

# POINTWISE: Predicting Points and Valuing Decisions in Real Time with NBA Optical Tracking Data

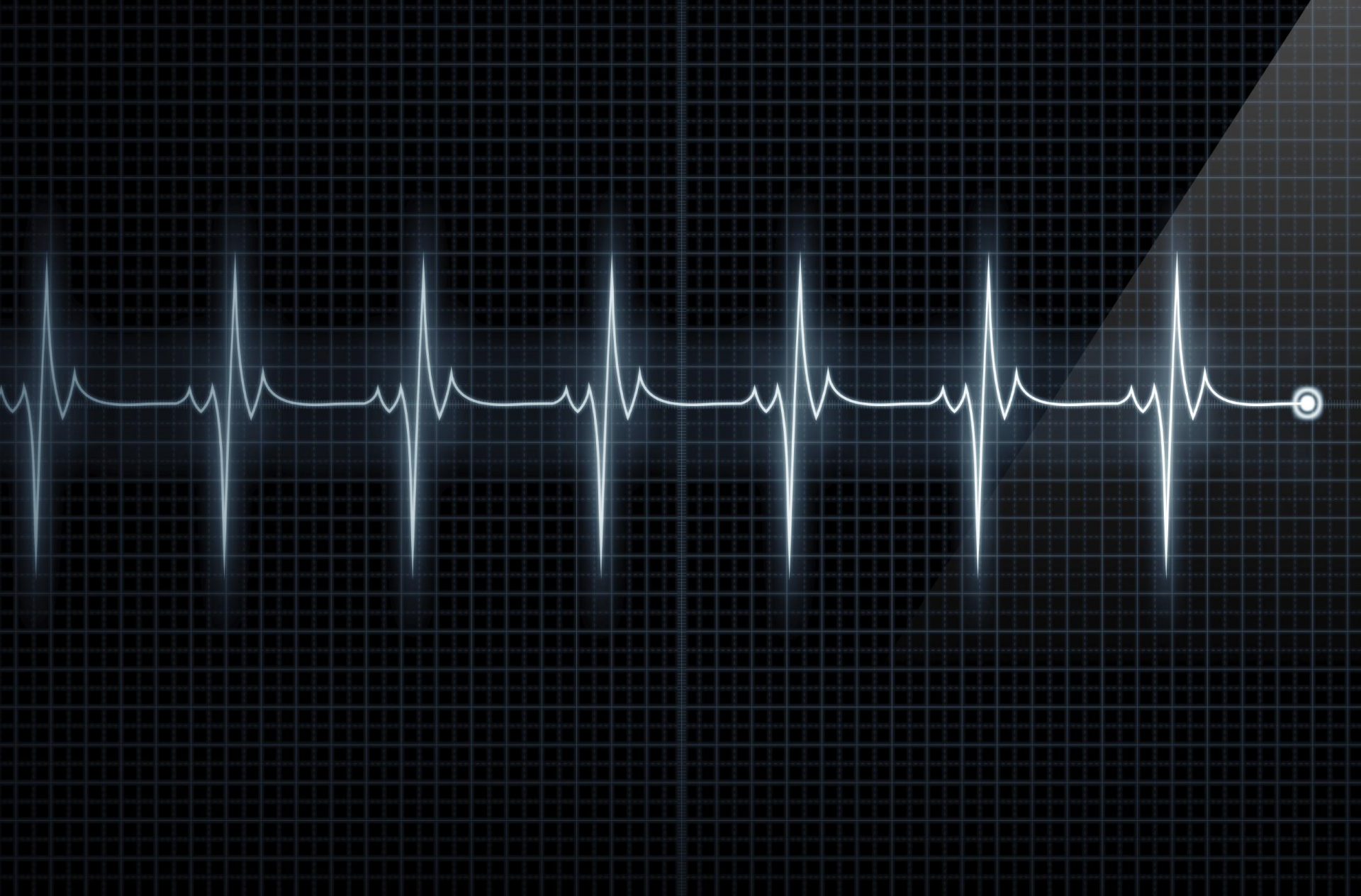
Dan Cervone, Alex D'Amour, Luke Bornn, and Kirk Goldsberry (Harvard University)



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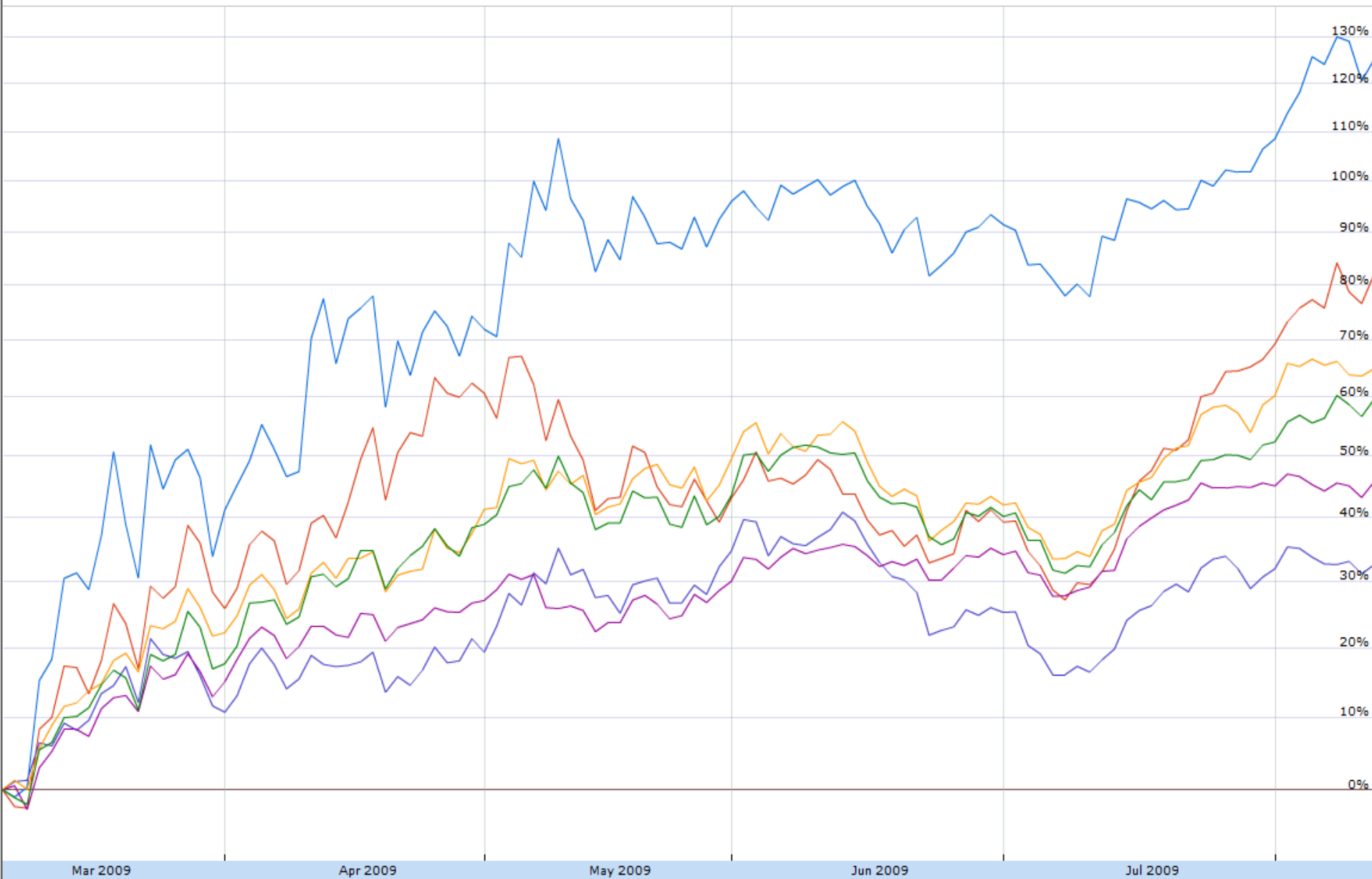
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Zoom: 1d 5d 1m 3m 6m YTD 1y 5y 10y Max

● XLF +125.00% ● NYSE:XHB +81.98% ● NYSE:XLE +32.53% ● NYSE:XLK +45.72% ● NYSE:XLB +64.93% ● NYSE:XLI +59.60%

Mar 06, 2009 - Aug 12, 2009



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**QUESTION**

**DEBATE NIGHT IN AMERICA**

**What are the major differences between the two of you on how you'd create new jobs?**

**LIVE CNN**

**COLORADO UNDECIDED VOTERS**

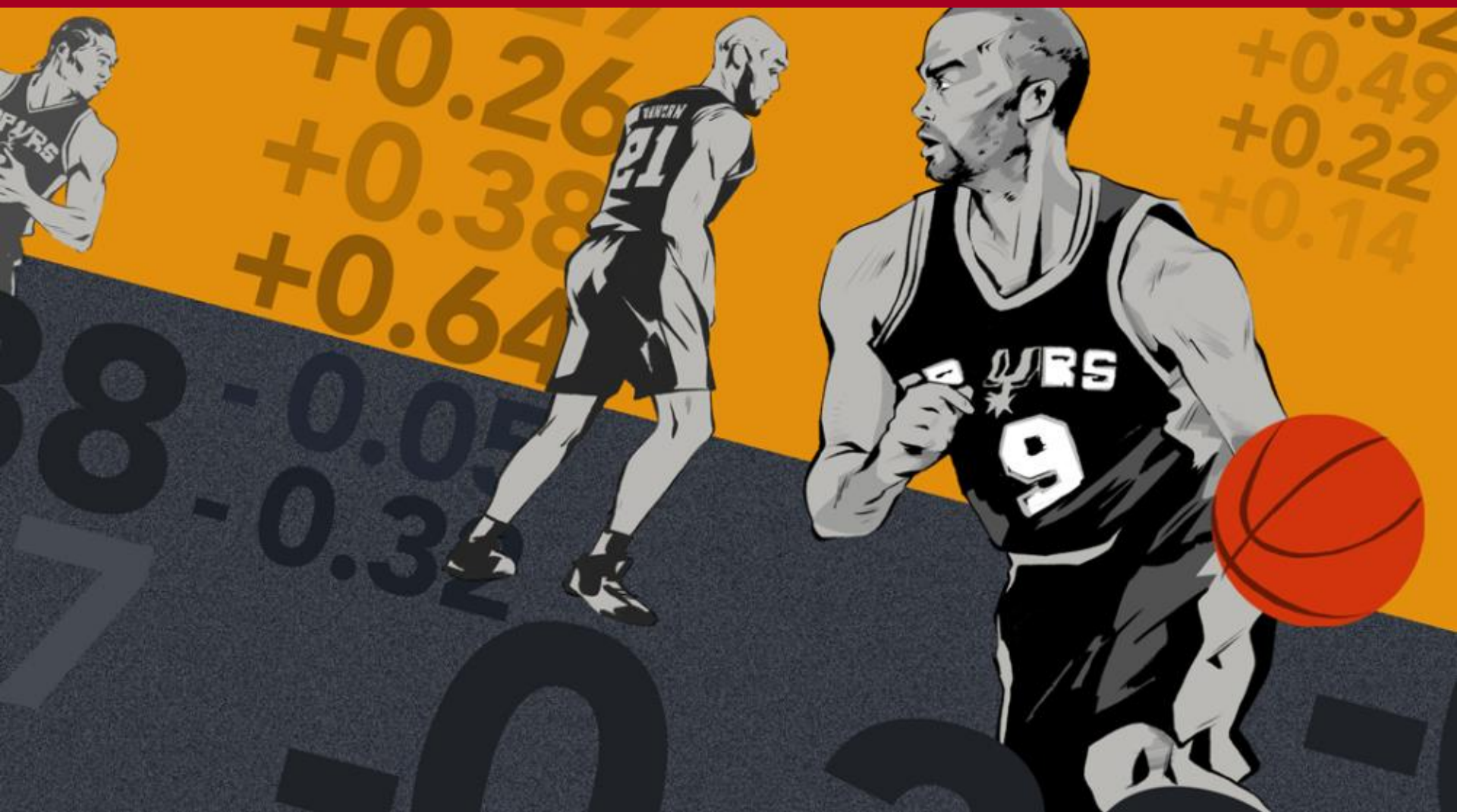
**MEN WOMEN**

**SPEAKING TIME**

**OBAMA 01:38**

**ROMNEY 00:00**

The line graph shows two data series: a green line and a yellow line. Both lines start at a low level and rise sharply, then level off. The green line is consistently higher than the yellow line. A red circle highlights the entire graph area.



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|             |    |           |    |     |       |
|-------------|----|-----------|----|-----|-------|
| SAN ANTONIO | 93 | CLEVELAND | 95 | 4TH | :08.8 |
| BONUS       |    | BONUS     |    |     |       |

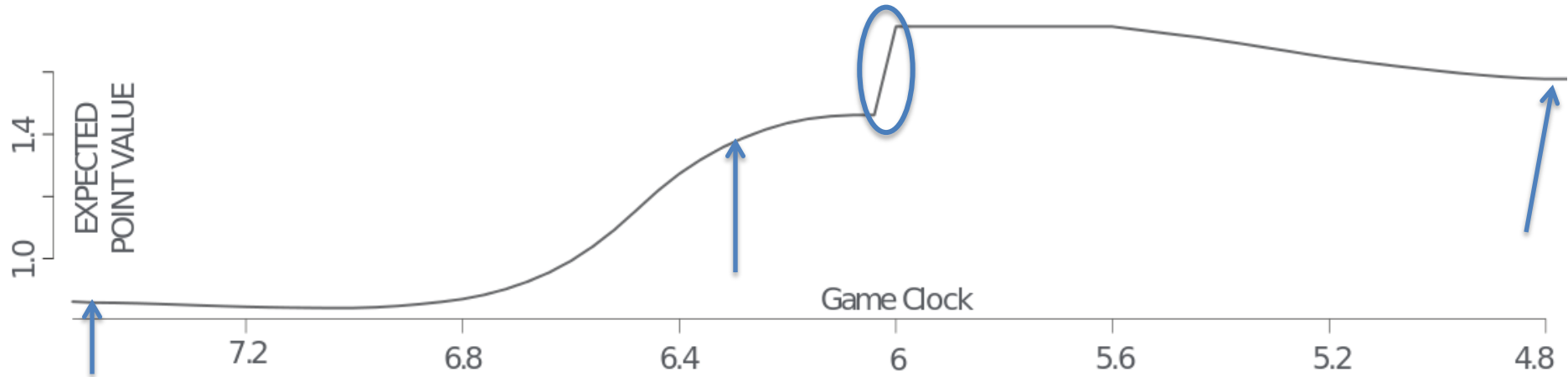


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# Introducing Expected Possession Value

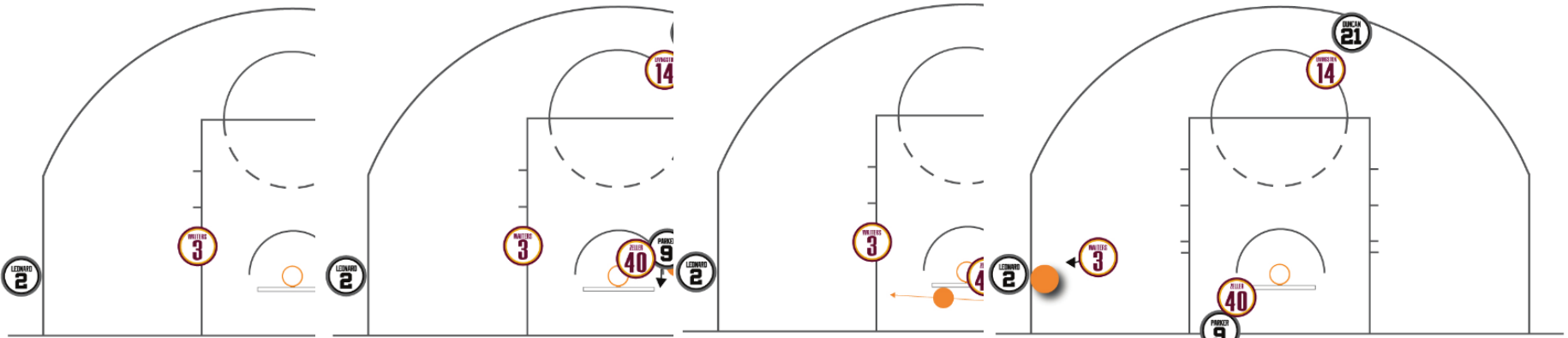


Tim Duncan Screen For Tony Parker  
Expected Points: 0.86

Tony Parker Enters Restricted Area  
Expected Points: 1.36

Tony Parker Passes The Ball To Kawhi Leonard  
Expected Points: 1.46 → 1.7

Kawhi Leonard Shoots The Game Winning Shot  
Expected Points: 1.58



# EPV Defined

Expected possession value (EPV) is the **number of points** the offense is **expected** to score by the end of the possession, given **everything** we know **now**.

- **Points:** The currency of the NBA.
- **Expected:** On average, with “luck” removed.
- **Everything:** Full resolution spatial information.
- **Now:** Any moment in time.

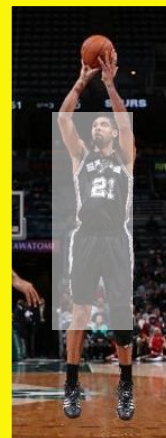


# Calculating EPV

REGRESSION?

MARKOV CHAINS?

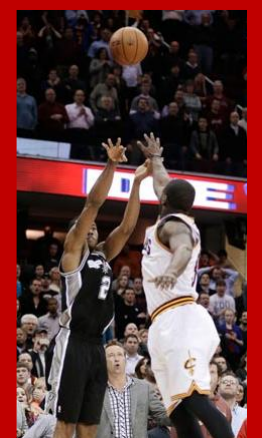
# EPV is a path average



+

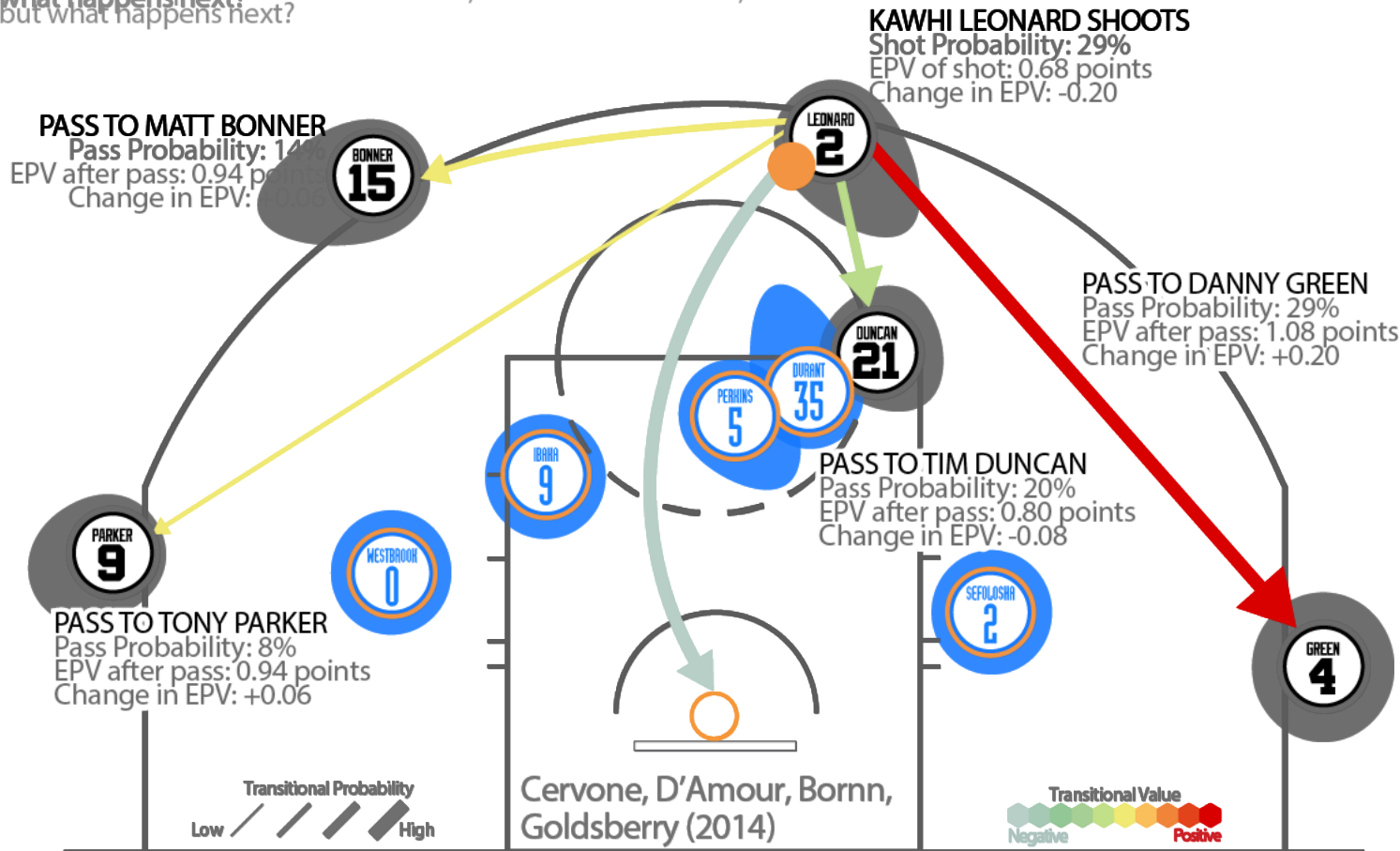


++



# What happens next?

Kawhi Leonard of the Spurs has the ball near the top of the arc...  
The current Expected Possession Value, or "EPV" is 0.88 Points,  
but what happens next?



Raw data

Dynamics layer

Microtransitions

“Action” layer

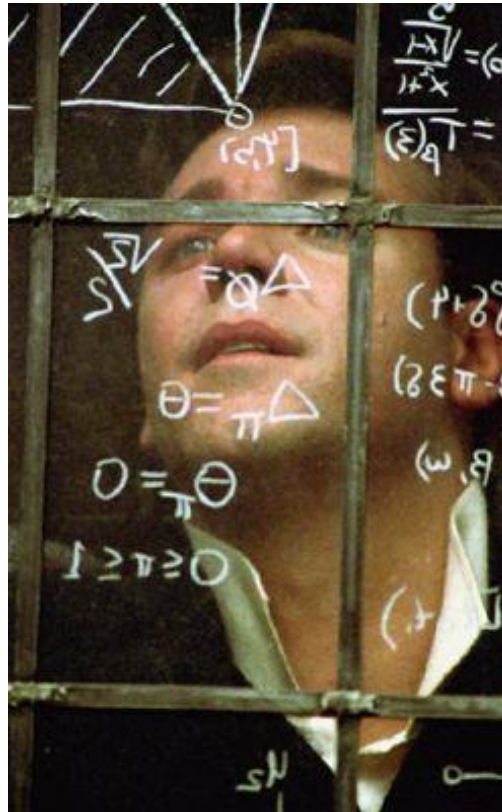
Macrotransitions

Combined

Value layer



# The math



# Transition models

Microtransitions model dynamics: forecast future player locations based on velocities, accelerations

$$(\text{pos}, \text{veloc}, \text{accel}) \text{ at } t + \epsilon = f(\text{pos}, \text{veloc}, \text{accel at } t) + \gamma_t$$

KALMAN FILTER

Macrotransitions model actions: predict changes in ball behavior such as passes, shots, turnovers

$$\lambda_j(t) = \lim_{\epsilon \rightarrow 0} \frac{\mathbb{P}(\text{macro type } j \in (t, t+\epsilon] | \text{data})}{\epsilon}$$

COMPETING RISKS  
HAZARD

Coarsened Markov Chain: computes expected possession value given the observed macrotransition

# Weaving our models together

EPV PSEUDOCODE

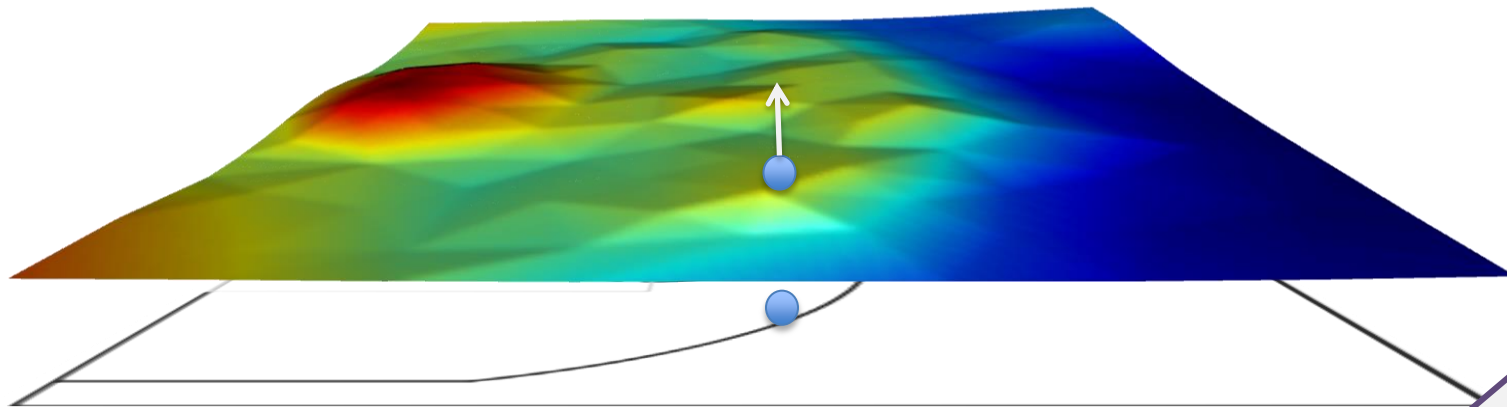
```
 $s \leftarrow t$   
 $d_s \leftarrow d_t$   
 $M_s \leftarrow \text{macro}(d_s)$   
while  $M_s = \text{FALSE}$  do  
   $d_{s+\epsilon} \leftarrow \text{micro}(d_s)$   
   $s \leftarrow s + \epsilon$   
   $M_s \leftarrow \text{macro}(d_s)$   
end while  
 $\text{EPV}(t) \leftarrow \text{value}(M_s, d_s)$ 
```



Microtransition model  
simulates small-scale  
evolution until the  
macrotransition model  
predicts and values a  
pass, shot, or turnover  
event.



# Systematic treatment of space



LEBRON JAMES

$$\log(\lambda_i(t)) = \beta_i + z_i(t)$$

PLAYER'S LOCATION

$$\log(\lambda_i(t)) = \beta_i + \zeta_{ij}(z_i(t))$$

SPATIAL EFFECT

$$\log(\lambda_i(t)) = W_{ij}(t)' \beta_{ij} + \zeta_{ij}(z_i(t))$$

SITUATIONAL EFFECTS

$$\log(\lambda_{ij}(t)) = W_{ij}(t)' \beta_{ij} + \zeta_{ij}(z_i(t))$$

$i$  = PLAYER  
 $j$  = EVENT TYPE

Which court locations have the strongest effect on my chance of attempting a shot?



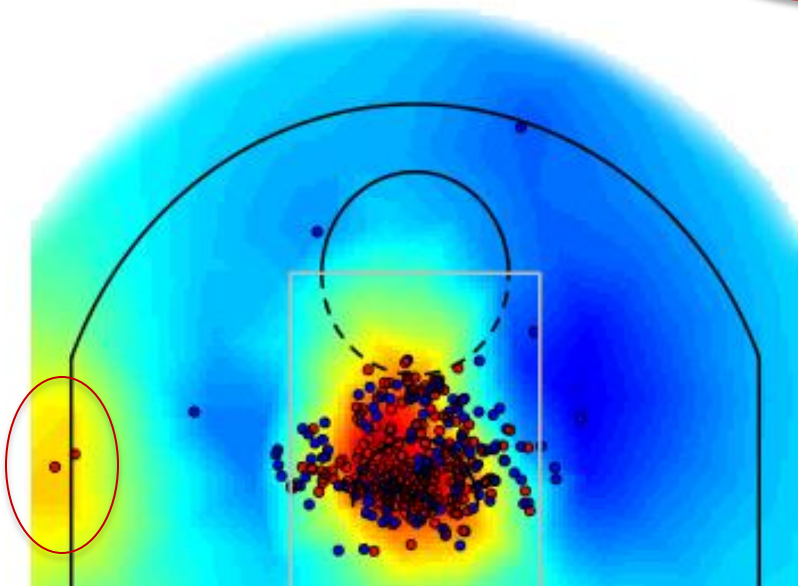
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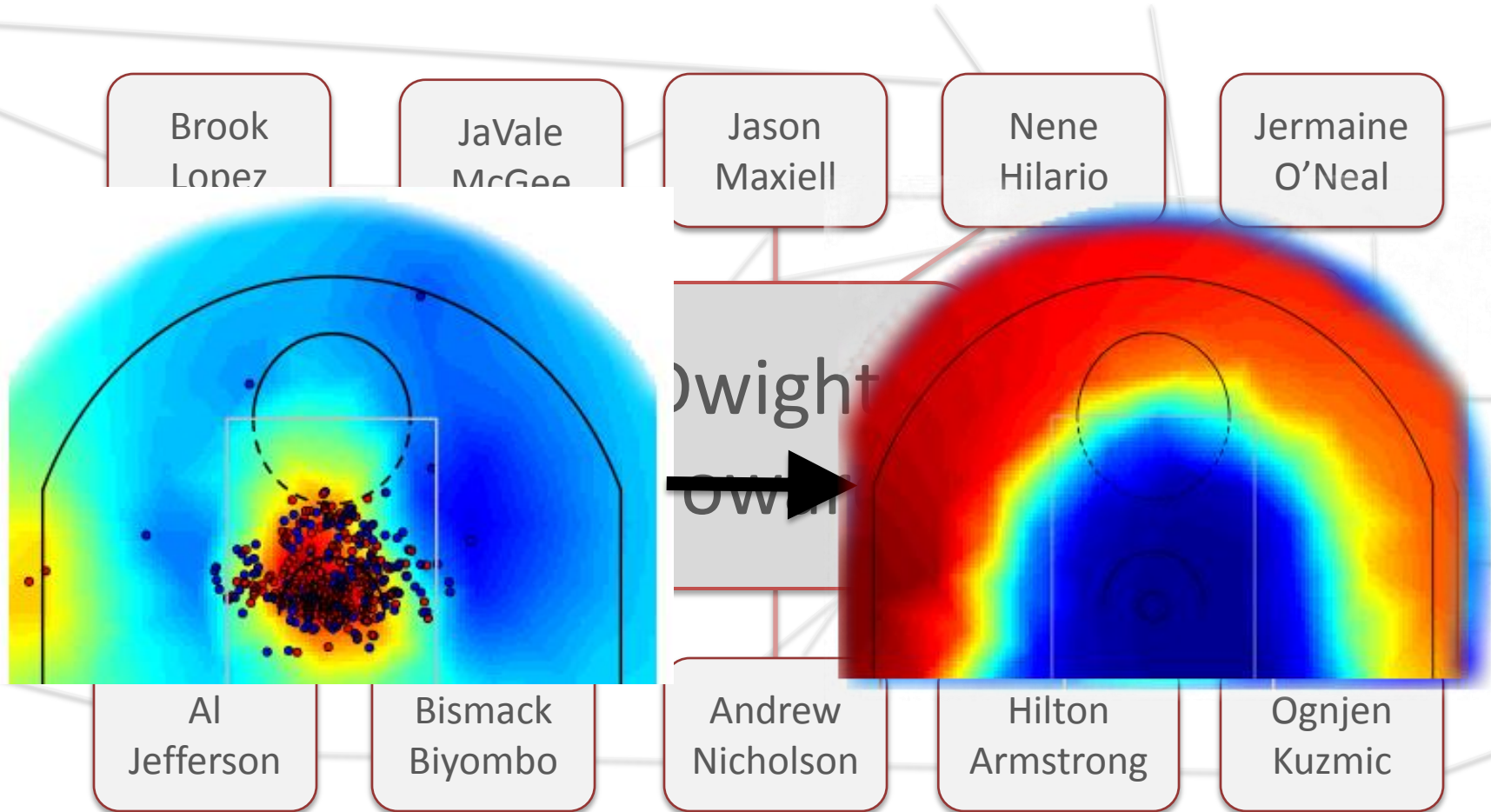
# Space is sparse

I'm the best  
corner 3 shooter  
in the NBA



DWIGHT HOWARD

# Dwight Howard's neighbors

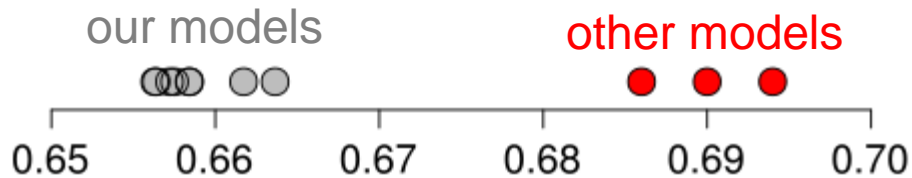




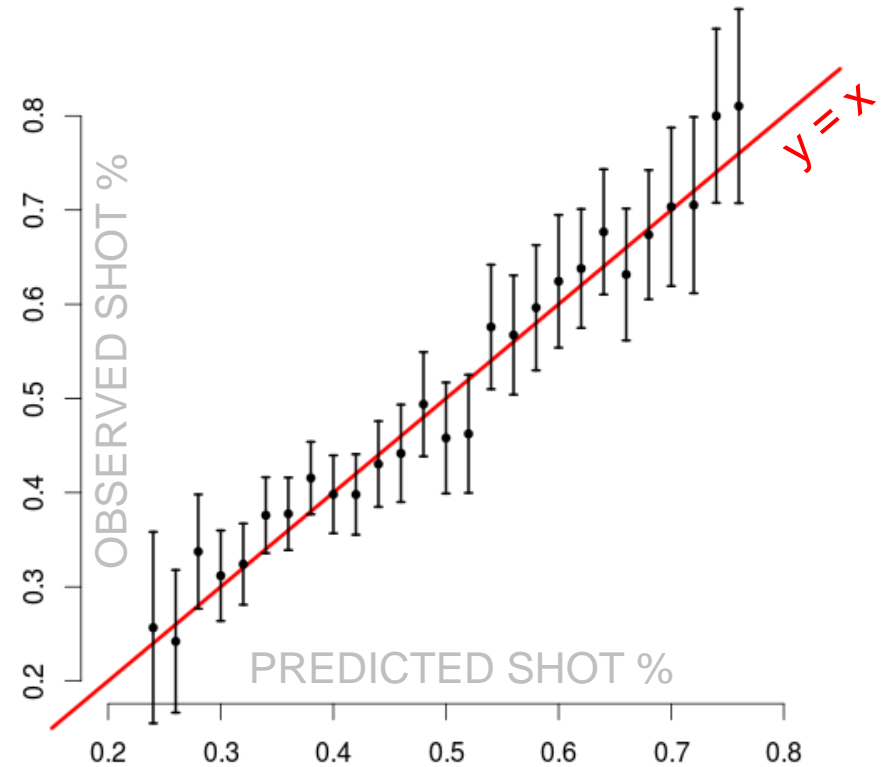
# Model checking

Unit testing: Verify small sections of code block by block.

Internal replication: Independent and redundant data and results checks.

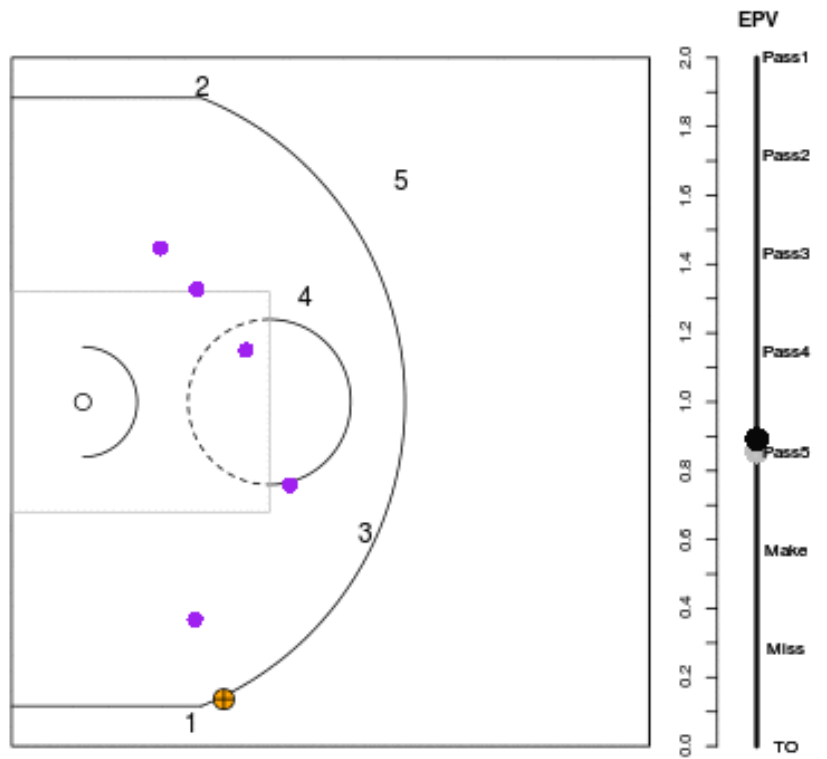


Cross entropy: predicted probabilities and observed outcomes (out of sample). Lower is better.



Calibration plot: predicted vs. observed shot make probabilities (out of sample). Should lie on  $y = x$  line.

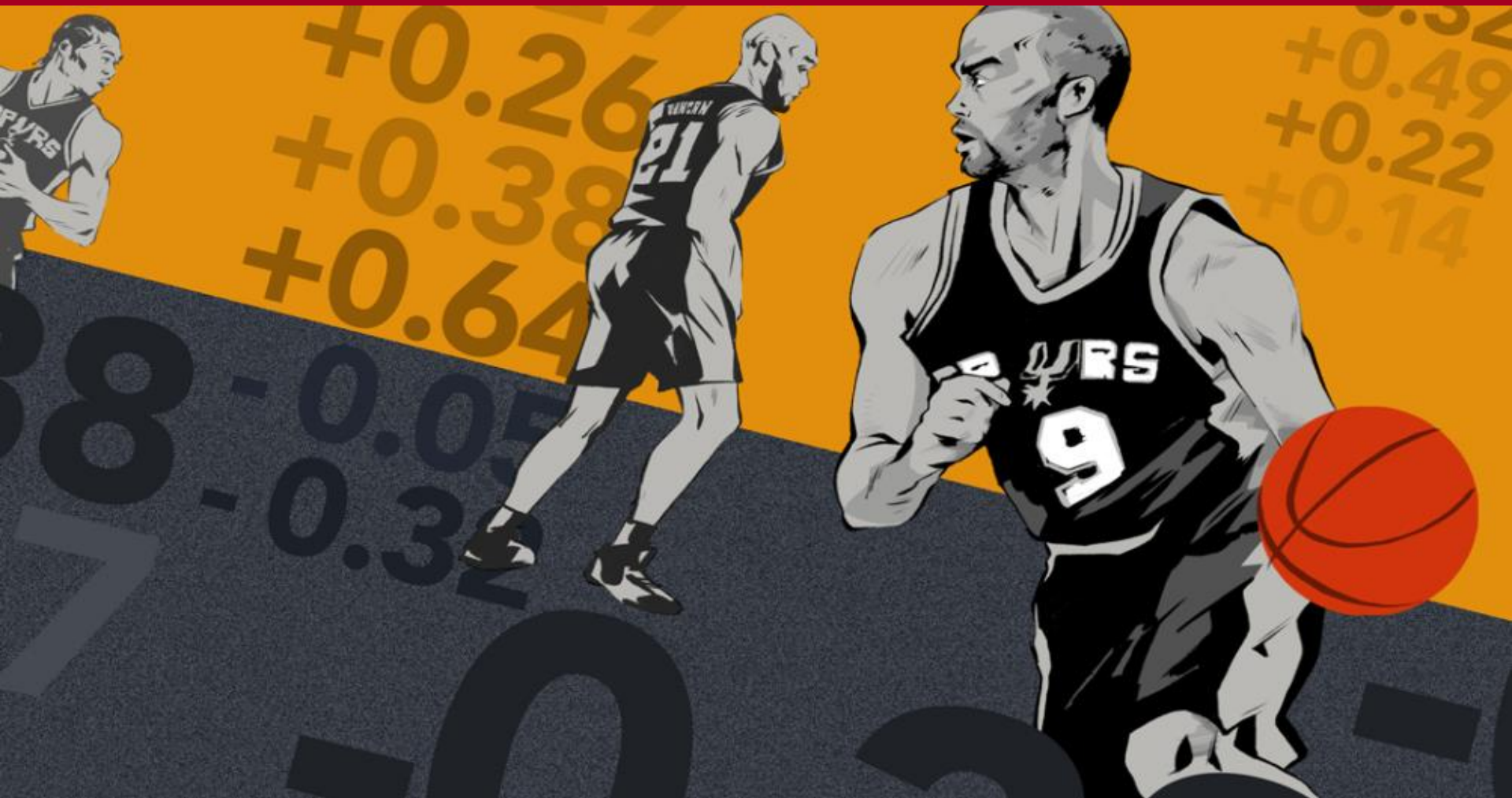
# Model checking



THE  
EYE  
TEST

# EPVmetrics:

## A new microeconomics for the NBA



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# Best decision-makers? EPV-Added

## TOP 10, 2013-14

| NAME             | EPVA  |
|------------------|-------|
| Jose Calderon    | +3.36 |
| LeBron James     | +2.77 |
| Dirk Nowitzki    | +2.54 |
| Channing Frye    | +1.90 |
| Chandler Parsons | +1.85 |
| Kyle Lowry       | +1.71 |
| Al Horford       | +1.66 |
| Kyle Korver      | +1.66 |
| Kevin Durant     | +1.63 |
| Wesley Matthews  | +1.57 |



JOSE  
CALDERON



JOSH  
SMITH

(min 500 touches)

## BOTTOM 10, 2013-14

| NAME             | EPVA  |
|------------------|-------|
| Josh Smith       | -2.23 |
| Brandon Jennings | -1.75 |
| Gerald Henderson | -1.72 |
| Paul Pierce      | -1.58 |
| Ricky Rubio      | -1.58 |
| Victor Oladipo   | -1.39 |
| Jeff Teague      | -1.29 |
| Steve Blake      | -1.27 |
| Evan Turner      | -1.19 |
| Tayshaun Prince  | -1.17 |

# Selfish shooters?

## Shot satisfaction

### TOP 10, 2013-14

| Name             | Shot Sat |
|------------------|----------|
| Jose Calderon    | +0.29    |
| Andre Iguodala   | +0.28    |
| Martell Webster  | +0.26    |
| Lance Stephenson | +0.25    |
| Kyle Korver      | +0.25    |
| Spencer Hawes    | +0.25    |
| LeBron James     | +0.25    |
| Jodie Meeks      | +0.24    |
| Kawhi Leonard    | +0.23    |
| Darren Collison  | +0.23    |



JOSE  
CALDERON



KEVIN  
GARNETT

(min 500 touches)

### BOTTOM 10, 2013-14

| Name              | Shot Sat |
|-------------------|----------|
| Kevin Garnett     | -0.04    |
| Ricky Rubio       | -0.04    |
| Tayshaun Prince   | -0.04    |
| Tim Duncan        | -0.01    |
| Cody Zeller       | -0.01    |
| LaMarcus Aldridge | -0.01    |
| Marc Gasol        | +0.01    |
| Brian Roberts     | +0.01    |
| Jerryd Bayless    | +0.02    |
| Jeff Teague       | +0.03    |

# More EPVmetrics

SITUATIONAL

EPV-added over specific player.  
Pass satisfaction.

OFF BALL

Screens, cuts. Who gets credit?

DEFENSE

Lowering EPV. Most valuable option.

TURNING POINT

# Limitations and the way forward

TRACKING

Players aren't (x,y) points.

DETAILS

SHOT CLOCK, FOULS, DEFENSIVE  
MATCHUPS, SCREENS, FAST BREAKS,  
PICK AND ROLLS, END OF GAME SITUATIONS, IN-GAME WIN  
PROBABILITY, MOMENTUM, TRADE VALUES, PLAYER EVOLUTION,...

MORAL

– Big data?

Bigger questions. Better models.



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# THANK YOU



ALEX FRANKS



ANDREW MILLER

BRIAN KOPP, CARL MORRIS, EDOARDO AIROLDI,  
NATESH PILLAI



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