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Verification and Validation of Sensors and Systems Using Systems Engineering Methods

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10 times more likely to be struck by lightning than be killed in a plane crash

Is drilling willing to adopt this proven solution?

- Are drilling sensors good enough?
- How should we characterize data quality?
- What is Systems Engineering Verification and Validation as applied to commercial aviation?
- Is aviation industry experience appropriate for drilling?
- Can we map the application to criticality levels in drilling?
- Should drilling adopt V & V methods??

Data errors are not only sensor generated – multiple sources

- Sensor: design, maintenance, calibration, ……
- Installation: offsets, placement, ……
- Compensation: re-zero surface WOB, adjust block height, mud pump efficiency, friction tests, proximity to purported measurement (WOB),….
- Signal processing: sample rate versus signal (frequency dynamic behavior being measured), mismatch sensor / processor, unfiltered noise, ….
- Calculation: derived WOB from surface measurement, actual drill string length this hole depth, ……
- Transmission: time stamping, weak protocols, ……

Mid 1900's sensors driving 2020 drilling technology and processes

What is the real status of drilling data? Not Good!

Warning was raised

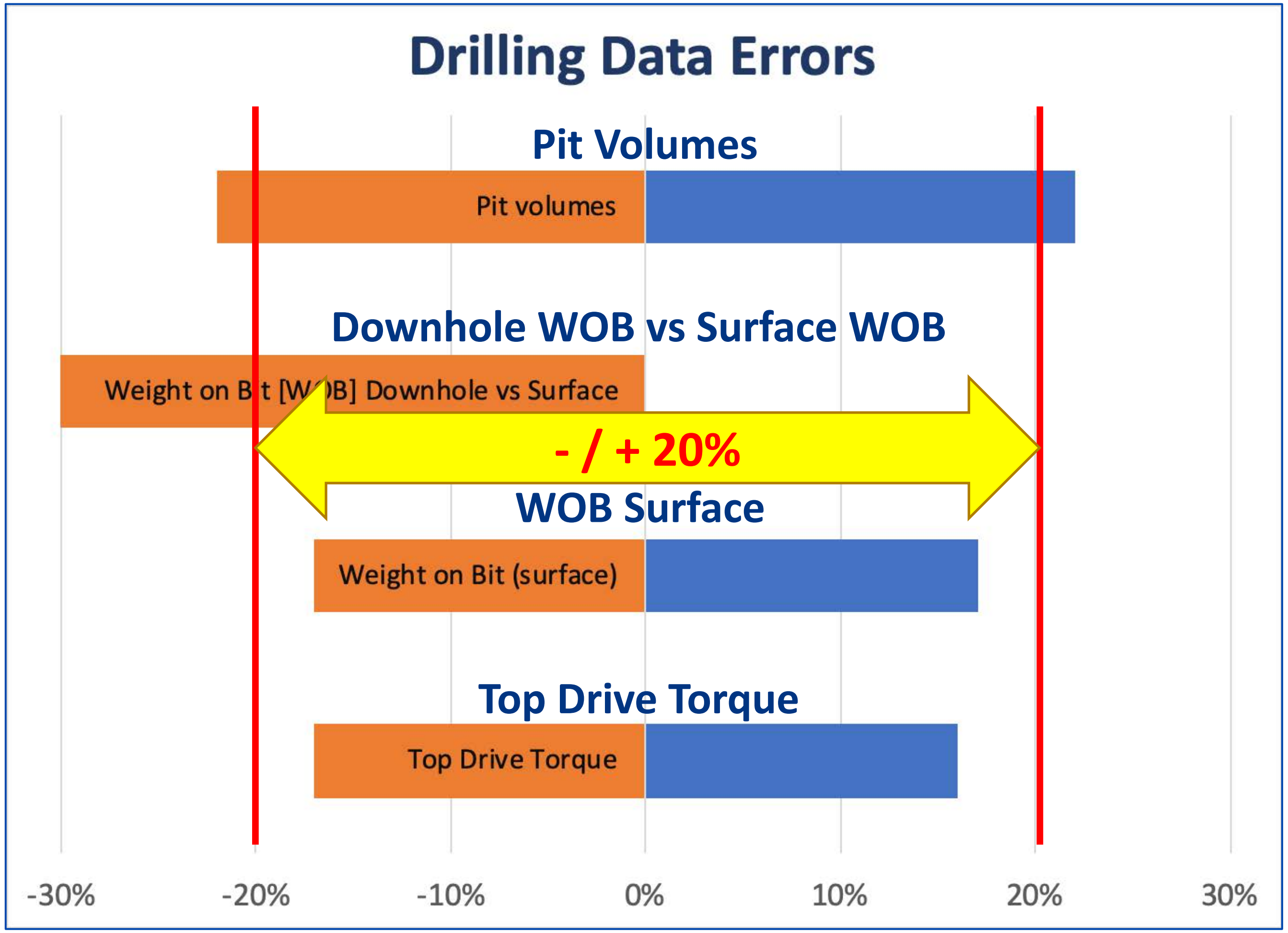
	Rig A	Rig B	Rig C	Rig D	Rig E	Rig F
Rotary Torque	17%	17%	22%	24%	21%	18%
Makeup Torque	23%	11%	12%	17%	60%	13%
Rotary RPM	1%	1%	1%	1%	2%	1%
Block Position	6"	<0.5”	<0.5”	6ft	<0.5”	<0.5”
Hookload	11%		18%		12%	
Pit Volumes	15%	12%	18%	16%	15%	22%
Pump Rate	1%	32%	1%	1%	40%	1%
Pump Pressure	5%	4%	4%	4%	3%	5%

What is the real status of drilling data? Not Good!

Warning was raised

Researched SPE papers
Pit volumes
WOB
Torque

Recognize there are areas of high-quality data due to rigorous calibration, maintenance and error modeling.



We need to characterize data quality

- Precision: reproducibility and repeatability of the measurement
- Accuracy: proximity of measurement to real value
- Latency: time delay data acquisition to data consumption
- Calibration: restoring the data to meet agreed criteria
- Validity: invalid status flagged

Drilling data is not "good enough" in many aspects.

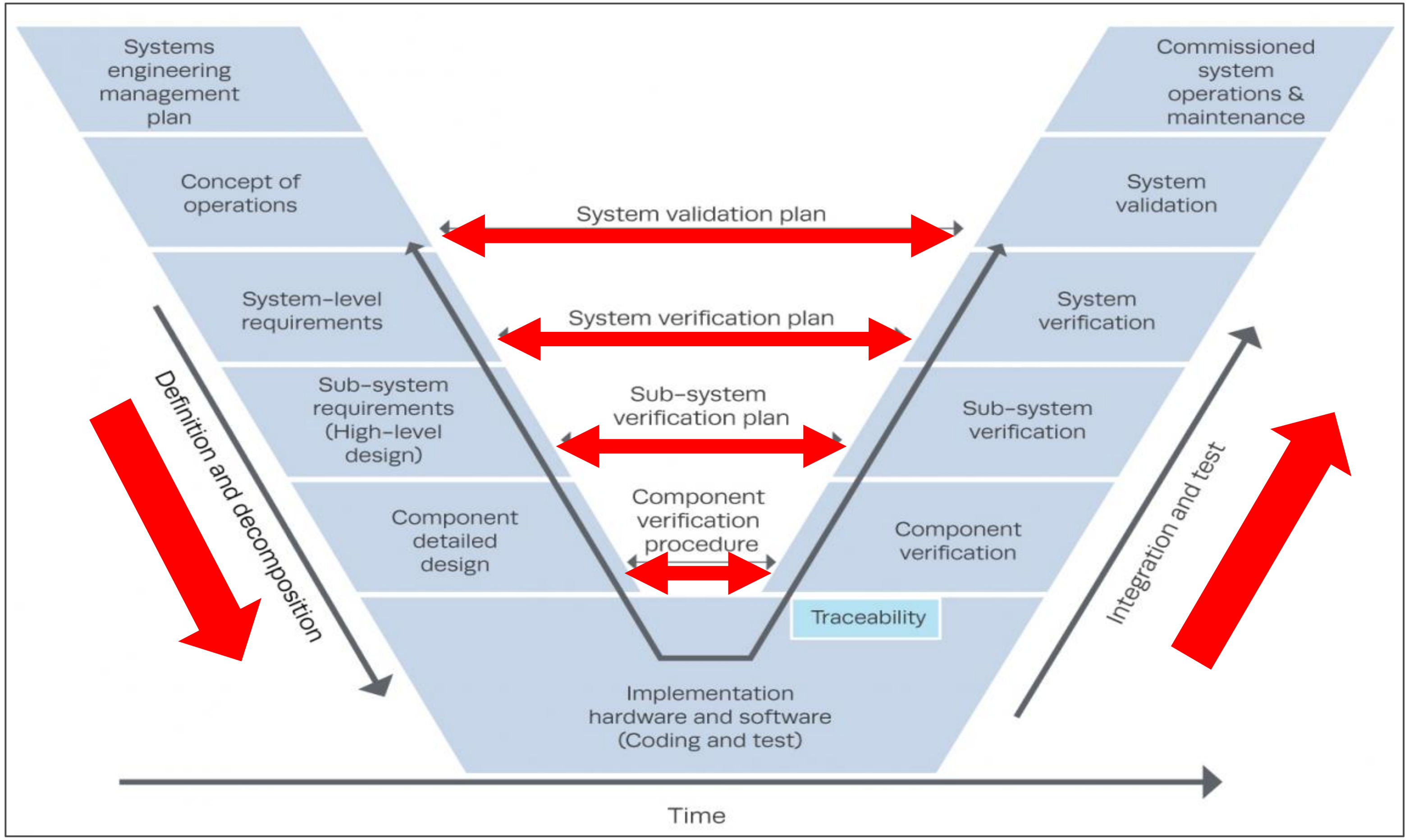
ERD data is not what the driller is acting on!

Data consumers need meta data

Source: IMS Team on DSA Roadmap

An introduction to Systems Engineering Verification and Validation

- Validate the concept
  - Validate the solution
- Verify the system requirements
  - Verify the solution
- Sub system verification
  - Design and testing
- Component verification
  - Design and test



Sensors and software V&V in the aviation industry

- International standard DO-178C – Software Considerations in Airborne Systems and Equipment Certification (RTCA).
- Software response to the sensor data:
  - defined correctly (requirements).
  - implemented correctly (verification).
  - do the right thing in operation (validation).

Levels of criticality in aviation

Software Level	Failure Consequence	Target Failure Rate
A	Catastrophic - Failure may result in a crash. The failure could cause a loss of a critical capability required to fly and land an aircraft.	10^{-9}/h
B	Hazardous - Failure may have a significant negative impact on safety or performance. Serious or fatal injuries of passengers possible.	10^{-7}/h
C	Major - Failure would be significant but would lead to customer discomfort rather than injuries	10^{-5}/h
D	Minor - Failure would be observable and could lead to customer inconvenience or altering of flight plans.	10^{-3}/h
E	No Effect - The failure would have no impact on safety, aircraft operation, or workload.	N/A

Does V & V work in the aviation industry?

- Yes – we all fly "heavier than air" vehicles everyday
- Boeing 737 MAX incident
  - Indeed – they went outside the protocol of V&V
  - Systems failure, human training
- MCAS installed on military tanker 10 years ago
  - Required multiple sensors
  - Greater pilot control

MCAS stands for the Maneuvering Characteristics Augmentation System

RPK - Revenue Passenger Kilometers

Is Systems Engineering V & V appropriate for Drilling?

- Significant Influence - of sensor data and software
  - Sensor data and software output influences decision making in manual, semi-automated, and automated drilling operations.
- Limited Assurance - of performance
  - The influence of data on the drilling process is occurring with limited assurance that the sensor output data will enable the systems to adequately perform, will not fail, nor risk hazardous or catastrophic events.
- Smart Adoption - will reduce risk
  - Adopting proven aerospace V&V methodologies can provide the means to reduce risk in critical systems.
- Legacy Risks - need evaluating
  - Legacy sensors expose modern semi-automated and automated drilling operations to major risks that have not been evaluated.

Mapping application of systems engineering V&V to drilling

Software Level	Aviation Example Function	Drilling Candidate Function
A	Autopilot	Closed-Loop Control of primary movers in drilling equipment lifting, rotating and pumping. Integrated fully automated drilling systems for Managed Pressure Drilling, drill-a-stand, mud treatment and circulation
B	Passenger supplemental oxygen at the time of need	Supervisory Control of automated subsystems Fully automated independent subsystems such as Managed Pressure Drilling
C	Passenger environmental controls leading to emergency landing a possibility	Machine level control issues causing the operator significant stress in overseeing the system
D	Lavatory systems delaying flight	Surface equipment failure, downhole equipment failure resulting in NPT
E	Inflight entertainment systems	Displays that are not directly connected to operating machinery and tools

To adopt or not to adopt V&V – that is the question

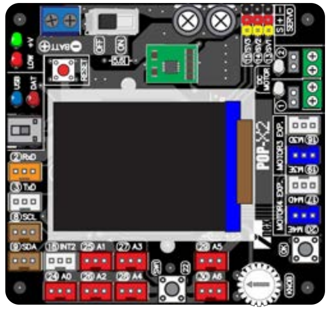
Apologies to William Shakespeare

Adopt V&V – what is the future scenario?

- Extra expense: design through application
  - scale to criticality
- Ability to rely on data: know what you get
  - Confidence in analysis, decisions and actions (human and automated)

- Safer, improved operations
  - Sensors / systems rigorously designed and implemented

Scalability and appropriateness are the keys to successful implementation



Not adopt V&V: what is the future scenario?

- Muddle forward with data analytics of unknown quality and attributes
  - Work with “good enough” data and miss the real opportunity
- Automated systems fail to ‘act’ as expected
  - Delays and undue stress on operators (rig alarms!)
- Major incident: wrong data, wrong decisions, lives and assets at risk of calamity
  - Investigation

IADC DEC approved a JIP to develop a Proof of Concept for V&V in drilling data.

Abandoned on April 1st , 2020 – lack of funding.

Acknowledgements

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V&V JIP Information at: http://dsaroadmap.org/ivv-ss/

Thank You / Questions

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