ESP Data Analytics: Predicting Failures for Improved Production Performance

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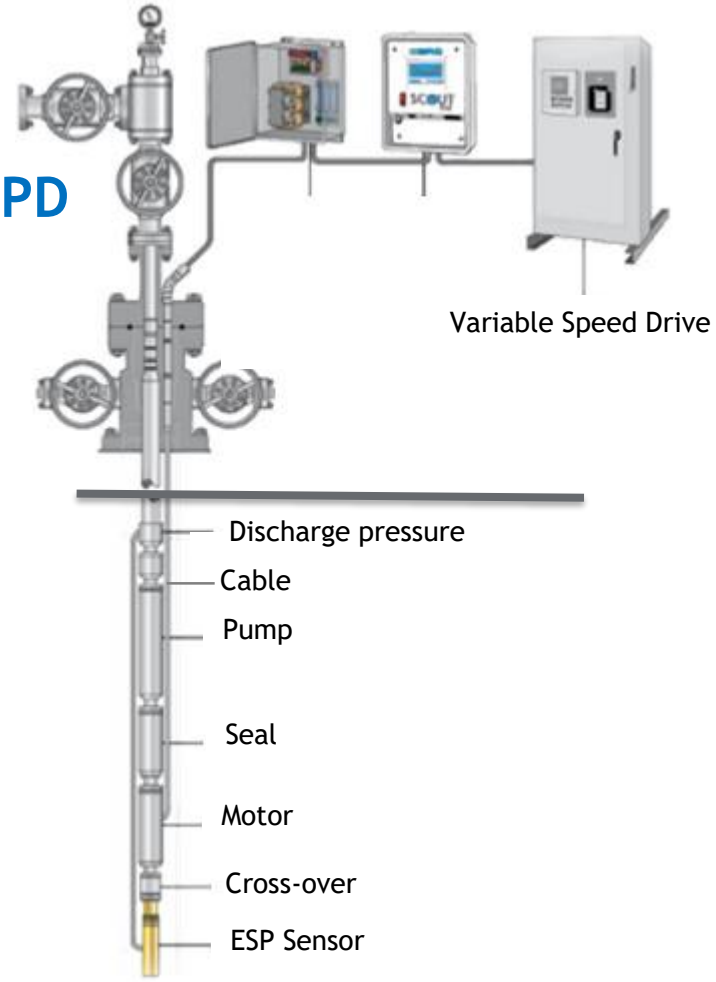
where energy is opportunity™

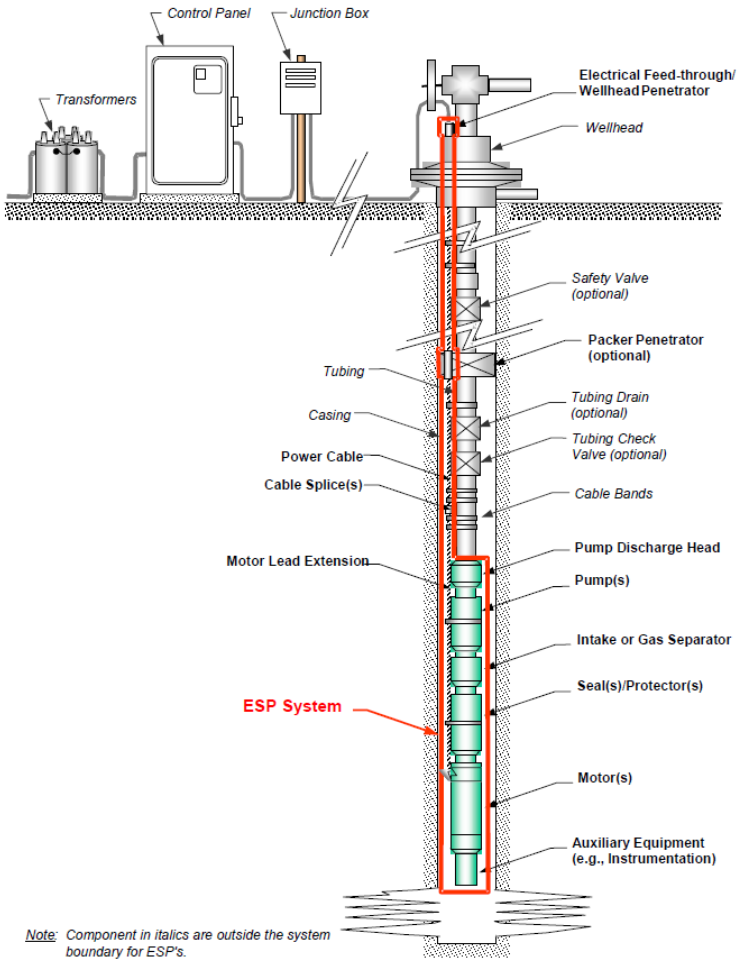
Electrical Submersible Pumps (ESPs) & World Energy

- **High production rates** – up to **60,000 BPD**
- **60%** of the total **world oil production** (1)
- **130,000 installations worldwide** (1)

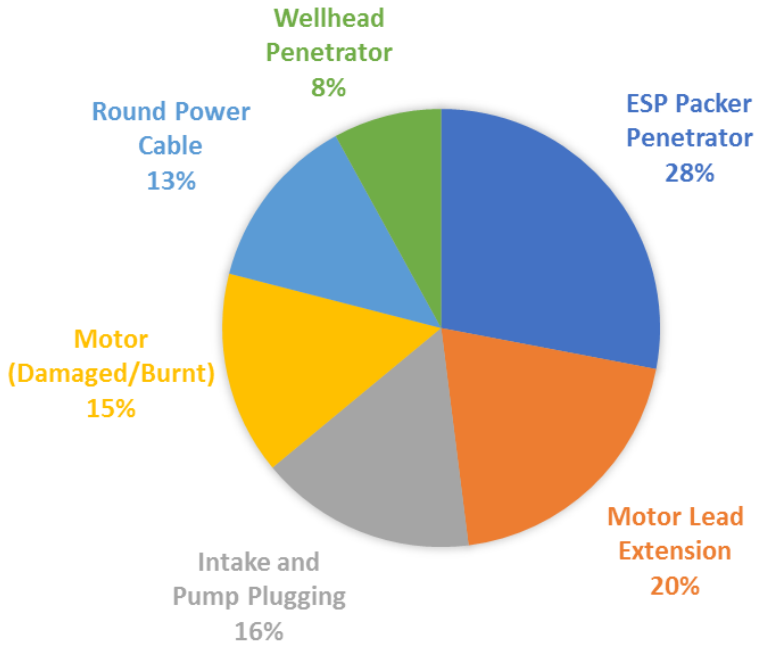
(1) Dunham, 2013)



ESP Failures

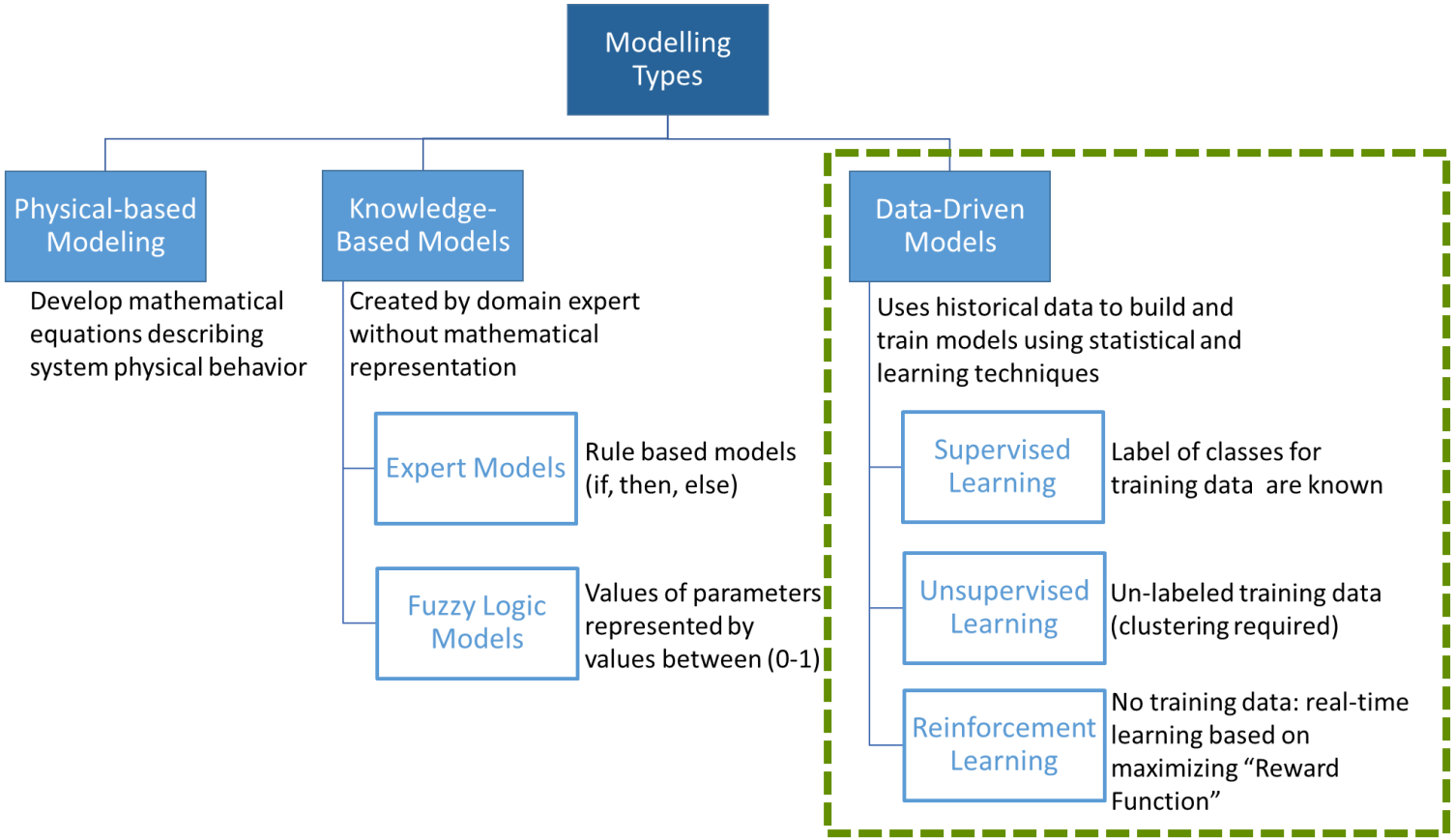


Components of ESP [from (Alhanati, Solanki, & T. A. Zahacy, 2001)



Example of ESP Failed Item Statistics for One Field - After (Xiao, Shepler, Windiarto, Parkinson, & Fox, 2016)

Models Available



Data Available

Dynamic Data:

Downhole

- *ESP Data*
  - Discharge Pressure:
  - Suction Pressure:
  - Discharge Temperature:
  - Motor Temperature:
  - Vibration

SCADA

- Motor Current:
- Leakage Current:
- Speed (Frequency)

- *Wellhead Data*
  - Wellhead Temperature:
  - Wellhead Pressure

~Monthly

- *Production Data*
  - Well flow rate
  - Water cut and GOR
  - BS&W

Static Data:

- *Well Completion Data*
- *ESP Pump Design Information*
- *Reservoir Fluid Properties*

Historical Data:

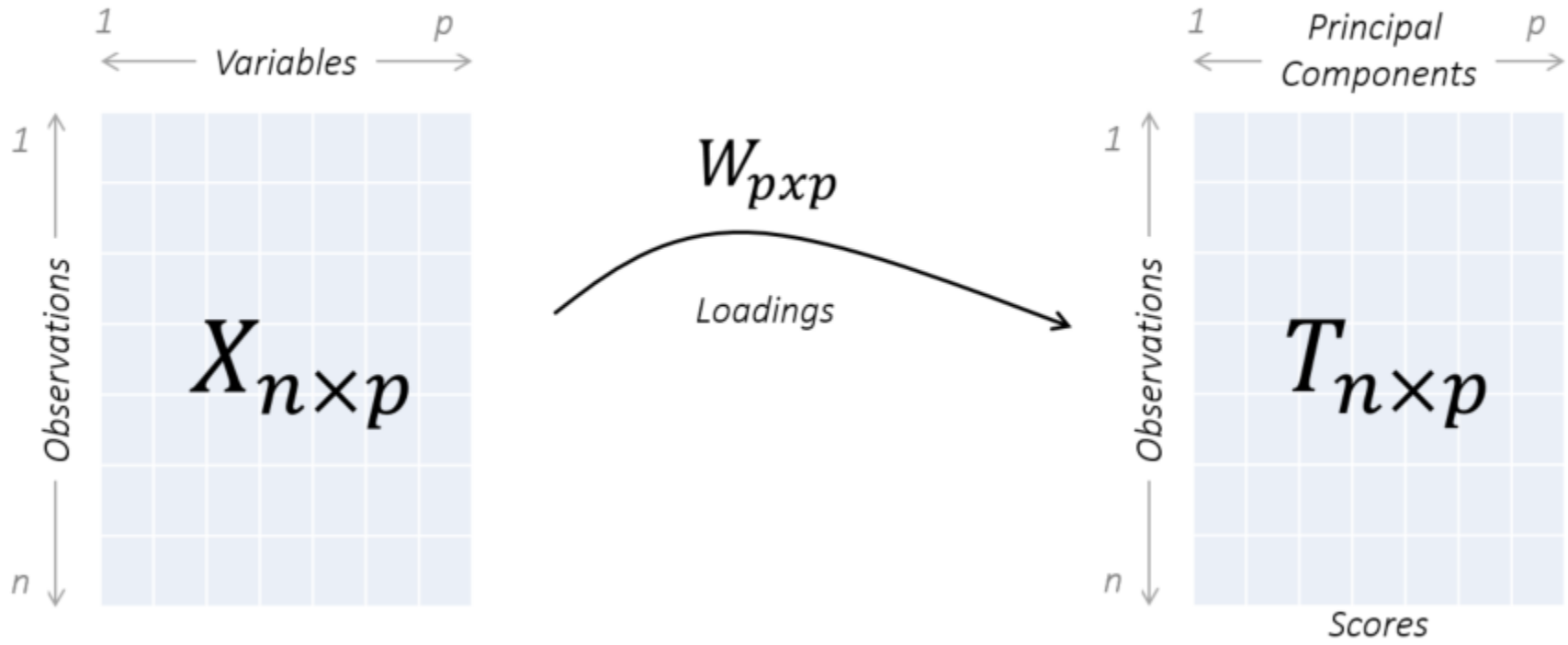
- *Historical Well Events*
- *Investigation Reports*
- *Failure and Pull Reports*
- *DIFA Reports*

Required for One Investigation!

Principal Component Analysis (PCA)

A multivariate analysis technique that is used for dimensionality reduction

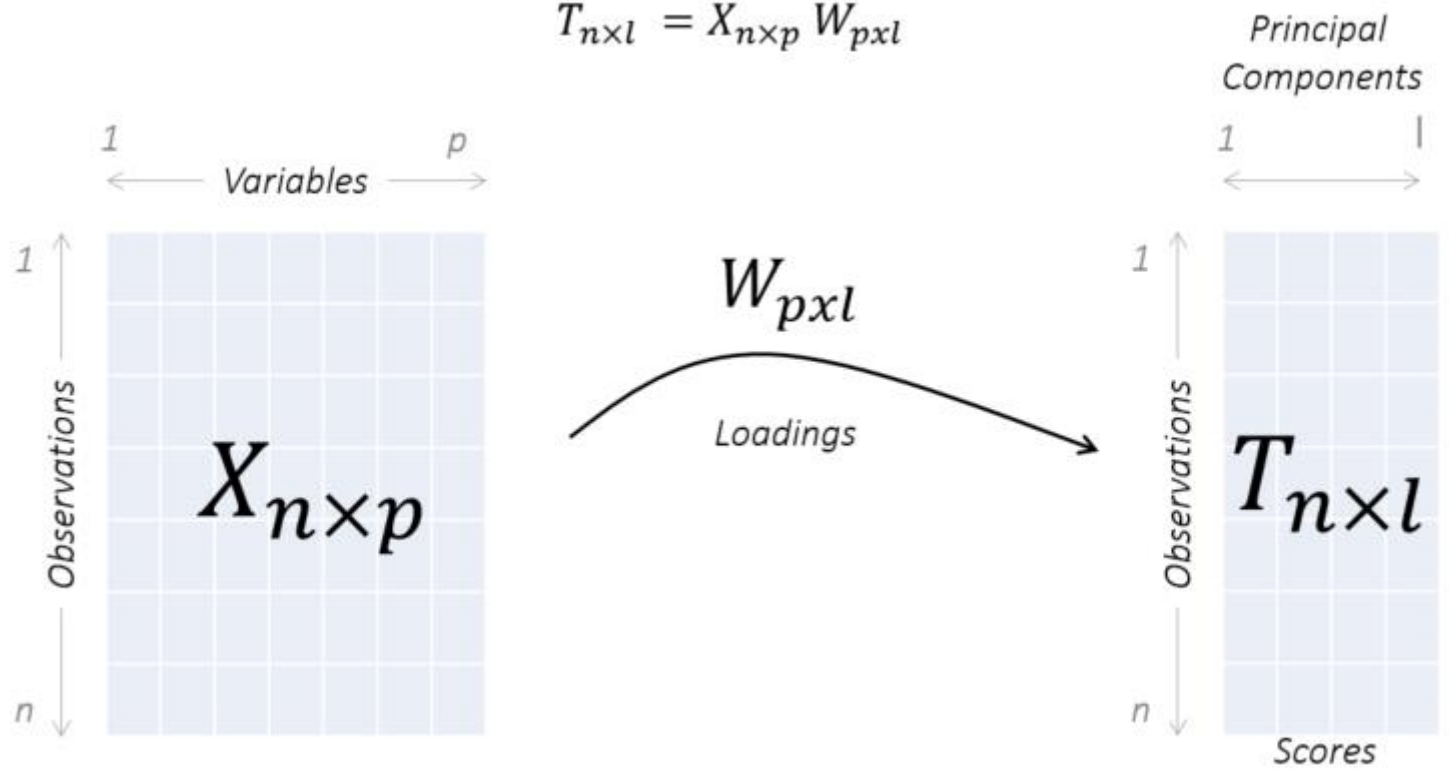
$$T_{n\times p} = X_{n\times p}\, W_{pxp}$$



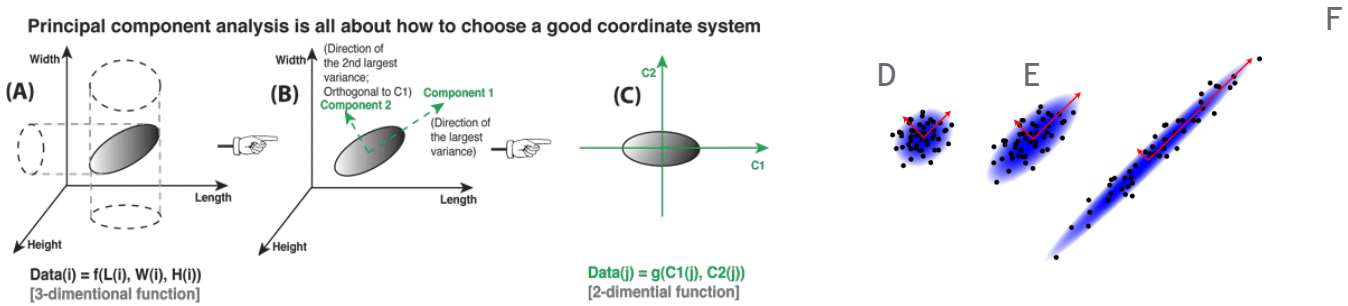
Principal Component Analysis (PCA)

Multivariate analysis technique that is used for dimensionality reduction

$$T_{n\times l} = X_{n\times p}\, W_{pxl}$$



Principal Component Analysis (PCA) made simple



(A) Data scatter in XYZ (3D) space, lies on plane => possible to resolve into 2D space (B)using the 1st and 2nd largest orthogonal variance i.e. Component C1 and C2 respectively (C) owing to linear dependency

(D) C1 and C2 equal => difficult to determine change in C2 as result of C1

(E) Start to see a differentiation between C1 and C2, more opportunity to jump from 2D to 1D space

(F) Noticeable differentiation between C1 and C2 => straight forward jump from 2D to 1D space

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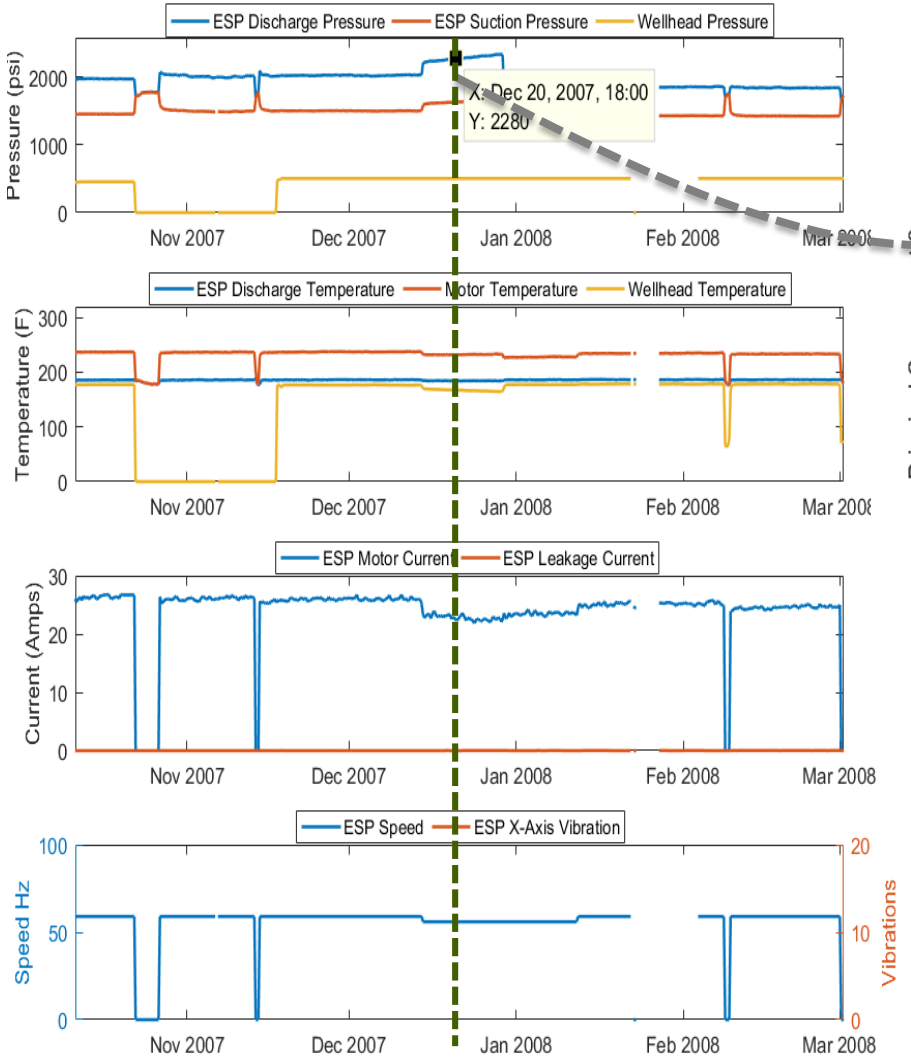
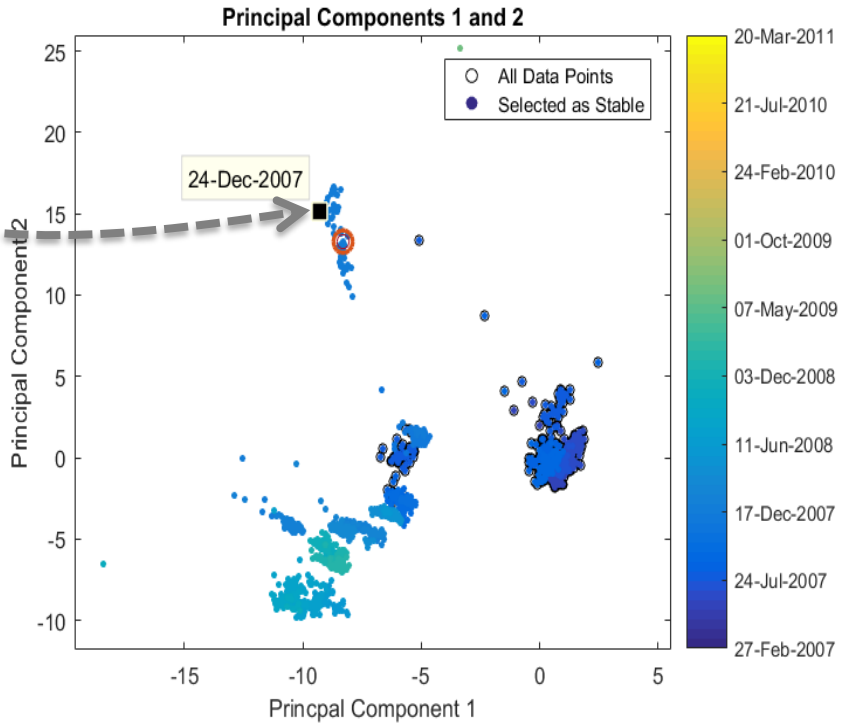
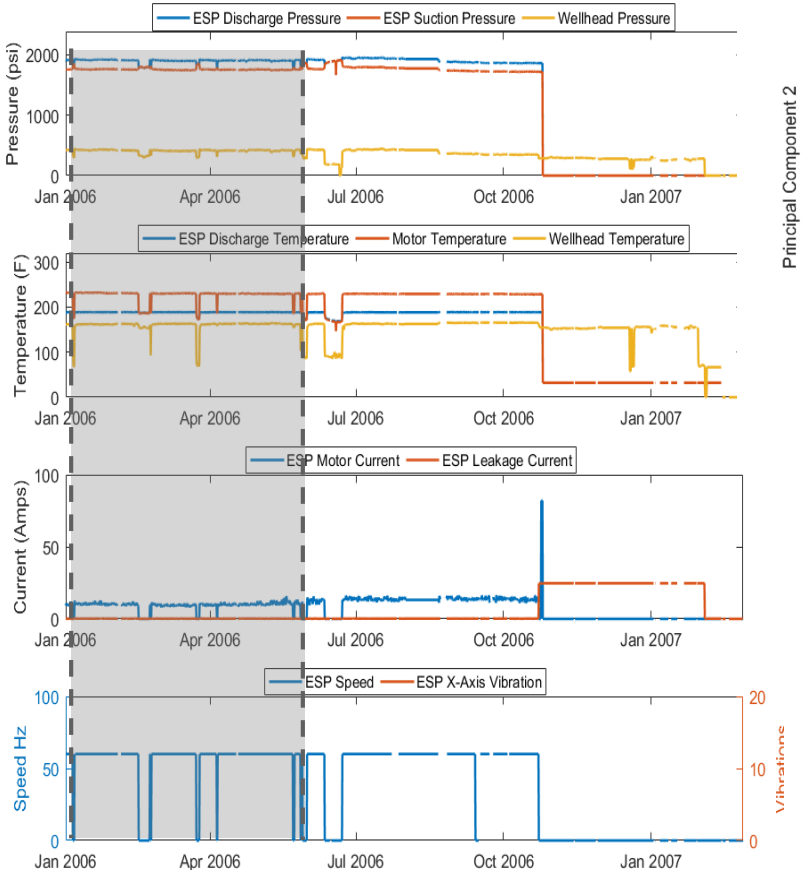
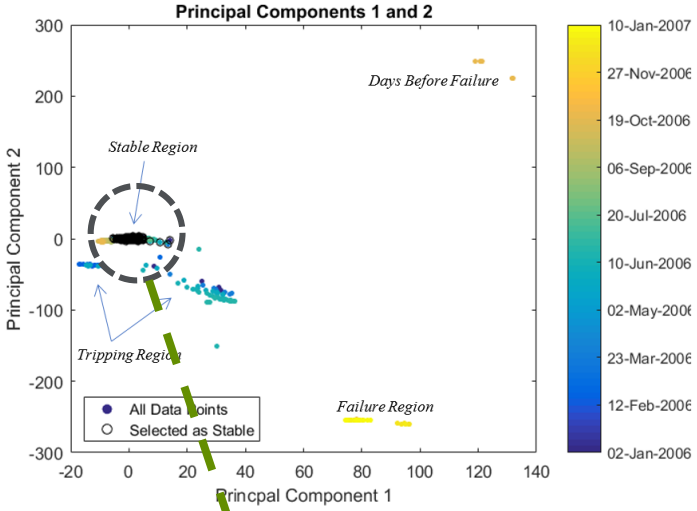
Software Tools Built

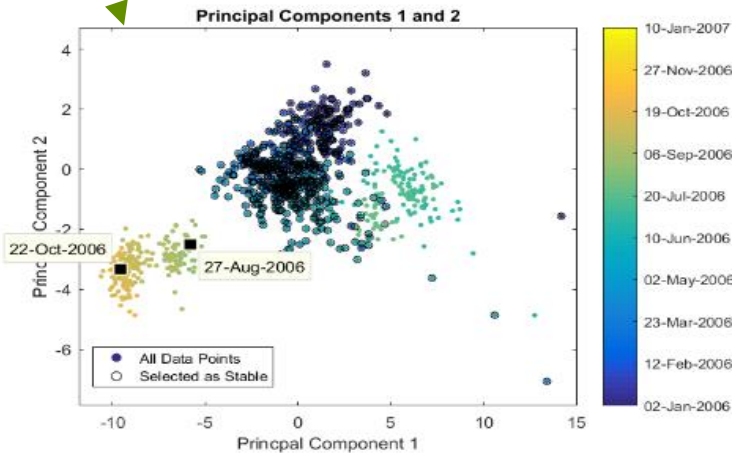




First Installation



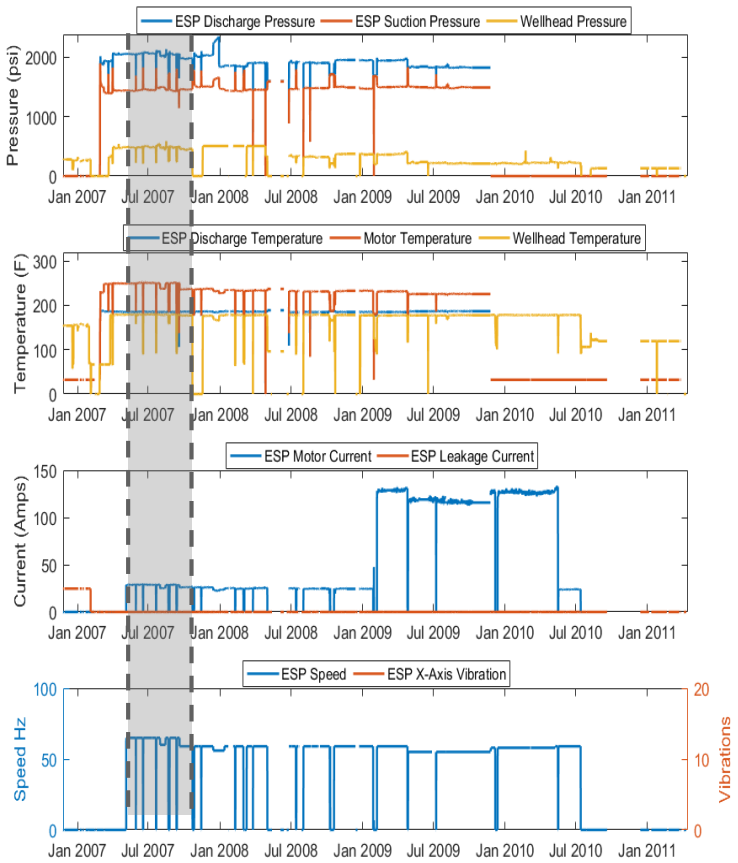


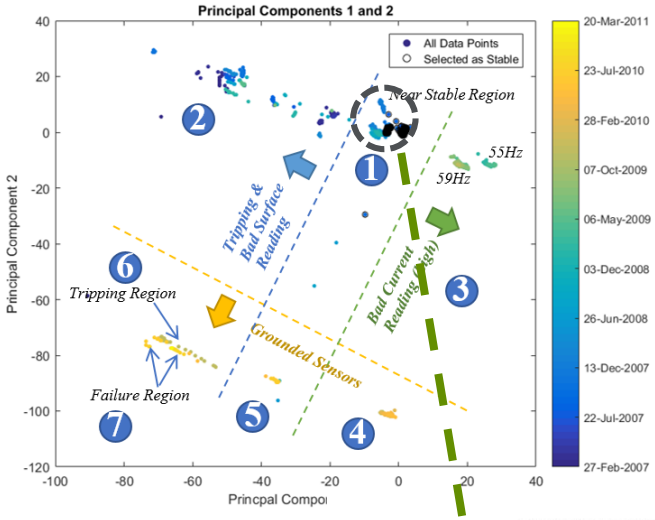


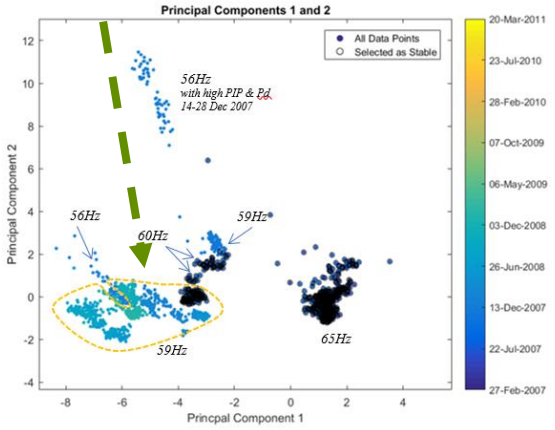
1st and 2nd PCs explained more than 66% of the data

Installation Date	Start-up Date	Failure Date	Root Cause
9-Apr-2004	6-Dec-2004	22-Oct-2006	Burnt/Damaged MLE

Second Installation



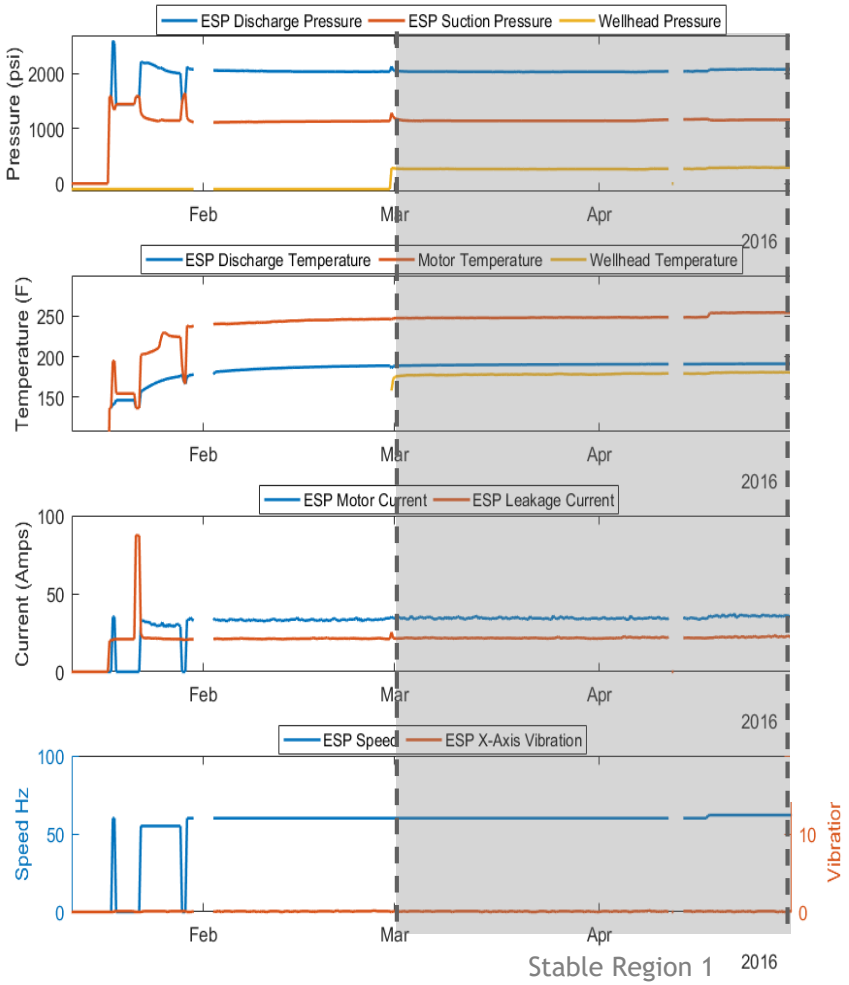




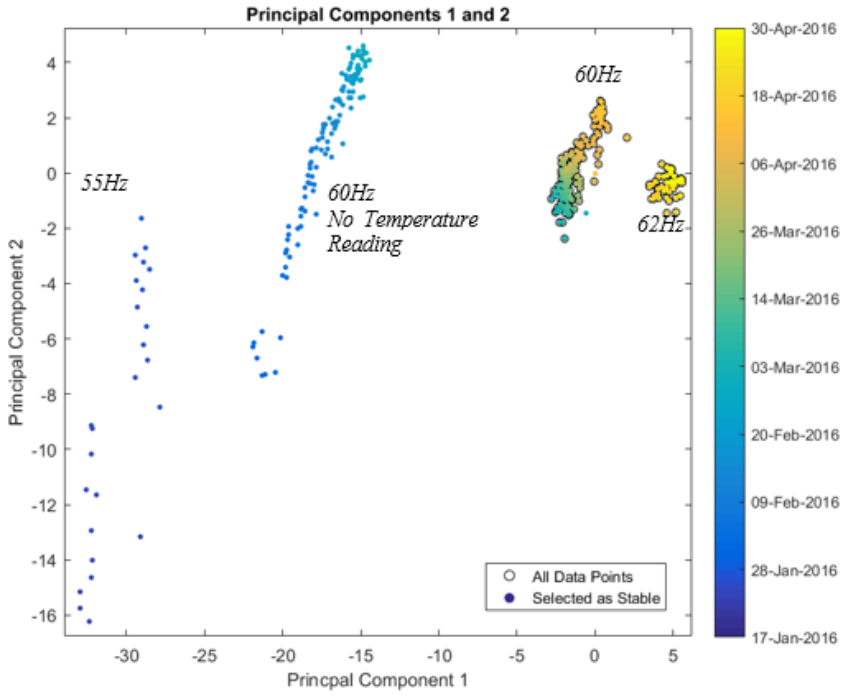
1st and 2nd PCs explained more than 79% of the data

Installation Date	Start-up Date	Failure Date	Root Cause
13-Feb-2007	26-Feb-2007	11-Aug-2010	Burnt/Damaged MLE

Fifth Installation



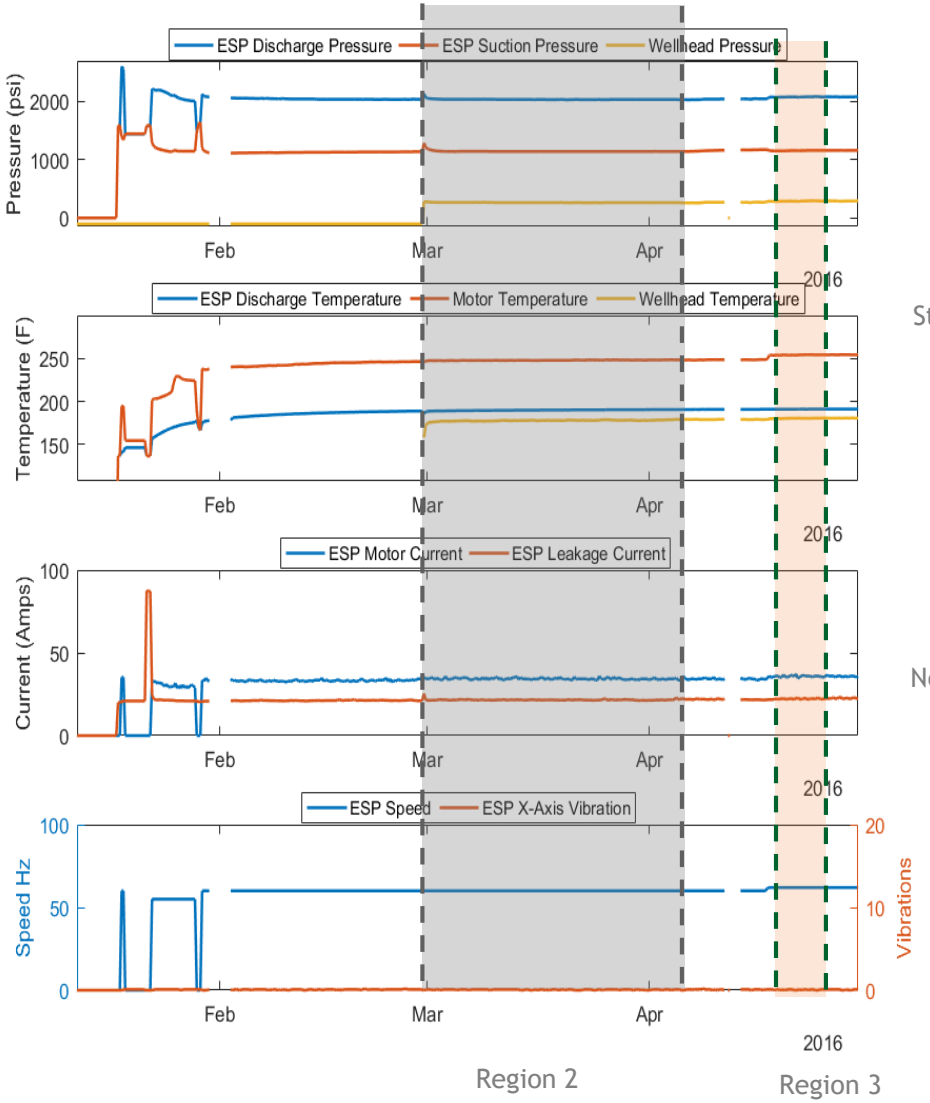
Stable Region 1



1st and 2nd PCs explained more than 87% of the data.

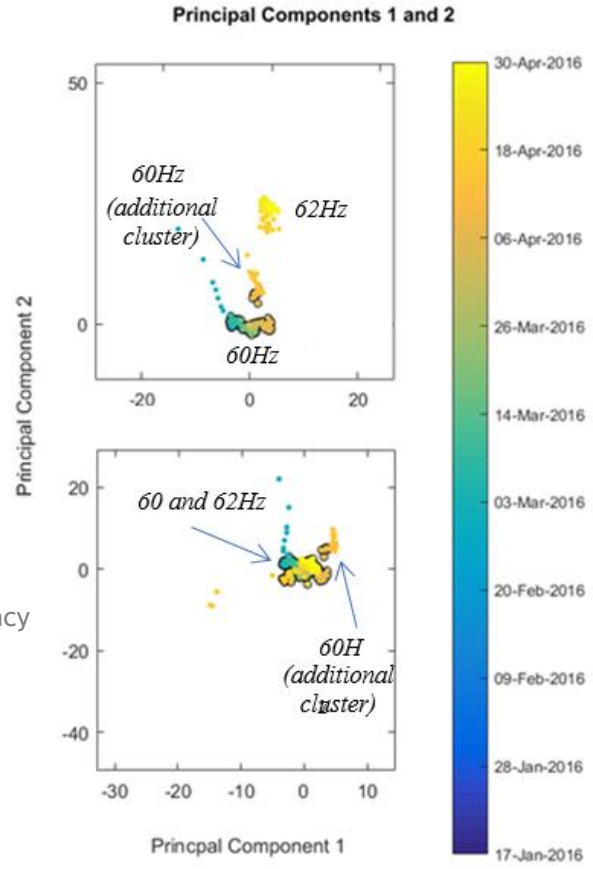
Installation Date	Start-up Date	Failure Date	Root Cause
18-Jan-2016	21-Jan-2016	NA	NA

Fifth Installation



Stable Region 2: 60Hz
PC1 & 2 describe
71.6% of data

Stable Region 2 + 3
Normalised for frequency

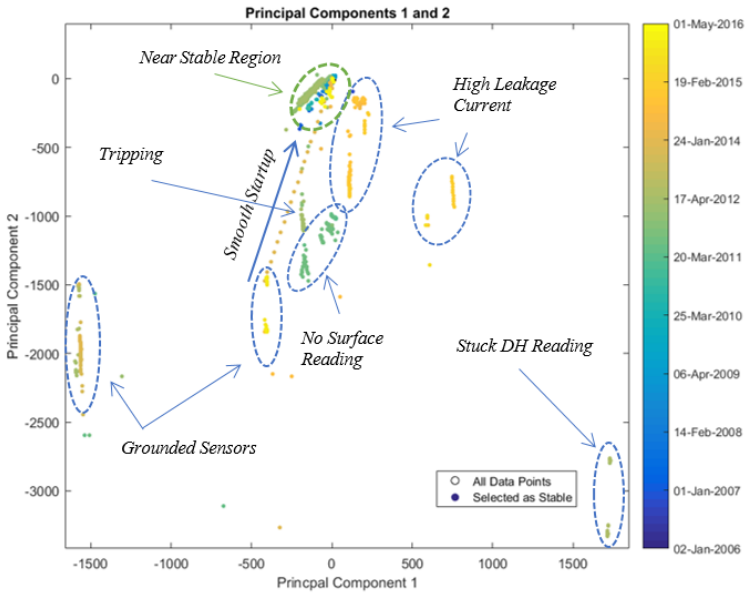


One central cluster for normal operating condition

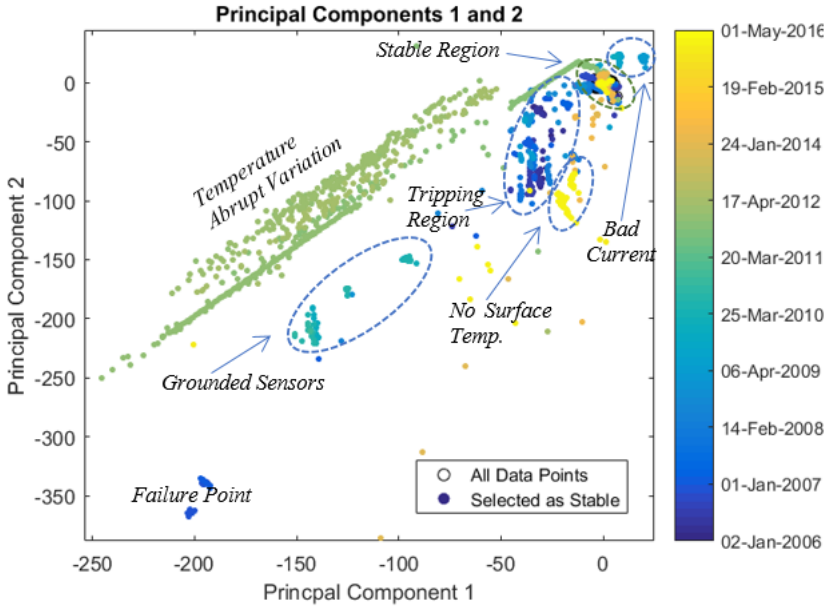
Generalized PCA Model for all Installations

- **One PCA model** - all installations
- **Uniform** conclusions about **"failure modes"** that are **applicable to all**
- **Set the stage** for generalization **across** other **wells** and **fields**
- Less susceptible to stable region selection

Generalized PCA Model for all Installations



Combined PCA - For all installations



Combined PCA – All stable regions

Summary of Results

- Failure of downhole sensor has major impact on PCA
- Method presented allowed detection of **anomalies**:
  - Motor temperature variations
  - High current reading
- PCA allowed **additional dynamical changes** in ESP systems:
  - Cluster shift two months prior to failure (1st installation)
  - Distinctive clusters (5th installation)
- Generalized Model Construction

Thank You

Questions?


aramco