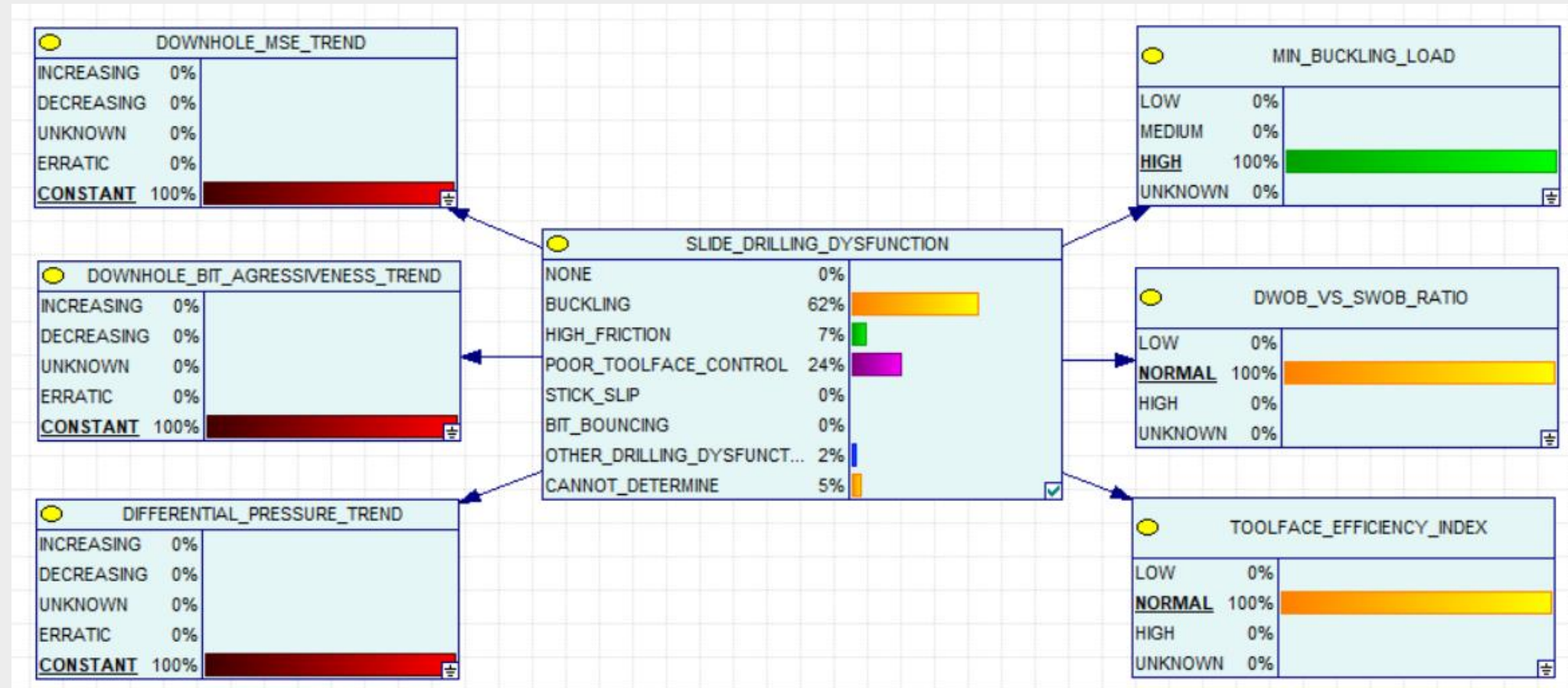


Buckling



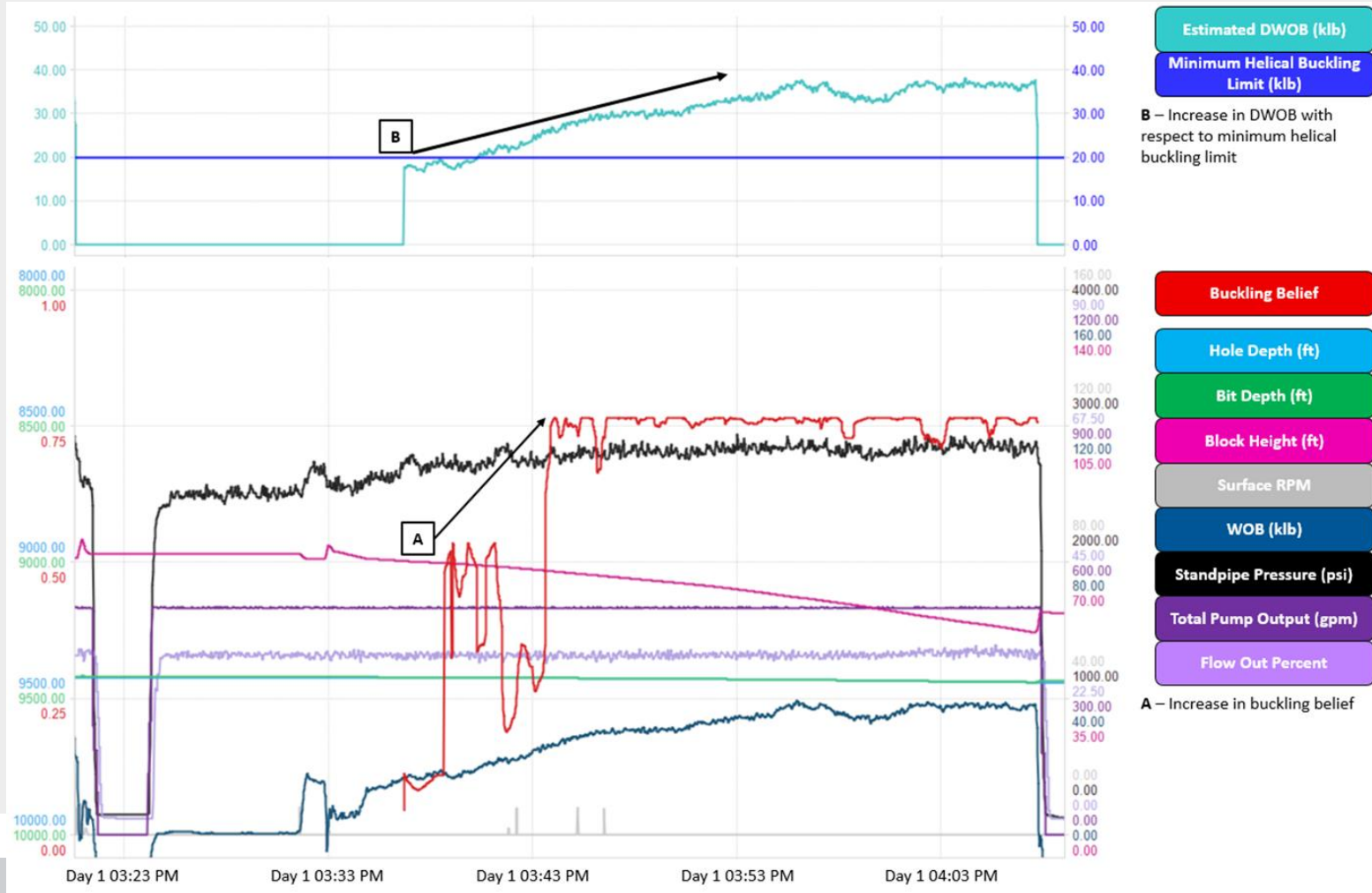
Bit Weight - Helical Buckling

- Compressed drill pipes deform easily, and adopt different shapes. The most dangerous scenario is helical buckling, in which the drill pipe deforms as a spring pressing against the formation, increasing friction severely and potentially locking up the drillstring into the wellbore
- The following calculation steps provide one relevant feature input that helps detect buckling
 1. The axial load on each joint is estimated with the torque and drag model
 2. At the same time, the critical compression load required to buckle a drill pipe into a helical geometry is calculated based on the pipe geometry, material, radius of curvature in which it is deformed inside the wellbore and inclination angle
 3. The minimum difference between the critical load and the actual load on all the joints in the drillstring is the minimum axial load required to buckle at least one pipe
 4. The risk of buckling a drill pipe is quantified as low, medium or high and is an input to the MIN_BUCKLING_LOAD node in the Bayesian network

Buckling: Influential Features

Node	Feature Description	Node State Breakdown	State Conducive to Belief
DWOB vs SWOB Ratio	Raw WOB with respect to the modeled downhole WOB: $\frac{DWOB}{SWOB}$	LOW: DWOB with respect to WOB is much lower than expected NORMAL: DWOB with respect to WOB is slightly lower than expected HIGH: DWOB with respect to WOB is ideal	Normal
Min Buckling Load	Modeled DWOB with respect to the calculated helical buckling limit: $DWOB - HBL$	LOW: DWOB acceptably low compared to HBL MEDIUM: DWOB is close to HBL HIGH: DWOB is very close to or exceeds HBL	High
Toolface Efficiency Index	Current toolface with respect to the average toolface over the course of the current slide: $\frac{ TFA_{current} - TFA_{avg} }{180}$	LOW: Current TFA varies greatly from average NORMAL: Current TFA varies moderately from average HIGH: Current TFA varies little from average	Normal

Buckling Example



Poor Toolface Control: Influential Features

Node	Feature Description	Node State Breakdown	State Conducive to Belief
DWOB vs SWOB Ratio	Raw WOB with respect to the modeled downhole WOB: $\frac{DWOB}{SWOB}$	LOW: DWOB with respect to WOB is much lower than expected NORMAL: DWOB with respect to WOB is slightly lower than expected HIGH: DWOB with respect to WOB is ideal	Normal
Min Buckling Load	Modeled DWOB with respect to the calculated helical buckling limit: $DWOB - HBL$	LOW: DWOB acceptably low compared to HBL MEDIUM: DWOB is close to HBL HIGH: DWOB is very close to or exceeds HBL	Medium
Toolface Efficiency Index	Current toolface with respect to the average toolface over the course of the current slide: $\frac{ TFA_{current} - TFA_{avg} }{180}$	LOW: Current TFA varies greatly from average NORMAL: Current TFA varies moderately from average HIGH: Current TFA varies little from average	Low

Poor Toolface Example

