AADE
AMERICAN ASSOCIATION of DRILLING ENGINEERS
HOUSTON CHAPTER
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Granules, Flakes or Fibers?

"How to Design & Select a Successful Particulate Lost Circulation Solution"

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Halliburton – Baroid

September 25, 2013

HALLIBURTON | Baroid

Preventative and Mitigation Techniques

Classification	Typical Loss Rate	Typical Formation Characteristics	Preventative Solutions	Mitigation Solutions
Seepage	<10 bbl/hr	• Sands • Sandstones • Silt	• **Particulate LCM** • Managed Pressure Drilling • Drilling with Casing	• **Particulate LCM**
Partial	10-50 bbl/hr	• Unconsolidated sand or gravel • Small natural fractures • Small induced fractures	• **Particulate LCM** • Managed Pressure Drilling • Drilling with Casing • Solid Expandable Systems	• **Particulate/Fiber LCM** • Cross-linkable LCM
Severe	>50 bbl/hr	• Unconsolidated sand or gravel • Large natural fractures • Large induced fractures	• Managed Pressure Drilling • Drilling with Casing • Solid Expandable Systems	• **Particulate/Fiber LCM** • Cross-linkable LCM
Total	No returns	• Cavernous formations • Large, and/or numerous natural and/or induced fractures	• Managed Pressure Drilling • Drilling with Casing • Solid Expandable Systems	• **Particulate/Fiber LCM** • Cross-linkable LCM

Classifications of LCM

"Chemical"	"Fiber" "Flake"	"Granular"

Lost Circulation Materials

- crosslinking polymers
- cement
- DVC plugs
- barite plugs
- swellable polymers
- bentonite/OBM squeeze

Loss Prevention Materials

- shredded paper
- sawdust
- fiber
- mica
- cellulose
- cellophane
- flaked graphite

Wellbore Strengthening Materials

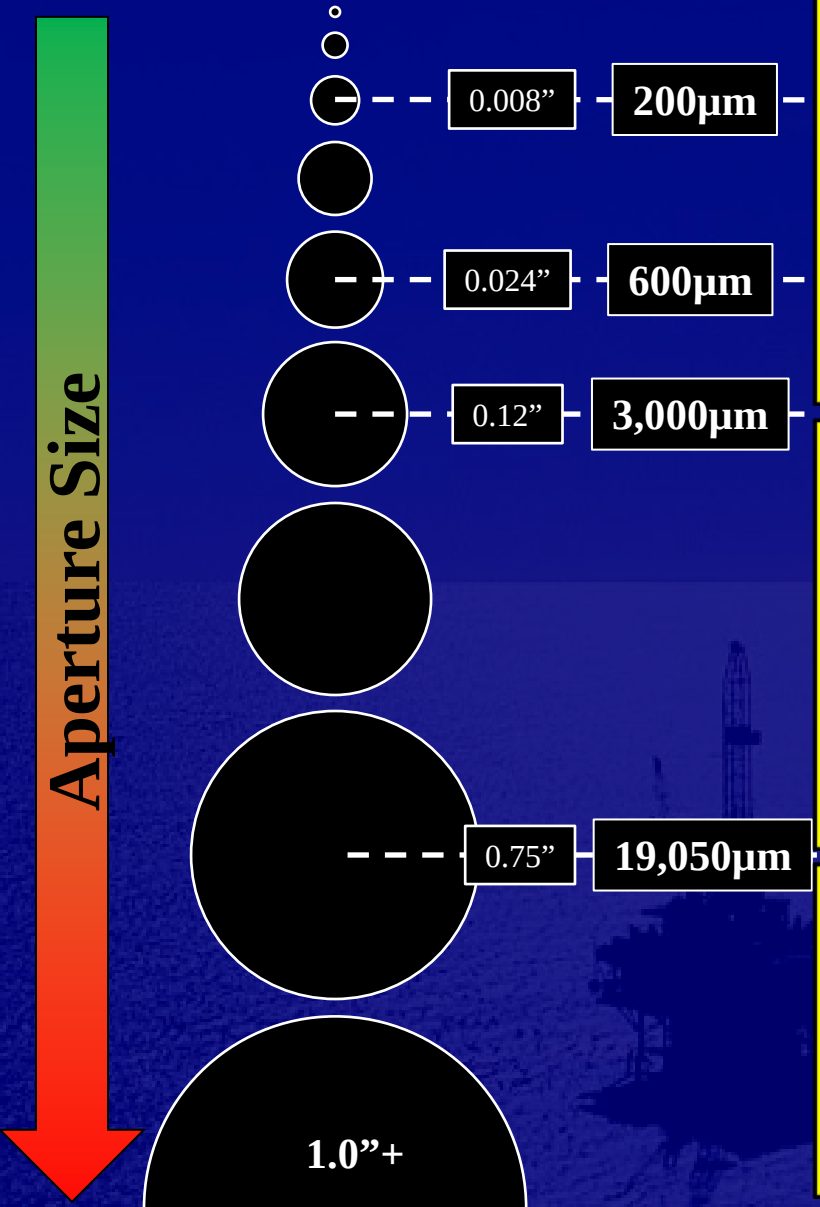
- resilient graphitic carbon
- amorphous graphite
- sized ground marble
- nut hulls
- petroleum coke

PREVENTION

MITIGATION

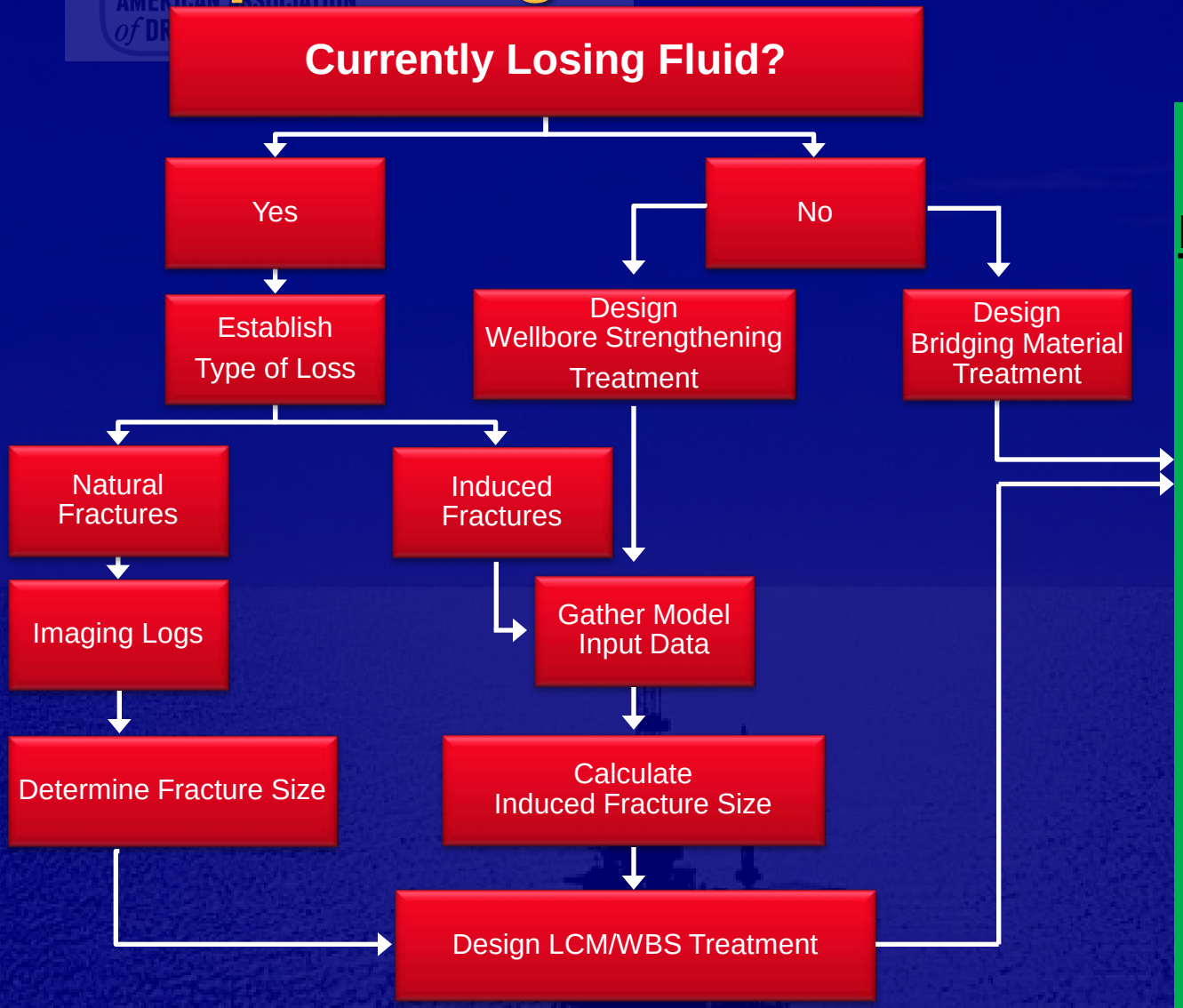
MITIGATION

What to Use?



Material Type	Treatment Type	Application Type
Particulates	Optimized Bridging Material	Continuous Treatment
	Optimized Plugging Material	
Particulates + Fiber	Engineered Composite Solutions	Dedicated Pill
Cross-linkable Sealants	Engineered Chemical Solutions	

Optimizing Particulate Treatments



Provide Laboratory Assurance

Continuous Treatment

Pill Treatment

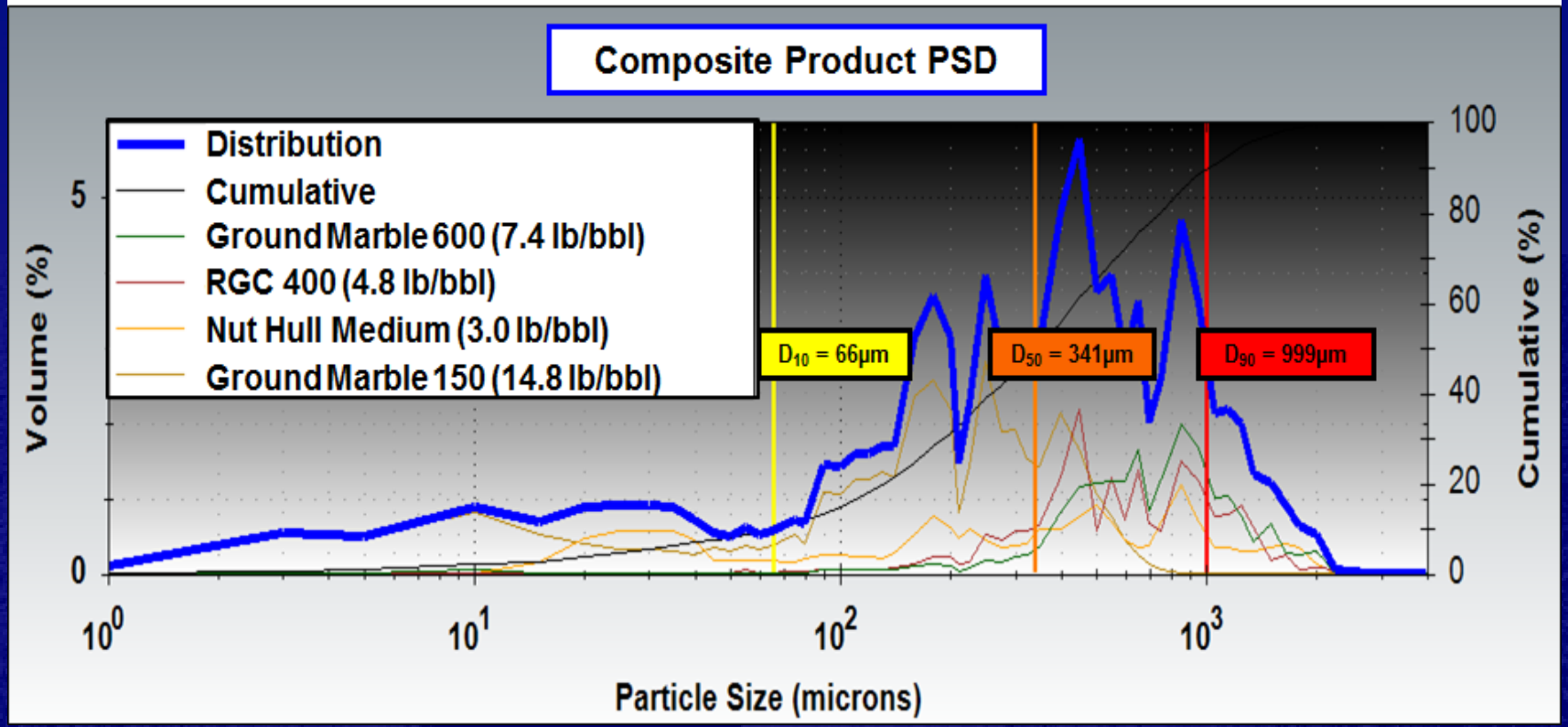
- ***Pore Plugging (PPA)***
- ***Fracture Plugging (PPA)***
- ***Vugular Plugging (Vug Simulator)***

- ***Calculate PSD Maintenance Treatment Schedule***
- ***Model Rheological Effect from LCM***

Particulate-Based Solutions

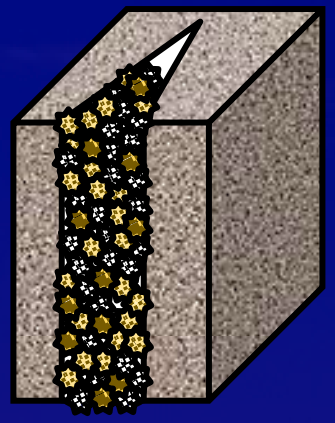
Products | Solutions | Test Mix | Fracture Width

Formulation	D50	D90	% Modal	% Fiber	% CaCO3	% RGC
Ground Marble 600 (20%) RGC 400 (20%) Nut Hull Medium (20%) Ground Marble 150 (40%)	341	999	26	0	60	20

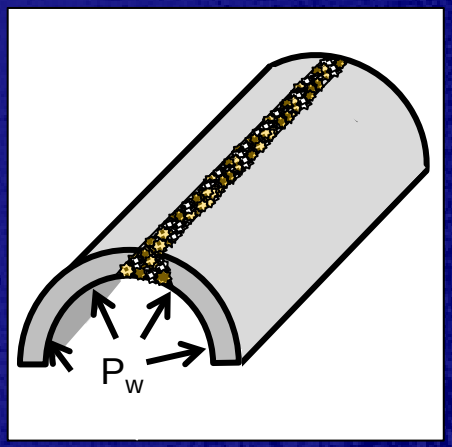


Role and Importance of Particles/Fibers

- Key Features of “Successful” Particulate LCM:
  - particle size and Particle Size Distribution (PSD)
  - concentration
  - type
  - shape, aspect ratio, etc.
  - strength, resiliency, etc.



- How will your **LCM** resist:
  - shear at bit
  - temperature
  - fluid invasion
- How will your **LCM seal** resist:
  - swab/surge
  - pressure shocks
  - mechanical abrasion
  - bit reaming



CoP Study: Attrition of Wellbore Strengthening Materials *(March, 2012)*

Intent:

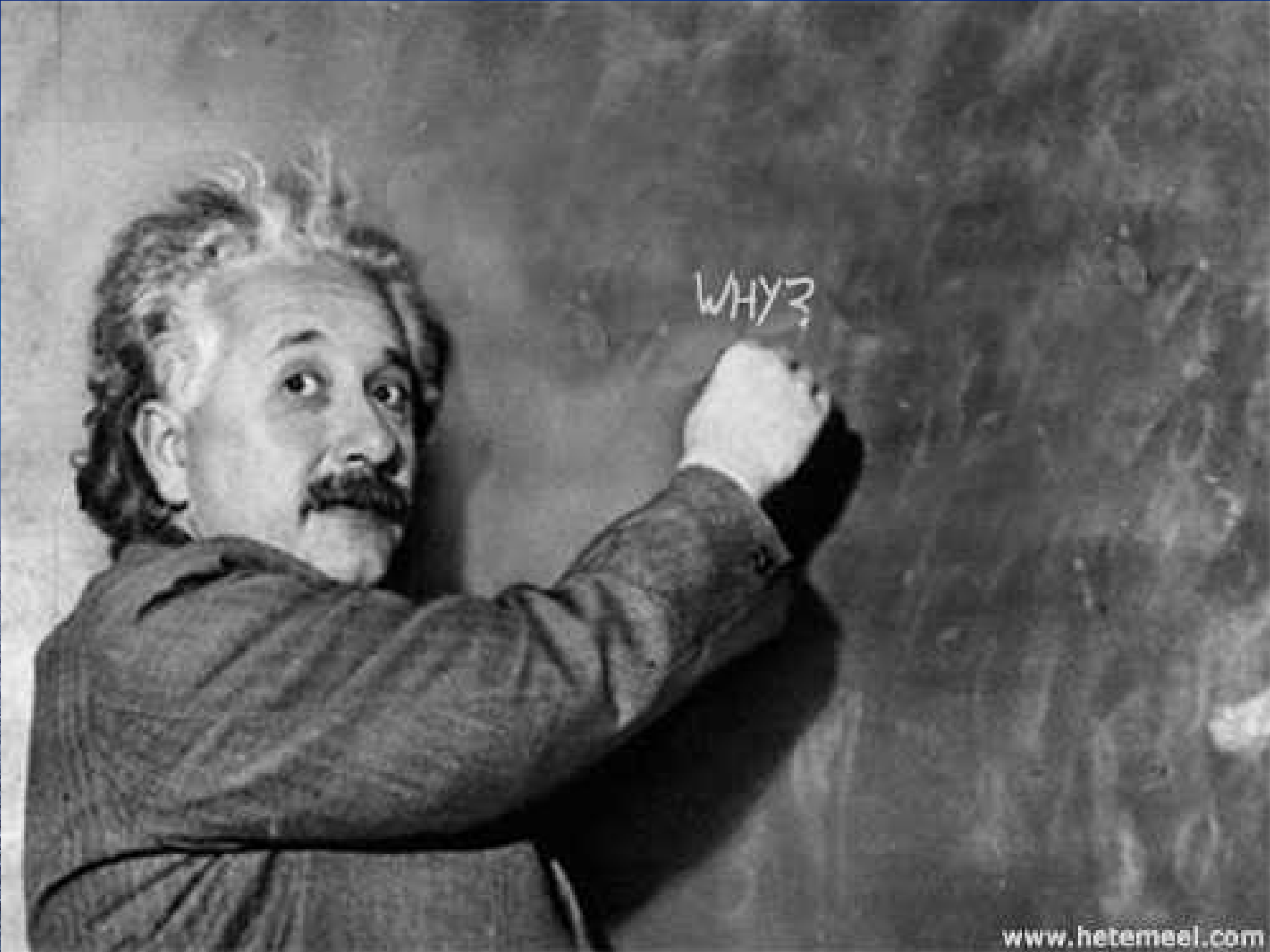
Analyze shear attrition of wellbore strengthening materials

Key Findings:

- All granular LCM degrade with increasing shear intensity and time
  - Ground Marble completely shear degrades
  - Walnut and Resilient Graphitic Carbon survive degradation the best

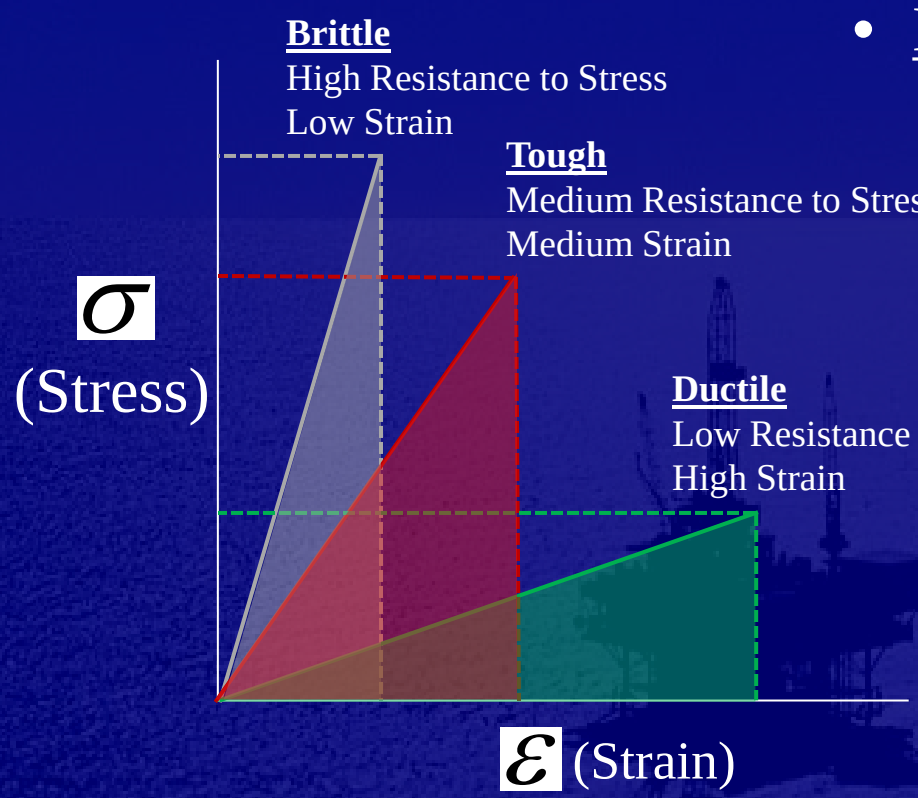
Table 3: Phase 1: Shear Degradation of 30-60 Mesh LCM

7000 rpm Shear	Hamilton Beach 5 min	Hamilton Beach 10 min	Hamilton Beach 15 min	Silverson 5 min	Silverson 10 min	Silverson 15 min
Black Walnut Hulls Shear Degradation %	1.5	2.0	2.0	9.0	9.3	9.9
English Walnut Hulls Shear Degradation %	3.3	3.3	4.3	7.7	9.5	9.9
Pecan Hulls Shear Degradation %	11.7	14.3	15.0	24.2	26.9	28.3
Resilient Graphitic Material Shear Degradation %	0.5	0.5	1.5	7.6	15.9	16.9
Ground marble Shear Degradation %	5.2	9.6	12.1	99.5	99.5	99.5


WHY?
www.hetemeel.com

Materials Science Properties

- Stress (y-axis): Measurement of applied pressure
- Strain (x-axis): Measurement of change due to stress
- Ultimate Failure: Measurement of **Force** needed to break a material

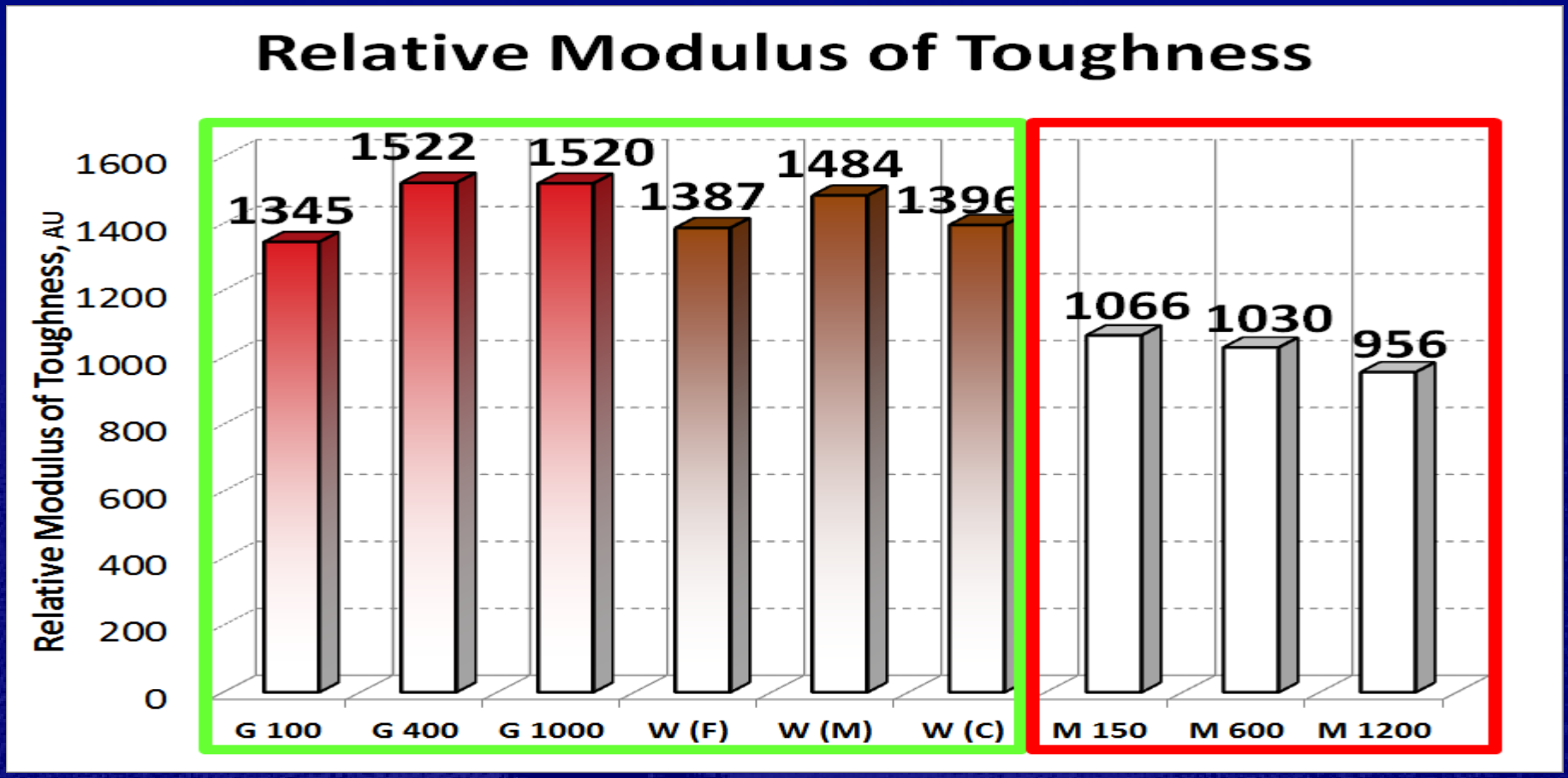


- Modulus of Toughness:
  Measurement of **Energy** needed to break a material

Lost Circulation Materials should provide a seal with a high Modulus of Toughness to resist downhole pressures

Summary* of a Materials Science Analysis

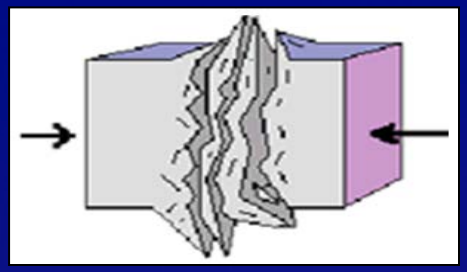
*Room Temperature
*Dry Testing Environment



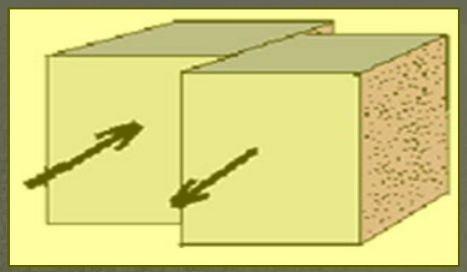
How 'Tough' is Your Sealed Zone?

Types of Stress

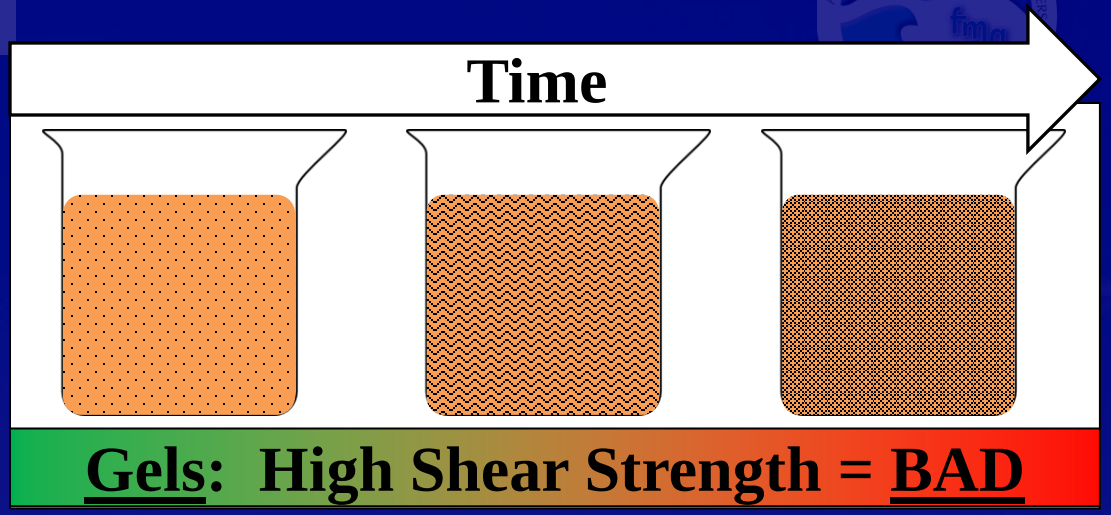
Compression

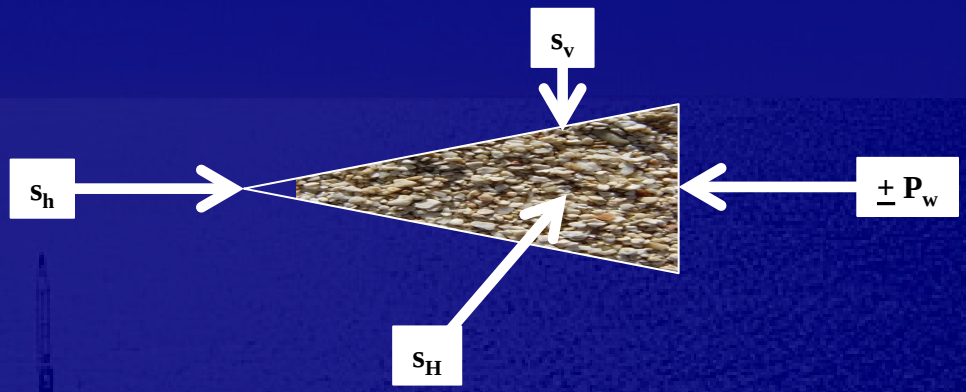


Shear



Tensile





Plugs: High Shear Strength = GOOD

Shear Strength Reinforcement

Brittle seals aren't naturally efficient… but CAN BE reinforced

Natural State

Reinforced

Ductile seals aren't naturally efficient… but CAN BE reinforced

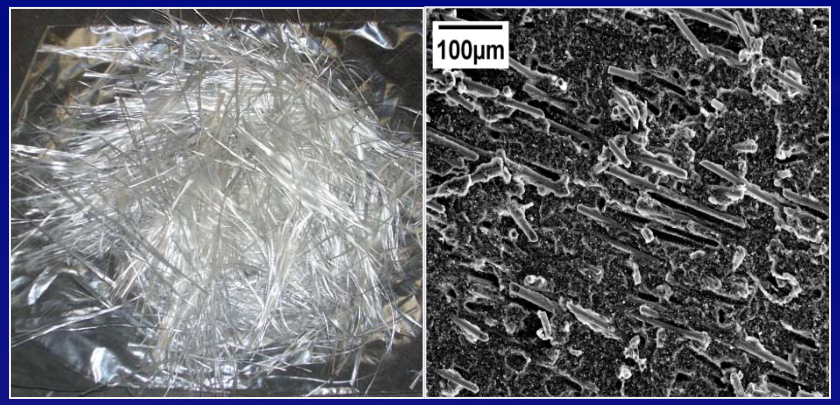
Natural State

Reinforced

Shear Strength Reinforcement Agents

Resilient Graphitic Carbon

Synthetic Fibers



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Summary

- Lost Circulation Control with particulate & fibrous LCM is possible…

  …but it's more than just "whatever plugs the fracture"

- Solutions MUST account for all of the downhole stress
- "Mechanical Integrity" of seal is an important factor
  - compressive and shear strength of a plug or bridge comes from materials science properties of its constituents – often in synergy
- The wellbore is only as strong as its weakest link!

SPE 105449: "Design of Well Barriers to Combat Circulation Losses"

Phase I	Phase 2	Phase 3	Phase 4	Phase 5
Seal Formation	Fracture Initiation	Fracture Growth	Further Fracture Growth	Seal Collapse

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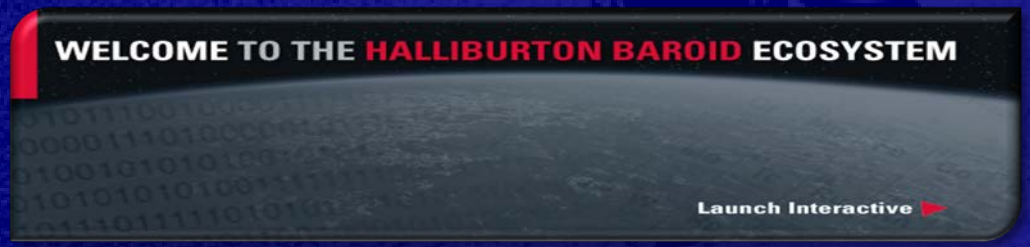
Thank You
Questions?



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