Evaluation of the Wildland/Urban Defensible Space using Computational Fluid Dynamics

February 26, 2010

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Study performed for Angel Fire, NM

- **The community is concerned about wildfires starting either from lightning or recreational users of the forest**
- **The permanent population of Angel Fire is estimated at 1,100 full-time and 1,100-1,200 seasonal residents**
- **There are approximately 250 registered businesses whose primary industry is tourism**

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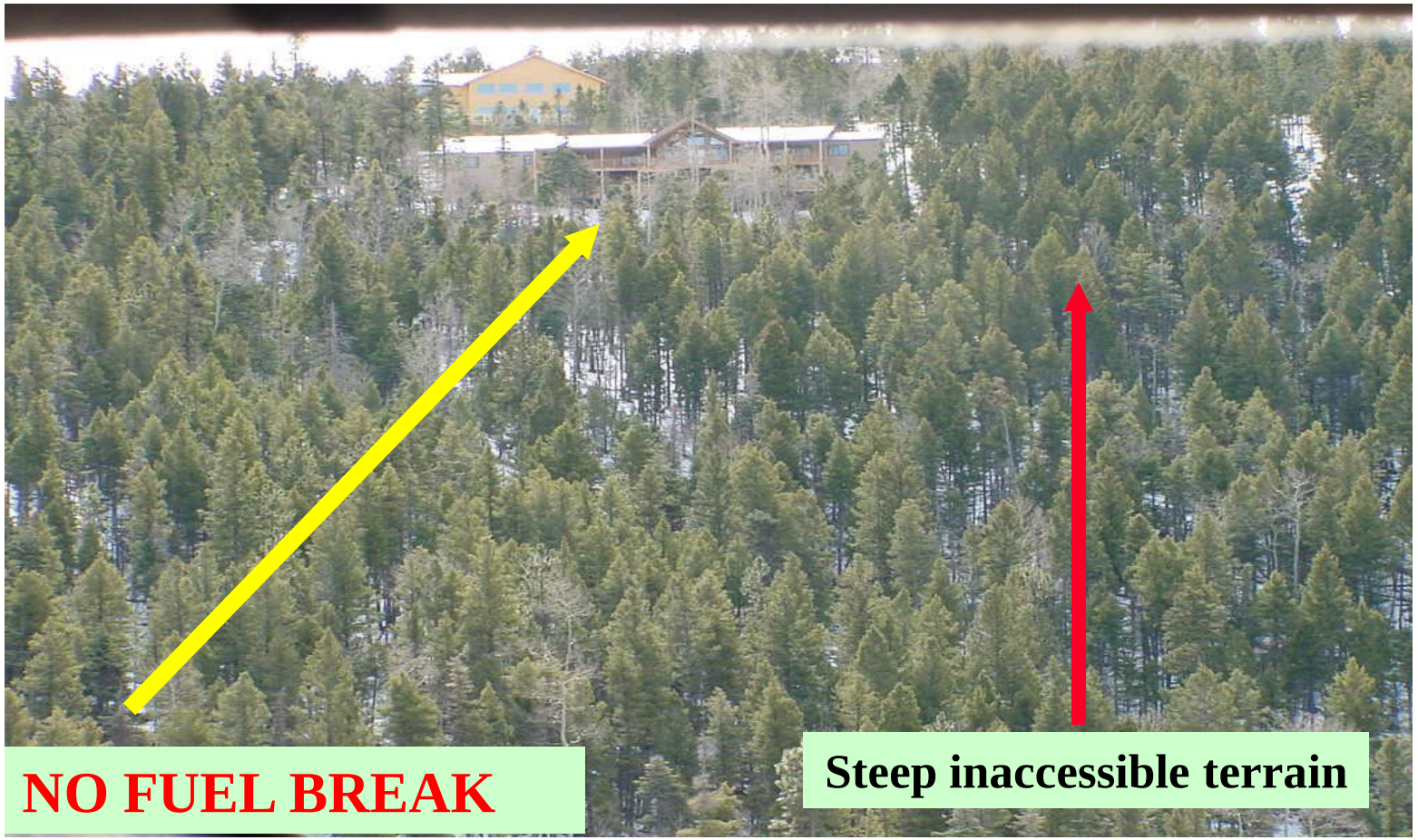
Fire Chief would like to see some change



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Current Recommendations for Fuel Management

- National Wildland/Urban Interface Fire Protection Program and Institute for Business and Home Safety provide strategies to reduce the likelihood of house ignition (www.firewise.org).
- Fuel management is separated into zones surrounding a house and the extents are determined by the level of hazard.
- The level of hazard is determined by surrounding vegetation type, terrain, climate, historical fire frequency, presence of human made fuels, and accessibility for fire trucks and to fire hydrants.

Current Recommendations for Fuel Management

- **Zone 1, the nearest to a house, a minimum of 30 ft irrigated area with very little vegetation and possibly extended 100 ft or more depending on the level of hazard of the area.**
- **Zone 2 should have low growing plants and if trees are present they should be placed at least 10 ft apart. The irrigation system should also extend to this zone.**
- **Zone 3 areas should be slightly modified such as removing highly flammable vegetation.**
- **In low hazard area zone 2 and 3 should extend about 20 ft past zone 1 to provide a total modified landscape of 50 ft. In a moderate and high hazard area the total extent is 100 ft and 200 ft, respectively**

Objective of Study

- The objective of this work is to determine if a 30 ft stand-off distance is sufficient to reduce the likelihood of ignition of a house surrounded by both a thinned and unthinned forest
- The Sandia Computational Fluid Dynamics Fire code, SIERRA/Fuego, was used to investigate four cases with a house surrounded by forest:
  - Case 1, thinned forest with 30 ft stand-off
  - Case 2, thinned forest with 5 ft stand-off
  - Case 3, unthinned forest with 30 ft stand-off
  - Case 4, unthinned forest with 60 ft stand-off

SIERRA/Fuego CFD Fire Model

- Several turbulence models to choose from – RANS and LES variants
- Participating Media Radiation (PMR) coupling using discrete ordinance
- Combustion models available: Eddy Dissipation Concept (EDC) Model and Laminar Flamelet Turbulent Combustion Model
- Trees/shrubs/grass are modeled as a collection of Lagrangian fuel elements within an Eulerian Field
- Multi-step pyrolysis model for solid fuel elements – water vapor formation and multiple path ways to char and pyrolysis via intermediate species tar

Assumptions and Specifications

- Crown fire
- Wind speed of 10 m/s (22 mph); representative of average high wind speeds
- No firebrands (can travel up to a mile or more, but fire resistant materials can mitigate)
- Tree dimensions and crown cover were provided from a survey of thinned and unthinned regions in Angel Fire
- Moisture content was assumed not to be a factor since only a 5% difference between thinned and unthinned regions

Simulation Specifications

Simulations Performed			
	Forest Density	**Number of Trees**	**Stand-off distance (ft)**
Case 1	**Thinned (40% crown cover)**	**152**	**30**
Case 2	**Thinned (40% crown cover)**	**152**	**5**
Case 3	**Unthinned (100% crown cover)**	**1032**	**30**
Case 4	**Unthinned (100% crown cover)**	**1416**	**60**

Each case was performed using 64 processors taking approximately from 15 to 50 CPU hrs.

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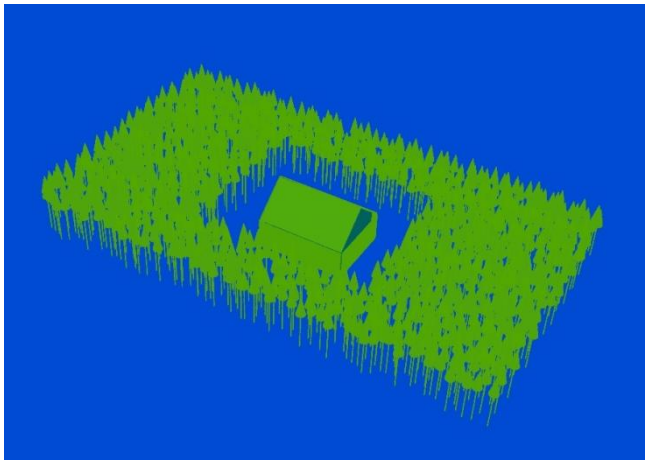
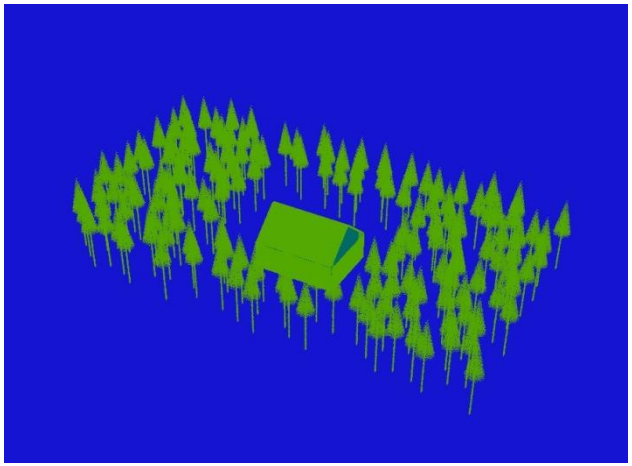
Simulation Specifications

Dimensions (ft) (m)			
	Domain	House	Forest
X - direction	1312 (400)	59 (18)	315 (96)
Y - direction	1312 (400)	39 (12)	177 (54)
Z - direction	492 (150)	39 (12)	Tree height



unthinned



thinned

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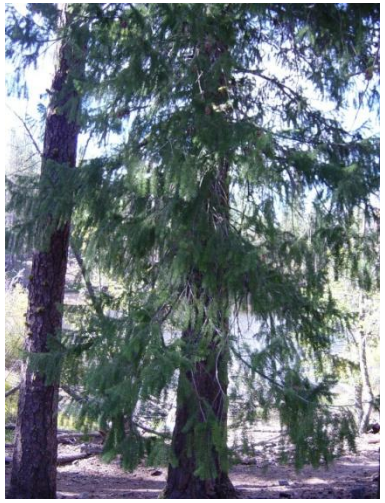
Simulation Specifications

Average	Height (ft) (m)	HtB D (in) (m)	Crown Diameter (ft) (m)	Crown Height (ft) (m)	Crown Cover (%)
Thinned	58 (17.7)	11.4 (0.3)	12 (3.66)	30 (9.2)	40
Unthinned	38 (11.6)	8.5 (0.2)	6 (1.82)	25 (7.6)	99

White fir

Aspen



Douglas-fir

spruce

Ponderosa pine

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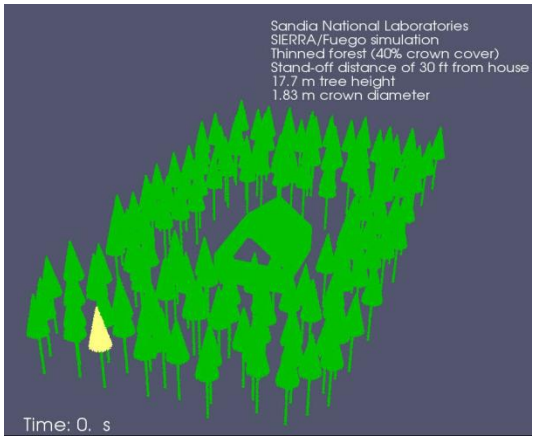
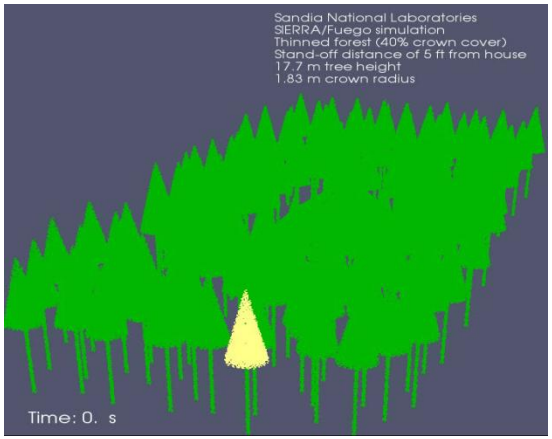
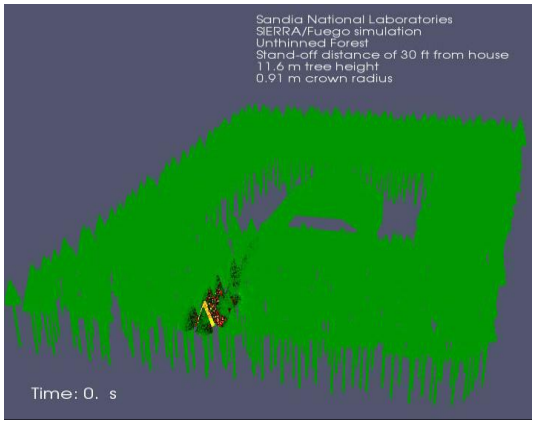
Results



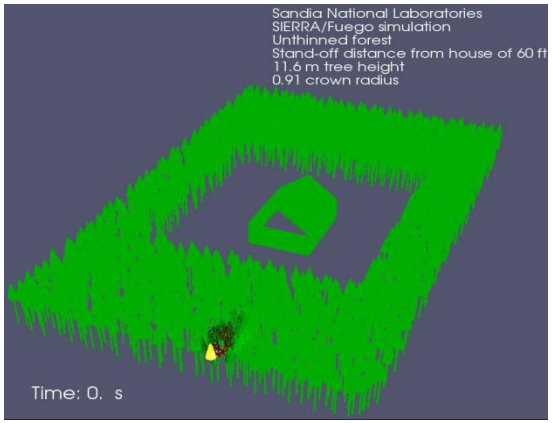
Case 1



Case 2



Case 3



Case 4

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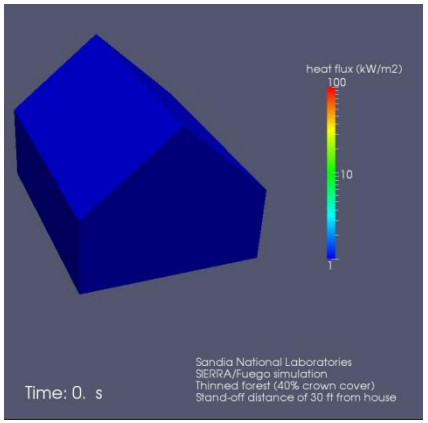
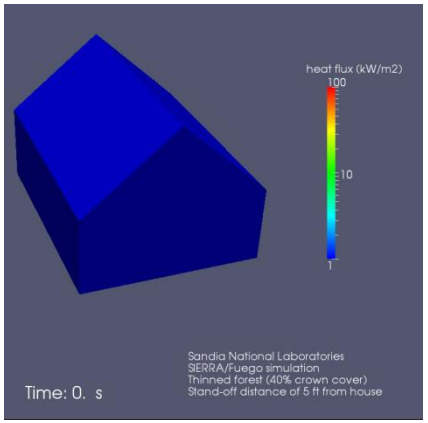
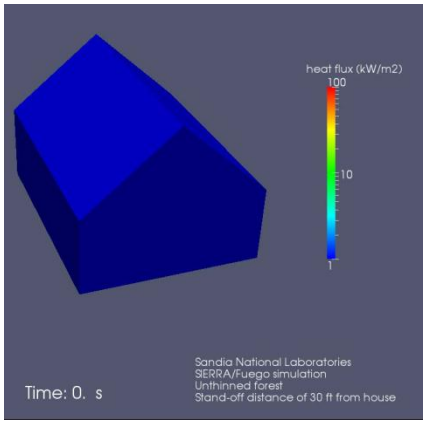
Results



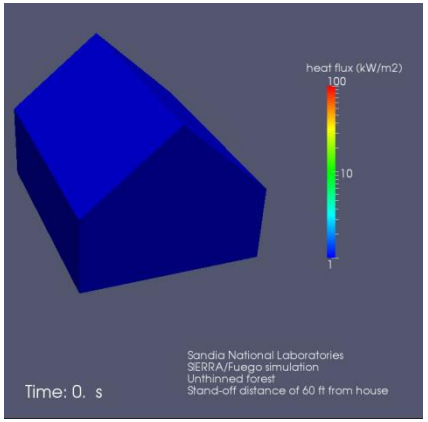
Case 1



Case 2



Case 3



Case 4

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Results

	Forest Density	Stand-off distance (ft)	Approximate maximum heat flux to house (kW/m2)	House ignition?
Case 1	Thinned (40% crown cover)	30	10	No
Case 2	Thinned (40% crown cover)	5	80	Yes
Case 3	Unthinned (100% crown cover)	30	50	Yes
Case 4	Unthinned (100% crown cover)	60	1	No

Conclusion

- **Case 2 reinforces the recommendation to trim vegetation very near a structure (thinning alone is not sufficient)**
- **Case 1, 3, 4 reinforces the recommendation that in a high hazard area such as what is assumed in these simulations, namely a crown fire, vegetation should be thinned beyond the 30 ft stand-off distance.**
- **If zone 2 (beyond 30 ft) is not thinned as representative of case 3, then the results indicate ignition occurs**
- **The results indicate that a 30 ft stand-off distance is sufficient when a house is surrounded by a thinned forest for the given conditions**

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