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Sandia National Laboratories

SHOCK THERMODYNAMICS STAR APPLIED RESEARCH

Fragment Simulating Projectile for Damage Characterization

Presented by

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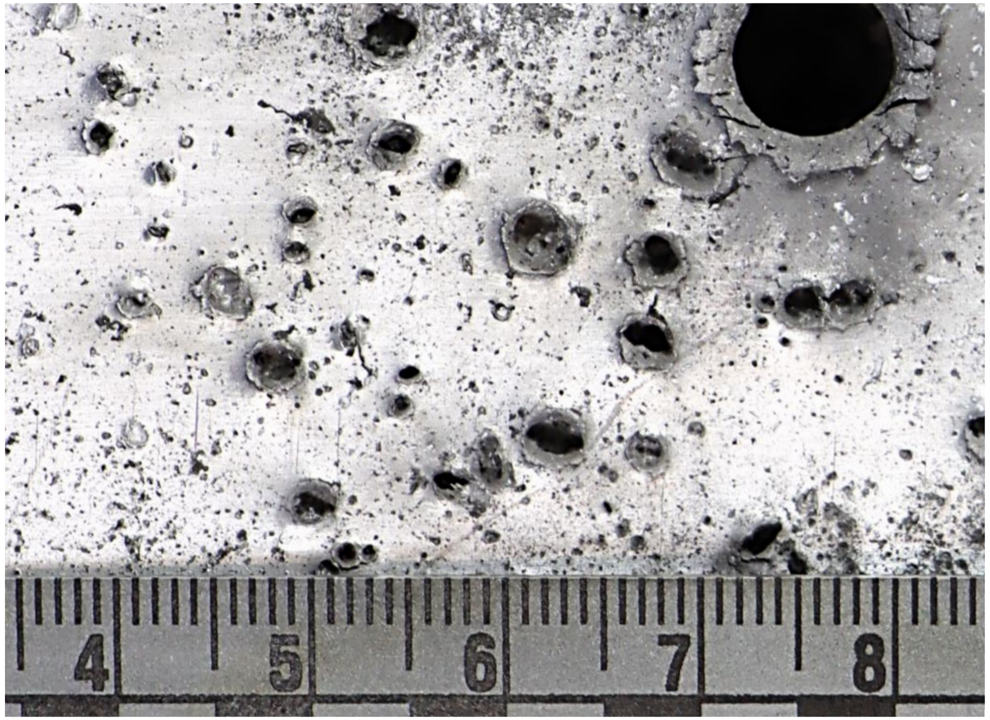
Introduction| Motivation

High velocity fragments produced during dynamic materials experiments can be particularly damaging to the containment structures and surrounding diagnostics and must be mitigated.

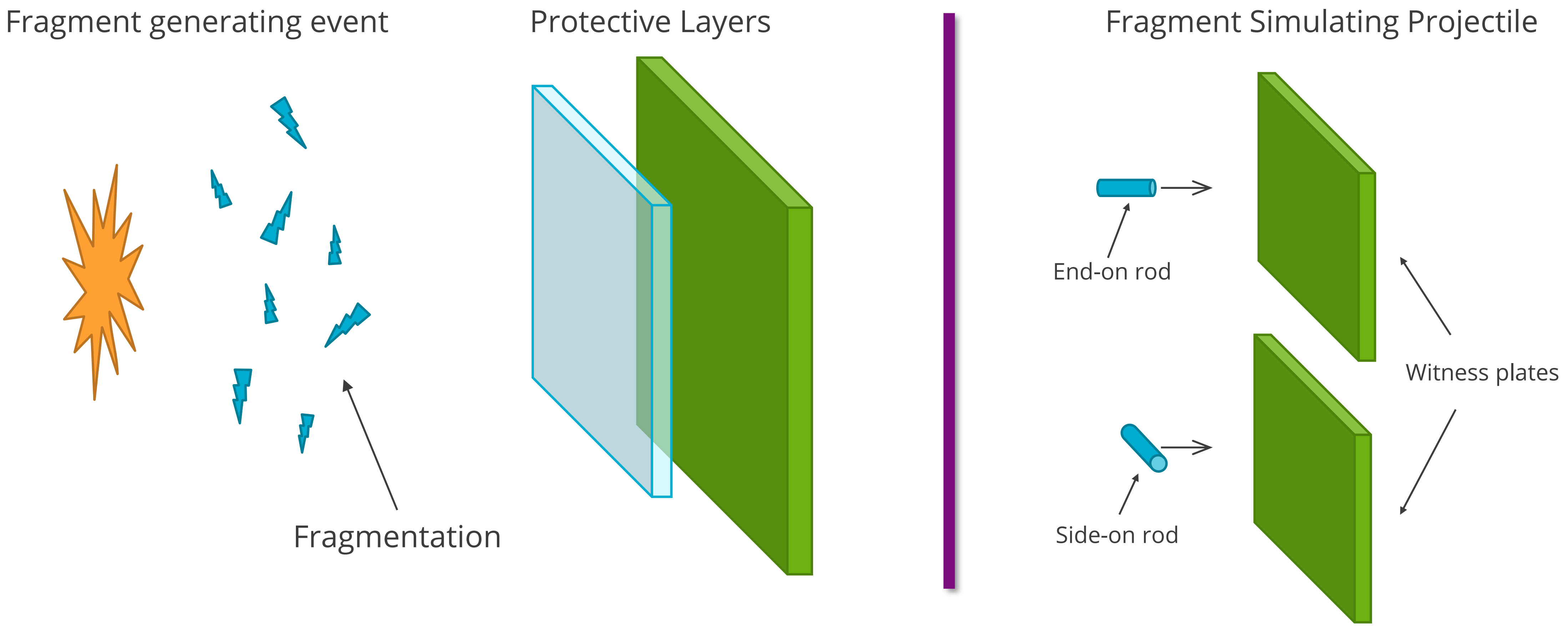
NEED FOR:

- A ballistics platform to emulate fragment impact
- Assessment of fragments mitigations techniques
- Understanding materials' responds to fragments



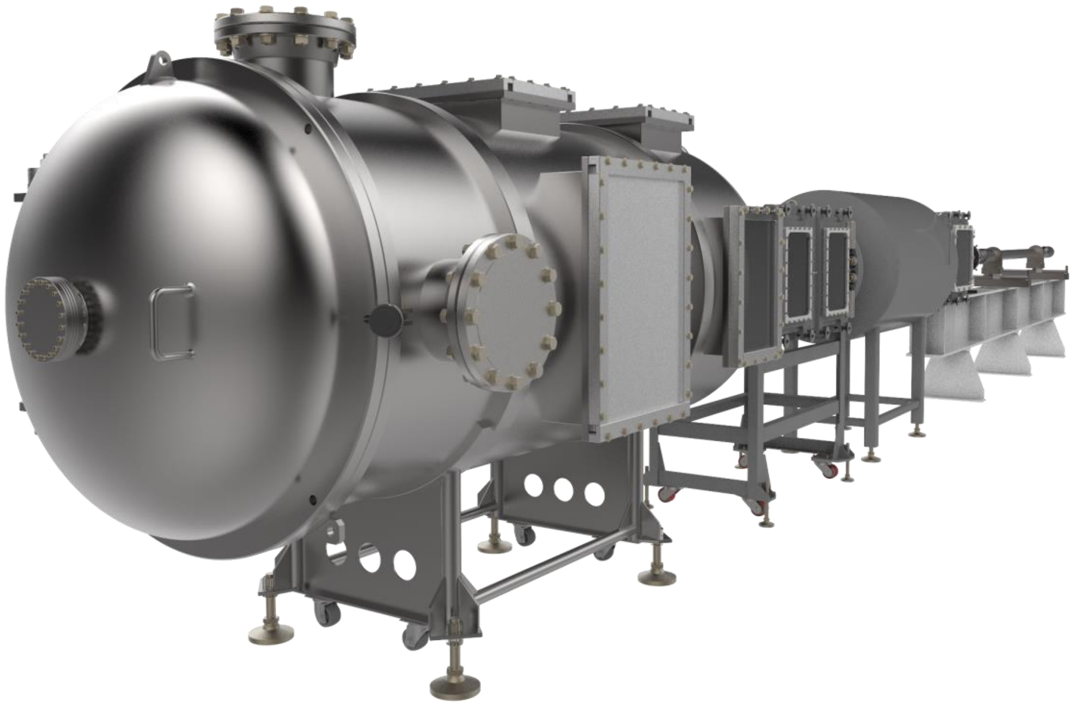
Introduction| Scope of Work

We developed a projectile lunching system to emulate fragment flight and impact for fragment damage characterization to evaluate mitigation techniques.



Introduction| Approach

STAR's terminal ballistic range was configured to launch fragment simulating projectiles (FSPs) of different densities in a controlled manner into witness plates of different materials to evaluate their performance as damage mitigation material.



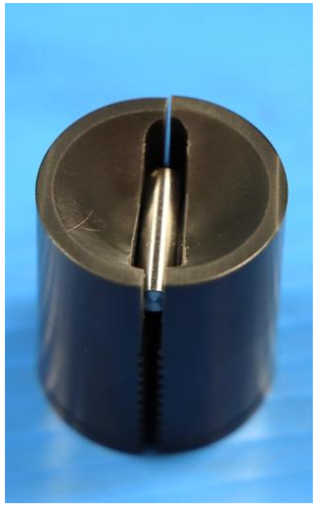
FSP materials

- Tantalum
- Tungsten
- Aluminum

Witness materials

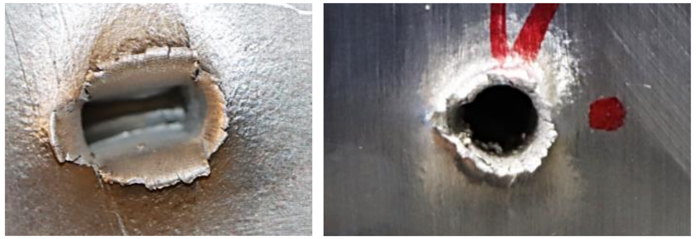
- AA6061-T6 Aluminum
- A514 Steel
- Starphire glass

Side-on FSP



End-on FSP

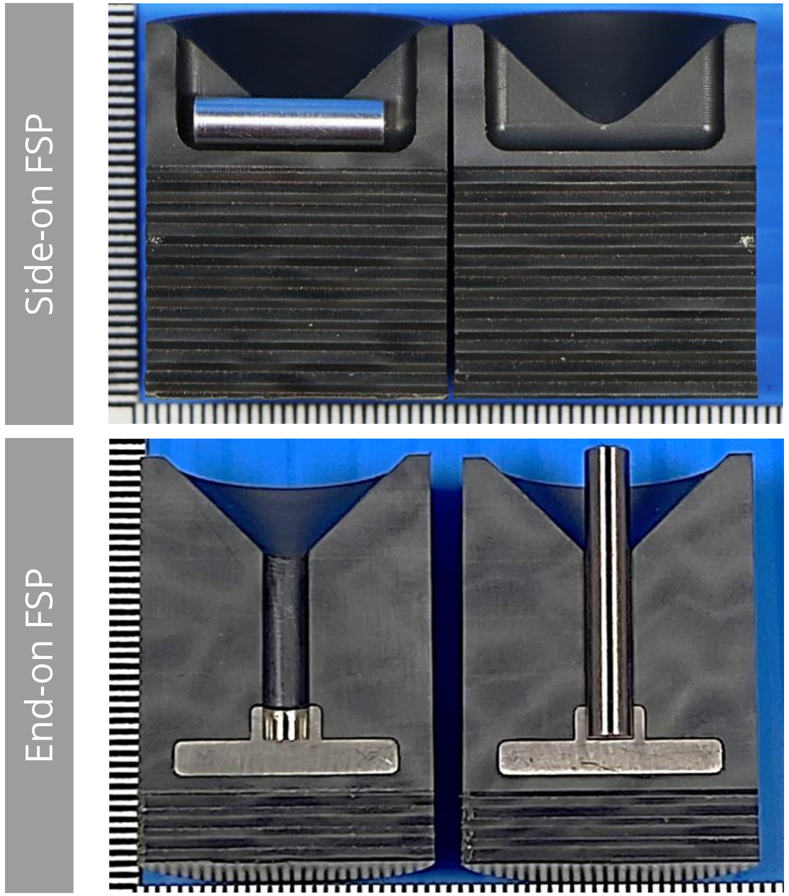
Witness plates



Experimental setup| Fragment Simulating Projectile

End-on and side-on FSP configurations to cover the range of fragment orientations.

- Tantalum, tungsten and aluminum FSP materials
- 4 mm dia. and 15 mm long rod for side-on FSP
- 4 mm dia. and 25 mm long rod for end-on FSP
- Nylatron 2-piece sabot for encapsulation



Experimental setup| Target setup

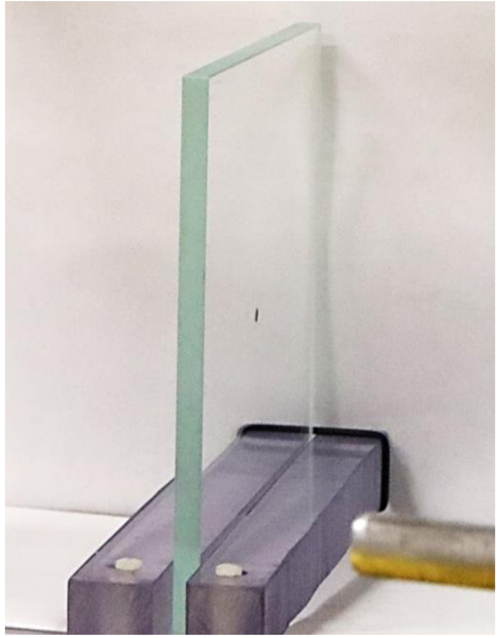
Three different materials were tested as witness plates to study the response to fragments and potential use as damage mitigating material:

- AA6061-T6 aluminum, A514 steel, Starphire (soda-lime) glass

Aluminum blocks and sheets

Steel blocks and sheets

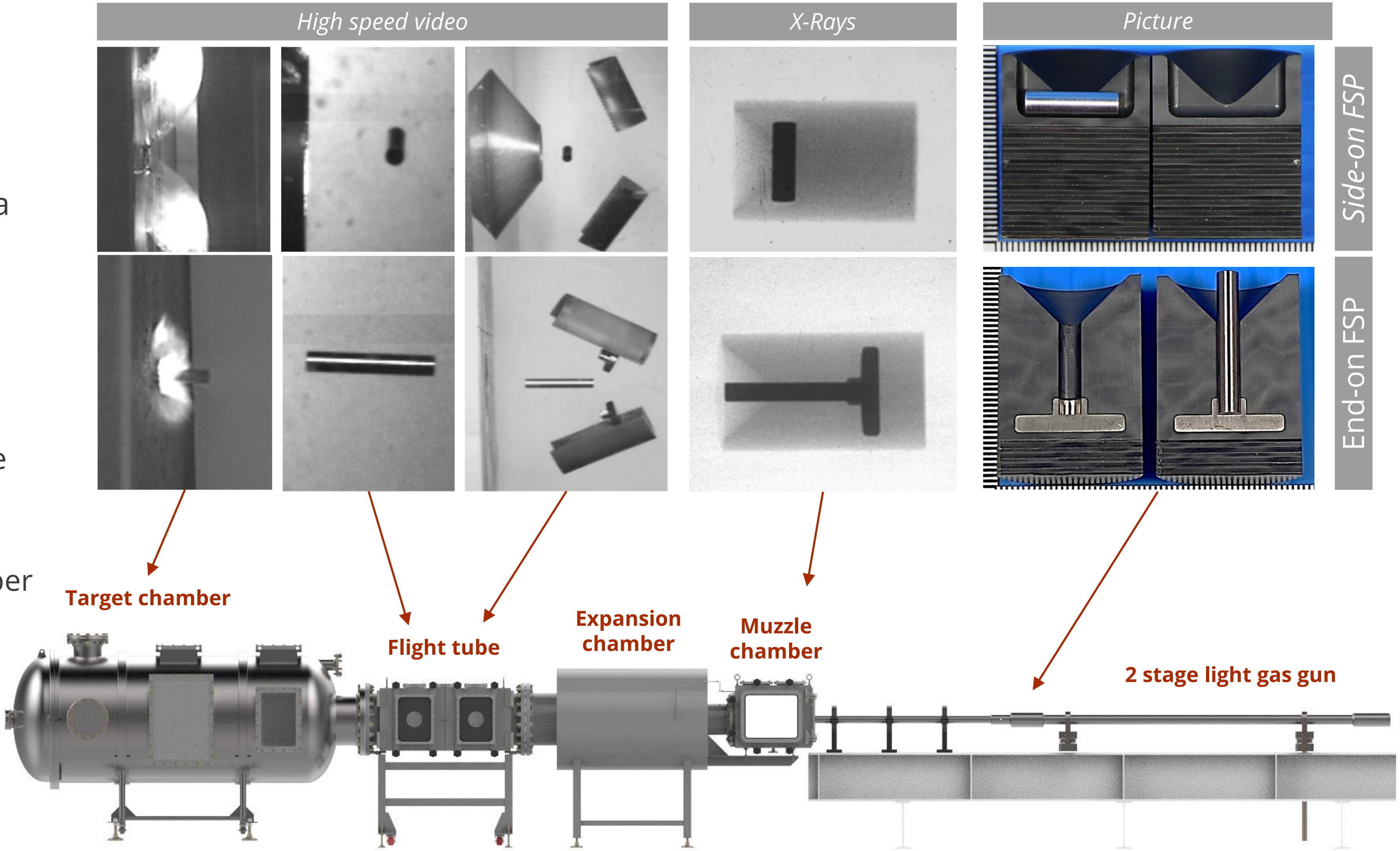
Glass panels



Experimental setup| Fragment Launch

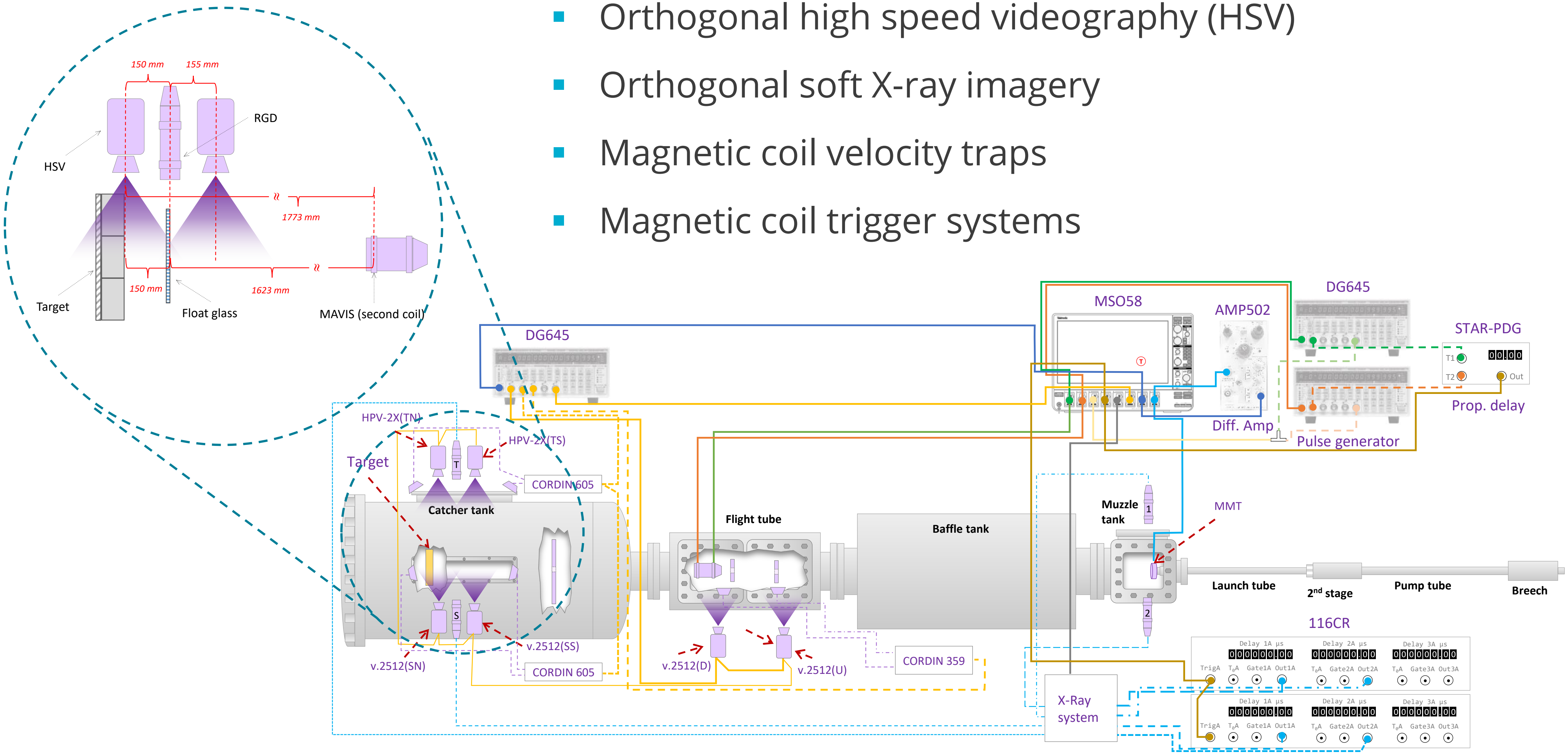
STAR's Terminal Ballistic Facility (TBF) was utilized to accelerate FSPs encapsulated in a Nylatron separating sabot downrange to a target tank.

- 1" diameter launch barrel
- 1 km/s to 2 km/s velocity range
- Stripping in flight tube
- Witness plates in target chamber



Experimental setup| Diagnostics

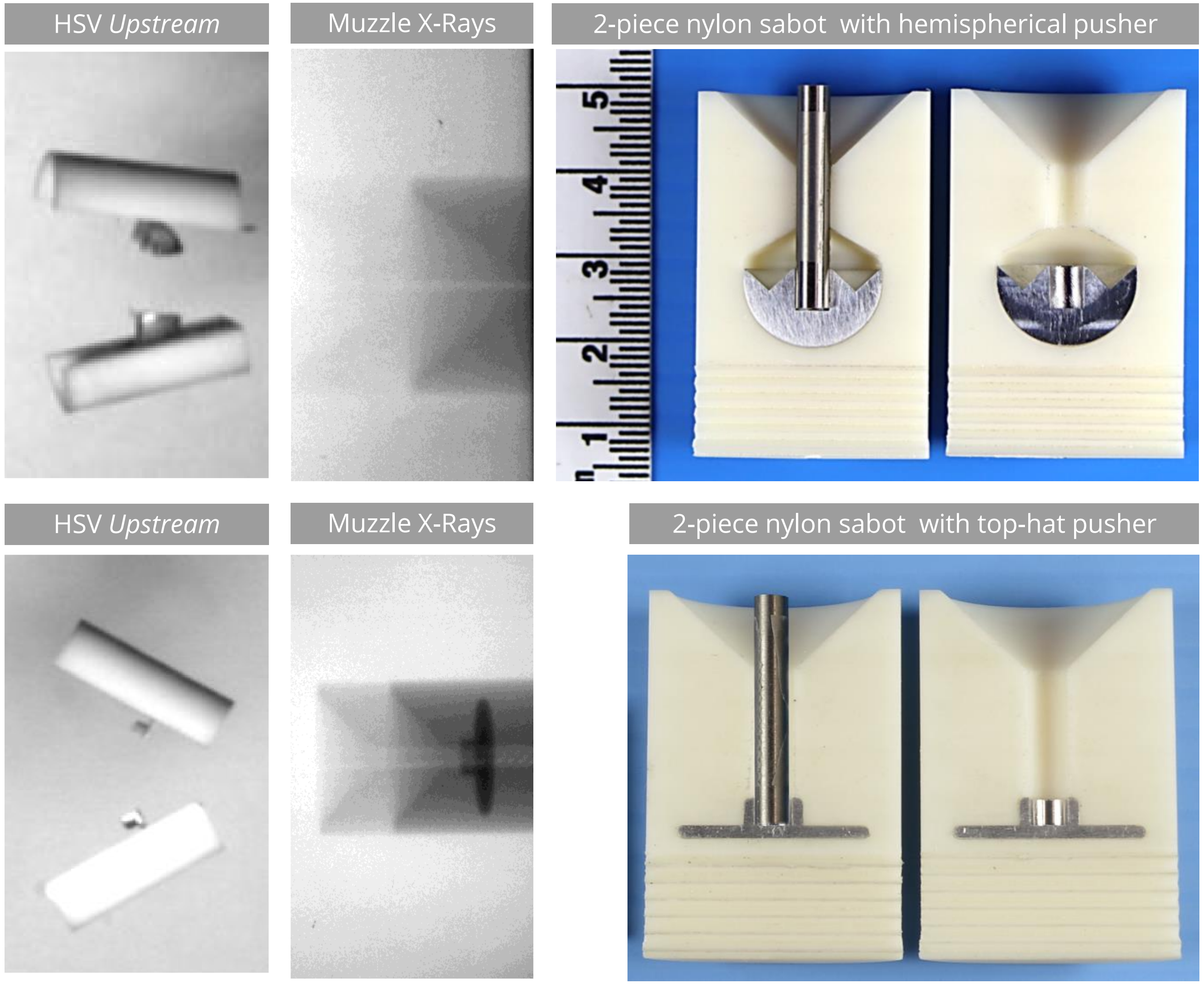
- Orthogonal high speed videography (HSV)
- Orthogonal soft X-ray imagery
- Magnetic coil velocity traps
- Magnetic coil trigger systems



Development| End-on Fragment Simulating Projectile

For the end-on FSP, support on the back side of the rod is required. We explored the <u>hemispherical</u> and <u>top-hat</u> aluminum pusher design in a 2-piece nylon sabot.

Weak support was observed in both cases. Rod stayed behind and detached from sabot assembly. The nylon material is most likely the weak point.



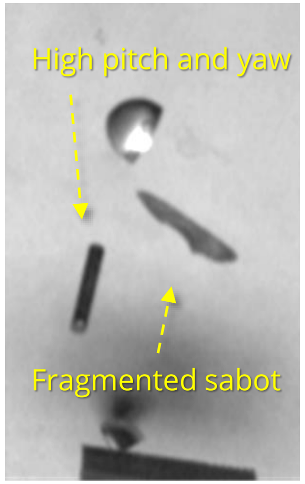
Development| End-on Fragment Simulating Projectile

Nylatron (Molybdenum disulfide reinforced nylon) sabot material was used instead of regular nylon to improve stability.

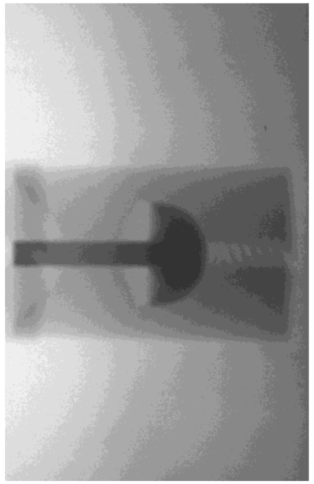
Some random instabilities were observed in the hemispherical pusher design. The <u>Titanium top-hat</u> pusher design showed better performance.

- Low sabot failure
- Minimal pitch
- Minimal yaw

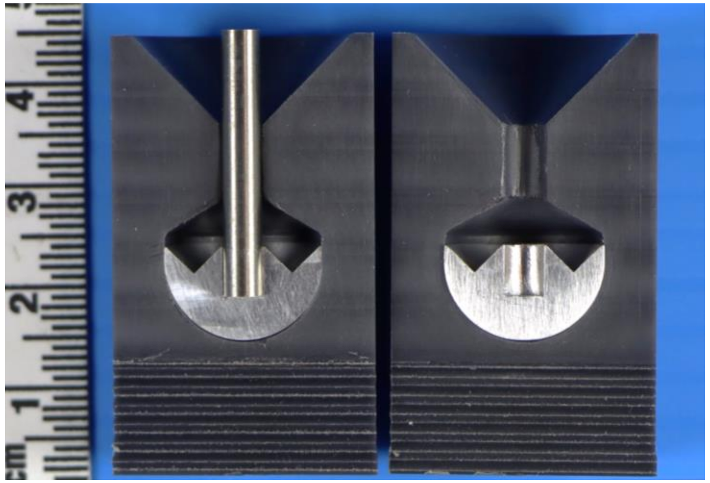
HSV *Upstream*



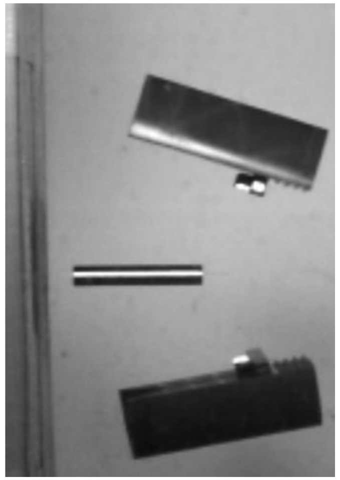
Muzzle X-Rays



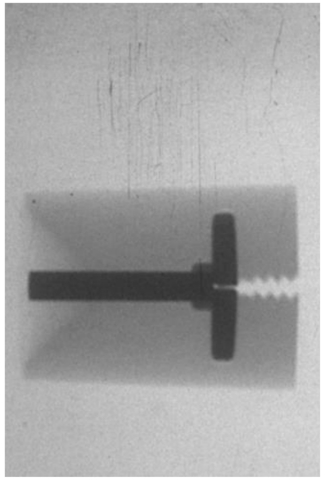
2-piece Nylatron sabot with hemispherical pusher



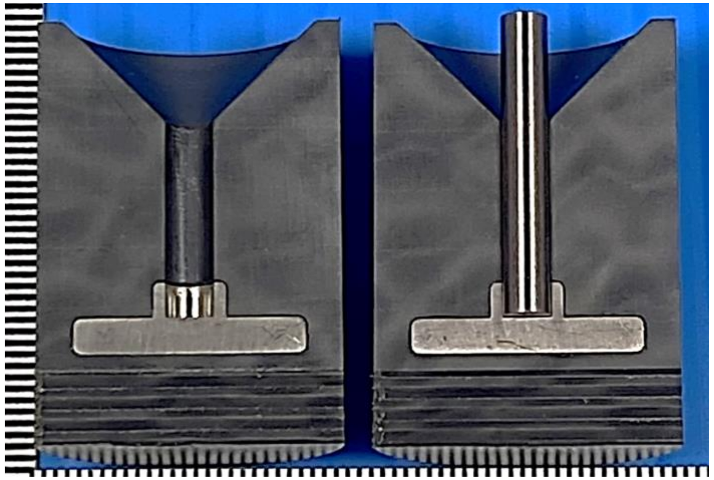
HSV *Upstream*



Muzzle X-Rays



2-piece Nylatron sabot with Ti top-hat pusher

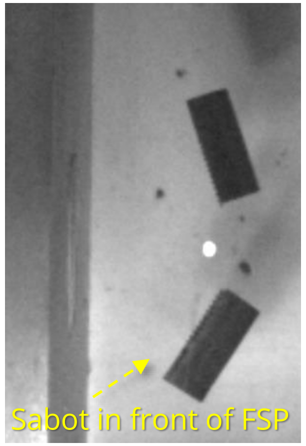


Development| Side-on Fragment Simulating Projectile

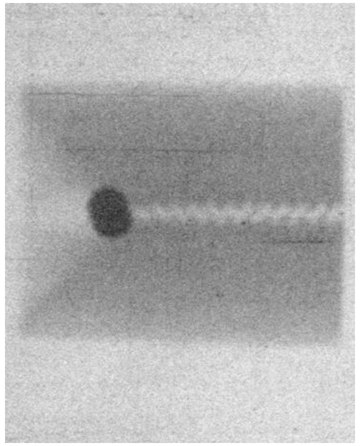
For the side-on FSP, a Nylatron (Molybdenum disulfide reinforced nylon) 2-piece sabot with a rod pocket was used.

The projectile launch was successful but the stripping mechanism had some disturbances in the projectile path that caused projectile divergence.

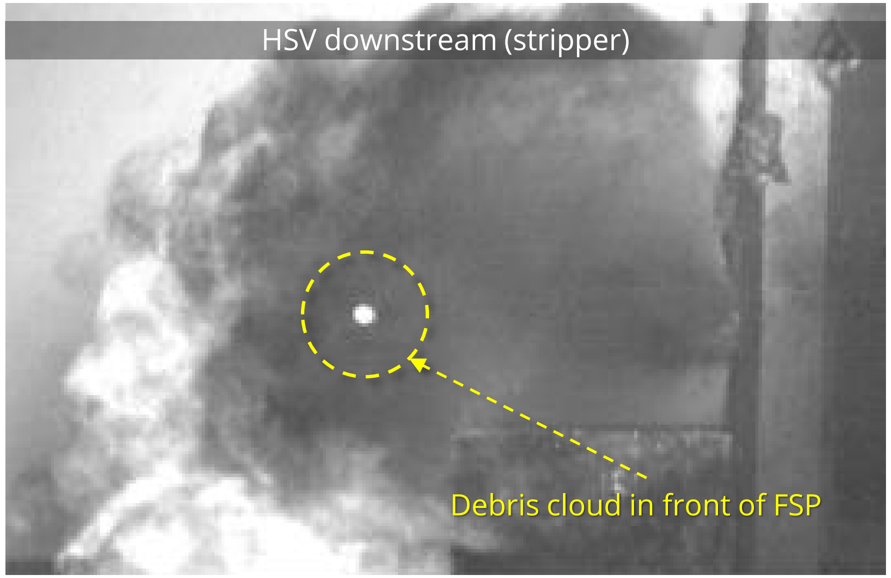
HSV *Upstream*

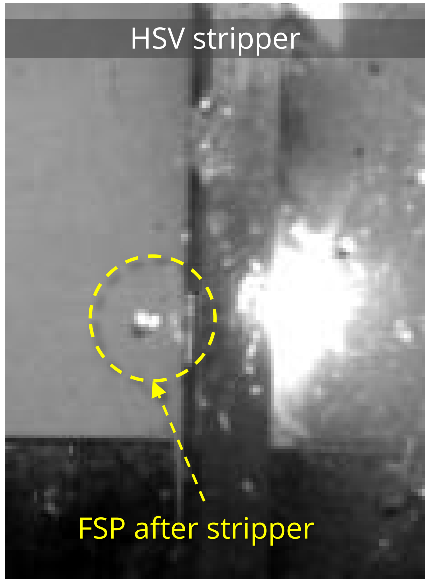


Muzzle X-Rays



2-piece Nylatron sabot with rod pocket





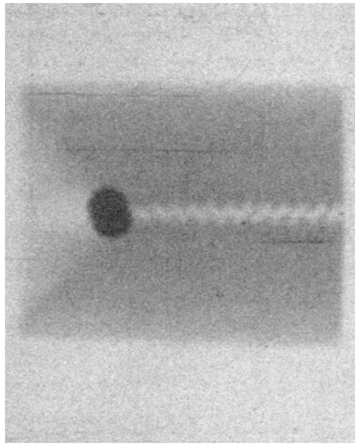
Development| Side-on Fragment Simulating Projectile

A 3D printed conical plastic stripper was employed to delay the debris cloud and achieve an undisturbed FSP launch.

The cone angles matched the sabot separation angles for optimum debris cloud retardation effect.

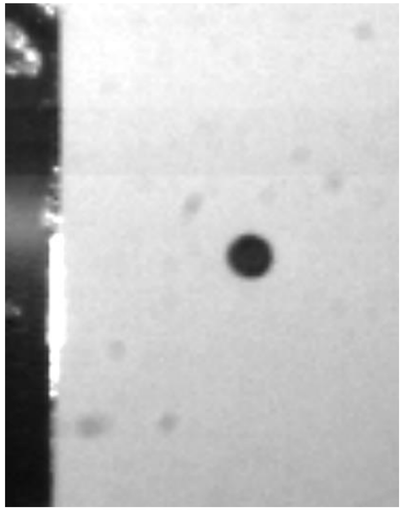
The approach was successfully tested.

Muzzle X-Rays

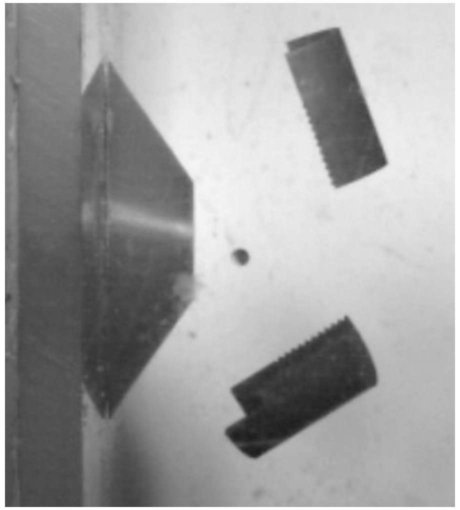


2-piece Nylatron sabot with rod pocket

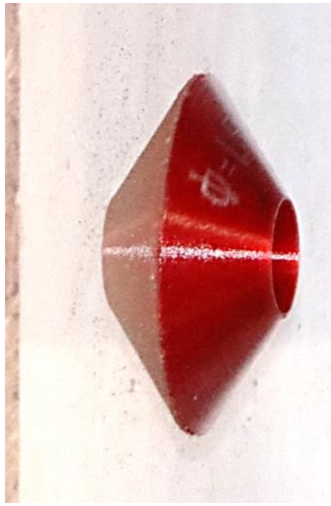
HSV <u>after</u> stripper



HSV <u>before</u> stripper

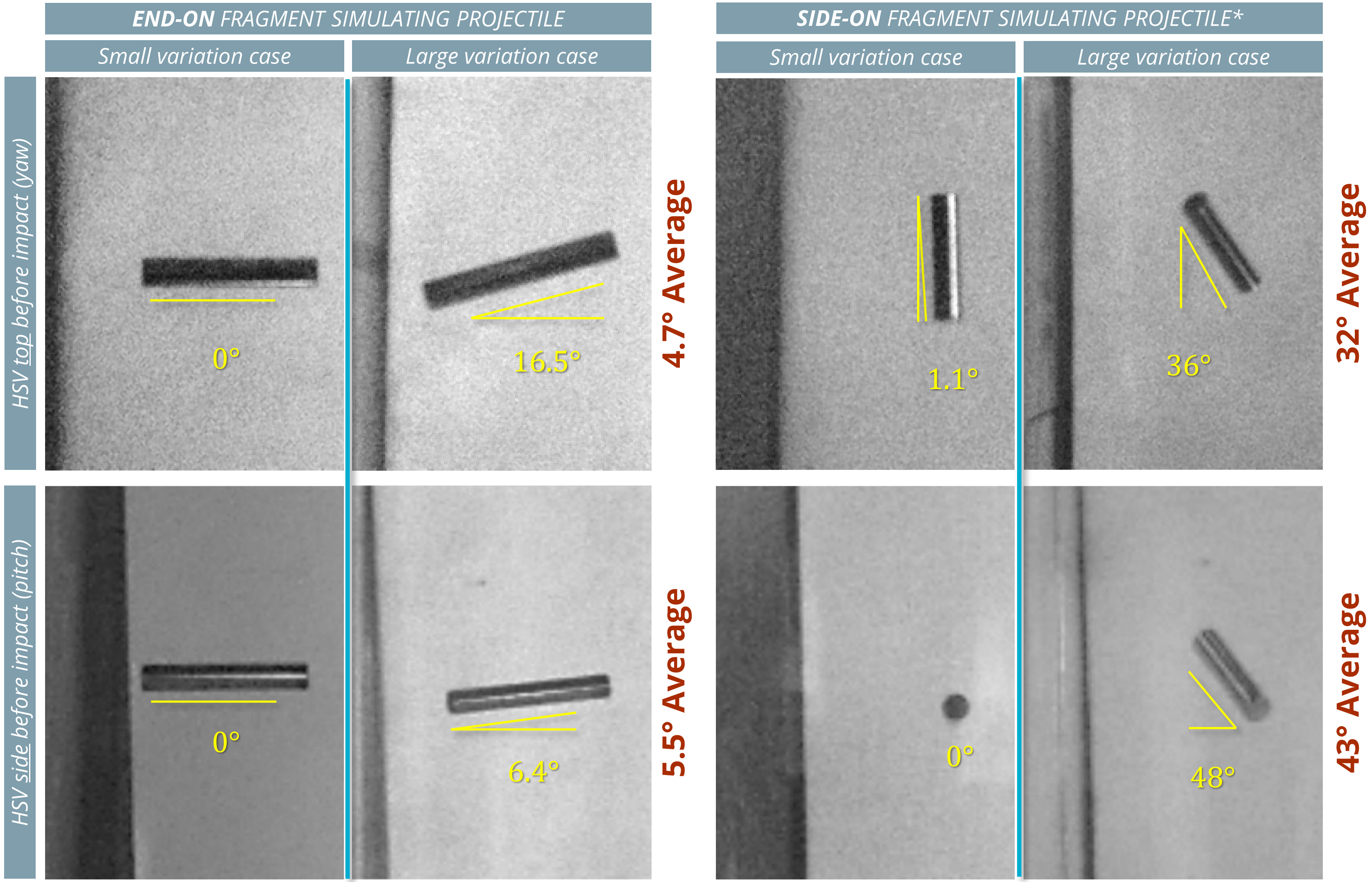


Cone stripper



Results| Impact variability

Impact orientation angles are difficult to control and vary in each experiment. However the variations are well characterized with orthogonal camera views to collect the proper parameters.



*Apparent pitch and yaw

Results| Experimental series

The experimental matrix below was executed to validate the ballistics platform capable of emulating fragment impact. Fragment simulating projectiles (FSPs) of different densities were launched in a controlled manner into witness plates of different materials to study their response.

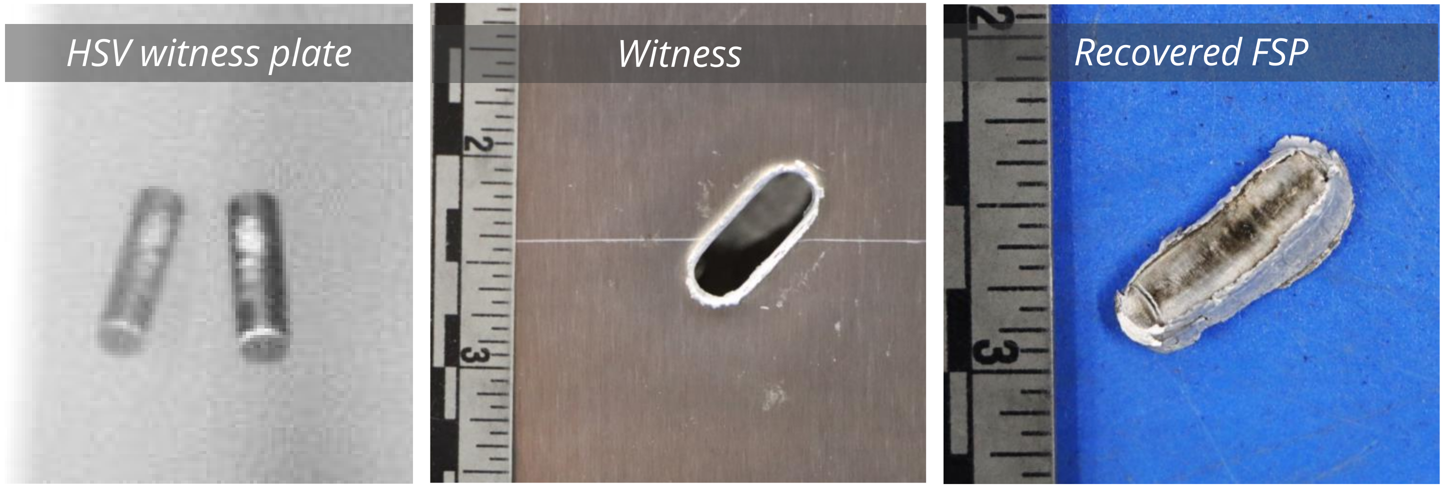
		Witness material		
		Steel	Aluminum	Glass
FSP material	Aluminum	X	X	
	Tantalum	X		
	Tungsten	X	X	X

Results| Aluminum FSP

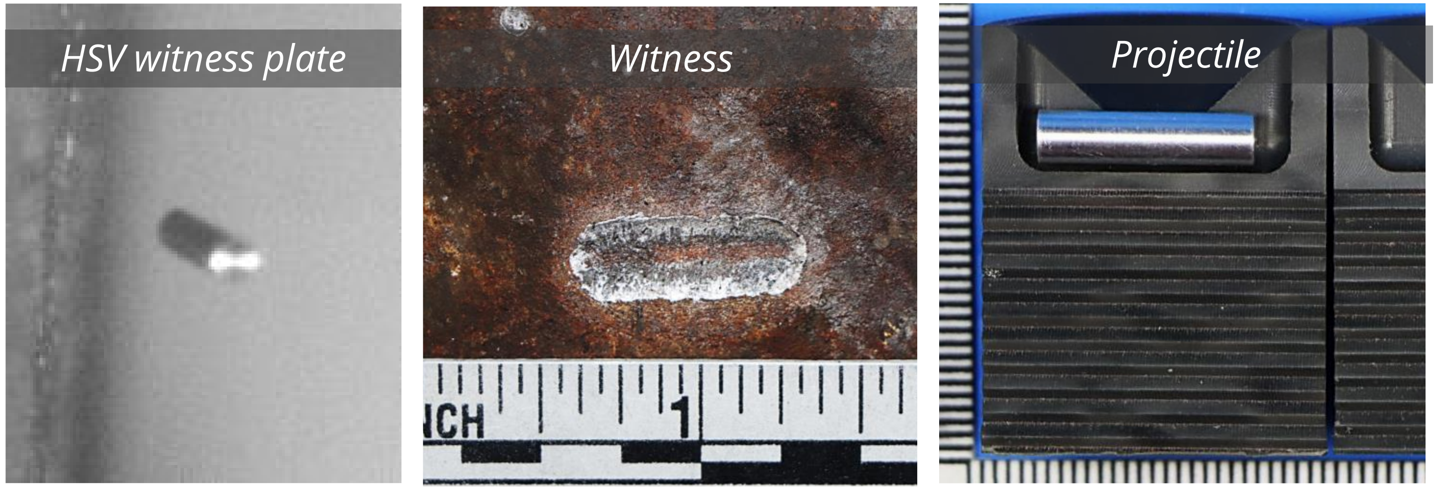
Aluminum FSPs on steel and aluminum witness plates

- Side-on FSP
- Thin plate witness
- Ballistic limit reached in Al
- Steel didn't penetrate

Aluminum on aluminum (1/8" plate) at 1.23 km/s side-on FSP



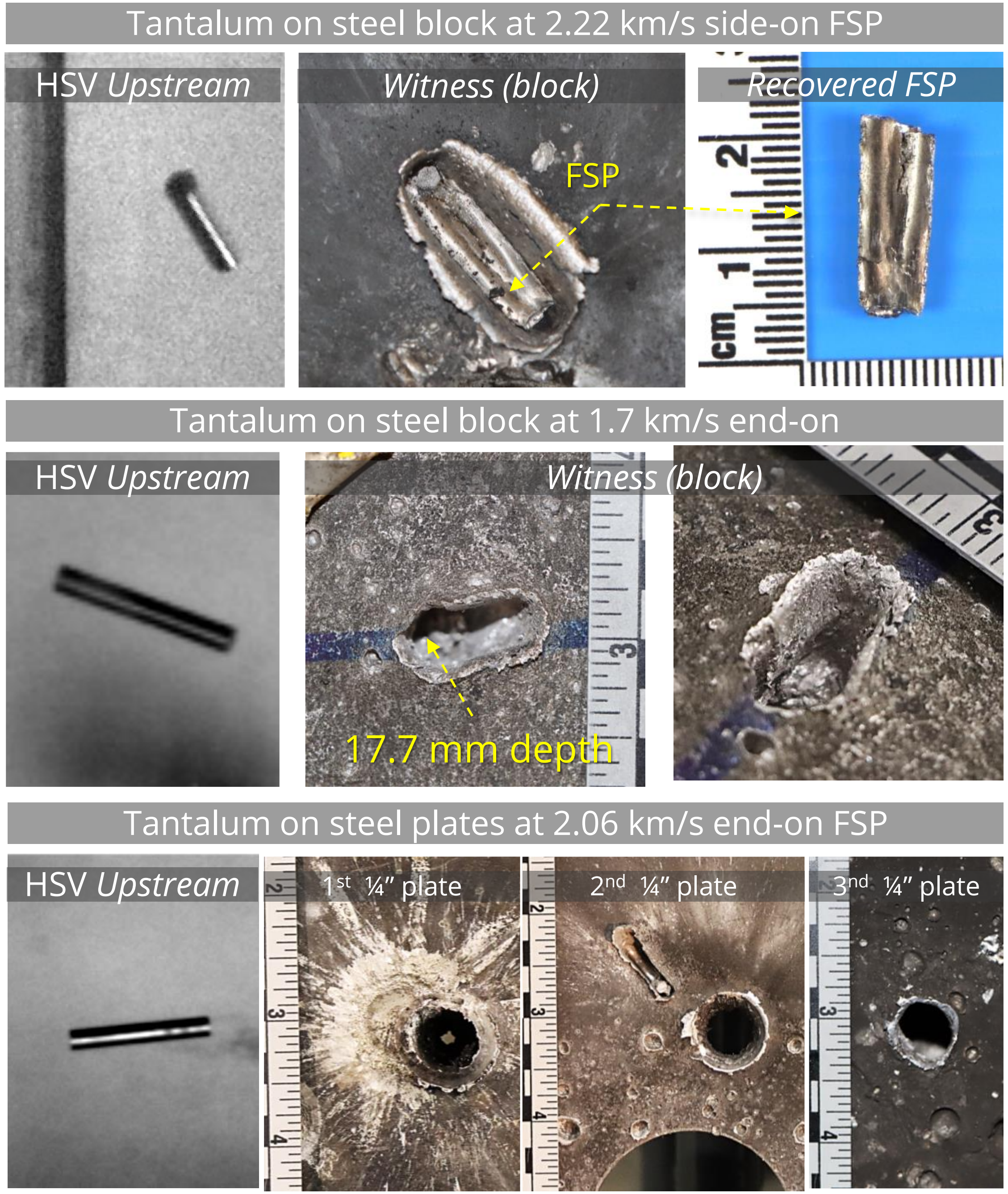
Aluminum on Steel (1/4" plate) at 1.24 km/s side-on FSP



Results| Tantalum FSP

Tantalum FSPs on steel witness plates and blocks

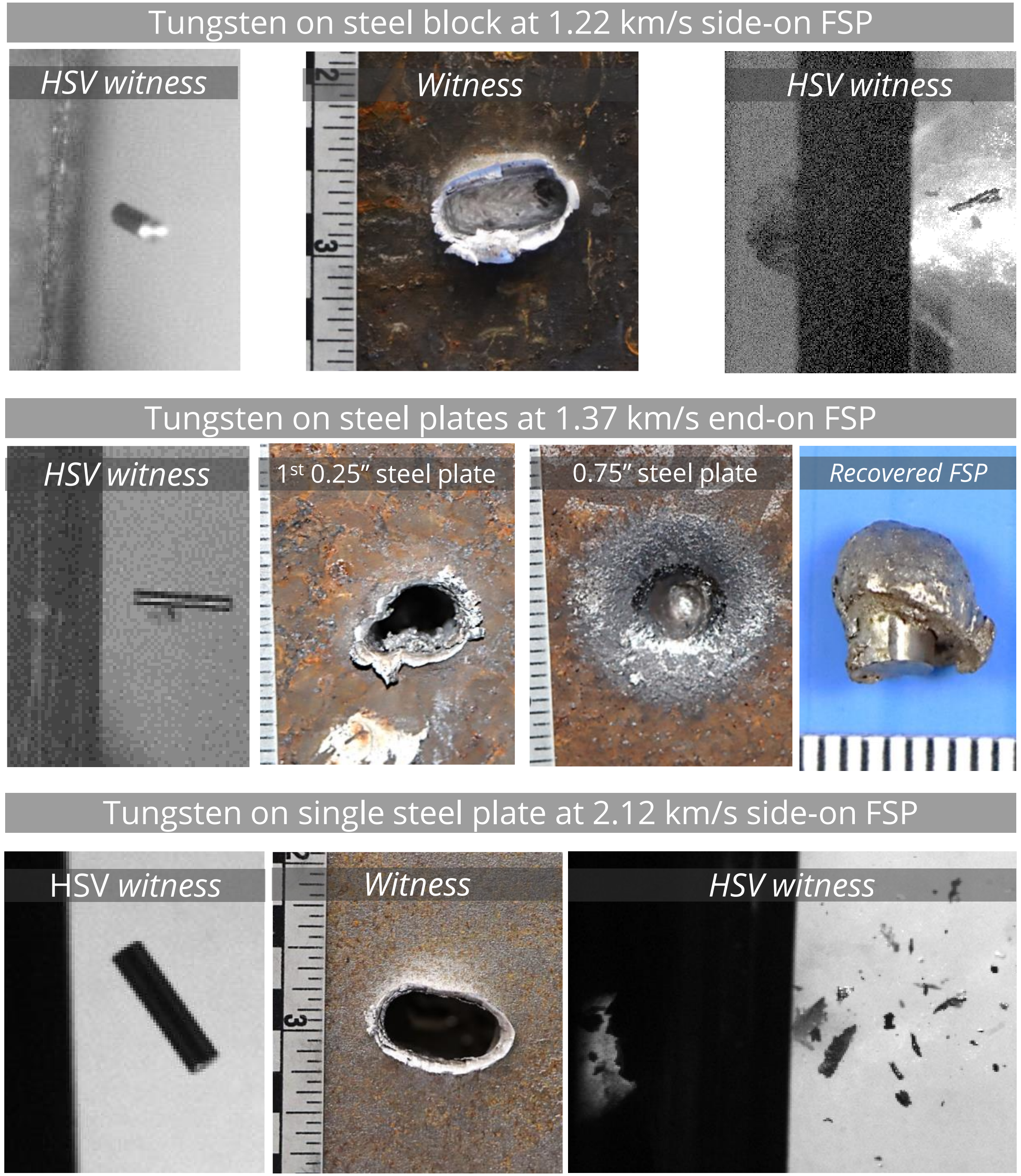
- Side-on and end-on FSPs
- Plate and block witness configuration
- Ballistic limit reached in steel plates



Results| Tungsten FSP

Tungsten FSPs on steel witness plates and blocks

- Side-on and end-on FSPs
- Plate and block witness configuration
- Ballistic limit reached in steel

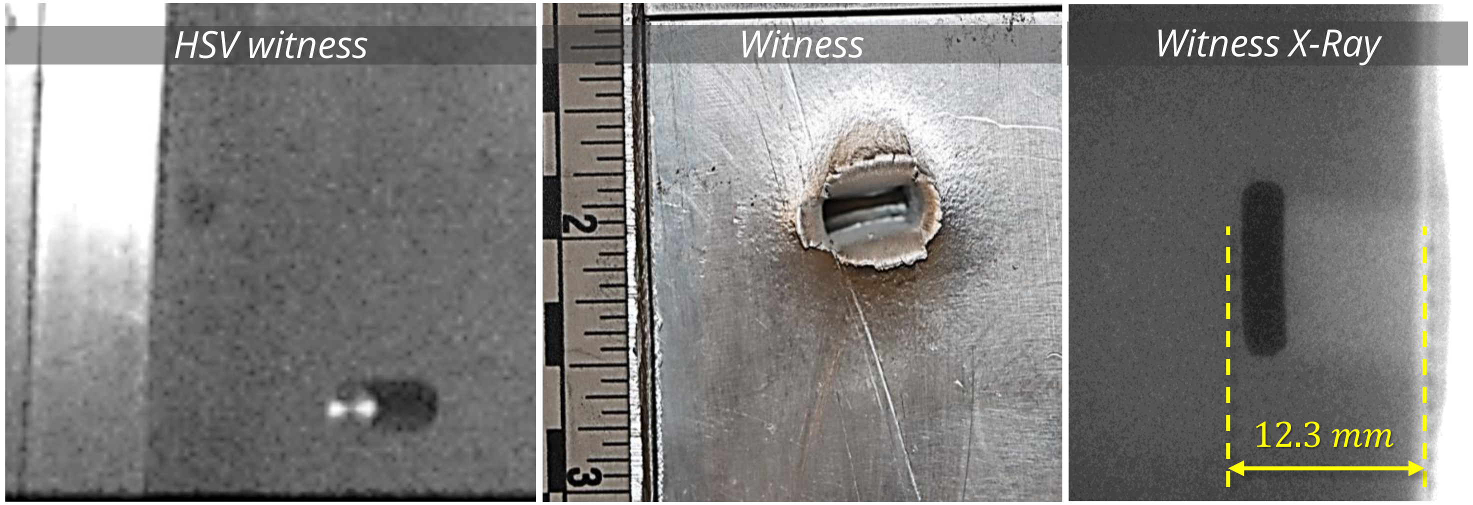


Results| Tungsten FSP

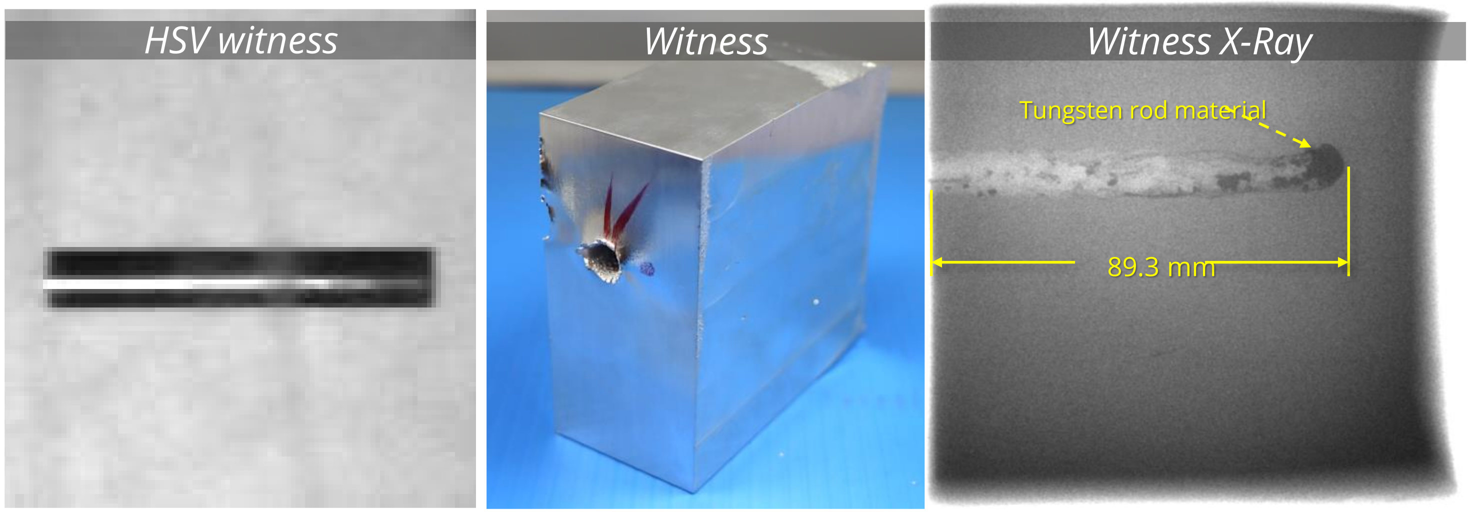
Tungsten FSPs on aluminum witness blocks

- Side-on and end-on FSPs
- Penetration depth quantified
- Damaged characterized

Tungsten on aluminum block at 1.12 km/s side-on FSP



Tungsten on aluminum block at 1.91 km/s end-on FSP

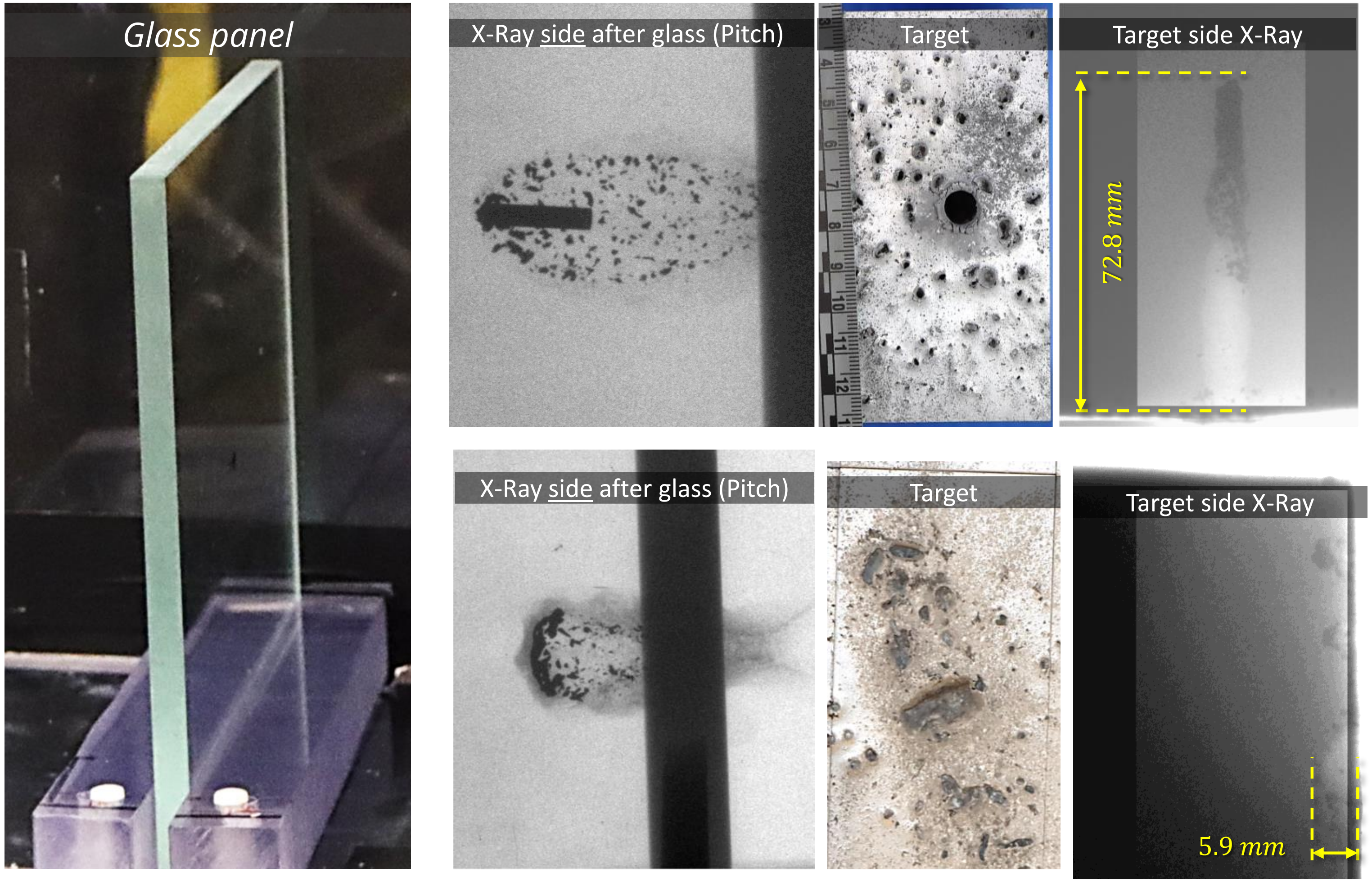


Results| Tungsten FSP on glass

Tungsten FSPs on soda-lime glass and aluminum witness blocks

- Side-on and end-on FSPs
- Secondary fragmentation characterized
- Significant side-on FSP fragmentation observed

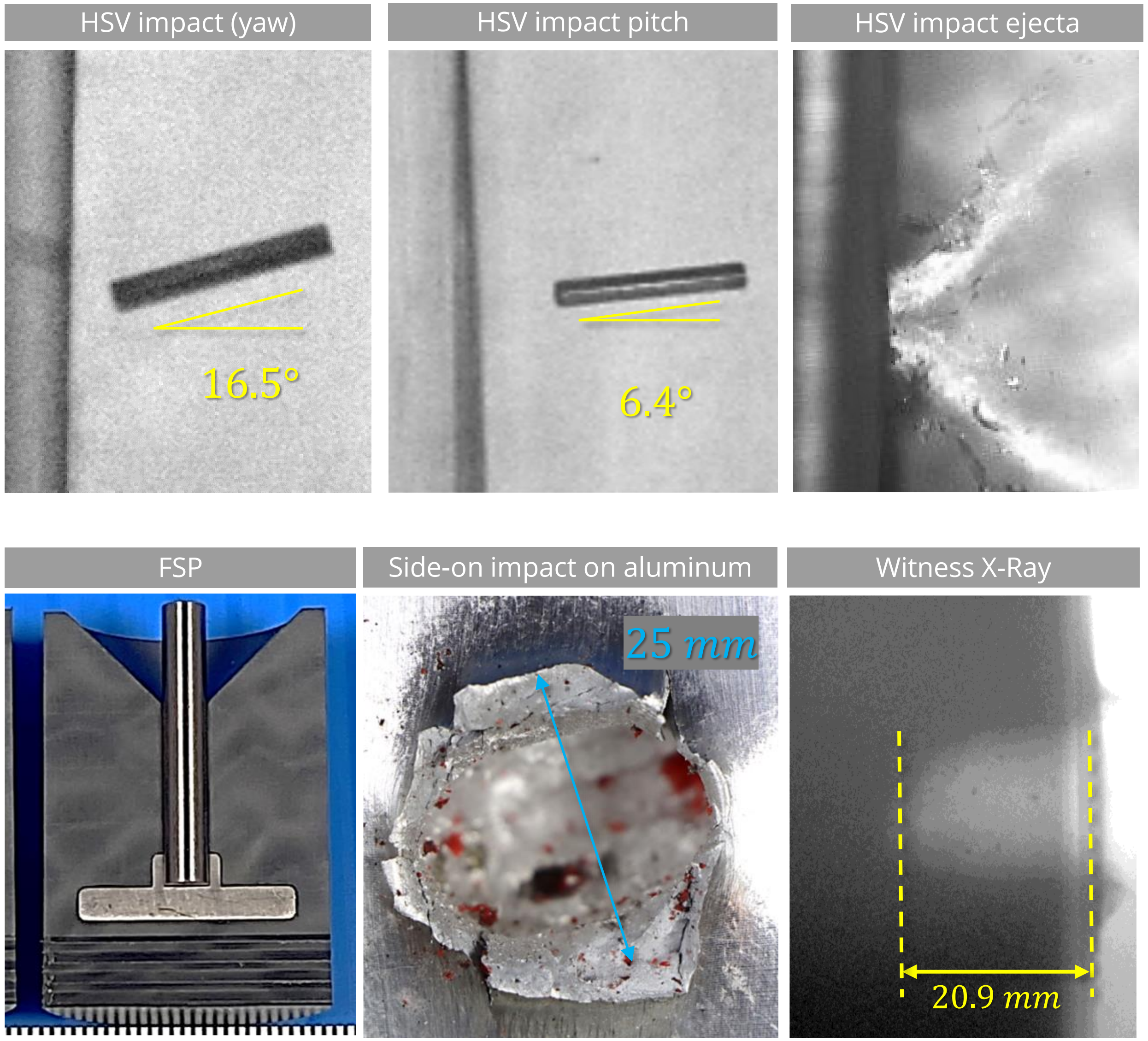
Tungsten on glass at 1.9 km/s side-n and end-on FSP



Discussion

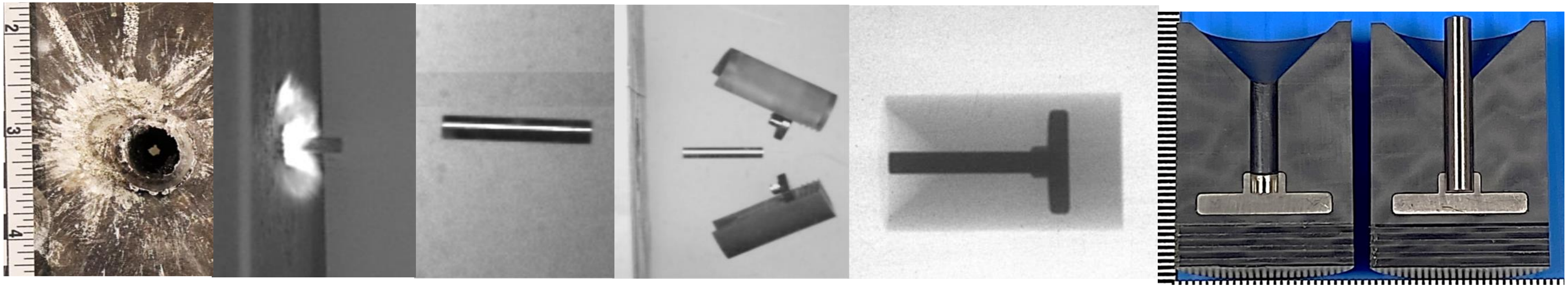
The developed ballistics platform for emulating fragment flight and impact is capable of:

- Testing high density FSPs
- Evaluating mitigant materials
- Quantifying FSP’s pitch and yaw at impact
- Characterizing ejecta/debris cloud
- Characterizing damage extend



Conclusions

- We successfully developed a ballistics platform to emulate fragment flight and impact to characterize damage by fragment impact
- We studied aluminum, tantalum and tungsten as three different fragment simulating projectile materials
- We studied aluminum, steel and glass as fragment mitigation materials
- Data obtained is being compared to computational models



Thank you

This work would not have been possible without the hard work of Sandia National Laboratories' STAR facility team: John Martinez, Robert Palomino, Rafael Sanchez, Brent Demone