Hybrid Lubrication as a Practical Candidate for Space Mechanism Applications

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A. Kent & A. Vortselas

European Space Tribology Laboratory (ESTL)

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Outline

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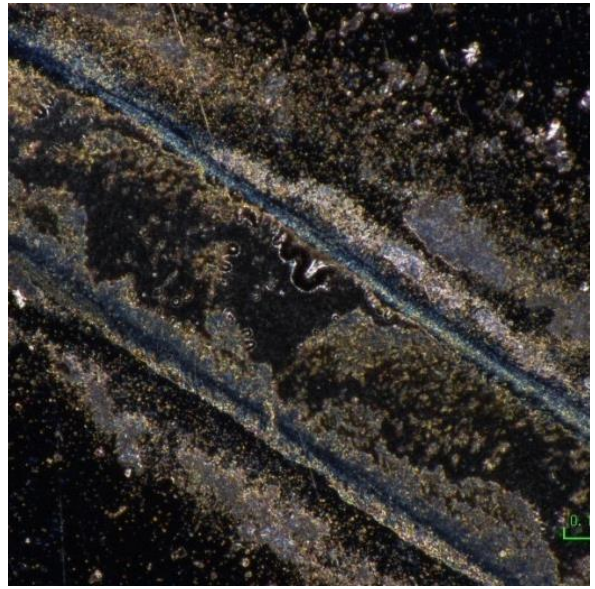
Hybrid lubrication is a promising candidate for spacecraft applications – with an extension in lifetime greater than the sum of each applied lubricant alone.

- Background
- Novel Research
- Factors Affecting Hybrid Lubrication Success
- Potential Applications and Recommendations for Use



Hybrid Lubrication

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- Hybrid lubrication is the application of a viscous fluid medium (typically a low vapour pressure oil) on top of a thin-film solid lubricant coating (typically sputtered MoS_2)

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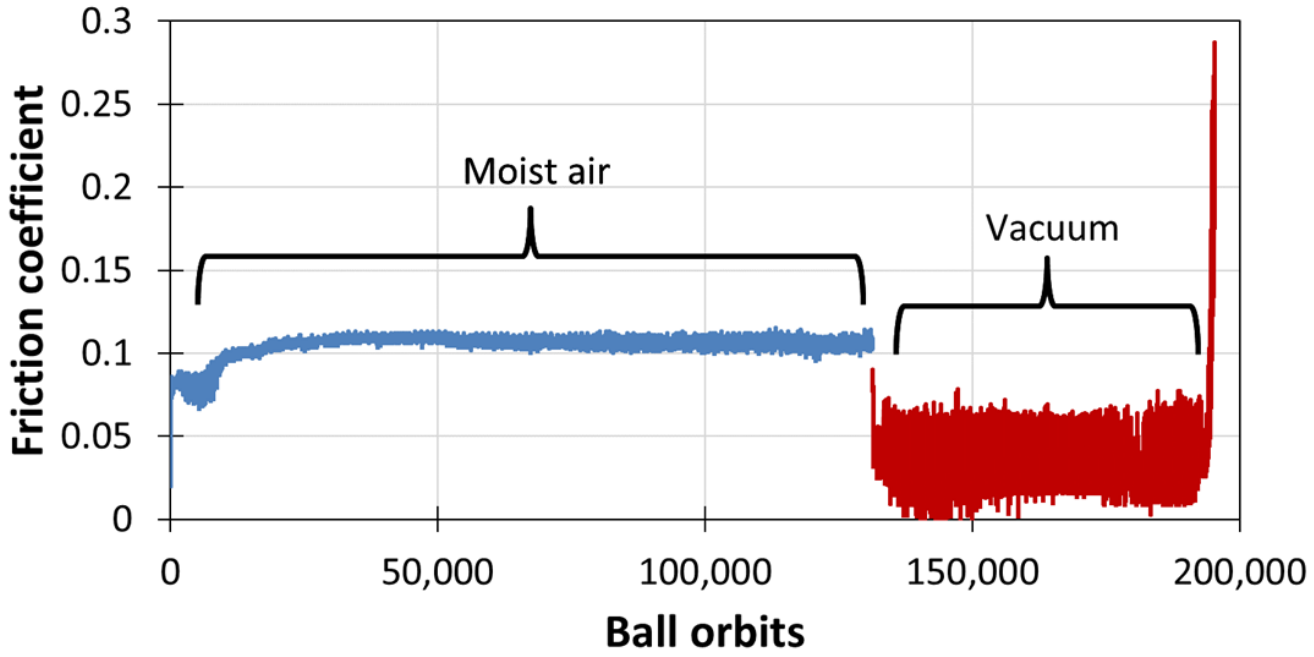

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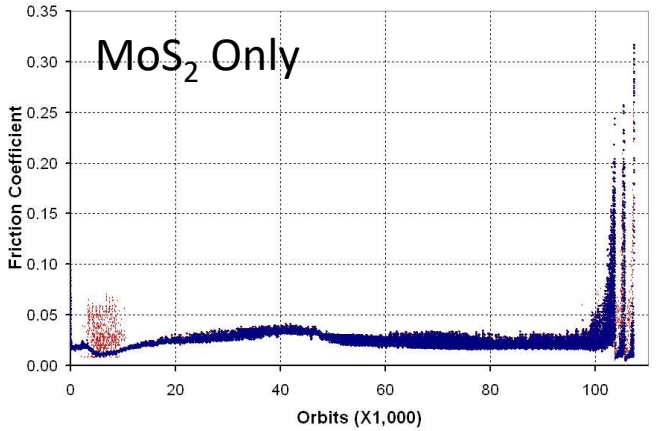

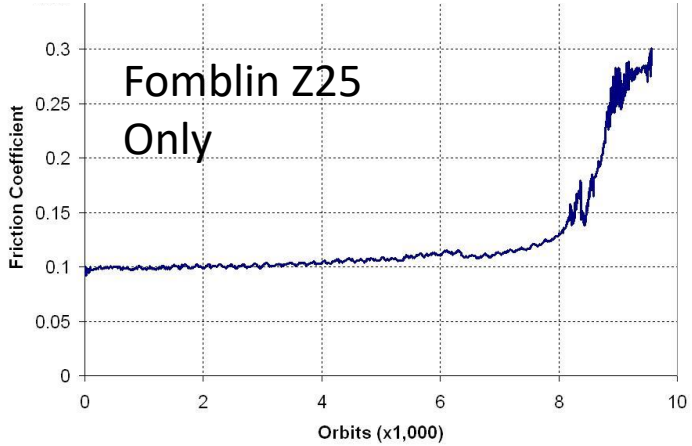

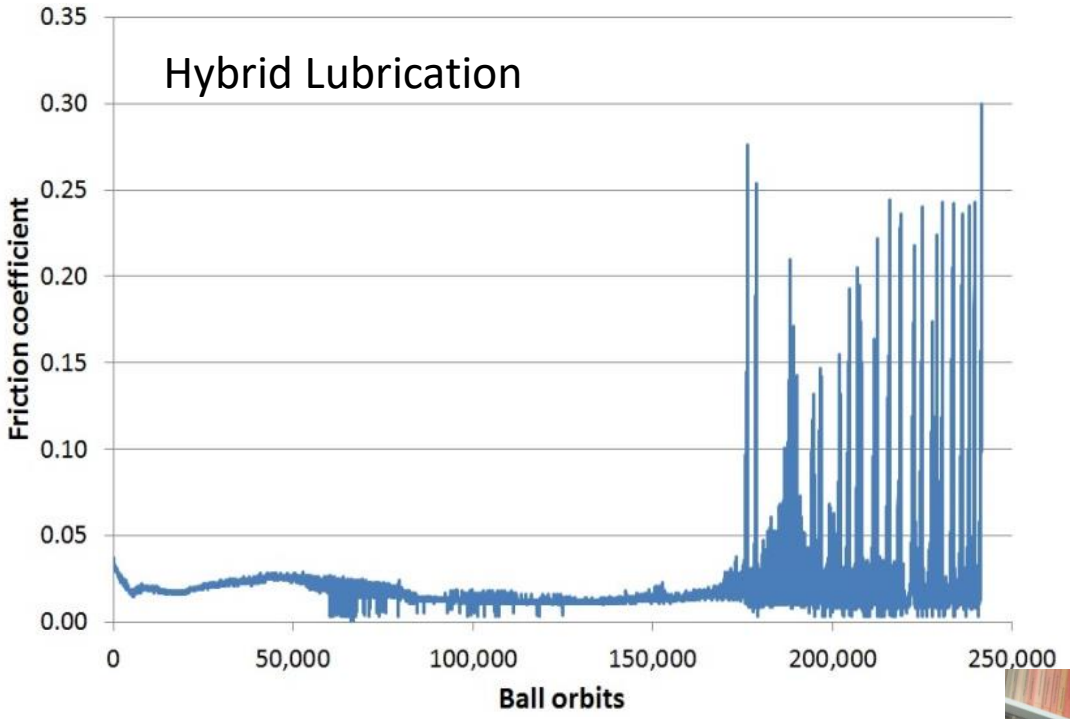

Life of PFPE/MoS_2 lubrication > Life of MoS_2 lubrication + Life of PFPE lubrication

Current Hypothesis

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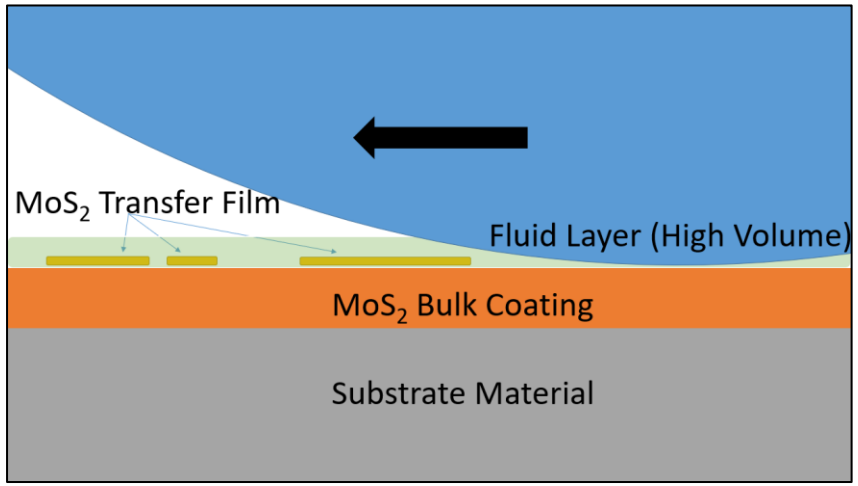
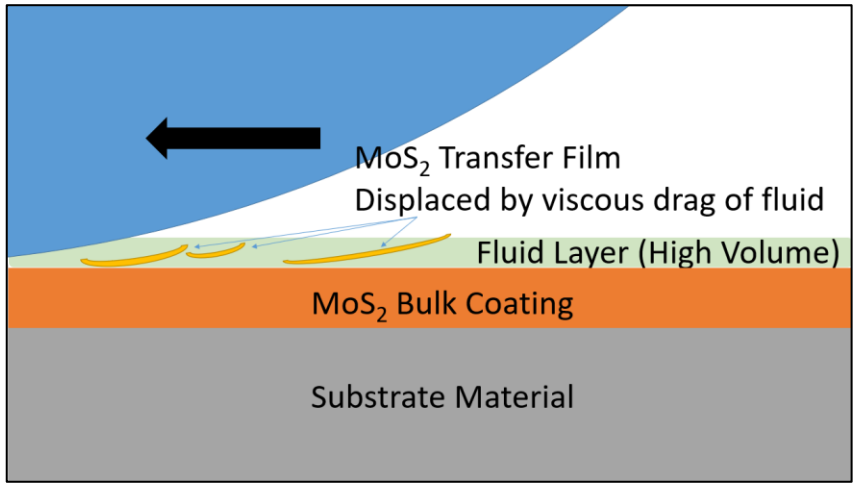
TIME





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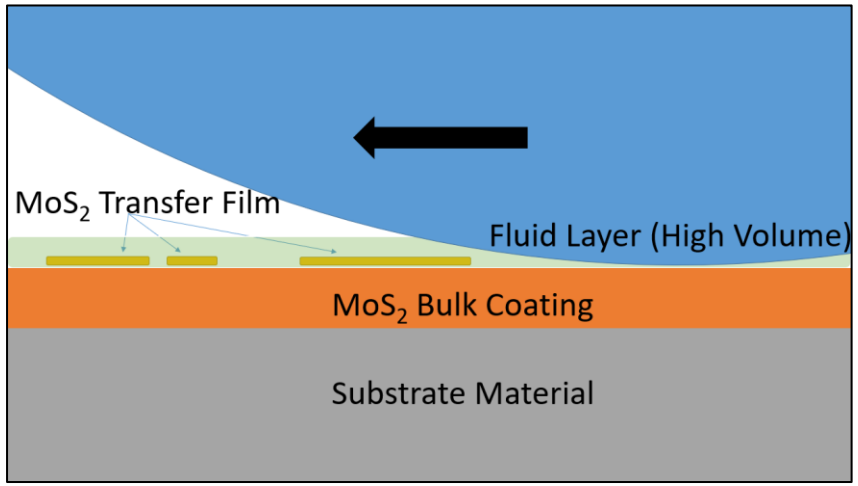

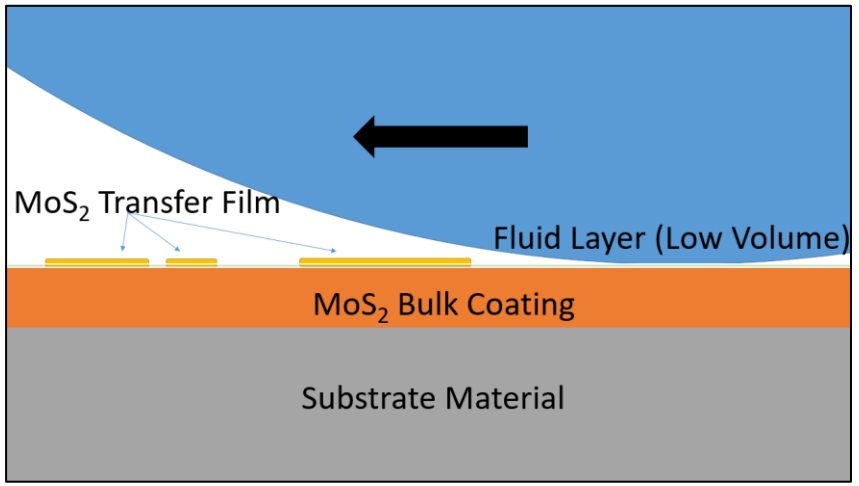

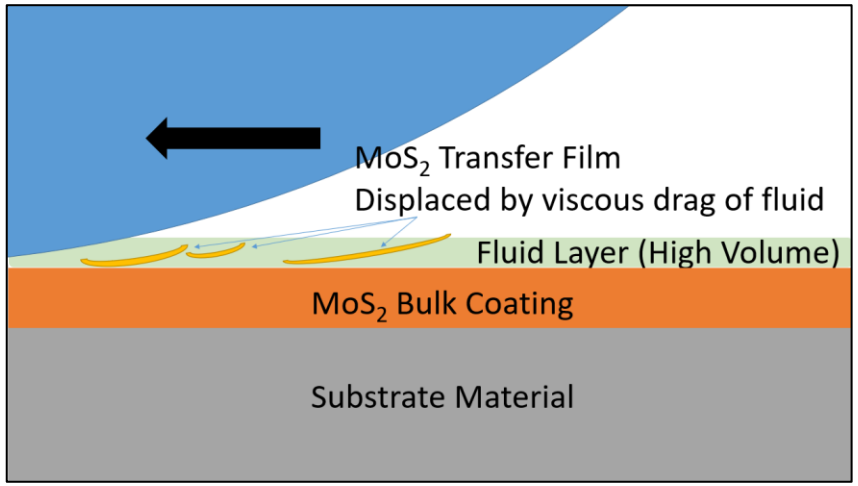

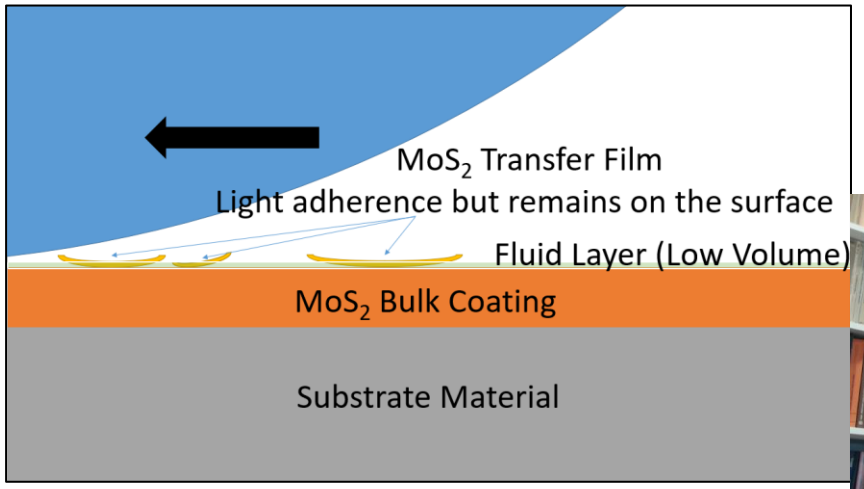

Is it right??

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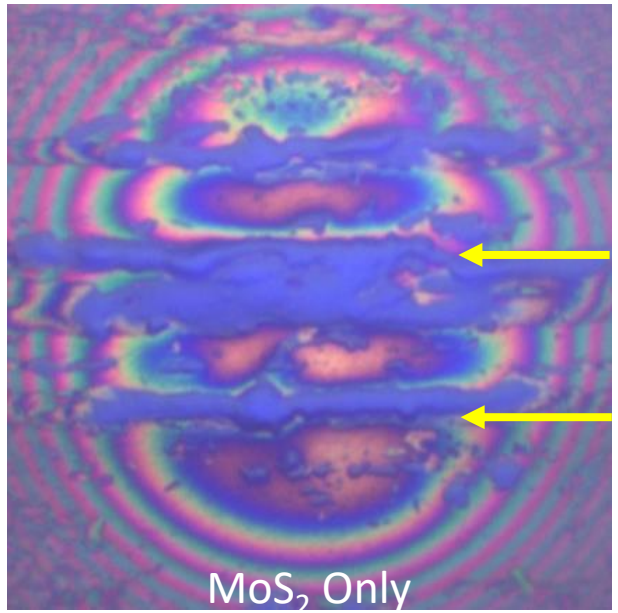

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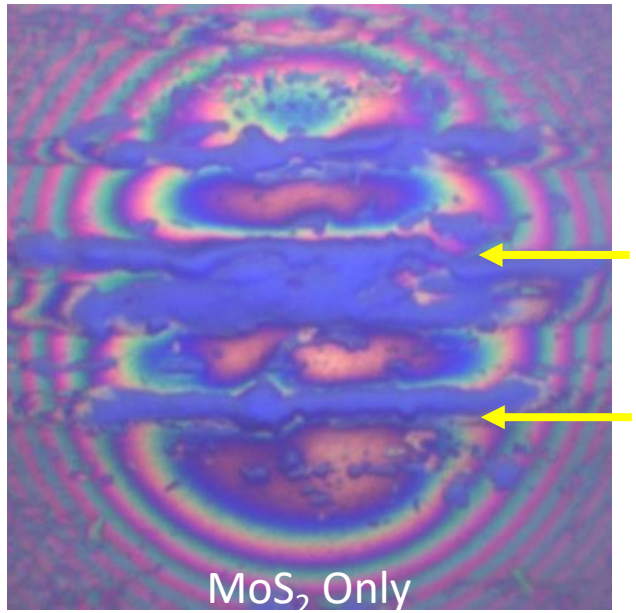

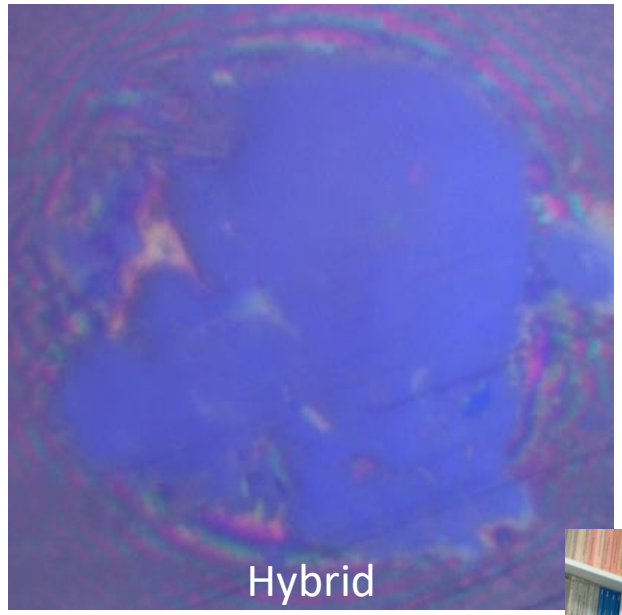

Hypothesis

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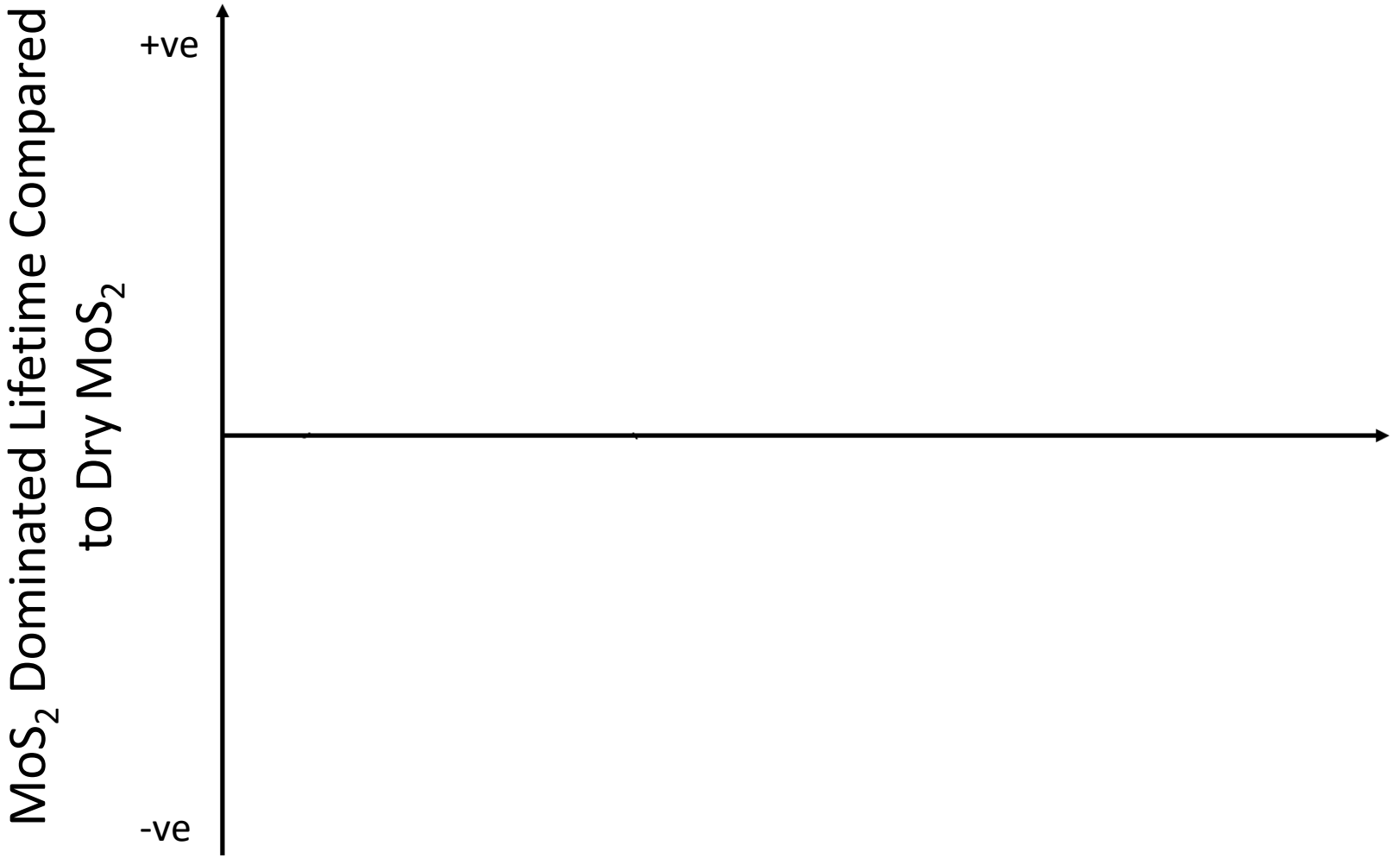
→ Fluid Film Thickness

Hypothesis


+ve
-ve
MoS_2 Dominated Lifetime Compared to Dry MoS_2
Fluid Film Thickness

Hypothesis

- **The blue region corresponds to MoS_2-only behaviour.**
- The red region corresponds to a fluid lubricant only behaviour.
- The yellow region corresponds to a reduced lifetime (compared to MoS_2-only) but with an MoS_2 dominated friction behaviour.
- The green region corresponds to an extension in lifetime of MoS_2 dominated behaviour.

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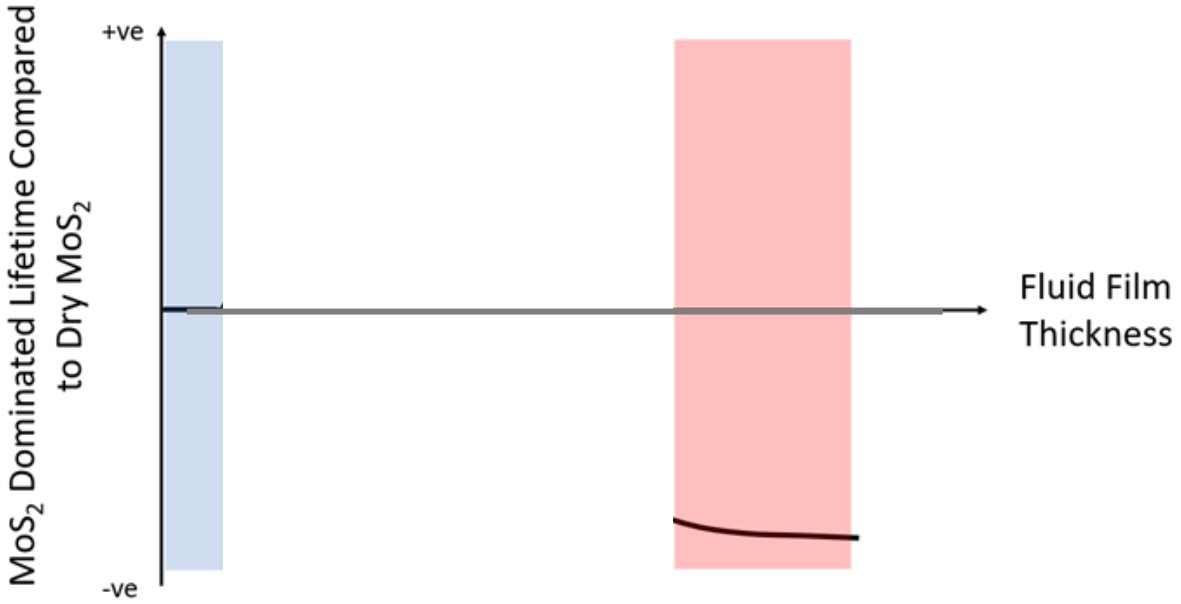

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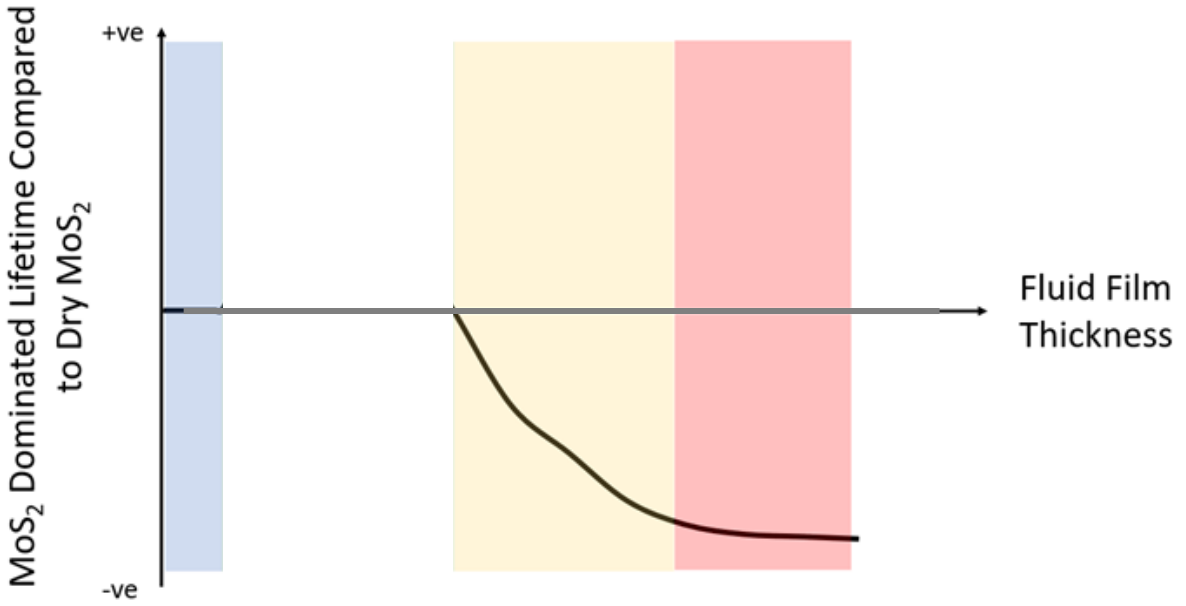

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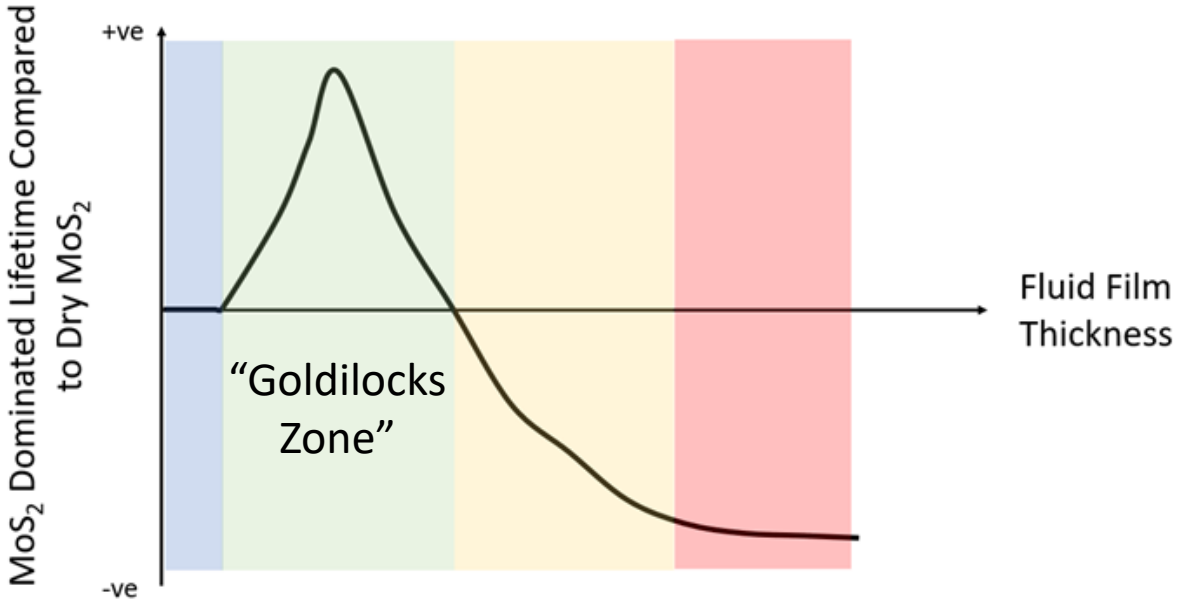

So where are we?

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- What controls location on x-axis??
  - Applied Fluid Volume

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  - Temperature
  - Fluid lubricant viscosity (e.g. grease vs oil)

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Combination???

Temperature

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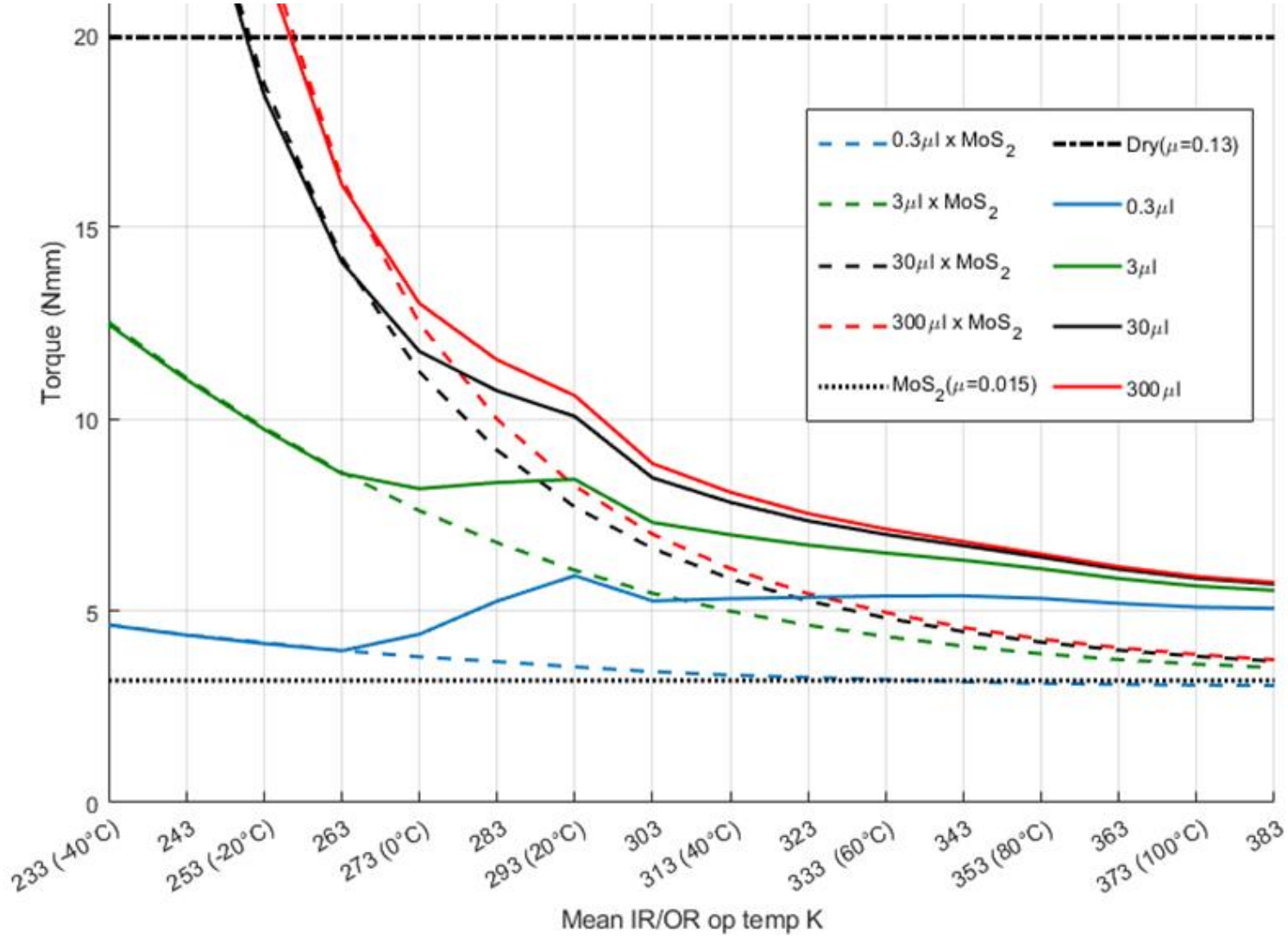
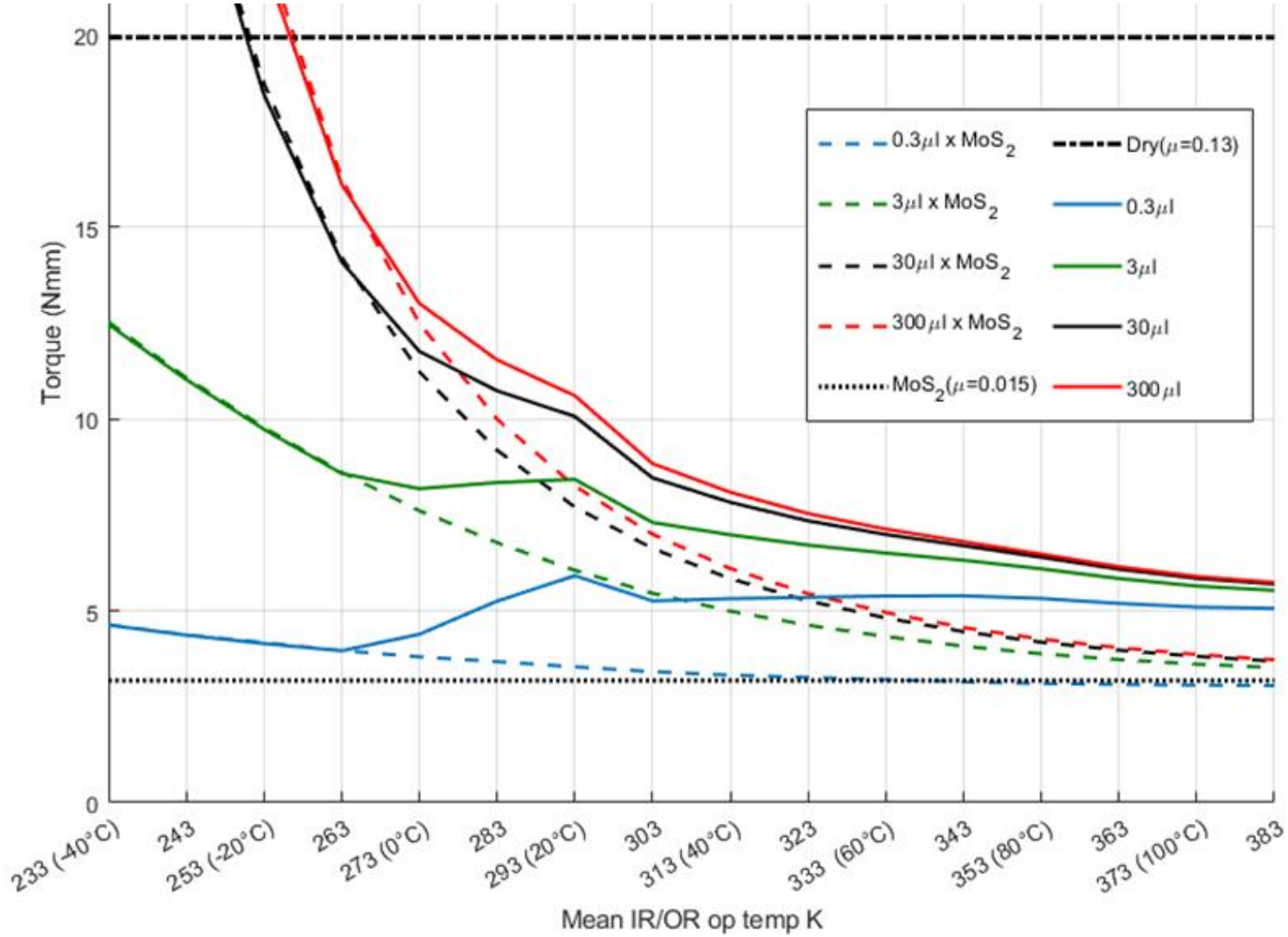
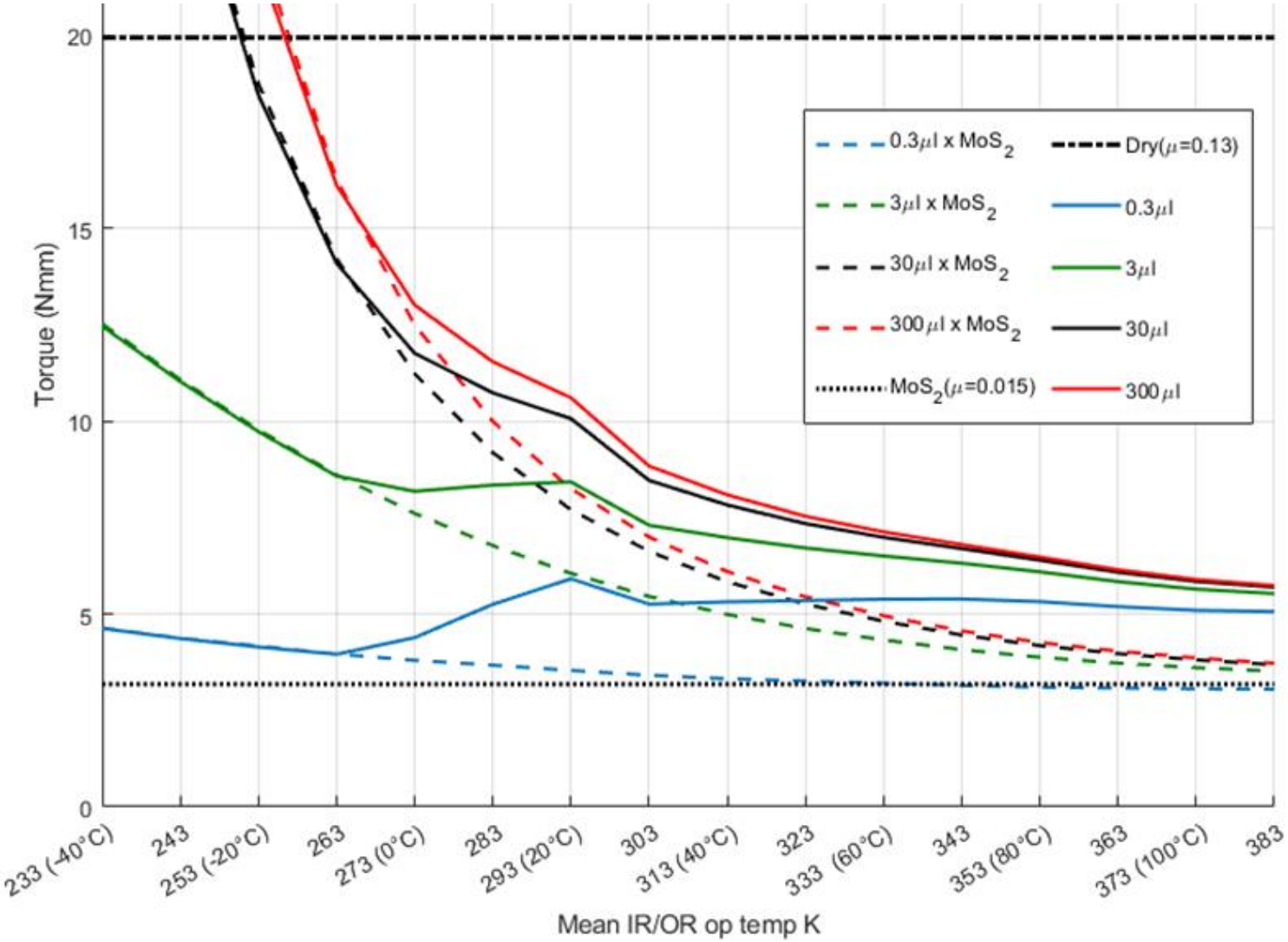


Temperature



- What if we go hot?

Temperature



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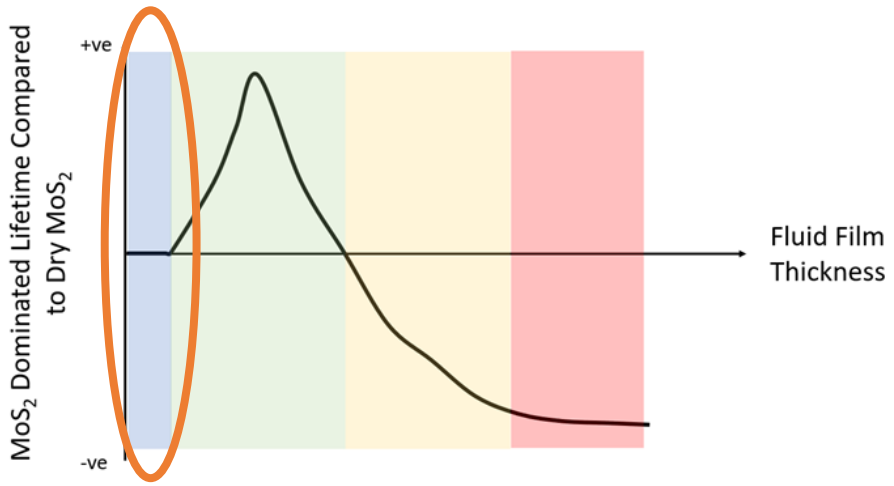

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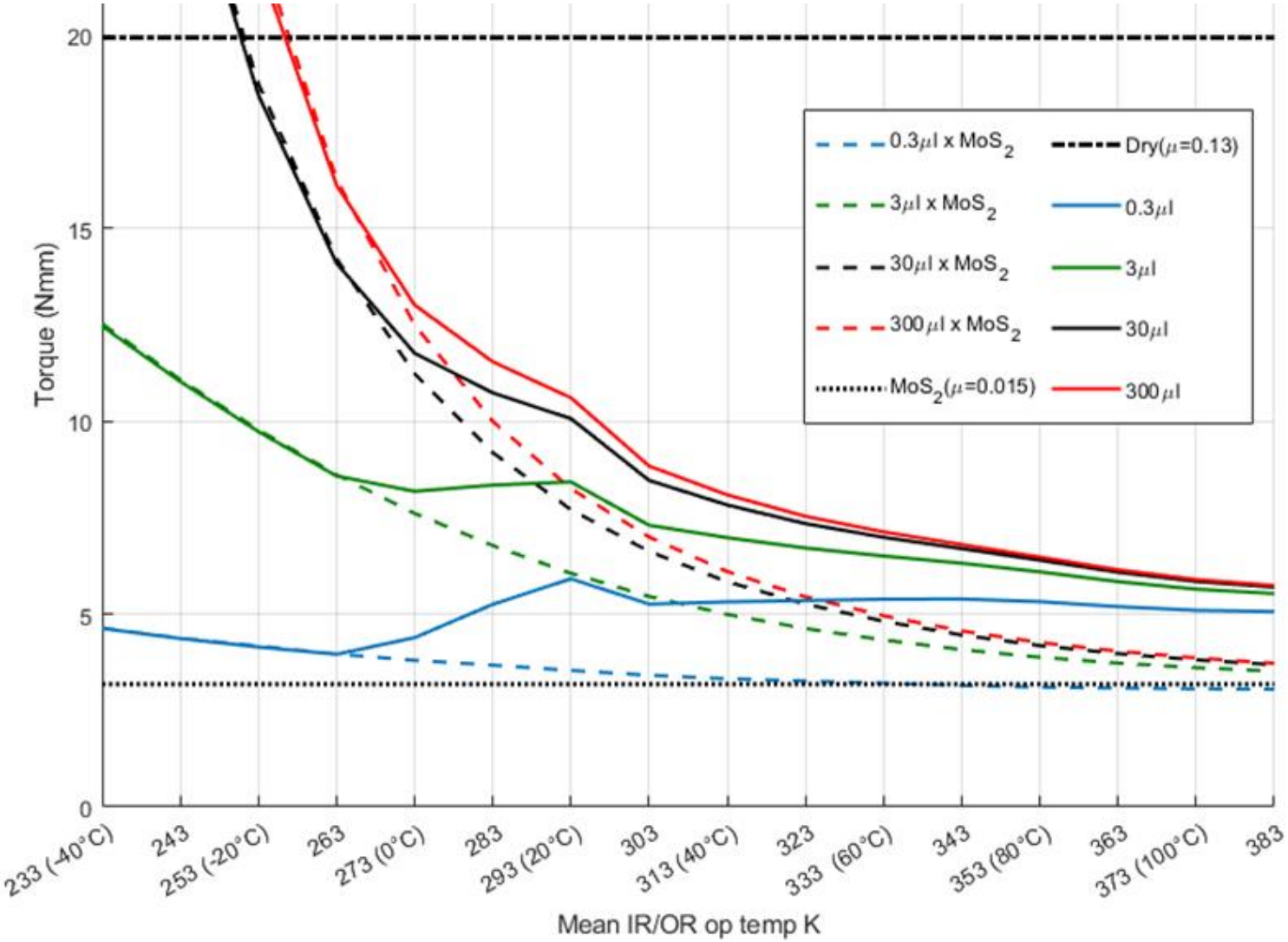
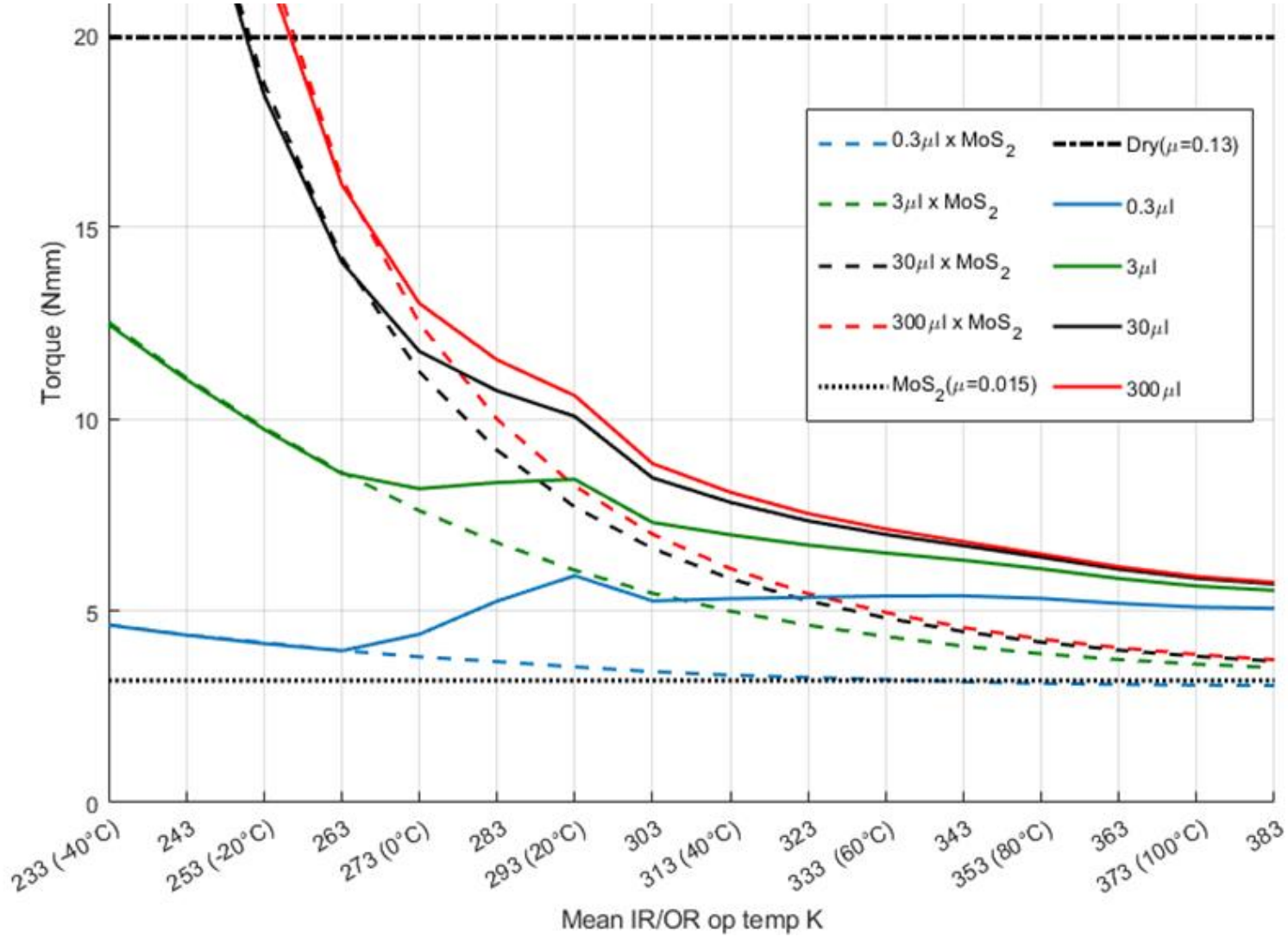


- What if we go cold?

Temperature



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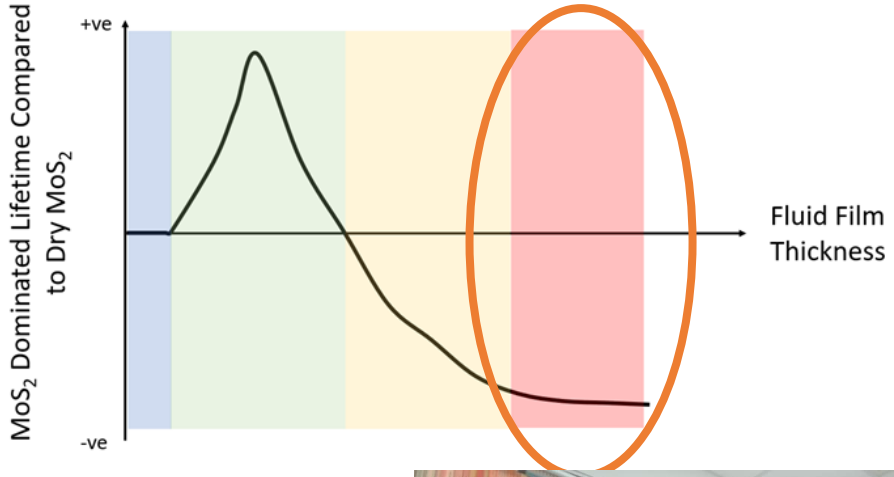

Volume

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- The thinner the fluid film the better….

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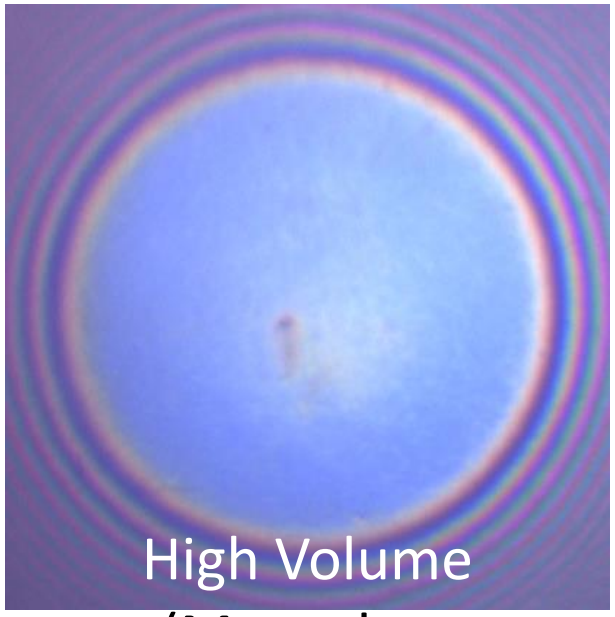
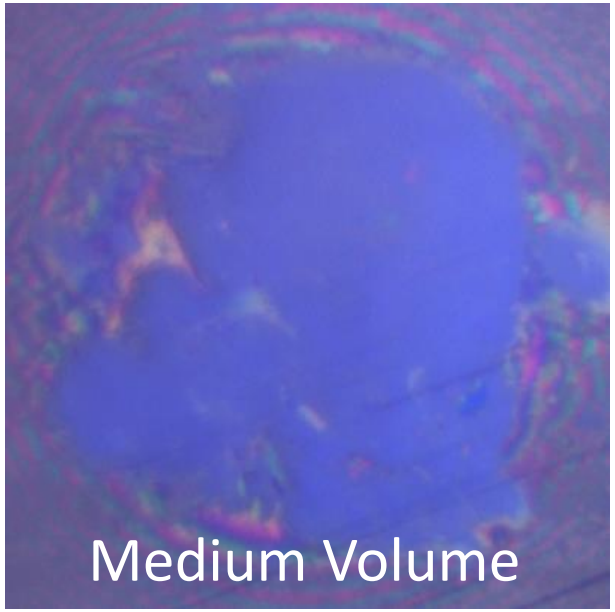
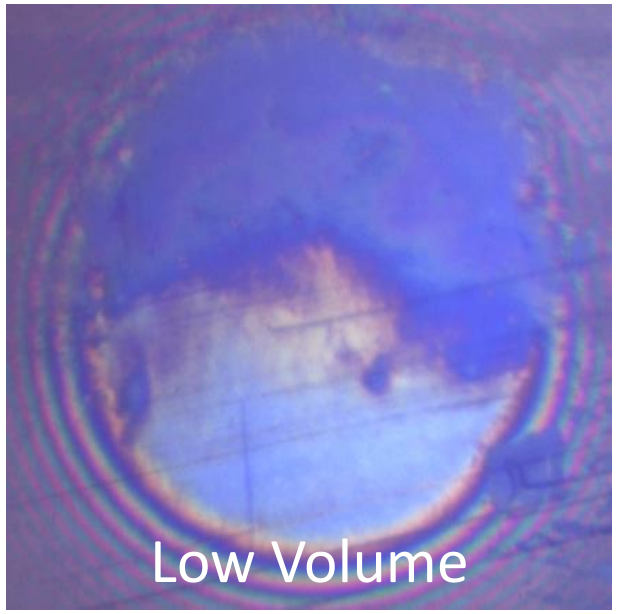


(More than recommended 1µl/mm of PCD)



(Approx recommended 1µl/mm of PCD)



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Expanded Hypothesis

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- Concentration of debris in contact is significant to success of hybrid lubrication

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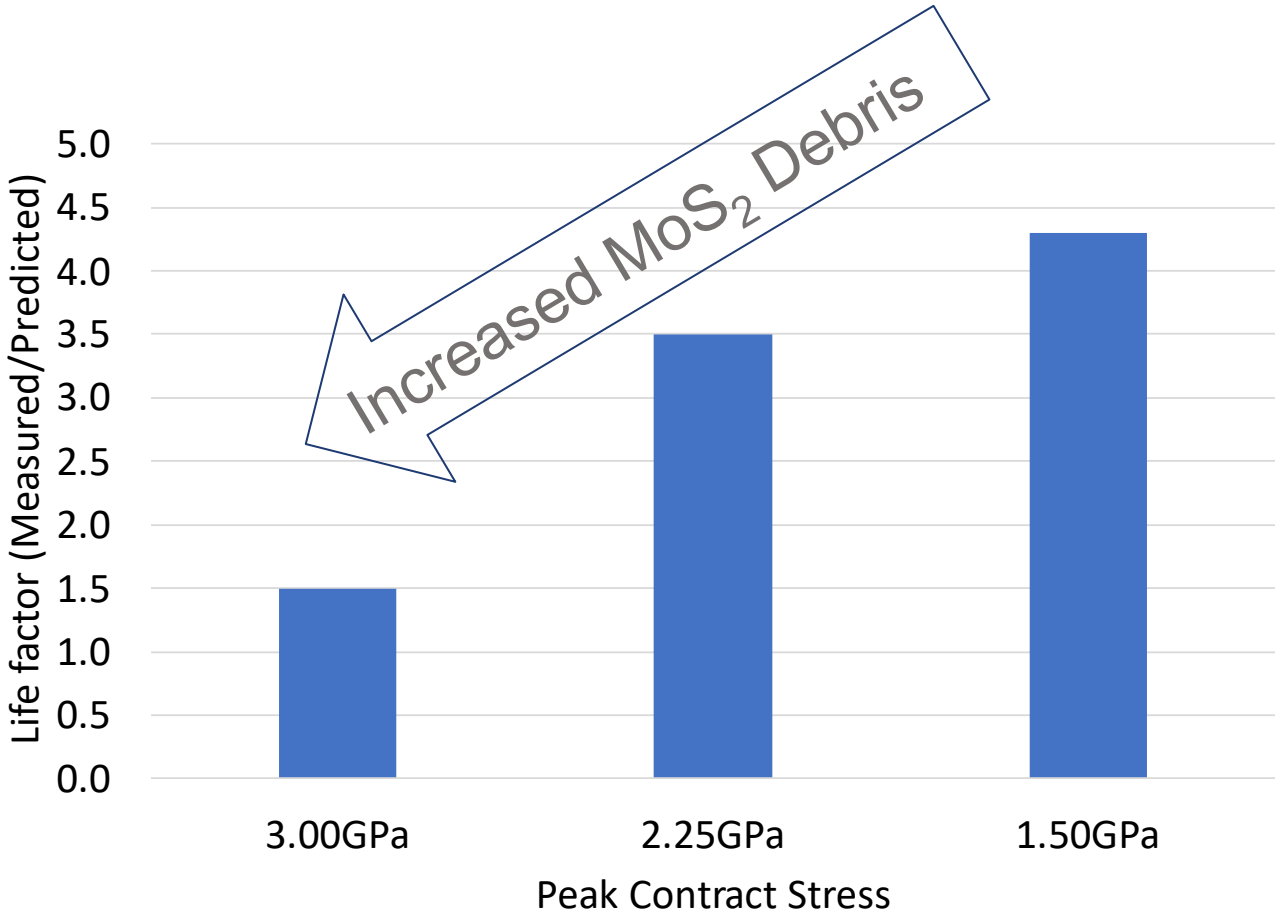
- Concentration of debris in contact is significant to success of hybrid lubrication
- Could be impacted by:
  - Wear rate of MoS_2
  - Fluid Film thickness and/or Viscosity
  - Other Factors???

Substrate Properties

- Roughness
  - Fluid chemical degradation
  - Optimum for MoS_2 adhesion
- Hardness
  - Necessary for MoS_2 adhesion

MoS_2 Debris Generation



- Increase in stress = Less lifetime extension
- MoS_2 debris not generated linearly

Combined Hypothesis

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- Hybrid lubrication relies on the retention of solid lubricant debris
- A goldilocks zone exists for thickness, to give the best performance of hybrid lubrication, but operating outside this range isn't necessarily a disaster
- The concentration of the debris is significant and so more factors can impact "success" than just fluid volume and temperature

Potential Applications

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- Because of the low fluid amounts:
  - Applications with a wider temperature requirement than would be appropriate for fluid lubrication alone, both lower temperatures and higher temperatures
  - Applications where cleanliness requirements would ordinarily preclude the use of fluids, due to lower evaporation rates

Further Potential Applications

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- Where a low torque margin would be advantageous but need a longer life than MoS_2 only can provide – e.g. gear applications
- Where a fluid would typically be employed but would benefit from a reduction in torque
- Where the ECSS requirements require significant on-ground operation, e.g. HDRM
  - As the oil will protect the MoS_2 in a moist environment

Recommendations for Use

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Run-in with no oil (as if a normal MoS_2 coated bearing)

Add an “appropriate” volume of fluid lubricant (oil)

Characterise the “complete” hybrid lubricated bearing

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MoS_2 Only + Fluid Only + Hybrid (MoS_2 + Fluid)

Acknowledgements

- Work funded under contract to ESA
- ESTL acknowledge the following:
  - ESA TEC/MSM (F. Romera and & L. Gaillard) for project management and guidance

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