Modeling Spot Fires—U.S. Modeling System Comparisons for Practitioners* (October 2010)

*In all geospatial systems, embers are only generated from passive and active crown fires, not from surface fires, fire whirls, burning piles, or structures. Spotting can be turned off or set to zero in all tools.
*None of the systems that model spot fires account for Probability of Ignition (Bradshaw et. al. 1984)—this is an independent calculation in BehavePlus or the Fireline Handbook.

Model	Inputs	Spotting Process	Outputs	Limitations/Assumptions
Spot Distance Nomo-grams (Non-spatial)	• Torching tree height • Torching tree species (9)/dbh • Average tree cover height • 20-foot wind speed	Simplification of Albini's (1979) in Rothermel (1983). Predictive mathematical model where a single firebrand is lofted from a torching tree to calculate maximum distance.	Maximum spotting distance from a single torching tree on flat ground is read from a nomogram.	Gives maximum distance only. Assumes level terrain; single torching tree; and does not account for likelihood of trees torching, firebrand material availability, or the number of spot fires.
BehavePlus v.5.0.2 (Non-spatial)	• Torching tree height • Torching tree species (14)/dbh • Downwind canopy height • 20'-foot wind speed • Number of torching trees (1-30) • Ridge/Valley elevation difference • Ridge/Valley horizontal distance • Spotting source location • Flame Length (for spotting from wind-driven surface fire) • Flame height (for spotting from burning pile) • 1-h moisture, temp, shading (for probability of ignition)	Spotting from torching trees based on simplified nomograms with option of multiple torching trees and terrain adjustment (Albini 1979, Chase 1981, Rothermel 1983). B+ calculates spotting from wind-driven surface fire (Albini 1983, Chase 1984, Morris 1987) and spotting from burning piles (Albini 1981), which are not available in other programs (Andrews 1986).	Maximum spotting distance from torching trees (single or multiple), burning piles, or surface fire is displayed in a table or graph. Ember distance can be calculated independent of crown fire calculation. Probability of ignition can be calculated separately.	Gives Maximum distance only. Accounts for terrain and number of torching trees. Does not account for likelihood of trees torching, firebrand material availability, or the number of spot fires. Number of torching trees is used to calculate firebrand lofting height; higher firebrands travel further, all else equal. B+ can be used to calculate crown fire potential, although this is unrelated to the spotting model.
FlamMap 3.0, desktop (Spatial)	None	None	None	Spatial fire behavior, but spotting is not modeled in FlamMap 3.0.

Model	Inputs	Spotting Process	Outputs	Limitations/Assumptions
STFB: Short Term Fire Behavior, WFDSS version of FlamMap 5.0 (Spatial)	• Canopy characteristics from spatial layers. • User sets Foliar MC (to calculate passive crown fire). • Spotting tree species/dbh is always Grand Fir/ 20cm. • User sets "spotting probability". • Wind speed/direction is constant for entire burn period, but can be gridded. • Weather is static, though fuel moistures can be conditioned.	FlamMap calculates fire behavior for cells. Nodes are on fixed grid equal to LCP spatial resolution. For active or passive CF nodes, 16 incrementally-sized embers are lofted. Max ember distance & azimuth are calculated using canopy cover, crown fraction burned, elevation, and all available wind information. User-set spotting probability determines which predicted crown fire cells (and associated nodes) can produce spots. Those nodes generate a single ember with random distance from zero to the max for that node. Embers landing on unburnable or already burned substrate do not ignite. Embers landing on burnable substrate always ignite (Finney 2002).	Models fire behavior for every cell simultaneously for a single scenario, and uses MTT to calculate fastest fire travel paths. Embers produced only with passive and active crown fire. Randomly lofts a single ember from a node if the predicted fire type is passive or active crown fire.	Spotting only occurs when passive or active crown fire is modeled. Finney and Scott & Reinhardt methods are available for crown fire; each calculates Crown Fraction Burned (CFB) differently. CFB and canopy cover are used to determine "number of torching trees" (1-10) used in firebrand lofting height. More embers will be lofted at finer landscape resolutions. Faster ROS will encounter more nodes, but absolute number of nodes is static. One ember per node; less chance than in NTFB/FARSITE that ember will travel the maximum distance. **NOTE: Users will probably want to set "spotting probability" higher in STFB than for FARSITE/NTFB tools.**
FARSITE v. 4.1.055, desktop (Spatial)	• Canopy Characteristics from spatial layers • User sets Foliar MC (to calculate passive crown fire), • User inputs spotting tree species (9) and dbh (default is Grand Fir, 20cm). • User sets "spotting probability". • Variable weather. • Wind speed/direction input can be fine, coarse, or gridded. • Ignition delay is optional. • User determines Distance & Perimeter resolutions and Timestep.	Fire behavior calculated for cells. Vertices loft embers. The number of vertices depends on perimeter and distance resolutions & timestep. If crownfire occurs, that vertex lofts 16 incrementally-sized embers. Each ember goes through a random draw process based on user-set spotting probability. Ember distances and azimuth based on canopy cover, crown fraction burned, elevation, winds, & spp/dbh. Embers tracked until they burn out or land. Burned out embers and embers landing on unburnable substrate do not ignite. Embers landing on burnable substrate ignite spot fires (Finney 1998).	Models hourly/daily fire behavior and growth from an expanding fire front over time/space for single scenario. Display shows where embers land. Simulates lofting and downwind travel of individual embers of different sizes from each vertex that exhibits passive or active crown fire.	Spotting only occurs when passive or active crown fire is modeled. Finney and Scott & Reinhardt methods are available for crown fire; each calculates Crown Fraction Burned (CFB) differently. CFB and canopy cover are used to determine "number of torching trees" (1-10) used in firebrand lofting height. The same chosen spp/dbh is used for entire landscape. More embers are lofted with more vertices resulting from finer timesteps and distance/perimeter resolution. Faster ROS can produce more vertices. **NOTE: Users will probably want to set "spotting probability" lower in FARSITE than in tools using MTT (STFB, FSPro).**

Model	Inputs	Spotting Process	Outputs	Limitations/Assumptions
NTFB: Near Term Fire Behavior, WFDSS version of FARSITE (Spatial)	Same as FARSITE, except: • Spotting tree species/dbh is always Grand Fir, 20cm. • Wind speed/direction input can be fine or coarse (gridded not yet available). • Distance & Perimeter resolutions and Timestep are determined from the LCP resolution; Timestep is 60 minutes.	Same process as FARSITE.	Same as FARSITE, except display does not show where embers land.	Same as FARSITE, except that 20 cm Grand Fir is always used for entire landscape, gridded winds are not (yet) available; and distance resolution, perimeter resolution, and Timestep are automated. **NOTE: Users will probably want to set "spotting probability" lower in NTFB than in tools using MTT (STFB, FSPro).**
FSPro (Spatial)	• Canopy characteristics from spatial layers. • Foliar MC always 100%. • Spotting tree species/dbh is always Grand Fir, 20cm. • User sets "spotting probability" for each fire danger (ERC) bin. • Winds can be probabilistic or forecast or combination. • Weather can be probabilistic or forecast or combination. • Ignition delay is optional.	Same process at STFB.	Fire probability surface output that may or may not distinguish spot fire activity. Embers produced only with crown fire as calculated with the Finney method.	Same as STFB, except only Finney method available for crown fire (and thus, CFB) calculations. **NOTE: Users will probably want to set "spotting probability" higher in FSPro than for FARSITE/NTFB tools. Calibrating FSPro with STFB utilizes consistent spotting methods.**

*Tonja Opperman, Fire Applications Specialist, Wildland Fire Management RD&A, assembled this table based on contributions and discussions among many fire behavior researchers, programmers, and practitioners, including: Pat Andrews, Mark Finney, and Chuck McHugh at the Missoula FireLab; Brian Sorbel at the Alaska Region of the NPS; Mitch Burgard and Erin Noonan-Wright at the Wildland Fire Management RD&A; Stu Brittain with Systems for Environmental Management in Missoula; Joe Scott with Pyrologix in Missoula; and Rick Stratton at the Pacific Northwest Region of the USFS. Corrections can be forwarded to Tonja Opperman at tonja_opperman@firenet.gov.

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