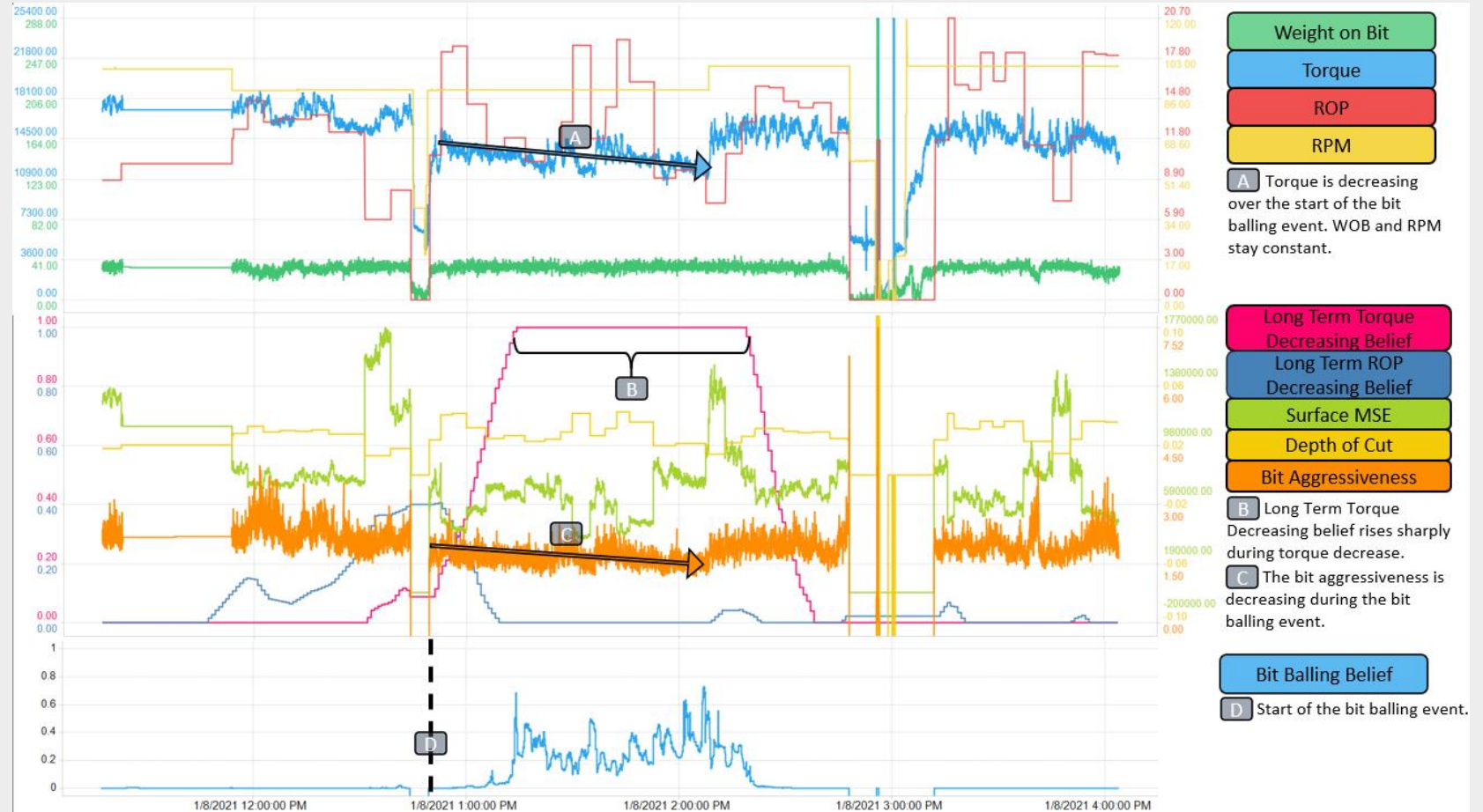
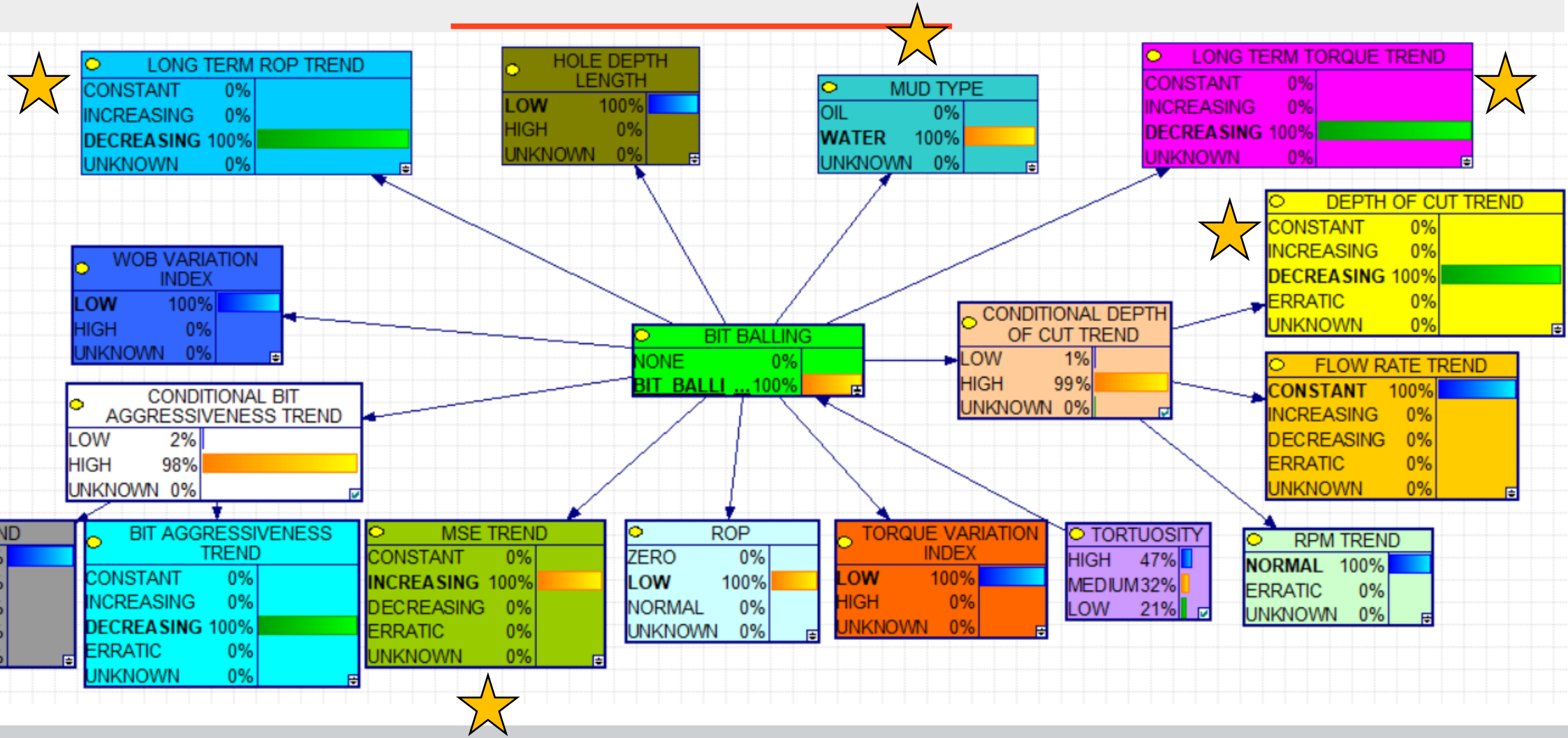


Detecting Bit Balling from Surface Data



Note: the balled bit in the slide does not correspond to the data shown on the right.

Bit Balling Detection Model



Influential Features

Node	Feature Description	Node State Breakdown	State Conducive to Belief
Conditional Bit Aggressiveness Trend	Surface bit aggressiveness decreasing given constant WOB, where: $\text{Surface Bit Aggressiveness} = \frac{12 * T}{WOB * d}$	LOW: Bit aggressiveness not decreasing given constant WOB HIGH: Bit aggressiveness decreasing given constant WOB	High
Conditional Depth of Cut Trend	Depth of cut decreasing given constant flowrate and non-erratic RPM, where: $\text{Depth of Cut} = \frac{12 * ROP}{60 * (RPM + Q_{in} * RPG)}$	LOW: DOC not decreasing given constant flowrate and non-erratic RPM HIGH: DOC decreasing given constant flowrate and non-erratic RPM	High
Hole Depth Length	Hole depth with respect to a configurable depth value at which bit balling is more likely	LOW: Depth is low enough for bit balling to be plausible HIGH: Depth is high enough such that bit balling is unlikely	Low
Long Term ROP Trend	ROP trend over long time window	CONSTANT: Constant long-term ROP trend INCREASING: Increasing long-term ROP trend DECREASING: Decreasing long-term ROP trend	Decreasing
Long Term Torque Trend	Torque trend over a long-time window	CONSTANT: Constant long-term ROP trend INCREASING: Increasing long-term ROP trend DECREASING: Decreasing long-term ROP trend	Decreasing

Some More Influential Features

Node	Feature Description	Node State Breakdown	State Conducive to Belief
Mud Type	Mud Type	OIL: Oil-based mud WATER: Water-based mud	Water
MSE Trend	Surface MSE trend over short time window where: $MSE_{surface} = \frac{4 * WOB}{\pi * (d)^2} + \frac{480 * RPM * T}{(d)^2 * ROP}$	CONSTANT: Constant MSE INCREASING: Increasing MSE DECREASING: Decreasing MSE ERRATIC: Erratic MSE	Increasing
ROP	Real-time .5ft cut foot ROP with respect to configurable expected ROP values	ZERO: Zero ROP LOW: ROP low compared to expected value NORMAL: ROP meets or exceeds expected value	Low
Torque Variation Index	Erraticity of torque: $Torque\ Variation\ Index = \frac{Torque_{max} - Torque_{min}}{Torque_{avg}} \times 100$	LOW: Non-erratic torque HIGH: Erratic torque	Low
WOB Variation Index	Erraticity of WOB: $WOB\ Variation\ Index = \frac{WOB_{max} - WOB_{min}}{WOB_{avg}} \times 100$	LOW: Non-erratic WOB HIGH: Erratic WOB	Low