Fire Program Analysis

From an ambitious mandate a complex modeling framework emerges

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Disclaimer and thanks

- What follows is my perspective, unedited and unsanctioned, based on 10 months of interactions with FPA and my California perspective on fire management
- The best slides were contributed by Mark Finney, Danny Lee, and Don Carlton, based on their work– I'm grateful!

Impetus for FPA

- Rapidly increasing fire expenditures screamed out for justification
  - Area burned/yr has not changed much, but expenditures doubled in just a few years
- Existing models were unrealistic and looked under the lamp-post
- Landscape-scale fuel treatment paradigm needs to be worked into economic analysis
- GAO mandated one federal model

Concerns from Washington

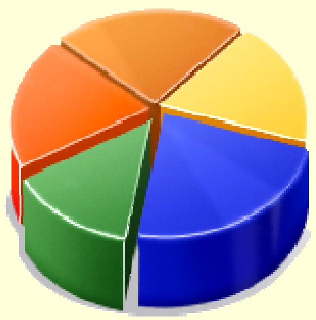
- Growing annual suppression costs for large fires
- Fires that occur and cause significant damage within the wildland-urban interface
- Fires that cause severe impacts to highly valued resources
- Prevention and suppression of unwanted and unplanned fires
- Attaining fire and fuels management objectives on federal lands

What is FPA?

- Vital statistics
  - Began in 2002
  - Staff consisted of a couple of dozen “domain experts”, trainers, database and GIS folk, and support personnel
  - Staff included no scientists or proven modelers
  - A sizeable, multi-year contract with IBM for programming and analysis support
  - One professor contracted to provide guidance
  - Until very recently, management/oversight was slight considering the scope of this project
- Mission: Develop a modeling framework to support budget analysis of the federal fire program across agencies, locations and components

A universal field theory of fire

- Program components
  - Preparedness (initial attack)
  - Suppression (large fire)
  - Fuels Management
  - Prevention
  - Rehabilitation



- Ambition: a model that optimally allocates a national fire budget among these programs, among regions and agencies
- Hubris: claiming to optimize this complexity

Consequences

- Budget expended (25 to 50 million $)
- Model considered DOA by field managers
  - Also, science and management reviews were critical
- Problem not solved, fire expenditures still rising
- Powers-that-be were ready to pull the plug
- What could possibly be salvaged?
  - Database assembly effort was laudable
  - But a new engine was needed,
  - and a larger and more diverse brain trust...

Interagency Science Team (to the rescue)

Forest Service R&D

- Danny Lee, **Southern Research Station, Asheville, NC,** IST Co-Lead
- Michael Bevers, **Rocky Mountain Research Station, Fort Collins, CO**
- Mark Finney, **Rocky Mountain Research Station, Missoula, MT**
- Jeremy Fried, **Pacific Northwest Research Station, Portland, OR**
- Miles Hemstrom, **Pacific Northwest Research Station, Portland, OR**
- Keith Reynolds, **Pacific Northwest Research Station, Portland, OR**

Contractors

- Steven Carty, **IBM, Boulder, CO**
- George Willis, **IBM, Boise, ID**
- Thomas Quigley, **METI, Saratoga Springs, UT,** IST Advisor and Facilitator

US Geological Survey

- Jack Waide, **Biological Resources Discipline, Reston, VA,** IST Co-Lead
- Bill Labiosa, **Western Geographic Science Center, Menlo Park, CA**
- James Vogelmann, **EROS Data Center, Sioux Falls, SD**
- Anne Wein, **Western Geographic Science Center, Menlo Park, CA**

Universities

- Doug Rideout, **Colorado State University, Fort Collins, CO**
- John Sessions, **Oregon State University, Corvallis, OR**

IST Charge and Operation

- The Interagency Science Team was charged to:
  - Develop a detailed recommendation for a global architecture or conceptual structure to guide Phase II development
  - Address "a common interagency planning and budget information system, with a cost-effective trade-off analysis incorporating land and resource management objectives" (Hubbard and others, 2001)

- The Interagency Science Team
  - Reached consensus on this product
  - Some now work with the FPA Development Team

FPA “Criteria for Success”

- ☑ Full scope of fire management activities/AMR
- ☑ Assess trade-offs among major program components
- ☑ Performance-based measures of attainment of “national” and “resource” objectives
- ☑ Temporal dimension (fuels mgt, resource status)
- ☑ Cost-effectiveness over a range of budget strategies
- ☑ Appropriate scale (National, FPU, shared resources, interagency)
- ☑ Based on sound science – validated/peer reviewed
- ☑ Provide for state involvement
- ☑ Fully spatial (seen as shortcut for generating model inputs)

A new hope

- Economic, Effectiveness and Performance crtieria (EEPs) developed
  - Probability of costly fires
  - Probability of costly fires within the WUI
  - Proportion of land meeting or trending towards meeting fire and fuels management objectives
  - Proportion of highly valued resources areas with a high probability of a costly fire
  - Initial attack success rate
- Ideal model would output these for any scenario
- Devil in the details, thresholds, definitions, etc.

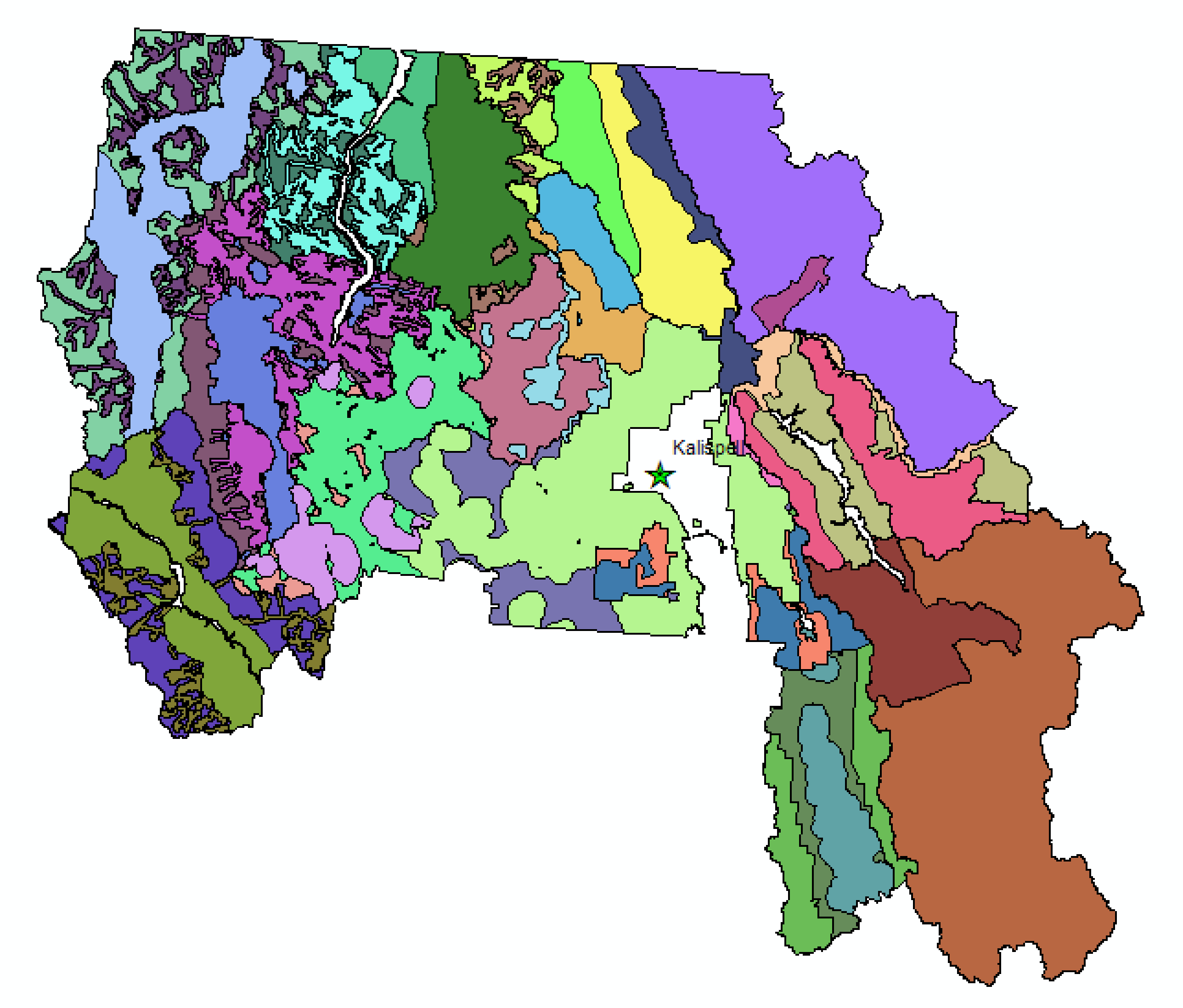
Managers want to know

- Where- wildland/WUI, values at risk?
- When- frequency, time of year, duration?
- How- natural or human-caused?
- Why- escaped due to weather, resources?
- What- intensity, fire effects, prescribed/wild?
- Standard errors- are scenarios/solutions really different?

Out with the old...

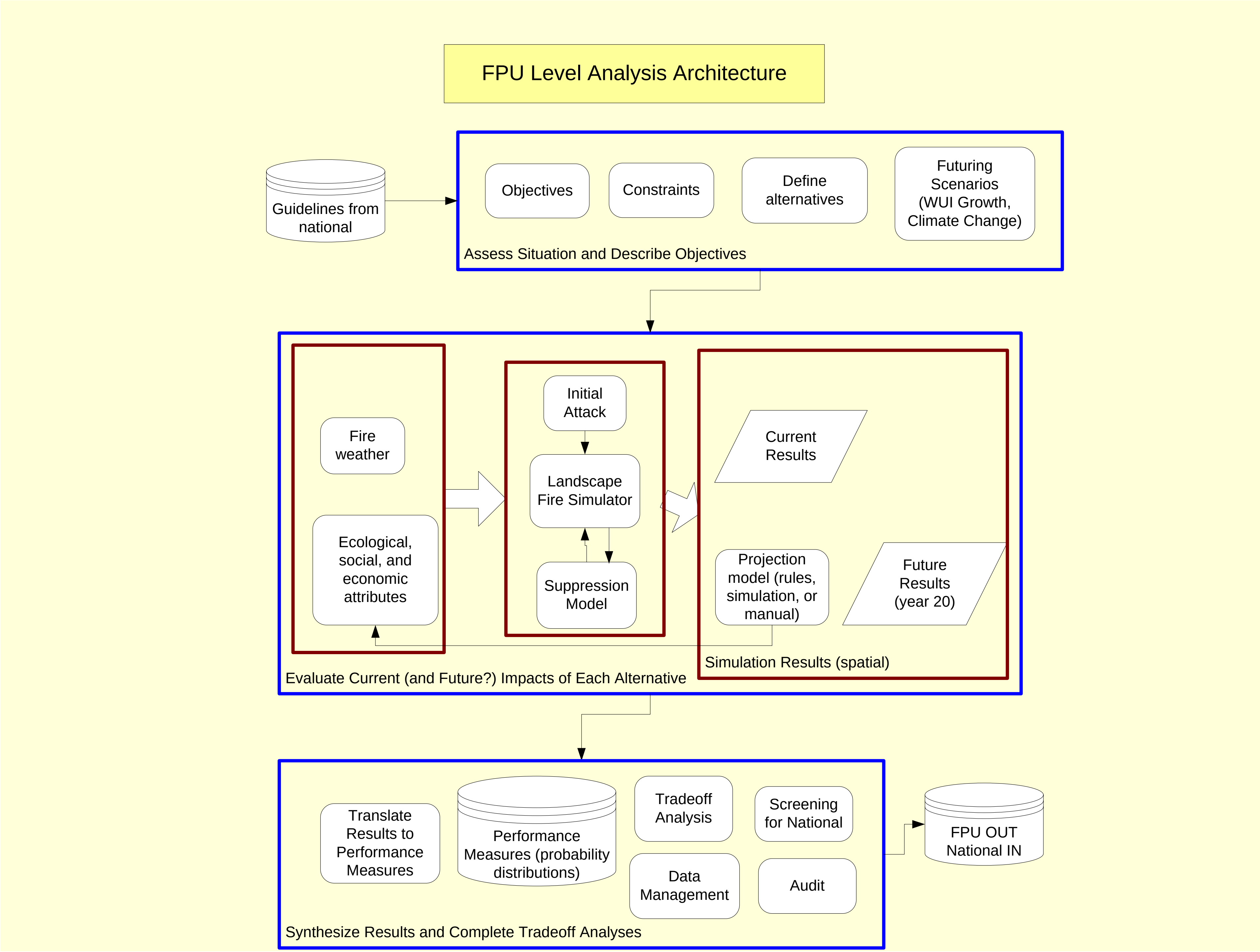
- IST consensus: Replace optimization with simulation
- This was not easy due to concerns about
  - gaming behavior by those assembling parameters
  - how to objectively select “best”
  - organizational inertia/reluctance to write off sunk cost of the preparedness module (PM)
- Most other concepts/databases retained
  - FPU (fire planning unit)
  - FMU (fire management unit)
  - WP (Workload Point)
  - PCHA (PC Historical fire Analysis)

NW Montana FPU showing FMUs



... and in with the new

- IST recommendation for “Phase II” architecture
  - Reliance on simulation
  - Split focus: national and FPU models/requirements
  - Back to the drawing boards for preparedness
  - Extension to address large fires, costs, and three program components
    - Preparedness/initial attack
    - Suppression
    - Fuels management

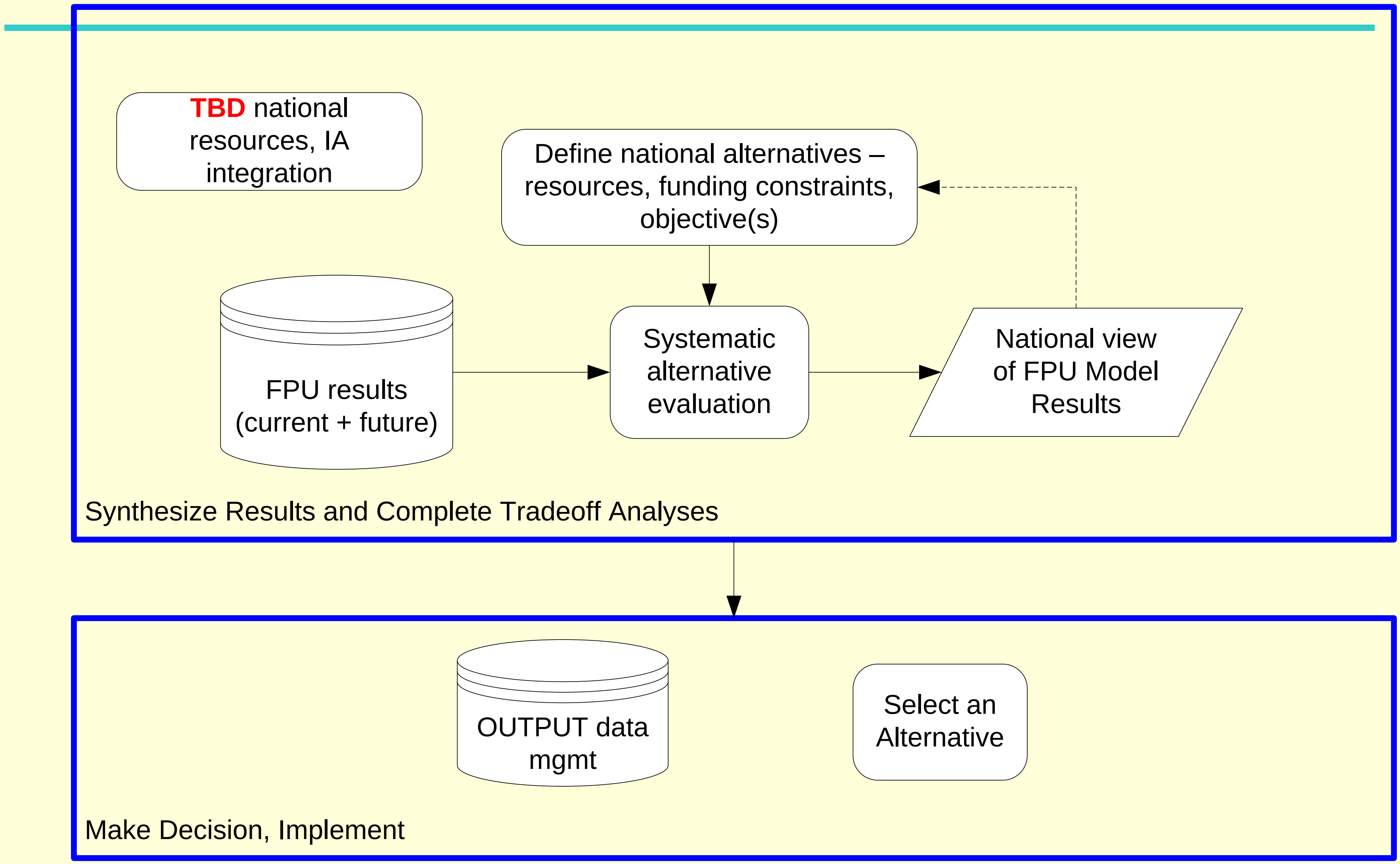


FPU Level Analysis Architecture
Guidelines from national
Objectives
Constraints
Define alternatives
Futuring Scenarios (WUI Growth, Climate Change)
Assess Situation and Describe Objectives
Fire weather
Ecological, social, and economic attributes
Initial Attack
Landscape Fire Simulator
Suppression Model
Current Results
Projection model (rules, simulation, or manual)
Future Results (year 20)
Simulation Results (spatial)
Evaluate Current (and Future?) Impacts of Each Alternative
Translate Results to Performance Measures
Performance Measures (probability distributions)
Tradeoff Analysis
Screening for National
Data Management
Audit
Synthesize Results and Complete Tradeoff Analyses
FPU OUT National IN

Overview of FPU Level

- Purpose of FPU Level Analyses
  - Inform FPU decisions regarding potential fire program distributions
  - Explore range of management options at various budget levels
  - Explore alternative distributions of budget among program components for a given budget level
- FPU-level analysis involves
  - Detailed simulation module
  - Decision support, data synthesis, and management
- Why simulation?
  - Highly flexible; capable of realistic representation of processes
  - Better equipped to account for variability in weather, topography, vegetation, firefighting strategy, etc. that influence fire outcomes
  - Better addresses impacts on spatially distributed resource values and other performance measures

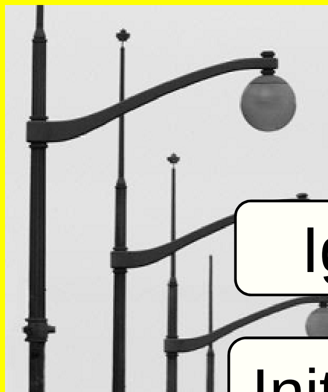
National Level Analysis Architecture



National Decision Tools

- Search among the alternatives
- Evaluate trade-offs
- Weigh performance measures differently
- Explicitly address risk and uncertainty
- Synthesize detailed FPU level simulations of consequences of different fire program investments
- Reveal the structure of the decision space
- Reveal consequences of alternative allocation strategies
- Quantify economic, effectiveness, and performance measures

Looking under the lamppost



Ignitions ← Prevention

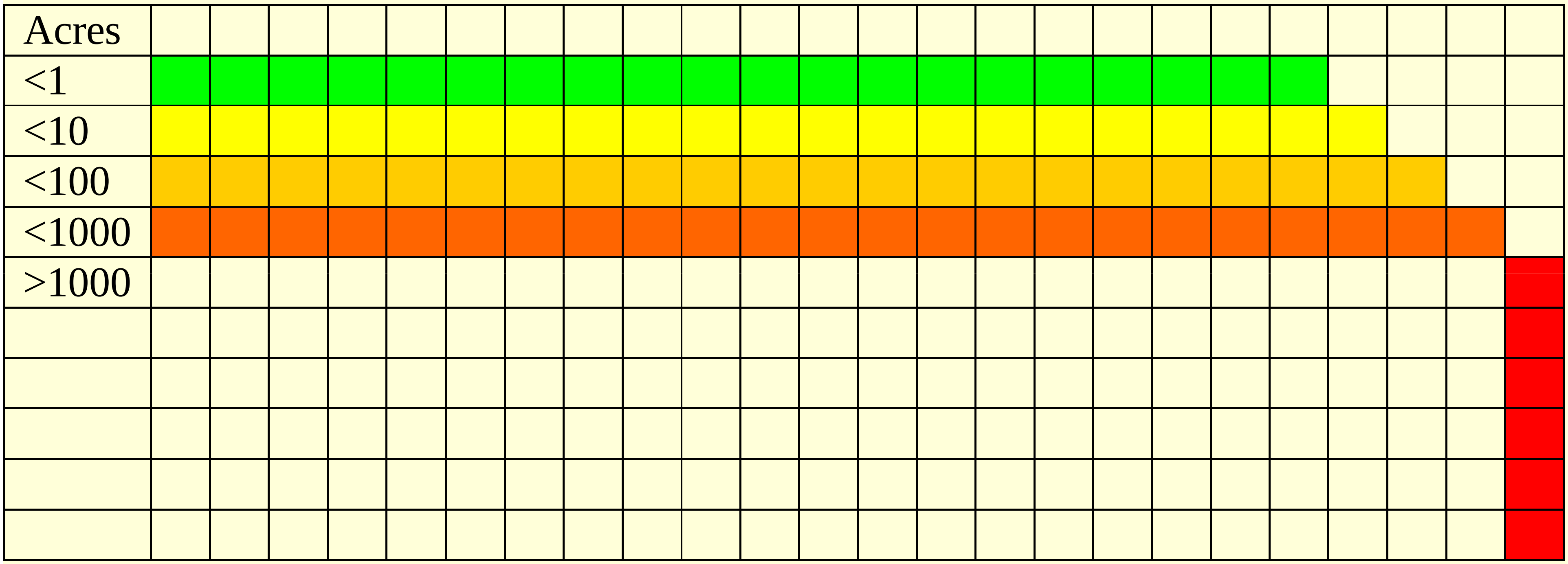
Initial attack ← Preparedness

Large Fires ← Suppression, Fuels Management

- Large Fire Costs
- Large Fire Consequences

← Rehabilitation

Initial attack model filters out the small fires; still need to model large fires



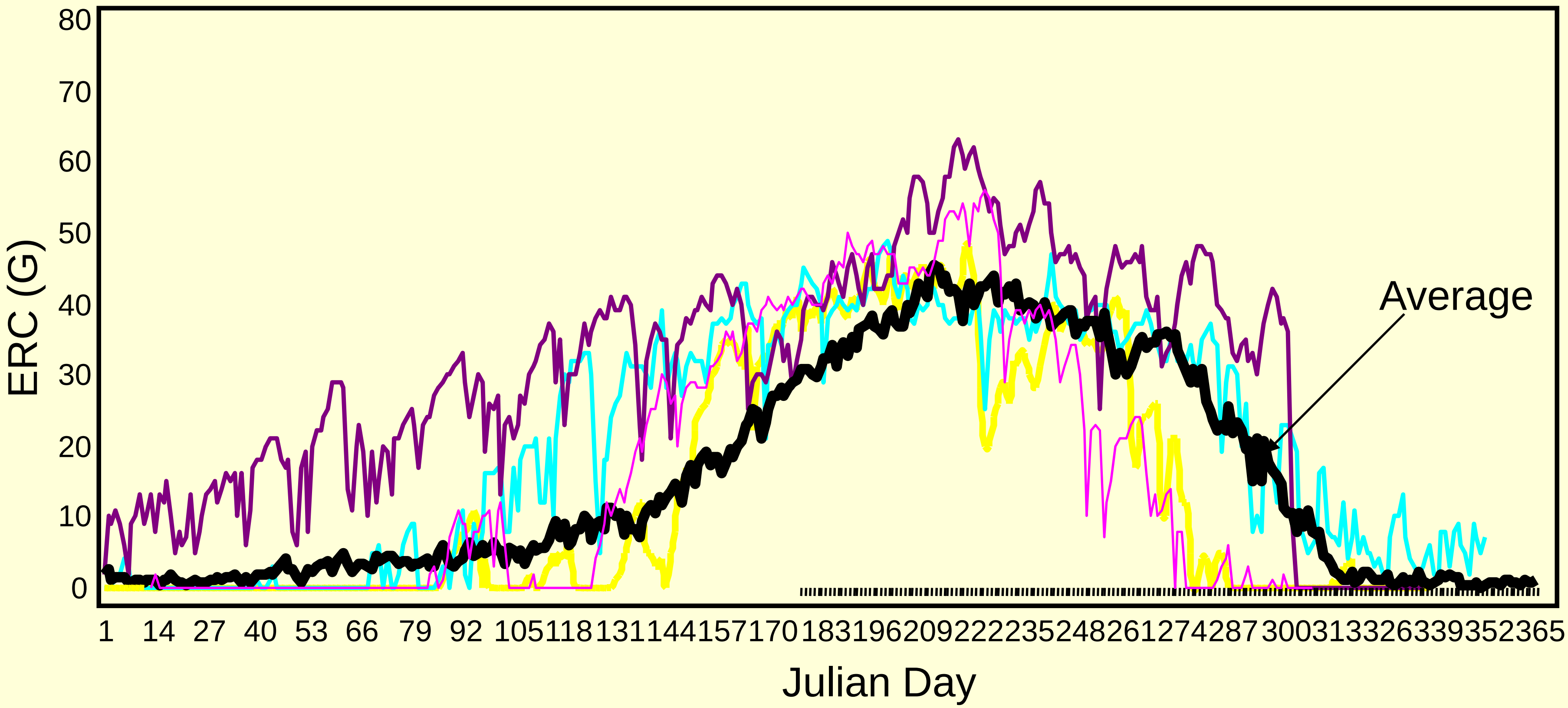
FPA/IRS (Initial Response Simulator)

- Adapted California Fire Economics Simulator (CFES)
- Containment algorithm source code ported directly
  - Line-building affects future fire growth
- Clock-driven, event-based, stochastic simulation
- Option to link incidence and fire behavior
- Outputs
  - Escapes (mean, 95th %ile, etc) addresses 1 EEP directly
  - Utilization of firefighting resources also useful
  - Area burned by contained fires comparatively minor
- Status: IBM completing PC and server beta versions

Weather analysis → behavior, incidence

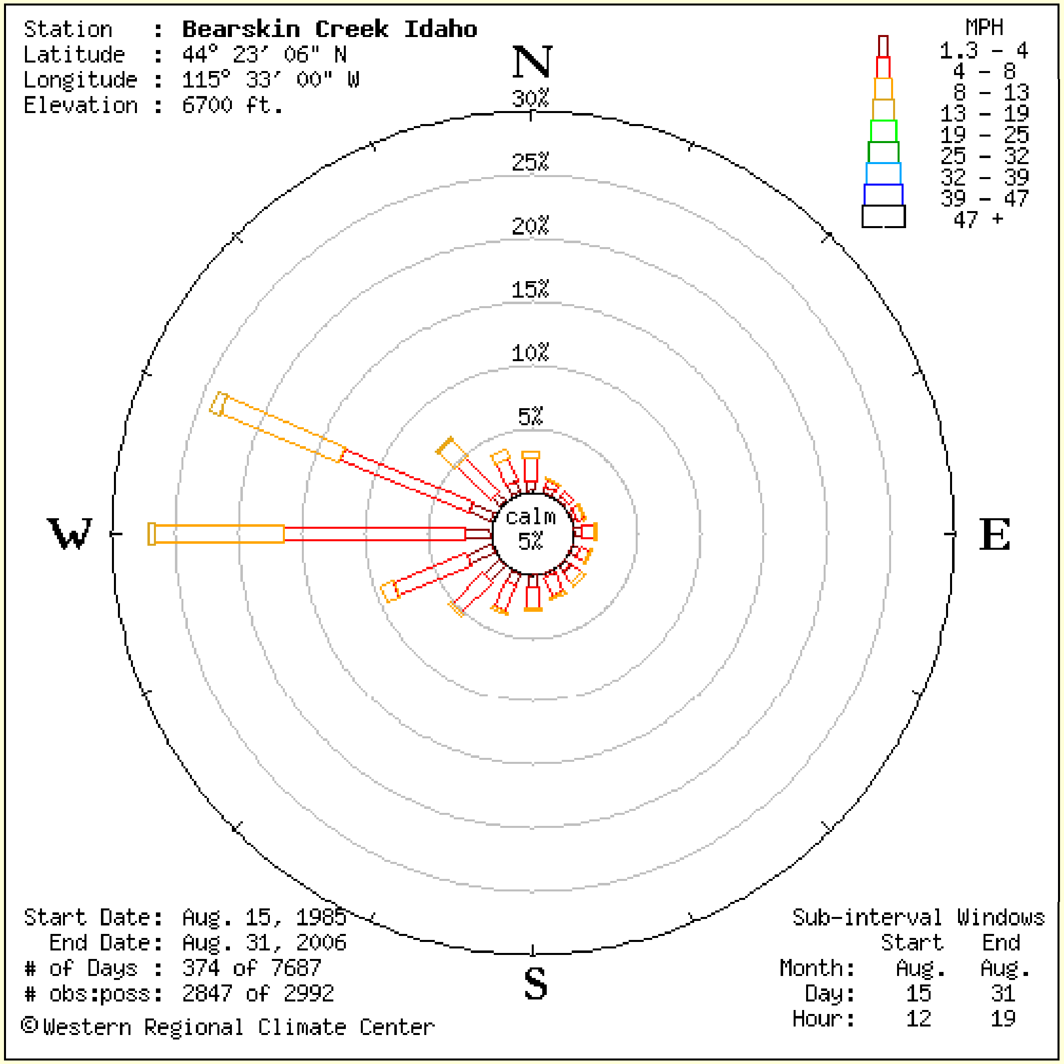
- Use ERC (Energy Release Component) from NFDRS as proxy for fuel moisture
- Changes in ERC are only sensitive to moisture content (not wind or slope)
- Time-series analysis of ERC observations
  - Trend (fitted to average ERC daily values)
  - Average autocorrelation (30+ days)
  - Daily standard deviation
- Generate artificial ERC scenarios for each year to be modeled

Energy Release Component generated via time series analysis



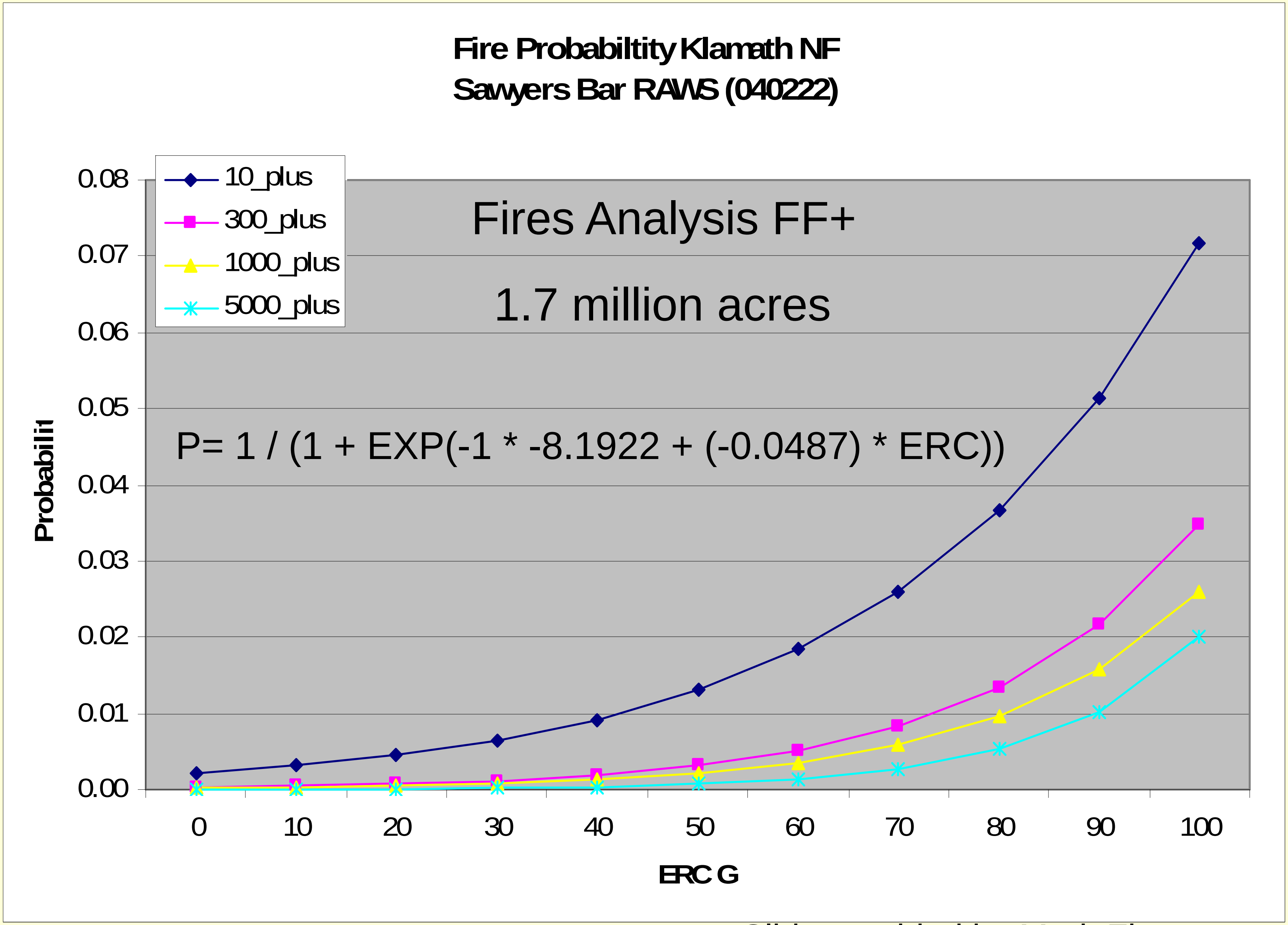
Slide provided by Mark Finney

Wind speed, direction from historical observations



- ERC + Wind + Slope → behavior (ROS)
- ERC can also be basis for predicting fire incidence
- Combine info on next two figures to generate fire sequence

Graphic provided by Mark Finney



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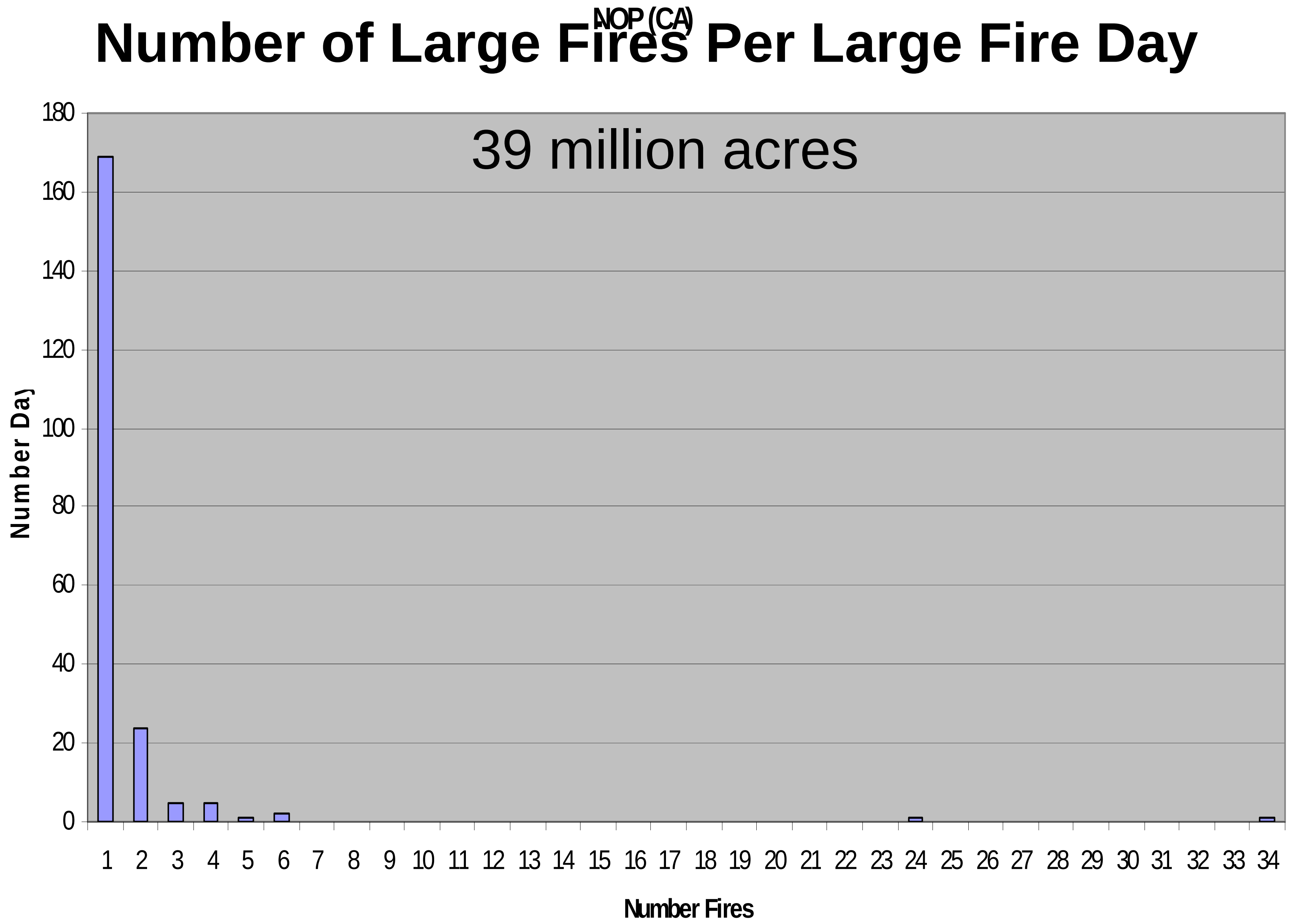
Number of Large Fires Per Large Fire Day



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Large Fire Module

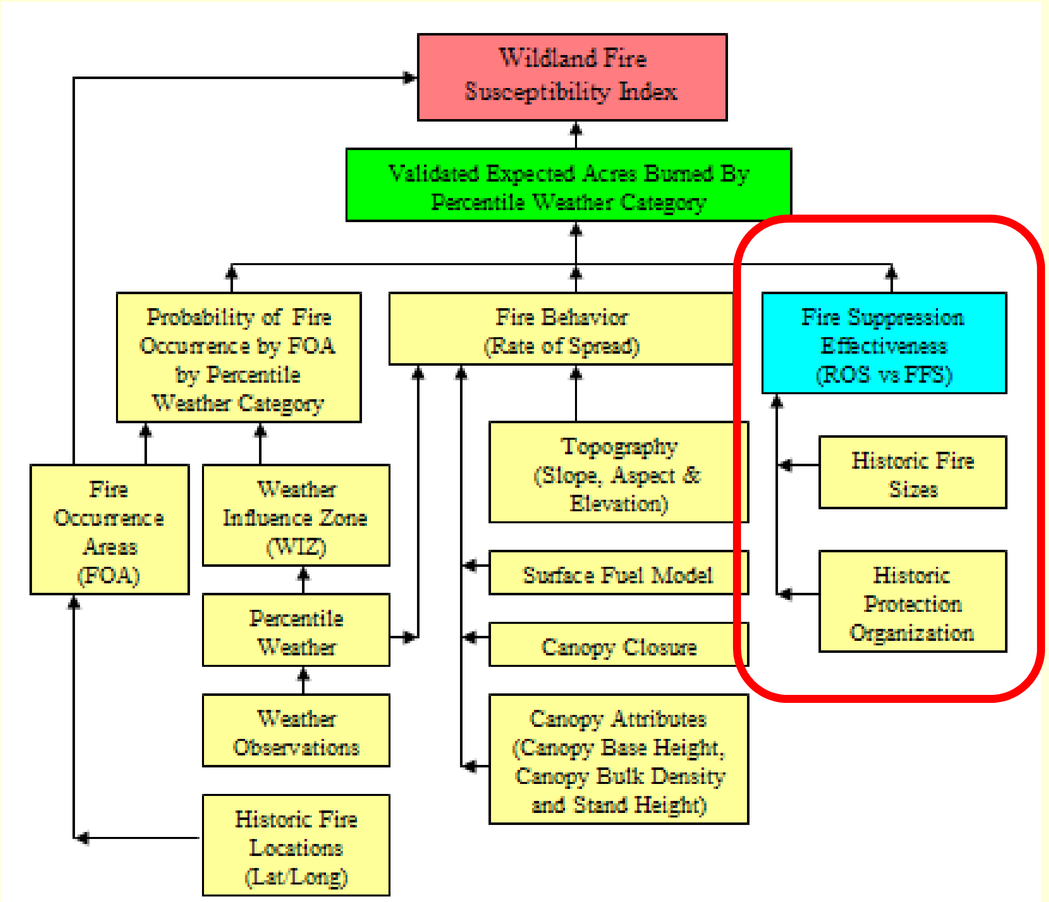
The 6.4 billion dollar question:

What is the outcome of fires that escape initial attack?

Evaluating three approaches

- WFSI/LFI – Don Carlton's non-spatial, stratification and binning based approach
  - Relies on final fire size (FFS) to rate of spread (ROS) relationship
- FSpro fire event simulation – Mark Finney
  - Exhaustive, spatially explicit simulation of thousands of realizations of fire years
- BDN/FSpro hybrid – Mark Finney & Danny Lee
  - Run simulations that span the decision space, then build Baysian Decision Network to support decisions and facilitate experimentation

Wildland Fire Susceptibility Index (with thanks to Don Carlton)



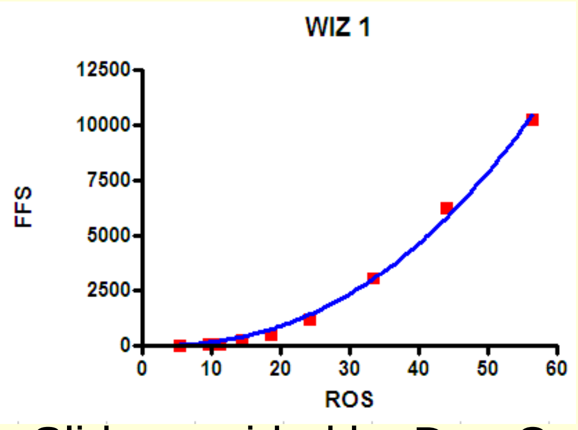
- a.k.a. WFSI
- Also Large Fire Index based on relationship between rate of spread and final fire size for fires larger than a specified size

Slide provided by Don Carlton

Deriving the Final Fire Size to ROS Relationship

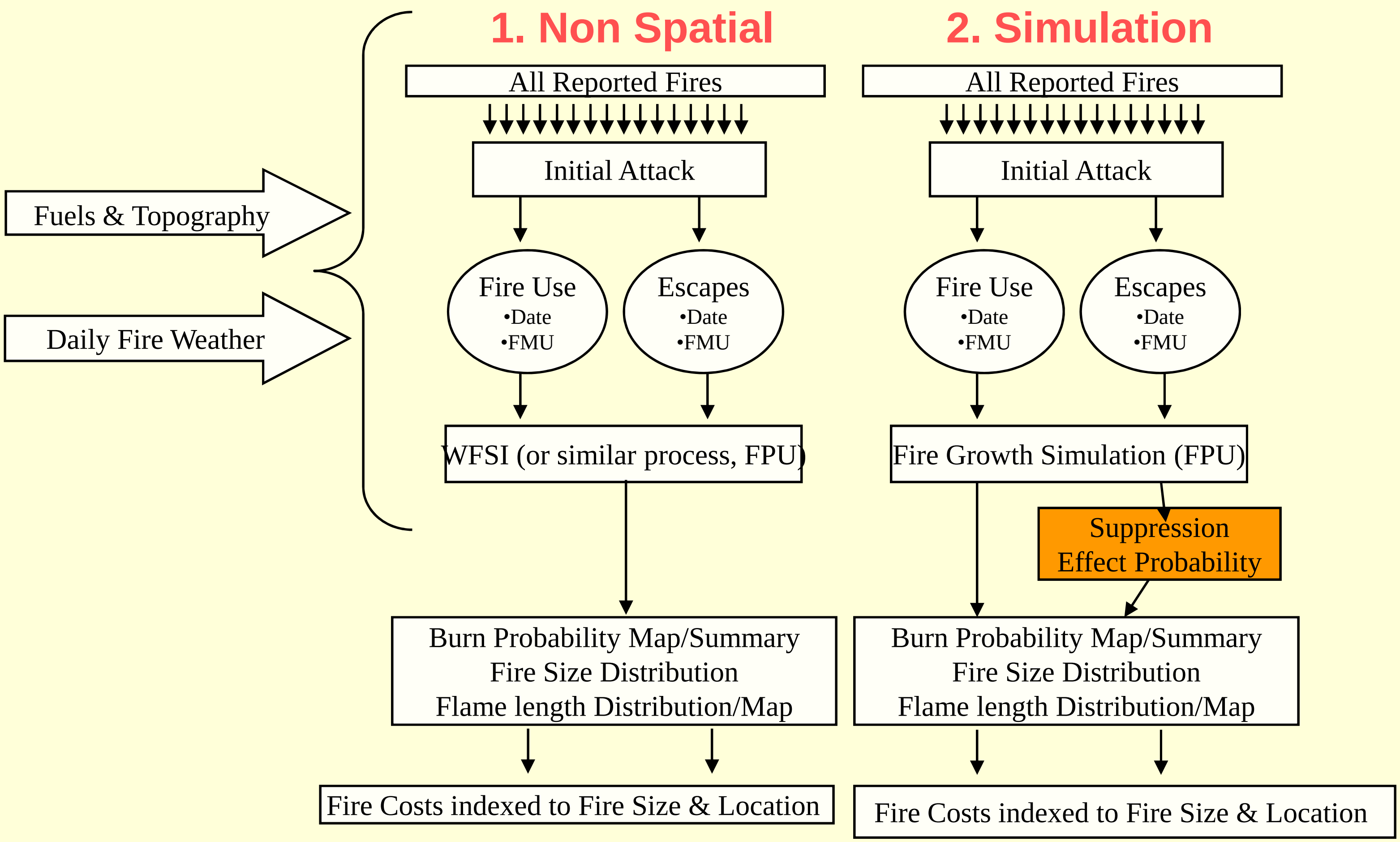
								0.30	0.30	Calc		3.0				Avg	Avg	Avg	
Disc_Date	Disc-Time	C/C	Ctrl-Date	Ctrl-Time	E-Min	E-Hrs	E-Days	C-Ftr	SD-Ftr	S-Days	S-Days	Burn-Hrs	Size	MD		Acres	E-Hrs	E-Days	Comments
8/11/2000	10:00	2	9/13/2000	16:00	47,880	798.0	34.0	0.3	0.3	3.1	3.1	9.2	11,115.0						STONE HILL
8/11/2000	13:00	2	9/25/2000	18:00	65,100	1085.0	46.0	0.3	0.3	4.1	4.0	12.0	9,423.0			10,269	10.6	40.0	UPPER BEAVER
8/10/2000	23:00	2	9/13/2000	16:00	48,540	809.0	35.0	0.3	0.3	3.2	3.2	9.5	6,660.0						CLIFF POINT
8/11/2000	15:00	2	9/13/2000	16:00	47,580	793.0	34.0	0.3	0.3	3.1	3.1	9.2	5,895.0			6,278	9.3	34.5	LYDIA MTN.
9/2/1998	13:30	2	9/22/1998	22:00	29,310	488.5	21.0	0.3	0.3	1.9	3.0	9.0	3,340.0						DOME
8/11/2000	9:00	2	9/6/2000	18:00	37,980	633.0	27.0	0.3	0.3	2.4	3.0	9.0	2,768.0			3,054	9.0	24.0	KELSEY CREEK
8/10/2000	22:00	2	9/20/2000	18:00	58,800	980.0	42.0	0.3	0.3	3.8	4.0	12.0	1,311.0						TAYLOR PEAK
9/3/1998	12:21	2	9/13/1998	18:00	14,739	245.7	11.0	0.3	0.3	1.0	1.1	3.3	1,060.0			1,186	7.7	26.5	KOPSI
8/12/2000	14:00	2	9/1/2000	16:00	28,920	482.0	21.0	0.3	0.3	1.9	1.9	5.7	875.0						YOUNG J
8/10/2000	22:05	2	8/20/2000	18:00	14,155	235.9	11.0	0.3	0.3	1.0	2.0	6.0	794.0						GRAMBAUER FACE
8/11/2000	11:00	2	9/13/2000	16:00	47,820	797.0	34.0	0.3	0.3	3.1	3.1	9.2	785.0						FAN CREEK
8/15/2000	11:00	2	9/1/2000	16:00	24,780	413.0	18.0	0.3	0.3	1.6	1.6	4.9	635.0						LOOP L.N.F.
8/11/2000	8:04	2	8/29/2000	19:00	26,576	442.9	19.0	0.3	0.3	1.7	1.7	5.1	510.0						GREEN MOUNTAIN
8/12/2000	10:00	2	9/12/2000	18:00	45,120	752.0	32.0	0.3	0.3	2.9	2.0	6.0	454.0						OKAGA
8/11/2000	14:00	2	9/6/2000	18:00	37,680	628.0	27.0	0.3	0.3	2.4	2.0	6.0	423.0						LUCKY POINT
8/11/2000	12:00	2	9/20/2000	18:00	57,960	966.0	41.0	0.3	0.3	3.7	1.1	3.3	423.0			489	5.1	27.4	RUNT
5/30/1995	14:15	2	6/2/1995	18:00	4,545	75.8	4.0	0.3	0.3	0.4	1.1	3.3	395.0						S.fk. Bull River.
8/11/2000	6:00	2	8/25/2000	19:00	20,940	349.0	15.0	0.3	0.3	1.4	2.0	6.0	317.0						RODERICK SOUTH
8/11/2000	9:00	2	9/20/2000	18:00	58,140	969.0	41.0	0.3	0.3	3.7	2.0	6.0	274.0						FEEDER MOUNTAIN 2
8/11/2000	17:00	2	9/20/2000	18:00	57,660	961.0	41.0	0.3	0.3	3.7	1.1	3.3	236.0						PROSPECT
8/11/2000	8:00	2	9/5/2000	18:00	36,600	610.0	26.0	0.3	0.3	2.3	1.1	3.3	229.0						KEDZIE CREEK
8/11/2000	6:00	2	9/10/2000	18:00	43,920	732.0	31.0	0.3	0.3	2.8	2.8	8.4	226.0						OBRIEN
8/17/2000	8:00	2	8/30/2000	8:00	18,720	312.0	14.0	0.3	0.3	1.3	1.3	3.8	225.0			238	5.0	30.6	ENGLE

ROS (ch/hr)	Size (Acres)	EWS (mph)	Time Hours	
5.3	10	2.0	2.0	3.4
9.6	52	2.0	2.5	3.3
11.2	95	4.0	3.4	3.4
14.4	238	5.0	4.5	5.0
18.6	489	5.0	5.0	5.1
24.1	1186	5.0	6.0	7.7
33.4	3054	7.0	8.0	9.0
44.1	6278	8.0	9.3	9.3
56.4	10269	10.0	10.6	10.6



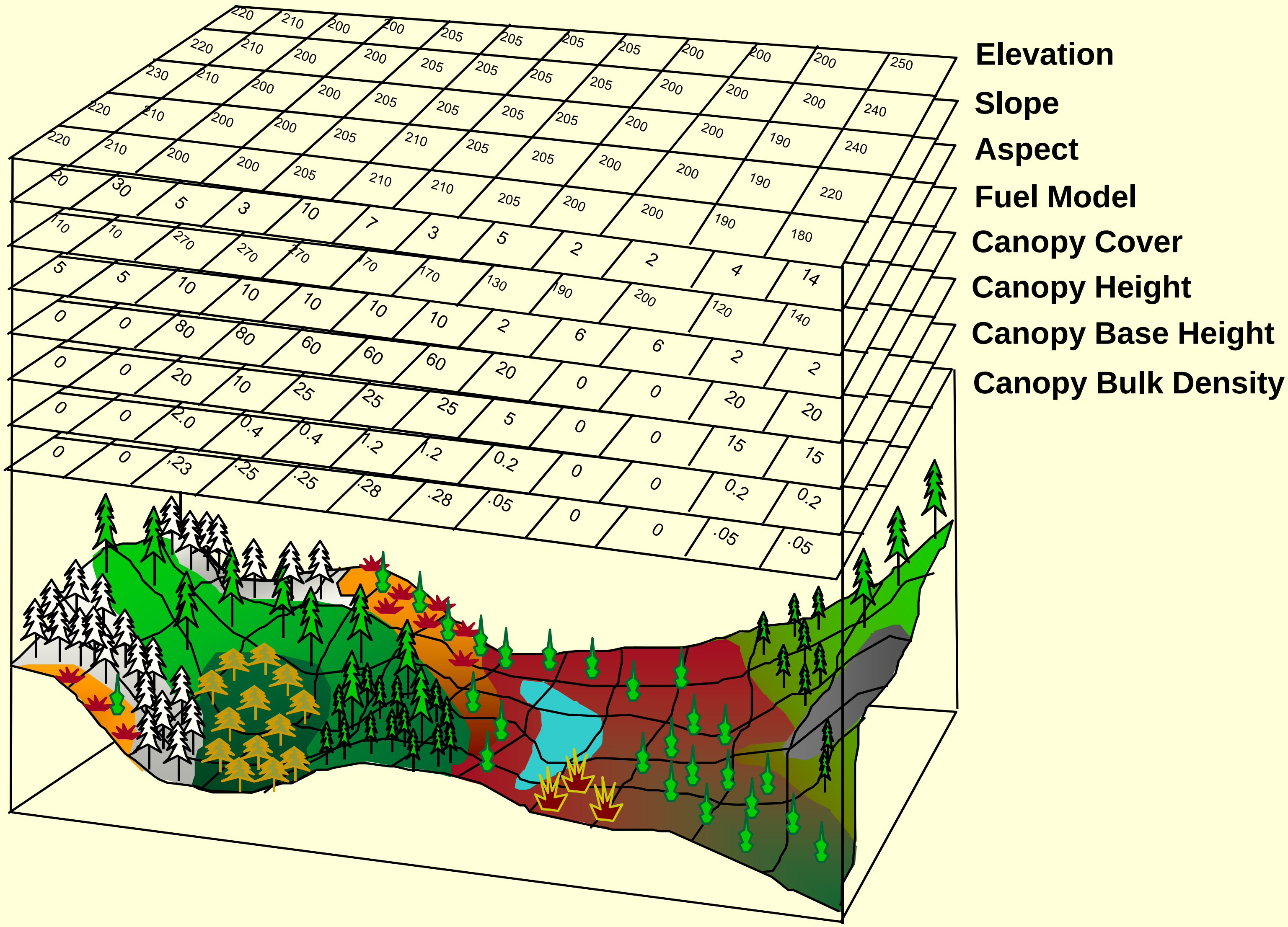
Slide provided by Don Carlton

The Finney simulation alternative



Big difference: Simulation can predict FFS with and without suppression

Fuels and Topography



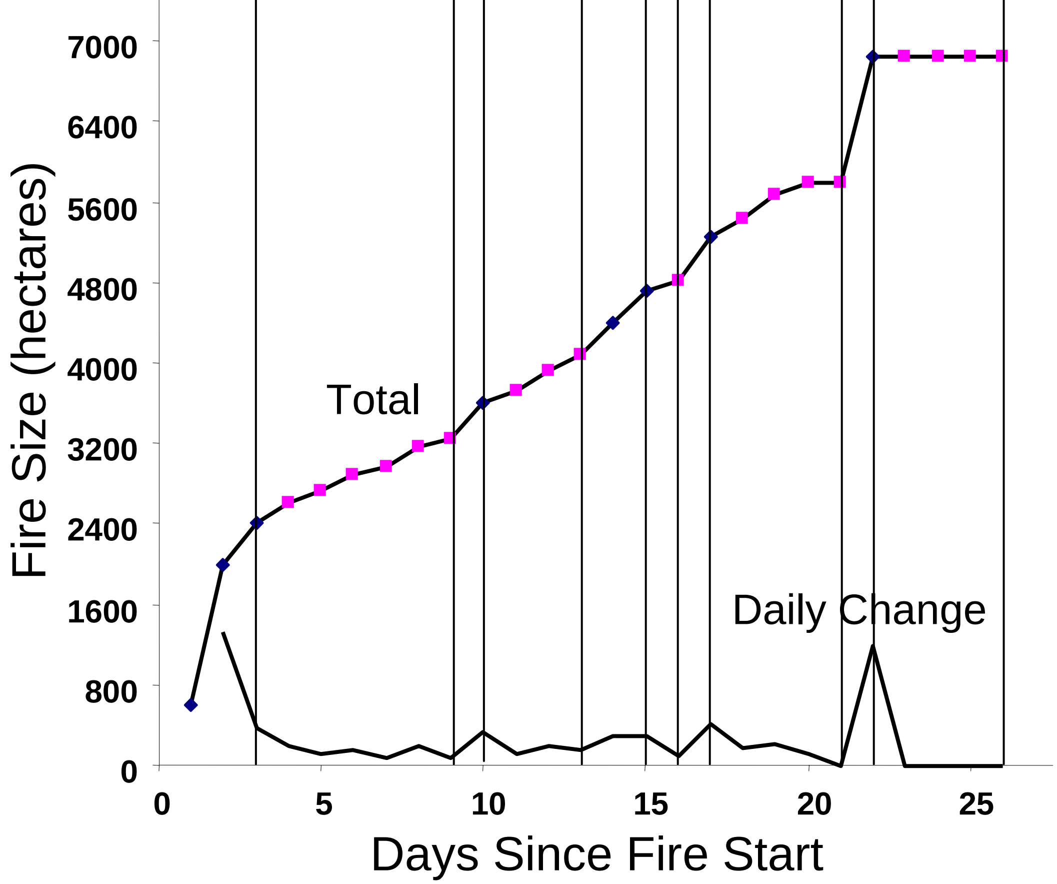
Large Fire Simulation

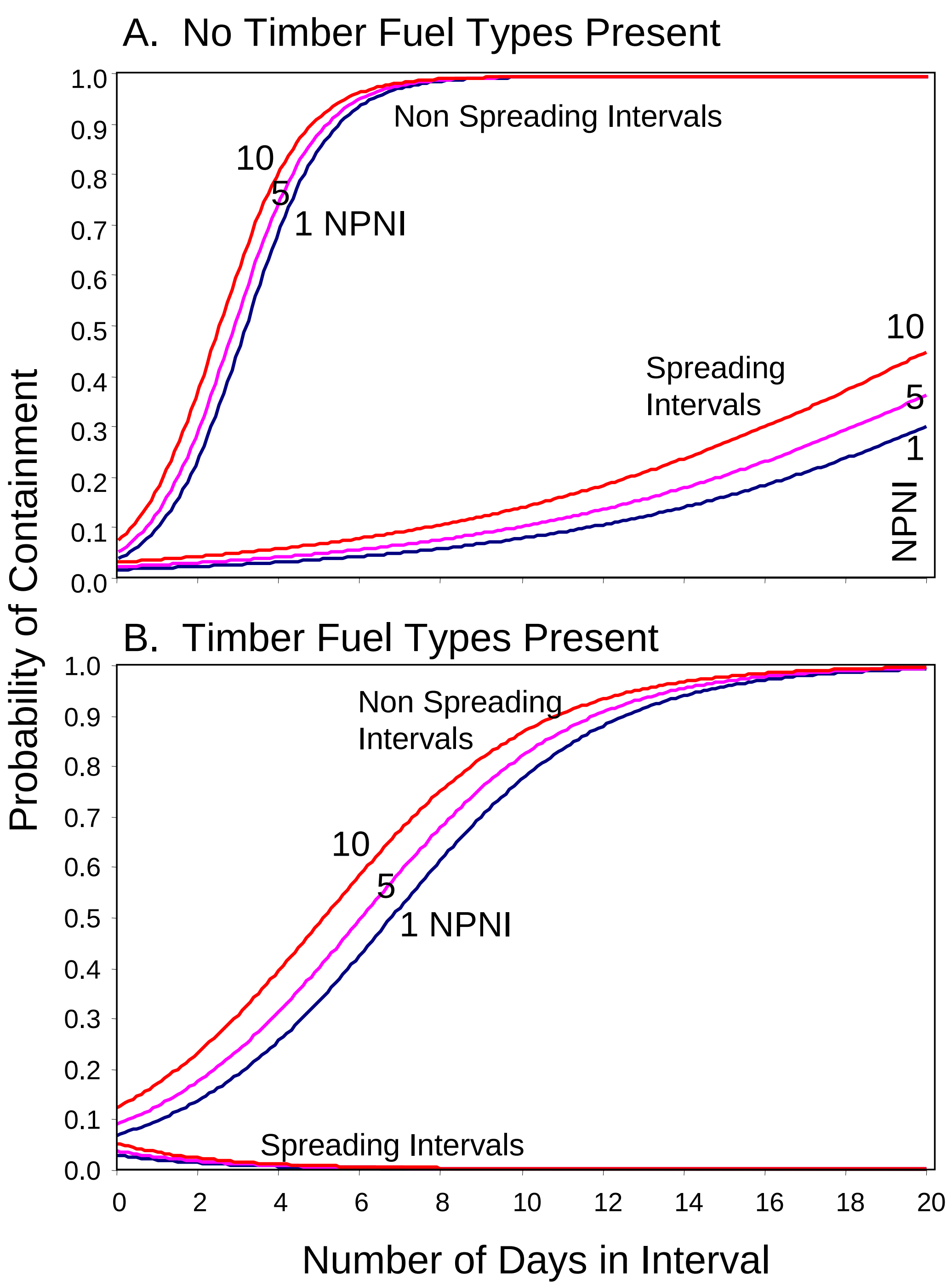
- For each fire that exceeds simulation limits
  - Use ERC, wind info from FPA/IRS
  - Ignite fires at hundreds of points in the landscape consistent with the representation in IRS
  - If not attacked (WFU), grow to end of season
  - Else grow for stochastically generated period
    - Growth period determined from ERC/wind stream and statistical relationship fit to historical large fire data

Suppression Effects

- Raw ICS-209 data used for analysis
- Analysis showing large fire survival probability
  - Number of days between fire growing events
  - Number of previous opportunities
  - Spreading or not spreading
  - Fuel type (presence of timber)

spreading	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**0**
ndays	**3**	**6**	**1**	**3**	**2**	**1**	**1**	**4**	**1**	**4**
npni	**0**	**0**	**1**	**1**	**2**	**2**	**3**	**3**	**4**	**4**
grass	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
brush	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
tmber	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
contained	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**





A. No Timber Fuel Types Present
Non Spreading Intervals
10
5
1 NPNI
Spreading
Intervals
10
5
1
NPNI
B. Timber Fuel Types Present
Non Spreading
Intervals
10
5
1 NPNI
Spreading Intervals
Probability of Containment
Number of Days in Interval
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
2
4
6
8
10
12
14
16
18
20

Danny Lee's BDN/FSpro Hybrid

- Spread (sqrt of final fire size) = **f(**
  - Days (burn period) and $Days^2$
  - Weather (scaled index of weather intensity)
  - Location (location-inherent spread potential)
  - Treat (Percent of landscape treated) **)**
- Statistical model fit to 14000 escape fires generated by Finney for northwest Montana in FSpro under 5 treatment scenarios

Model 4: Spread = Days Weather Location Treatment

The GENMOD Procedure

Model Information

Data Set	FPA.MODEL_4	Predicted Values and Diagnostic Statistics
Distribution	Poisson	
Link Function	Log	
Dependent Variable	spread	

Number of Observations Read	13670
Number of Observations Used	13670

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	14E3	8857.6198	0.6482
Scaled Deviance	14E3	8857.6198	0.6482
Pearson Chi-Square	14E3	8534.9388	0.6246
Scaled Pearson X2	14E3	8534.9388	0.6246
Log Likelihood		56952.6392	

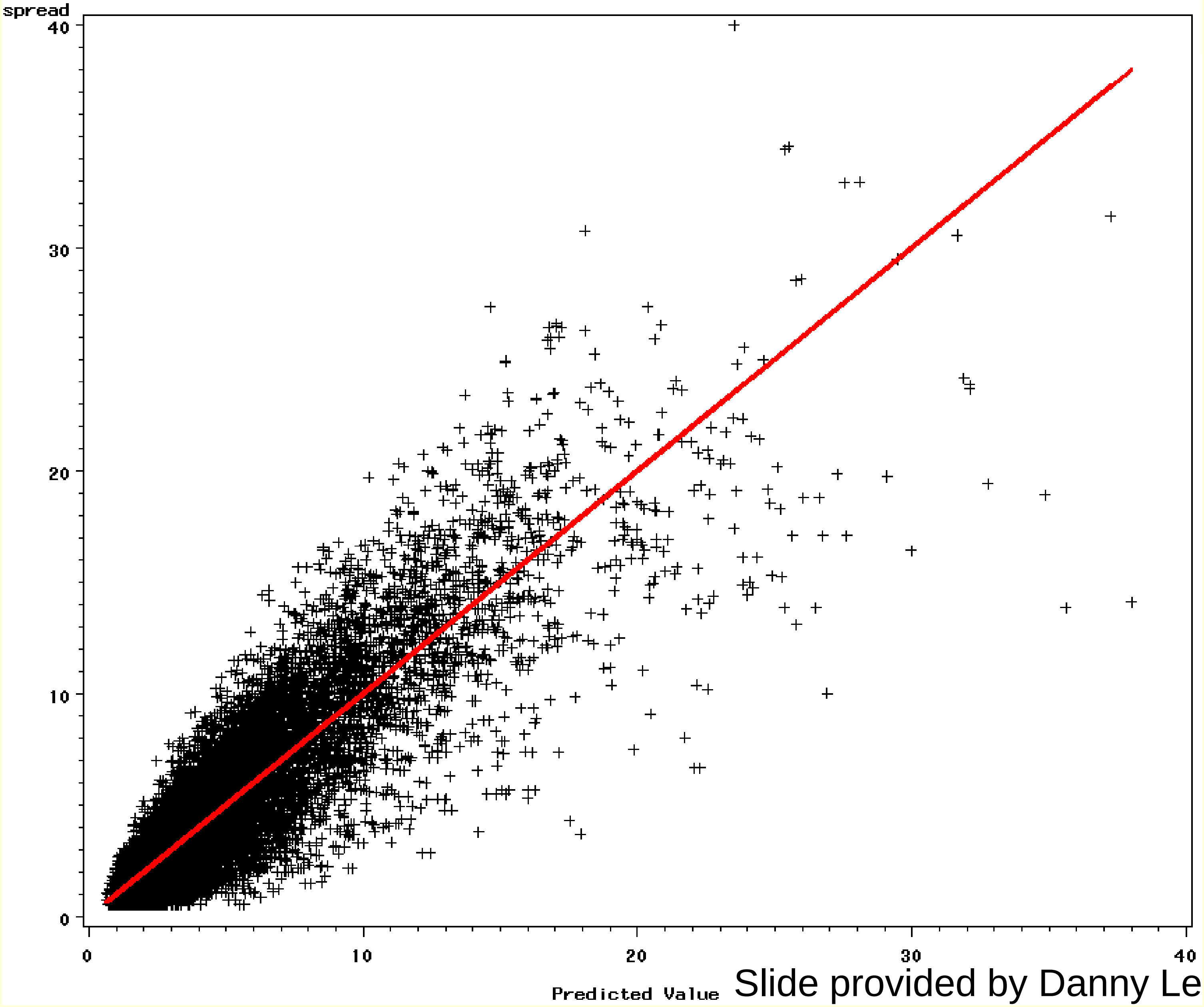
Algorithm converged.

Analysis Of Parameter Estimates

Parameter	DF	Estimate	Standard Error	Wald 95% Confidence Limits		Chi-Square	**Pr > ChiSq**
Intercept	1	-0.9674	0.0208	-1.0081	-0.9267	2171.19	**<.0001**
days	1	0.0579	0.0009	0.0562	0.0597	4400.46	**<.0001**
days*days	1	-0.0003	0.0000	-0.0004	-0.0003	1164.58	**<.0001**
weather	1	8.8857	0.0991	8.6915	9.0799	8040.94	**<.0001**
location	1	0.1613	0.0032	0.1550	0.1676	2526.76	**<.0001**
treat	1	-1.1000	0.0030	-0.1160	-0.1040	1310.71	**<.0001**

Slide provided by Danny Lee

Model 4: Spread = Days Weather Location Treatment



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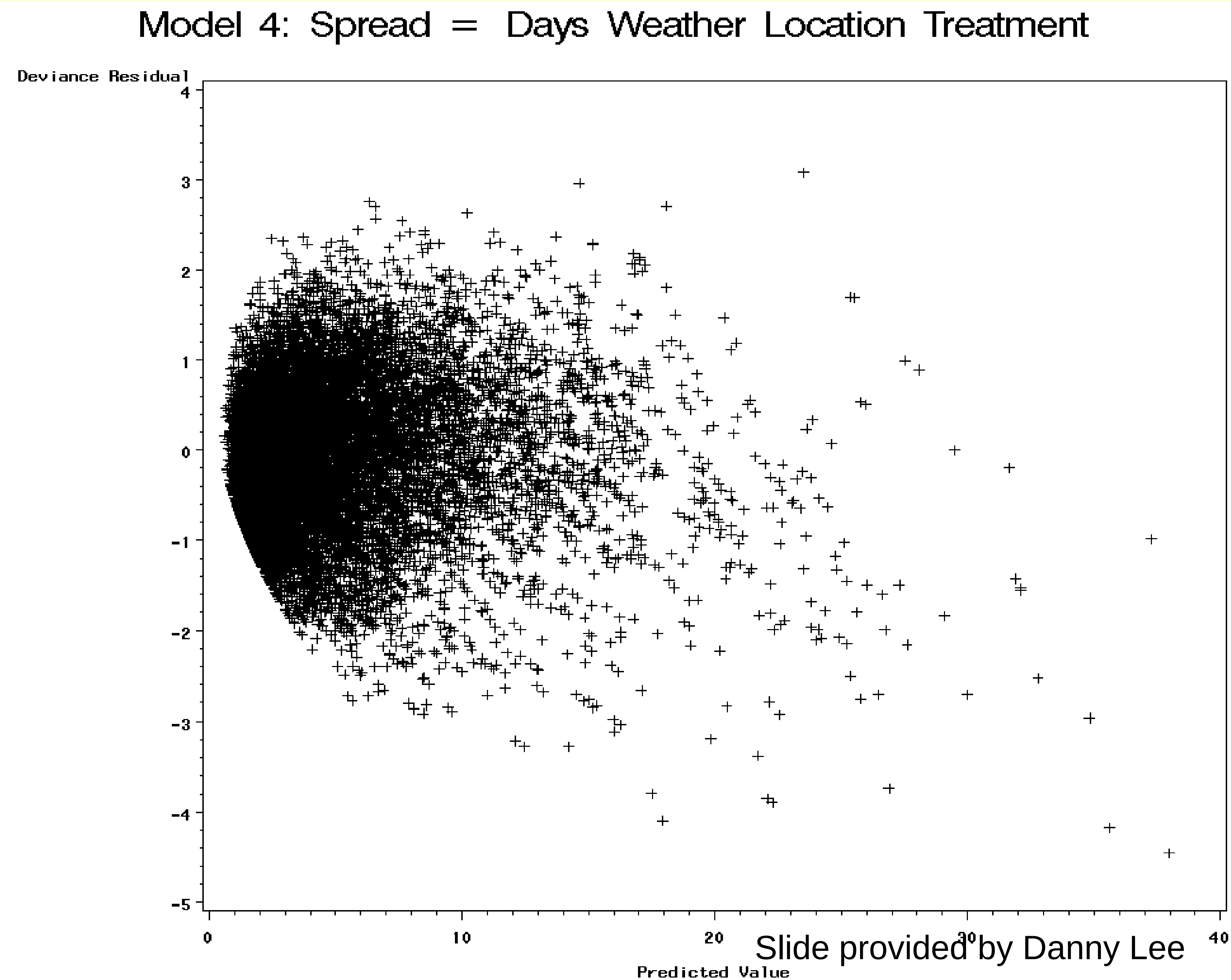

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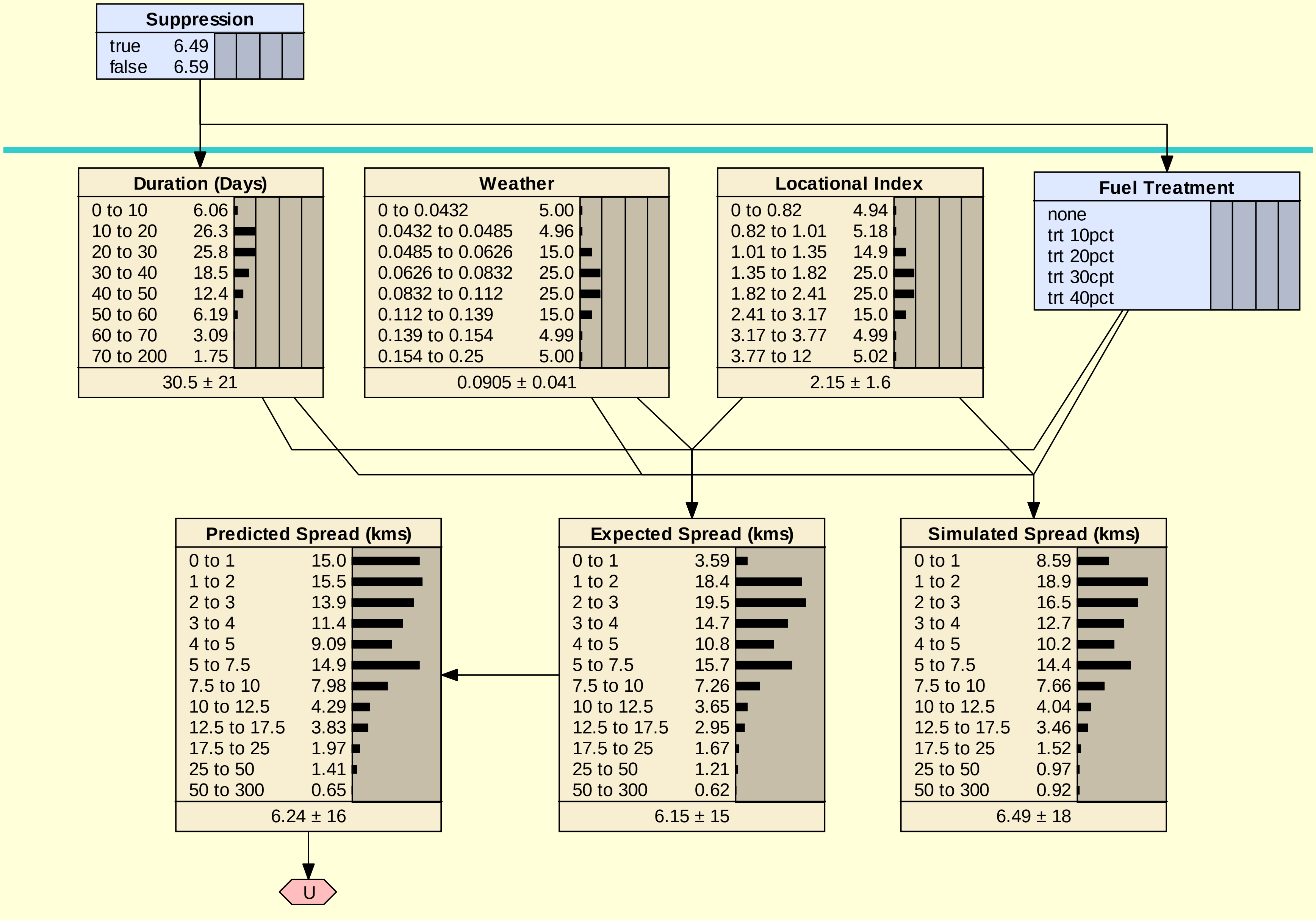

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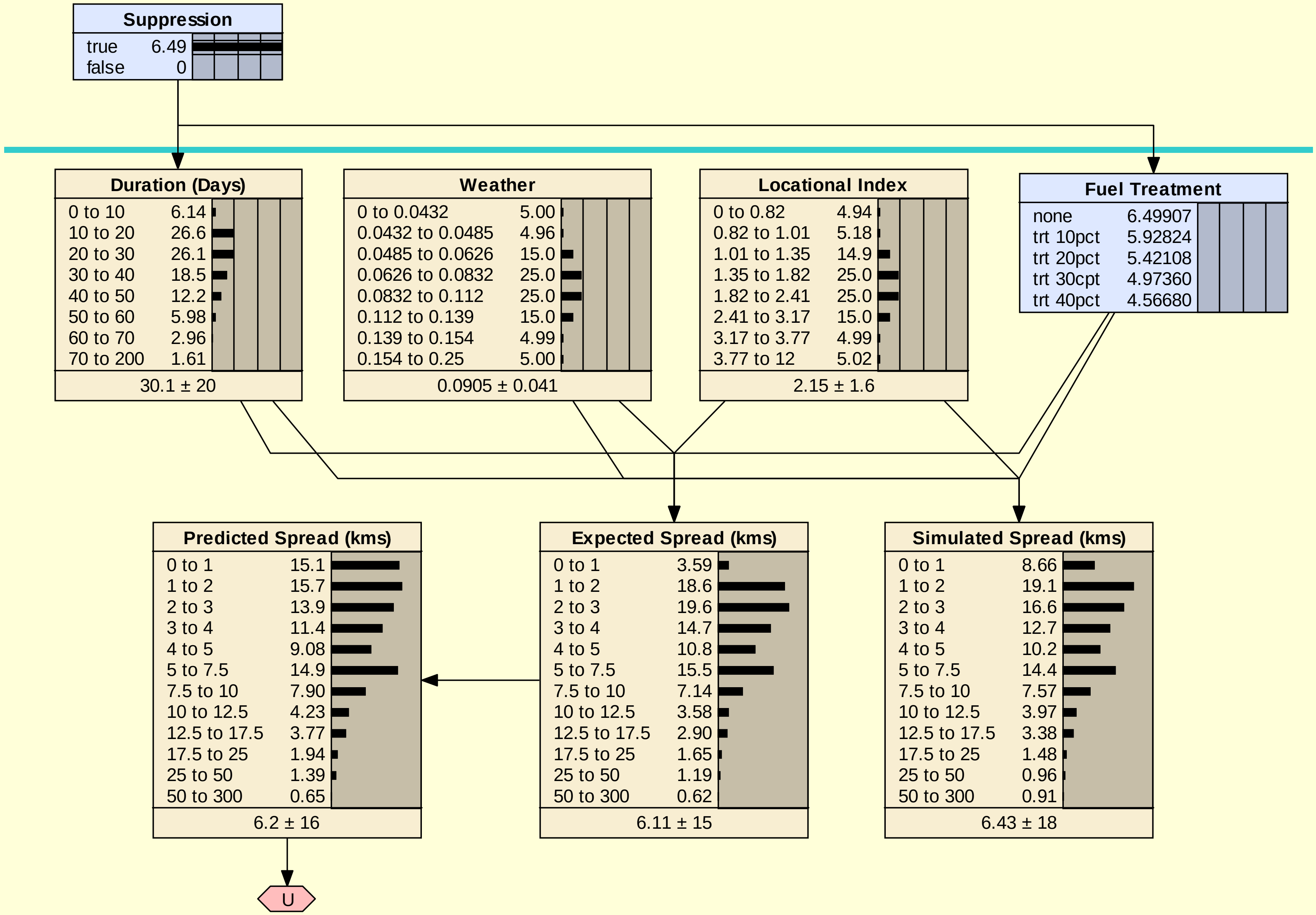

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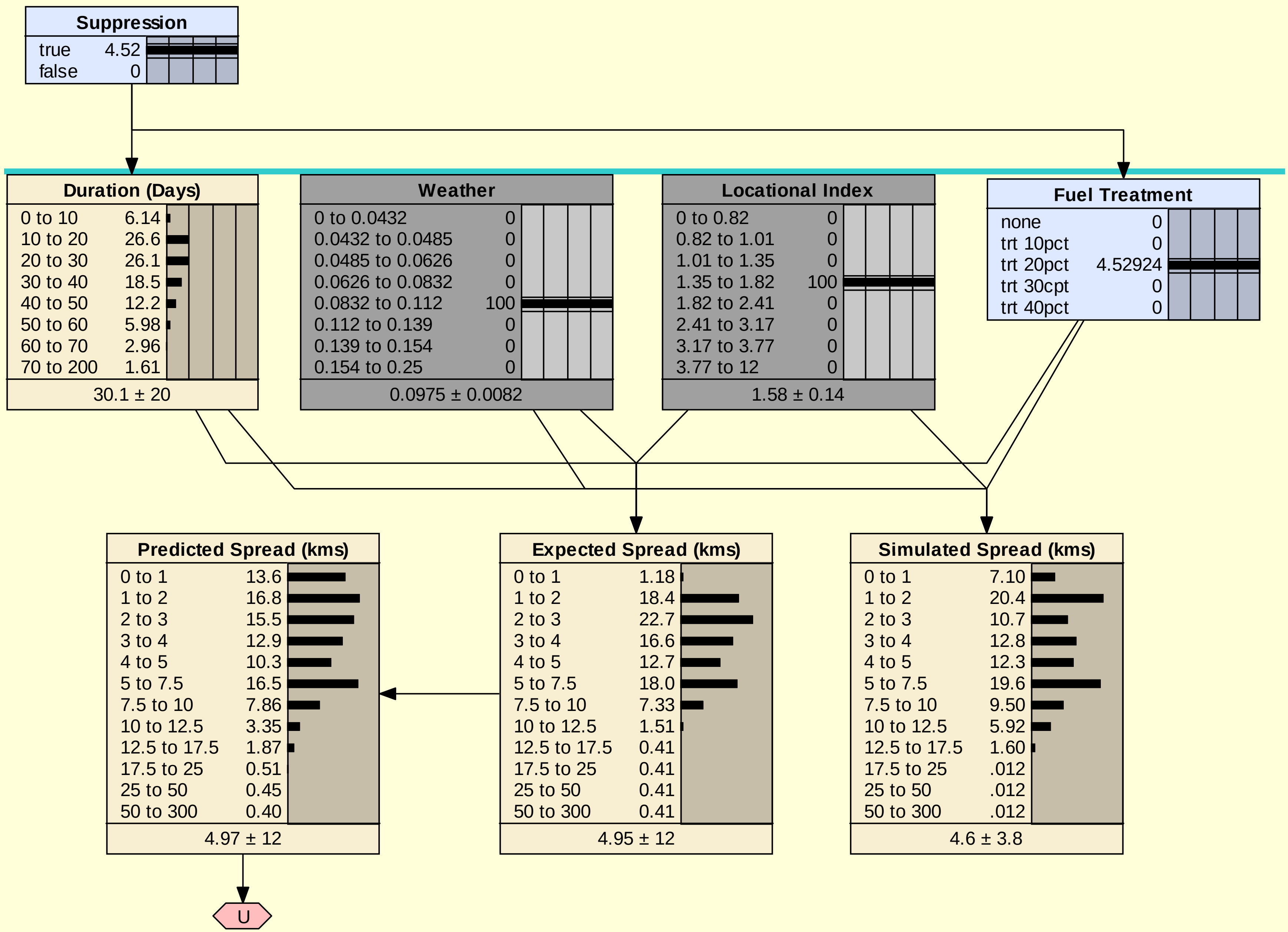

Slide provided by Danny Lee

Large Fire Cost Prediction (thanks to Krista Gebert)

- Cost per acre = f(
  - Size
  - Aspect
  - Slope
  - Elevation
  - Fuel type
  - Fire intensity level
  - ERC percentile
  - Distance to nearest town (Eastern US)
  - Total housing value within 20 miles (West)
  - Distance to wilderness boundary
  - Detection time
  - Region

)
- Prediction intervals enormous (order of magnitude)

Next steps

- At least 1 prototype FPU through all steps by end of June
- Large fire options need to be evaluated
- Parameterize cost models
- Capabilities fall short of what was initially specified (no vegetation modeling, probably not full-blown spatial simulation on-the-fly)– will this be OK?
- National model remains to be developed

Lessons learned

- Start with clear objectives
- Develop business rules
- Seek diverse expertise and advice
- Watch the scientists argue/discuss
- Acknowledge what can’t be done
- Develop a clear and agreed-upon plan
- Prototype and iterate before implementing
- In an ideal world, do the science first!