National Aeronautics and Space Administration

TBD

Particle Impact Simulation and Ignition Prediction

PM / PI Info Jonathan Tylka | jonathan.m.tylka@nasa.gov

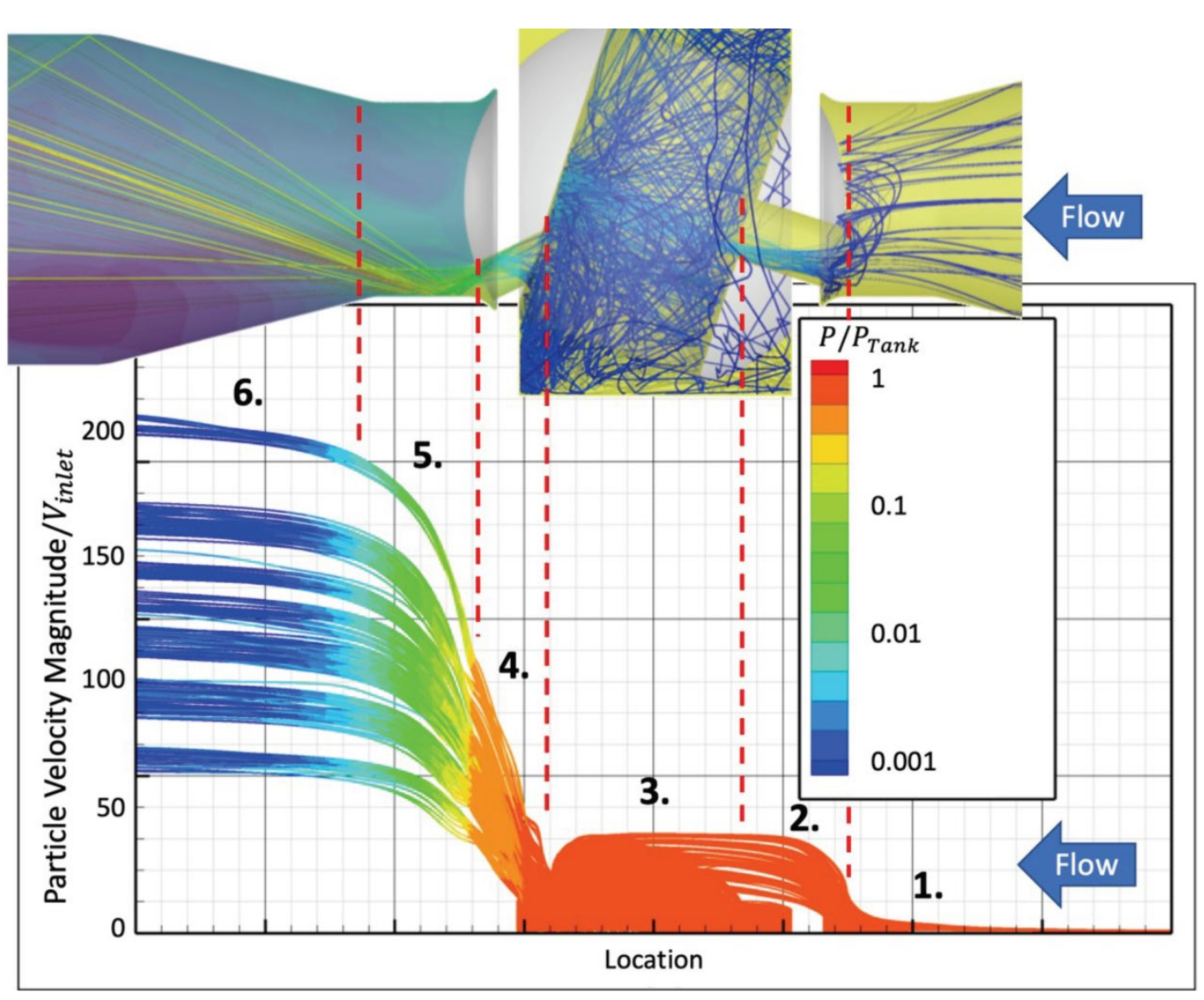
EXECUTIVE SUMMARY

An experimentally calibrated tool is needed to predict if a system is susceptible to failure by particle impact ignition (PI) based on use conditions, materials, and flow geometry. This tool will accelerate new components, evaluating existing hardware, and help disposition anomalies.

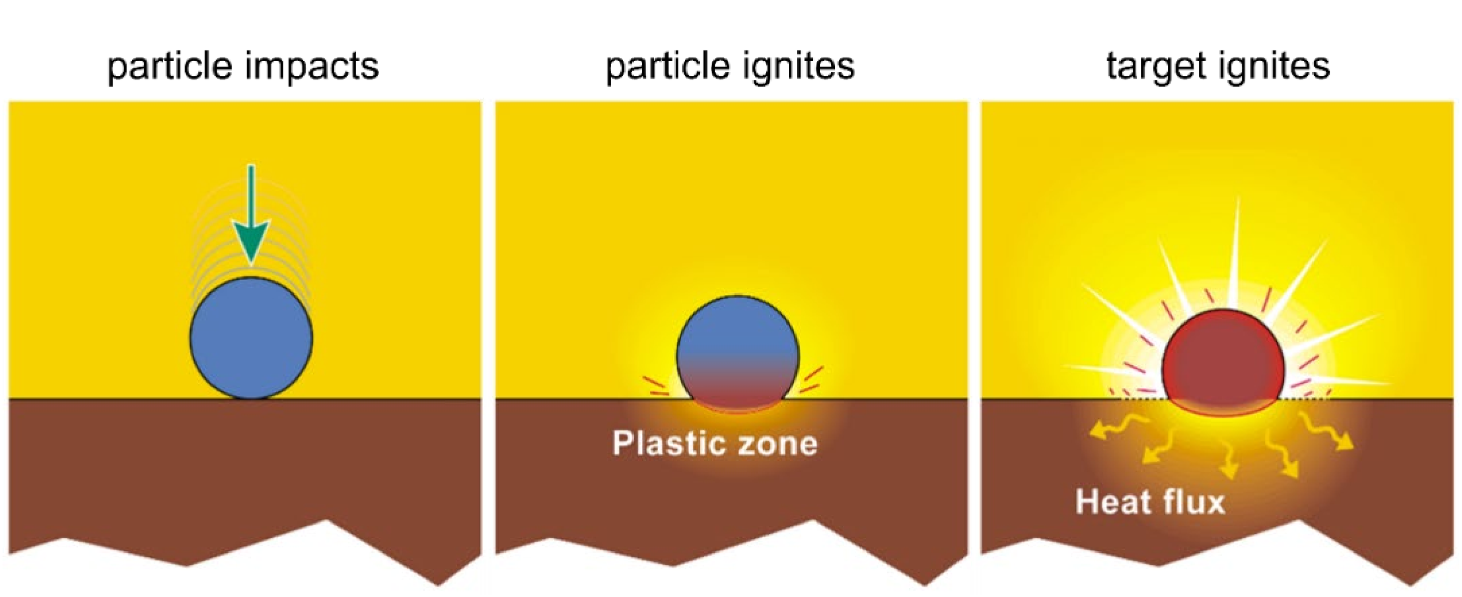
- Conduct particle impact testing with in-situ diagnostics and complementary simulations on subset of key engineering materials (IN718, M400, 316L, 6061, Ti64, Zr) to develop a proof-of-concept predictive tool for assessing the risk of PI for idealized geometries (spherical particles) in realistic environments.
- Assess particle/target interactions (coefficient of restitution, ignition, kindling) using instrumented particle impact rigs while systematically varying key parameters (materials, particle size, environment, target configuration).
- Determine key field variables (temperature, strain, stress) in particle impacts using Multiphysics finite element and hydrocode simulations validated through comparison with experimental measurements and observations.
- Synthesize experiments and simulations into constitutive models for PI that can be integrated with existing computational fluid dynamics (CFD) and Debris Transport Analysis (DTA) tools in future efforts

INNOVATION

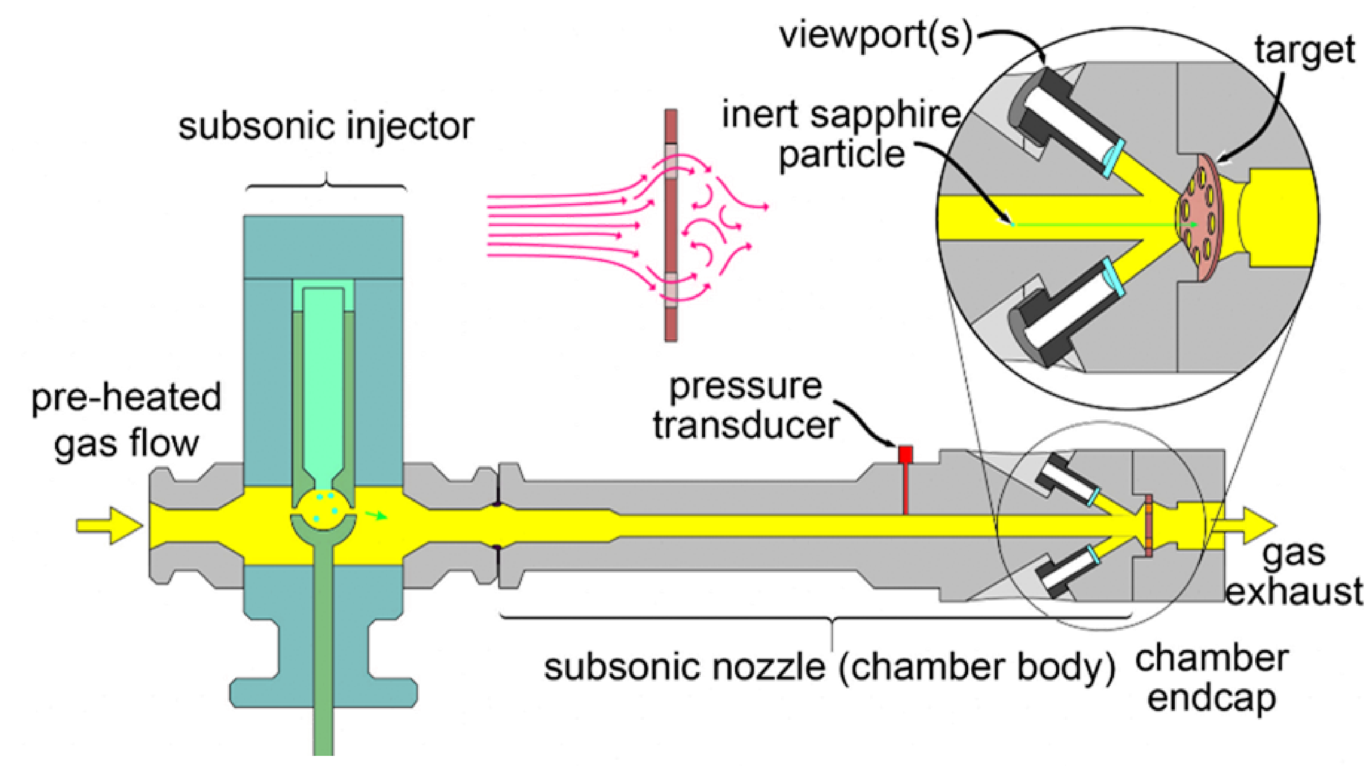
There are several critical technology developments creating a tipping point for understanding PI. Academia has developed a complimentary particle launching apparatus that can more precisely measure critical particle/target interactions, such as coefficient of restitution. This new testing technology in combination with higher fidelity flowing particle impact conditions performed at WSTF can anchor models of PI. Computational tools for modeling particle interactions with flow, and high strain rate hydrocode allow for a deeper and more fundamental understanding of materials and ignition behavior.

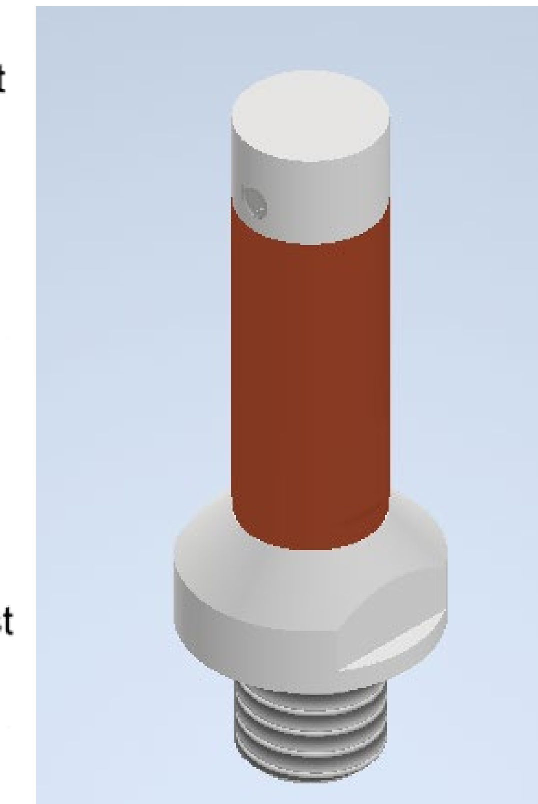


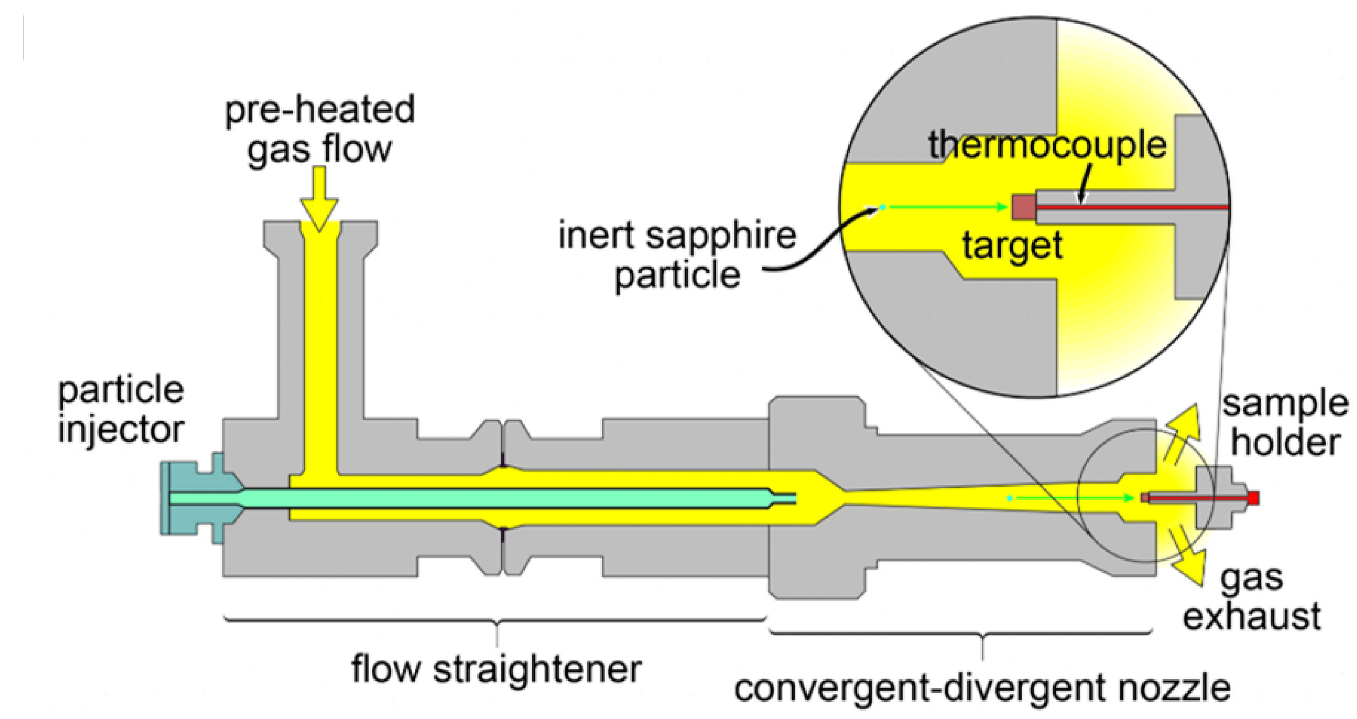
Programmatic example of CFD/DTA for evaluating particle impingement locations/ impingement angles/pressures/ particle velocities in an oxidizer valve to inform ignition risk assessment

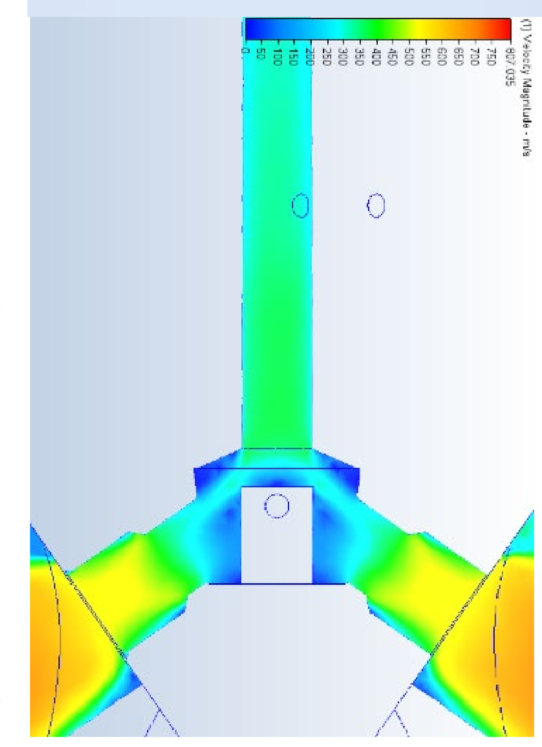


Particle Impact Ignition and Kindling Process









Left: Historical particle impact flow diagrams. Upper: Subsonic; Lower; Subsoinic

Right: Upper: Unified particle impact sample geometry. Lower; Unified geometry subsonic configuration CFD.

COLLABORATION

1. Massachusetts Institute of Technology
    1. Dr. Zachary Cordero (Assistant Professor)
    2. Dr. Suhas Eswarappa Prameela (Post-doc)
    3. Spencer Taylor (PhD Candidate)
2. MSFC- Matthew Fischels, Kelsey Buckles
3. NESC- Gregory Harrigan
4. SpaceX- Aleksey Volodchenkov
5. Blue Origin- Tony Chung
6. White Sands Test Facility- Steven Mathe, Stephen Peralta, Jonathan Tylka, David Hendon, Albert Cuvelier

OUTCOMES & INFUSION

- MIT lead a Journal of Materials (JOM) publication, WSTF as co-authors
- Improved the WSTF coefficient of restitution apparatus (CORA)
- Developing computer vision data processing algorithm for WSTF CORA data
- Developed a unified subsonic and supersonic sample geometry for WSTF ignition testing.
- Integrated several modeling efforts at MIT to describe particle ignition and kindling. Resulting in predicted initial conditions required for ignition model.
- Performed several round of ignition testing. Achieving qualitative agreement with the model. Continuing to test to improve calibration.
- Successfully pitched successive year 3 and 3 funding to the NESC
- Successfully selected by JSC CIF IRAD for year 3/3
- Successfully performing COR/ ignition testing at MIT in oxygen
- Integrating MIT and WSTF forward testing plans

FUTURE WORK

1. Perform remaining particle impact ignition factor screening testing
2. Conduct analysis of testing results
3. Perform testing at MIT and WSTF on flammable target materials

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