National Aeronautics and Space Administration

TBD

Particle Impact Simulation and Ignition Prediction

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

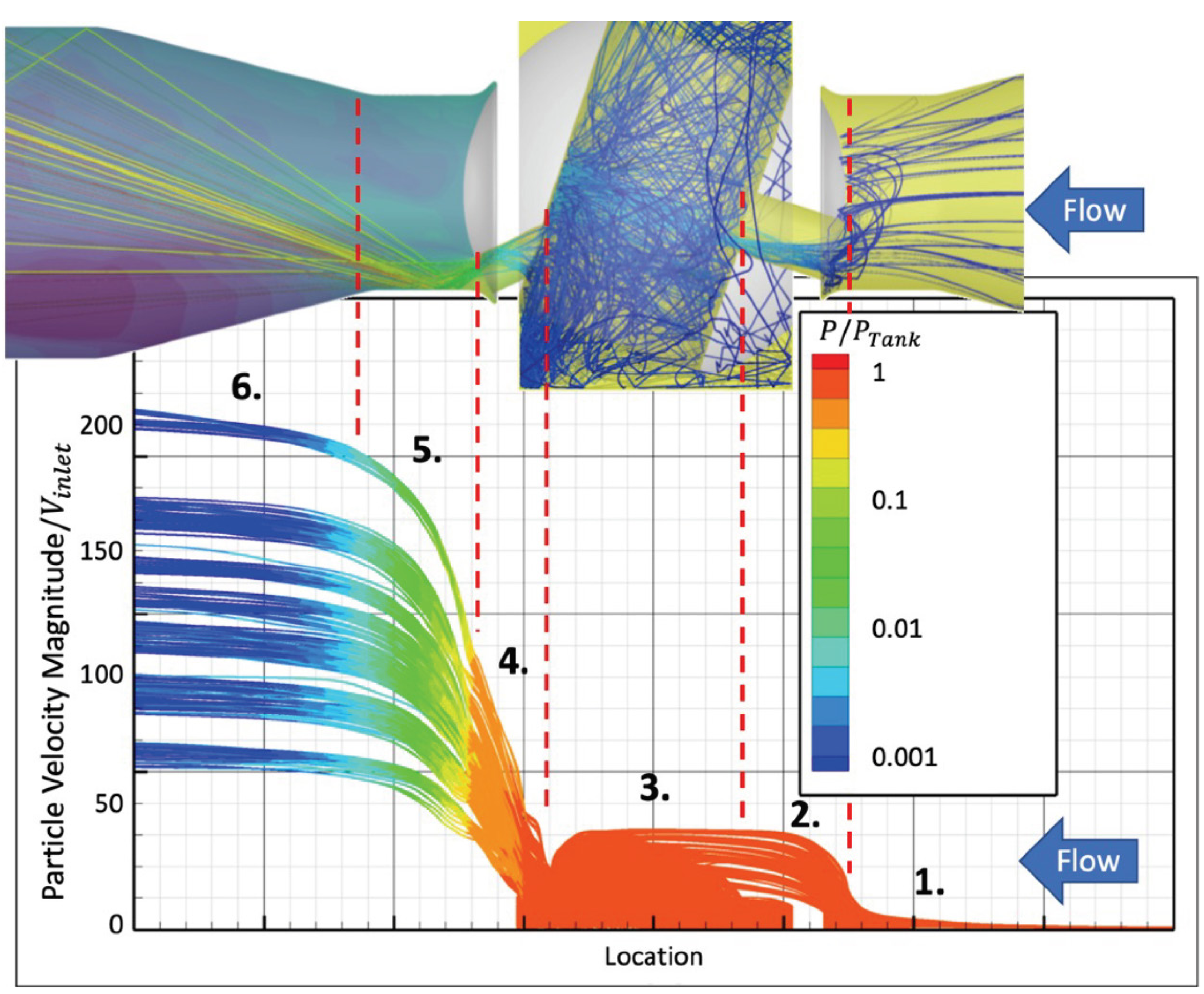
EXECUTIVE SUMMARY

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.

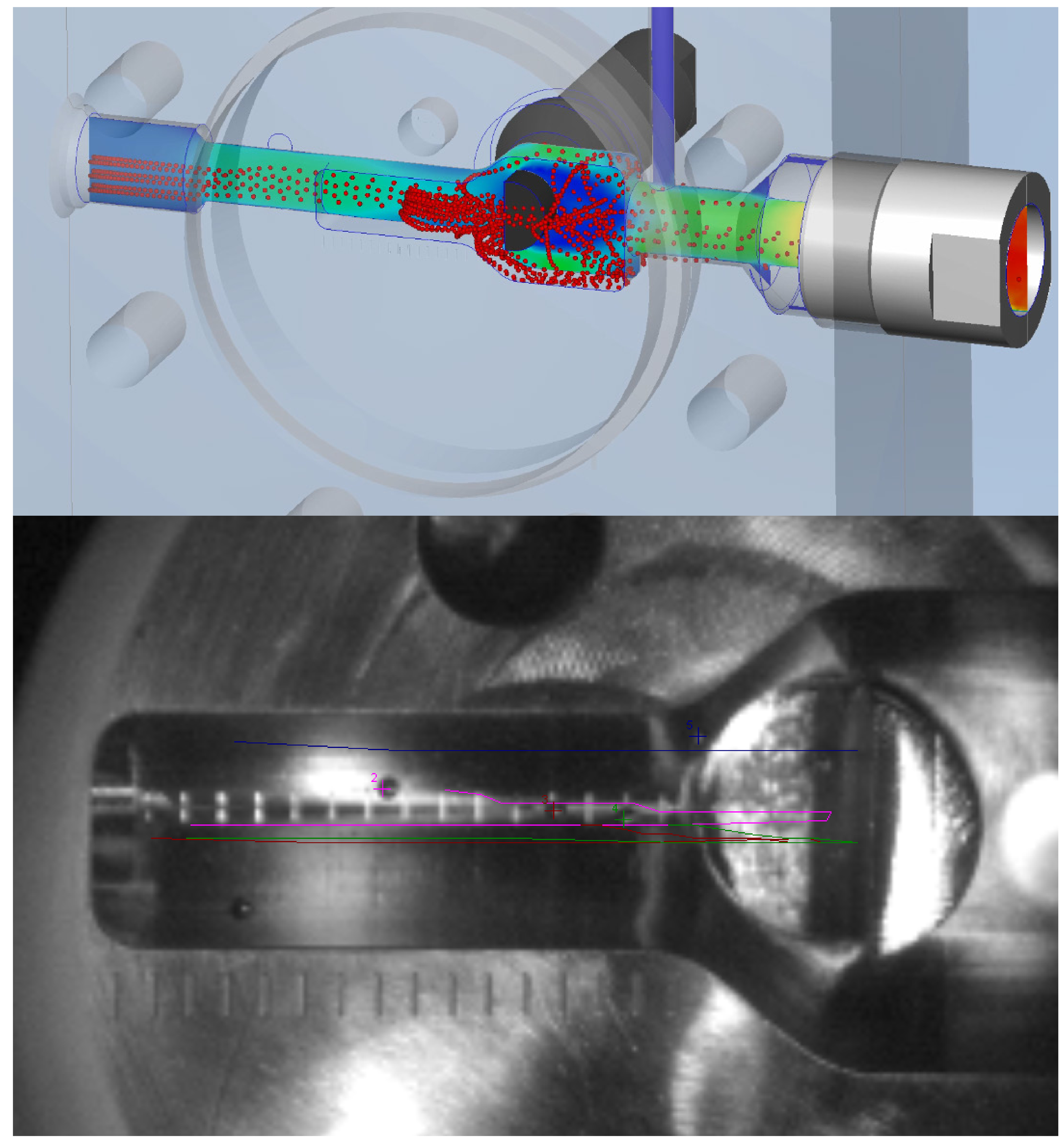
- Conduct particle impact testing with in-situ diagnostics and complementary simulations on subset of key engineering materials (IN718, M400, 316L, 6061, Ti64, Zr) to develop a proof-of-concept predictive tool for assessing the risk of PI for idealized geometries (spherical particles) in realistic environments.
- 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



Above: CFD/DTA Simulations of coefficient of restitution / particle ignition apparatus (CORA)
Below: Post test analysis of high-speed video from CORA testing in nitrogen

COLLABORATION

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

OUTCOMES & INFUSION

- Tested prototype coefficient of restitution apparatus (CORA)
- Processed data off prototype CORA
- Redesigned and built updated CORA
- Testing started in September 2023
    - Performed COR testing in nitrogen on three particle materials, three particle sizes, two inert target materials, and three velocities
    - Performed particle ignition testing on one particle material, two particle sizes, one inert target material, ambient & elevated temperature, 10 velocities.
- Successfully pitched successive year 2 and 3 funding to the NESC
- Successfully selected by JSC CIF IRAD for year 2/3
- COR/ ignition testing at MIT initiated
- Construction of high-pressure MIT COR chamber at WSTF
- 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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