drilling

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Systems Architecture and Operations States for Drilling and Completion

Foundation to Real Performance Measurement and Drilling Systems Automation

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A complicated topic with immense value

- Industry fragmentation is a drag on systems automation
- Defining and distinguishing systems architecture is a must
- Understand methodology to develop systems architecture
- Applying systems architecture to drilling is new and unique
- Define system states: needs and value
- Descriptions of the various states relevant to DSA
- Using epics, user stories and use cases to detail interactions
- The industry route forward

Drilling operations are complex & inadequately organized

- Control loops cannot be logically organized in drilling operations
- Default data / control flow construct from contracts is not designed
- Automation requires a “map” to define data / control flows
- Complex systems with advanced technologies use systems architecture

Understanding what systems architecture is

- "Systems architecture" applied to many different meanings
    - miscommunications & misunderstandings
- Architecture - a top-down description of the structure of the system
- Software architecture
    - structure of a program or computing system comprising software components
- Technical architecture
    - describes the IT hardware that enables a computer system to operate

Understanding what systems architecture is

International Council on Systems Engineering (INCOSE) definition of systems architecture:

System Architecture is a representation of a system conveying interactions and behaviors of its components through several graphical viewpoints

Elements include people, hardware, software, facilities, policies, and documents - everything required to produce systems-level results

Defense systems and drilling systems are analogous

- Need for interoperability of complex interrelated technologies and processes from multiple sources
    - “plug and play” in a joint, global environment
- Need for highly effective and reliable operations in an uncertain environment

- DoD Architecture Framework (DoDAF) provides direction on how to
    - enables design / implementation of a Reference Architecture
    - leads to Solutions Architecture for specific projects.

Developing Systems Architecture

- Systems architecture is a methodical means to define how systems, their components and elements interact to deliver efficiently a result
- Start with a reference architecture
    - objective of DSA roadmap is to share reference architecture
- Department of Defense six step process
    - delivers architecture using a framework

Views of the architecture

- Three related architecture views at high level
  - operational, systems, and technical
- Multiple DoDAF products under each view
  - Next step is to identify which apply
  - Many aligned with DSA Roadmap challenges
  - States and State Transitions are critical products

DoDAF six-step process for Drilling Systems Automation

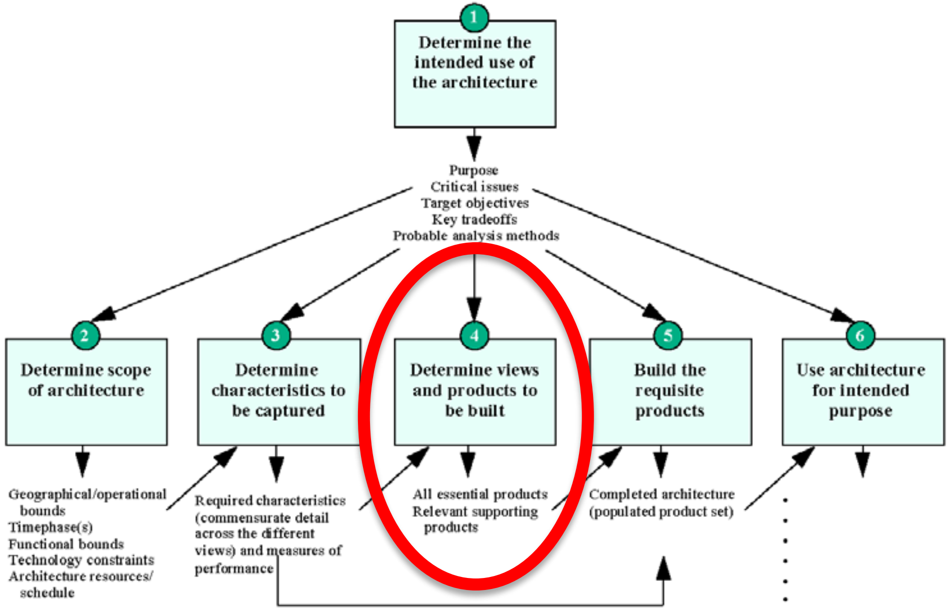


Figure 3-1. The Six-Step Process of Building an Architecture

- DSA – R is well aligned to DoDAF six steps
- Focus on step 4 to ascertain the aspects of DoDAF applicable to DSA Reference Architecture
- DSA – Roadmap adaption of DoDAF will enable industry to move forward in systems automation

Systems Architecture Applied to Drilling and Completion

- Rarely applied to drilling operations
  - Applied to specific high technology equipment applications
  - Traditional contract work scopes do not match optimum architecture
- Drilling industry can benefit from a systems architecture model
  - DSA-R team introduced a high level model in 2015
- Advantages to building a reference model from DoD framework
  - Companies can then detail operations specific systems architecture
- Operator or General Contractor (IPM / turnkey) has best overview
  - Reference Architecture will provide all companies with a common overview

Multiple states definition required for automation

- Knowing multiple states is fundamental to drilling systems automation
  - fully defined without human interpretation
  - high fidelity - any instant in time
  - communicated to all parties in real time for tasks, models, simulations, activities, machine control, …..
- Methodology is an automated distinction with common output
  - a so called “state machine”
- Some states require:
  - Modelling
  - New sensors

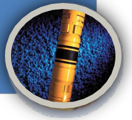
Multiple states definition required for automation

- Drilling
- Tripping In
- Tripping Out
- Cementing

Drilling State

- Tripping In
- Setting packers
- Perforating
- Circulating

Completion State



- ROPO
- Trajectory
- Influx management
- *User Stories*

State Intent

- Which system
- Which human
- Level of Automation Taxonomy

Automation State

- Cleanliness
- Stability
- Pore Pressure
- Influx

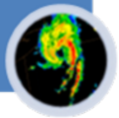
Well State

- BHA Components
- Pump configuration
- Top Drive

Equipment State

- Weather
- Sea State
- Roads
- Logistics

Environment State



Drilling State – Example

- 18 rig states have been defined based on 4 measurement channels:
  - Position of travelling block
  - Hook load
  - Rotary drive torque
  - Mud pressure
- Defined states include activities such as :
  - Rotary drilling
  - Slide drilling
  - Reaming
  - Run in

Drilling State – Example

B du Castel version:

- first two columns give a name and a numerical value to each rig state.
- The eight other columns are discriminative traits that classify the rig states.
- For example, when the rig state Back Ream is on, the block moves up, the bit is off bottom, the pump is on, the drillstring is rotating, and, of course, the drillstring is not in slips.

Comment	Input ▲	block	bottom	pump	rotate	slips	absent	classified	datagap
Rotary Drill	0	slow	onbottom	on	on	notslips	no	yes	no
Slide Drill	1	slow	onbottom	on	off	notslips	no	yes	no
InSlips	2	...	offbottom	...	...	inslips	no	yes	no
Ream	3	down	offbottom	on	on	notslips	no	yes	no
Run In, Pump	4	down	offbottom	on	off	notslips	no	yes	no
Run in, Rotate	5	down	offbottom	off	on	notslips	no	yes	no
Run In	6	down	offbottom	off	off	notslips	no	yes	no
Back Ream	7	up	offbottom	on	on	notslips	no	yes	no
Pull Up, Pump	8	up	offbottom	on	off	notslips	no	yes	no
Pull Up, Rotate	9	up	offbottom	off	on	notslips	no	yes	no
Pull Up	10	up	offbottom	off	off	notslips	no	yes	no
Rotate, Pump	11	stop	offbottom	on	on	notslips	no	yes	no
Pump	12	stop	offbottom	on	off	notslips	no	yes	no
Rotate	13	stop	offbottom	off	on	notslips	no	yes	no
Stationary	14	stop	offbottom	off	off	notslips	no	yes	no
Unclassified	15	...	...	...	...	...	no	no	no
Absent	16	...	...	...	...	...	yes	yes	no
Data Gap	17	...	...	...	...	...	no	yes	yes

Figure 4: The 18 rig states

Drilling State – Needs

- Real time computation of rig state validated at rig site
    - All parties rely on same rig state machine
- Define state transitions accurately and immediately:
    - Models and controls change
    - Increase level of reliable measurements or physics-based modelling
- Increase ability to automatically detect states that can only traditionally be detected by manual means:
    - Install wellhead
    - Nipple up
    - Pressure test

Well states need to be real time and NOT subjective

- Today, humans primarily define well states from intuition (retroactively)
- Additional sensors and new sensor technologies
    - Video graphics
- Inaccessible states require models and are probabilistic
- Hierarchical impact on automation from low to extremely high in the case of an influx
- Real time measurement of well states is a huge opportunity
    - Advanced Spline Curve calculation tortuosity (SPE178796)
    - Bending moments = tortuosity
    - Cuttings detection on shale shaker
    - MPD for more than just “un-drillable” wells

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- Additio…
  - V…
- Inacces…
- Hierarc… the case of…
- Real ti…
  - A… lation tortuosity (SPE1787…6)
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Very high value work in progress

Requires collaboration

What the heck are Epics, User Stories and Use Cases

- Welcome to the new world of clear distinctions in drilling and completion operations

Epic

- A large user story that requires other smaller user stories
  - *Drill a quality wellbore in right location*

User story

- Something a user wants
  - *"As a Driller I want to automatically drill a stand"*

Use case

- A list of steps to achieve a goal
  - *Break gel*
  - *Ramp up pumps*
  - *Tag bottom*
  - …..

Relating Use Cases and States

- A set of states defines the beginning and end of a use case
- Example:
    - Drilling State: “The bit is on-bottom drilling.”
    - User Story: This state (action) is realizing the User Story “Drill a Stand”.
    - While this action is active, the automation system engages a drilling control system designed to maximize rate-of-penetration.
    - Use Case: This engaged control system enables the use case “Maximize ROP within constraints”.

Relating Use Cases and States

- Abnormal conditions occur
- Example:
    - Use case “Monitor for off nominal conditions” running concurrently
    - Use case condition “degrades from controlled to uncontrolled”
    - Automation state changes for “Automated maximized ROP drilling “ to “Automated handling influx”
    - Automation state could change again to “Shut in well”
    - Next state could be “deactivation” = driller takes control

The Industry Route Forward

- Systems architecture is the foundation
    - Reference architecture from DoD framework method
    - Organization of systems that overcome fragmented make up of suppliers
- Standard definitions for states important for automated control
    - Operations (drilling / completion) state
    - Well state
    - Equipment state
    - ……..
- Hierarchy of epics, user stories and use cases are the path to control automated activities
    - Common, shared understanding of intent

Insight from developing automation maps

- All the improvements from systems definition, state definition and use cases will significantly benefit the driller and other operational personnel to achieve their objectives with high performance.

While solving the automation application, do not forget the driller of today

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