Overview of NIST Research on Wildland-Urban Interface Fires

June 18, 2014

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Fire Research Division
Engineering Laboratory

NIST WUI Fire Group
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- Nelson Bryner
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- Glenn Forney

Key Collaborators
- Ruddy Mell, USFS
- JFSP
- DHS
- CAL Fire
- TX FS
- Colorado Springs FD
- San Diego FD

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

NIST: Basic Stats and Facts about NIST

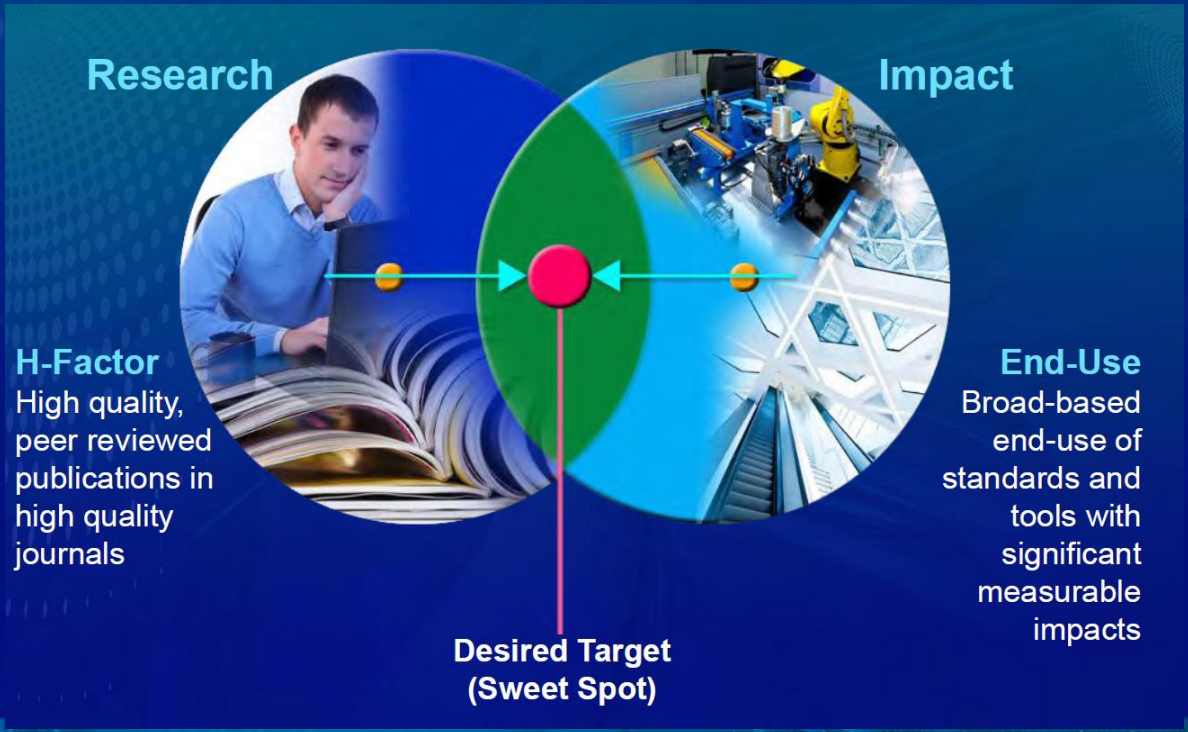
- A non-regulatory agency n the Dept. of Commerce
- 2800 federal employees, 2600 associates
- Composed of 4 labs and 3 centers:
  - Physical Measurement Laboratory
  - Material Measurement Laboratory
  - **Engineering Laboratory**
  - Information Technology Laboratory
  - Center for Nanoscale Science and Technology
  - Center for Neutron Research
  - Center for Advanced Communications
- Fire research authorized by NIST Organic Act (Section 16) to provide scientific/technical knowledge for fire prevention & control
- Fire research focus on resilience of buildings and communities


Gaithersburg, MD


Boulder, CO

NIST's Engineering Laboratory (EL)

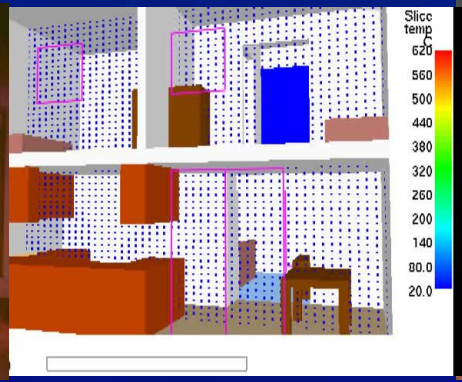
Mission: To promote U.S. innovation and industrial competitiveness in areas of critical national priority by anticipating and meeting the measurement science and standards needs for technology-intensive manufacturing, construction, and cyber-physical systems in ways that enhance *economic prosperity* and improve the *quality of life.*

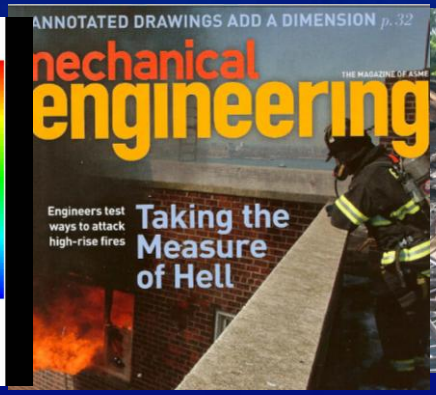


Scope of Measurement Science

Measurement science research and services include:

- development of performance metrics, measurement and testing methods, predictive modeling and simulation tools, knowledge modeling, protocols, technical data, and reference materials and artifacts
- conduct of inter-comparison studies and calibrations
- evaluation of technologies, systems, and practices, including uncertainty analysis
- development of the technical basis for standards, codes, and practices—in many instances via testbeds, consortia, standards and codes development organizations, and/or other partnerships with industry and academia





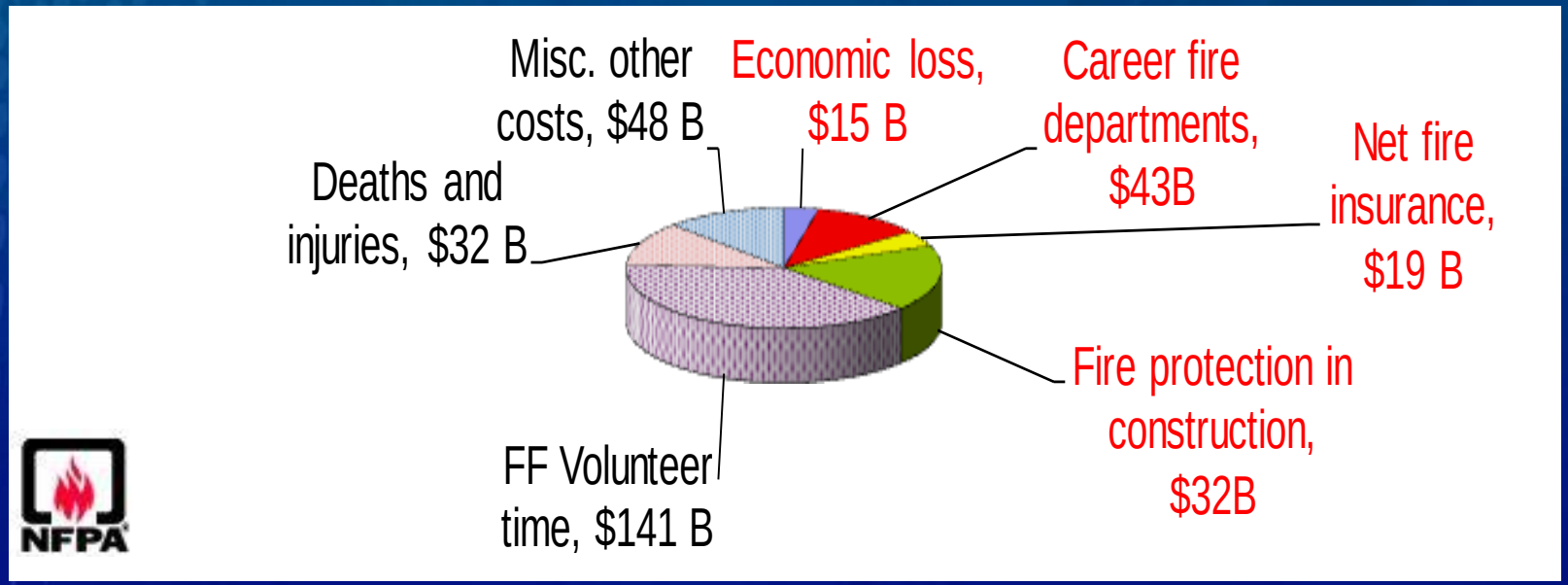
materials **models** **measurements** **investigations** **standards**

The U.S. Fire Problem

3,100 fatalities & 18,000 injuries (2010 Civilian losses)

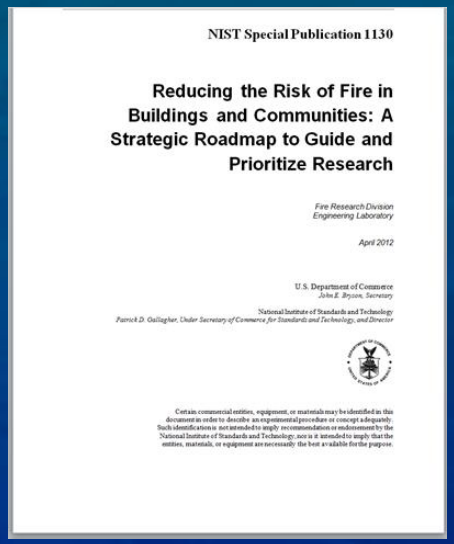
72 fatalities & 72,000 injuries (2010 Firefighter line of duty)

2010 U.S. Total Social Cost of Fire: ~ $330 B ± 100B (~2 % GDP)



Prioritizing Research through Roadmapping

- Technology-focused strategic roadmaps
- Aligned with NIST and EL missions
- Traceable national needs
- Literature review & stakeholder input
- Focused on cost-effective and [illegible] technological solutions
- [illegible]gy
- What ar[illegible]
- What ap[illegible]
- What research barriers


NIST Special Publication 1130

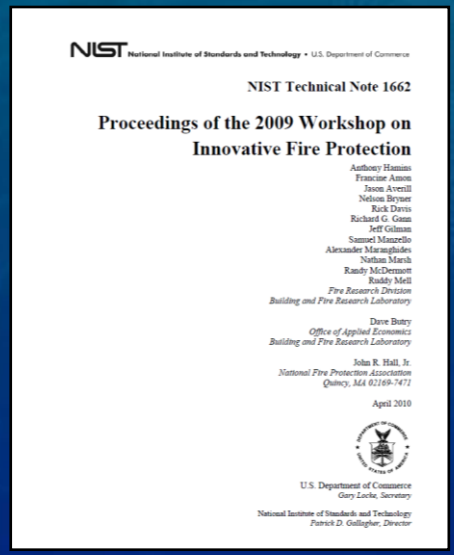
Reducing the Risk of Fire in Buildings and Communities: A Strategic Roadmap to Guide and Prioritize Research

Fire Research Division
Engineering Laboratory

April 2012

U.S. Department of Commerce
John E. Bryson, Secretary

National Institute of Standards and Technology
Patrick D. Gallagher, Under Secretary of Commerce for Standards and Technology, and Director


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

NIST Technical Note 1662

Proceedings of the 2009 Workshop on Innovative Fire Protection

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April 2010

U.S. Department of Commerce
Gary Locke, Secretary

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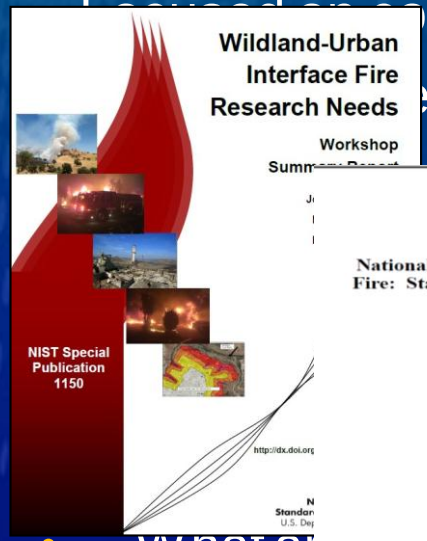
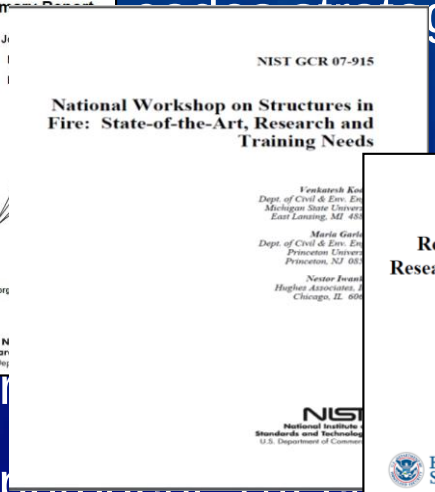



NIST GCR 07-915

National Workshop on Structures in Fire: State-of-the-Art, Research and Training Needs

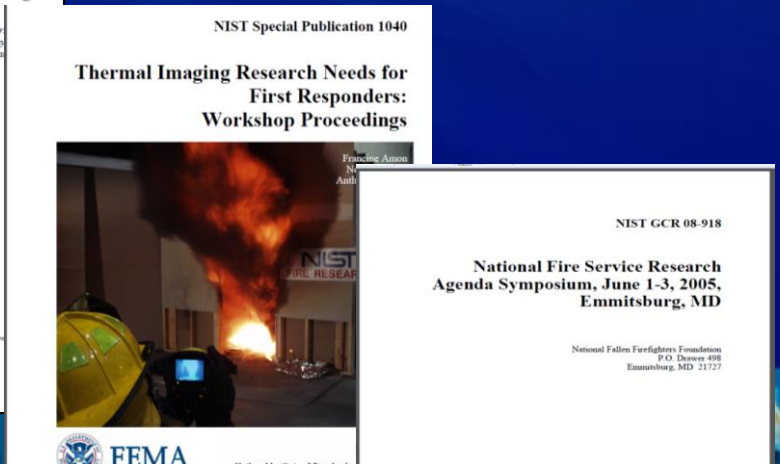

NIST Special Publication 1066

Residential Kitchen Fire Suppression Research Needs: Workshop Proceedings

Homeland Security

Sponsored in part by
Department of Homeland Security

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


NIST Special Publication 1040

Thermal Imaging Research Needs for First Responders: Workshop Proceedings

FEMA

NIST GCR 08-918

National Fire Service Research Agenda Symposium, June 1-3, 2005, Emmitsburg, MD

National Fallen Firefighters Foundation
P.O. Drawer 498
Emmitsburg, MD 21727

What is the new technical idea?

Fire Research Program Objectives

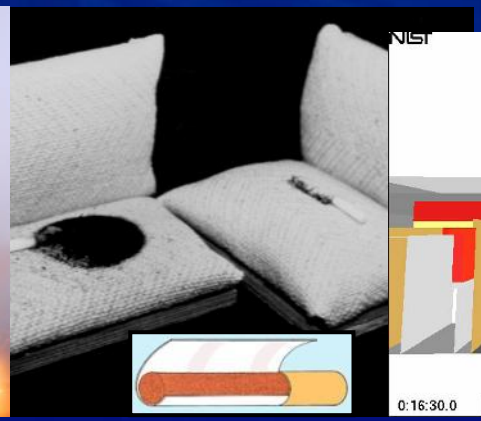
Fire Risk Reduction in Communities: To improve the resilience of communities and structures to unwanted fires through innovative fire protection and response technologies and tactics

Fire Risk Reduction in Buildings: To increase the safety of building occupants and the performance of structures and their contents by enabling innovative, cost-effective fire protection technologies

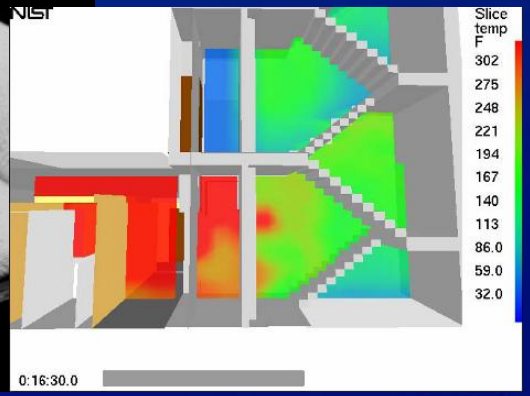
Four Thrust areas:

Fire Service

Wildland-urban interface fires



Residential safety



Performance-based design

Strategic Standards Activities

National Fire Protection Association (19 committees)

NFPA 1981: New thermal exposure test methods for SCBA lenses
NFPA 1971: Durability test standards for fire fighter protective turn-out gear
NFPA 921: Guide for Fire and Explosion Investigations
NFPA 1410: Tactics for non-mechanical ventilation of structures during fires
NFPA 1800: Test methods for high temperature performance of portable radios

ASTM International (2 committees)

ASTM E5.14.03: Ember ignition resistance test method for building elements
ASTM E 2187: Test method measuring ignition strength of cigarettes
ASTM Technical Symposium on Structure ignition in WUI Fires
ASTM E5 Research Executive

American Society of Mechanical Engineers (1 committee)

ASME A17: Safety Code for Elevators and Escalators

International Code Council (2 committees)

ICC Int. Wildland Fire Code: Post-WUI fire data collection methods

International Standards Organization (2 committees)

ISO TC92: Assessment of the toxicity of fire products

Underwriter's Laboratories (2 committees)

UL217: Specifications for nuisance resistant alarms

Investigation and Post-Fire Analysis

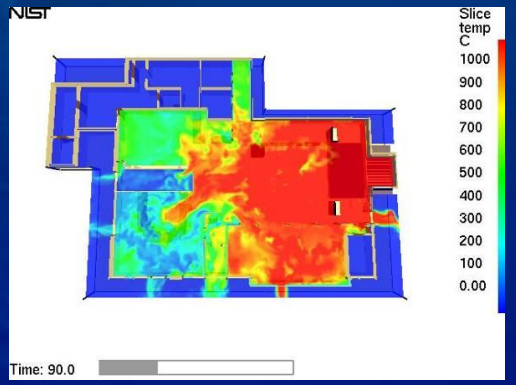
Earthquakes
Hurricanes
Construction/Building
Tornadoes
Fires

DuPont Plaza Hotel, San Juan, PR (1986)
First Interstate Bank, Los Angeles, CA (1988)
Loma Prieta Earthquake, CA (1989)
Hillhaven Nursing Home (1989)
Pulaski Building, Washington, D.C. (1990)
Happyland Social Club, Bronx, NY (1990)
Oakland Hills, CA (1991)
Hokkaido, Japan (1993)
Watts St, New York City (1994)
Northridge Earthquake, CA (1994)
Kobe, Japan (1995)
Vandaila St, New York City (1998)
Cherry Road, Washington, DC (1999)
Keokuk, IA (1999)
Houston, TX (2000)
Phoenix, AZ (2001)
World Trade Center (2001)
Cook County Administration Bldg Fire (2003)
The Station Nightclub, RI (2003)
Charleston, S.C., Warehouse Fire (2007)
Witch Creek Fire, San Diego, CA (2008)
Amarillo, TX (2011)
Waldo Canyon, Colorado Springs, CO (2012)

Purpose:

- Probable technical cause
- Lessons learned
- Improve standards, codes, practices
- Improve forensic methodologies
- Disaster and failure studies repository
- Future research priorities

2001 WTC



2003 RI Station Nightclub

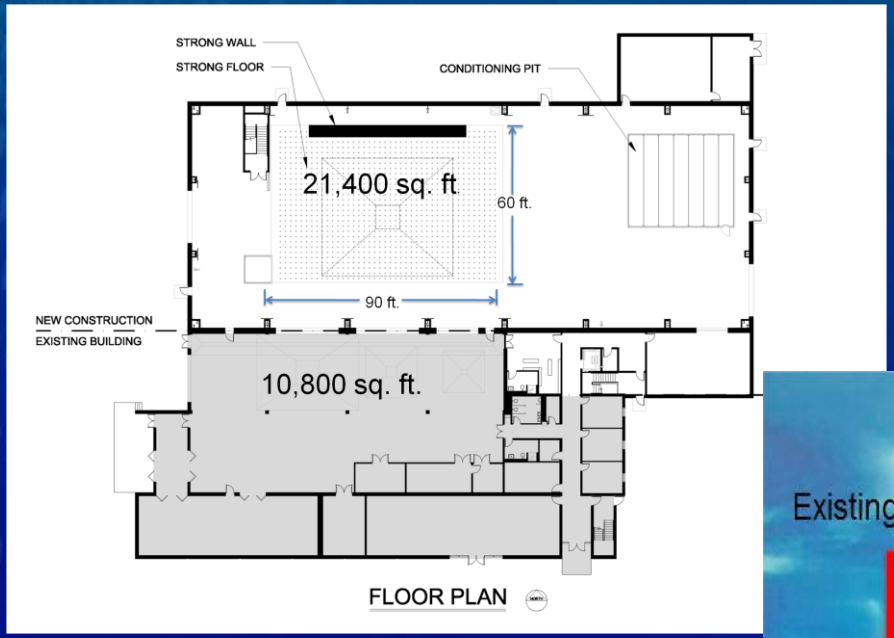
Authorities:

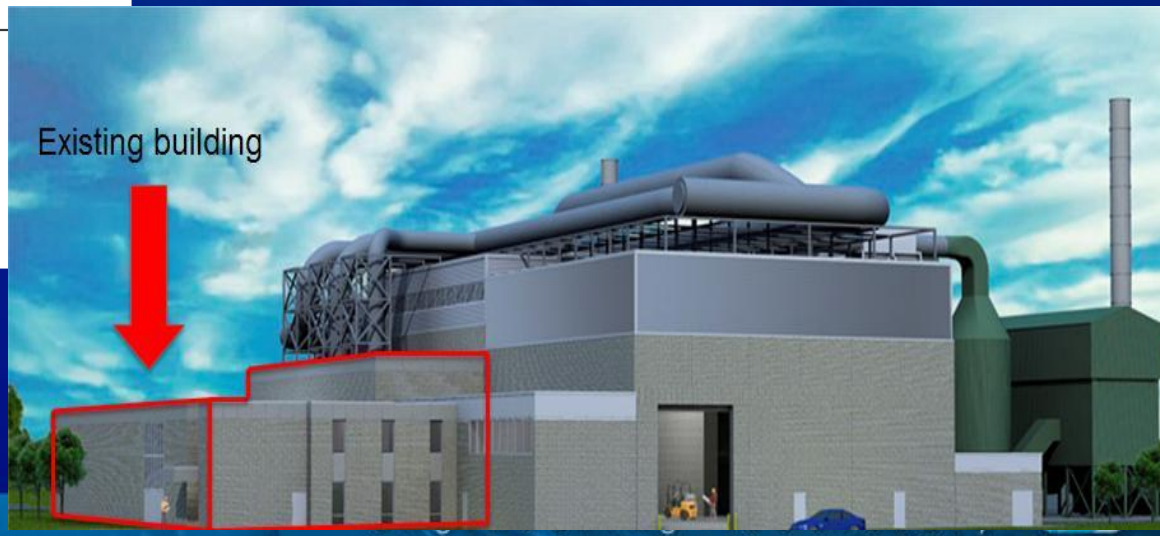
- **Fire Prevention and Control Act (1974)**
- **NCST Act (2002)**
- **NIST Act (1986)**
- **NEHRP Reauthorization Act (1990): National Windstorm Impact Reduction Act (2004)**
- **Federal Response Framework**

2007 Charleston Furniture Store Fire

Expanded NIST National Fire Research Laboratory

- Advance real-scale fire metrology
- Develop metrics for performance-based standards and codes
- Enable model validation
- Support fire investigations





Who Cares? Examples of Research Partnerships

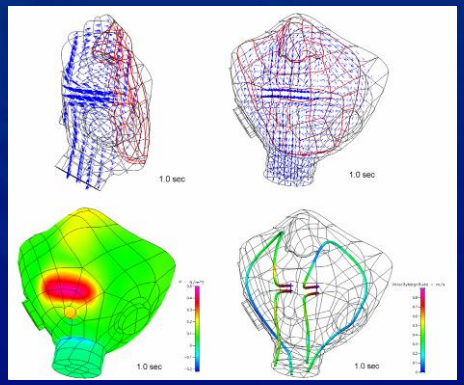
FEMA, IAFC, IAFF, WPI
Firefighter safety/deployment

FEMA, USFA, NFPA
Fire fighting tactics

CALFire, TX FS, DHS
WUI fires

NIOSH
Charleston fire study

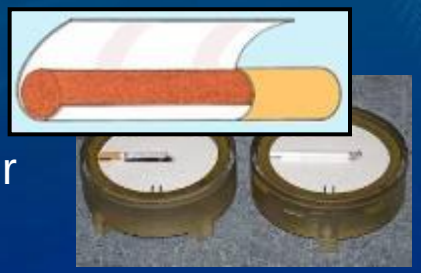
DHS, NFPA
Fire fighter technology

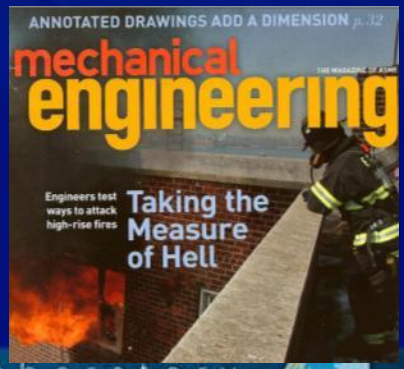


USFA, DHS, NIOSH
Personal protective equip

NIST Fire Research Success Stories

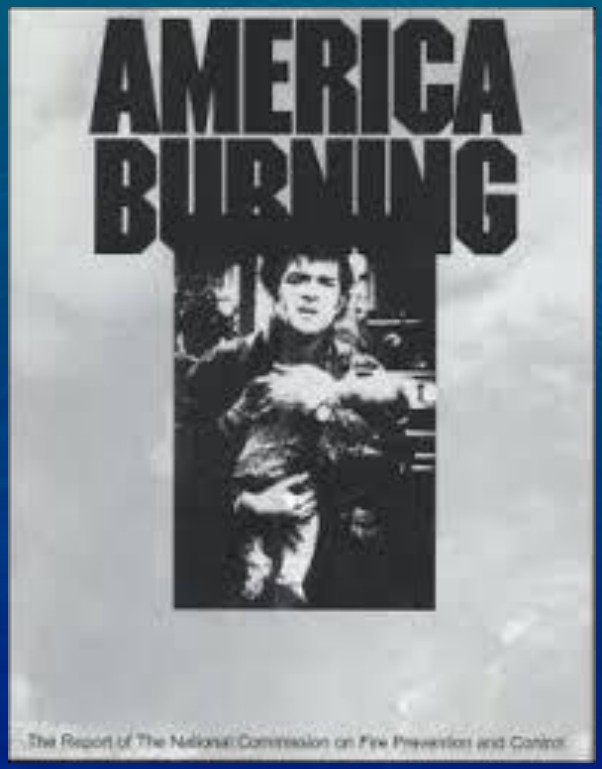
- **Reduced Mattress Flammability and Cigarette Ignition** – standard test methods for reduced-ignition-propensity cigarettes and mattress flammability, reducing smoking related fires and unsafe mattresses.
- **Fire Dynamics Models** – tools to predict the spread of fire, smoke, and toxic products, enabling a transformation from prescriptive to performance standards.
- **Fire Fighter Protective Equip.–** performance metrics and standards for thermal imagers and personal alert safety systems, facilitating safer and more effective fire fighting.
- **Fire Fighting Tactics** – guidelines for wind driven fires and positive pressure ventilation firefighting tactics.
- **Heat Release Measurements** – improved standard test method, enabling fundamental heat release rate measurements worldwide.
- **Automatic Fire Sprinkler Standards** – installation & design standards for residential sprinkler systems, reducing fire losses.
- **Smoke Alarm Standards** – supported development of smoke alarm standards, enabling large reduction in fire deaths from the mid-1970's.
- **Material Flammability** – knowledge on the mechanisms and effectiveness of nanoparticle fire retardants, enabling a new generation of sustainable commercially available materials.





WUI Fires in Historical Context

- In 1970s, the U.S. experienced ~3 M fires and 9,000 fatalities per year
- America Burning Report (1973): led to *Federal Fire Prevention & Control Act, c*reating US Fire Admin and Center for Fire Research (NBS/NIST)
- Last 40 years, focus has been on structural fires (not WUI) and responsive technology:
  - smoke detectors
  - residential sprinklers
  - reduced Ignition propensity cigarettes
  - reduced heat release rate mattress regulation
  - improved fire fighting equipment and tactics



- Standards referenced in building codes:
  - 1,154 inside buildings vs 20 for WUI
  - existing WUI building codes and standards not science-based

Science & engineering are needed for WUI standards and codes

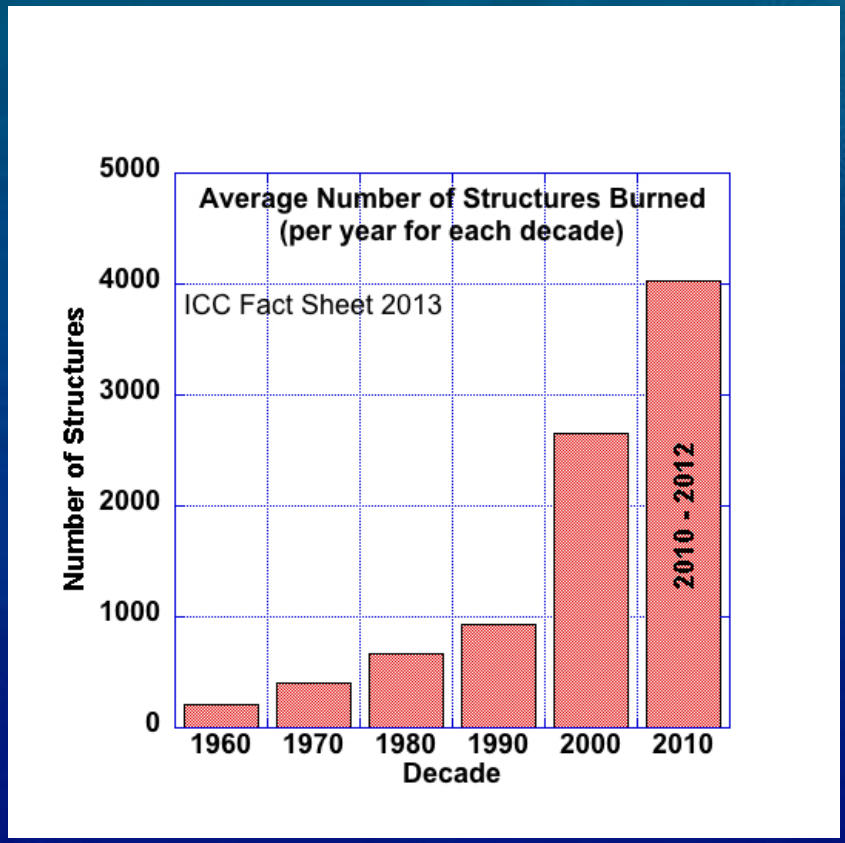
The WUI Fire Problem

WUI communities involve:

- About 40% of all U.S. homes
  At least 46 million structures

- About 10% of USA is WUI
  Over 70,000 communities at risk

NIST perspective: The WUI fire problem is multi-disciplinary and will take expertise in wildland fuels, fire science, and standards and codes to solve



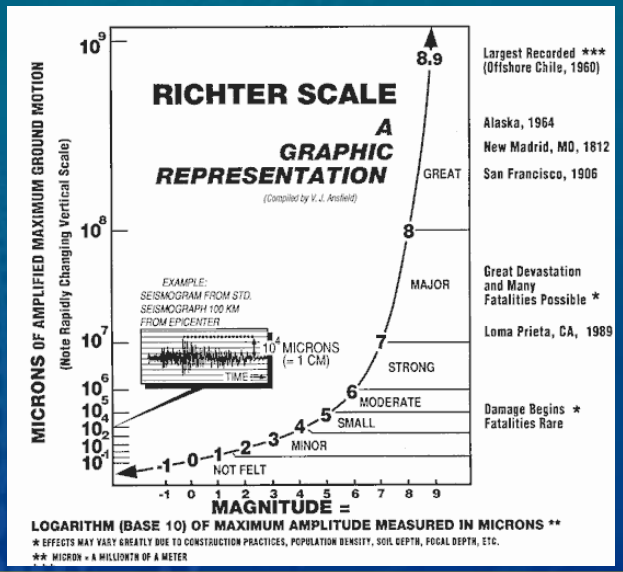
What do we know about WUI fires?

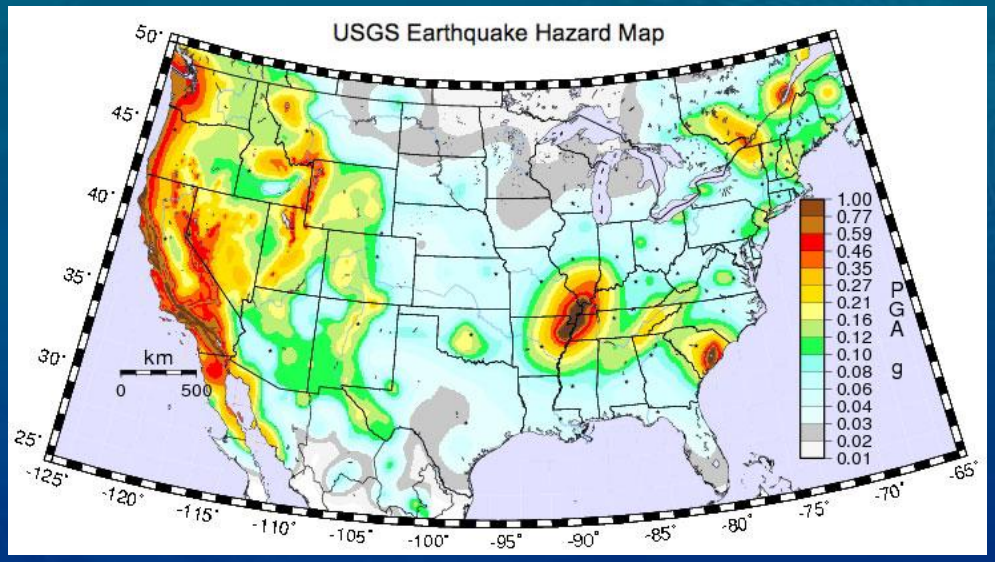
- WUI fires originate in the wildlands (95% of the time)
- Structures ignite due to exposure from fire and embers
- Currently, codes, standards and best practices are not linked to representative fire and ember exposures

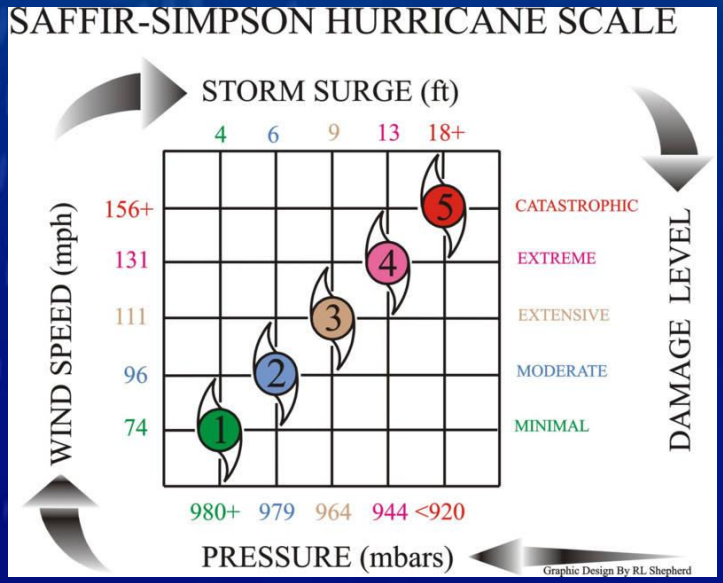
Quantifying Flame and Ember Exposures is Key

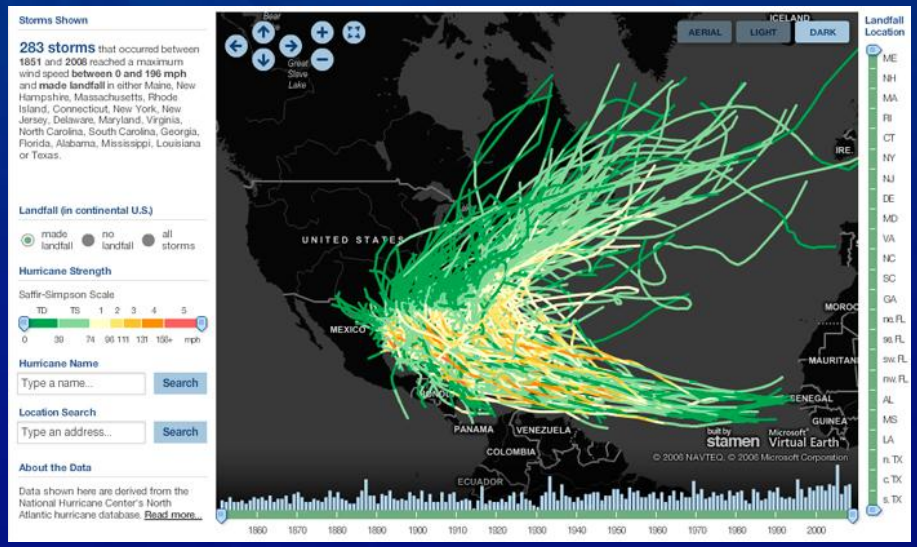
Courtesy US Forest Service

Existing Scales Characterizing Hazards

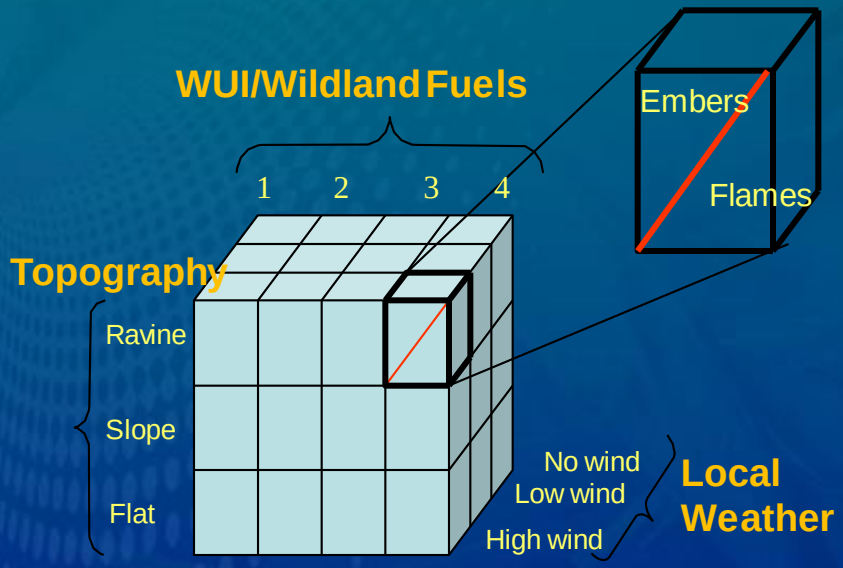




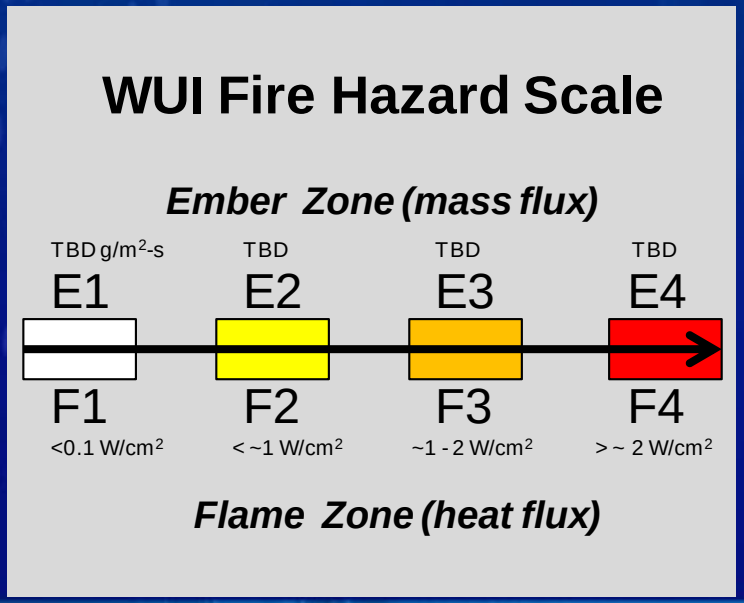


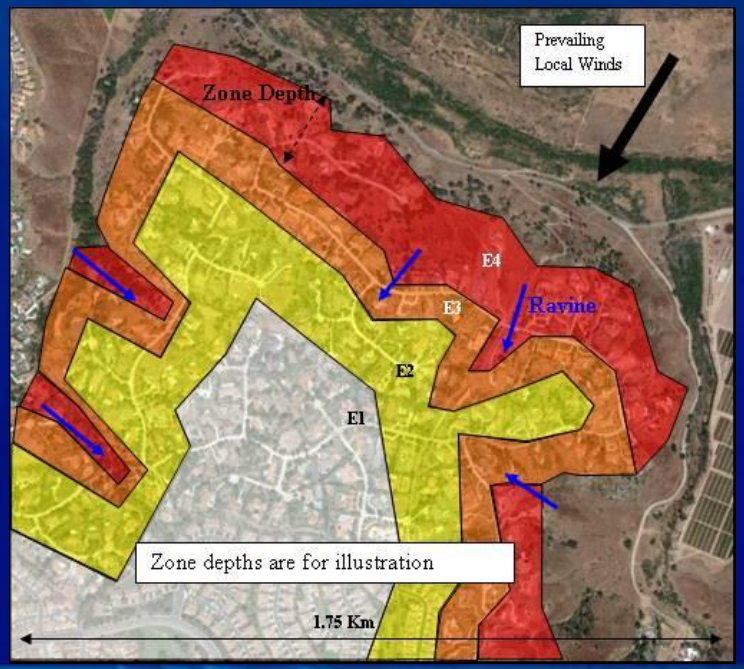


Conceptual Framework: WUI Fire Hazard Scale



- Measure expected risks from flame and ember exposure for locations within a community
- Takes into account fuel type, topography, and local weather
- Data is needed to populate the Hazard "Cube" and quantify WUI fire risks

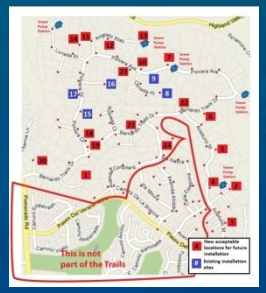




WUI Fire Research at NIST

Pre- and Post-Fire Data Collection & Analysis

Colorado Springs, Texas Forest Service, CAL FIRE, City of San Diego, SDSU, *McNamara Consult., USFS, JFSP*



Full Scale Structure Vulnerabilities

USFS, CALFIRE, ASTM, DHS, BRI

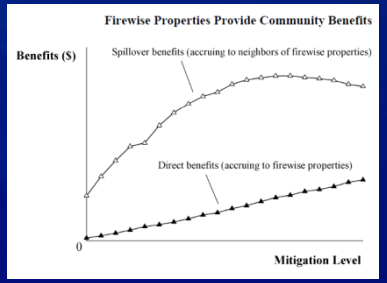
Outdoor Fire Modeling

NOAA, USFS, JFSP, U Utah. Tribe, McNamara

EXPOSURE
HAZARD

Economic Modeling

USFS, DHS



Field Scale Fire Behavior & Wind Measurements

USFS, NOAA, CU, RIT, SDSU

Lab Scale Fire Behavior and Test Method Development

FRI, USFS

Existing Fire Data Collection Systems

National Fire Information Reporting System (NFIRS) managed by USFA

- Largest national database of fire incident information designed for structural fires
- 35 years of data on the nature, frequency, casualties, & causes of structural fire
- Wildland module, but incomplete information on nature and magnitude of WUI fires

National Incident Fire Center (NIFC) Database managed by federal partners

- Focus on wildlands, not structures
- Incomplete information on nature and magnitude of WUI fires

Multiple state and local Data Collection Systems

- Local mandate and focus; non-standardized data formats
- Data content varies by locale
- Count of burned structures only (little detail such as defensive actions, exposure, surviving structures)
- limited sharing of data

WUI fire data does not exist!

Leading Losses from Home Structure Fires

National Fire Incident Reporting System (USFA) data (2003-2006), NFPA

First Item Ignited (2003-06)	Fires	Deaths	Deaths per Fire	Injuries	Property Damage ($ B)
Upholstered furniture	7,400	590	0.08	900	0.4
Mattress/bedding	11,200	380	0.03	1390	0.4
Thermoplastics	29,400	280	0.01	1160	0.7
Structural member, component or insulation	32,500	240	<0.01	620	1.3
Other furniture or utensils	6,000	170	0.03	500	0.2
Confined cooking fire/materials	134,900	130	<0.01	3670	0.3
Interior wall covering	8,200	120	0.01	340	0.3
Subtotal of Above Categories	229,600	1,910	0.0083	8560	3.6
Totals	378,600	2,850	0.0075	13,090	6.1

NFIRS data identifies fire vulnerabilities:

- Upholstered furniture
- Mattress/bedding

Limited WUI data:

- Count only the structures that burned
- Lack of standardization in data collection

WUI Residential Fire Loss

First Item Ignited (2003-06)	Fires	Deaths	Deaths per Fire	Injuries	Property Damage ($ B)
Wood shingle roofs					
Decks					
Exterior walls					
Attic					
Fences					
Vegetation					
Gutters					
Mulch					
Re-entrant corners					
Subtotal of Above Categories					
Totals	2400				14 (2009)

Difficult to develop science-based building and fire codes without data to identify full scope of vulnerabilities

Need to collect post-WUI fire data

Outdoor Fires
Engineering Approach is needed

"Building (indoor) Fires"

Sprinklers:

- Science based development
- Engineering guidelines included in Building Codes and Standards
- Building Code and Standards adopted by local jurisdiction
- System designed by Accredited Engineer
- System *Accepted* by Building Official
- Sprinklers implementation is transparent to homeowner

"Outside Fires:"

- Primarily Homeowner Hazard Mitigation Checklists
- Limited Building Codes and Standards are not Exposure based

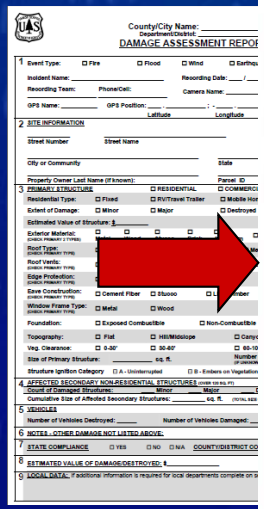
Post-Fire Data Collection (Maranghides, NIST)

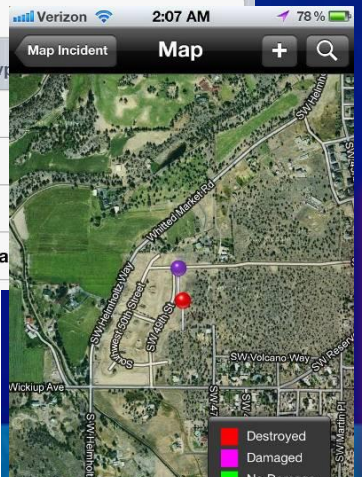
Basic System (WUI 1)

- Identify number of structures lost
- Group structures by incident
- **iPhone/iPad** application (Beta tested at Waldo Fire, CO)
- WUI data collection being explored with: Colorado/ Northern California/ Florida/ Georgia/ Virginia/ North Carolina

Advanced System (WUI 2)

- Identify structure and landscaping attributes, exposure, and defensive actions
- Document pre-fire environment to fully characterize WUI hazards
- GIS linked property parcels and digital photos
- **Tablet** (Beta tested by TXFS)





WUI 0 (identify vulnerabilities)

WUI 1 (damage in context of defensive actions)

WUI 2 (damage in context of defensive actions and exposure)

WUI Post-Fire Studies

	Trails Community during Witch Fire, San Diego, CA	Tanglewood Complex Fire, Amarillo, TX	Waldo Canyon Fire, Colorado Springs, CO
Year	2007	2011	2012
Buildings Destroyed/ Total	74 / 250	35 / 150	350 / 1000
Conditions	dry; high winds (54 mph)	dry; high winds (63 mph)	dry; high winds (~60 mph)
Team	NIST, USFS, and CALFire	NIST, USFS, and TX FS	NIST, USFS, and CSFD
Probable ignition	Arcing power lines	Arcing power lines	undetermined
Fire duration (~80% loss)	6 hours	6 hours	6 hours
Lessons learned	• NIST Tech Note 1635 • 0.2 building lost/min • Pre-staged data collection efforts • Data acquisition methodology needed	• NIST Tech Note 1708 • 0.1 building lost/min • Exposure varies locally • Pre-fire data key • Data acquisition training needed	• NIST Tech Note (in prep) • 1 building lost/min • FD pre-planning needed


Courtesy, San Diego Fire Dept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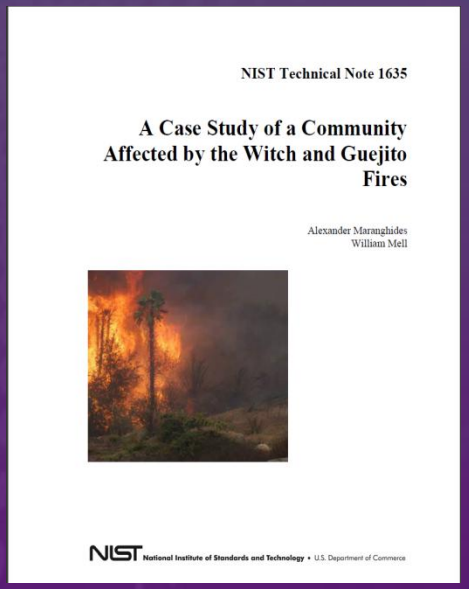
Courtesy, Colorado Springs Fire Dept

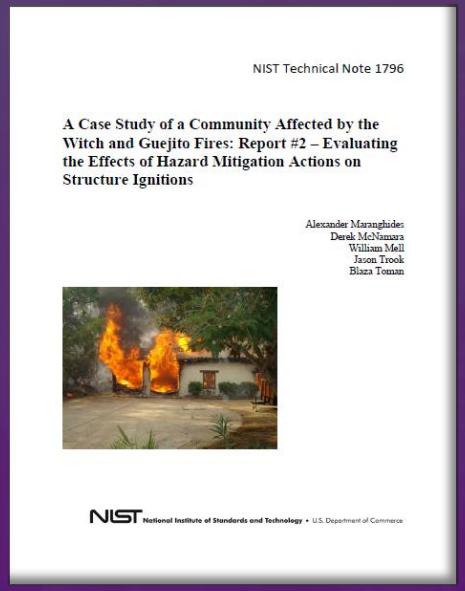
Published Reports

NIST TN1635 (Witch #1)



- Timeline reconstruction
- Structure Ignitions
- Defensive Actions
- Methodology for future developments

NIST TN1796 (Witch #2)



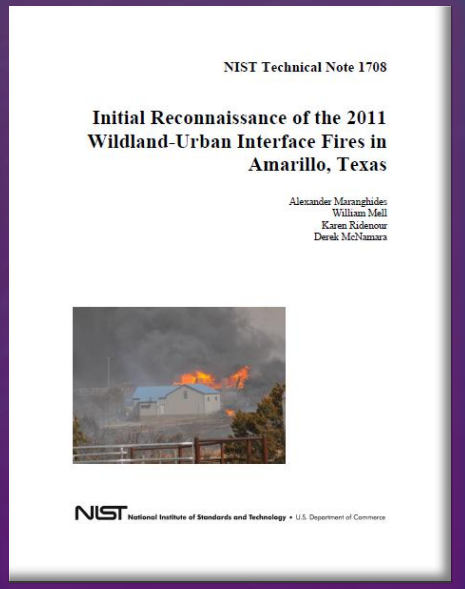
- Exposure quantification!!!

WUI EXPOSURE SCALE

NIST TN-1748

- Defensive Actions
- Effectiveness of Mitigation

NIST TN1708 (Amarillo #1)



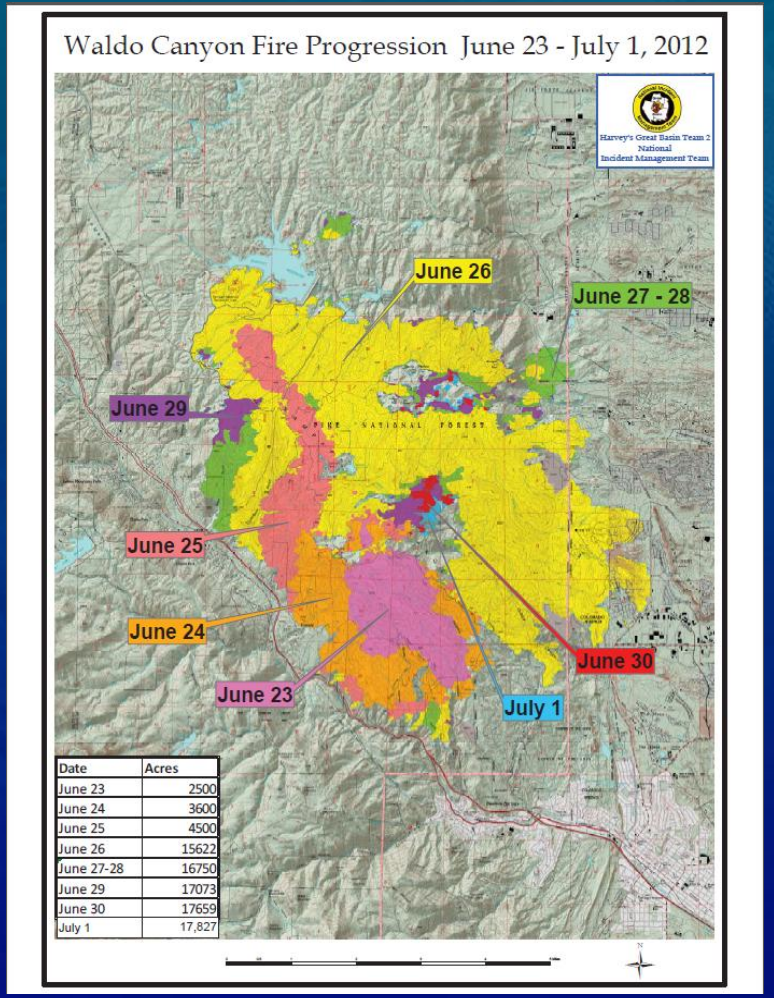
- Deployment methodologies
- Damage Assessment Summary

Event Reconstruction

- Timeline reconstruction
  - Technical discussions with first responders and residents
  - Images and video during the fire
  - Radio Logs
  - Automatic Vehicle Location (AVL) systems
- Pre-fire imagery
- Pre-fire LiDAR
- Post-fire imagery
- Digital Elevation Map
- Weather data
- Building construction attributes (pre and post)

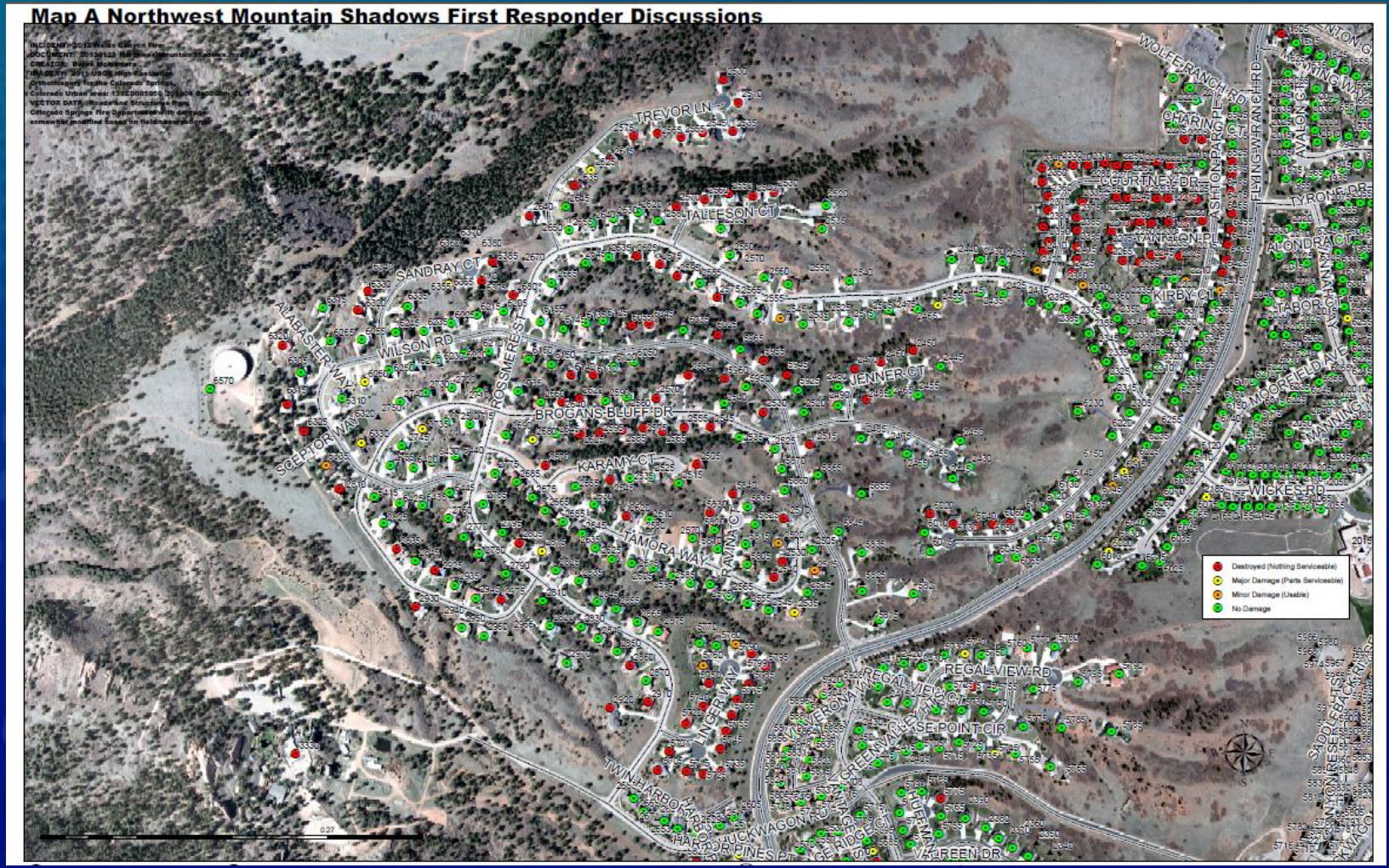
Waldo Canyon Fire Case Study

- JFSP, NIST, USFS, NOAA, NGIA, USGS, Colorado Springs Fire Department and numerous State and Local Jurisdictions
- 346 Homes Destroyed
- About 300 homes destroyed in 4 to 6 hours (about 1 home/min)
- 1000 Homes within Fire Line
- 3500 Hours data collection effort to date. Data collection 95% completed.
- Detailed timeline emerging
- Defensive actions – essential to interpreting post fire data

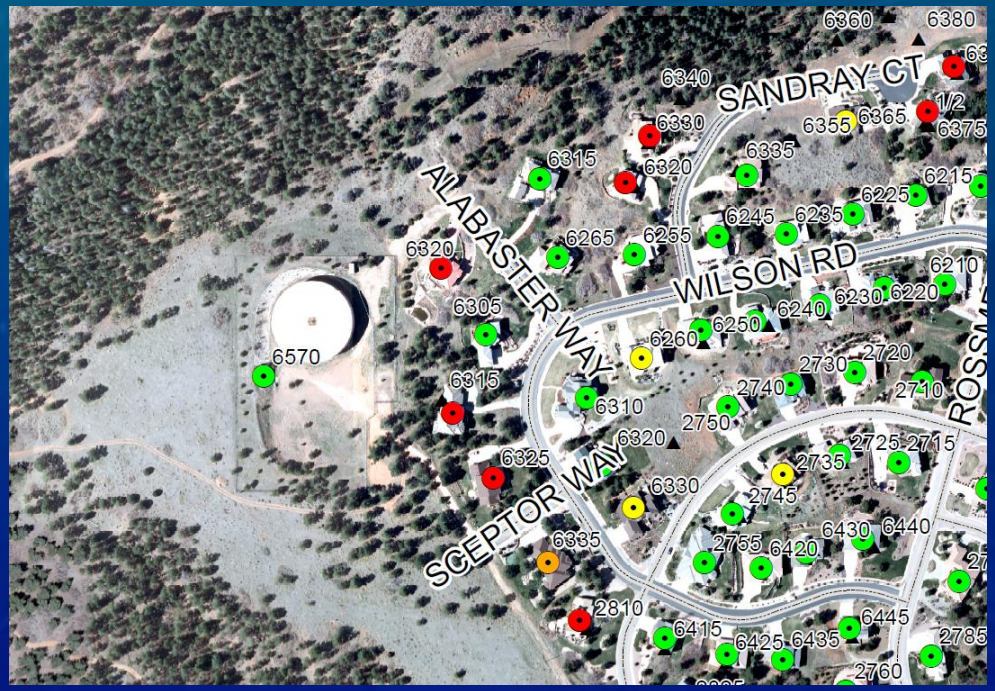


Data Collection/Analysis to be Completed in FY14 (Maranghides)

A Case Study – What happens at the WUI?
(Maranghides)



Waldo Canyon Fire Case Study – Wildfire spread into the community (Maranghides)



Exposure varies over sub-parcel scales

Waldo Fire Case Study (summary)

- Fire arrived from the wildlands
- Relatively few structural ignitions from wildland fire (only 10 to 20% of structures) at wildland/community boundary (interface)
- The (small) number of initial ignitions overwhelmed the traditional fire response (single structural response of 7-9 minutes for Colorado Springs)
- The wildland fire caused the WUI fire problem
- Structure to structure ember-driven fire spread accounted for 80 to 90% of structural ignitions/losses
- Local exposure (fire and embers) is critical to fire spread – sub parcel level

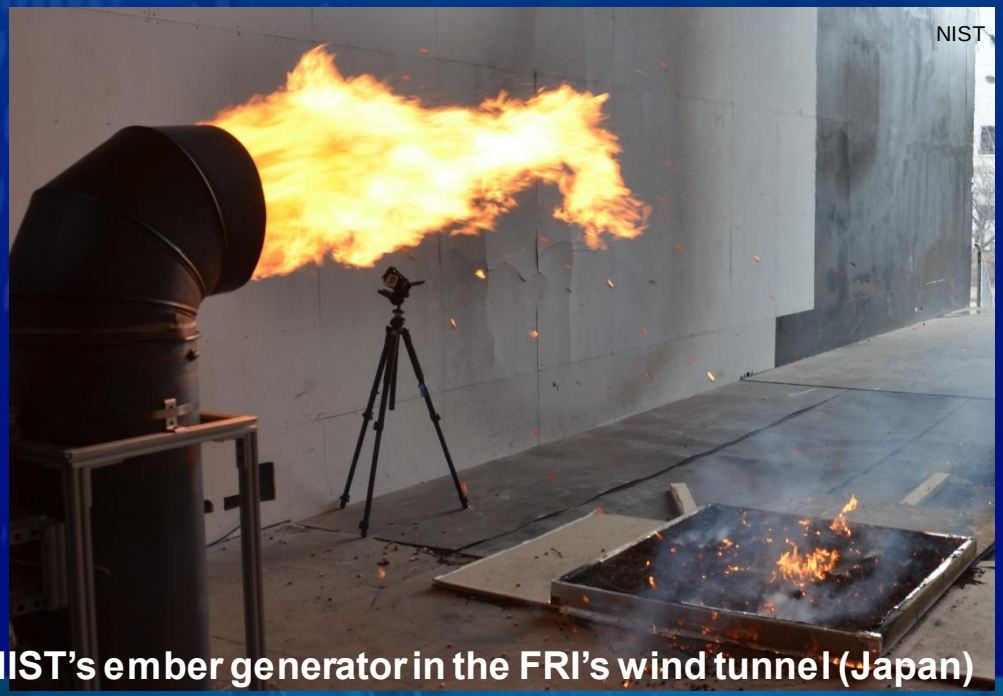
The WUI fire problem is an ignition problem – it does not matter where the exposure comes from – all that matters is (quantifying) the exposure

Post-WUI Fire Data Collection and Analysis
Witch Fire Case Study (Maranghides)

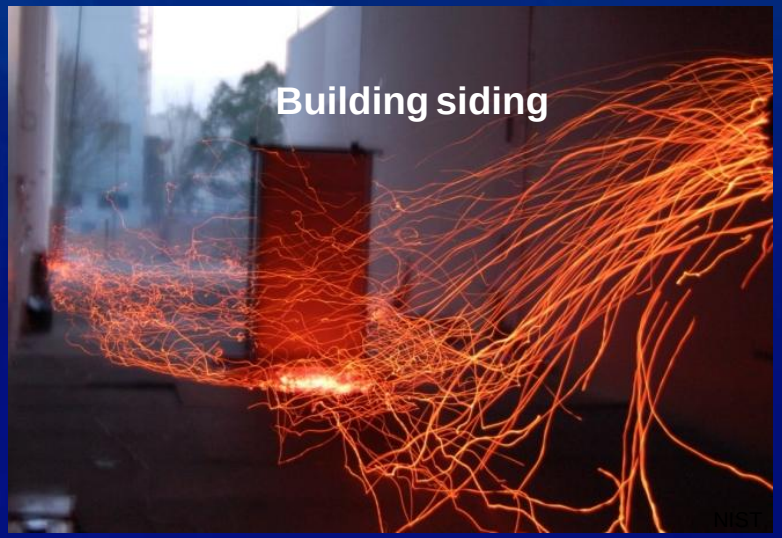
	Sample Population	Destroyed Structures with Wood Shake Roofs	Destroyed Structures with Spanish Tile Roofs	Typical Comparisons	
Typical (only destroyed homes)	74	12	37	**16% of destroyed** homes had wood shake roofs	**50% of destroyed** homes has Spanish tile roofs
Complete (all structures within fire line)	275	12	154		
Technically Valid Comparisons		**100% of exposed** wood shake roofs were destroyed	**24% of exposed** Spanish tile roofs were destroyed		

Hardening Vulnerable Building and Community Elements

Science based tools and test methods are being developed to evaluate the fire resistance of materials, building components, structures, parcels, & communities during WUI fires in an effort to provide the technical basis to improve WUI building codes & standards.



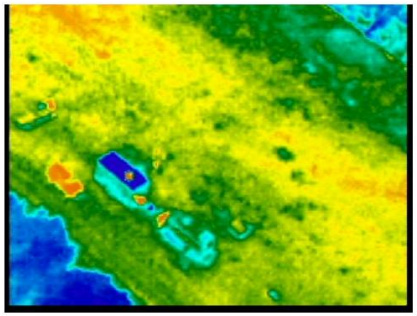
NIST's ember generator in the FRI's wind tunnel (Japan)

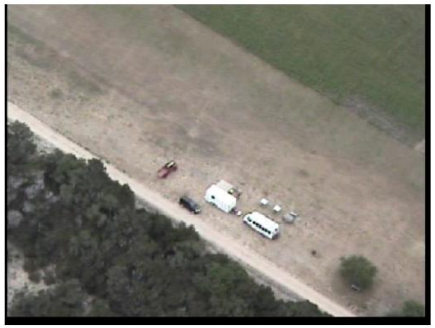


UAV Measurements

- Unmanned aerial vehicles (UAVs)
  - COA – Certificate of Authorization (license to fly)
  - Five MLB Super Bats
- Metrology Development
  Wind: Air vs Ground
  - Towers and anemometers
  - SoDARs
  - Met-probes (new)
  - Wind-dart (new)
- Prescribed burns with USFS

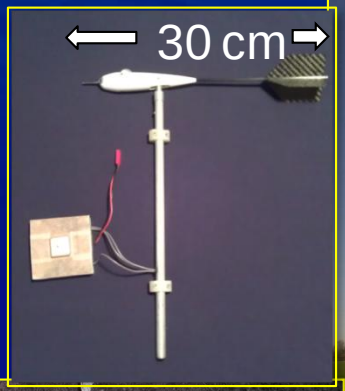

NIST UAV

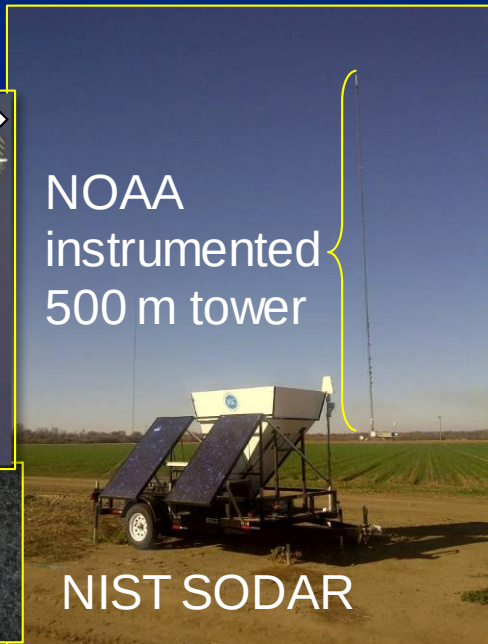

IR – Multi-color


Visible

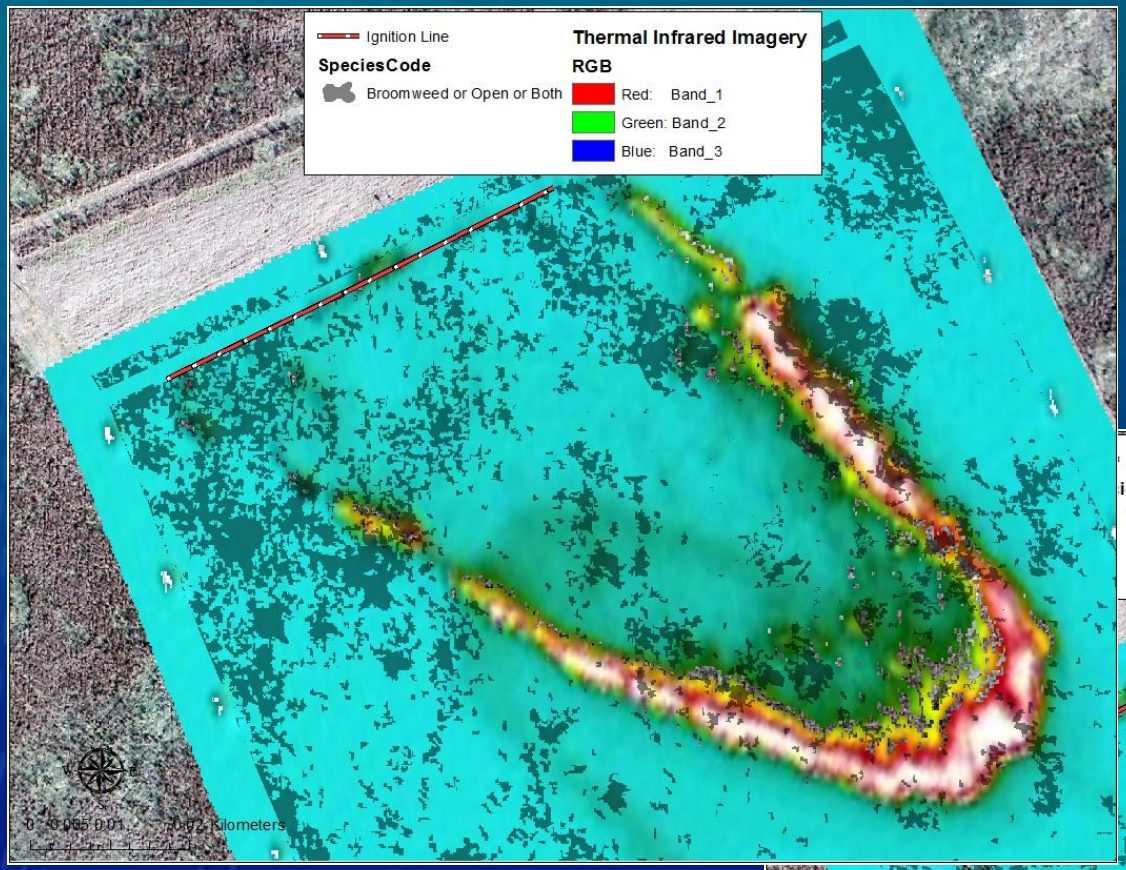
NIST Flight Profile Information

Aircraft Type	**MLB SuperBat**
Wing Span (ft)	8.5
Length (ft)	5.0
Gross Take Off Weight (lbs)	35 with payload
Propulsion	26cc internal combustion
Fuel on Board (lbs)	6.9 lbs (gas/oil mix)
Duration (typical)	10 hours/ 400 miles
Take Off Type	Catapult launch
On board electrical	3 X 5Ah Lithium Polymer
Electrical Duration (typical)	10 hours
Guidance/Avionics	Cloud Cap Piccolo II
Pilot-In-Loop/Manual Over ride	Yes
Launch Type	Catapult
Landing Type	Conventional/Skid
Failover Recovery	Parachute
Aircraft Performance	----------
Max Climb (fpm)	1000
Max Descent (fpm)	800
Airspeed (max, kts)	60
Airspeed (cruise, kts)	39
Max Altitude (ft)	10,000
Active Frequencies (Transmitted)	----------



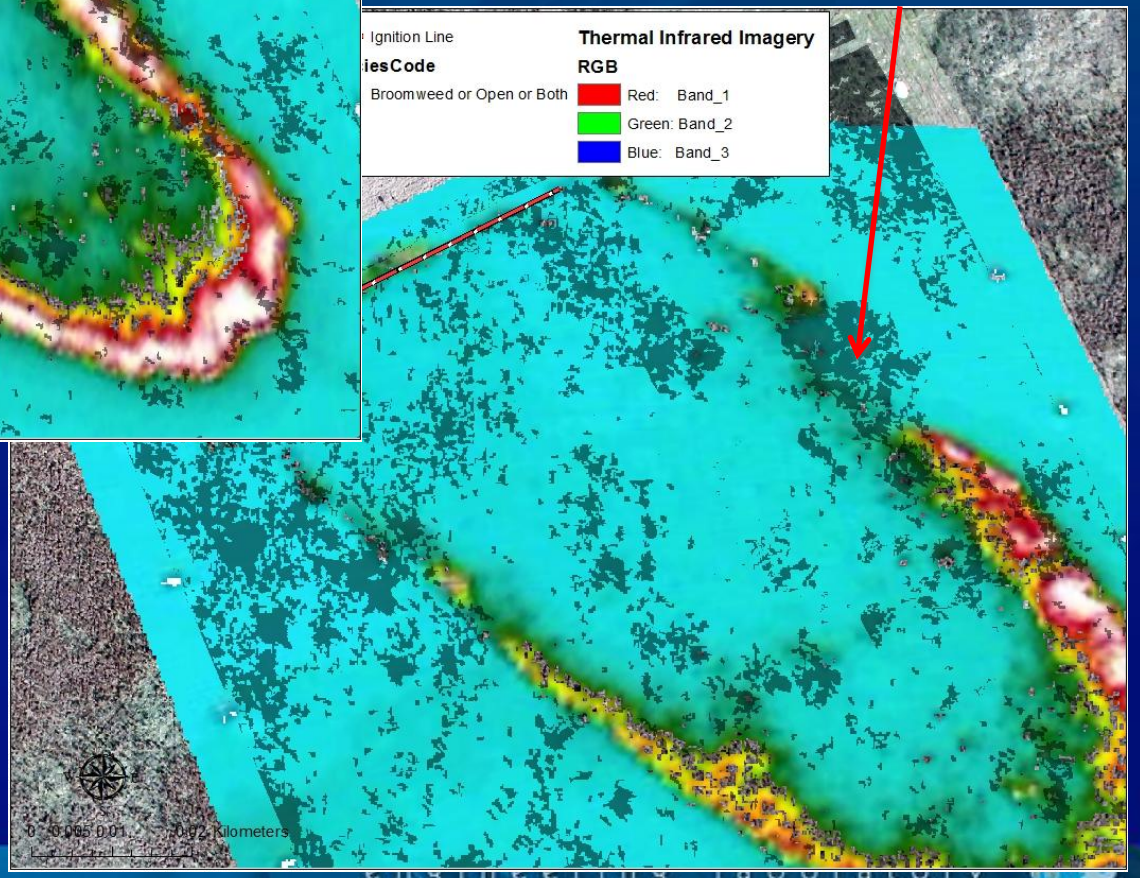


Vegetation/Fuel Treatment influence on Fire Behavior



Georectified and overlaid infrared and "open/broomweed" veg imagery

Fire line broken due to change in vegetation



Summary

- Development of science-based codes and standards is critical to reducing WUI structural loses
- Quantifying WUI fire exposure will help provide a technical basis for development of codes and standards to attack the WUI fire problem
- This approach mirrors what was successfully done for interior fires
- NIST is conducting post-fire analysis, lab and field experiments, and modeling studies to provide the technical basis for the development of standards, codes, and technologies that address WUI fires

Questions?

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Backup Slides

2009 NSTC Grand challenges for Disaster Reduction

Implementation activities and progress relevant to the 2009 challenges?

- Fire Dynamics Simulator model (FDS) Version 6
- WUI fire incident investigation case studies
- WUI post-fire data collection methodologies
- Conceptual framework to quantify WUI fire hazard

What activities are planned that address the 2009 challenges?

- Technology transfer of the NIST WUI data collection methodology
- Implementing the WUI Fire Hazard Scale – Filling in the Exposure Matrix
- Wildland Fire Dynamics Simulator Model Development with USFS
- Measurements of Ignition and Fire Spread Behavior Near Homes
- Development of Bench-Scale Test Methods of Structural Vulnerabilities
- Development of a WUI Technical Solution Implementation Guide on Science-Based Best Practices to harden and maintain WUI communities and buildings.

Existing Coordination and Application

How are results/deliverables made accessible and delivered?

- NIST research emphasizes development of technical basis for standards and codes that reduce risk of fire in buildings and communities
- Post-WUI fire data collection has been piloted with local and state jurisdictions.
- NIST is working with ASTM and California on standards to test the performance of building elements subjected to ember storms.
- NIST is working with the National Fire Protection Association (NFPA) and the International Code Council (ICC) on standards for WUI buildings
- NIST works closely with the US Fire Service to transfer its results into practice.