Shock Release Experiments (SRE) platform development for JASPER

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SRE aims to investigate the off-Hugoniot release path of metals needed for predictive capabilities

Simple and direct measurement that provides a release isentrope in a single experiment

- Based on well known measurement in Cu by (M. Lowe 2014).
- Partial release of shockwave into materials of lower shock impedance
- Measure single release per witness material
- Equate partial release state in the target material to the shock state in the witness
- Requires accurate materials data for release witness materials

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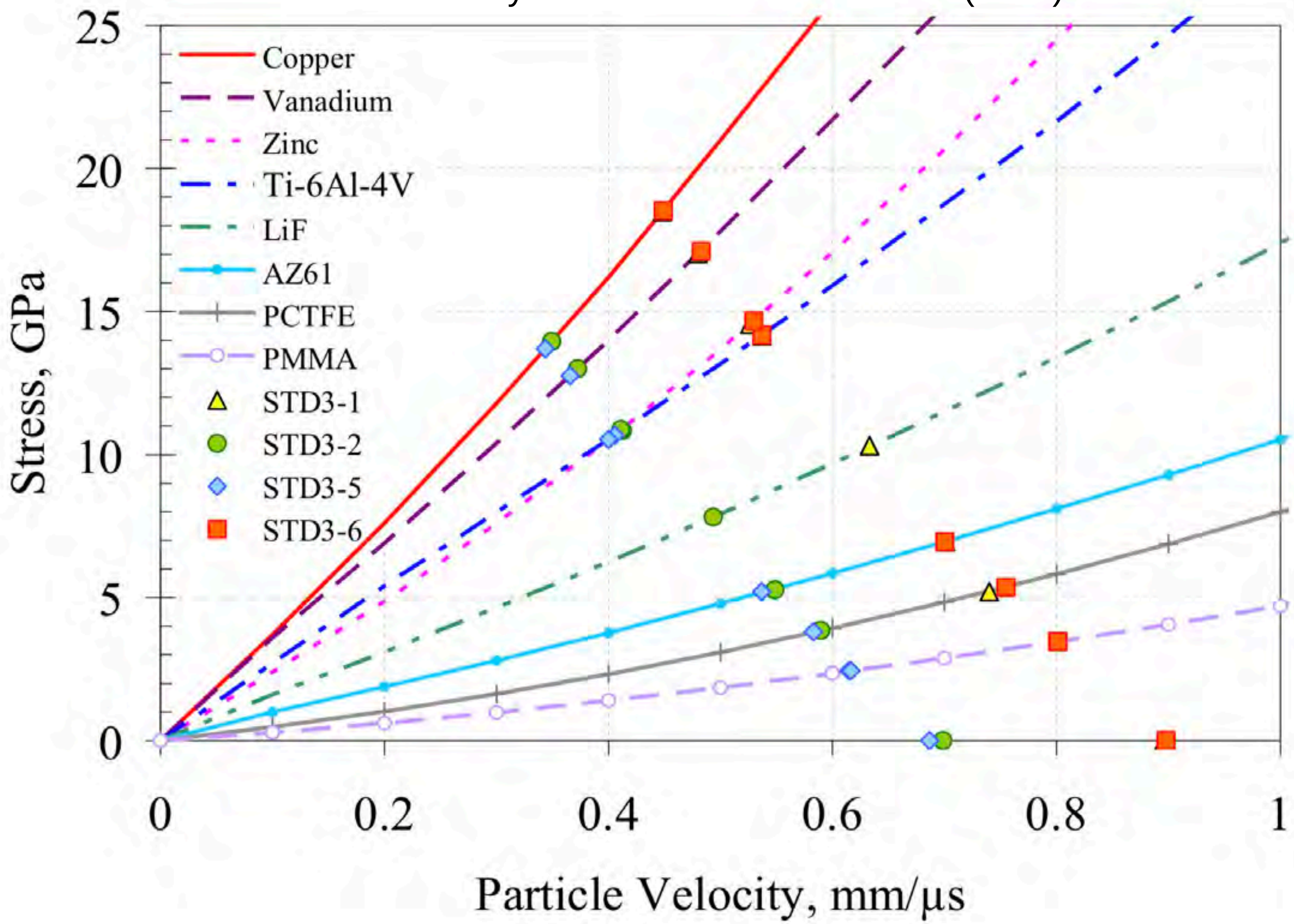
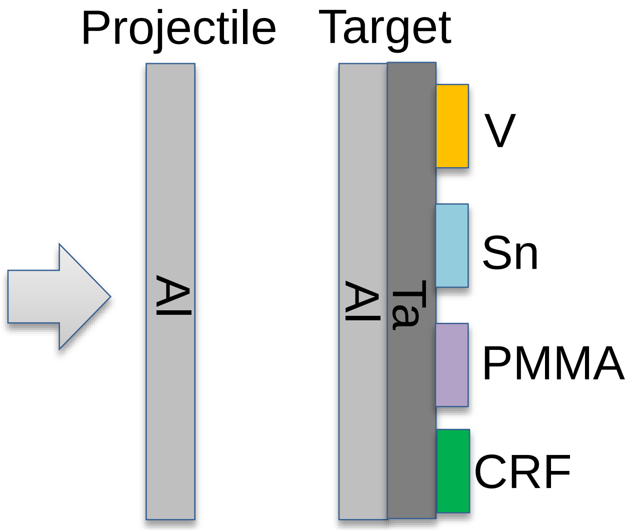
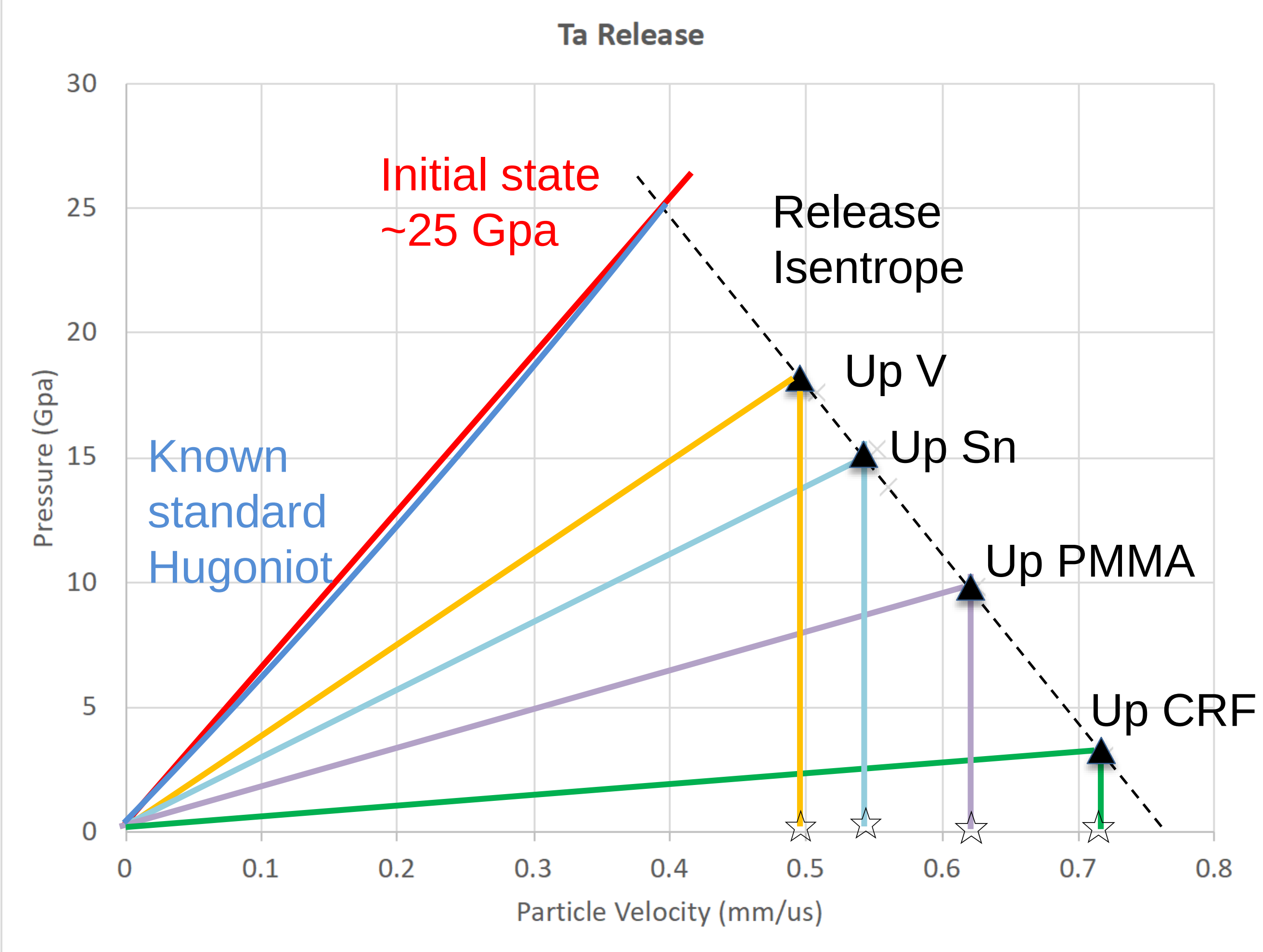


The release path is determined by measuring the particle velocity of each witness material

SRE probes the release pressures along the isentrope of the shocked Ta sample



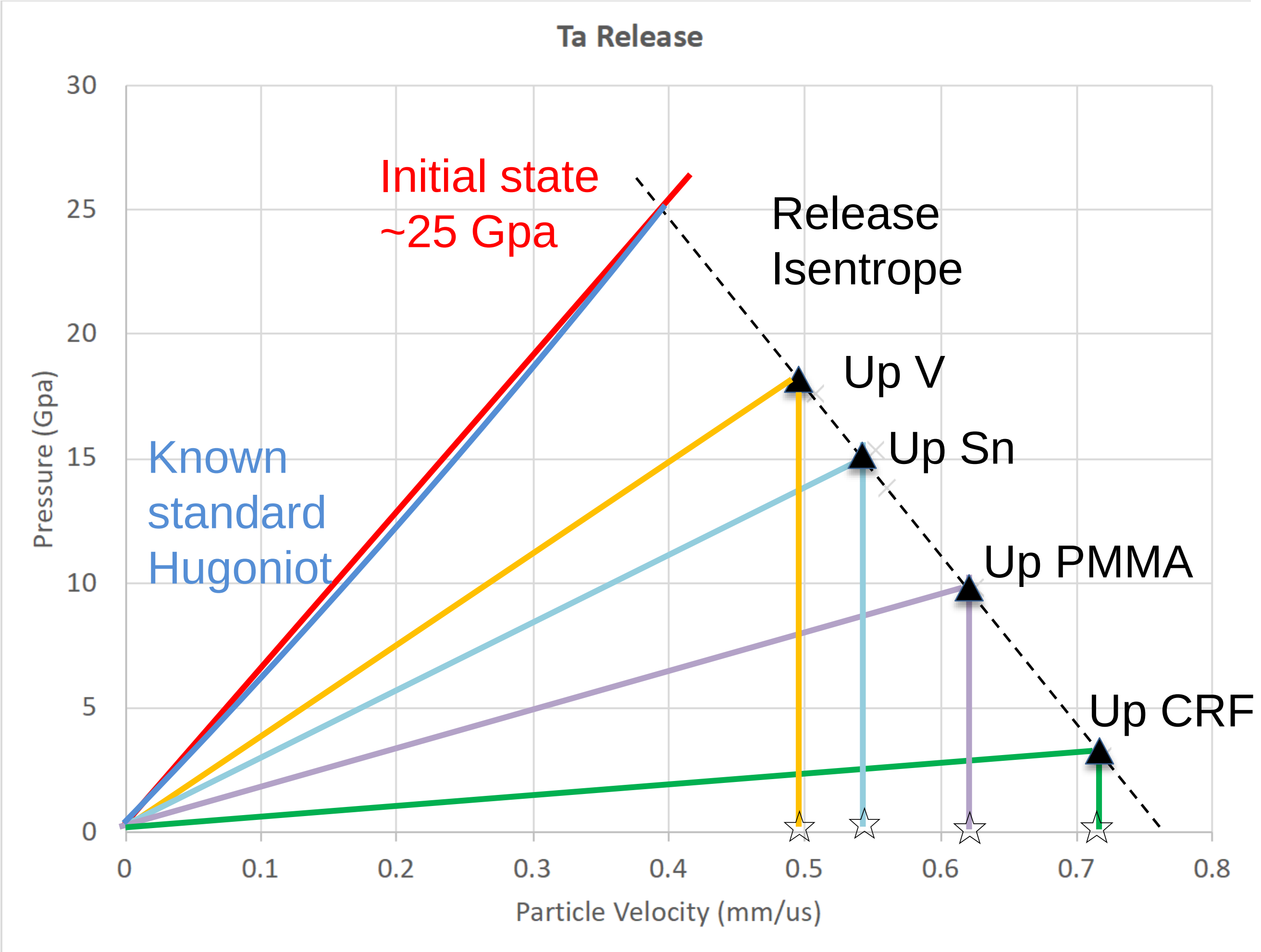
- Sample has higher impedance than witness
- P, Up stays constant at interface until equilibrium reached
- Sample undergoes isentropic release and a shock is launched into the witness
- We capture Up at the witness surface (LiF interface) and transit time throughout each witness



The release path is determined by measuring the particle velocity of each witness material

PDV is used to determine the shock breakout time and free surface velocity of the witness surface

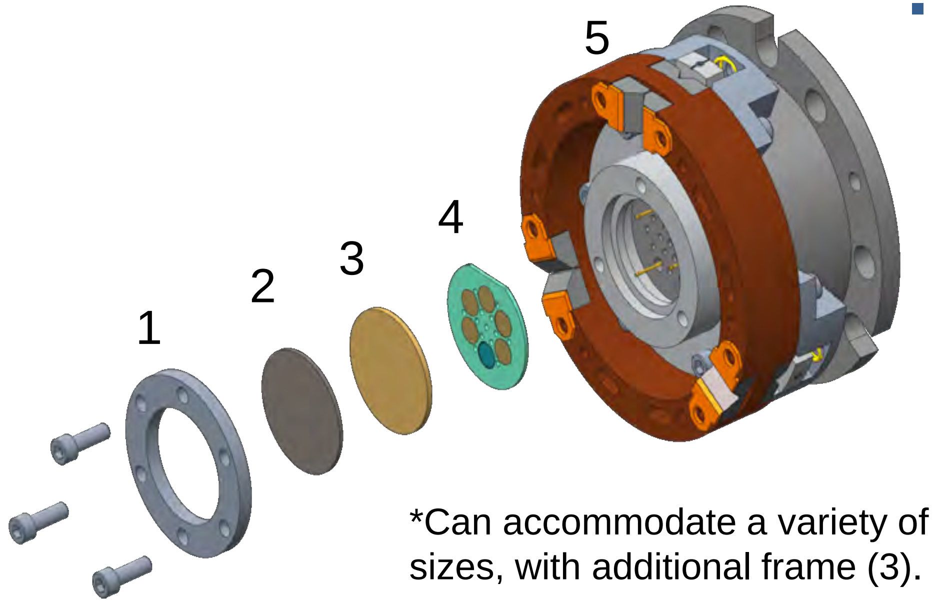
- Measure Up, calculate Us and P via Us=C+Sup. C, S values and witness density must be well known.
- PDV also provides Us measurement
  - Breakout time and sample thickness are measured
- Evaluation of both methods showed that for Ta, Up produces a reliable release curve



The SRE target design enables up to six release states to be captured in a single experiment

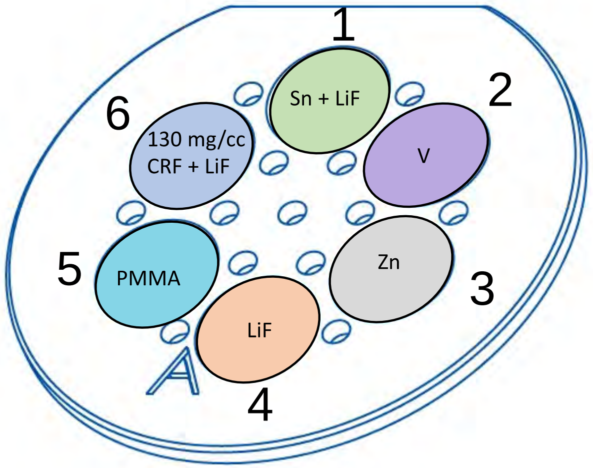
Target Design

1. Clamp
2. Al baseplate
3. Ta Sample
4. Frame and witness materials
5. Target body, 16 PDV probes and diagnostic trigger cap pins.



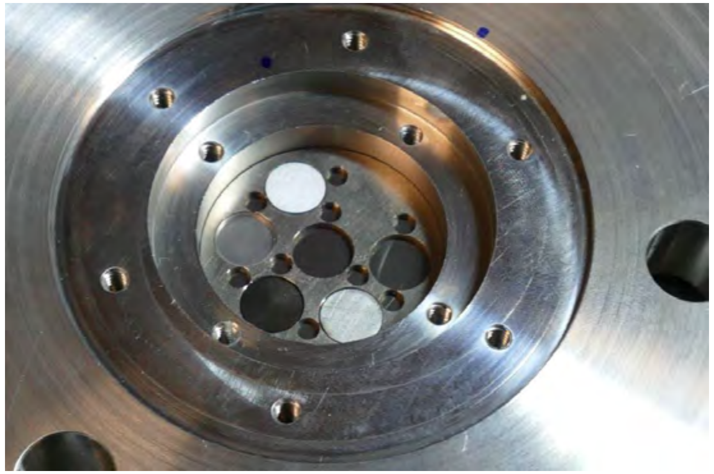
*Can accommodate a variety of sample sizes, with additional frame (3).

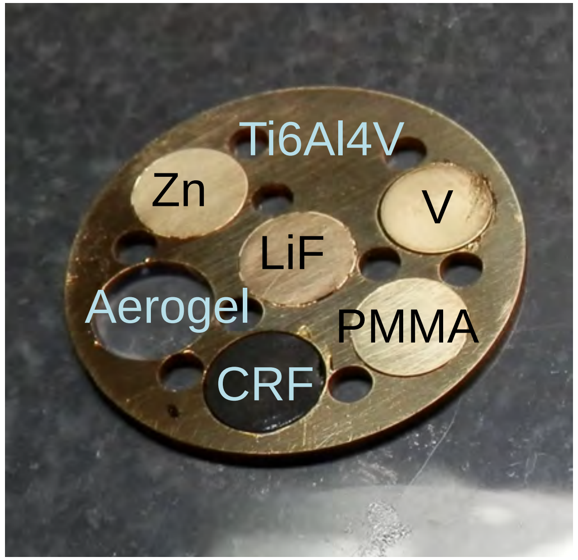
- Accommodates a variety of sample materials and sample sizes.
- Witness materials are held in a stainless-steel or Cu frame for ease of assembly.
- Witness material EOS must be well characterized.
- 16 PDV probes are used to capture PDV traces at the sample and witness surfaces. This is used to determine Up for both Ta and witnesses, along with shock breakout times.
- PDV traces taken at the Ta surface provide both the zero pressure Up and the initial shock pressure state.
- LiF windows are used with materials (Sn and CRF) that have low strength in order to suppress potential RT growth and ensure good signal



The SRE platform went through several iterations throughout the development phase

Target Design v1





- Development shots were performed to qualify the platform and obtain the Ta release curve

- Several changes were made to improve the data quality
  - Aerogel was too brittle to use in our design and was swapped for a 130 mg/cc CRF material. (Phase 1)
  - Ti6Al4V witness was swapped for Sn due to a phase transition near our pressure of interest. Frame became Stainless Steel. Cu used to accommodate a smaller sample.
  - Hydro simulations performed to verify designs.
  - Frame design, material and probe locations modified to improve Up data quality.

All target components are metrologized and diagnostics calibrated for quality control

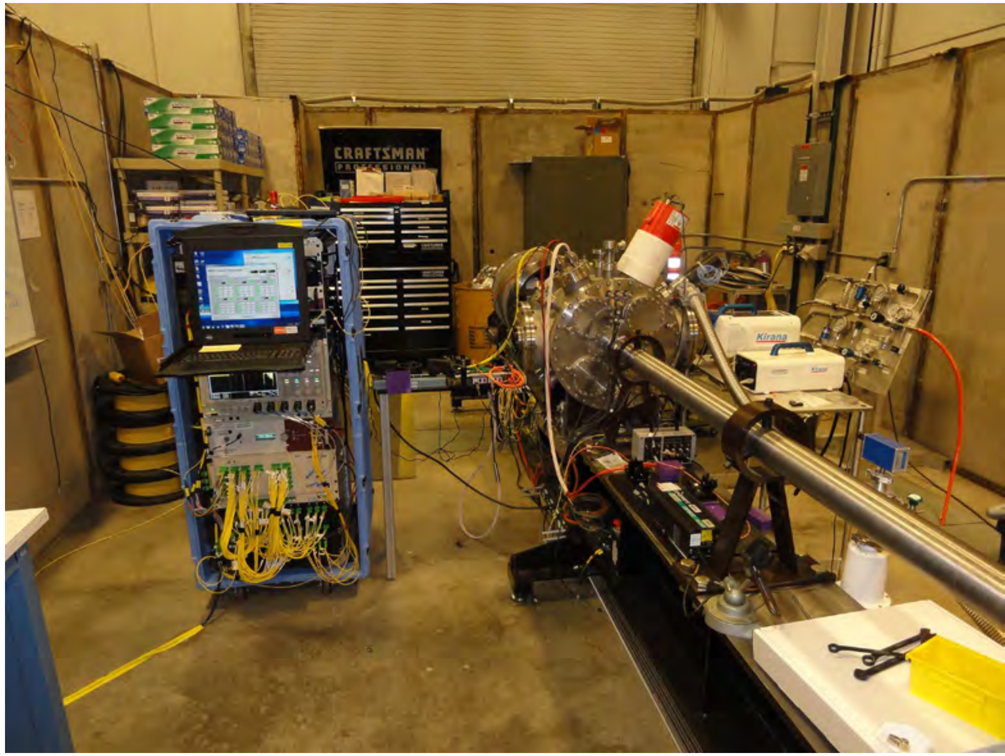
Target characterization

- The baseplate, sample, witnesses and frames were characterized using the Keyence VR profilometer and were flat and parallel to ~5-10 μm.
- LiF windows are specified to have a roughness of 0.2 μm with an Al coating on the roughened surface.
- Density (dry/wet and pycnometer) and thickness measurements taken for the projectile, baseplate, sample, windows and frame.

Diagnostic characterization

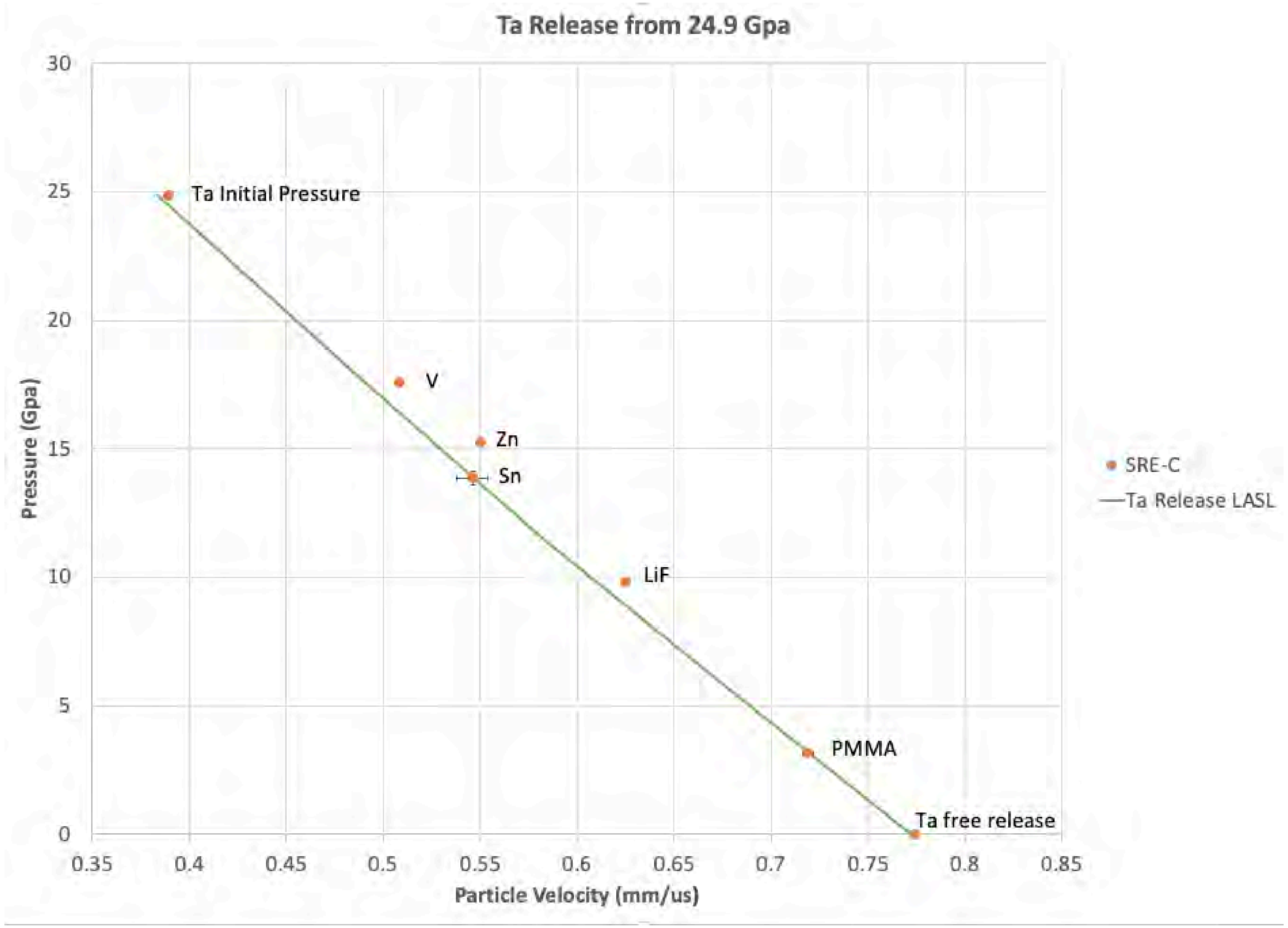
- PDV systems used to collect Ta data at all facilities had dedicated diagnostic characterization shots. The PDV system digitizers, scopes and wavelength are calibrated routinely.
- All PDV fiber lengths are measured during target build and with a LUNA system when installed at the facility (<100ps accuracy)
- Gap measurements were performed showing a ~4-5 μm gap between the sample and witness frame.

C3 experimental facility with 24-channel PDV



Diagnostic qual shots and initial Ta platform test shots were done at C3.

SRE Final Ta Target Design Results



- Clear Ta release path from 24.9 Gpa is seen.
- Ta reflected Hugoniot in green, derived from LASL.
- The Ta initial and zero pressures are close to the reflected Hugoniot curve.
- Zn and LiF deviate from the release path. Need to verify EOS.

Summary and Future Work

- We have successfully developed and demonstrated the viability of the SRE platform.
- The development required diagnostic qualification shots, careful metrology, simulations and several iterations of target designs.

Future Work

- Strength based release model in progress. We are curious to see if strength plays an effect in the release curve of Ta.
- EOS verification shots are needed for Sn, Zn and PMMA to improve confidence bounds in the SRE data.
- CRF EOS shots are in progress to completely cover two foam densities and generate a reliable Hugoniot.

Questions?

Error budget using the particle velocity analysis method

Error in Pressure:

$$\sigma P^2 = U_p^2 (C + SU_p)^2 \sigma \rho_0^2 + U_p^2 \sigma c^2 \rho_0^2 + U_p^4 \sigma s^2 \rho_0^2$$

We have three sources of error. Error in the density measurement $\sigma\rho_0$ (0.1%), from measurements and $\sigma C\ (6\%\ for\ Sn, 1.7\%\ LiF), \sigma S$ are from the Us-Up model of each witness. Typical error for Sn is 6% for C and 11% for S. Typical error for LiF is 1.7% in C and 2.7% in S.

Error in *Up*: is about 2% (Dolan RSI 2010), this is largely error in the diagnostic and analysis method. With a LiF window correction the error is increased to