ASSESSING STRUCTURE IGNITIONS IN THE WILDLAND/URBAN INTERFACE

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ABSTRACT

Major wildland/urban interface (WUI) fire losses, principally residences, continue to occur. Although the problem is not new, the specific structure ignition mechanisms associated with WUI fires are not well understood. The Structure Ignition Assessment Model (SIAM), currently under development, assesses the ignition risk of residences in relation to the WUI situation.

SIAM uses an analytical approach that relates the potential for sustained structure ignitions to the location and characteristics of adjacent fires and the structure's materials and design. SIAM's ignition risk assessment is based on a worst case estimate of the direct effect of flames leading to ignitions as well as ignitions from burning embers (firebrands). Initial SIAM results indicate that the flames of burning vegetation are not greatly effective in creating sustained ignitions. This suggests that firebrands and adjacent burning structures are significant causes of structure ignitions. Current experimentation is directed toward verifying these SIAM results.

THE WILDLAND/URBAN INTERFACE FIRE PROBLEM

Significant residential fire losses associated with wildland fires have occurred worldwide in recent years. The wildland/urban interface (WUI) or intermix refers to residences or vacation homes located in areas that are subject to wildland fires. The WUI fire problem is principally a property and life safety issue. This property and life safety consideration has taken priority over other more traditional wildland fire management concerns in the wildland/urban interface.

Demographics trends in the U.S. (Davis 1990) reveal an increase in the number of people who will reside in or adjacent to wildland areas, further increasing the WUI problem. Without mitigation, WUI losses are sure to continue or increase.

Commonly, severe WUI fires quickly involve many structures. Rapid fire growth in vegetative fuels commonly results in a fire front threatening numerous structures simultaneously and, most importantly, raining firebrands (burning embers) down on homes over a wide area. Advances in equipment, training, incident command systems, and multi-agency coordination, have produced the most effective firefighting capabilities in history. Yet these advances have not stemmed the increasing trend in WUI fire losses. A severe WUI fire can destroy whole neighborhoods in a few hours--much faster than the response time of the best fire services. For example, in October, 1993, the Laguna Hills fire in southern California destroyed nearly all of the 366 homes lost within 5 hours. This tendency of WUI fires to overwhelm fire suppression capabilities is often at odds with what society expects from fire protection.

The characteristic property losses during WUI fires differ dramatically from average residential fire losses. The 1991 U.S. residential fire loss statistics (including the Oakland, California fire losses) illustrate the characteristically higher WUI fire losses. Of the 1991 total residential fire occurrences, WUI fires account for less than .6 percent of the occurrences; however, WUI fire losses resulted in 27 percent of the property losses (Karter 1992). This reflects the higher fire losses per residence for WUI fires as compared to typical residential fires. During a WUI fire, ignited homes typically result in a total loss. For example, news media coverage of the WUI fires (Fleming *et al.* 1993) in the Laguna Hills of southern California show a few relatively unscathed houses adjacent to widespread, complete destruction. Partially damaged residences are the exception.

People often use terms such as "miracle" or "luck" to describe how some homes survive amid the destruction of their neighbors. These words imply helplessness, a lack of control, and a detachment from responsibility. While this may accurately describe the emotional states of those who just experienced wildfires, the assumption that homeowners cannot decrease fire losses is incorrect. Chance or "luck" does play a part in home survival, but the chances for home survival can be significantly improved with attention to WUI fire safety.

IGNITION ASSESSMENT FOR IMPROVING STRUCTURE SURVIVAL

What we observe after a WUI fire is, in varying degrees, structure survival. The degree of survival results from a complex, interactive sequence of events involving the ignition and burning of vegetation and structures, accompanied by varying fire protection efforts by homeowners and firefighters. The development of an assessment method requires an explicit description (at some resolution) of the processes involved.

Structure survival involves factors that influence ignition; and, if an ignition occurs, structure survival also involves factors that influence the fire suppression. Thus, structure survival assessments require consideration of the suppression effectiveness. Analysis reveals that the factors influencing suppression effectiveness greatly depend on the real time situation, thus making a prior description of the suppression factors unrealistic (Cohen 1991). Figure 1 diagrams the general process leading to structure survival or loss. As the figure illustrates, the structure survival process must "pass" through the occurrence or nonoccurrence of an ignition. By analyzing the ignition factors, and thereby improving ignition resistance, one can improve the chances for structure survival.

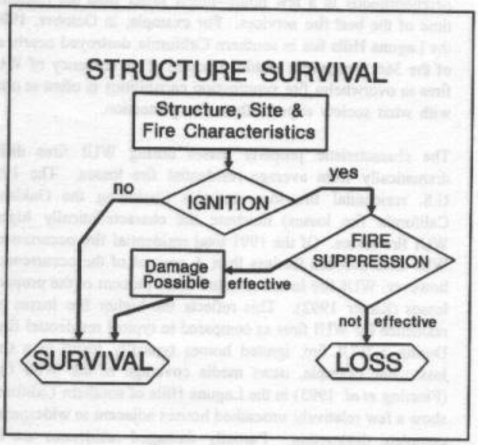

Figure 1–Structure survival depends on factors influencing ignition and factors influencing effective fire suppression. Regardless of the fire suppression effectiveness, survival initially depends on ignition.

The Structure Ignition Assessment Model (SIAM) is based on the premise that structure survival is the essence of the problem, and that structure ignition is the critical element for survival. That is, homes that do not ignite, do not burn. SIAM specifically addresses the potential for structure ignitions rather than the potential for structure survival.

THE STRUCTURE IGNITION ASSESSMENT MODEL (SIAM)

SIAM assesses the potential for structure ignitions during wildfires burning in vegetation and structures. The Model uses general descriptions of the structure, the topography at the building site, and the potential fire characteristics around the structure to compute an index of ignition risk. It is designed to provide a flexible approach toward achieving residential fire safety. That is, SIAM rates the potential for ignitions based on a structure's ignition resistance characteristics and its potential fire exposure. Thus, homeowners and developers can "tradeoff" various design features of a building's exterior and its surroundings to meet prescribed fire-safe requirements.

SIAM is intended for the facilitation of improving fire safety as well as for identifying potential WUI fire problems. In its basic form, the Model applies to a variety of applications from existing single home assessments to planned developments. The basic model applications can include:

- o A means for local regulators to establish fire safety requirements based on potential ignition risk for a mix of factors.
- o A means for integrating a resident's exterior home design and landscaping interests with fire safety requirements.
- o A means for integrating a developer's home and neighborhood design interests with fire safety requirements.
- o A means for fire agencies to assess WUI fire risks for pre-suppression and suppression planning.

To achieve these applications, SIAM uses an analytical approach to establish relationships between the structure design and the fire exposure that results in the assessment of potential ignitions. Since actual fire conditions of a future fire are unknown, worst-case assumptions are used. For example, it is not known how and in what sequence the flammables around a structure will burn; therefore, it is assumed that all flammables adjacent to the structure will burn at the same time. Also, a worst-case assumption regarding fire protection is that no fire protection will occur (a common occurrence during severe WUI fires). Where ignition processes are not explicitly understood, e.g., firebrand (flying embers) exposure and ignition, judgements based on physical reasoning are used. Because of the various unknowns, SIAM rates only the potential for structure ignition; it does not predict ignition.

A better understanding of the SIAM processes and my analysis of WUI structure ignitions can be obtained by examining the Model's components. Figure 2 diagrams the general processes from the input of information to the output of the resulting ignition risk rating.

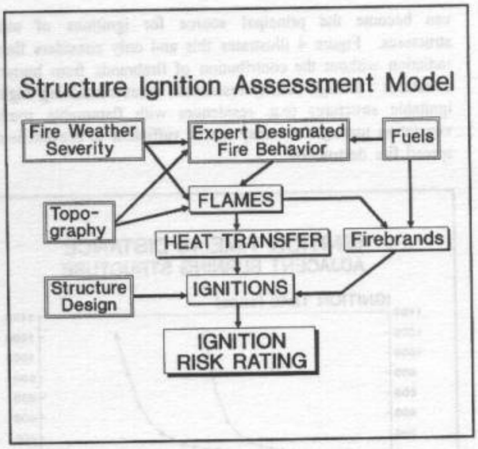

Figure 2--SIAM uses the inputs (double line boxes) to calculate the potential for ignitions from direct flame exposure and burning embers (firebrands). SIAM produces a dimensionless ignition risk rating index, not a prediction of ignitions.

The Model consists of six principal processing steps (items in the brackets refer to figure 2):

1) [Expert Designated Fire Behavior, Fire Weather Severity, Fuels, Topography, Structure Design]
SIAM inputs require the collection of the structure and site conditions that affect the potential for ignition. The Expert Designated Fire Behavior is the fire professional's estimate, from experience and/or calculation, of the flame length and rate of spread. This estimate considers and is consistent with the inputs for the Fire Weather Severity, Topography, and Fuels. The Topography, Fire Weather Severity, and Fuels also influence other factors such as the flame geometry, flame/structure geometry influencing convective and radiative heat fluxes, and firebrand characteristics. The Structure Design inputs relate to the general design, e.g., roof flammability, exterior materials, windows, nooks and crannies, and exterior dimensions.

2) [FLAMES]
Based on the input information of the fuel type, the fuel locations and the fuel length/width dimensions, windspeed, topographic slope, and flame lengths, FLAMES calculates the direct flame effects. Calculations include flame size, flame angle, burning residence time, and the structure/flame geometry. These factors determine the structure's potential exposure to flame radiant heating and flame or convection column contact. Flame sources, i.e., FUEL inputs, include neighboring structures.

3) [HEAT TRANSFER]
SIAM uses a physical heat transfer model to relate the calculated flame characteristics to the radiative and convective heat transfer. The heat transfer model calculates the incident heat transfer rather than the net heating at the structure's surface. Worst-case assumptions are used for the explicit description of such items as the flame temperature, the flame/wall geometry, and the variables influencing convective heat transfer.

4) [Firebrands]
Explicit understanding of firebrands and resulting structure ignitions does not exist. Using physical reasoning and experience, I assume that the firebrand exposure depends on the amount and size distribution of the firebrands generated. The firebrand exposure corresponds to the type of fuel (firebrand characteristics) and the fire intensity (lofting characteristics).

5) [IGNITIONS]
An empirical model (Tran *et al.* 1992) relates incident heat flux at a wood surface over time to the potential for piloted, sustained ignitions (pilot ignition--material is heated such that a small flame or hot spark can induce flaming; sustained ignition--flaming continues after the initial heat source is removed). SIAM calculates the influence of firebrands on the ignition potential based on firebrand exposure [Firebrands], the structure design, and the amount of heating from flames. The Model recognizes the potential effect of flame heating on firebrand ignitions. Structure heating from flames that is insufficient for ignition nevertheless, may enhance the potential for firebrand ignitions.

6) [IGNITION RISK RATING]
The rating process begins by assessing the ignition potential from flames and firebrands for each significant structure side and the roof covering. These assessments are then combined for the entire structure. The final rating is a dimensionless quantity, linearly related to potential structure ignition.

SIAM RESEARCH RESULTS

SIAM is currently under research and development and not ready for operational ignition assessments. However, the component models for heat transfer and ignition have been assembled and run, and experiments have been performed. The research results consider the effectiveness of flames as a radiant heat source for the ignition of wood walls, and the potential for thermally induced window breakage. The following summarizes the modeling and experimental results. Cohen (in press) provides more explicit information on the basis for the findings.

Flame Caused Ignitions

Preliminary SIAM results suggest that ignitions from vegetation flames occur from fires within the immediate surroundings of the structure. Except for the case of large flame heights and an extensive flame width, figure 3 indicates that ignitions result from flames within 15 meters of the structure. Initial laboratory testing with "large" flames (3 m high, 1.5 m wide, .8 m deep) and a wood surfaced wall section concurs with the SIAM results. However, ignitions on structures and adjacent vegetation commonly occur while wildfires burn at distances too far to be caused by flame exposures. This suggests that another factor is highly significant in structure ignition--firebrands. These results support personal observations that firebrands are a significant source for structure ignitions.

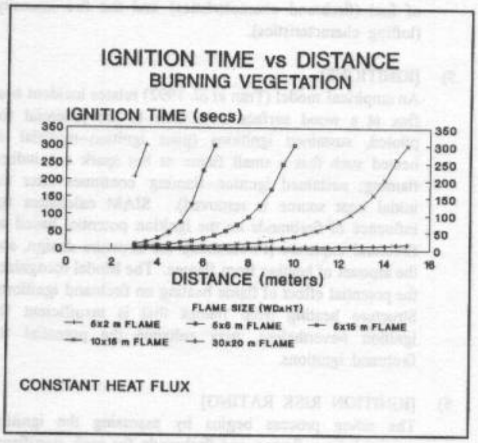

Figure 3–The SIAM heat transfer and ignition models generated these ignition times based on vegetation flame dimensions shown. Typically, vegetation fuels have flaming residence times less than 120 seconds.

This SIAM research suggests that for reducing ignitions, vegetation management beyond some relatively short distance from a structure (vegetation and topography dependent) has no significant benefit for reducing flame generated ignitions. And, vegetation management cannot be practically extensive enough to significantly reduce firebrand ignitions. Thus, the structure and its immediate surroundings should be the focus of activities intended for improving ignition risk.

Vegetation is often the focus of WUI mitigation actions, but in higher density residential areas, neighboring structures are a significant potential ignition source. SIAM results suggest that at distances between structures of less than 5 meters, structures can become the principal source for ignitions of other structures. Figure 4 illustrates this and only considers flame radiation without the contribution of firebrands from burning structures. In high density residential areas containing highly ignitable structures (e.g. residences with flammable roofs), vegetation management may not be sufficient to prevent wide spread fire destruction.

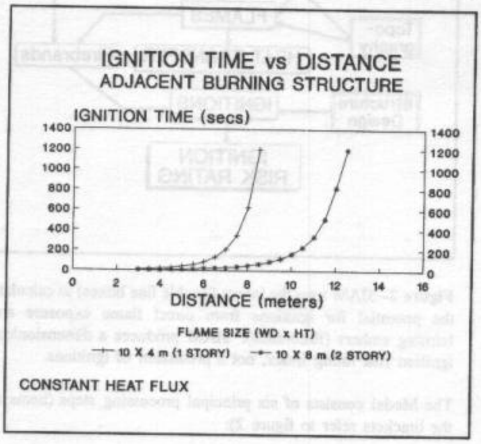

Figure 4–These SIAM generated ignition times are based on a totally involved burning wall of an adjacent structure. The flame is the same in the size as the wall and burns for 20 minutes.

Window Breakage

The structural fire problem regarding windows involves the fracture and subsequent collapse, thus leaving an opening. In the WUI context, firebrands are a very important structure ignition source. Experience indicates that any opening to the interior of the structure increases the potential for ignition. In the SIAM context of ignition assessment, windows are an important factor principally if a fire exposure results in a window fracture and collapse without a concurrent exterior ignition.

The experiments examined plate glass and tempered glass in single pane and double pane arrangements. The preliminary results indicate the following:

- o Single pane and double pane plate glass windows fractured and collapsed at heat flux/time exposures well below those necessary for piloted ignitions for wood. Thus, plate glass windows, particularly single pane, become a significant ignition risk factor.

- o Significant differences were found between plate glass and tempered glass. At the same exposures, no tempered glass window fractured. Tests have yet to be completed for determining whether tempered glass will remain unfractured until wall ignition. However, the completed tests indicate that tempered glass has nearly the same resistance (in terms of heat flux/time exposure) to thermal fracturing as a wood wall has to piloted ignition.

- o Window pane size influenced the potential for window collapse. Two sizes of glass were tested. For .61 by .61 meter panes, no collapse occurred after fracturing, even with inducement; however, 1.52 (vertical) by .91 (horizontal) meter panes collapsed. For each exposure level, breakage resulted in at least one window spontaneously collapsing and collapse was easily initiated for those that did not spontaneously collapse.

- o The experiments showed that interior ignitions from flame radiation through a glass window (without breakage, during WUI fires) are highly unlikely. The plate glass windows broke and collapsed well below a heat flux/time exposure that would produce an ignition at the inside glass surface. Data extrapolation for tempered glass indicates that a wood exterior will ignite before ignition would be possible at the interior glass surface.

REFERENCES

Cohen, J. D. 1991. "A Site-Specific Approach for Assessing the Fire Risk to Structures at the Wildland/Urban Interface." In *Proceedings of the Fire and the Environment: Ecological and Cultural Perspectives International Symposium* (Knoxville, TN, Mar. 20-24, 1990). Gen. Tech. Rep. SE-GTR-69. U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station, Asheville, NC.

Cohen, J. D. 1995. "Structure Ignition Assessment Model (SIAM)." In *Proceedings of the Biswell Symposium* (Walnut Creek, CA, Feb. 15-17, 1994). In Press.

Davis, J. B. 1990. "The Wildland/Urban Interface: Paradise or Battleground?" *Journal of Forestry* 88(1): 26-31.

Fleming, C.; A. Murr; M. Miller; J. Gordon; T. Morganthau. 1993. "Firestorm in California." *Newsweek* (Nov. 8): 28-37.

Karter, M. J. 1992. "NFPA Reports on 1991 U.S. Fire Loss." *NFPA Journal* 86(5): 32-43.

Tran, H. C.; J. D. Cohen; R. A. Chase. 1992. "Modeling Ignition of Structures in Wildland/Urban Interface Fires." In *Proceedings of the 1st International Fire and Materials Conference* (Arlington, VA, Sept. 24-25). Inter Science Communications Limited, London, UK, 253-262.