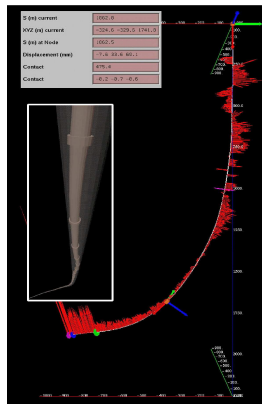


## Drilling Research & Development at Ecole des Mines



# Ecole des Mines



**One of the first higher educational institution in France**

Engineers and PhD

**4 geographical sites - 1600 persons including 1000 students**

120 engineers diplomas/year

80 PhDs/year

300 Postgraduate diplomas/year

**Academic excellence**

400 publications/year

Agreements with foreign universities (partners of IDEA League)

2 Nobel Prizes : Economy (M. Allais, 1988) ; Physics (G. Charpak, 1992)

**An applied research**

French Academic leader on contractual research (25 M€/an)

1000 contracts signed each year with industry



# Research

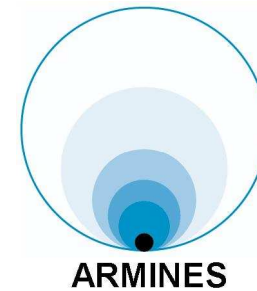


## 15 Research Centers dealing with :

- Earth and Environment Sciences
- Energy and Chemical Engineering
- Materials Sciences and Engineering
- Applied Mathematics, Computer Science Systems and Control
- Social and Economics Sciences



# ARMINES



- **Non profit contractual research association created in 1967**
- **60 research centers in France**
- **500 employees: 150 research engineers, 350 PhDs & technical staff**
- **1500 contracts/year, 100 EEC projets/year over 300 proposals**
- **35 M€ turnover**



## GeoSystems Department

Geology

Geophysics

Geostatistics

## Hydro-Geo-Engineering Department

Hydrological Systems  
and Reservoirs

Hydrodynamics  
and Reaction

Engineering Geology  
and Geomechanics



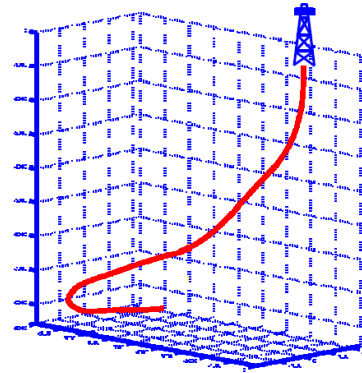
## Engineering Geology and Geomechanics

- Rock Fragmentation for Underground Excavation
- Blasting
- Hydraulic Cutting (high or medium pressure water jet)
- Oil & Gas Storage
- **Drilling**



# Drilling R&D activities

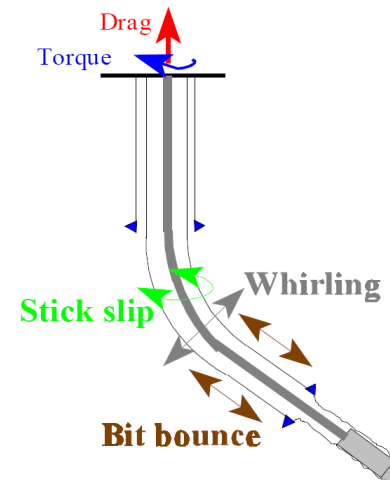
- Directional Drilling




- Drilling Bit Performances

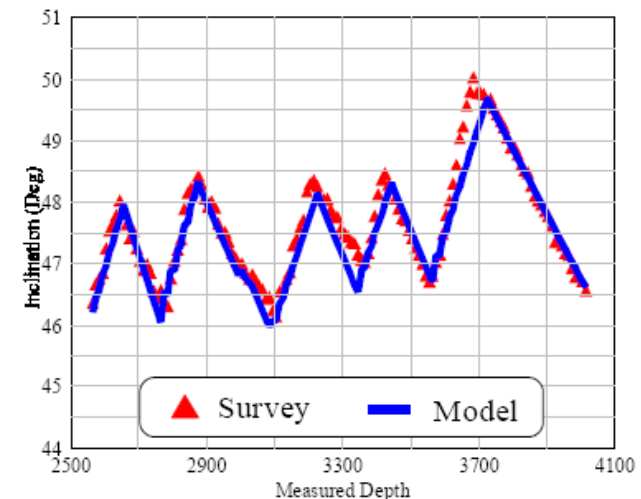
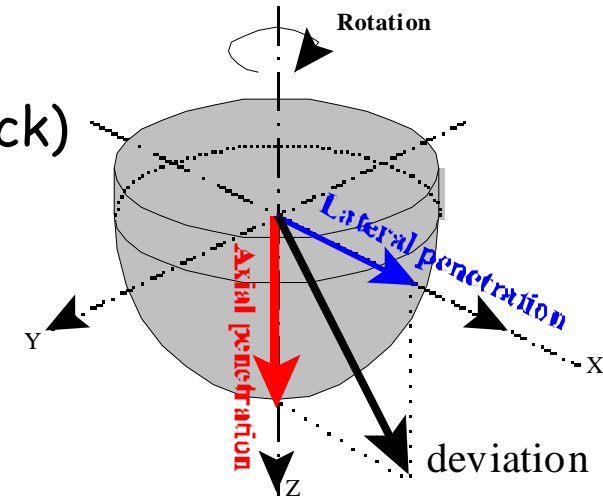


- Drillstring Mechanics



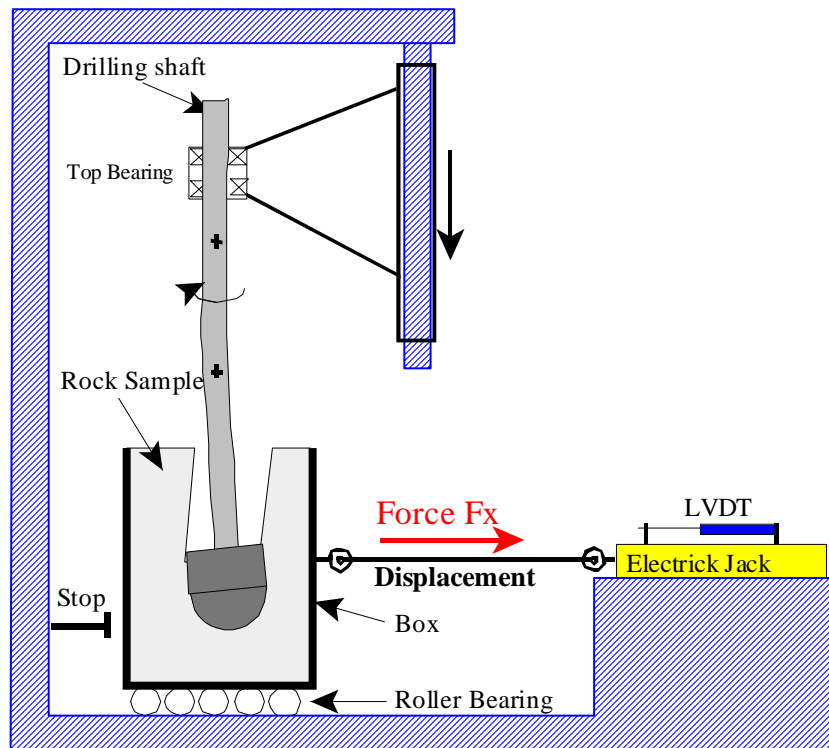
# Directional Drilling

- Bit Directional Behaviour
  - 3D Rock-bit interaction modelling
  - Bit Steerability =  $f(\text{Bit}, \text{SF}, \text{Tilt and Rock})$
  - Walking tendency
- BHA modelling (any directional system)
  - BHA Management (Development With Total) 
  - Bit-BHA coupling
- Trajectory prediction and reconstitution
  - Equilibrium curvature
  - Step by Step algorithm
- Anisotropic effects
- Experimental facilities



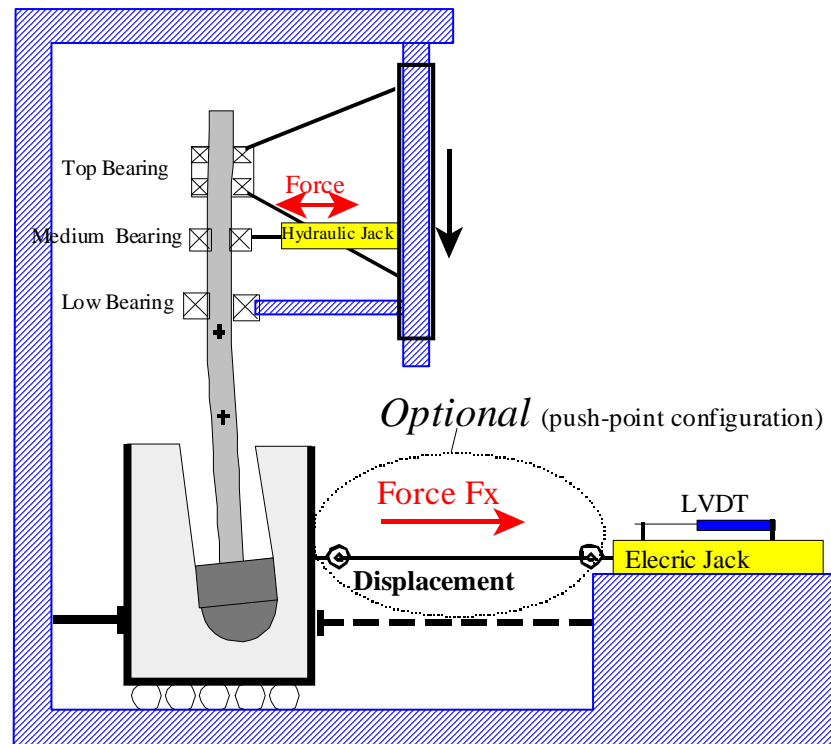
# Directional Drilling

## Drilling Simulator (Pau, France) Push-the-bit Configuration



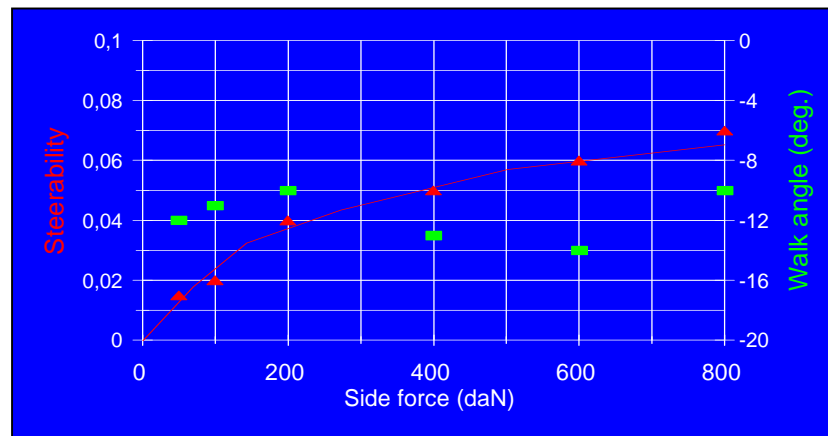
# Directional Drilling

## Drilling Simulator (Pau, France) Point-the-bit Configuration



# Directional Drilling

- Bit Directional Behaviour Measurements
  - Push, Point or Hybrid of Push-Point Configuration
  - Bit Steerability =  $f$  (Side Force, Tilt and Rock)
  - Walking tendency
  - Friction
  - Anisotropic effect (interbedded formation, shales)
  - Hole Quality evaluation (caliper)



# Drilling Bit Performances

## Drilling Bits Design & Modeling

- Drillability
- Vibrations
- Wear
- Directional
- Hydraulics



*3D PDC Bits*



*Self-penetrating Bits*



*Standard Bits*



*PAB BIT Concept*



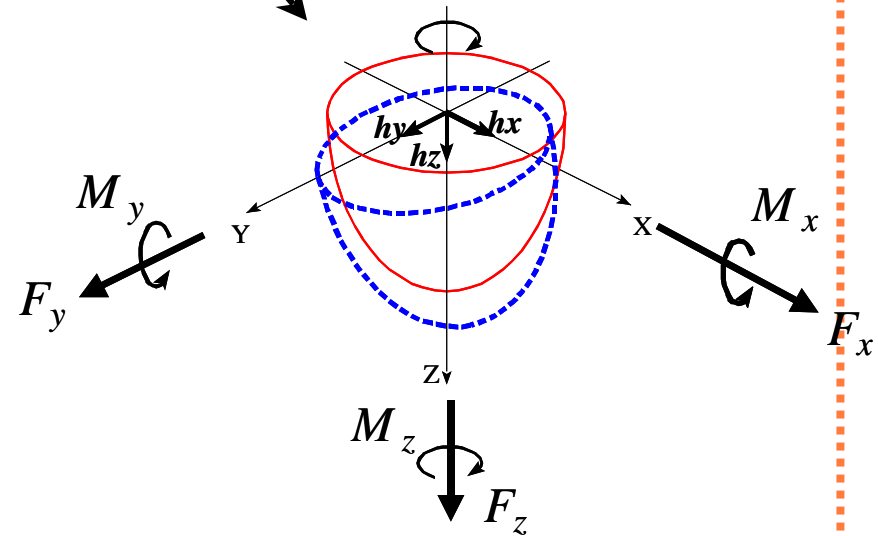
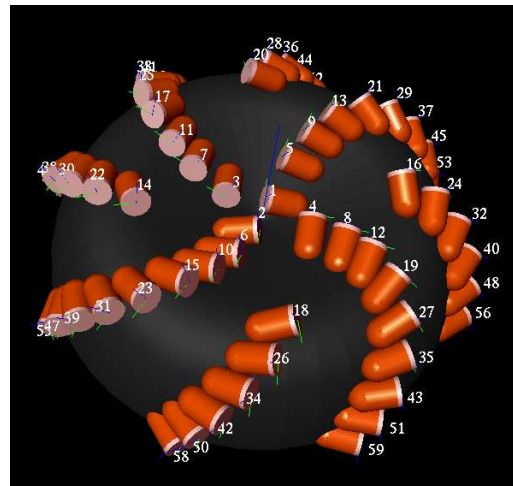
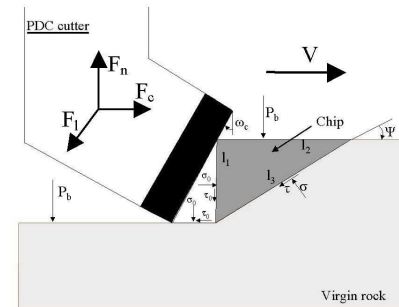
*Hybrid Bits*



# Drilling Bit Performances

## Drilling Bits Design & Modeling

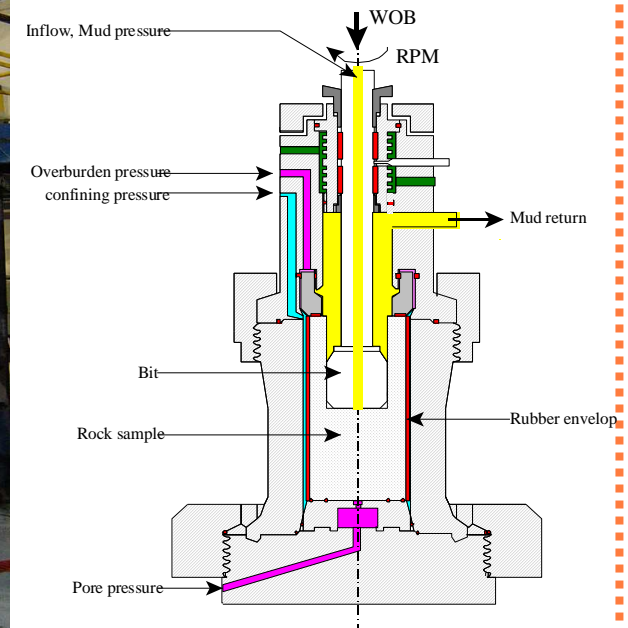
- Rock Formation Characteristics
- Cutter-Rock interaction model
- 3D Rock-Bit interaction model
- Design



# Drilling Bit Performances

## Drilling Simulator (Pau, France)

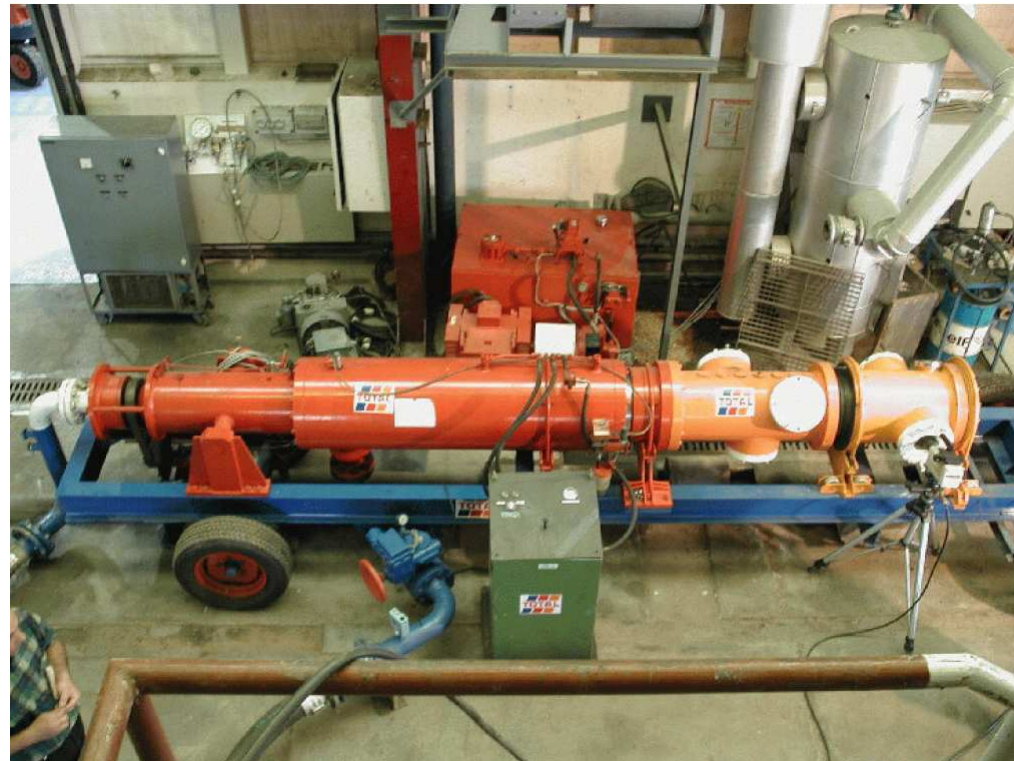
- In Situ Conditions
- Full Scale Bits
- ROP or WOB control
- Drilling length ~ 50 cm
- Flow rate up to 600 l/mn



# Drilling Bit Performances

## Hydraulic Simulator (Pau, France)

- Rotation speed : 0-1000 rpm
- Mud Flow Rate : 0-3000 l/mn
- Mud Pressure : 0 - 4 MPa
- High Speed Video Camera  
50 - 3000 scan/s



# Drilling Bit Performances

## Single Cutter Drillability Cell (Pau, France)

- Rotation speed : 0-60 rpm
- Hydrostatic Mud Pressure : 0 - 50 MPa
- High Speed Camera
- Max Cutter Forces = 8 000 N



# Drilling Bit Performances



## Some Ongoing Projects



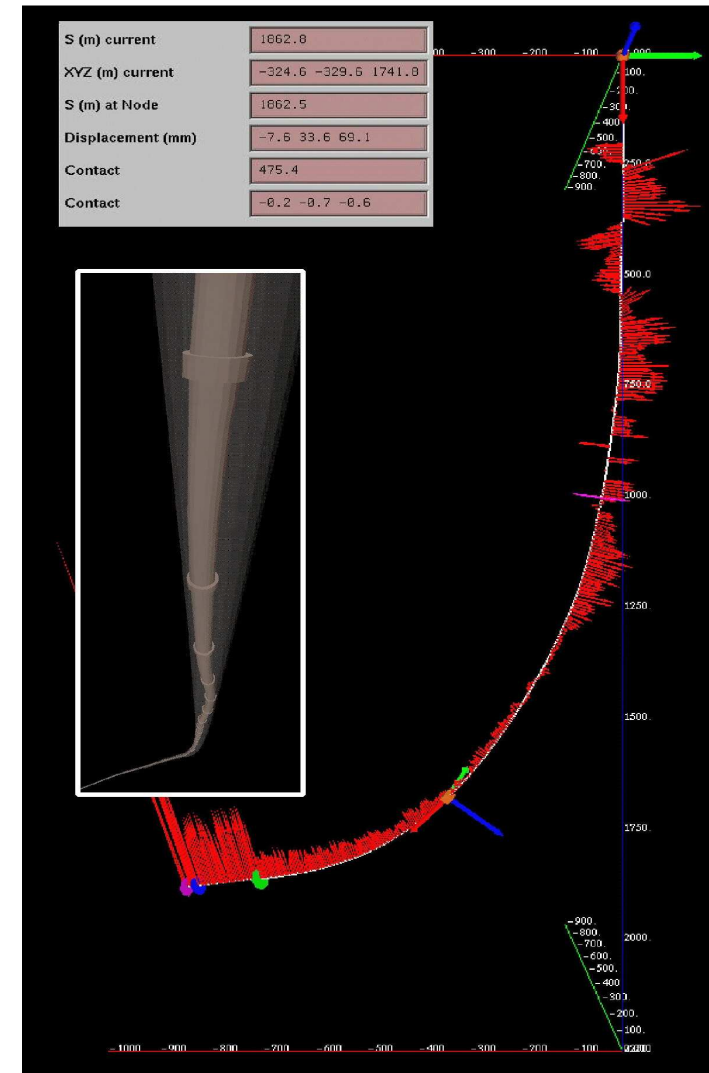
- Self Penetrating Bit (Armines/Geosciences Patent)
  - Development : DrillScan
  - Manufacturing : Varel
  - Field tests (Total, Gaz de France, ...)



# DrillString Mechanics

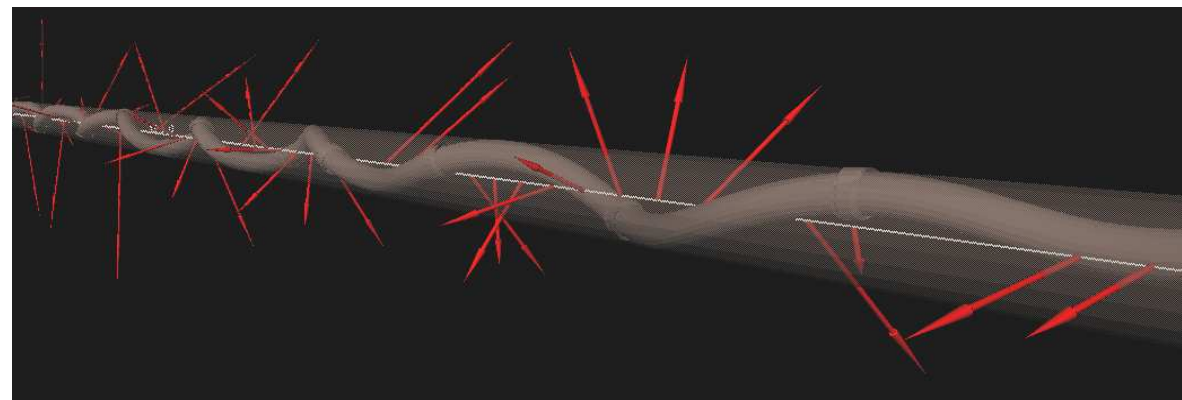
## Computer Code : ABIS

- 3D Integrated Model
  - BHA / Torque & Drag / Buckling
  - Coupled Buckling - Torque&Drag
- Without FEA → computation time reduced
- No assumption about the contact
- Rotation / friction / tortuosity effects
- Adapted to actual field conditions
- Mechanical model validated in the laboratory
- Adapted to real-time monitoring



# DrillString Mechanics

## ABIS Simulations vs Lab Experiments



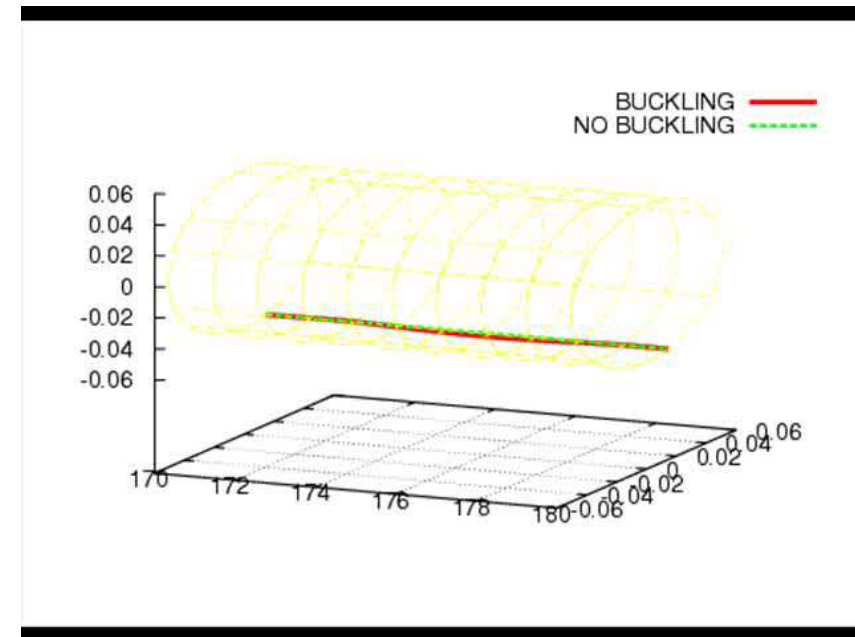
# DrillString Mechanics

Validation on a small scale buckling facility

Lab Experiment



ABIS Simulation



Simulation of Helical Buckling in a Horizontal Well Bore With Rotation



# Publications...



## To learn more...

- SPE 47340 : Application of yield design for understanding rock cutting mechanism
- SPE 59230 : A stick/slip analysis based on rock/bit interaction
- SPE 74459 : How Bit Profile and Gauge Affect Well Trajectory
- SPE 79795 : Classification of PDC bits According to their Steerability
- SPE 79915 : Gyrostab Project : The Missing Link Azimuth and inclination Mastered with new principles for standard rotary BHAs
- SPE 98865 : Effect of Formations Anisotropy on Directional Tendencies of Drilling Systems
- SPE 98965 : Advancements in 3D Drillstring mechanics: From the Bit to the Topdrive
- SPE 98988 : PDC Bits : All Comes From the Cutter Rock Interaction
- SPE 102850 : Buckling of Tubulars in Actual Field Conditions
- SPE 105522 : Drilling Without WOB, Dream or Reality ? An Effective Field Test by Total Angola
- ....

