IADC/SPE-178864
# An Instrumented Topdrive Sub System: Enabling Greater Drilling Efficiencies via Innovative Sensing Capabilities

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# Surface Drilling Mechanics System
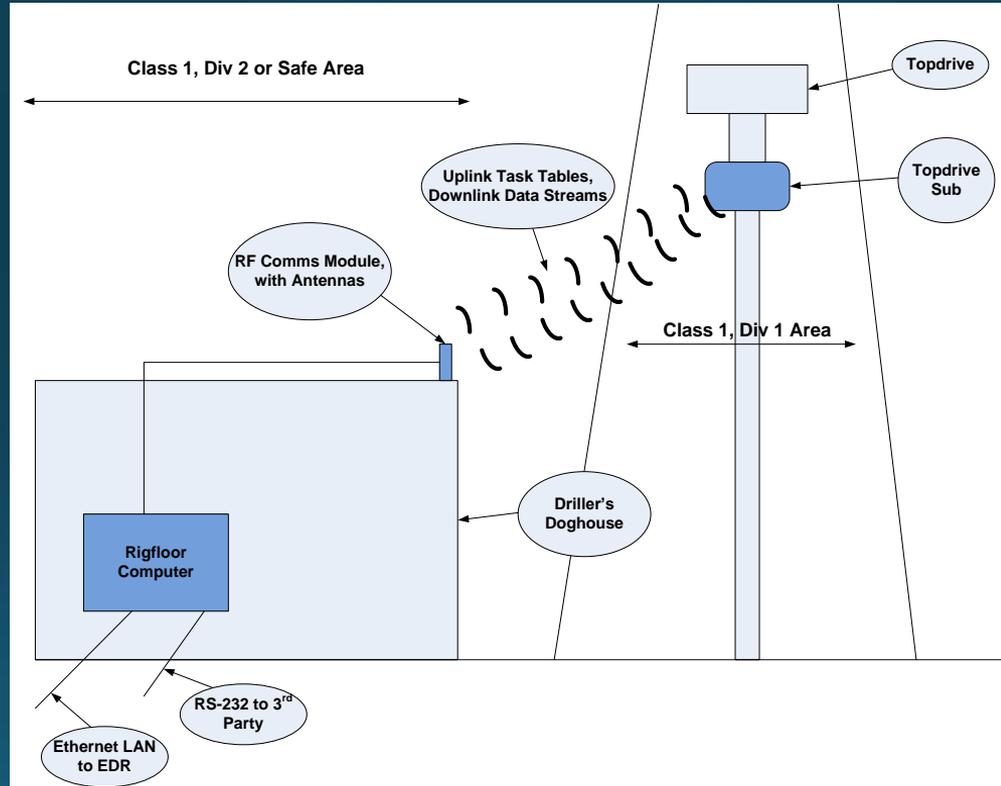
Why?

- Many rig surface sensor systems:
  - Utilize indirect measurements
  - Possess sensors that are inaccurate, not regularly maintained
  - Have sensors with missing or no calibration credentials
  - Fixed sampling rates
  - Do not identify measurement quality
  - Use EDRs that have high latency times

- These factors impede drilling efficiency, and may lead to non-productive operations

What?

A single point of service for a suite of measurements:

- Hookload
- Torsion
- Bending moment/angle
- Rotation speed
- Height (depth)
- Flowrate
- Mud density
- Mud pressure
- Mud temperature
- Drillstring vibrations
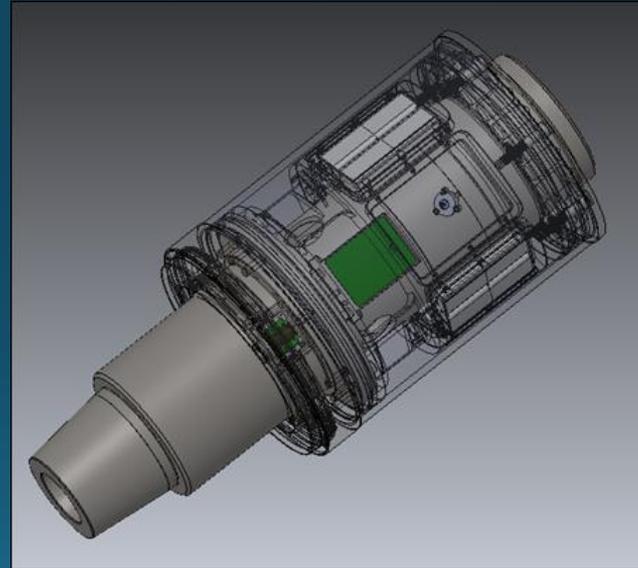
Primary System Features

- Reliability & quality
  - Robust communications, calibrated sensors

- Synchronicity of measurements
  - Priority for valid data correlations
  - Common sampling and data transmission clocks

- Power conservation
  - Sensor selection by rig activity
  - Maximizes run time between battery recharges

Measurement Commonalities

Each sensor:

- has a documented calibration
- has high accuracy, low power consumption
- acquires measurements at user-configured frequencies
- located in weatherproof, noble gas filled enclosure

Each measurement:

- is direct in relation to the load path
- is made simultaneously with all others
- is available on command

Measurement & Sensors

Measurement	Sensor Type
Weight, torque, bending moment & angle	Strain gages
Block height	Laser rangefinder
Rotation speed	Magnetometer, rate gyro
Pressure & temperature	Thin film strain gages
Flowrate and mud density	Ultrasonic
Axial, torsional, lateral vibrations	Strain gages

Measurement Ranges

Measurement	Estimated Range
Tension/compression	0 – connection yield
Torsion	0 – connection yield
Bending moment	0 – connection yield
Rotational speed	0 – 200 rpm
Height	0 – 150 ft
Pressure (mud)	0 – 7500 psi
Temperature (mud)	0 – 250 F
Mud flowrate	100 – 1800 gpm
Mud density	7.0 to 20.0 ppg

Primary SDM System Sensors
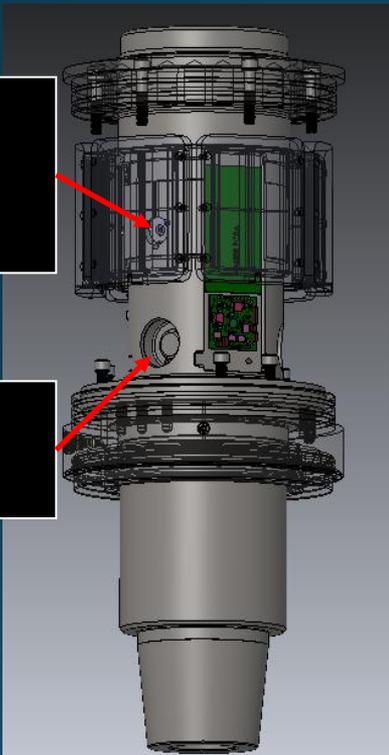
Other SDM Sub Features

Master Controller & Radios

Battery Pack (1 of 6)

Secondary Pressure Containment

Pressurized, argon filled chamber

Antennae Housing

Recharge, comms, and power port
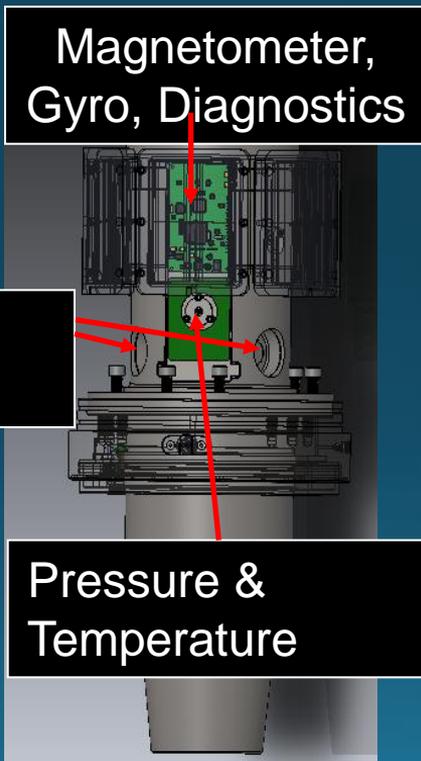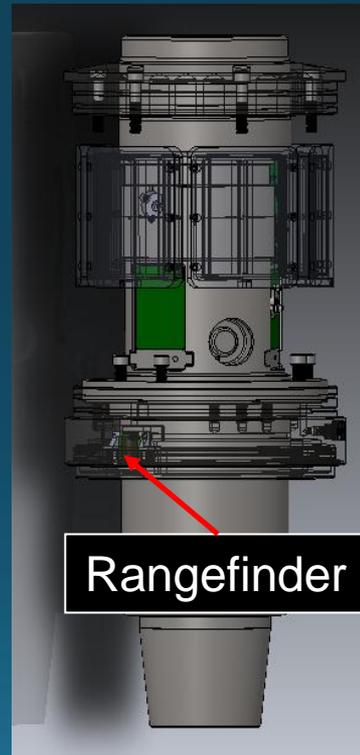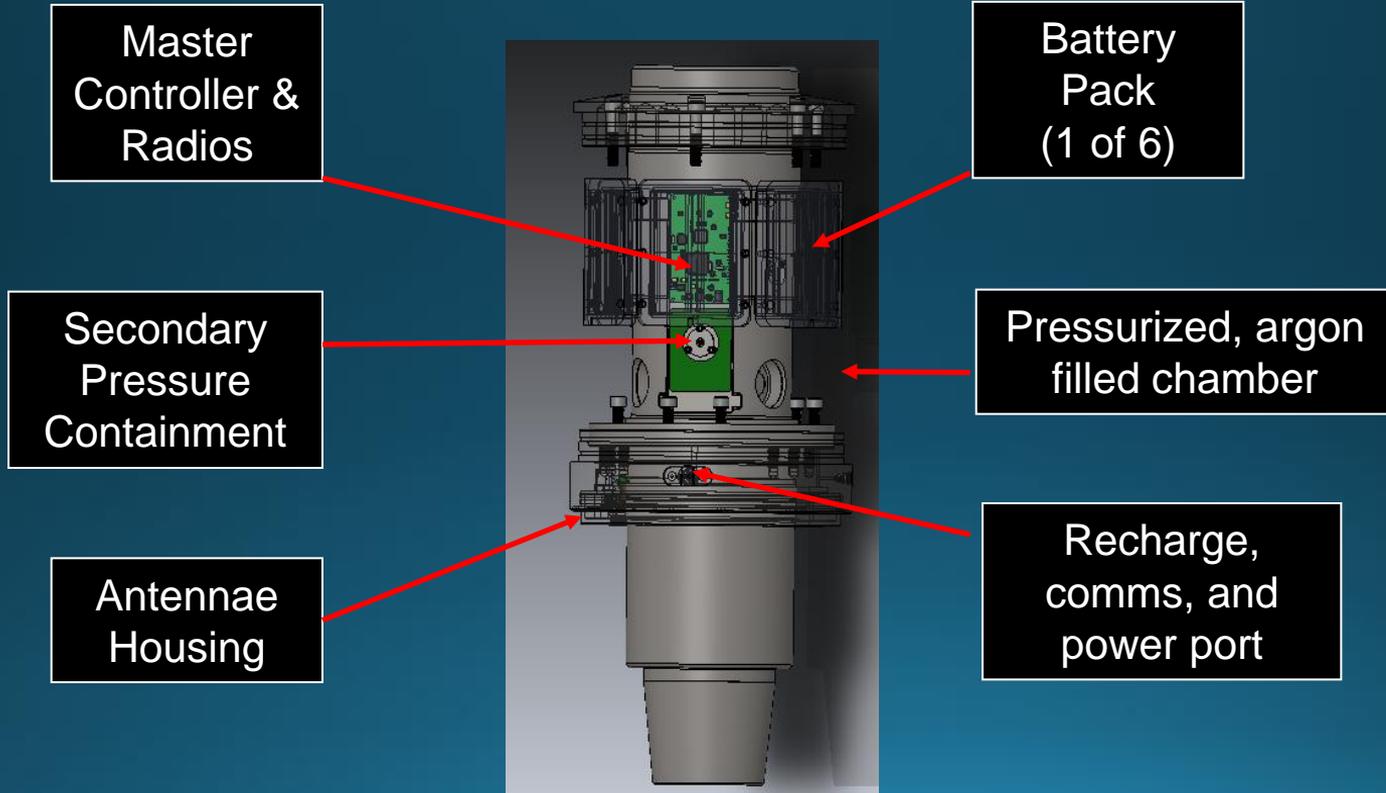
SDM Sub - Physical Envelope

- Connections

  - NC40, NC46, NC50, 6 5/8", 7 5/8"

- Mandrel

  - 8.0", 10.0" OD, with 3.0", 3.25" ID

- Length - 22 ½" shoulder-shoulder

- Chamber OD – 13.5" – 16.0"

Hookload, Torque, Bending Moment & Angle

- Strain gage measurements from 3 pockets
  - Oriented at 120° in same horizontal plane
- Sensors are full Wheatstone bridges
- Each pocket has 1 weight & 1 torque sensor
- Values are averages of 3 sensors
- Bending moment and Bending angle
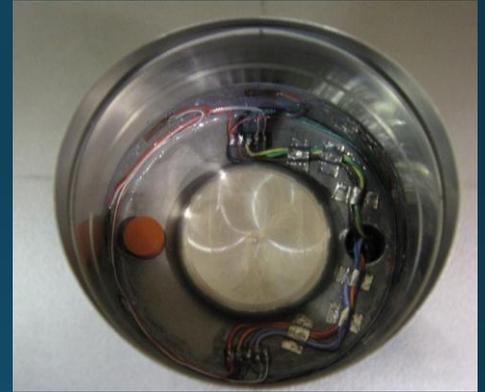

Strain pocket, gages attached to wall

Tension, Torsion & Bending Moment Calibrations

- Honeywell load cells with NIST traceability used for load calibrations

- 124 + calibration stations for 66 scale & bias factors

- Corrections for differential pressure and temperature
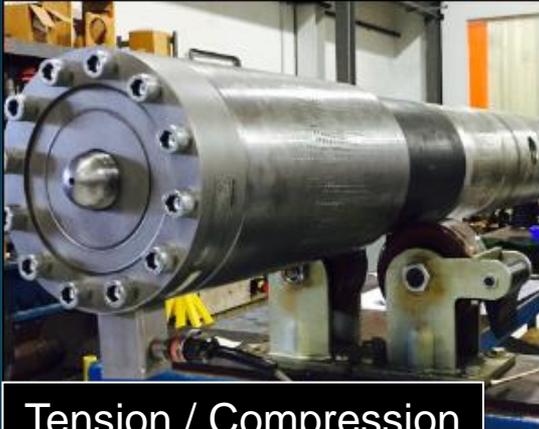
Tension / Compression
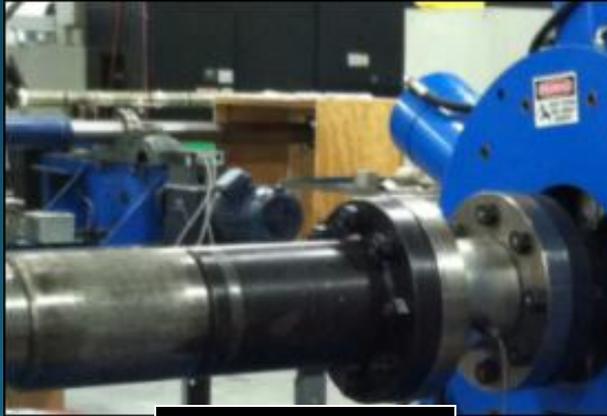
Torsion

Bending moment

Height (Depth) Sensor

- Eye-safe laser rangefinder
- Distance measured by time of flight
- No special target required
  - reflects from any surface
- Factory calibrated
  - 0.8" accuracy at 100', or 0.07% RD
- High sampling rate
  - can provide instantaneous ROP

Pressure & Temperature Sensors

- Digital sensors
- Thin-film strain gages
- Full Wheatstone Bridge
- Factory calibrated
- Full scale 7500 psi
  - 0.025% accuracy
- Nickel RTD temperature
  - Accuracy ≈ 1.0%
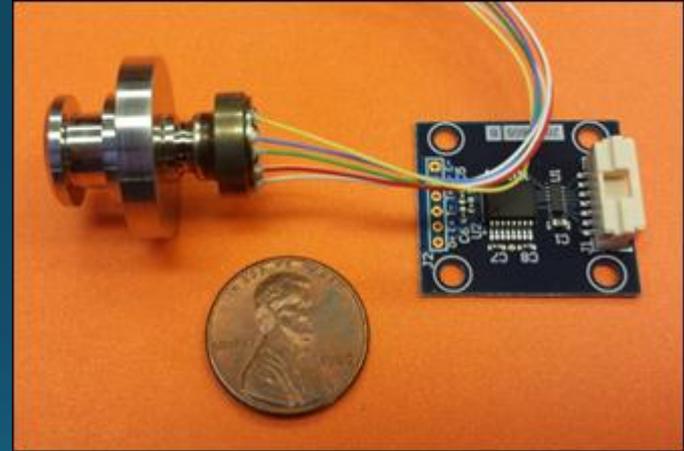
Mud Flowrate Sensor

- Flowrate derived from measurement of velocity
- Velocity measured by ultrasonic transit time differences
- Upstream & downstream sensors
- Independent of pressure, temperature & fluid density
- Accuracy ≈ 0.5% of reading

Flowrate sensors with PZT crystals

Ultrasonic Flowmeter Responses
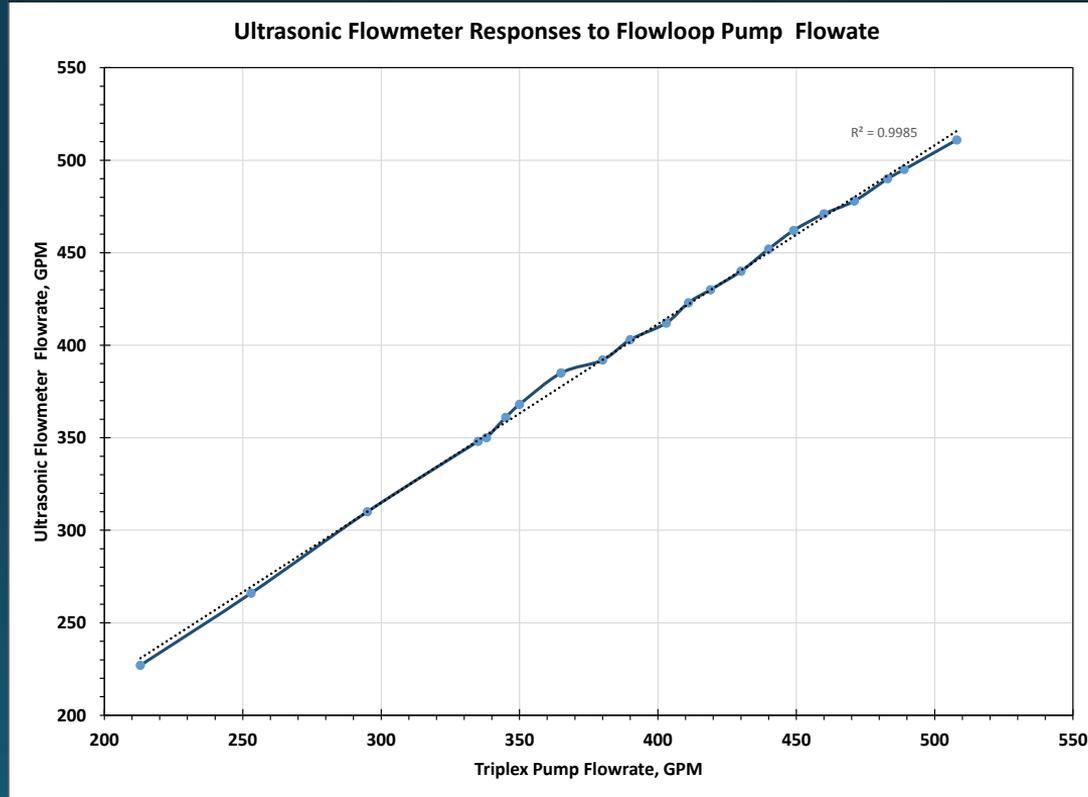
Mud Density Sensor

- Same sensor used for flowrate is used for mud density
- Density is derived from a speed of sound measurement together with a measure of signal attenuation
- Empirical tests are ongoing now
  - Results to date are very encouraging
    - 8.8 to 16.3 ppg WBM
  - Tests at temperature and pressure planned for summer 2016
  - Tests to 850 gpm, WBM & OBM at Houston flow loop in September
  - Accuracy is TBD

Telemetry Channels & Radios

3 data channels:

- Uplink – Instructions – 154.6 MHz

- Principal Downlink Channel – 154.6 MHz Radio
  - Data and quality indicators transmitted from sub to rig floor
  - Wrap-around antenna, no "dead" transmission spots

- Secondary / Fast downlink – 2.4 GHz Radio Frequency
  - Can be subject to multipath signal interference - Uses multiple "patch" antennas
  - Meant for possible transmission of vibration data not processed by onboard digital signal processor

Data Transmissions

- Data telemetered in packets, with redundancy checks, sequence identifications, acknowledgements

- Each sensor data packet contains a quality indicator

- Message frequency configurable, from 1 to 500 Hz

- Data rate of primary radio is 200 kbps; max. throughput is on the order of 1.4 Mb per minute

Data Sampling & Processing

- User creates "Tasking Tables", instruction sets uplinked to sub's Master Controller for :
  - sensors selection
  - sampling rate for each sensor (1 to ≈500 Hz for most sensors)
  - processing for each (type of averaging: mean, mode, RMS, etc)
  - number of samples to average for each (max 256)
  - sampling clock frequency (1 to 500 Hz)
  - radio (transmission) clock frequency (1 to 500 Hz)
- Custom Tasking Tables for different operations
  - e.g., drilling, short trip, well control, other user scenarios.

Example Setup of Sensor Sampling & Update Rates

Measurement	"Typical" Sampling Rate	Value Update Rate
	Hz	sec
Block Height	100	0.1
Hookload, Torque	50	1
Rotary Speed	50	0.25
Mud Pressure	10	1
Mud Temperature	1	60
Flow Rate	100	60
Mud Density	100	60
Vibrations	450	1

Rigfloor Console & Communications Module

- Rig floor Communications Module
  - Contains the antennas for the two radios
  - Contains the two radio circuits
  - Uses Power over Ethernet for comms to Rigfloor Console
- Rig floor Console (Can be integrated into Customer provided EDR system)
  - Receives all data from sub, timestamps, and passes transparently to EDR
  - Displays data for driller
  - Performs minimal processing, algorithms for basic functions (eg, connection identification, calculation of weight on bit)
  - Uploads instructions (Tasking Tables) to topdrive sub

Status of System Components: 4/1/2016

SDM Sub

Rig floor Comms Module

Rig floor Console

Performance EDR System

Mostly completed

Specs developed

Prototype made, limited tests performed; Flowrate & density sensors require more testing

Prototype made & tested

Basic GUI– Customizable for / by user

Customizable by user
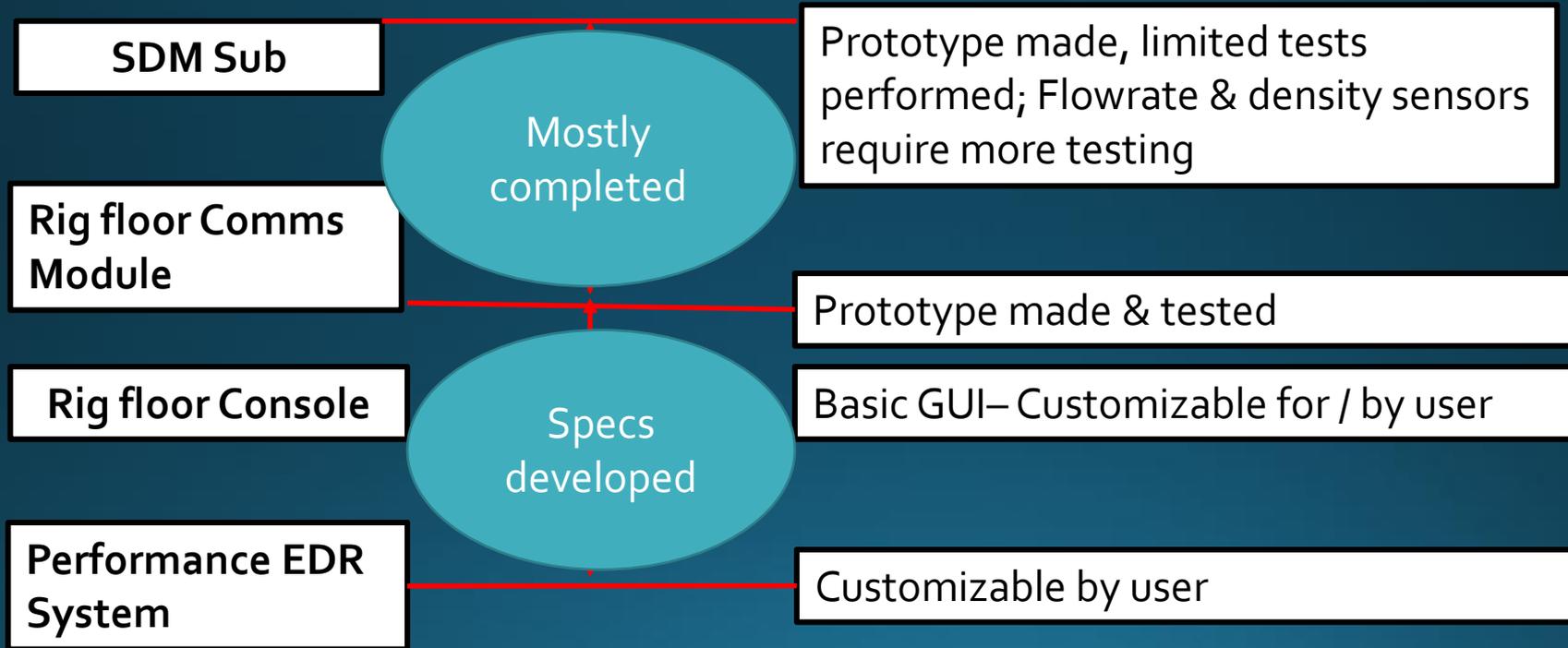
THANK YOU

QUESTIONS & COMMENTS

Instrumented Top Sub