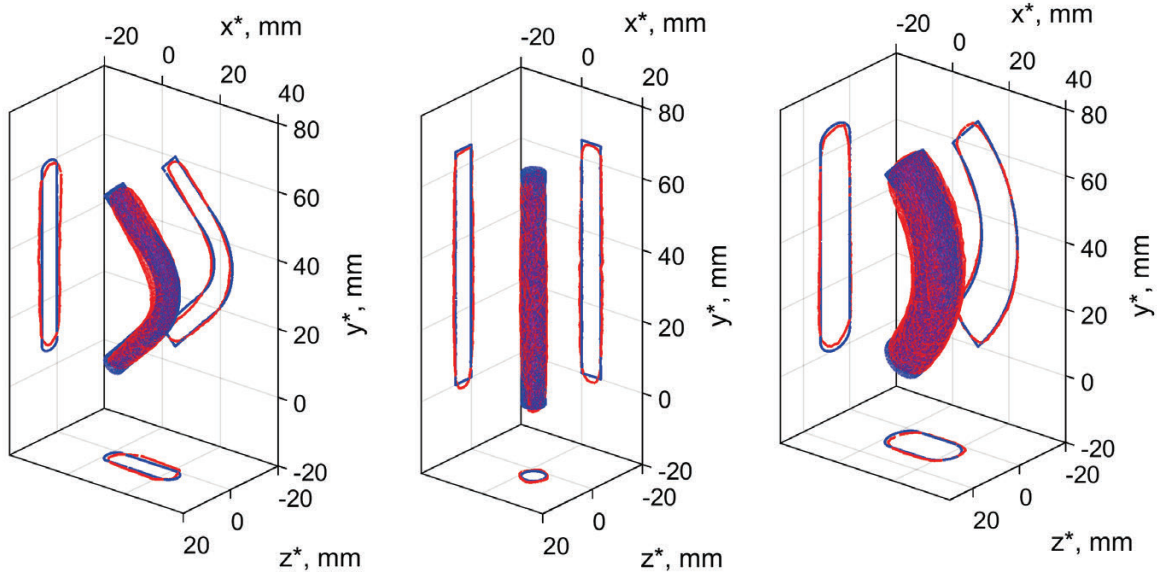
*Reconstructed Particle Pointclouds at Sequential Timesteps*



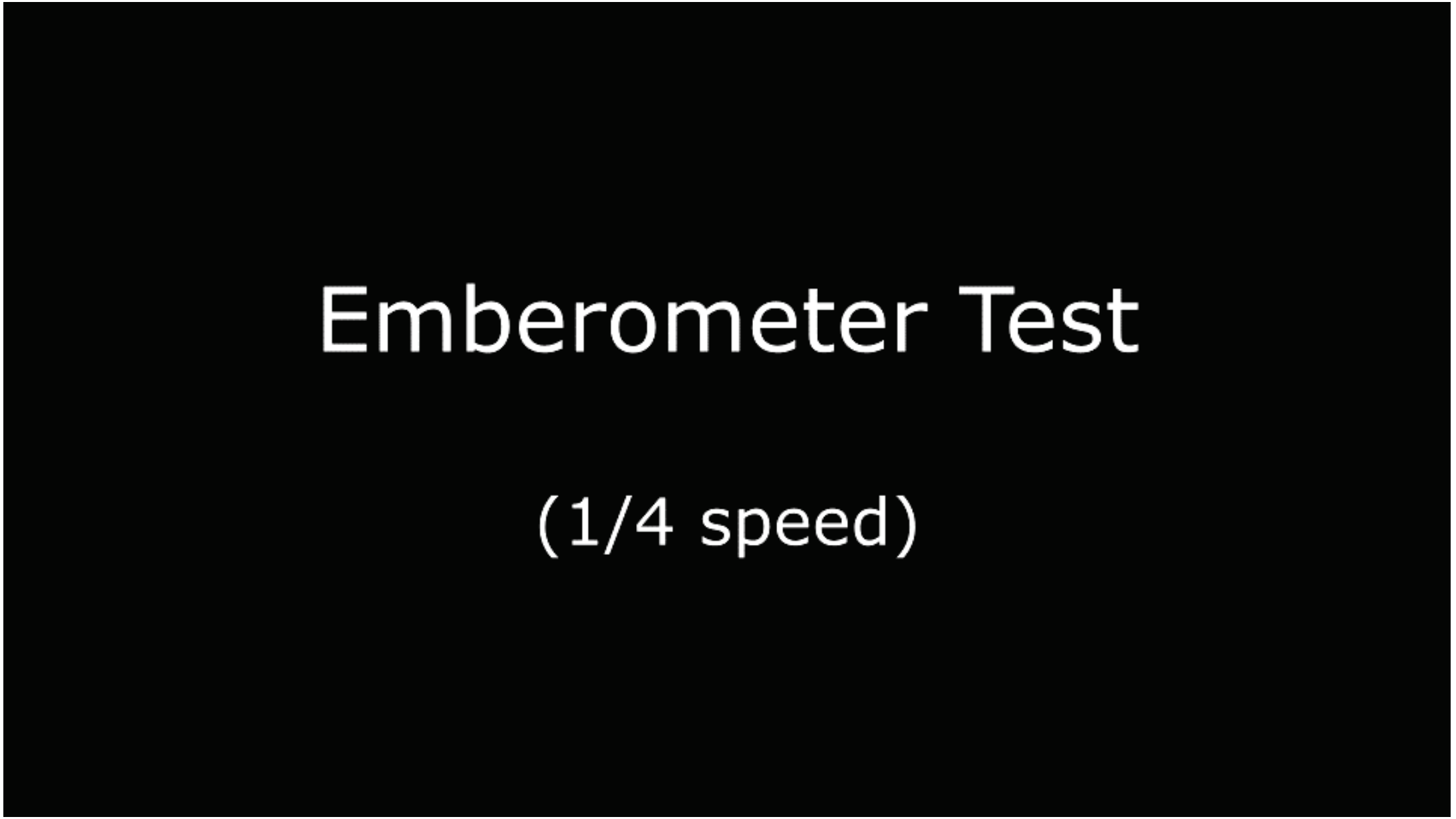




*Combined Reconstructed Pointclouds*

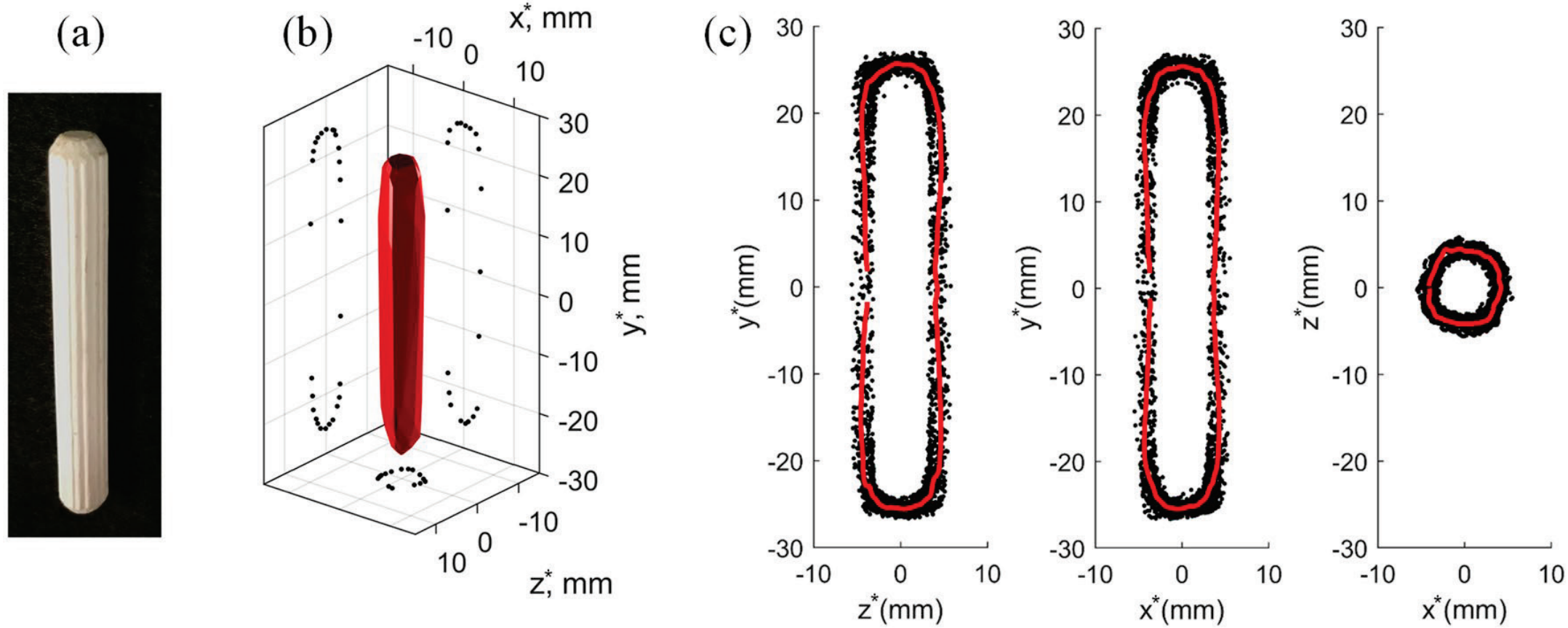
*Reconstructed Particles*



# Validation with Noncombusting Particles

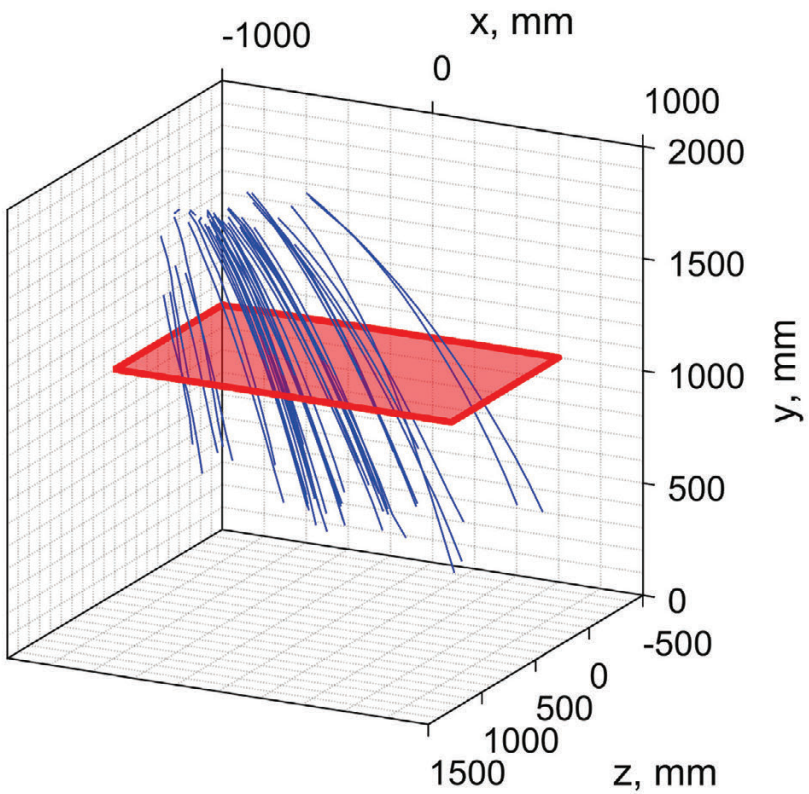


# Validation with Noncombusting Particles

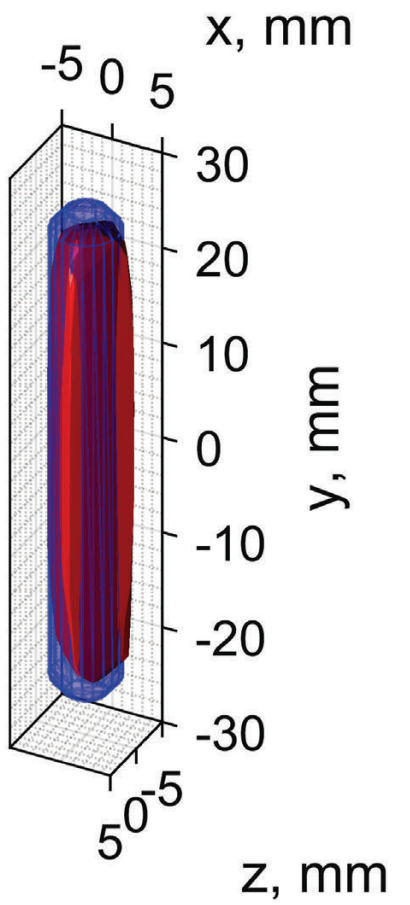



Bouvet N., Link E.D., Fink S.A. (2021) A new approach to characterize firebrand showers using advanced 3D imaging techniques. *Experiments in Fluids* 62:181. https://doi.org/10.1007/s00348-021-03277-6

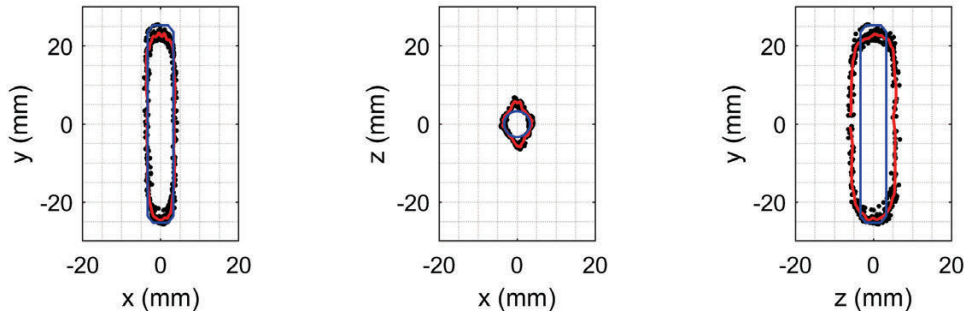
# Validation with Noncombusting Particles



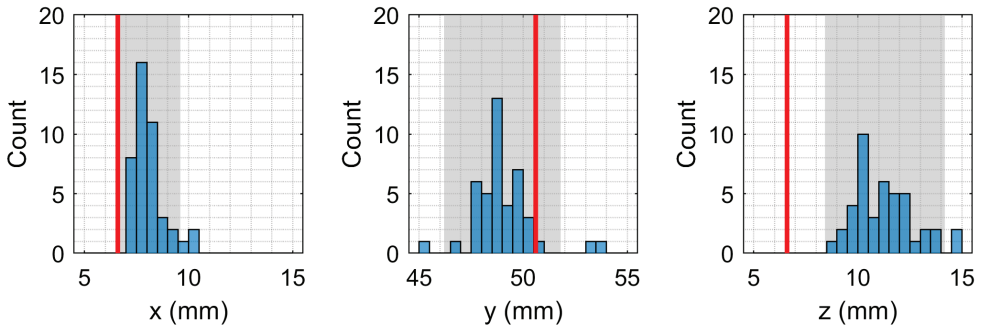

*Tracking of validation particles (N = 43, red: reference surface)*




*3D-reconstructed (red) and actual shape (blue) of validation particle (single time step)*

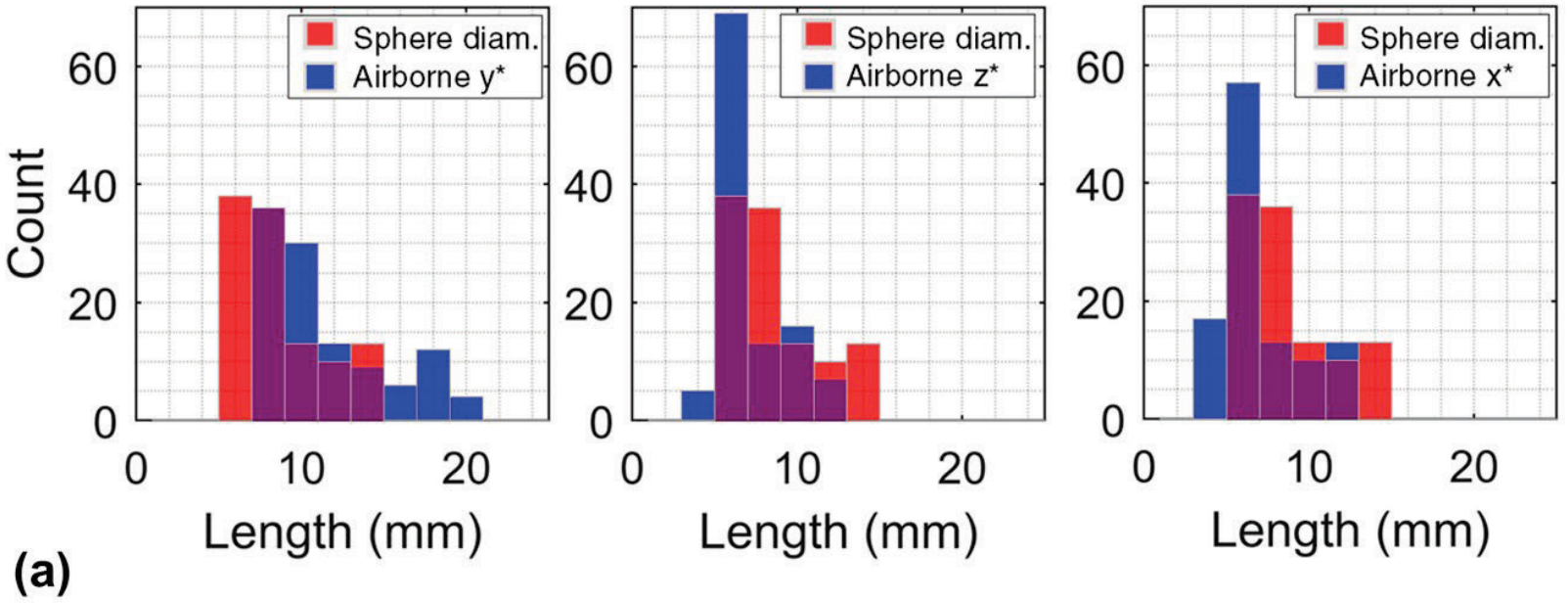


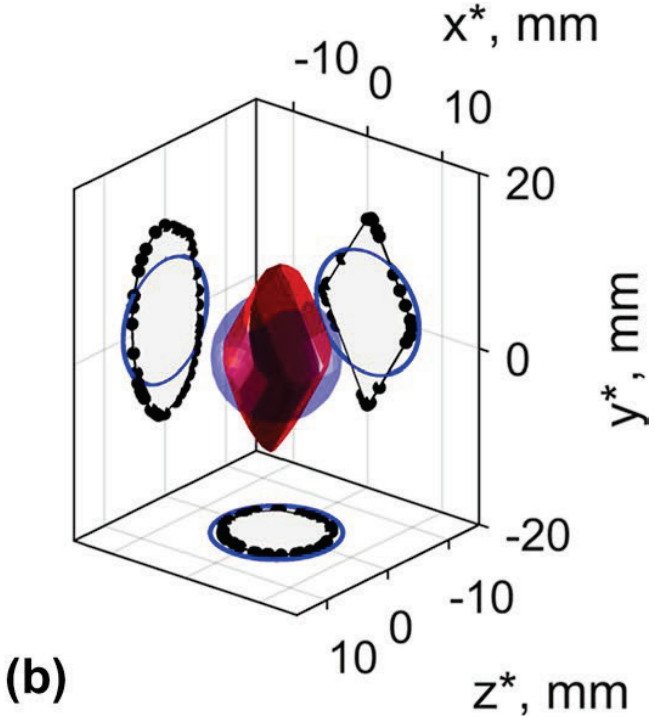

*Orthogonal views of reconstructed particle (all time steps)*




*Histograms of measured dimensions (red line: actual size, greyed area: expanded uncertainties)*

# Validation with Noncombusting Particles



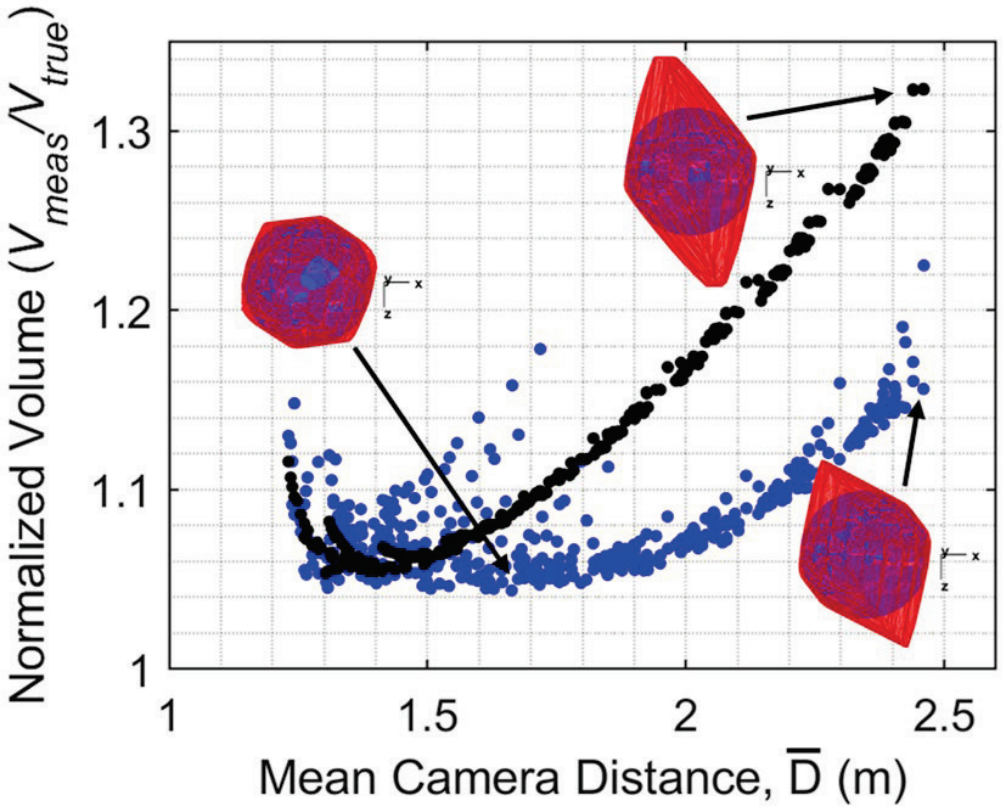




*Actual and Measured size distribution of 110 spherical particles*

*Sample Reconstruction*

Bouvet N., Link E.D., Fink S.A. (2021) A new approach to characterize firebrand showers using advanced 3D imaging techniques. *Experiments in Fluids* 62:181. https://doi.org/10.1007/s00348-021-03277-6

# Volume Reconstruction Artifacts



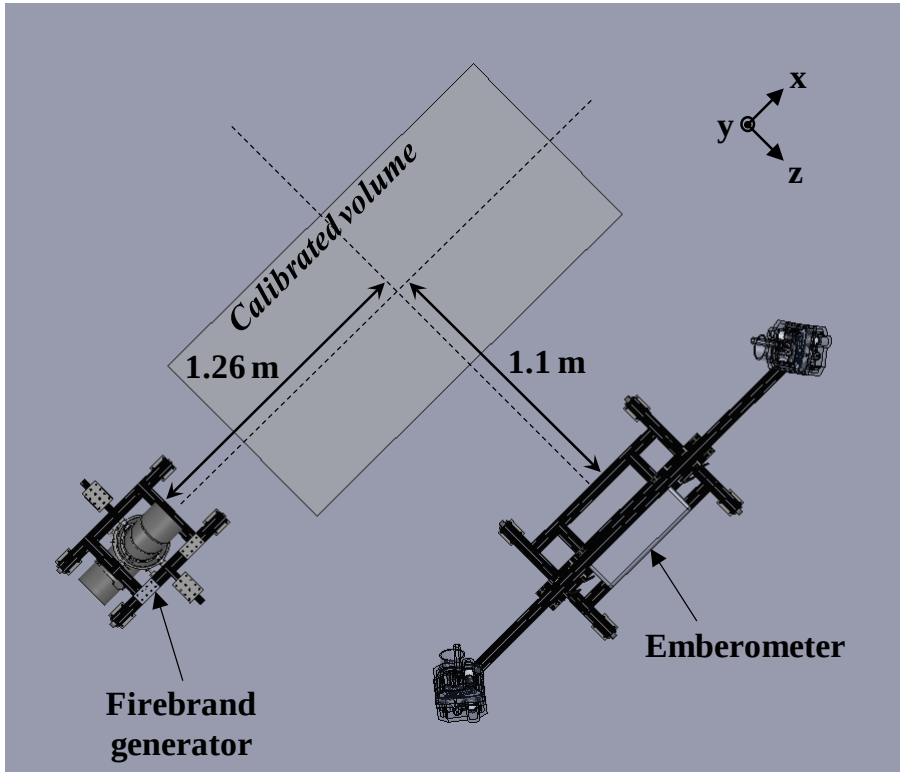

Effect of camera position
- actual
- alternate

Co-planar cameras cannot see back side of particles:
- Systematic error
- Tumbling particles
- Attempts to classify error by shape and orientation

Out-of-plane camera adds challenges for:
- Calibration
- Deployment

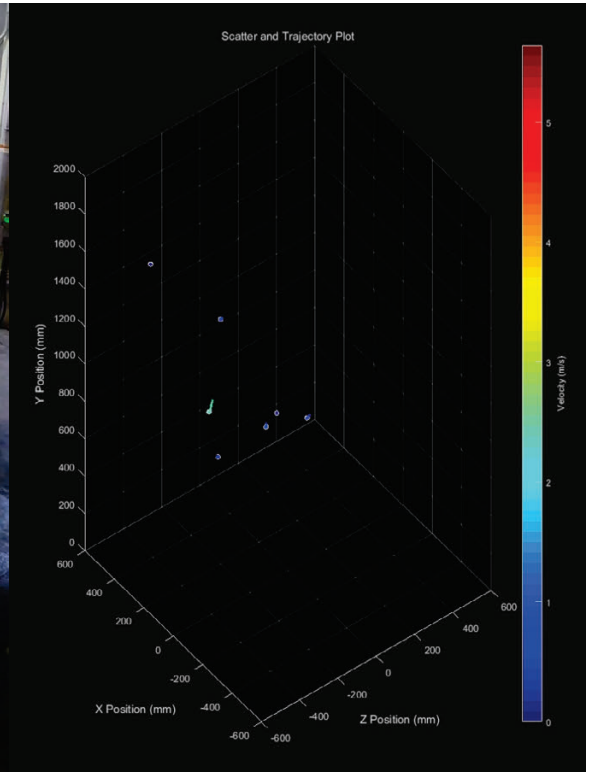
Bouvet N., Link E.D., Fink S.A. (2021) A new approach to characterize firebrand showers using advanced 3D imaging techniques. *Experiments in Fluids* 62:181. https://doi.org/10.1007/s00348-021-03277-6

# Laboratory Measurement of Combusting Particles



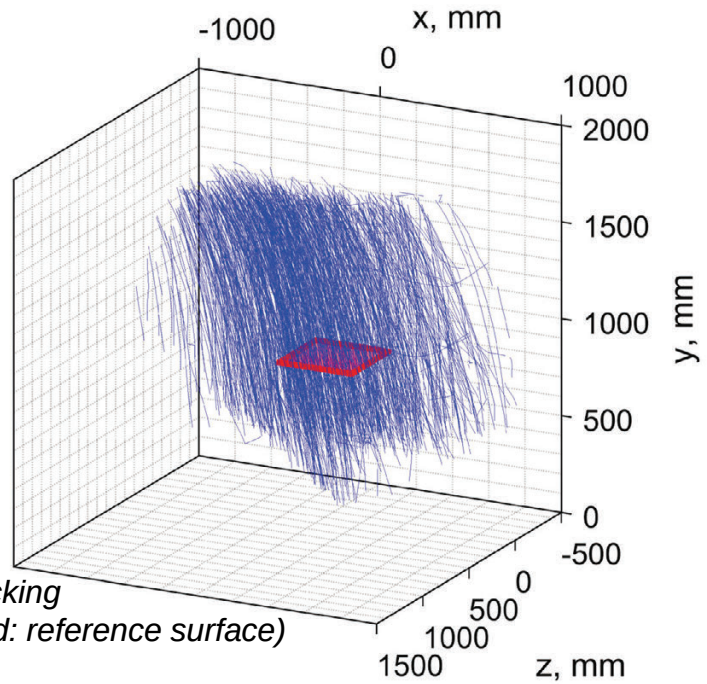

*Experimental layout (Top view)*

*Corner view during test*

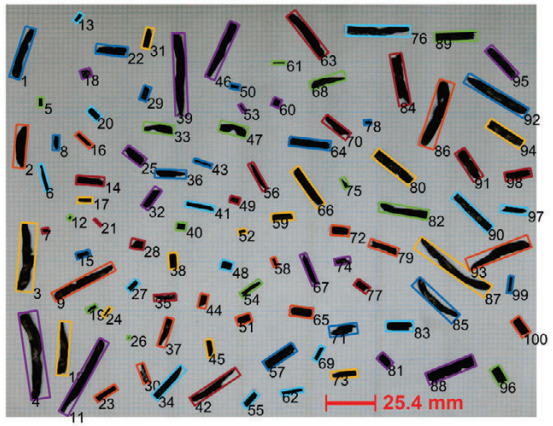



*3D-reconstructed firebrand motions*

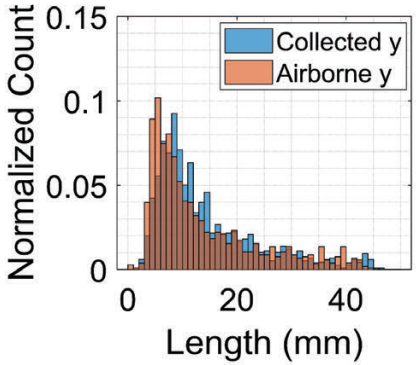
# Laboratory Measurement of Combusting Particles

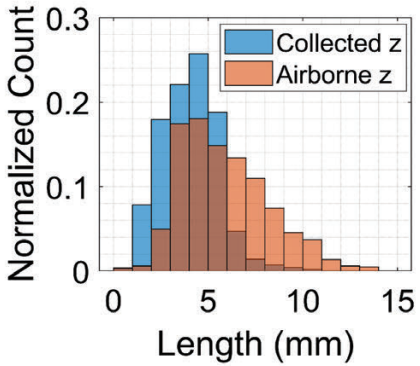


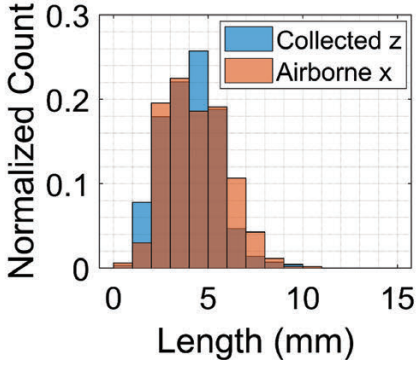

*Firebrand tracking*
*(N = 1032, red: reference surface)*



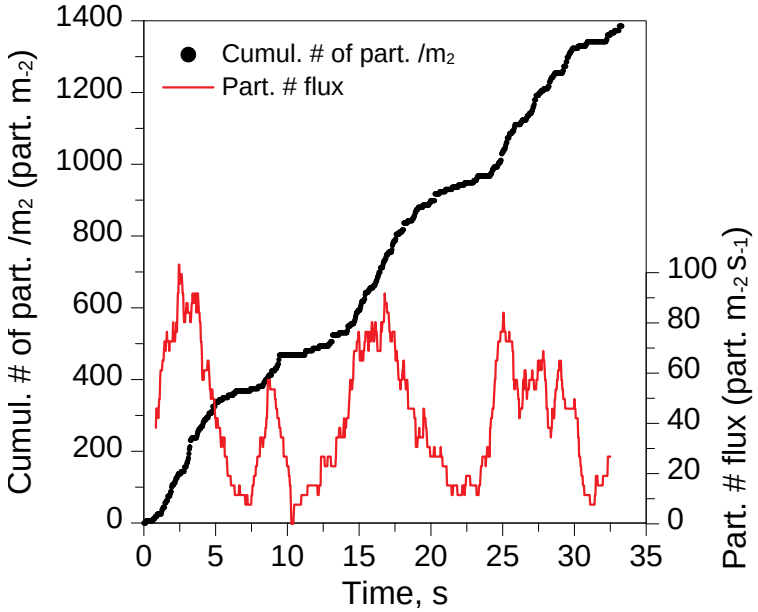

*Example of collected firebrands for size analysis*




*Comparison of firebrand dimensions:*
*emberometer measurements (red)*
*vs. water pan measurements (blue)*




*Cumulative number and number flux of firebrands during test period*

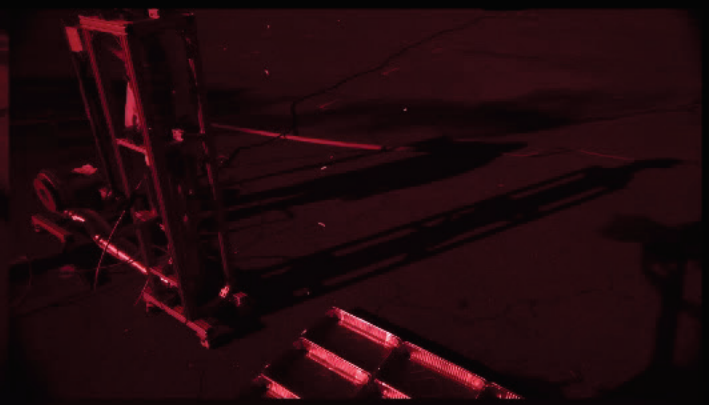
*Set-up view*

*Quad view*

*(Raw → Conditioned → Superimposed tracks & identifiers)*

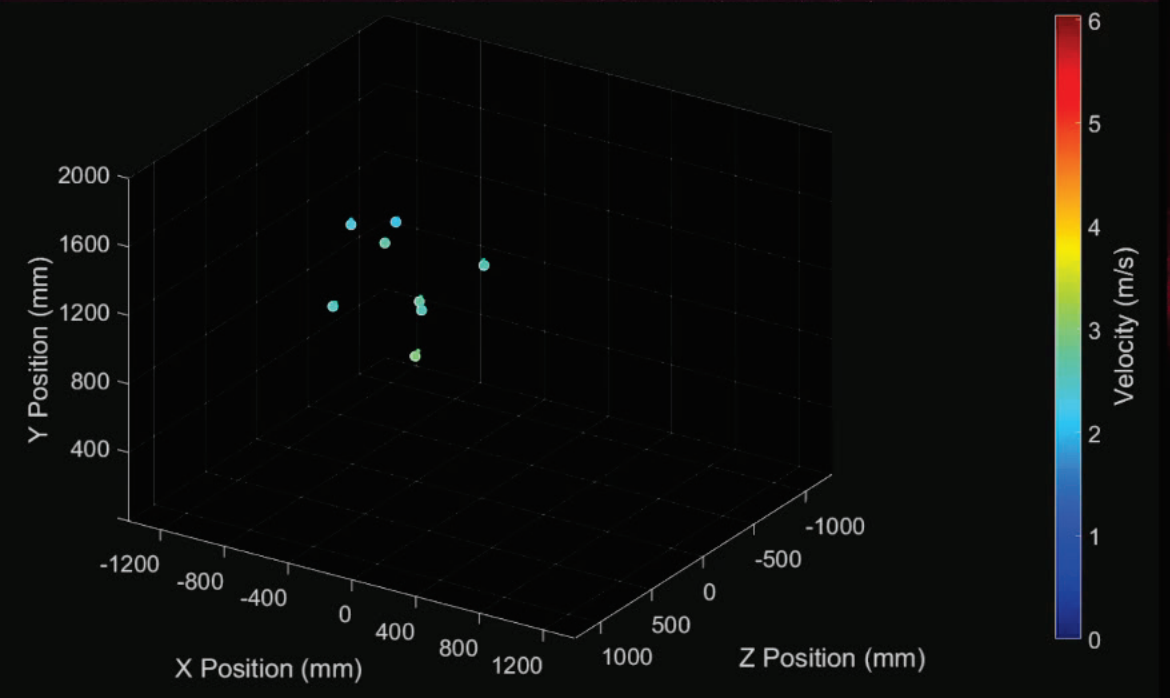
*Cam #1*

*Cam #2*



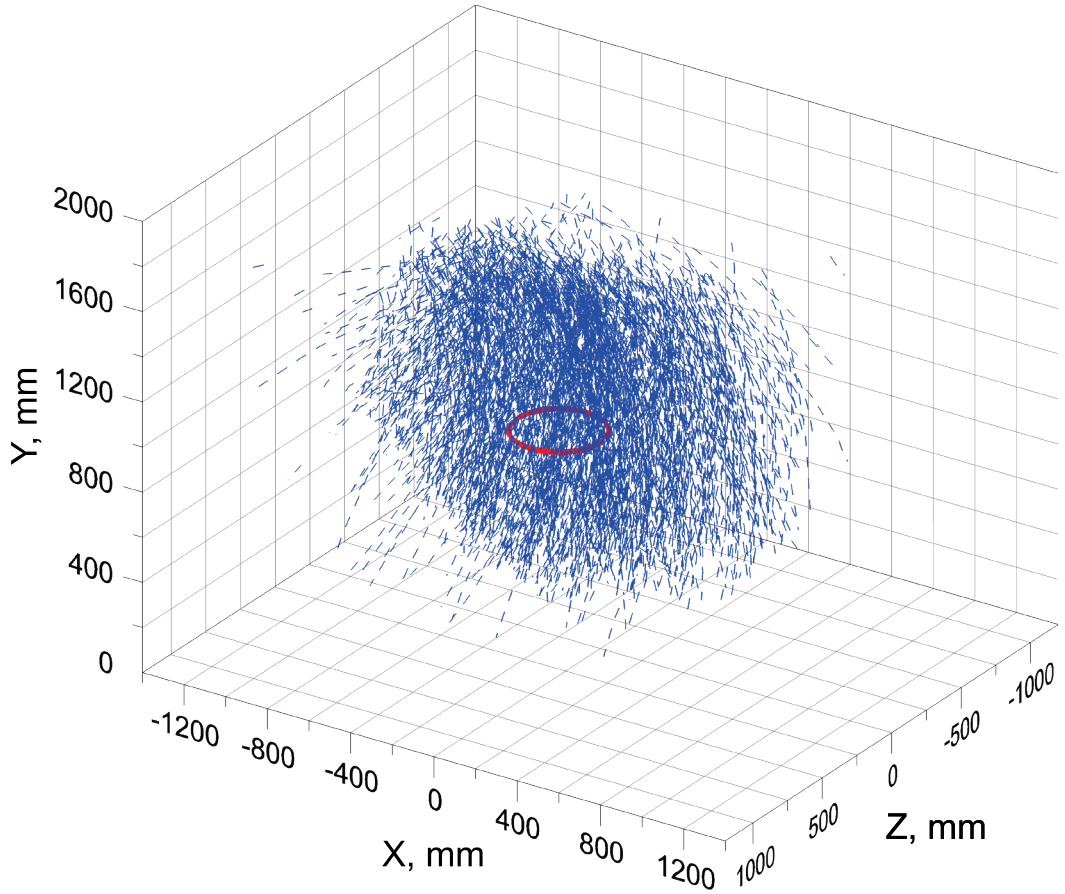
*Cam #3*

*Cam #4*

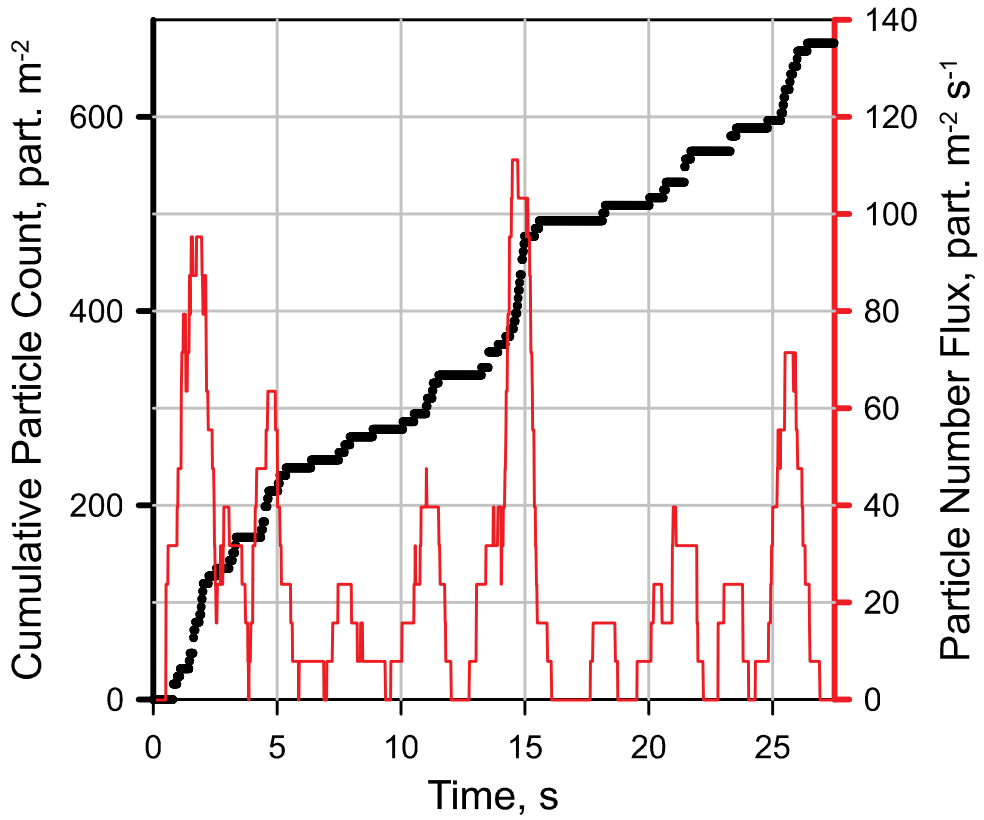



*Reconstructed firebrand 3D motions*

# Particle Number Flux




**Cumulative plot of firebrand 3D trajectories**
Reference surface is shown by the red circle (center location: *X* = -100 mm, *Y* = 1000 mm and *Z* = 150 mm, radius: 200 mm)




**Cumulative Particle Count (CPC) and corresponding Particle Number Flux (PNF) vs. time**
(60 timestep derivation window – ref. surface shown in left fig.)

Bouvet N., Link E.D., Fink S.A. (2021) A new approach to characterize firebrand showers using advanced 3D imaging techniques. *Experiments in Fluids* 62:181. https://doi.org/10.1007/s00348-021-03277-6

# Comparison of Measured Number Flux

| Work | Environment | Fire intensity (MW $m^{-1}$) | PNF (part. $m^{-2}$ $s^{-1}$) | |
|---|---|---|---|---|
| Filkov and Prohanov [1]* | NJ Pine Barrens | 0.18 – 4.37 | 0.03 – 2.4 | |
| Thomas et al. [2]* | NJ Pine Barrens | 7.35 – 12.59 | 0.8 – 1.4<br>3 – 7<br>(period of high firebrand activity only) | |
| Present** | – | – | Outdoor<br>24.5 | Indoor<br>49.1 |

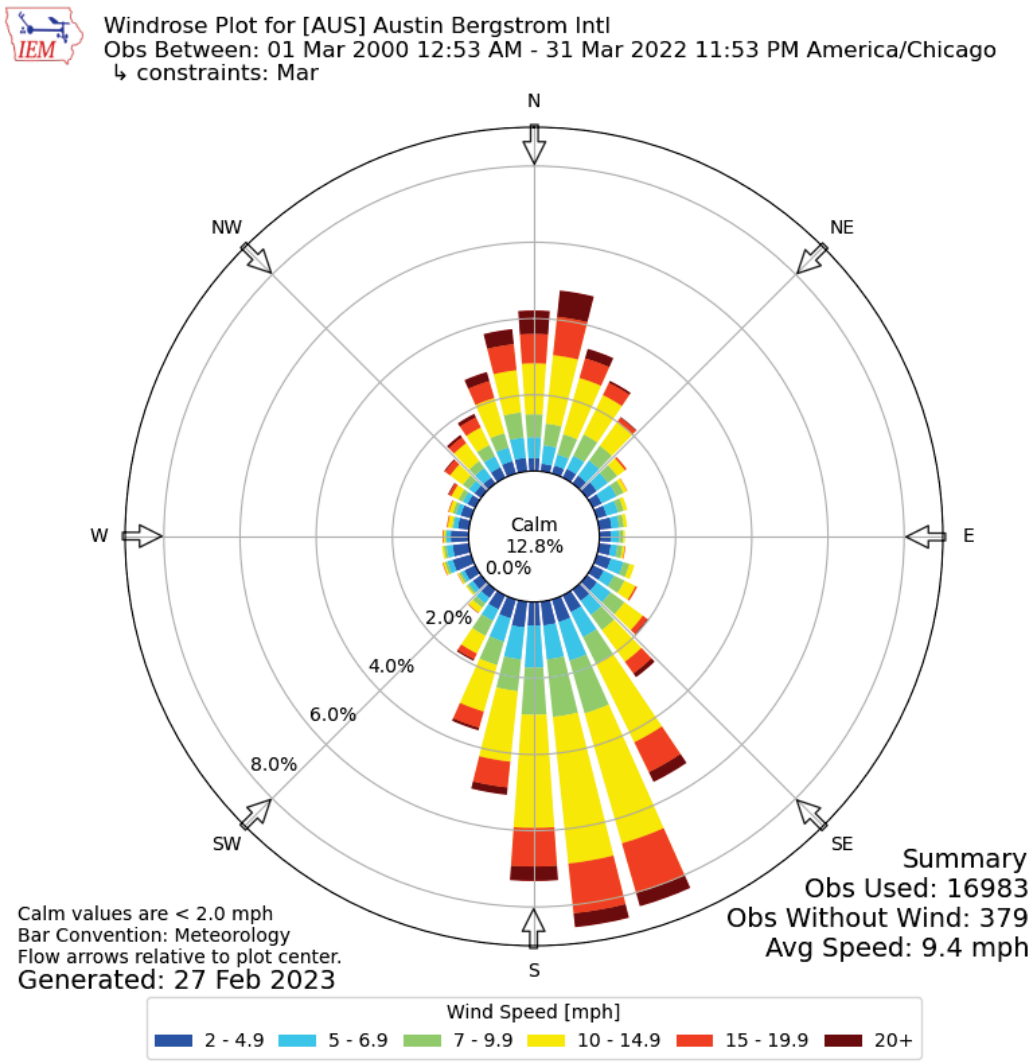
** Post-fire ground collection / firebrand areal number density normalized by duration of collection*

*** Average number fluxes based on airborne firebrands PNF time series / vertical direction, 1.2 m probing height*

[1] Filkov and Prohanov, *Fire Technol.* 55 (2018) 817-836

[2] Thomas et al., *Fire Safety J.* 91 (2017) 864-871

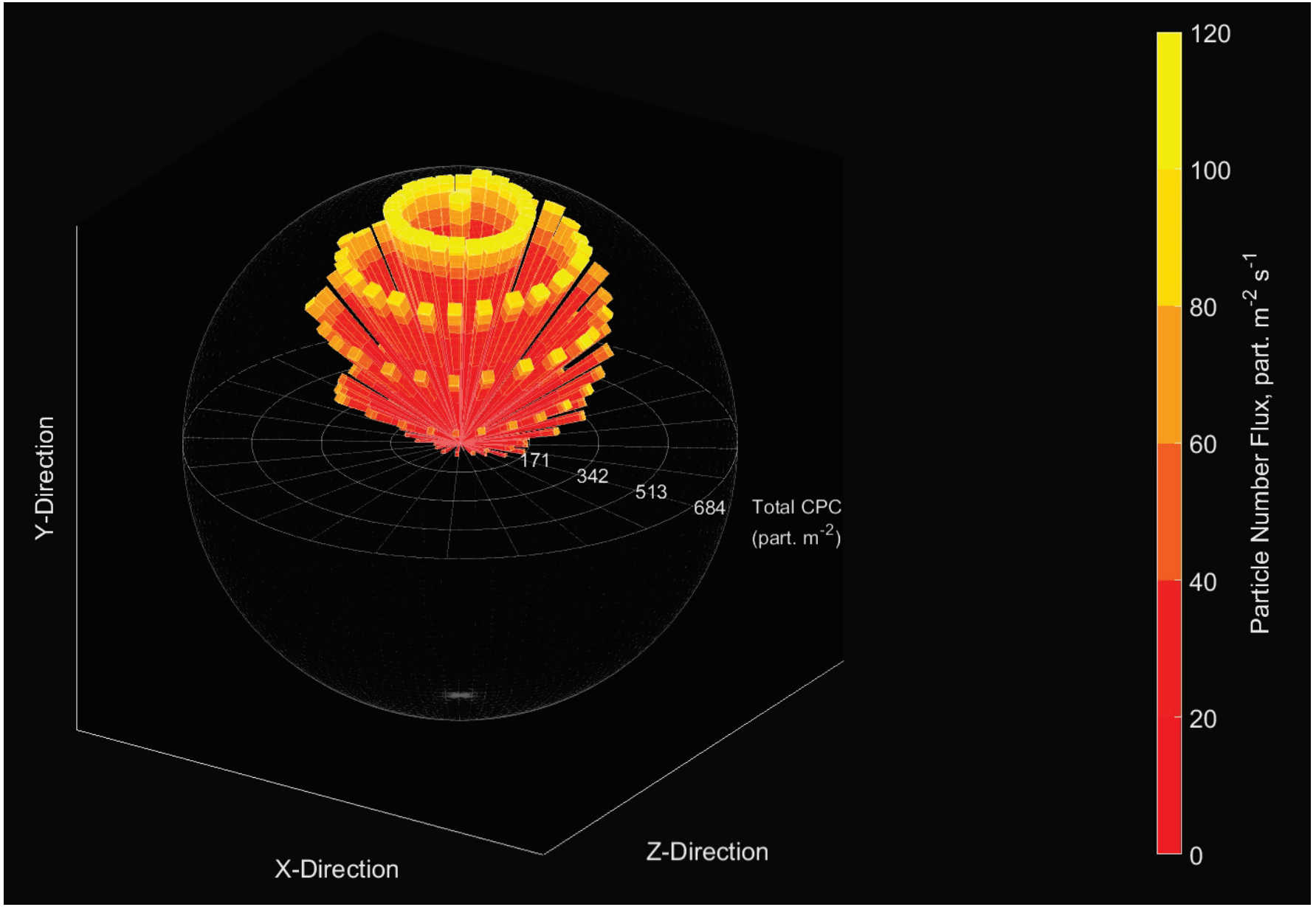
# Wind Rose Concept, 2D to 3D

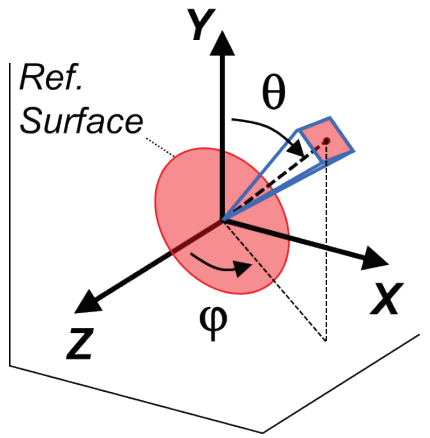



*Credit: Iowa Environmental Mesonet of Iowa State University*

| | WIND | FIREBRANDS |
|---|---|---|
| **Graphic Type** | **2D** | **3D** (*ember lofting, deposition*) |
| **Spoke Direction** | Wind direction | Direction perpendicular to ref. surface |
| **Spoke Length** | % time wind blew from specified dir. | Total Cumulative Particle Count (CPC) |
| **Spoke Class** | Range of wind speed | Range of Particles Number Fluxes (PNFs) |
| **Class Width** | % time wind blew in specified range | % time PNF recorded in specified range (spoke length = 100% time) |

# Firebrand Shower Number Flux

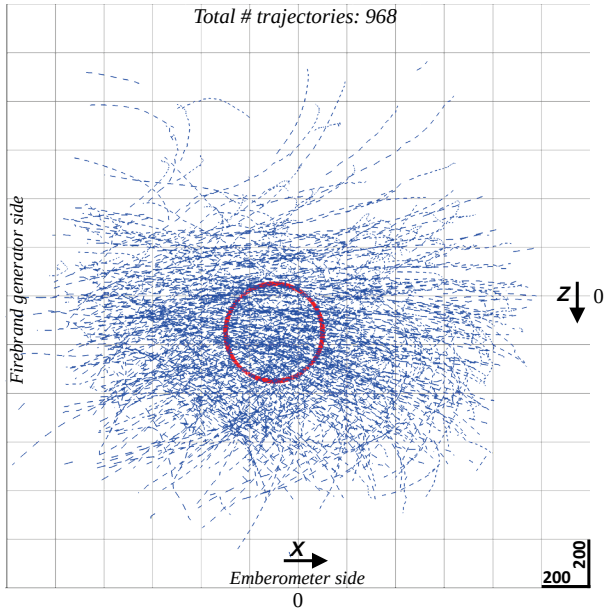


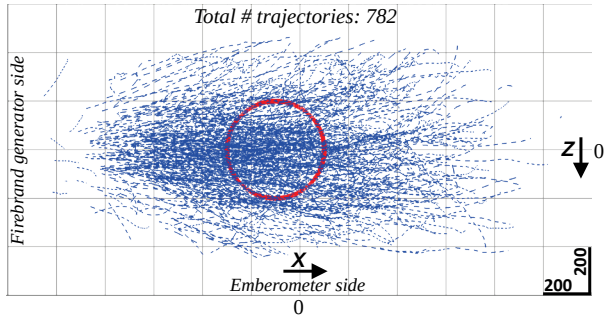
# Firebrand Shower Number Flux

NIST NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY U.S. DEPARTMENT OF COMMERCE

**OUTDOOR**

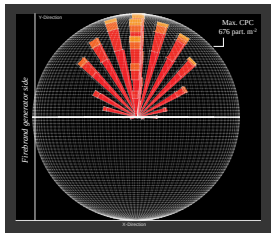


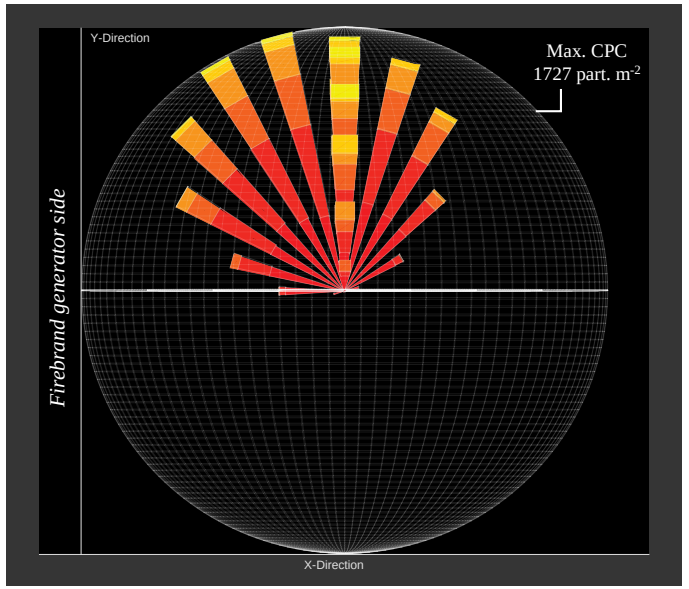

**INDOOR**



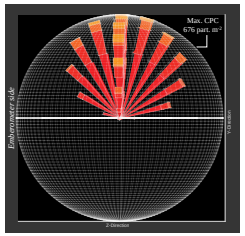

*Top view 3D trajectories*

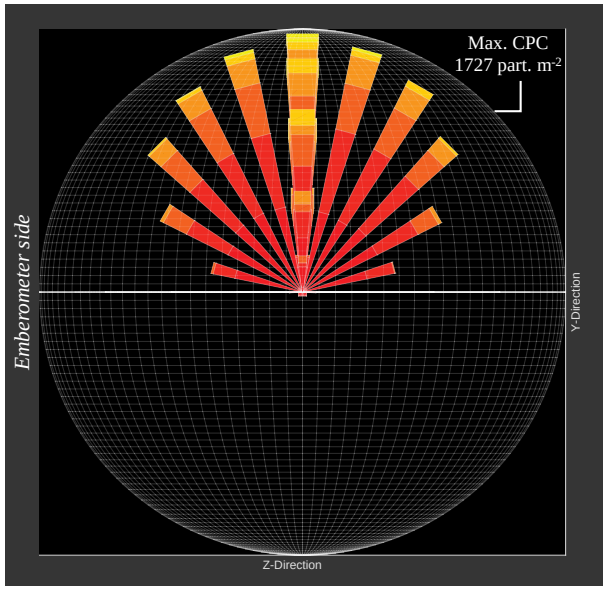
**XY**

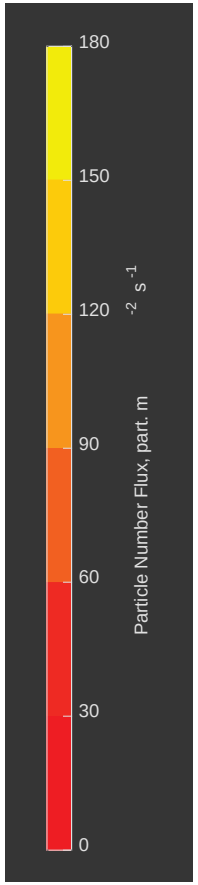





**YZ**



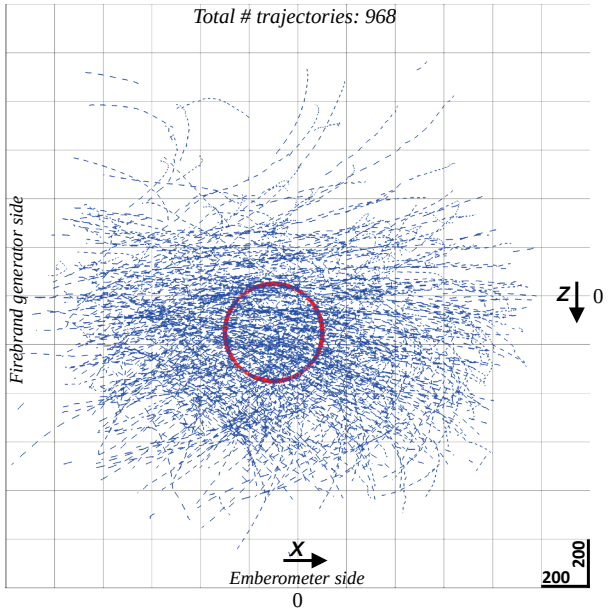


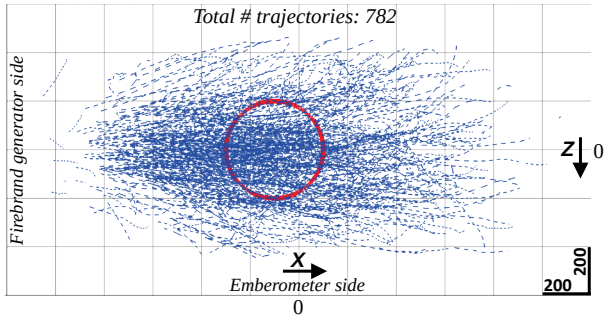

Bouvet N., *et al.* (2023) Enabling exposure comparison for firebrand showers generated during wildland-urban interface (WUI) fires. *13th US National Combustion Meeting* (March 19–22, 2023; College Station, TX).

# Firebrand Shower Number Flux

OUTDOOR

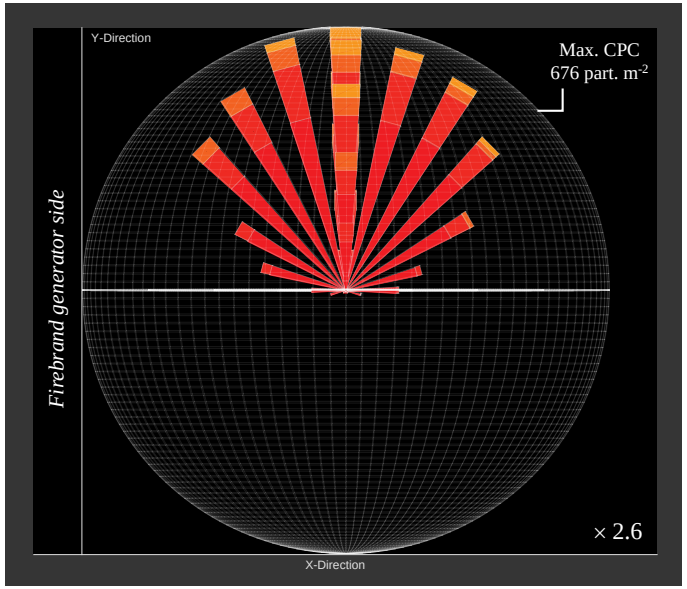


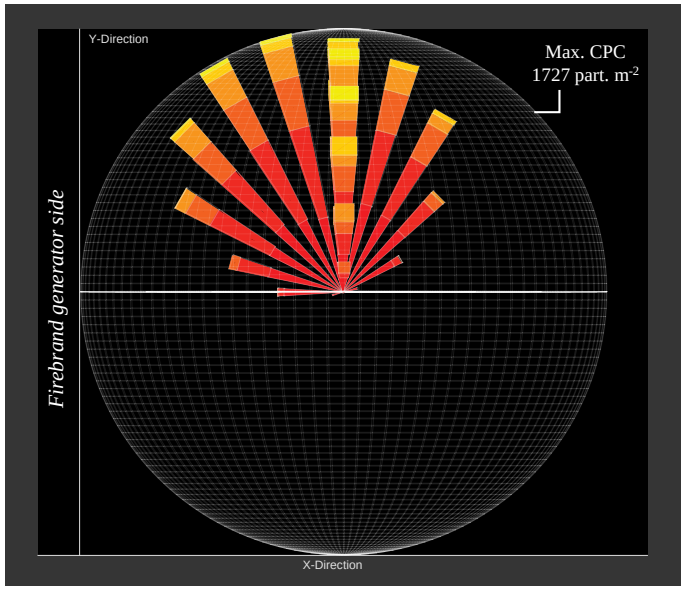

INDOOR



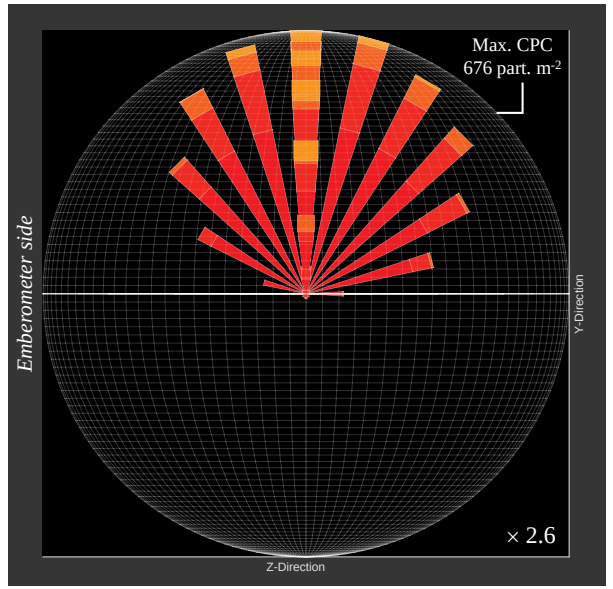

*Top view 3D trajectories*

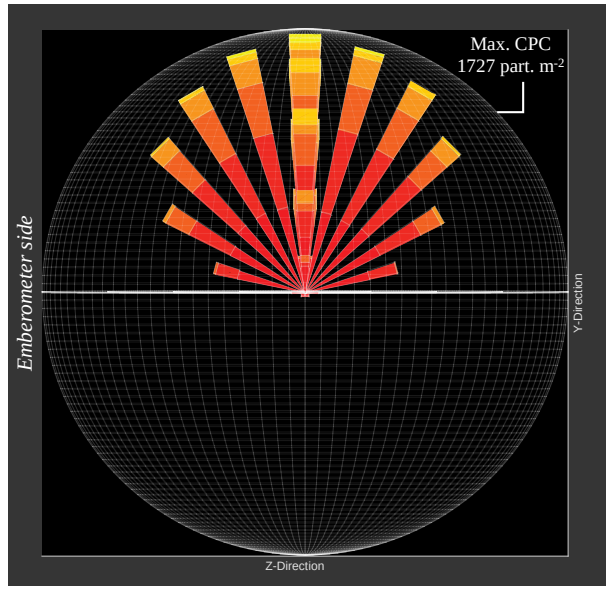
XY

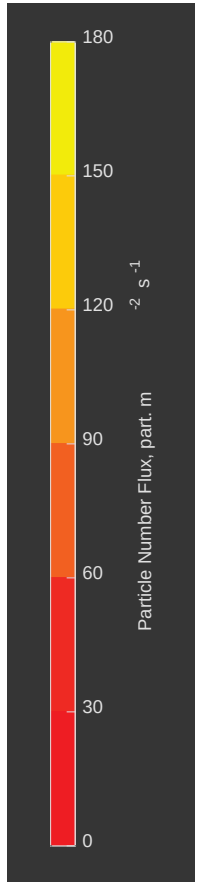



YZ

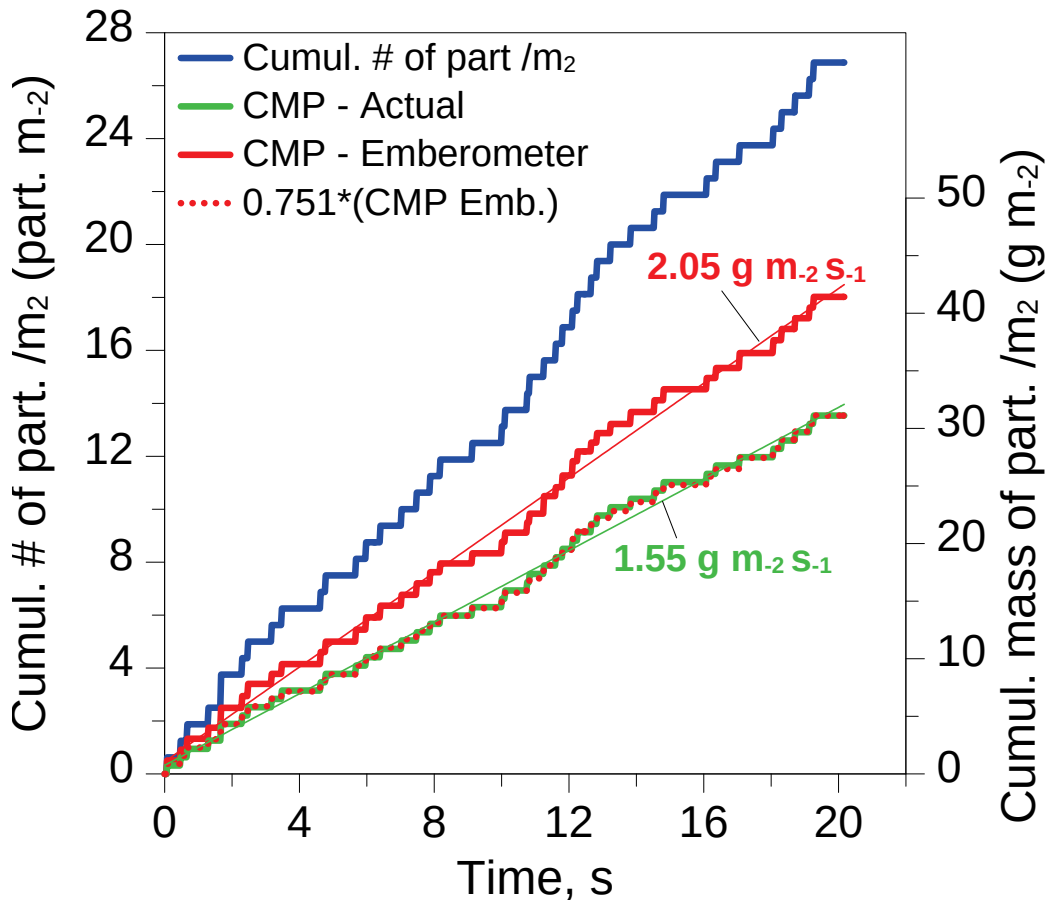


# Number Flux to Mass Flux

*(non-combusting sticks)*




- **Number flux** is relatively simple
- **Mass flux** would broaden interpretation of exposure
- **Correction of 3D volume measurement** converges with true mass flux
- **Refine firebrand sizing** approach by improved **3D shape model** and **camera orientation** configuration

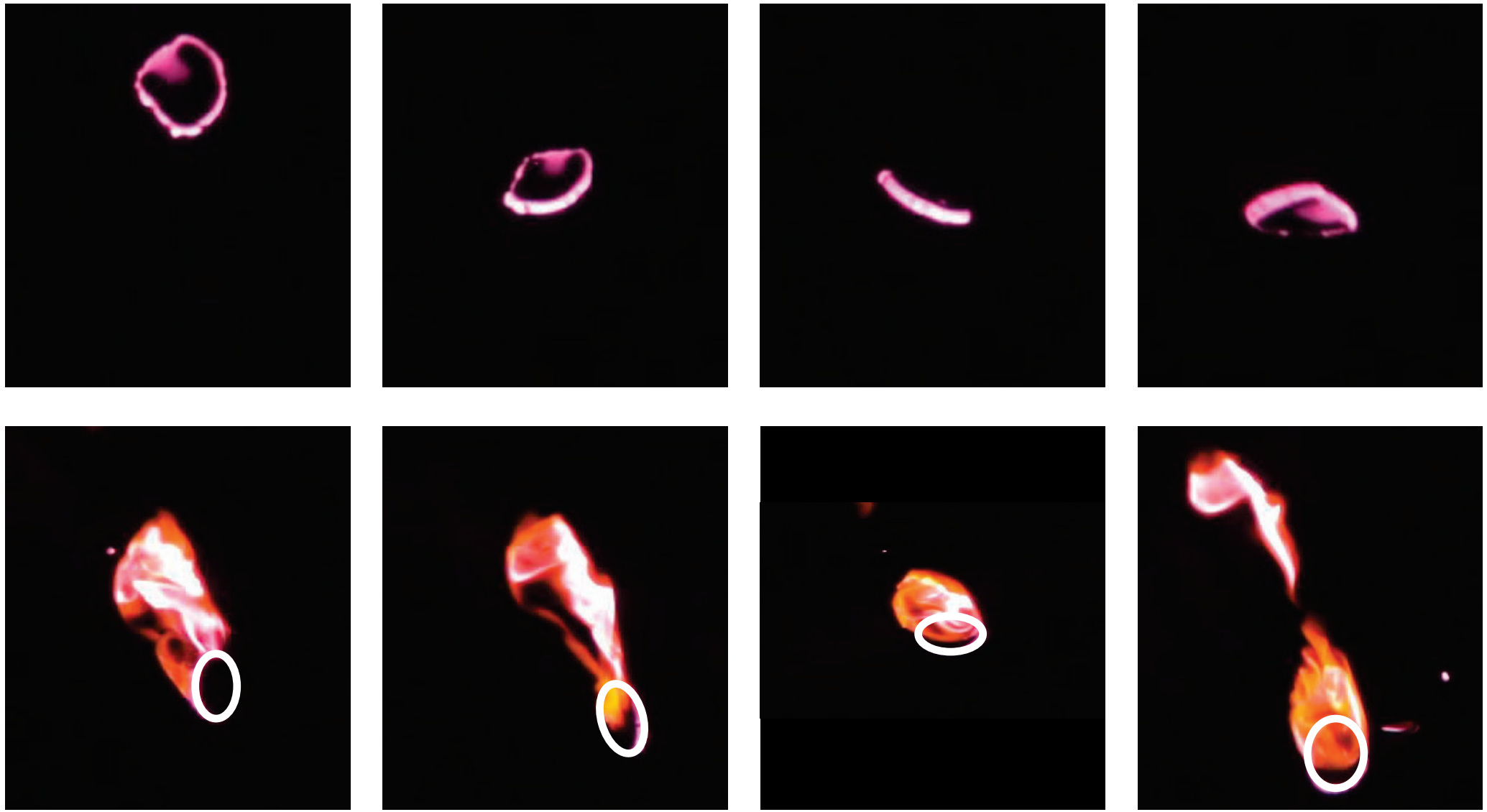

Bouvet N., *et al.* (2019) On the use of time-resolved three-dimensional diagnostics to characterize firebrand showers in the WUI. *Advances in Forest Fire Research 2018*, ed Viegas DX (Coimbra University Press), pp 826-836. https://doi.org/10.14195/978-989-26-16-506_91

# Sizing Challenge – Firebrand Combustion State

NIST NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY U.S. DEPARTMENT OF COMMERCE

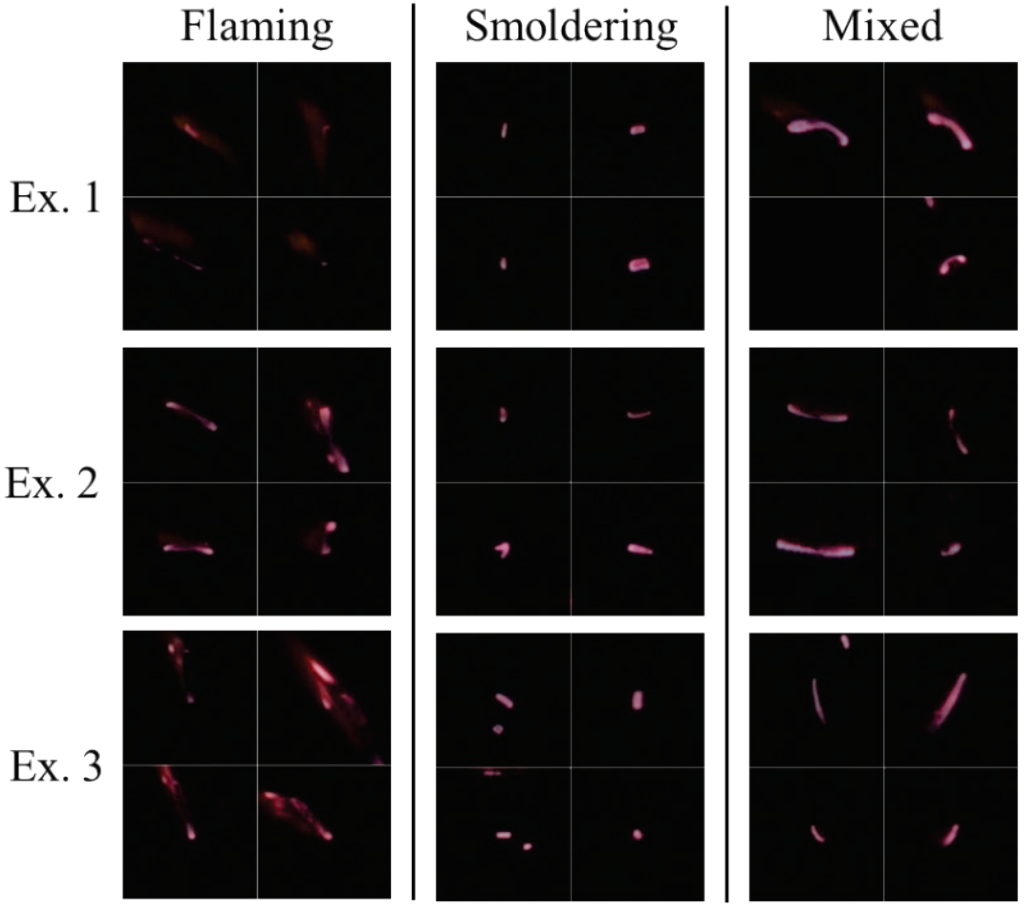
***Non-Flaming***

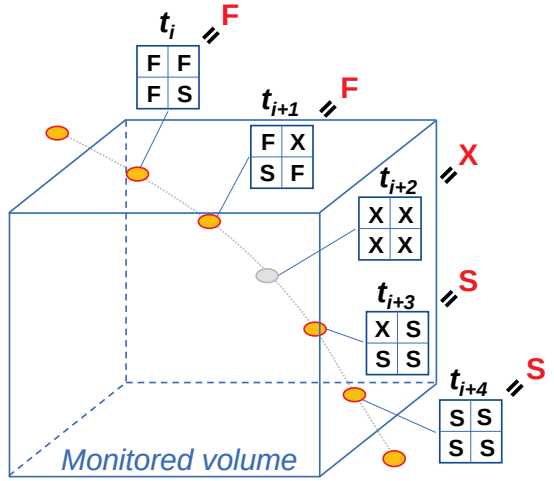
***Flaming***



*IR filtered images of 2 in diam. disks (fragments)*

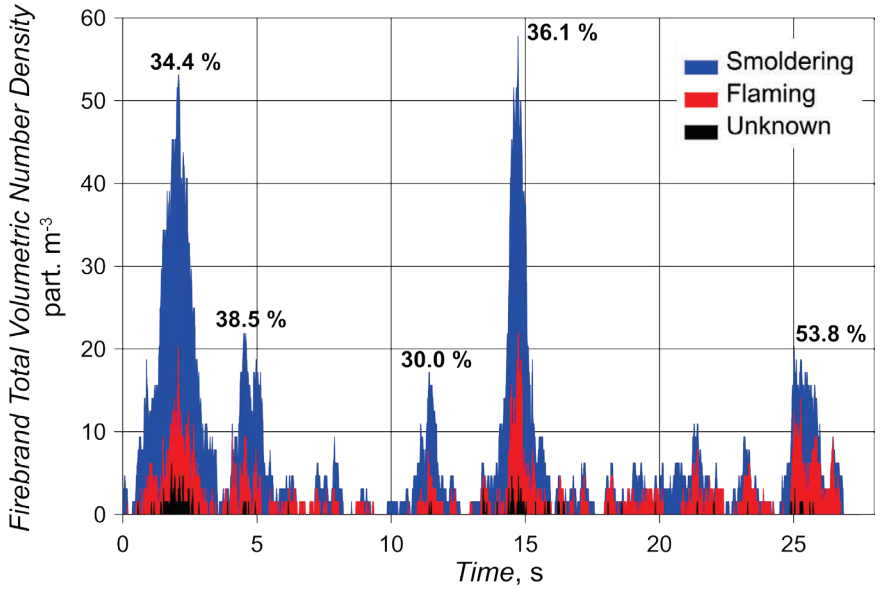
# Firebrand Combustion State




**Machine Learning Analysis**

- Human classification of 293 particles (>23K images)
- 9 different CNN tested
- 95% accuracy via transfer learning to existing pre-trained CNN




Wessies S., Bouvet N., Link E. (2023) Classification of airborne firebrand combustion state using a convolutional neural network. *13th US National Combustion Meeting* (March 19–22, 2023; College Station, TX).

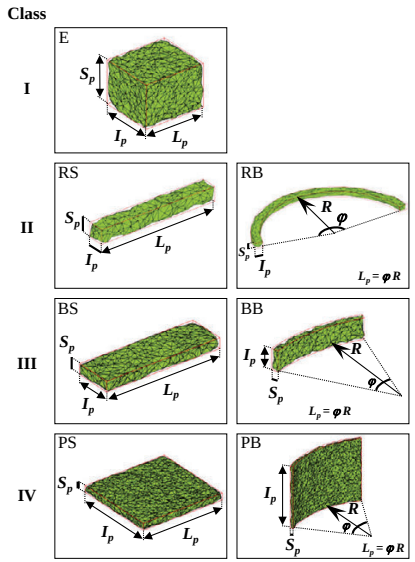
# Firebrand Morphology

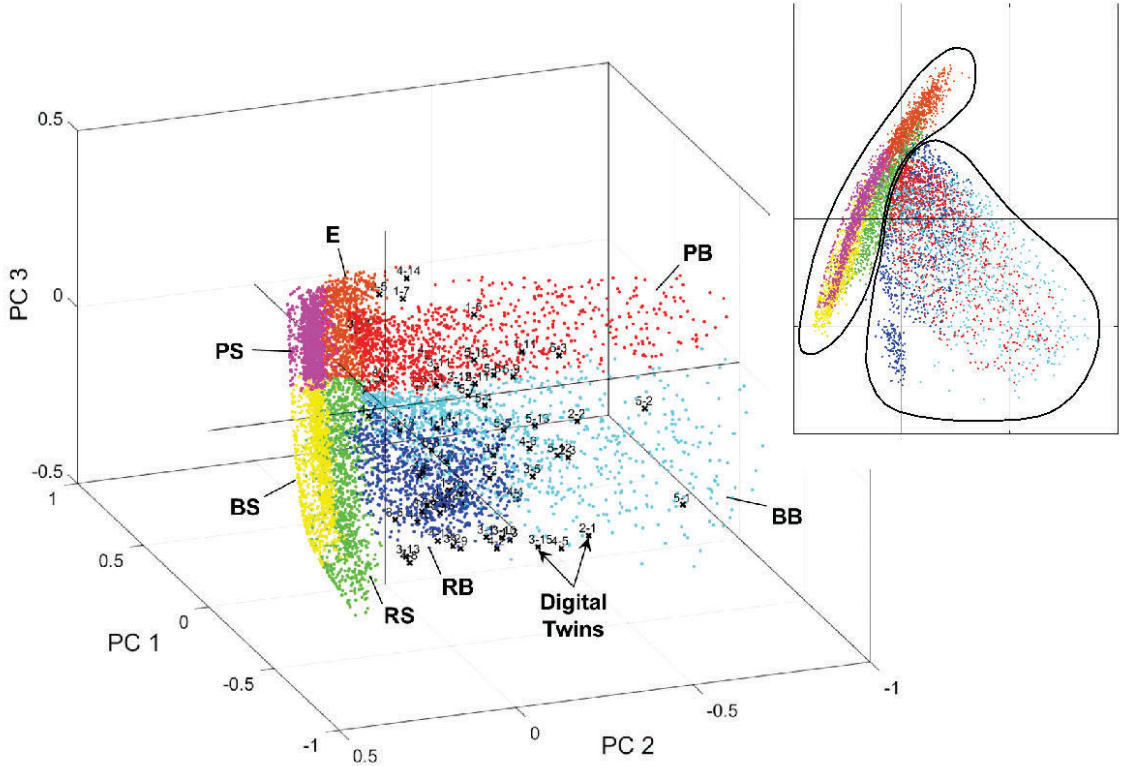
Measurements, e.g.:

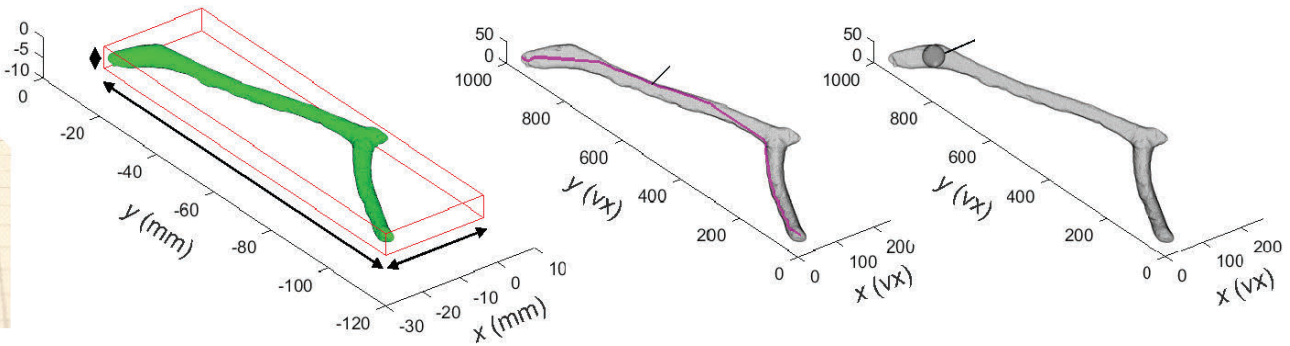
- bounding box
- volume
- surface area
- geodesic length

Descriptors, e.g.:

- elongation
- fatness
- sphericity
- convexity



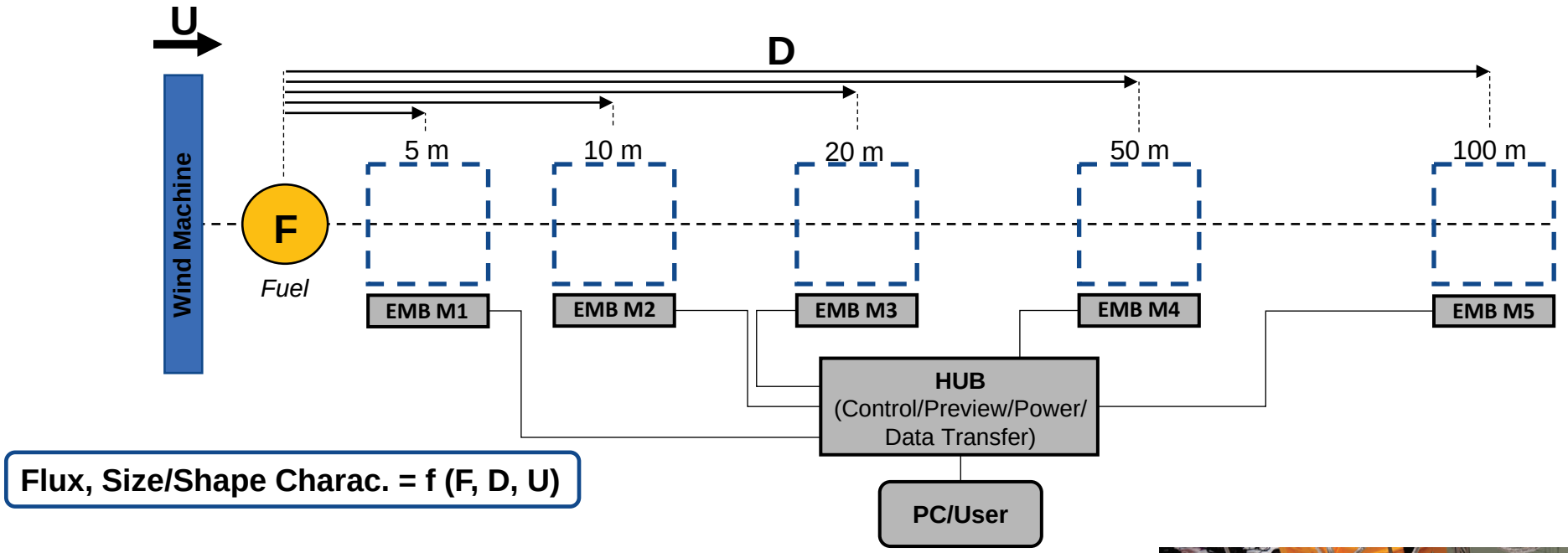




Bouvet, N. and Kim, M. (2023) [submitted]

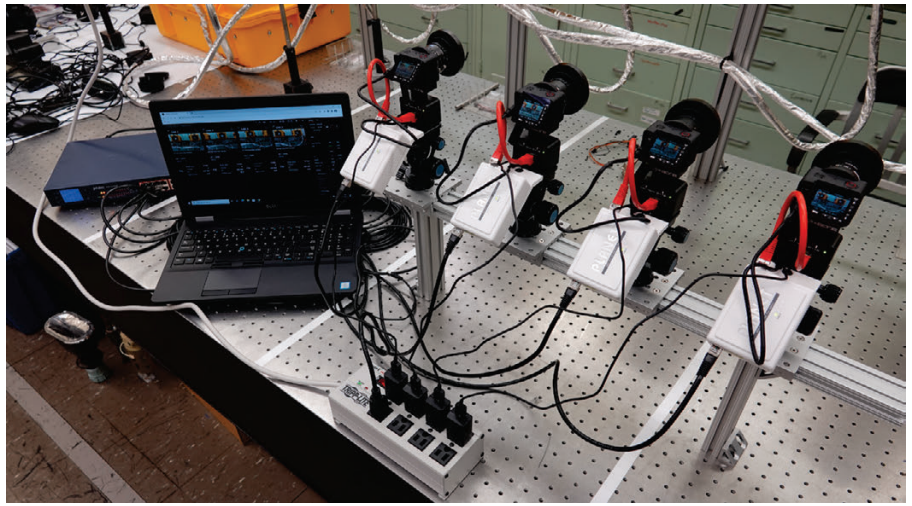
# Future Applications

- Routine laboratory measurement
- Field deployable measurement
- Definition of firebrand shower exposures, fluxes
- *Drone-based measurement platforms*
- *Weather radar-based measurement (pyrometeor)*

# Future Applications



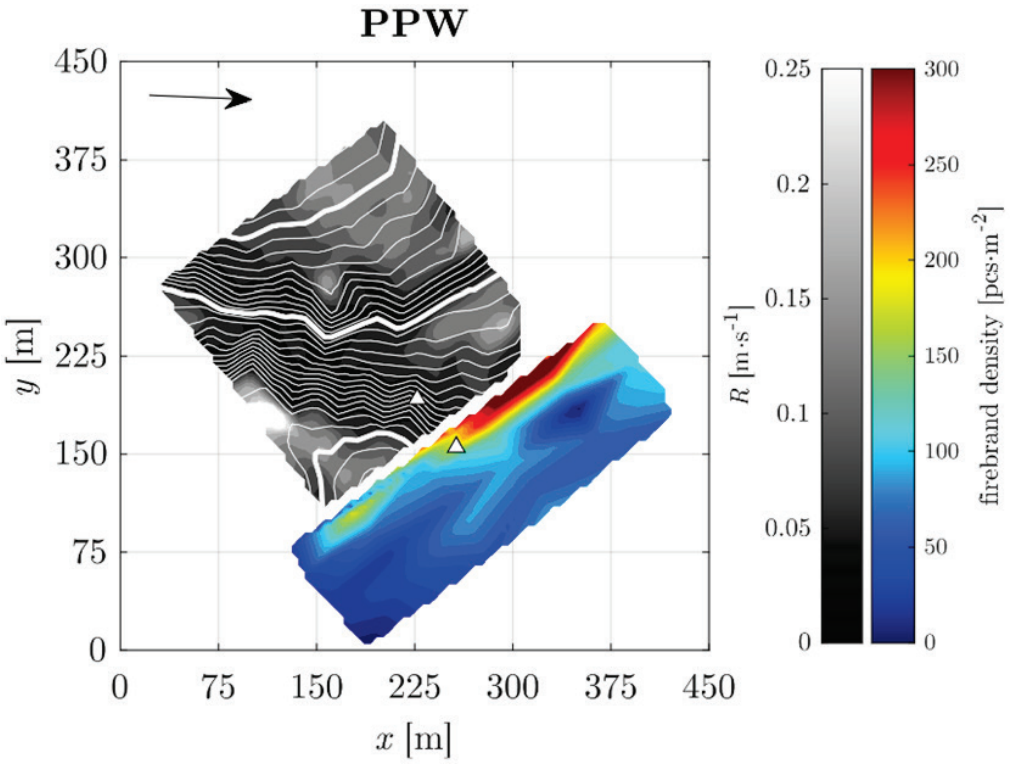

*E-Light / Prototype*



- Laboratory-based
- Non-hardened construction
- Multiple measurement stations

# Continuing Challenges

- Deployability, cost, resolution, geographic distribution (point measurement)
- Mechanism of firebrand deposition (airborne shower vs. ground flow)
- Image processing, particle detection (partially glowing, single particle detected as multiple pieces, etc.)
- Fuels characterization
- Relation to fire intensity, spread, wind




Zen S., *et al.* (2021) *Fire Tech* 57

# Final Remarks

**Emberometer:** device/system for the time-resolved measurement of firebrand and firebrand shower characteristics

*Usage:*

- Laboratory measurement tool; experiments; definition of standard
- Deploy in field to measure live exposures

*Applications:*

- Define firebrand exposures (number, size, energy, rate, etc.)
- Develop laboratory-scale testing for realistic exposure simulation
- Provide foundation for construction guidance, materials science
- Provide data to support fire spread modeling development

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