The Role of E&P Technologies

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Trends in Oil Supply and Demand and Potential for Peaking of Conventional Oil Production

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Outline

- The E&P Resource Factory
- Price and Cost
- The Ecology of E&P Technology
- Oil Field Productivity
- The Next Trillion Barrels
- Technology Opportunities and Challenges
E&P Resource Factory

Production Factory

Reservoir Management Factory

Exploration Factory

Current Resources

P1

P2-3

P4-6

New Resources

2005

2014

Major Capital Projects

Base

Exploration

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Production Costs

U.S. dollars per BBL

Source: A.G. Edwards and Sons, Inc.
Finding and Development costs (F&D)

U.S. dollars per BBL

Source: Goldman Sachs Commodity Research
The Ecology of E&P Technology

- Long-term investments; long-lived assets
- Technologies exist in the context of complex work processes and supply chains
- Integration is paramount
- Repeatability / scalability / reliability / safety are critical
- Substitution predominates; displacement is rare

- Concentrated R&D structure
- Highest level of digital intensity of any industry
- “Cost-plus” business model for technology suppliers
Oil Field Productivity

- Reliability and uptime
- De-bottlenecking operations over time
- Energy efficiency
- Optimization and automation
- Capital efficiency and drilling costs
- Revitalizing reservoirs and improving ultimate recovery
The Next Trillion Barrels

- Frontier exploration
- P4 / P5 / P6 conversion
- Enhanced oil recovery
- Unconventional reservoir development
Undiscovered Resources

Undiscovered Total Petroleum (MMBOE)

- 0 – 1000
- 1000 - 5000
- 5000 - 20,000
- 20,000 – 50,000
- 50,000 – 200,000

Source: USGS, 2000
Technology Opportunities and Challenges

- Advancing Core E&P Technologies
- Leveraging Major Technology Trends
- Meeting the Challenges
Advancing Core E&P Technologies

- Basin-scale 3D imaging and modeling
- Integrated subsurface workflows
- Fully-controllable intelligent well systems
- Advanced reservoir management and interactions
- Distributed production and processing infrastructure
- Field-scale integration and automation – “the oil field as a factory”

Live video camera and feed from rig
3D Imaging and Modeling of Entire Depositional Systems
Next-Generation E&P Technology: Integrated Workflows

Seismic Imaging

Well Design & Simulation

Interpretation & Earth Modeling

Reservoir Characterization

Reservoir Simulation

Workflow integrates ~ 1000 technical applications: proprietary + JV development + vendor supplied
Next-Generation Reservoir Simulation

- Increased geological realism and representation of uncertainty
- Increased realism and dynamics for wells
- Improved physics and chemistry
- Designed for integration with real-time production systems
- Designed for new and future computing environments
Distributed Production Infrastructure

Heavy Oil Recovery and Processing

Deepwater Seafloor Processing

FPSO

Gas-to-Liquids
Oil field Productivity: The Oil Field as a Factory
Leveraging Major Technology Trends

- Universal digitization, sensing, and connectivity
- Advanced materials and processing technologies
- Human-digital relationships
Meeting the Challenges

- The Digital Tidal Wave
- Organizational Capacity
- CO2 Capture and Sequestration
Digital Intensity in Exploration and Development

- 200 3D Seismic Cubes = 400 TB+
  - 2 TB / cube raw data
  - 100 GB / cube processed

- 500 Oil Field Simulation Models = 50 TB+
  - 100-million-cell earth model
  - 2-million-cell simulation model
The Digital Tidal Wave

Active Chevron technical data storage in terabytes (TB)

1000
100
10
1

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Organizational Capacity: The Big Crew Change

Current Average Age of U.S. Workforce by Job Group

<table>
<thead>
<tr>
<th>Job Group</th>
<th>Average Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process / Production Operators (Skilled)</td>
<td>38 years</td>
</tr>
<tr>
<td>Instrumentation / Electrical</td>
<td>40 years</td>
</tr>
<tr>
<td>Maintenance Crafts</td>
<td>42 years</td>
</tr>
<tr>
<td>HSE Professionals</td>
<td>44 years</td>
</tr>
<tr>
<td>Engineering / Geosciences</td>
<td>46 years</td>
</tr>
<tr>
<td>Analysts or Technologists</td>
<td>48 years</td>
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<tr>
<td>Geoscientists</td>
<td>50 years</td>
</tr>
<tr>
<td>Engineers</td>
<td>52 years</td>
</tr>
</tbody>
</table>

The global E&P workforce is much younger
CO2 Capture and Sequestration

Both a challenge and an opportunity
Summary Points

- The remaining resource base is very large... F&D costs, technology advancement, and environmental management are the issues.

- Many opportunity areas for technology advancement... leveraged on major trends outside of oil and gas.

- Growing organizational capacity is a challenge.