Module III – Fire Analysis

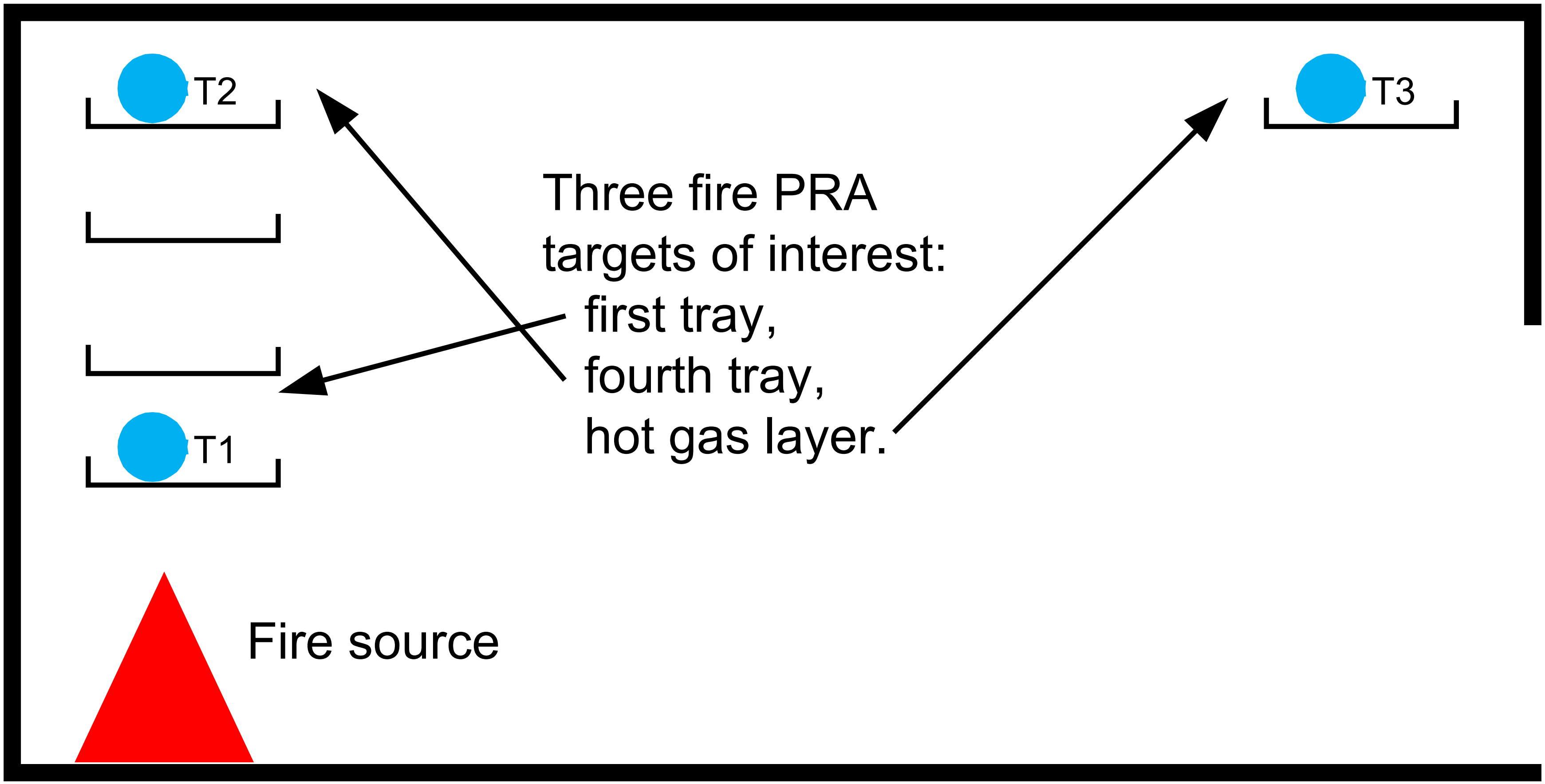
Special Topics in Detection and Suppression Analysis – General Approach for Treatment of Progressive Damage States

Joint EPRI/NRC-RES Fire PRA Workshop

August 21-25, 2017

A Collaboration of the Electric Power Research Institute (EPRI) & U.S. NRC Office of Nuclear Regulatory Research (RES)

Common challenge: multiple fire PRA damage targets with some degree of spatial separation



Damage state progresses in time

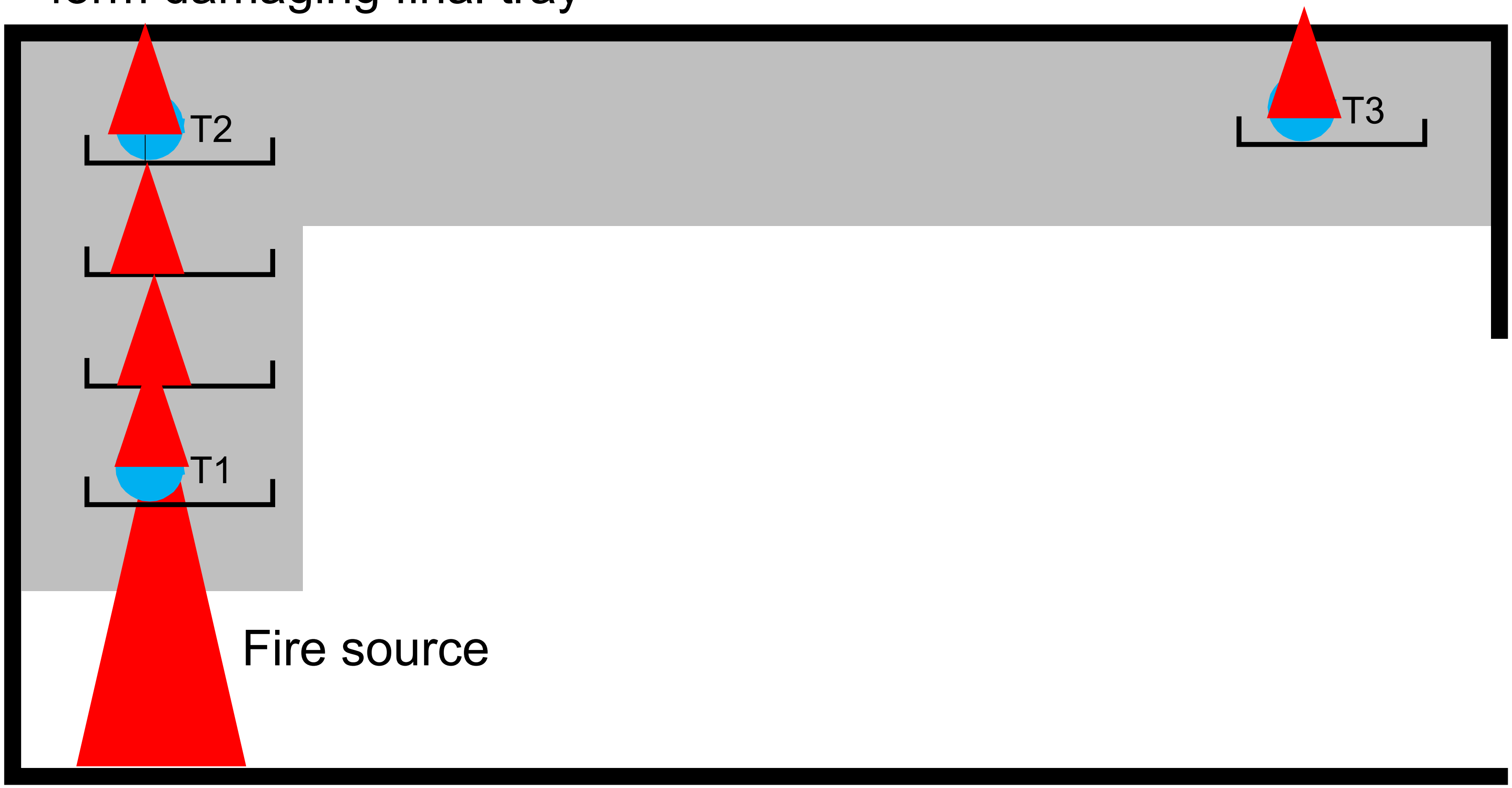
Fire will damage closest tray first:

Damage state progresses in time

As fire grows and spreads, it will progress through tray stack eventually reaching fourth tray:

Damage state progresses in time

If fire is large enough, hot gas layer may form damaging final tray



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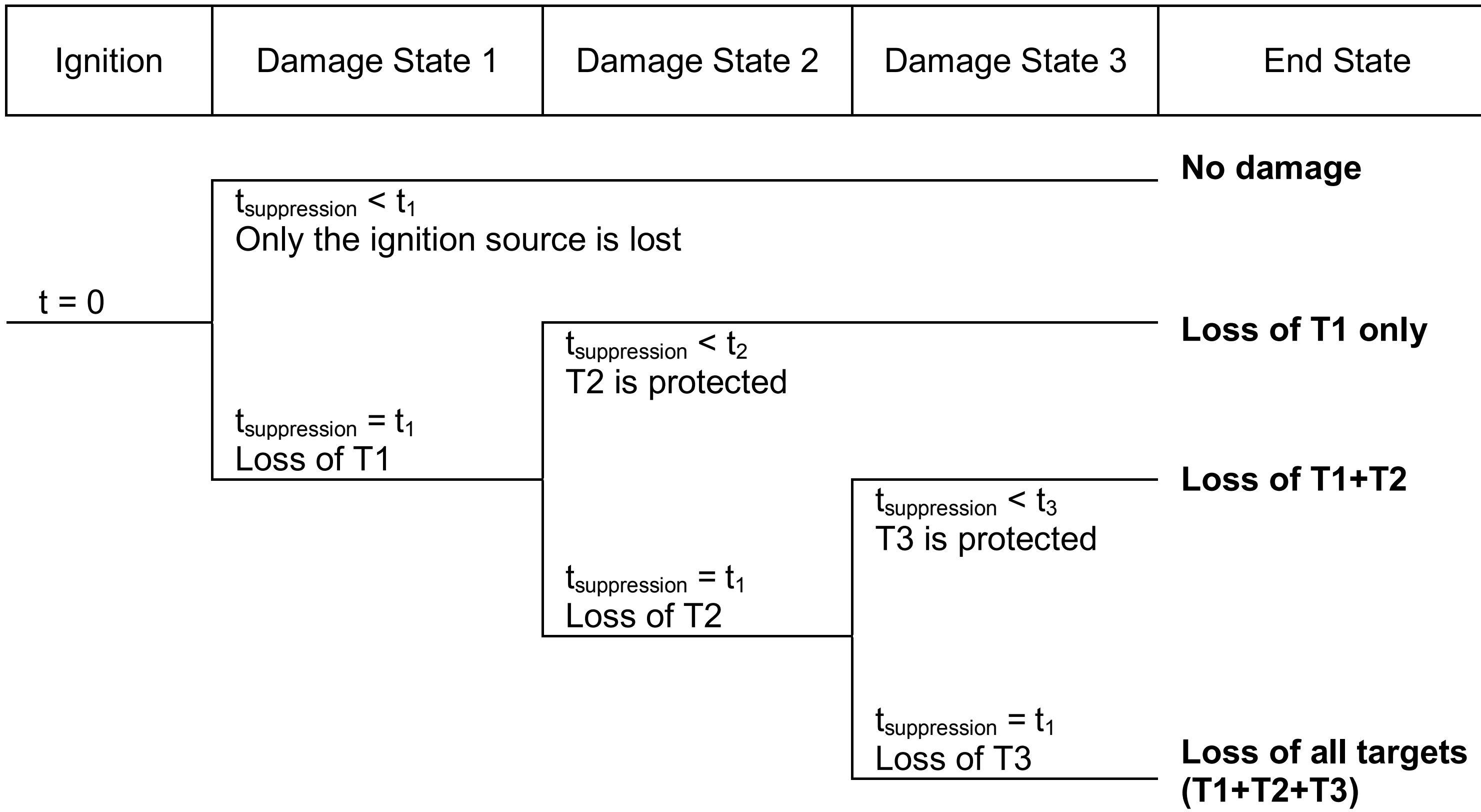
You can build an event tree to reflect a progressive damage state increasing with time

- The key is that the fire must burn long enough to cause the postulated damage, and the more extensive damage states take additional time
  - t_1 = time to damage for T1
  - t_2 = time to damage for T2
  - t_3 = time to damage for T3
  - $t_1 < t_2 < t_3$
- The likelihood of successful fire suppression gets better and better with longer times
  - Said another way – the probability of non-suppression gets smaller and smaller with longer time available before damage
  - $P_{NS}(t_1) > P_{NS}(t_2) > P_{NS}(t_3)$
- We can reflect this credit through a modified suppression event tree:

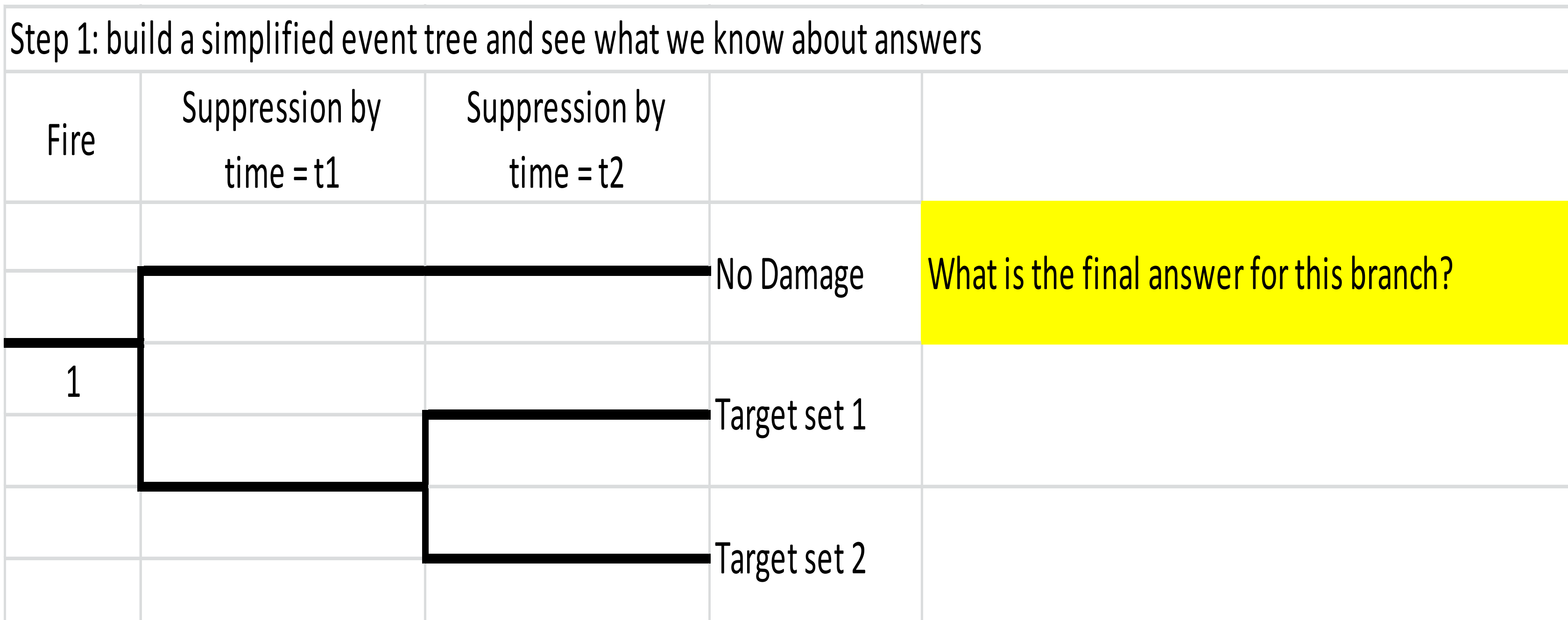
A modified suppression event tree for a three-stage set of fire PRA targets



The key is to properly calculate the branch point split fractions

- Branch point values depend on time to damage and the applicable non-suppression probability curve, but…
- The events are *dependent*
  - You can't just pick numbers off suppression curve for each branch
- For example - the second split fraction, for damage to T2, is:
  - the *conditional probability* that *given the fire was not suppressed before time* $t=t_1$, the fire will remain unsuppressed through time $t=t_2$
  - Same goes for final split fraction
- The formal approach to calculate these conditional split fractions lies beyond the scope of our course
  - You need to integrate the density function across time intervals…
- We can, however, illustrate the concept with an even simpler example that we can solve by inspection

Reduce our problem to a two-stage damage state

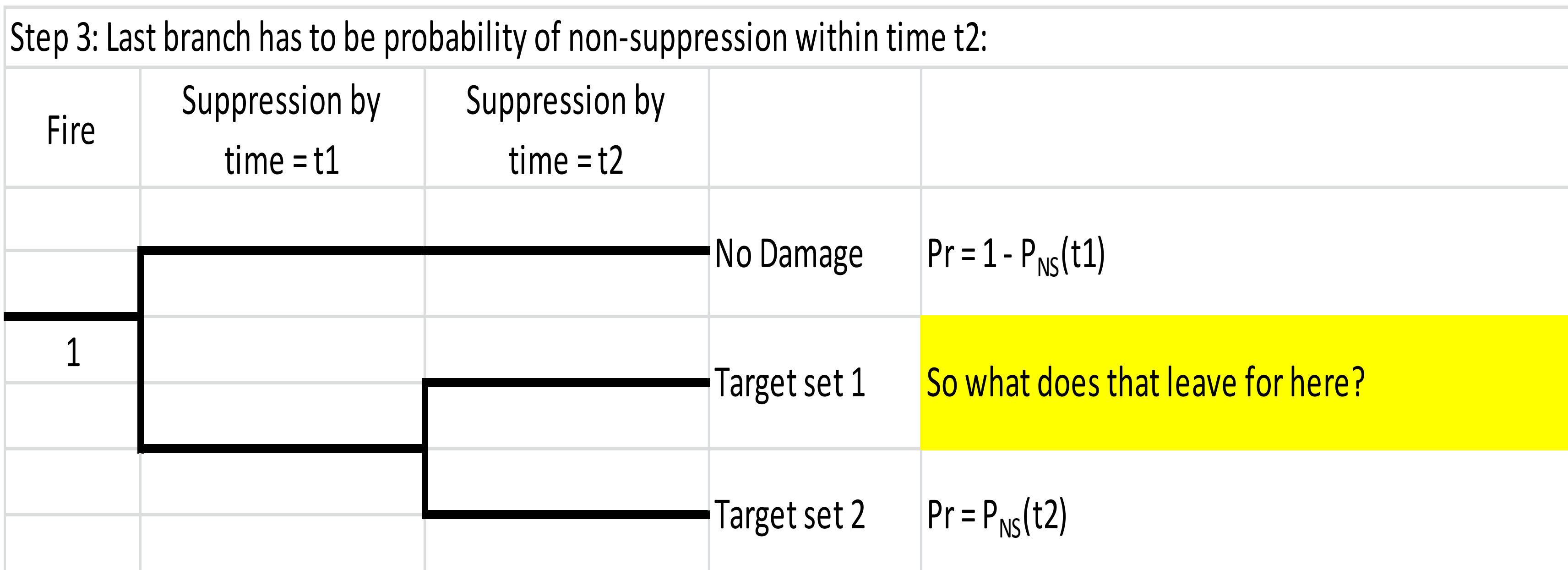


Two-stage example (cont.)

Step 2: What else do we know about answer?

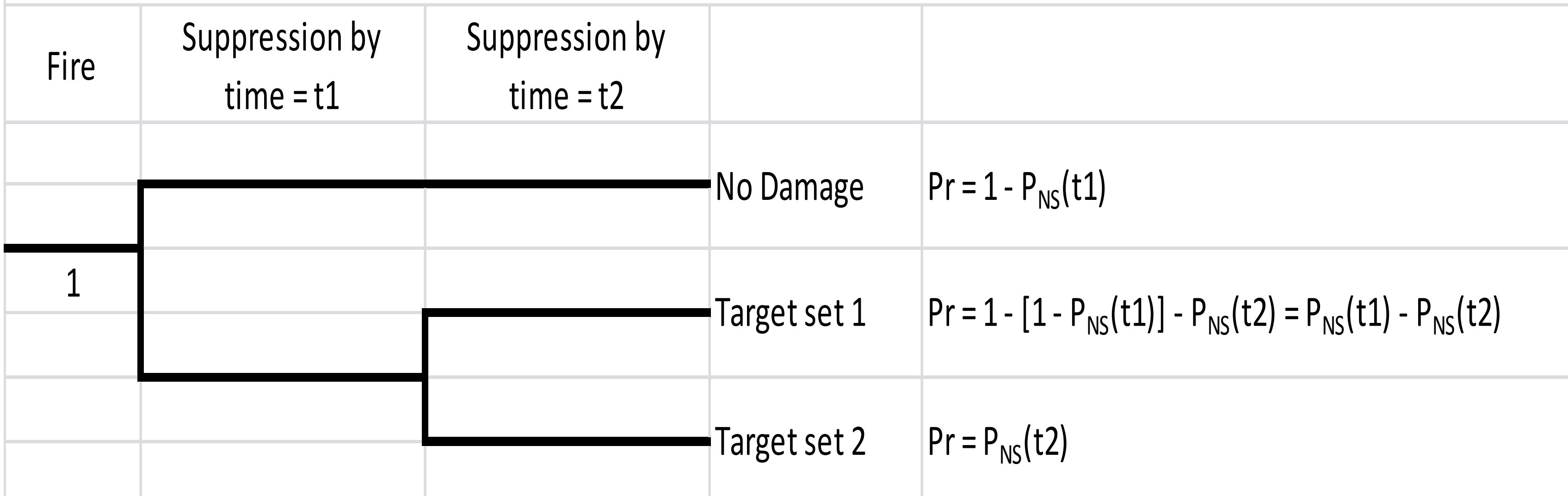
Fire	Suppression by time = t1	Suppression by time = t2		
			No Damage	Probability of suppression within time t1: $Pr = P_S(t1) = 1 - P_{NS}(t1)$
1				
			Target set 1	
			Target set 2	What is the final answer for this branch?

Two-stage example (cont.)



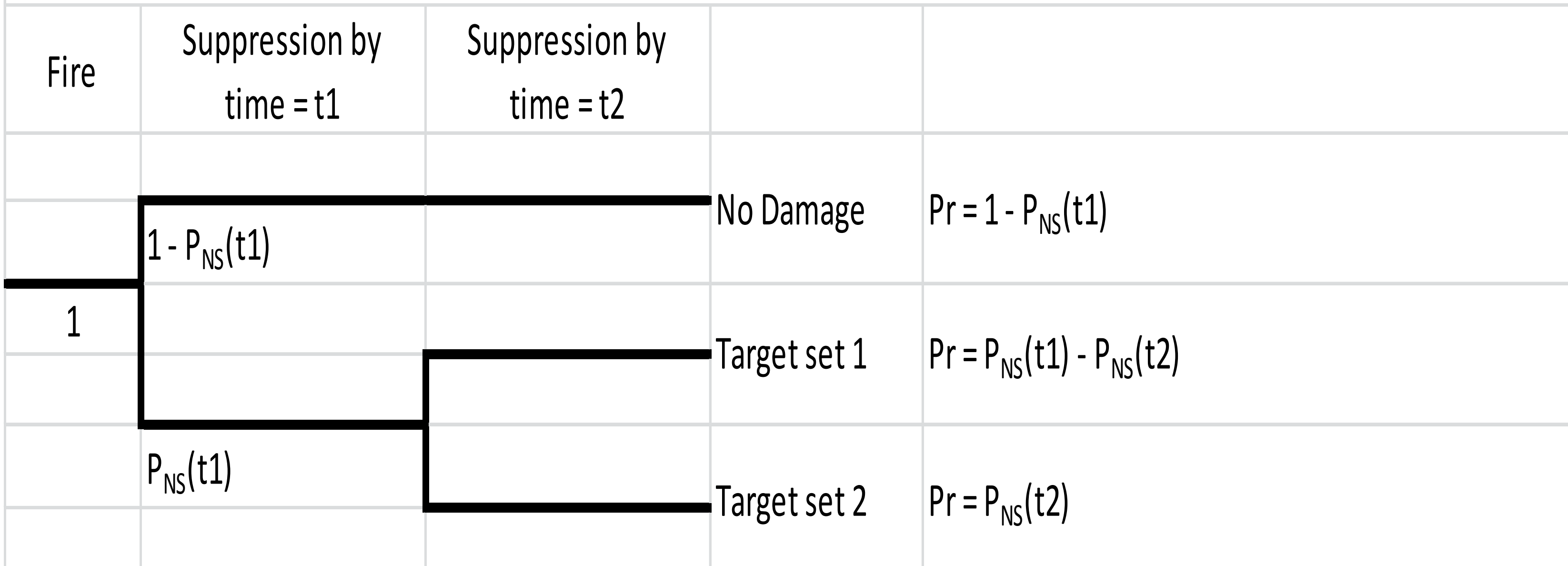
Two-stage example (cont.)

Step 4: Middle branch has to be the residual left over from a total of 1 for all branches:



Two-stage example (cont.)

Step 5: What are branch point values that yeild the known end state probabilities? Fill in known branch points:



Two-stage example (cont.)

Next step is to fill in sencond branch point so end state probability matches when multiplied:				
Fire	Suppression by time = t1	Suppression by time = t2		
	$1 - P_{NS}(t1)$		No Damage	$Pr = 1 - P_{NS}(t1)$
1				
		$1 - [P_{NS}(t2)/P_{NS}(t1)]$	Target set 1	$Pr = P_{NS}(t1) - P_{NS}(t2)$
	$P_{NS}(t1)$		Target set 2	$Pr = P_{NS}(t2)$
		$P_{NS}(t2)/P_{NS}(t1)$		

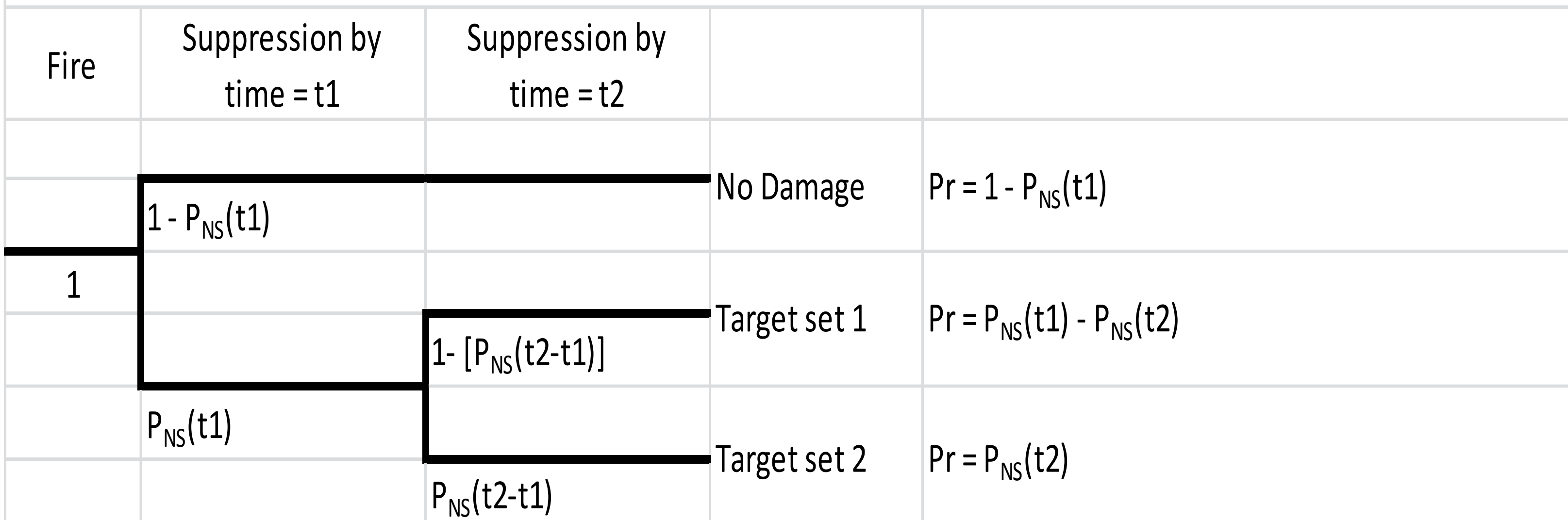
Two-stage example (conclusion)

One final simplification is possible given the behavior of exponentials:

$P_{NS}(t) = e^{-\lambda t}$

so

$P_{NS}(t2)/P_{NS}(t1) = e^{-\lambda t2}/e^{-\lambda t1} = e^{-\lambda(t2-t1)} = P_{NS}(t2\text{-}t1)$



Summary – multi-stage damage states

- The multi-stage damage state approach is a powerful tool
  - Any scenario with multiple targets threatened by the same fire source with discrete damage times
  - The key is some degree of spatial separation between targets
    - Tray stacks
    - Above the fire versus away from the fire
- The more damage stages you develop the more complicated it gets
  - You may need to seek the help of a good statistics person
- Two-to-three discrete states is relatively easy and works for many scenarios
- The event tree approach help
  - Individual end states must be properly weighed
  - Very easy to double count overlapping damage states