Fire Behavior at the Wildland Urban Interface

Modifying Building Codes to Reduce Building Loses

Alexander Maranghides
NIST

Rancho Bernardo Trails Development – 2007 Witch Fire

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Presentation Themes

- ***Solutions must be implementable (acceptable, affordable, technically feasible, tested)***

- ***Implementable solutions = custom solutions***

  (There is no silver bullet to the WUI Fire Problem)

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Presentation Outline

1. **The WUI Fire Problem**
2. **The NIST WUI Program**
   a. Old Risk Assessment and Mitigation (RAM) Tools
   b. The New RAM Tools
   c. Structure Ignition Research
3. **The NIST Case Study**
   a. Selecting the Community
   b. Data Collection
   c. Data Analysis
   d. Findings
4. **Building Codes and Standards**
   a. Wildland versus WUI
   b. New versus Existing Construction
   c. WUI Housing Density
5. **Future Research and WUI Fire Problem Solutions**

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The WUI Fire Problem

Range of scales, fuels, processes

regional

community

neighborhood

structure

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Integrated NIST WUI Program

Post-fire Analysis / Fire Behavior

Physical Modeling

Structure Ignition

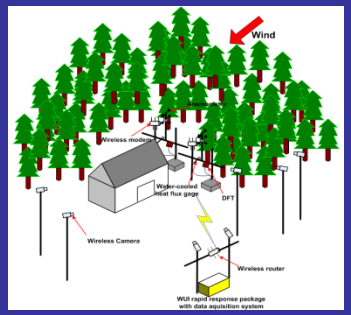
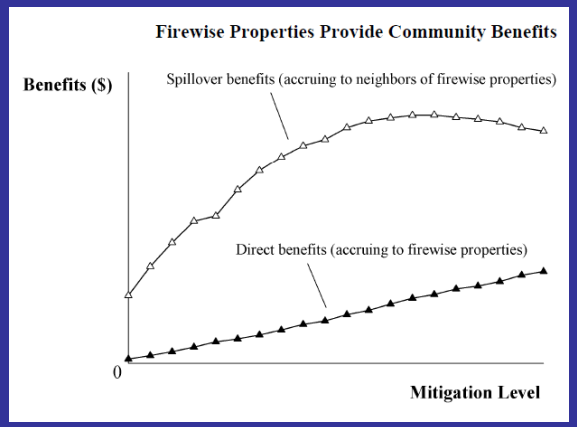


Photo by JOHN GIBBINS / Union-Tribune

Cedar Fire about to engulf the Scripps Ranch residential community

Economic Modeling



Large Scale Fire Behavior Measurements Needed

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Risk Assessment and Mitigation (RAM) Tools

Wildland Fire

BEHAVE Suite
NIST WFAST (new)

NIST WFDS (new)
Los Alamos Code (new)

Operational (Simple) → Strategic (Complex)

Firewise
NIST WFAST (new)

NIST WFDS (new)

WUI Fire

NIST is creating the tools to generate Custom WUI Fire Problem Solutions

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The Current Status

- Old RAM Tools do not provide a proven assessment of risk and do not provide usable risk mitigation solutions

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NIST RAM Tools

NOAA Fire Weather

900 km (domain) ~8 km (grid cell)

NIST Neighborhood Scale Model (WFDS)

1 km (domain) ~1 m (grid cell)

NIST Community Scale Model (WFAST)
(in early stage of development)

regional

community

neighborhood

structure

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Technical Approach for Next Generation RAM Tools

- **Need to use validated complex tools to develop reliable simple tools**
  - Validate WFDS in regimes / scenarios of interest – fuel treatments
  - Use WFDS to develop reliable simple (fast) WFAST capable of operational use

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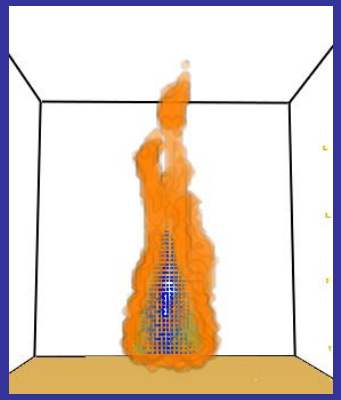
WFDS
Next Generation RAM Neighborhood-Scale Tool

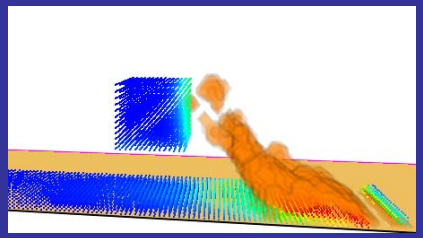
Tree Burn

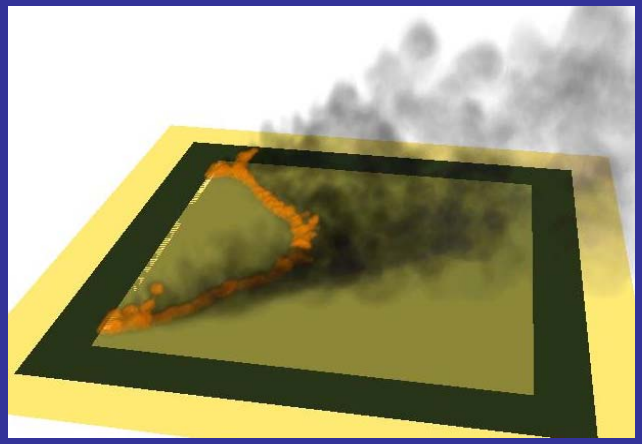


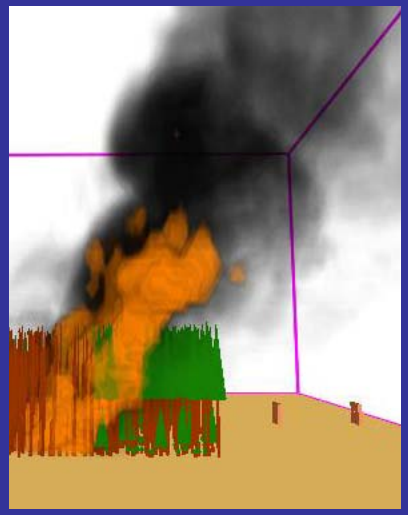
AU Grassland Fire

ICFME Crown Fire

Crown Ignition Exp.







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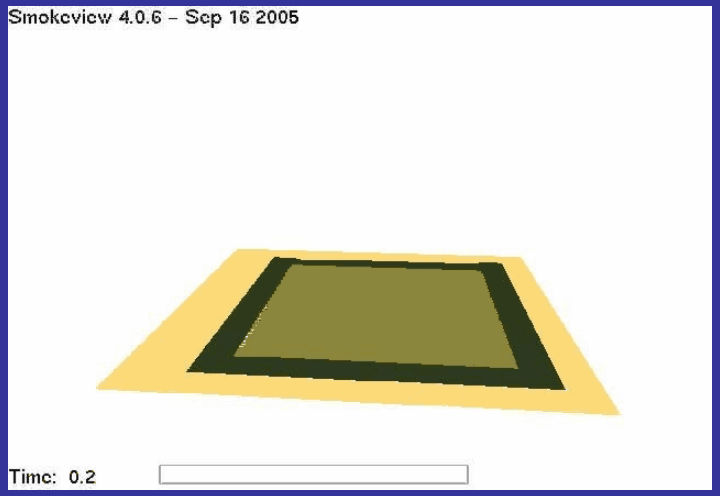
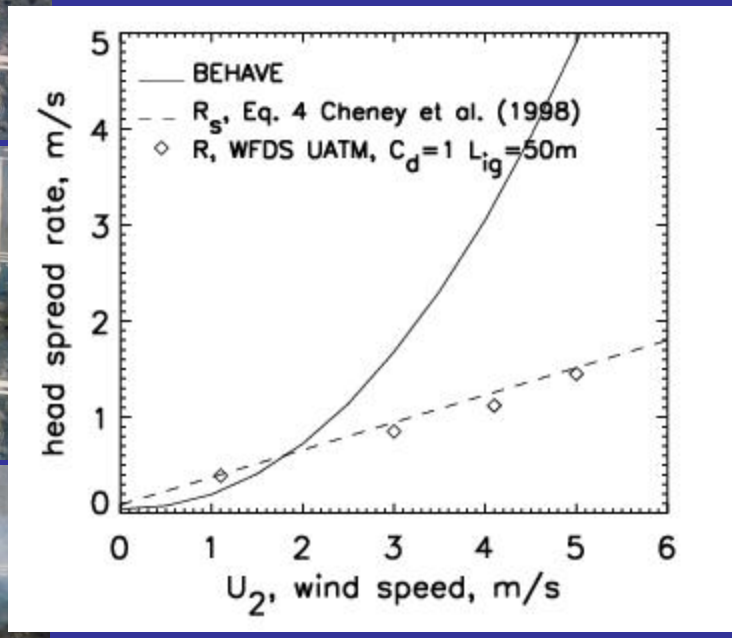
WFDS Validation Example: AU Grassland Fires

Animation of WFDS result

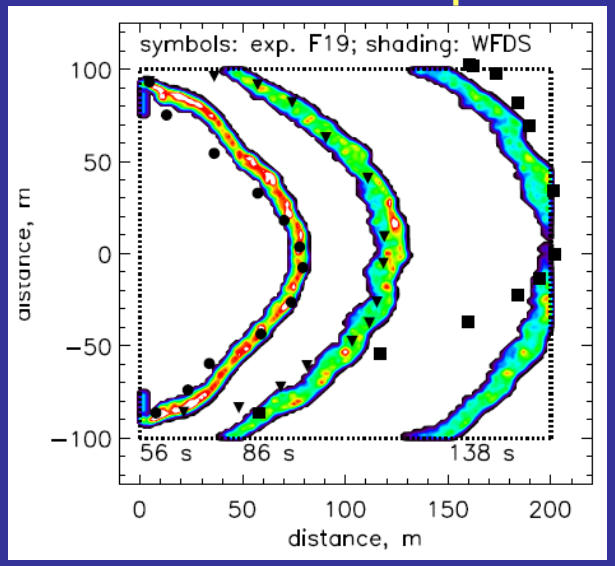


Fire perimeters from experiments

Head-fire spread rate versus wind speed



WFDS and measured fire perimeters

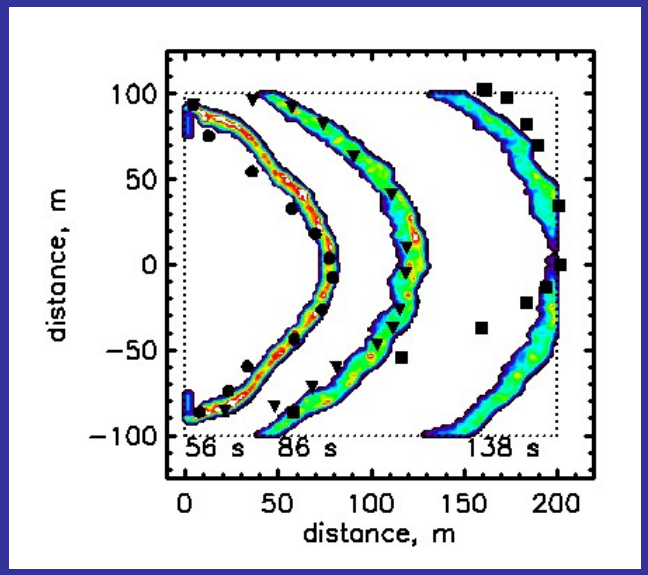


WFAST
Next Generation RAM Community-Scale Tool

In initial stages of development & testing

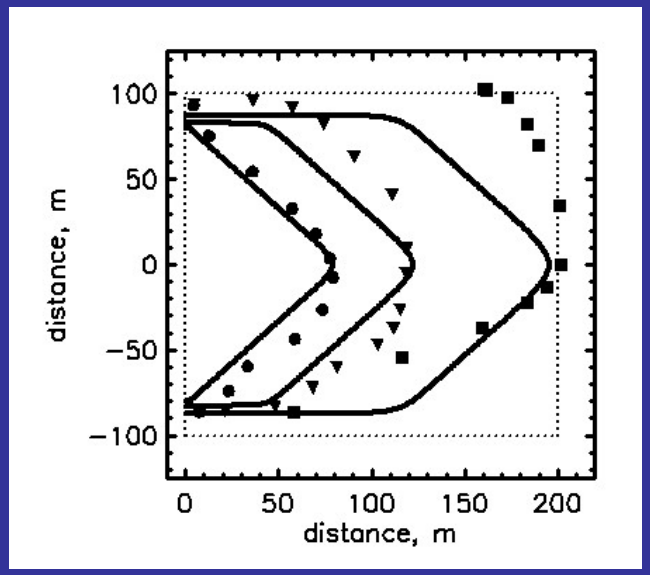
- Fireline spreads according to simple rules based on real scale measurement or modeling (e.g., WFDS).

WFDS & Measurements



400 times *slower* than real time

WFAST & Measurements



40 times *faster* than real time

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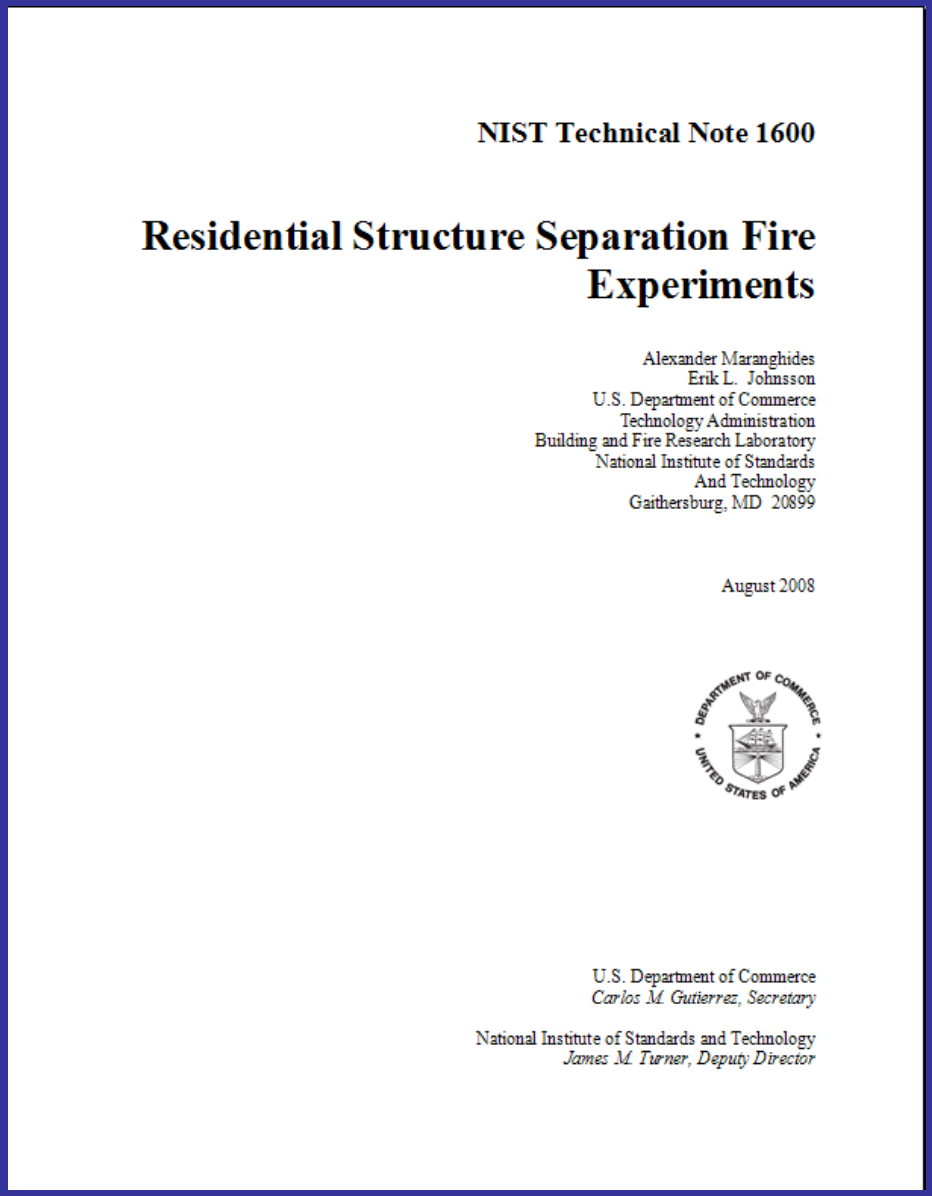
Structure Separation Experiments

Photograph of the side of the structure of origin facing the adjacent target wall.



NIST Technical Note 1600

Residential Structure Separation Fire Experiments

Alexander Maranghides
Erik L. Johnsson
U.S. Department of Commerce
Technology Administration
Building and Fire Research Laboratory
National Institute of Standards
And Technology
Gaithersburg, MD 20899

August 2008

U.S. Department of Commerce
Carlos M. Gutierrez, Secretary

National Institute of Standards and Technology
James M. Turner, Deputy Director

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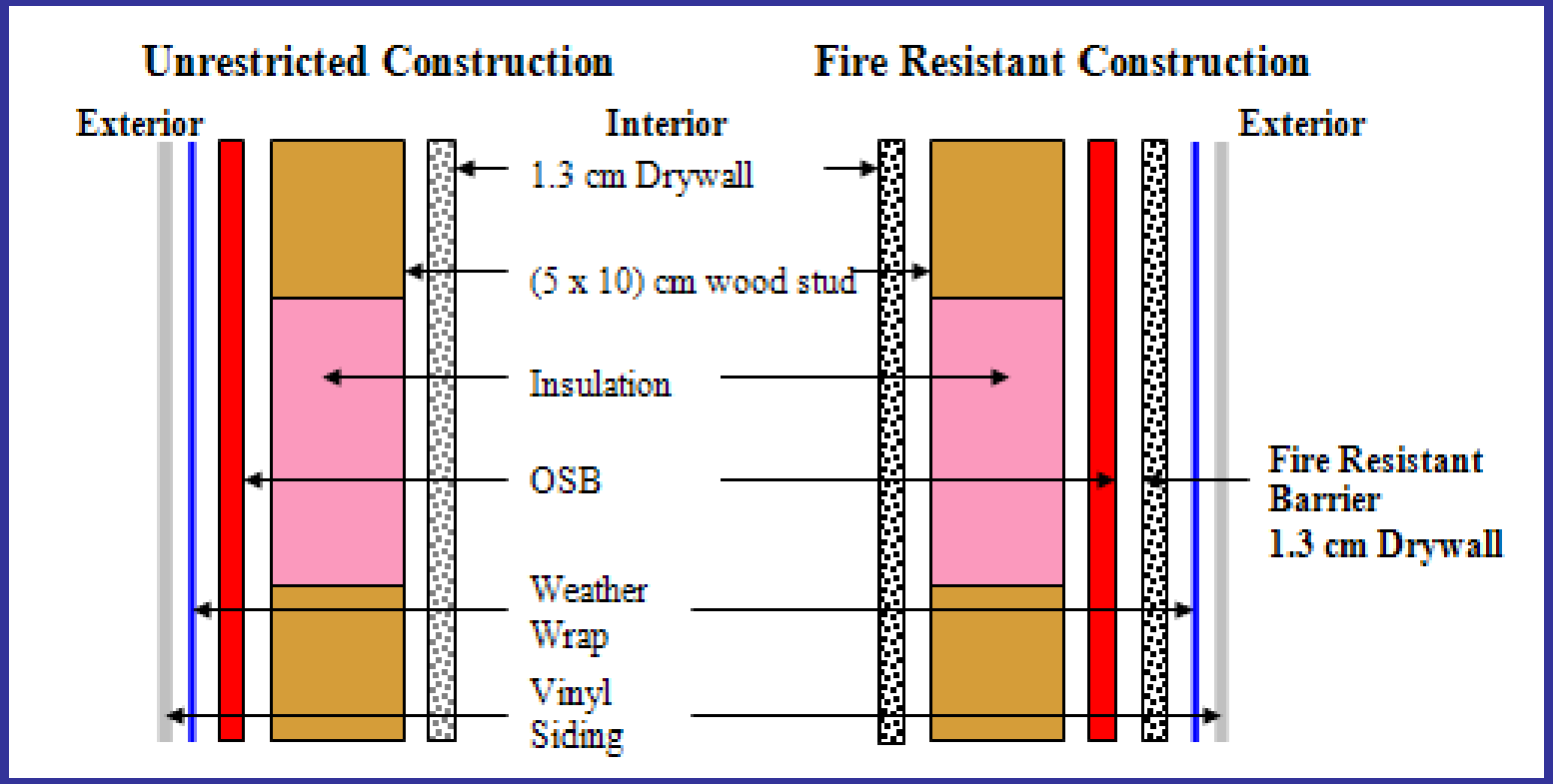
Structure Separation Experiments
Two Types of Construction



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Structure Separation Experiments
Scenarios Tested

- **3 ft setback from property line**
- **The scenarios tested were not the worst case, and the experiments conducted address several but not all fire spread scenarios.**
- **Fire spread between structures is a complex process primarily affected by:**
  - construction type,
  - separation distance,
  - placement and size of windows and
  - effects of weather.

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Structure Separation Experiment Results

Unrestricted Construction Experiment: Target Wall OSB Ignited 1 min 20 s after Window Failure

Fire Resistant Construction Experiment: 9 min after Window Failure – Target Wall OSB Not Ignited

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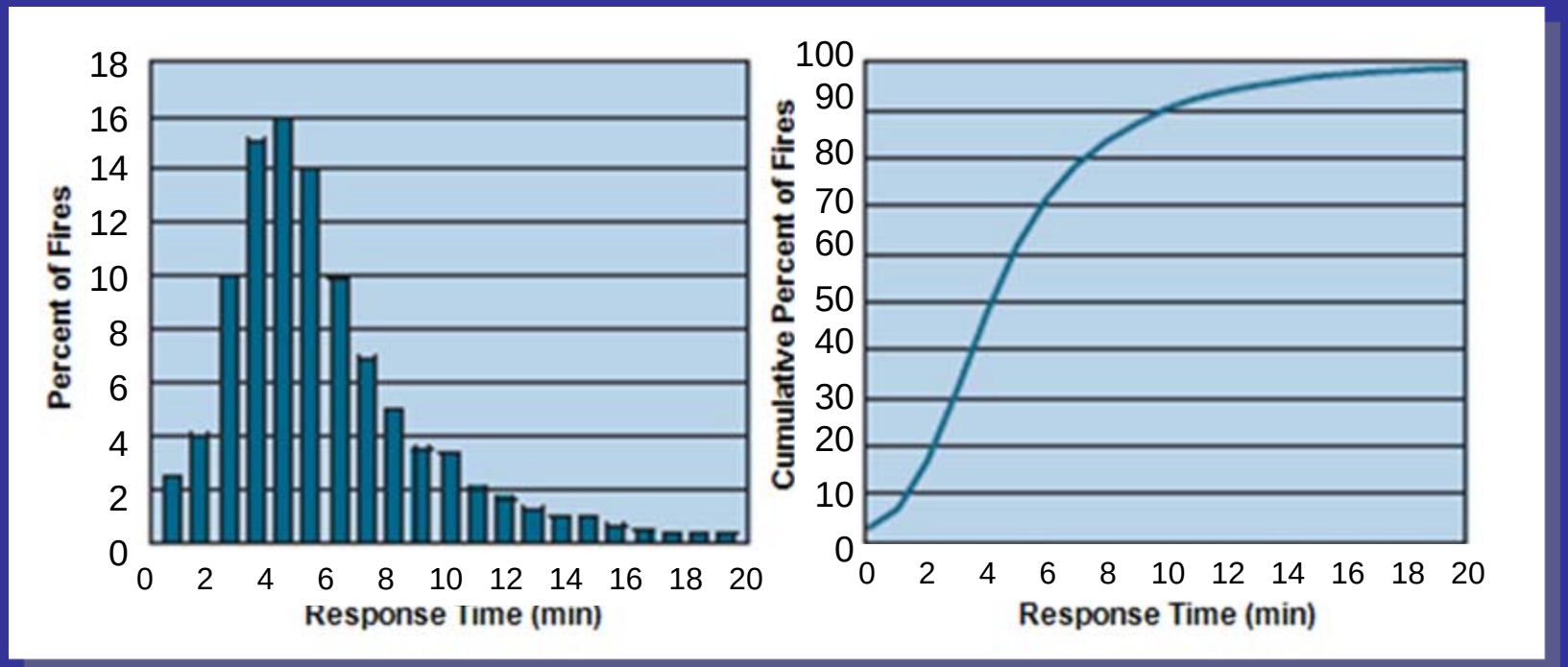
Structure Separation Experiments
NFIRS Data

Fire Service Response Times to Structural Fires



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Structure Separation Experiment Conclusions

- There are a number of options with respect to fire resistant material selection, and no attempt has been made to provide any materials recommendations at this time.
- The two experiments have demonstrated that fire resistant construction can significantly reduce the overall flame spread risk in communities where structures are placed in close proximity to each other.
- Even though NFIRS does not contain information on all fire incidents, the available fire department response data suggests that the delayed flame spread between adjacent structures associated with fire resistant construction can provide significant valuable time for fire department response.

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Need for Firebrands Research

- Structure ignition in WUI fires - not quantified
- Post-fire studies – firebrands a major cause of ignition
- Understanding firebrand ignition of structures – important to mitigate fire spread in communities

2007 Southern California Fire

2003 Southern California Fire

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Firebrand Research Approach

New Technical Idea: Firebrand Generator

- **Field scale, full scale, reduced scale experiments**
- **Focus: Parametric study on vents (ASTM/CALFIRE)**

2007 California Fire

NIST Dragon

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Firebrand Research Recent Results

Aged Roofing Simulated: OSB, then tiles (no tar paper)

U_∞ (m/s)	OSB/TP/CT No Bird Stops	OSB/TP/CT With Bird Stops	OSB/CT No Bird Stops	OSB/CT With Bird Stops
7	SI	NI	SI to FI	SI
9	SI	NI	SI to FI	SI

New Roofing Construction: OSB, Tar Paper, then Ceramic Tiles

Current standard no firebrand attack

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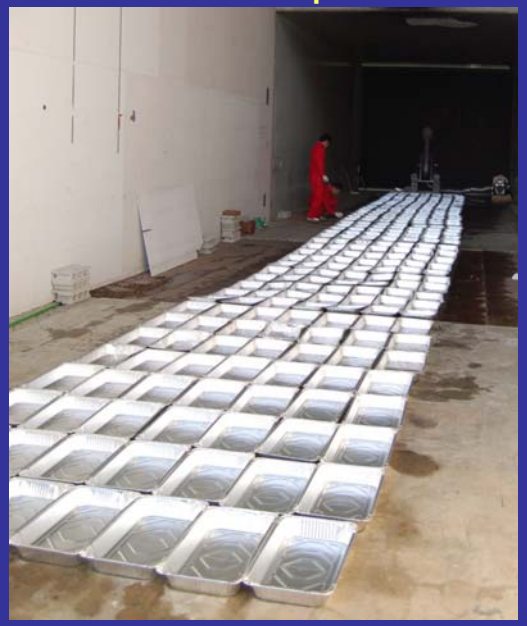
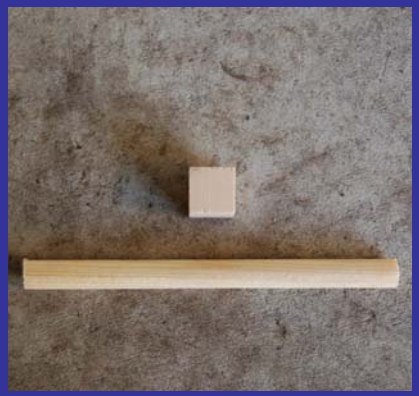
Firebrand Research Recent Results

Firebrand
Transport Testing
40 rows of pans





Firebrand Transport
Past Obstructions
Qualitative Comparison for CFD Simulations

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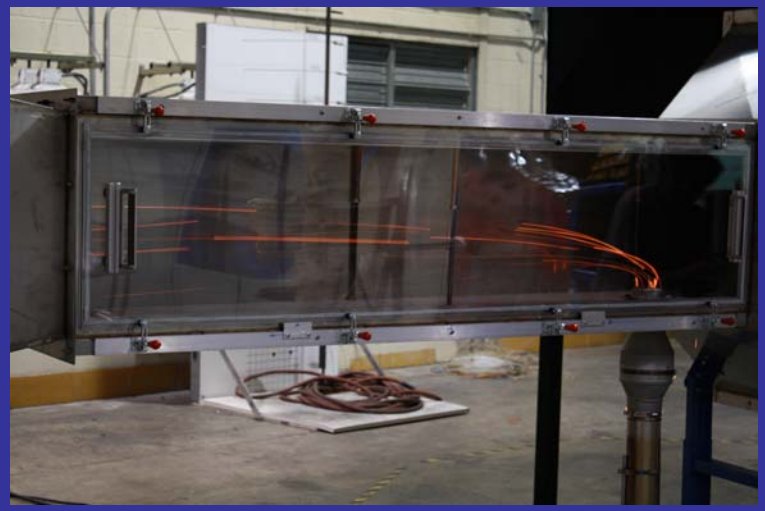
Firebrand Research Recent Results

- Reduced scale wind tunnel coupled with baby Dragon NIST DRAGON'S LAIR (Lofting and Ignition Research)



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The NIST Case Study

- NIST
- CALFIRE – Chief Chamlee
- SD Fire Department – Chief Jarman
- SD Police Department – Chief Lansdowne
- The Trails home Owner Association – Mr. Steve Arnold
- NIST Grantees
- USGS

Successful Joint Effort

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fire.nist.gov/wui

NIST Technical Note 1635

A Case Study of a Community Affected by the Witch and Guejito Fires

Alexander Maranghides
William Mell

NIST National Institute of Standards and Technology • U.S. Department of Commerce

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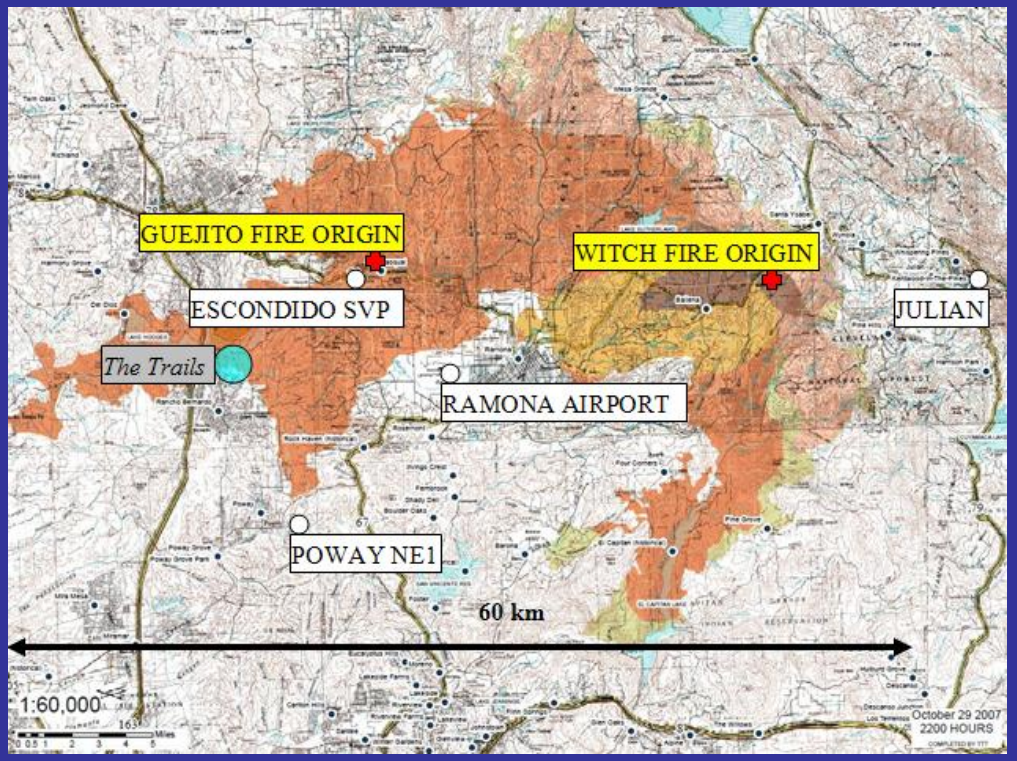
Selecting the Community

- The Trails at Rancho Bernardo
- Community Size
- Housing Density
- CALFIRE Maps
- Topographical Features
- Witch and Guejito Fires



Witch and Guejito Fire Origins, Weather Stations and *The Trails* community

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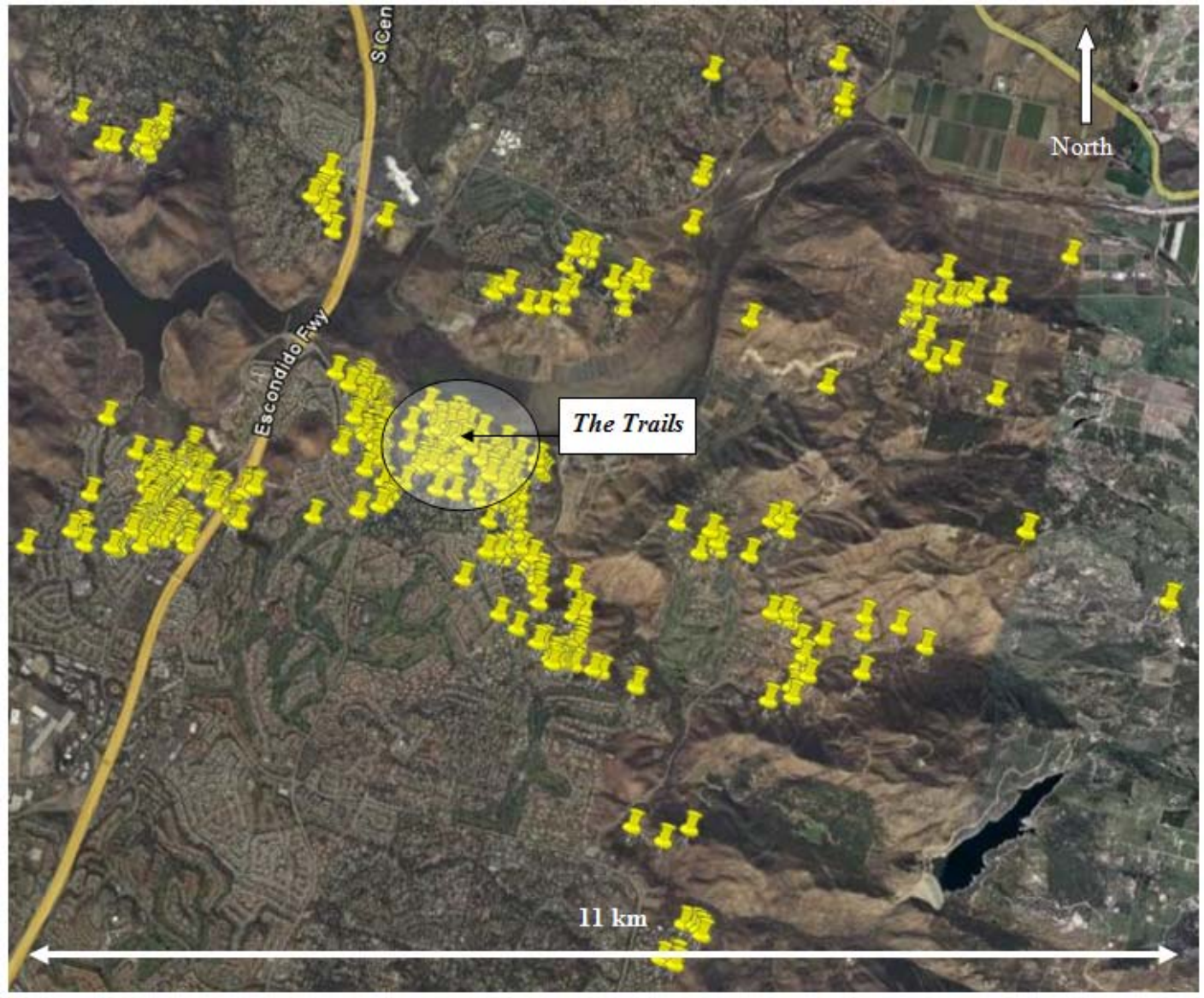
Destroyed Structures in the vicinity of Rancho Bernardo



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The Trails

- Identify structure ignitions and fire/ember exposure
- Develop timeline
- Identify suppression actions
- Firewise analysis
- Modeling
- Post fire incident data collection methodology

- 274 residences
- 245 within fire line
- 74 residences completely destroyed
- 16 partly damaged

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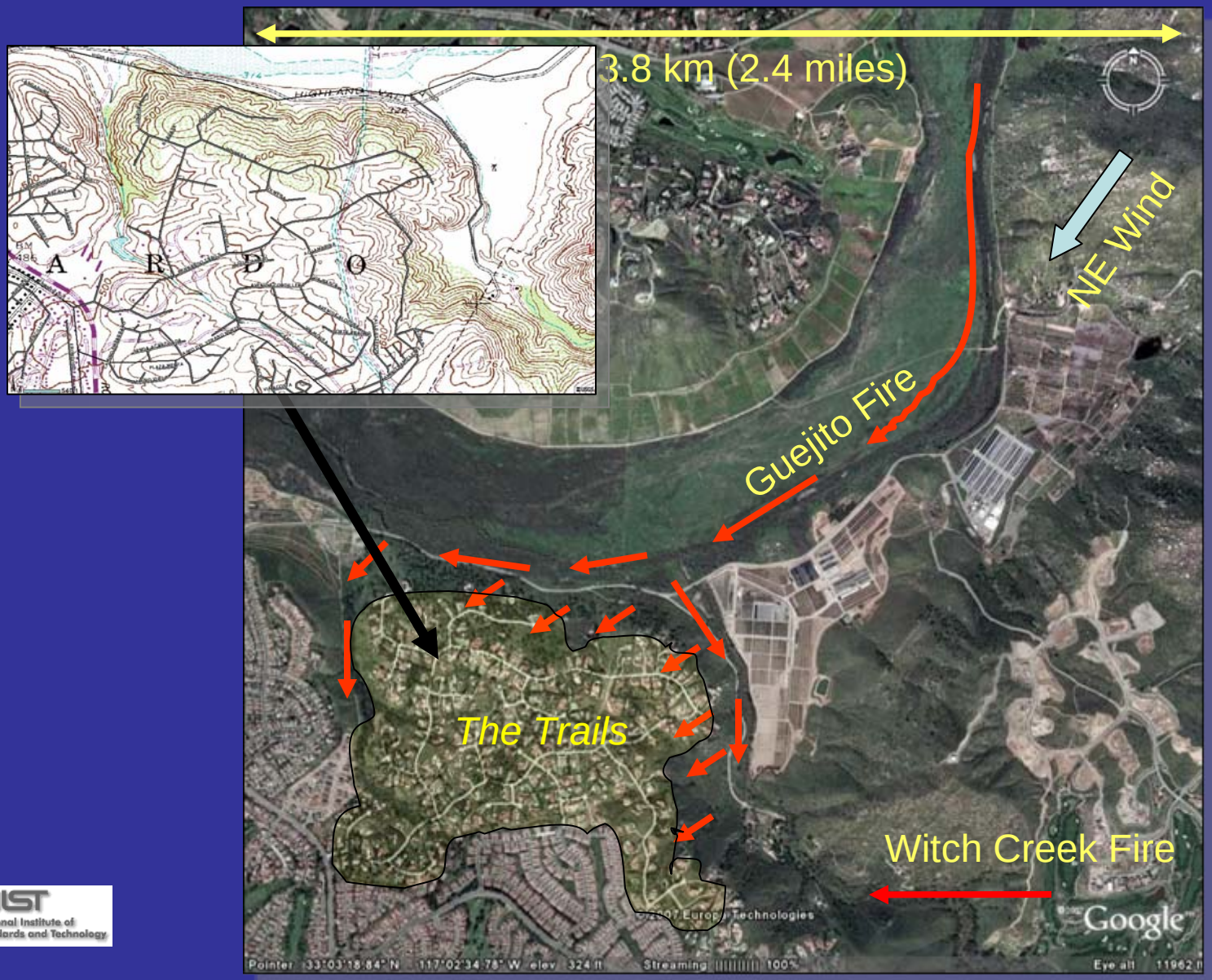
Fire Approach to The Trails



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The Trails Community, Destroyed Homes (in Yellow) and Fire Perimeter after the Guejito and Witch Fires

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Hardware and Software used

- Checklists
- Google Earth maps
- Pictometry
- CALFIRE Incident Maps
- Cameras
- GPS
- Geo-referencing software for pictures
- LIDAR

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Methodology and Timeline

1. Documented destroyed homes, damage to wildland and residential vegetation and fire behavior

2. Documented timeline reconstruction and defensive actions with first responders and homeowner association

3. Documented undamaged homes

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1. Destroyed Homes and Fire Behavior

- **When:**
  - Immediately after fire and for the next two months
- **How:**
  - Up to five teams with 2 persons each
- **Data Collected:**
  - Fire jumps across roads
  - Fire spread (needle freeze, golf balls, spotting)
  - Damage to wildland and residential vegetation
  - Particulars of destroyed homes

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2. Timeline Reconstruction and Defensive Actions

- **When:**
  - From two to six months after the fire
- **How:**

  Technical discussions with first responders (CALFIRE, SD FD and SD PD) and homeowner association
- **Data Collected:**
  - Defensive actions
  - Fire Behavior
  - Times when homes were burning

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3. Documented Undamaged Homes

- **When:**
  - Six months after the fire
- **How:**
  - Up to five teams with 2 persons each
  - Firewise-type methodology
- **Data Collected:**
  - Geo-referenced pictures
  - Database of Firewise-type attributes for entire community

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What did we accomplish?

- Fire Behavior report – in review to be issued in May, 2009
- Firewise-type assessment of community – report in progress
- Methodology for future development – under construction

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Methodology Lessons Learned

- **Having reliable Pre-fire information is critical**
- **A community with a strong HOA is highly desirable**
- **The residential vegetation and structure particulars change after a fire**
- **Data must be collected shortly after the fire:**
  - Damage to vegetation (residential and wildland)
  - Fire Behavior
  - Destroyed and damaged homes
  - Defensive actions
  - Undamaged homes
- **The low-tech checklist approach worked, however data processing becomes very expensive**

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Data Collection

Collect timeline information:

- **Fire behavior**
- **Structure burning**
- **Defensive actions:**
  - Size of response team
  - When actions were taken
  - Which homes were defended

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Data Collection Approach

- Track down strike team
- Technical meetings with strike team members at their stations (in order to minimize impact to operations)
- Cross reference timelines for Quality Control
- Focused event time window of interest (first twelve hours after the fire hit the community)

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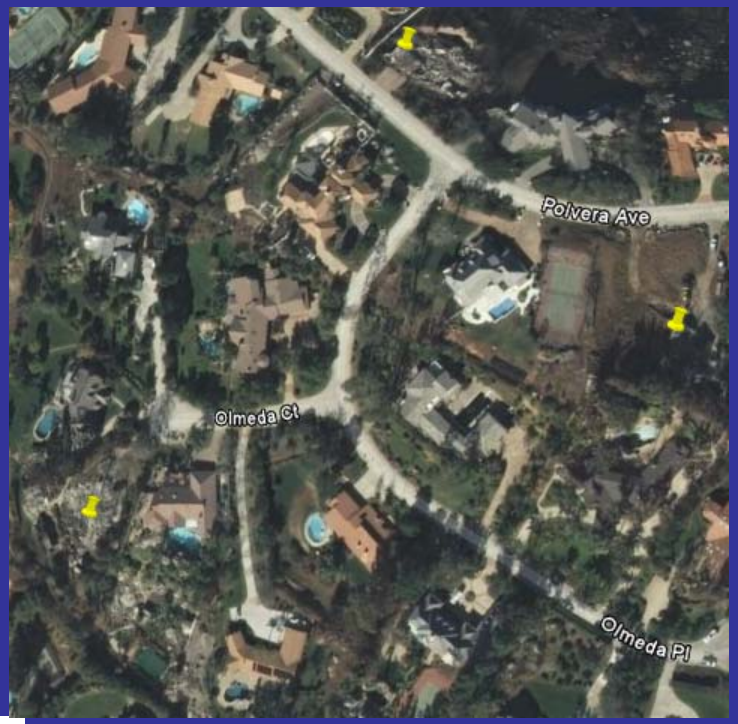
Tools Used

- Pictures of destroyed homes (over 4,000)
- Google Earth™ and Live Maps™ for aerials (free)
- GIS printed maps of community
- Transcripts of radio log



Google Earth updated with post fire data

maps.live.com

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What worked?

- Briefing the teams on the overall effort

- Having extensive library of pictures
- Knowing the community (i.e. having collected the data and spent significant time on the ground)

- Going to the Fire Stations
- Meeting with FD personnel on site

- Using the radio log and other time stamped data to refine timeline information

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What did not work?

- Waiting too long (4 - 6 months)
- Looking at Damaged Homes
- Using the FD and Police Vehicle Tracking Systems

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What did we learn?

- **Timeline of event:**
  - When the homes begun burning with respect to the arrival of the wildland fire front
  - How many homes burned as a function of time

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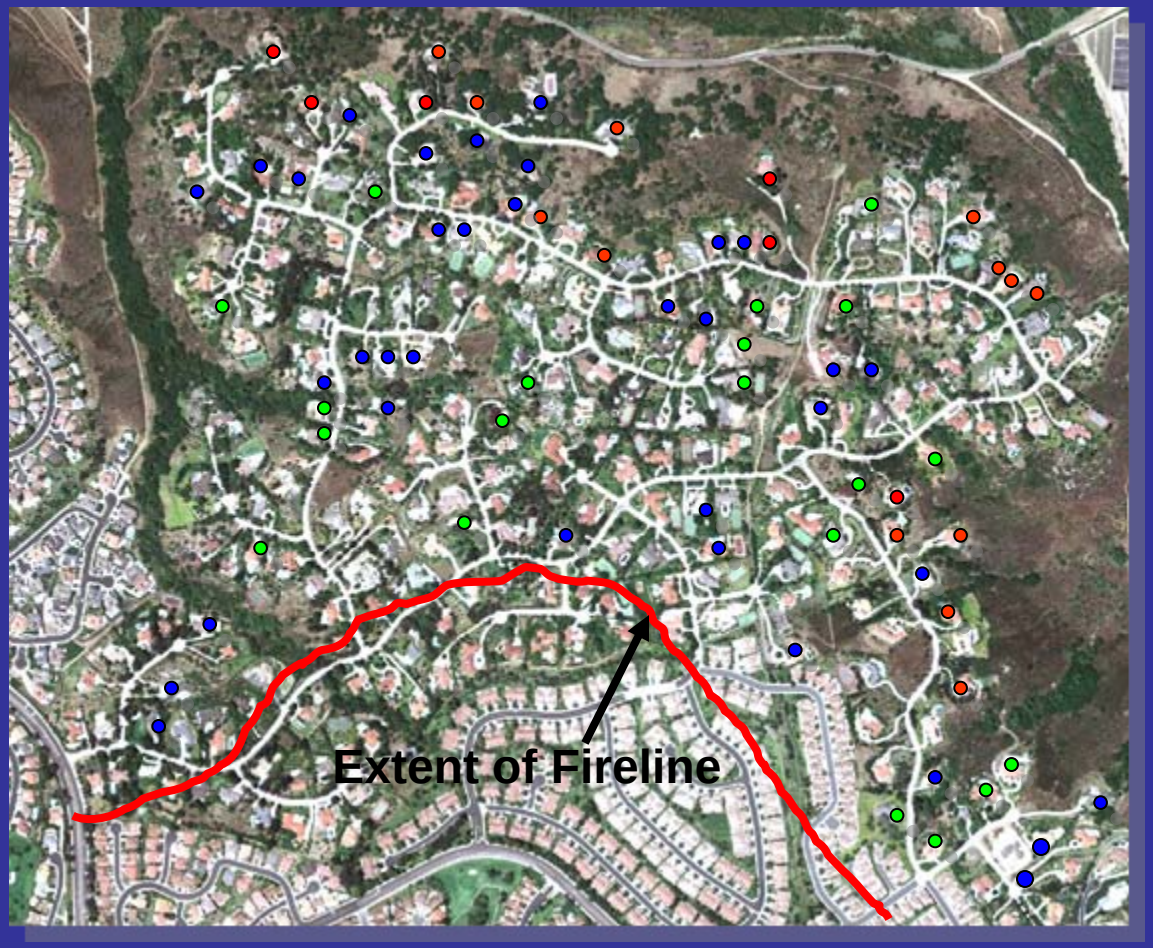
Structure Ignition Data



Surface fire within community from spotting

● Uninterrupted fire spread through vegetation (19/74)	○ Fire spotting over residential vegetation (35/74)	● Embers* (20/74)

* Embers could have ignited all structures

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Ignition Categories

Ignition Category A - Uninterrupted fire spread through vegetation (19/74)	Ignition Category B - Fire spotting over residential vegetation (35/74)	Ignition Category C - Embers* (20/74)	Total
Perimeter: 19/19	Perimeter: 11/35	Perimeter: 8/20	Perimeter: 38
Interior: -	Interior: 24/35	Interior:12/20	Interior: 36

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Time Distribution of Potential Structure Ignition Categories A, B, and C

Time window	2:30-3:30	3:30-4:30	4:30-5:30	5:30-6:30	6:30-10:30	10:30-12:30	12:30-3:15	Partial or Unknown time data	Total
A	1	7	1	2	1	0	0	7	19
B	2	12	3	2	2	1	0	13	35
C	0	4	3	2	2	0	1	8	20
Total	3	23	7	6	5	1	1	38	
Cumula-tive Total	3	26	33	39	44	45	46	74	74

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Structural Loses
Interior and Perimeter

- Definition: Interior and Perimeter

- Fire and Ember Exposure is critical to understanding fire behavior

- Perimeter destroyed /Perimeter total (P/P_T): 39/88 (0.4)

- Interior destroyed/Interior total (I/I_T): 35/158 (0.2)

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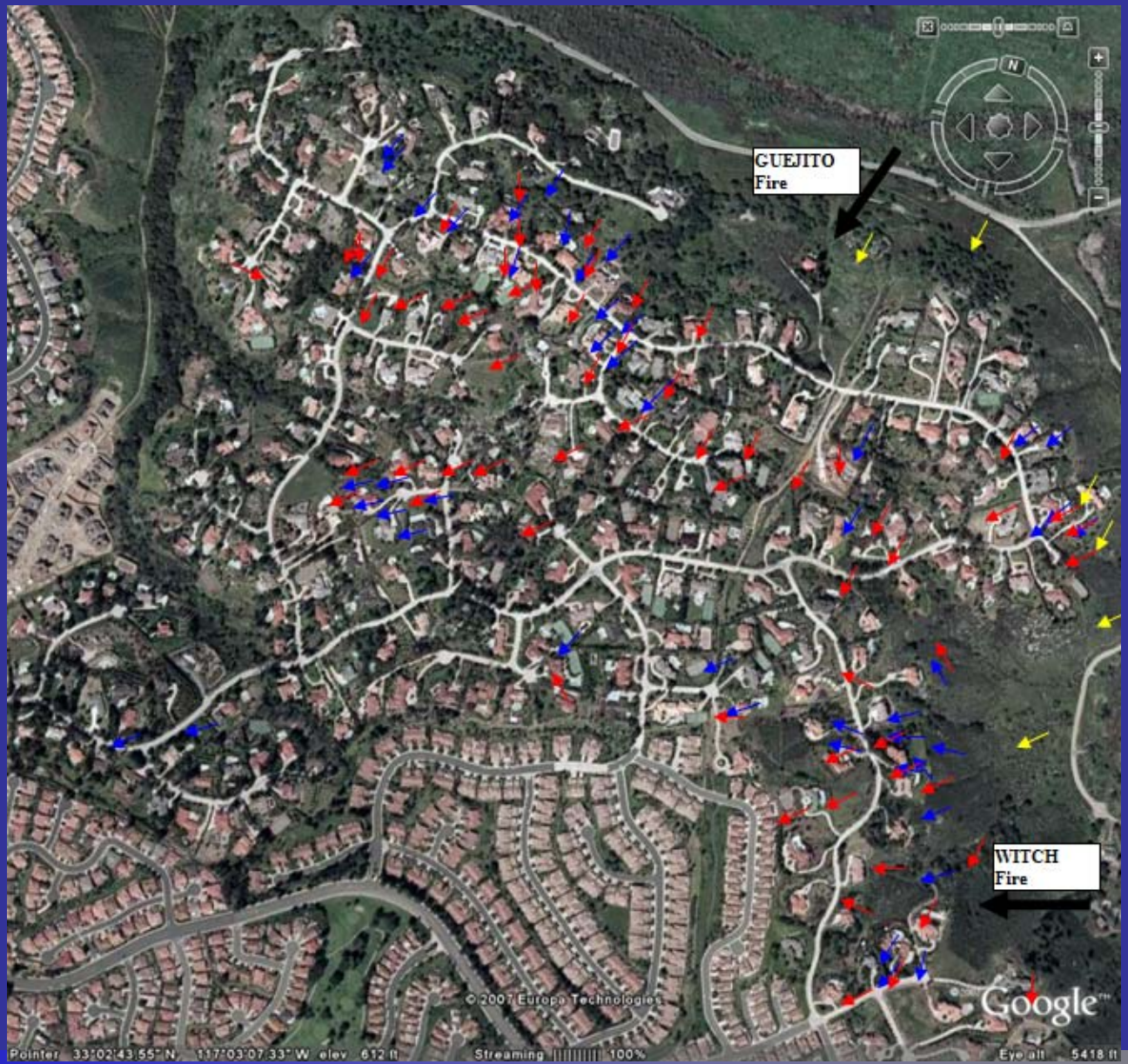
Flame Spread Indicators

Needle Freeze

Flame Spread

Flame Spread from Golf Balls



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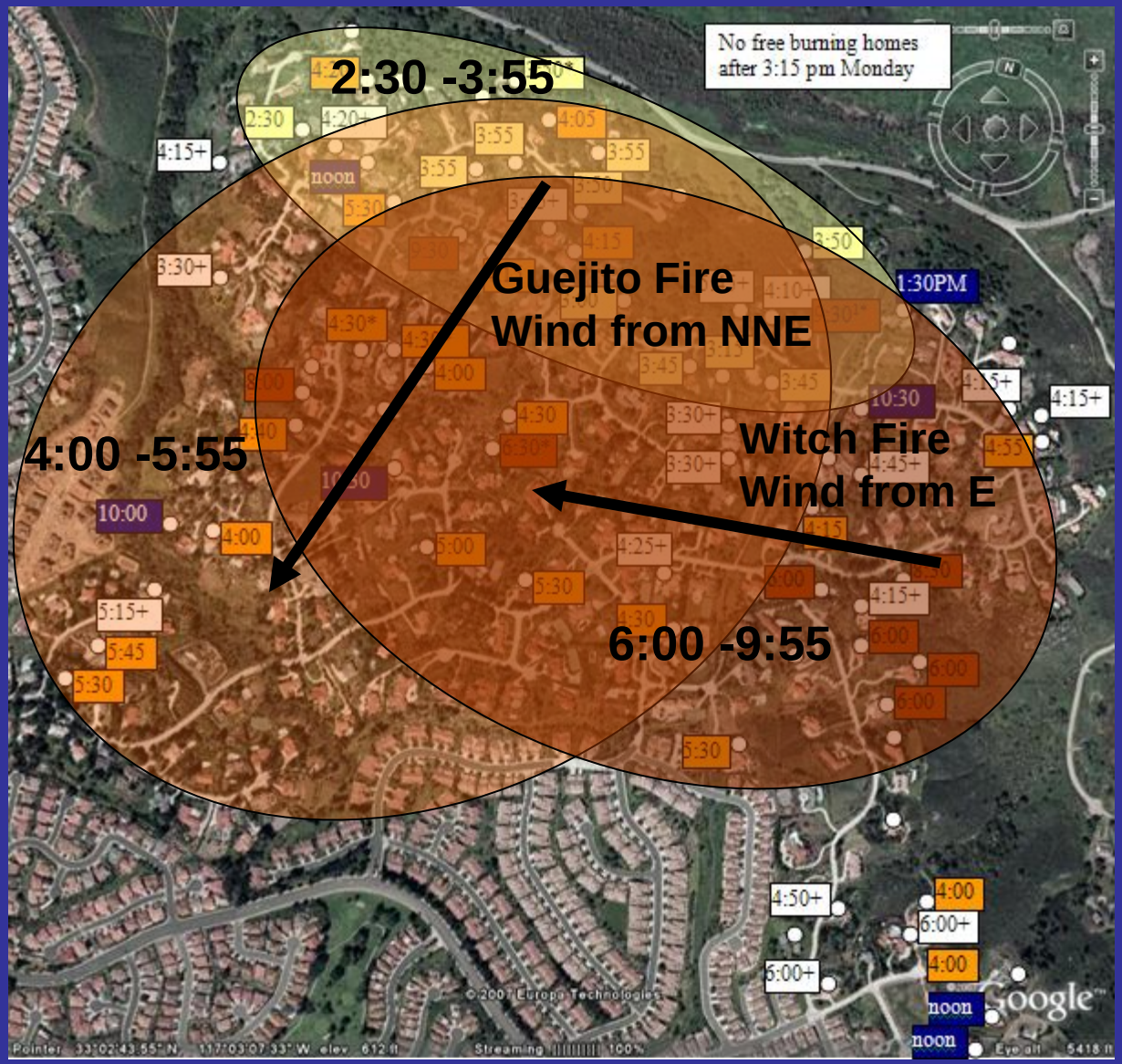
Timeline within The Trails

(issue date: 10/27/08)

Notes:
All times *AM* unless otherwise noted



2:30 – 3:55

4:00 – 5:55

6:00 – 9:55

10:00 - end

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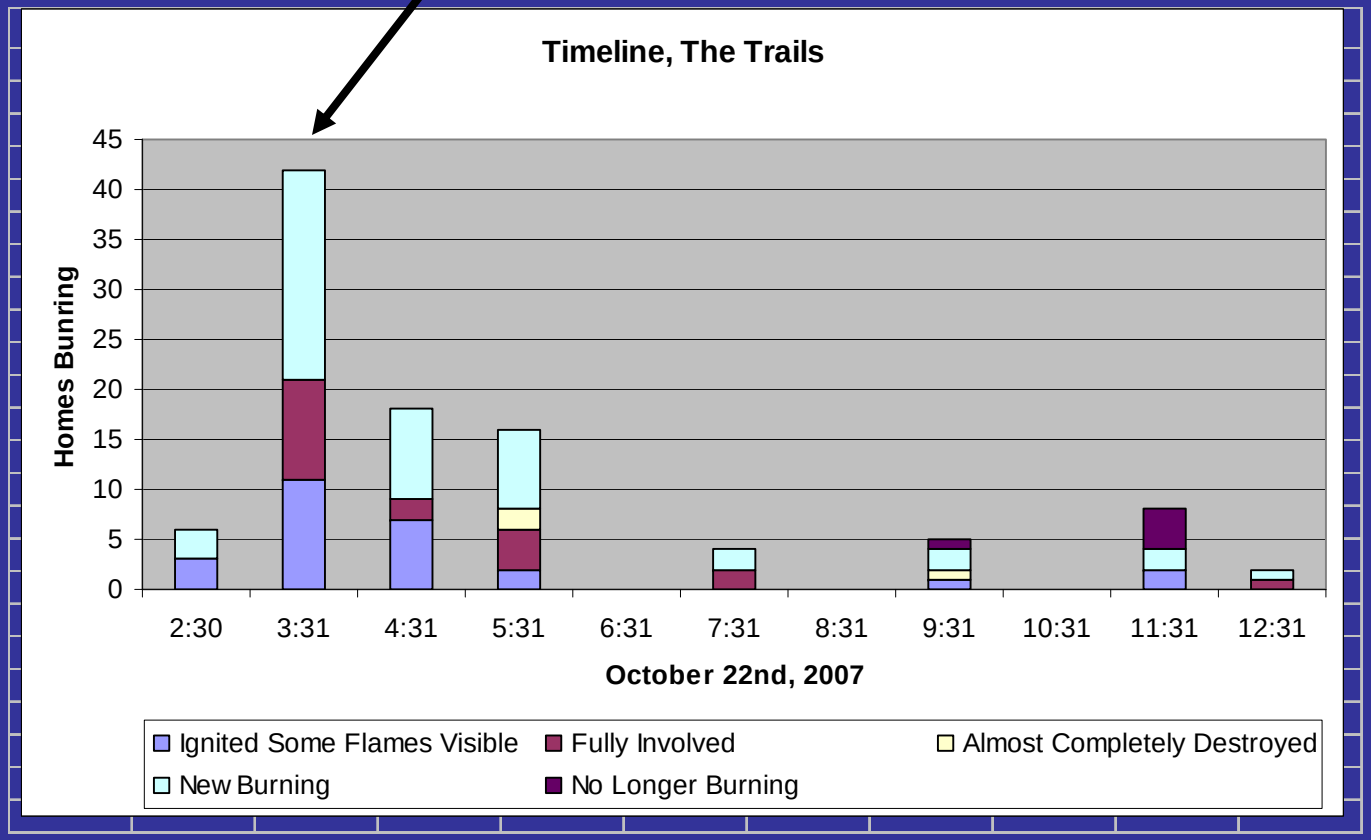
Timeline
Homes Burning at The Trails

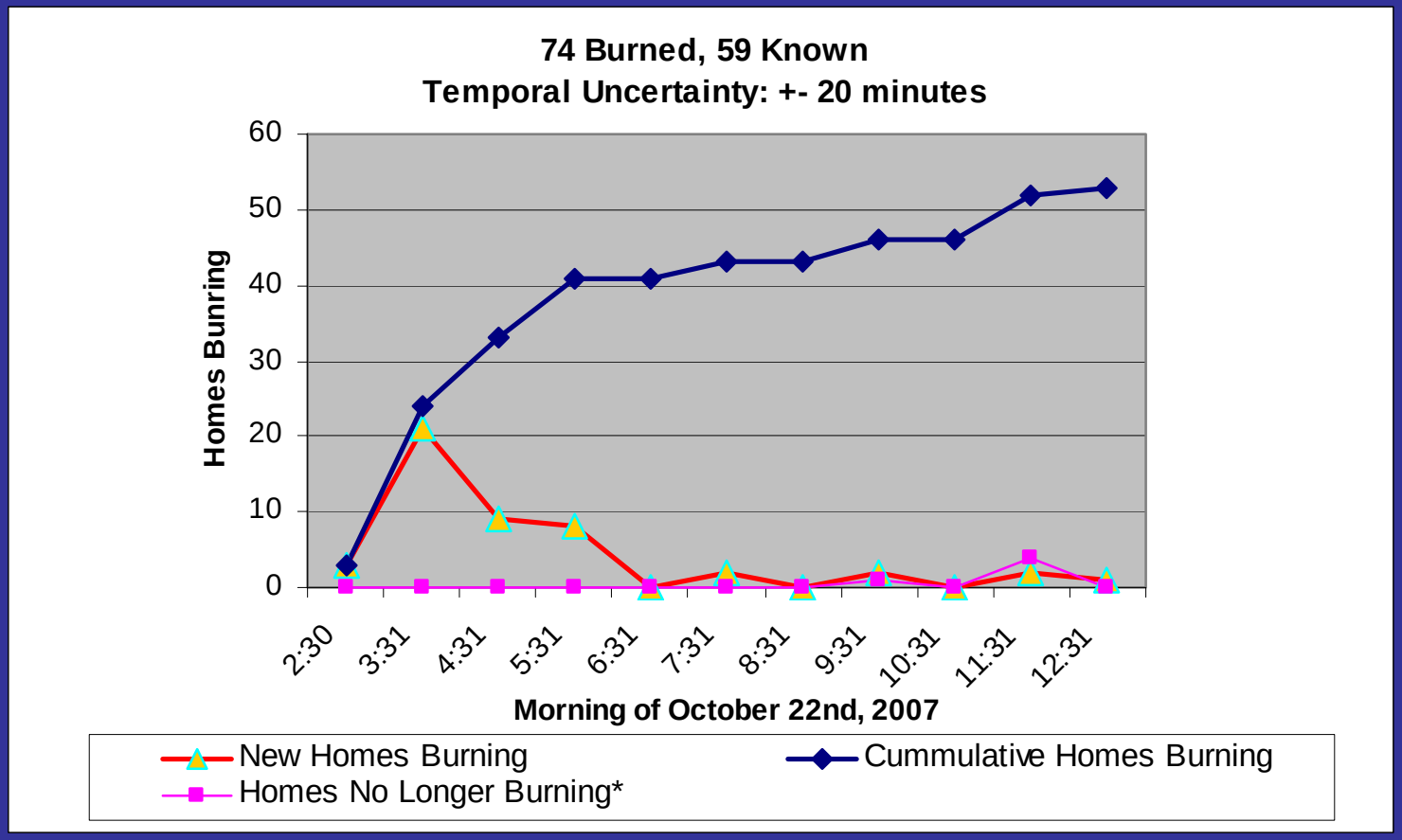
Guejito Fire Front Reaches The Trails



*

* Indicates first observation of destroyed homes not previously identified as burning

Cumulative Homes Burning at The Trails



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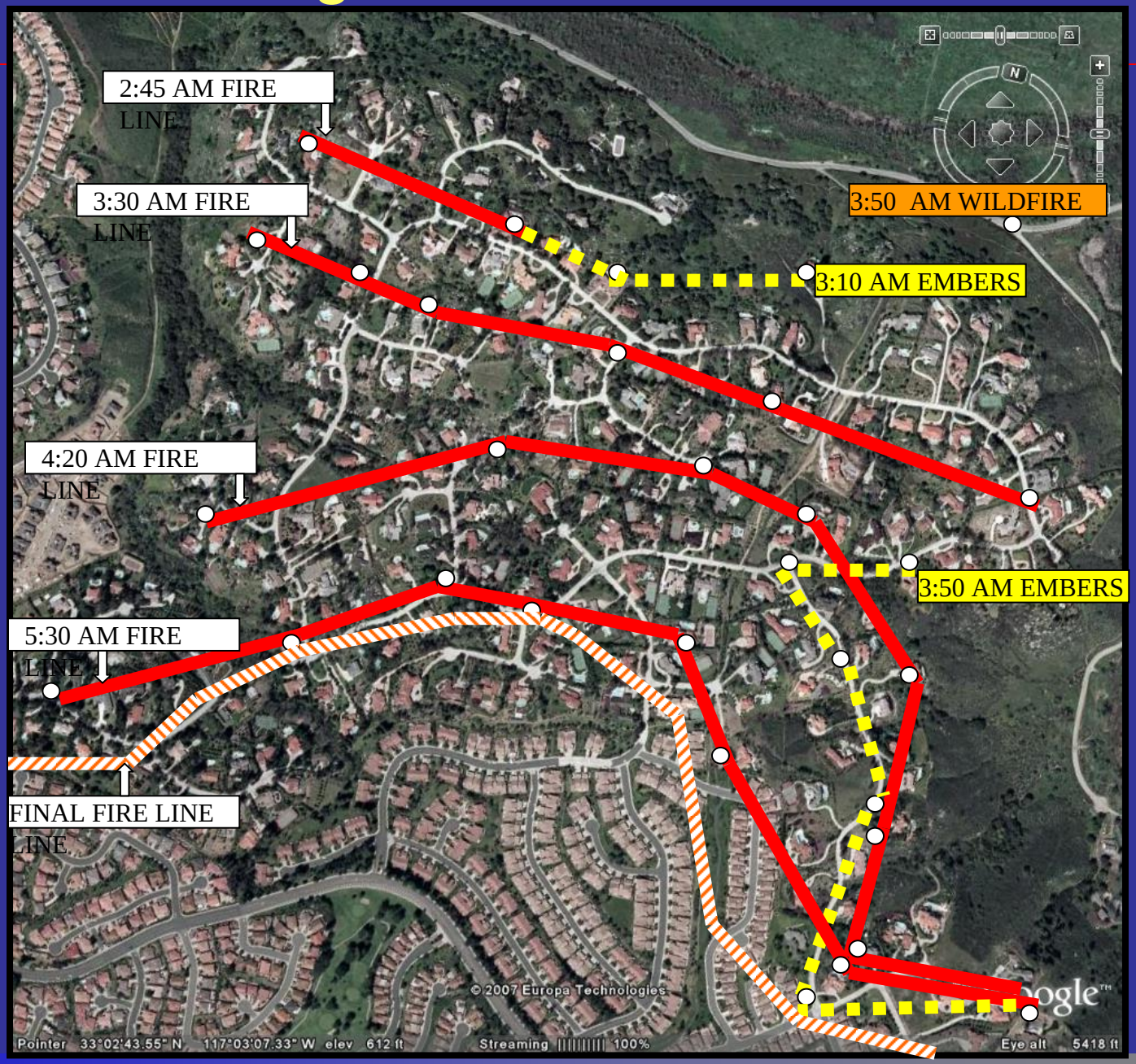
* Homes not previously reported

Fire Line Progression within The Trails



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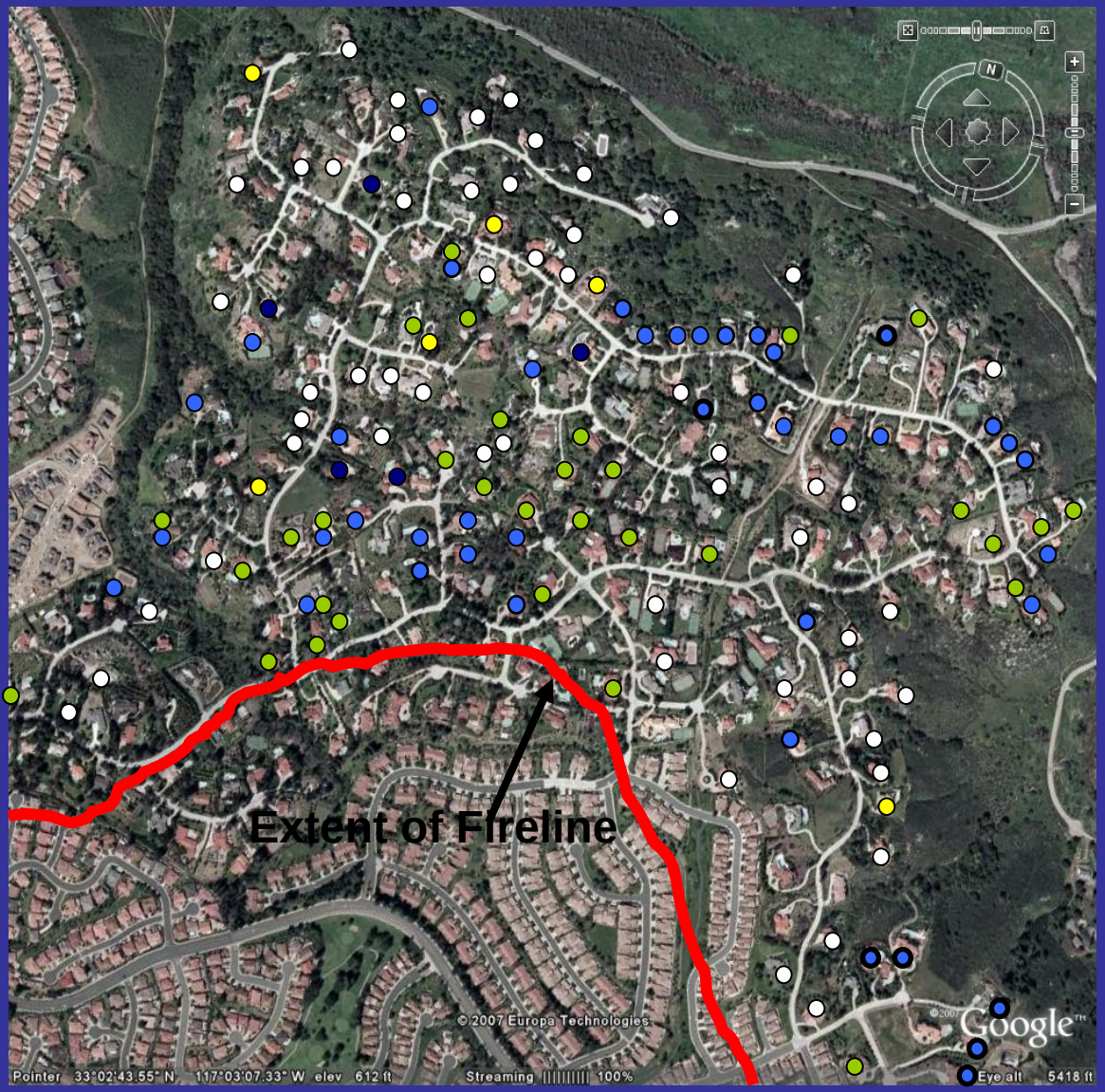
The Trails - Defended Structures (issue date: 10/28/08)

- Actions taken from 2 am until 3 pm October 22nd

- Spotting/ smoldering fires and reignitions continued after 3 pm



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Damaged Structures

House	Damaged area/ ignition location	Defensive Action (party responsible)	Time Action was Taken
1	decking and railroad ties	Garden hose used to extinguish fires (resident or SDPD)	before 6:00 am
2	detached garage and corner of main house/ unknown	Fire contained in garage (SDFD)	10:00 am to noon
3	detached garage/ unknown	Fire contained in garage (SDFD)	10:00 am to noon
4	Structure addition under construction	Water from suppression evident (SDFD)	unknown
5	main structure/ outside column (stucco over wood)	Fire contained to outside column (SDFD)	after 3:00 pm
6	detached garage/ unknown	Fire contained in garage (SDFD)	10:00 am to noon
7	detached structure/ unknown	Fire contained in detached structure (resident or SDPD)	7:00 am
8	main structure/ exposed wood beam	Garden hose used to extinguish fires (resident)	8:00 am
9	decking	Garden hose and bucket (resident)	9:00 am
10	main structure/ gutter	Garden hose used to extinguish fires (resident)	3:00 am to 5:00 am
11	decking	Garden hoses used (unknown)	3:00 am to 6:00 am
12	detached wood shed, wood fencing	Fire contained (SDFD)	3:00 am to 6:00 am
13	decking	Fire contained to location of origin (SDFD)	3:00 am to 6:00 am
14	roof top solar panels	Spot fires extinguished (SDFD)	after 10:00 am
15	deck and main structure	Fire contained to location of origin (unknown)	unknown
16	main structure/ wood crate	None known	-

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Presentation Outline

1. **The WUI Fire Problem**
2. **The NIST WUI Program**
   a. Old Risk Assessment and Mitigation (RAM) Tools
   b. The New RAM Tools
   c. Structure Ignition Research
3. **The NIST Case Study**
   a. Selecting the Community
   b. Data Collection
   c. Data Analysis
   d. **Findings**
4. **Building Codes and Standards**
   a. Wildland versus WUI
   b. New versus Existing Construction
   c. WUI Housing Density
5. **Future Research and WUI Fire Problem Solutions**

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The NIST Case Study

Findings

The NIST Case Study was limited to only 5% of the loses from the Witch and Guejito Fires

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Findings
General Fire Behavior

- The Guejito fire approached The Trails at a fire spread rate of 9 km/h.
- Fire spread rate within the community dropped to 0.35 km/h.
- Embers from the approaching wildland fire front started arriving at the community an hour before the main fire front, traveling a distance of 9.0 km.
- The ignitions generated by embers prior to the arrival of the main fire front were limited to three homes and several patches of ornamental vegetation. These ignitions occurred 9.0 km ahead of the main front.
- Fire spread up to 500 m (~1/3 mile) into the interior of the community.

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Findings
Structural Loses and Defensive Actions

- The arrival of the wildland fire front, not the preceding embers, caused the majority of the damage and overwhelmed the first responder resources.
- 70 % of the destroyed homes were not defended.
- 60 % of defended structures on fire were saved.
- Over 50 % of the structures were ignited within 3 hours after the main front of the Guejito fire hit the community.
- At its peak; right when the wildland fire front reached the community, structure ignitions reached 21 per hour.
- It is estimated that 29 of the destroyed structures (40 %) were burning at the same time.
- Two out of every three destroyed homes were ignited directly or indirectly by embers.

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Structural Loses and Defensive Actions (continued)

- Direct embers ignitions occurred from the arrival of the wildland fire front and for the next 9 hours.
- Direct ember ignitions accounted for 1 out of every 3 destroyed homes.
- Embers were responsible for the ignitions of structures on the perimeter and in the interior of the community.
- 40% of structures on the perimeter were destroyed compared to 20 % in the interior of the community.

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Structural Loses and Defensive Actions (continued)

- Defensive actions were taken on one out of every three homes in The Trails.
- 15 out the 16 damaged homes were successfully defended. No defensive actions have been identified on the sixteenth damage home.
- Impact of defensive actions was significant, and probably reduced losses from over 37% down to 30 %.

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WUI Fire Behavior
Post Fire Analysis Summary

- **EXPOSURE, EXPOSURE, EXPOSURE: Need to characterize fire/ember exposure from wildland fire and burning structures**

- **Risk Reduction Guidance Performance Assessment: Fire suppression actions need to be factored in an analysis of structure survival**

Guidance for existing communities should be implementable

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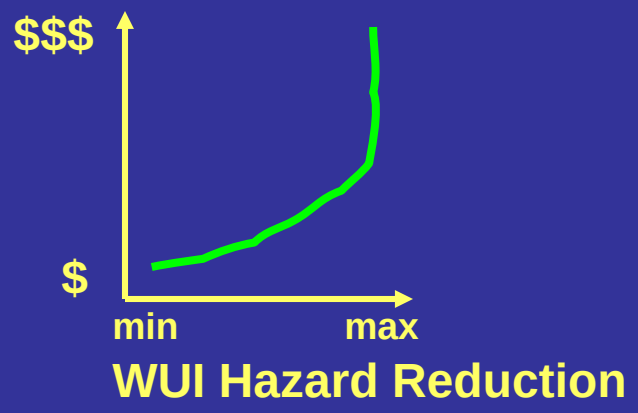
Wildland *AND* Community Hazard Reduction

Wildlands Fuel Treatment



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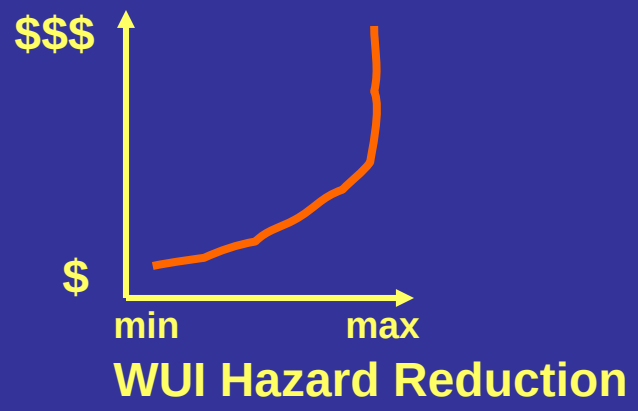
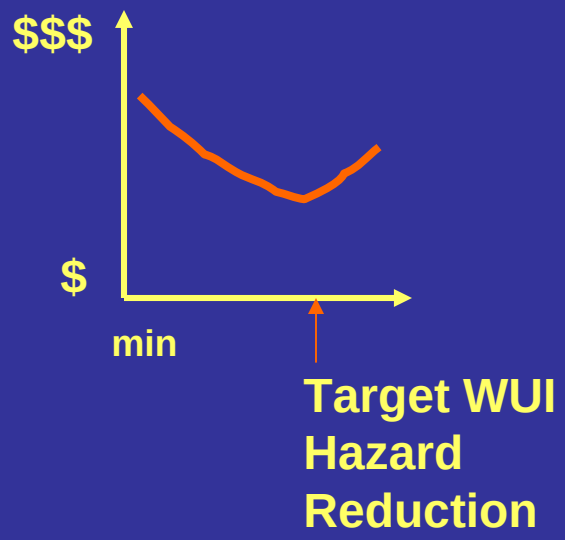


Community Fuel Treatment

Case Specific Cost Effective WUI Hazard Reduction (Wildlands + Community)



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New Versus Existing Construction

- **New Construction**
  - ***DRAFT*** two tiered approach:
    - High hazard area (from perimeter to ~¼ mile in ???)
    - Medium hazard area (from ~¼ mile to ~¾ mile in ???)

- **Existing Construction**
  - FIREWISE + guidance:
    - With supporting technical guidance
    - Improved plants selection guidance
    - Prioritized
  - Retrofit solutions (vents, wood treatments, vegetation selection guidance, etc.)
  - Solutions developed together with Building Code Officials and Insurance Industry

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Developing Implementable Solutions

Proven Risk Assessment and Mitigation tools for Homeowners, First responders and Land Use Managers

- **Technical Guidance for Testing Standards**
  - Vent Standard (ongoing ASTM)
  - Roofs, decks external exposure (new subcommittee ASTM)
- **Building Codes**
  - NFPA Forest and Rural Fire Protection & Firewise
  - ICC
- **Timeline Reconstructions for Fire Departments and First Responders**

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WUI and Housing Densities

300 structures/sq mile

80 structures/sq mile

10 structures/sq mile

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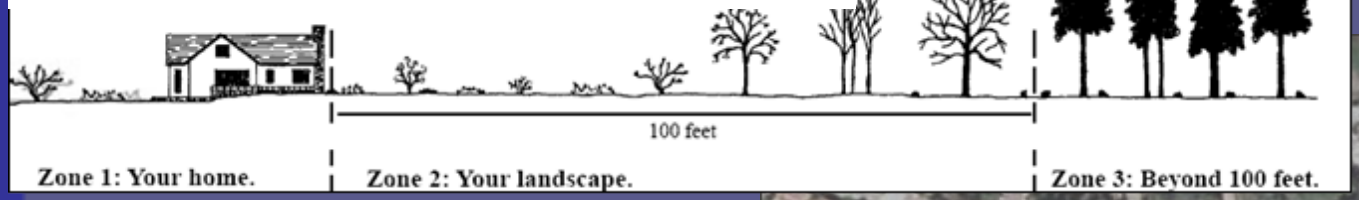
FIREWISE Analysis

Typically Recommended Treatment Zones



Analysis of destroyed and remaining structures made possible by:
- Home Owners Association
- CALFIRE
- San Diego Fire Dept.

Circles illustrate inability of property owners to create 100 ft radius Treatment Zones on their properties

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Conducting More Case Studies

- Partnership between Building Codes Officials, Standards Organizations and Research Community is essential to developing implementable solutions

- More case studies in different environments are needed in order to develop acceptable/ implementable solutions

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Future Work
NIST – CA WUI Data Collection Effort

- Participants include NIST, CALFIRE, Local Jurisdictions
- Development of a GIS based methodology to Standardize WUI data collection
- Framework for a two tiered data collection approach

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Ongoing and Future Work

- Complete the development of post fire incident data collection methodology
- Implement methodology across CA jointly with CALFIRE and City Fire Departments
- Complete 2nd report (Firewise Assessment) of *The Trails*
- Conduct additional tree and mulch experiments (specifically for CA ornamental and native veg.)

- Complete 3rd report (Evaluation of Fire Models for Risk Assessment) of *The Trails*
- Conduct house burning experiments

- Continue model development and verification/validation

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THANK YOU

Alexander Maranghides
Building and Fire Research Laboratory
National Institute of Standards and Technology
(301)975-4886; alexm@nist.gov

fire.nist.gov/wui

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