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Title: Silverleaf: An Experimental Series in Support of Nightshade

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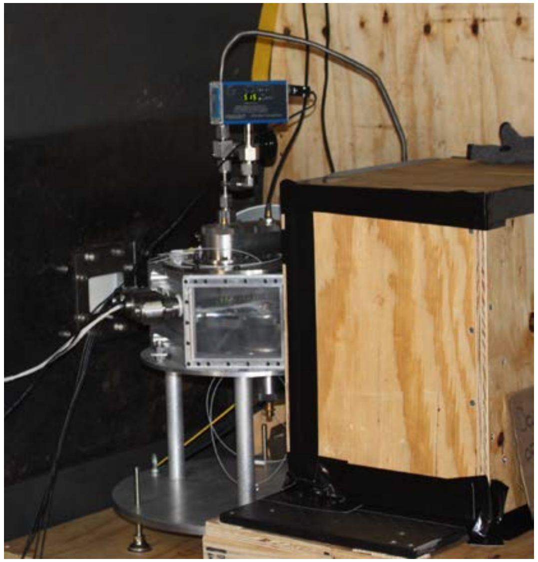
Silverleaf: An Experimental Series in Support of Nightshade



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and

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Sept 2016

LA-UR-26864

Silverleaf was an exercise of the prototype Nightshade package

In July and August a series of experiments were performed in Los Alamos to prepare for Nightshade at U1a.

The series was a cross-lab collaboration, including important contributions from Los Alamos, Livermore, and NSTec.

In this series, a prototype package was designed and fielded to address a major technical risk of Nightshade: A comprehensive suite of drives and diagnostics must fit within a small space. In addition, this series satisfies a milestone for the project.

The package performed well: There was little cross-drive interference, and each of the diagnostics returned data.

In this series, we learned a great deal about package and drive performance. We can now implement a number of improvements to Nightshade, which will enhance the build efficiency and data quality.

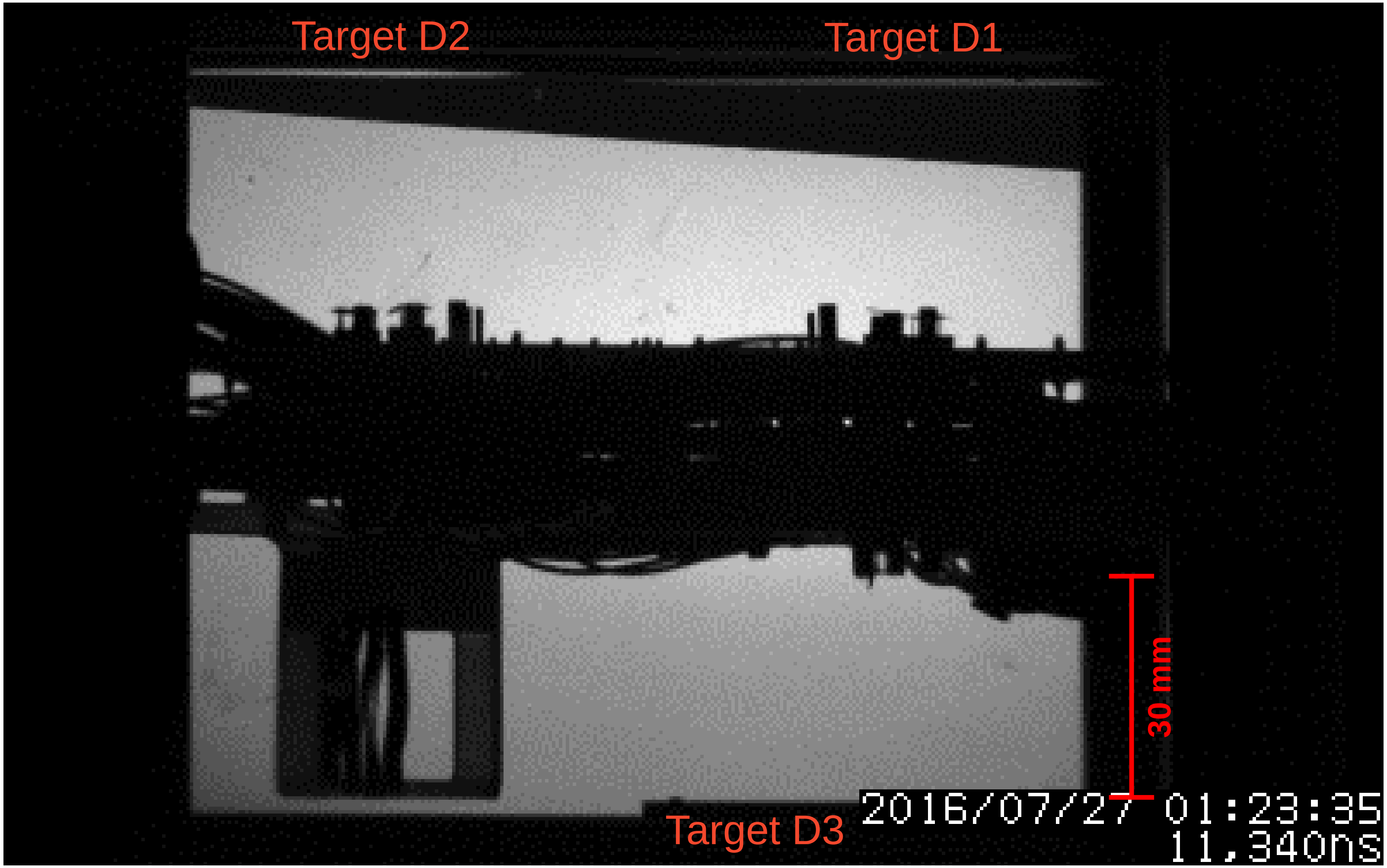
Silverleaf was a multi-lab collaboration

LANL:
A-3: Bob Gentzlinger
C-PCS: David Oschwald
J-8: Ray Guffee, Daniel Naranjo, Steve Rivera
M-6: Chris Campbell, Angelo Cartelli
MST-7: Derek Schmidt
P-23: Matt Briggs, Billy Buttler, Jeremy Danielson, Dana Duke, Pat Harding, Tymothy Mangan, Ruben Manzanares, Patrick Medina, Pete Pazuchanics, Jeremy Payton, Danny Sorenson, Benjie Stone, Lenny Tabaka, Patrick Younk
PF: Daniel Aragon, Ernie Aragon, Martin Herrera, Vince Hesch, Tony Martinez, Louis Montoya, Jose Olivas
Q-6: Roger Hall, Gary Liechty
Q-7: Rueben Roybal
W-5: Craig Cunico, Robert Gonzales, Rudy Originales, Morgan Tompkins, David Villareal
XTD: Amy Bauer, Mike Furlanetto, Carl Hagelberg

NStec, Santa Barbara: Brandon Lalone, Jerry Stevens
Nstec, LAO: Stuart Baker, Duane Smalley, Andrew Corridor, Al Lopez, Dave Phillips
Nstec, NLV: Ed Daykin, Mike Hanache, Mike Pena

LLNL: Corey Bennett, Steve Compton, Louis Ferranti, Adam Lodes, Jose Sinibaldi, Paul Steele

Silverleaf incorporates multiple drives in one experiment



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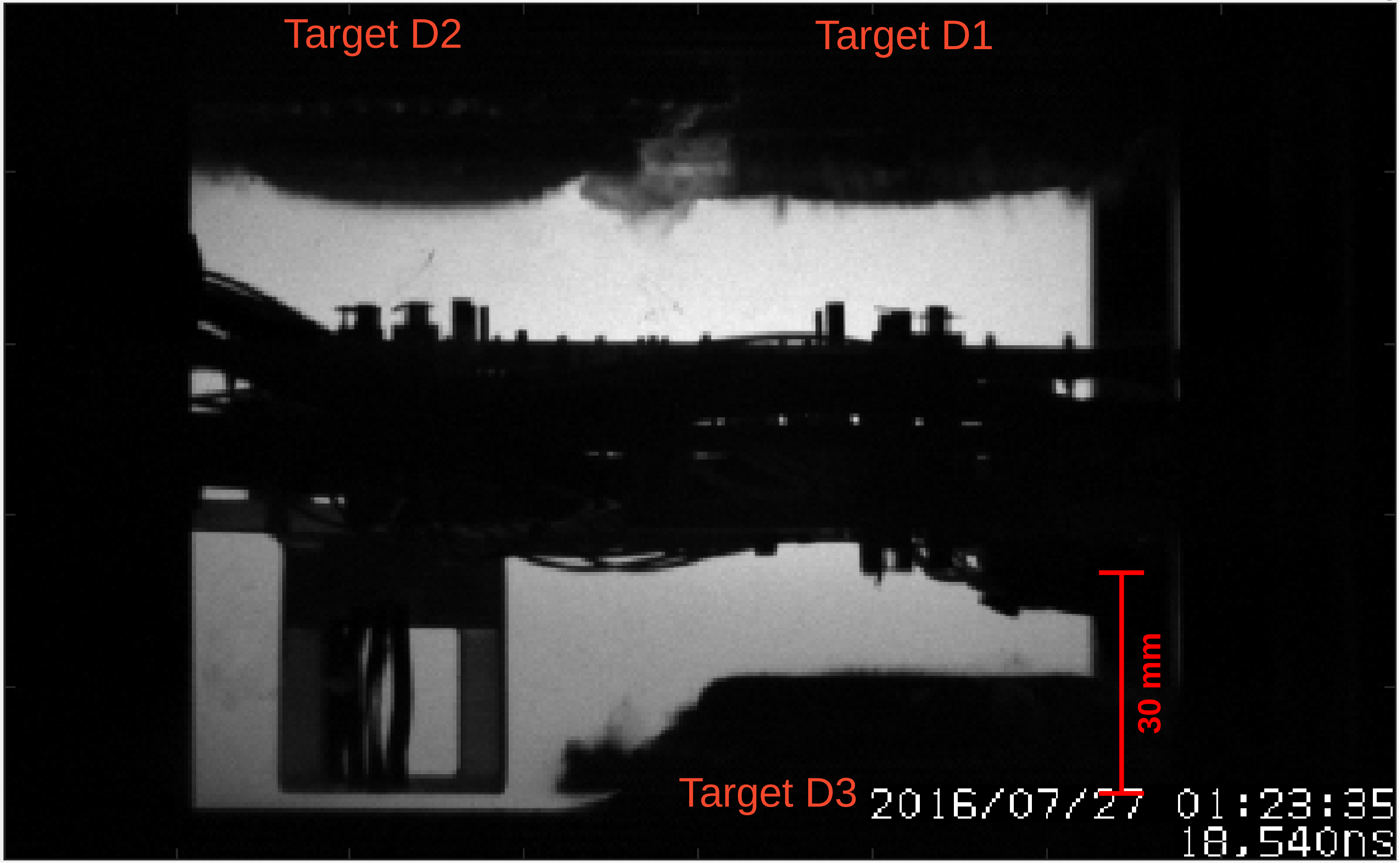
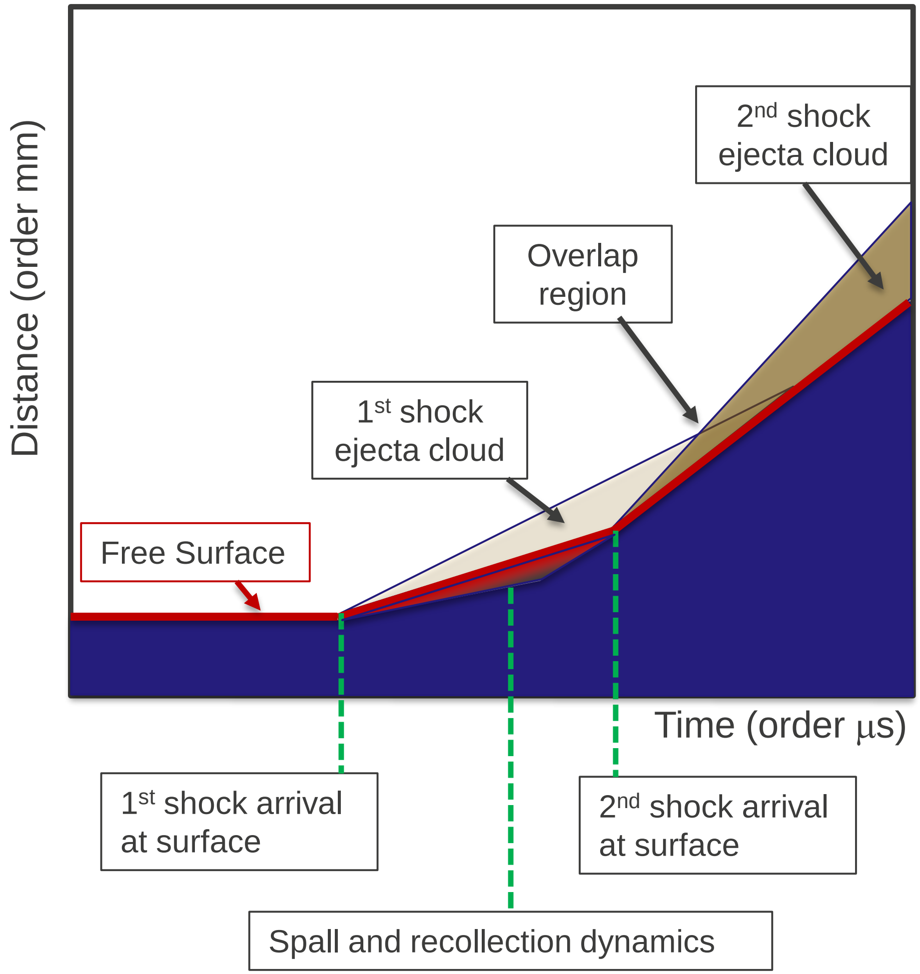


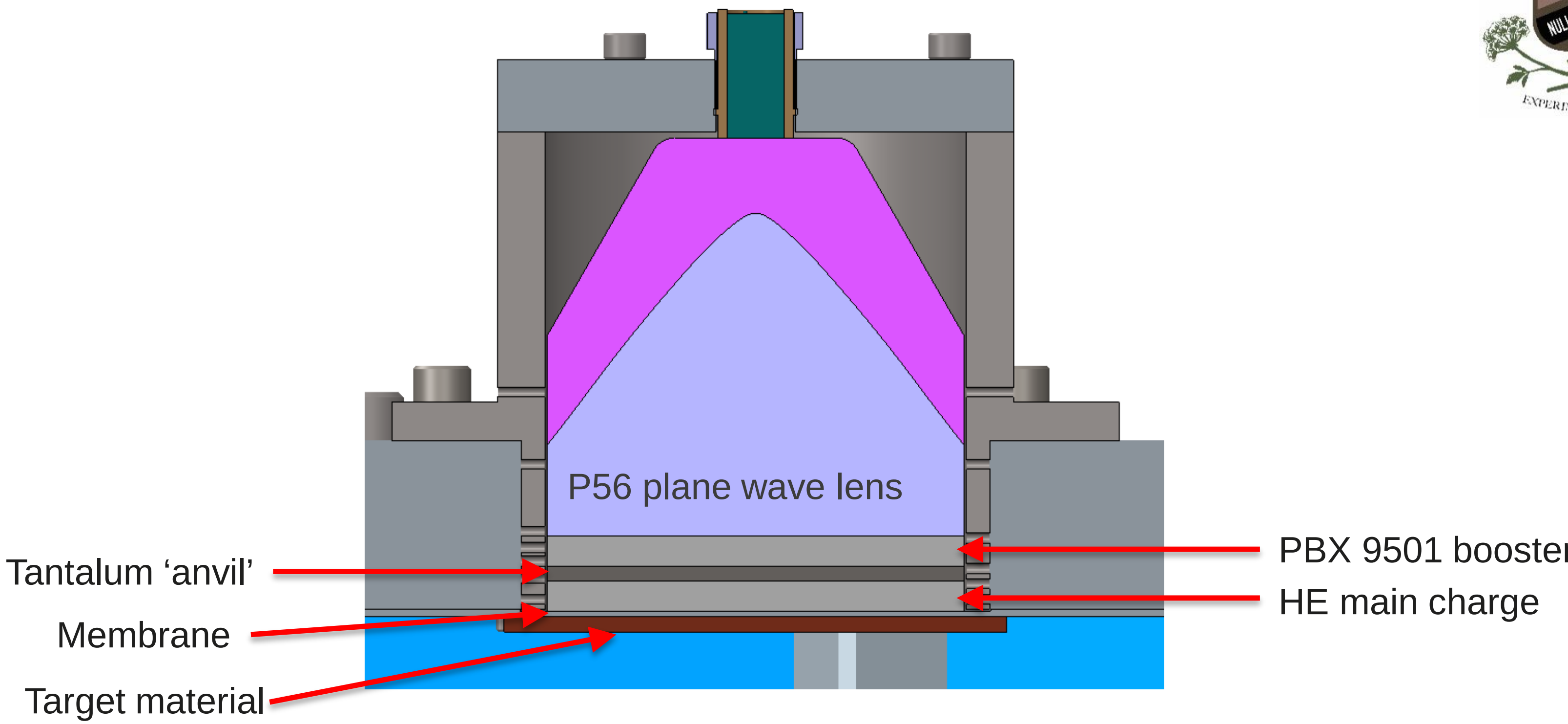
2nd shock ejecta emission is a complicated process



The Nightshade series is designed to measure ejecta emission from a doubly-shocked surface.

This is a complicated measurement, and quite sensitive to the drive conditions and surface preparation.

The Nightshade drive reflects a second shock on the sample



The design is a modification of double shock packages developed by Billy Buttler.

A tantalum layer within the drive provides a reflected shock at the surface.

The sample has a specified triangular groove machined into the surface. In the following work, the sample was tin, with a groove spacing of 100 - 150 μm and height of 5-10 μm.

In Nightshade, we will make precision measurements in a complicated environment

Second-shock ejecta creation is very sensitive to surface roughness and the explosive drive.

The physics of spall and recollection causes inhomogeneity in the second-shock ejecta emission even with careful control of the surface and drive.

First-shock ejecta can interfere with the free flight of the second-shock ejecta. We will still measure momentum, but the data will be more complex in interpretation.

To address these issues, we are applying as many *independent* diagnostics as possible. Each has different systematic difficulties and failure modes. **By fielding multiple diagnostics, we will provide a comprehensive measurement of the ejecta emission to calibrate models.**

Nightshade will have a comprehensive suite of diagnostics

Primary Diagnostics

Momentum diagnostics:

- Lithium niobate ($LiNbO_3$) pins
- Asay foils

Mass-density diagnostics:

- Soft X-ray radiography
- Cygnus radiography

Drive Diagnostics:

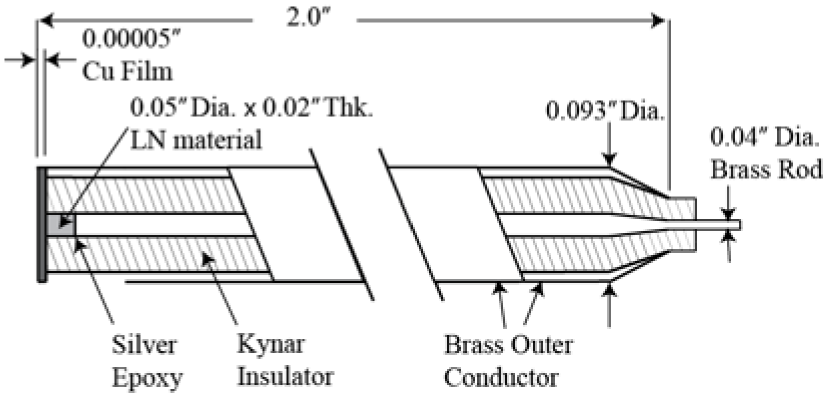
- Photonic doppler velocimetry (PDV)
- Broadband laser ranging (BLR)
- Time of arrival diagnostic (TOAD)

Surface state diagnostic

- Optical reflectance measurement (preshot)

Lithium niobate pins are an electrical pressure sensor

- Based on a piezoelectric crystal which provides voltage proportional to d^2P/dt^2.
- Pins can be sensitive to electrical interference, such as that generated by radiography sources.
- The ejecta field must be constant across the crystal region. The traditional probe head is ~ 2.4 mm across, with a smaller active region.
- LANL (esp. Billy Buttler) has extensive experience with and validation of the technique.



Asay foils measure momentum transfer

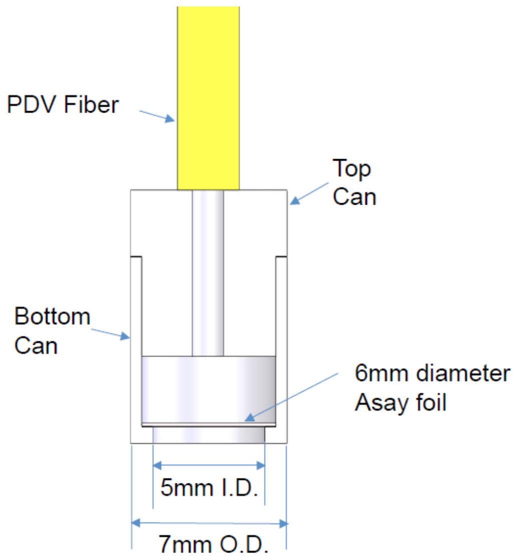
An Asay foil is a thin foil suspended above the ejecta field. As ejecta accumulates on the surface the foil starts to move. This motion measured with velocimetry.

While Asay foils measure momentum like a lithium niobate pin, they use a completely different physical principle.

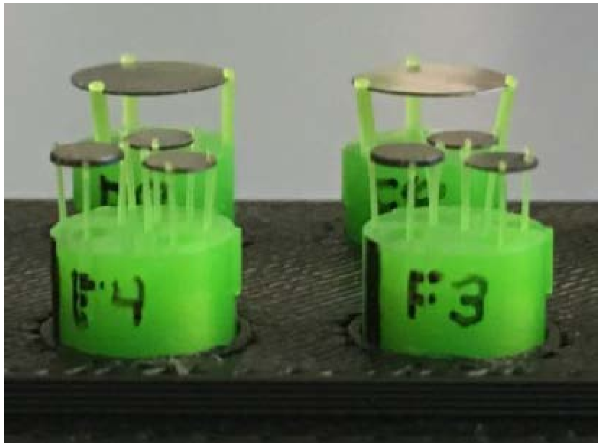
They are immune to electrical interference.

The support structure can interact with the ejecta and moving surface, contaminating the measurement.

Legacy Design



LLNL Developmental Design



Radiography measures the amount of mass along a line of sight

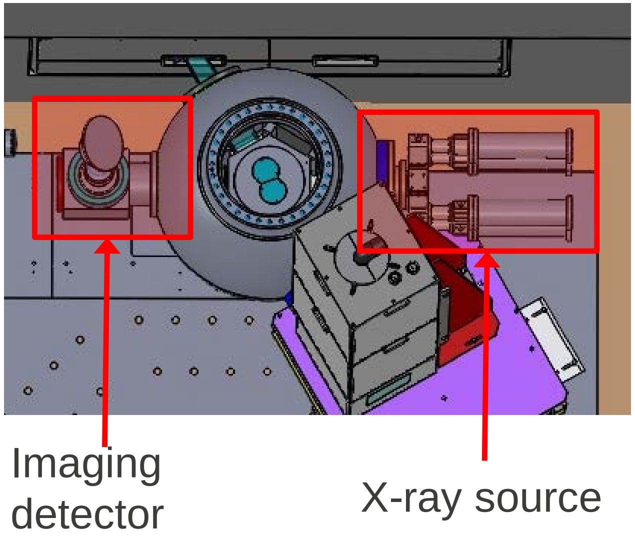
We will attach small X-ray heads to provide radiography. The absorption along each ray is proportional to the amount of mass it passes through.

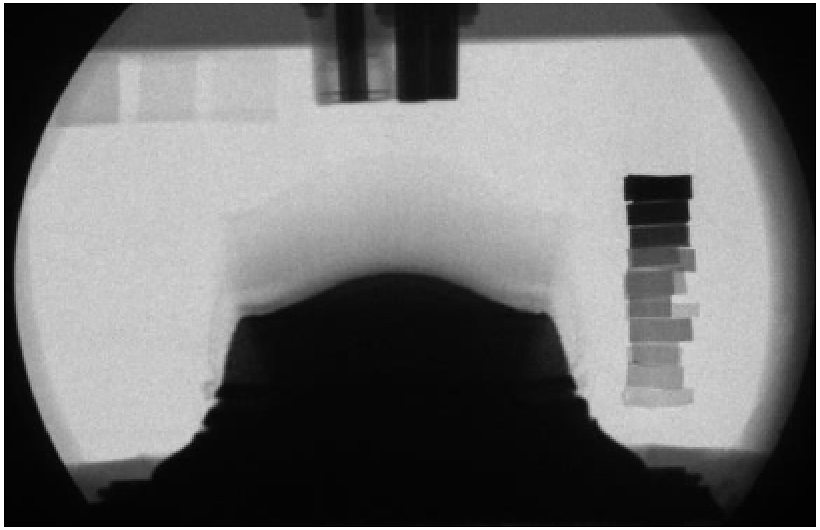
The energy of these sources is <200 keV, concentrated in a 50 ns pulse.

The measurement can be made very sensitive to small ejecta masses, as low as ~50 $\mu g/cm^2$

The heads are small enough that several can be placed together, giving multiple images. We plan to field four frames on Nightshade.

The multiple frames will allow us to disentangle ejecta interactions.





The Nightshade drives will be measured with PDV and laser ranging

To use the momentum diagnostics, we must field PDV. It also provides valuable data about the shock profile driving the ejecta emission.

To interpret the momentum diagnostics, we require:

- Time of 1st shock at the surface
- Time of 2nd shock at the surface
- Position of 2nd shock at the surface

PDV (velocity) can be integrated to give surface position, but requires a correction if the flow is not normal to the laser beam.

Similarly, integration across signal dropouts requires assumptions about the motion.

Broadband Laser Optical Ranging is a developmental diagnostic being implemented as a complement to PDV. It is a direct measurement of distance.

The Nightshade package is constrained by nuclear safety requirements and vessel geometry

The experiment will be fielded in a thee-foot vessel. To stay within explosive and space limits, we plan to field six drives + samples in each experiment. We need to independently time each package to ensure maximum radiographic return.

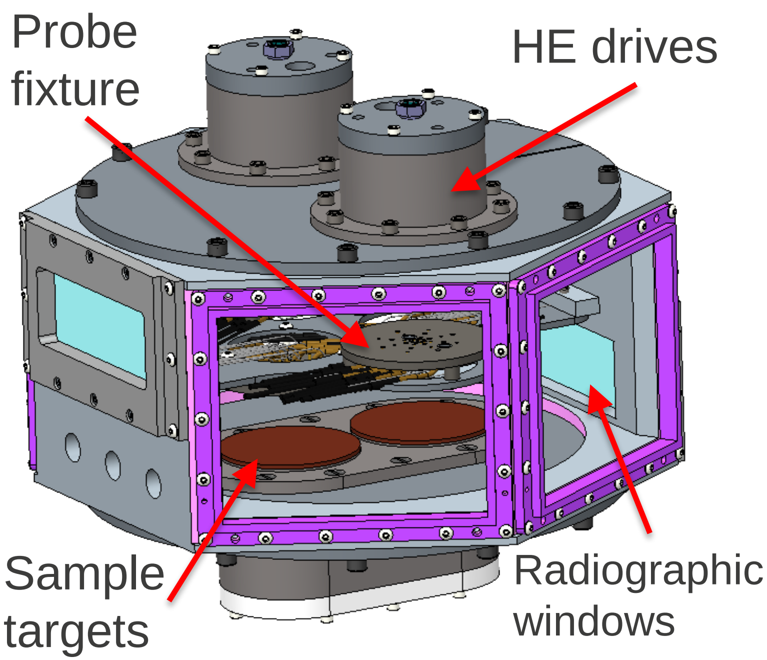
The confinement vessel has two radiographic ports set 60 degrees apart.

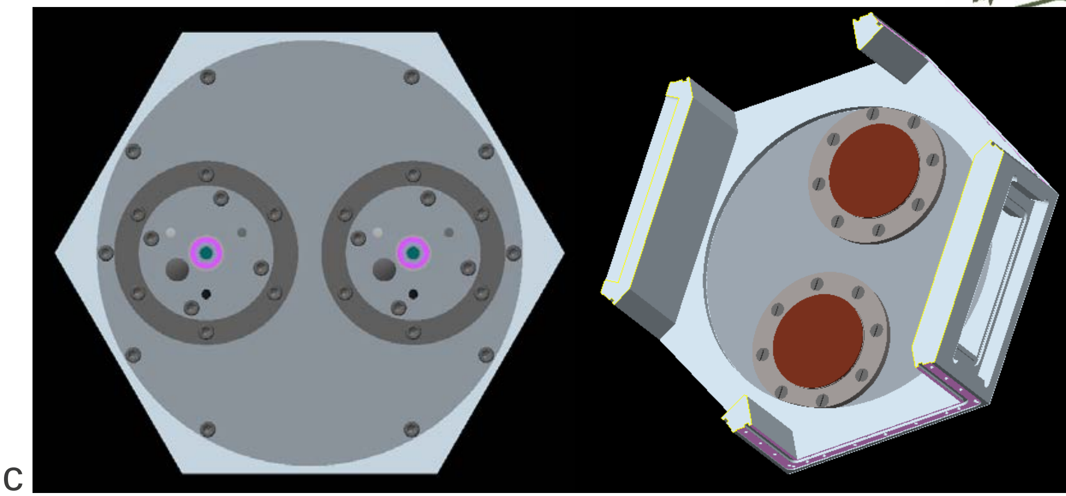
The samples and internal diagnostics will need to be assembled and sealed at TA-55.

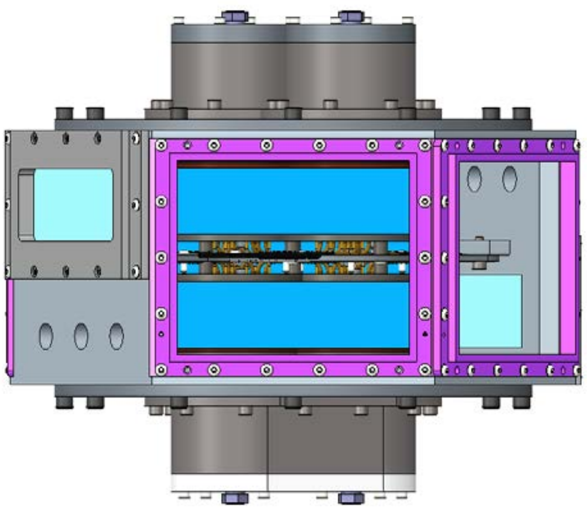
Final attachment of the HE to the package will happen at the DAF, and the experiment executed at U1a.

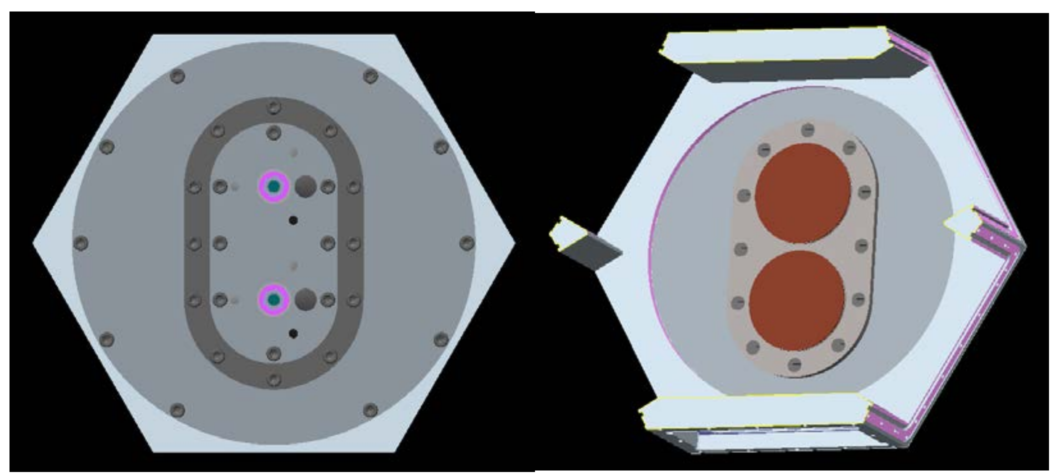
The assembly and flow of the package to the experimental area resembles the Barolo series, but with a more complex suite of diagnostics.

The Silverleaf package fits the fielding constraints of Nightshade

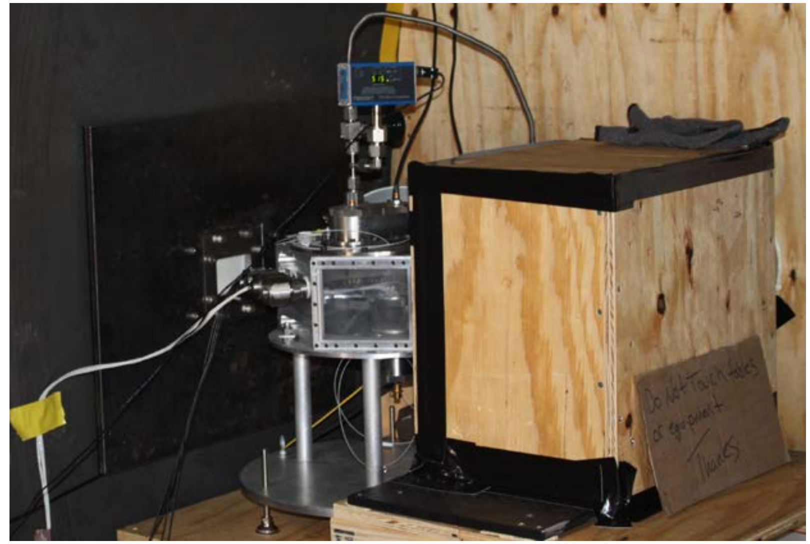


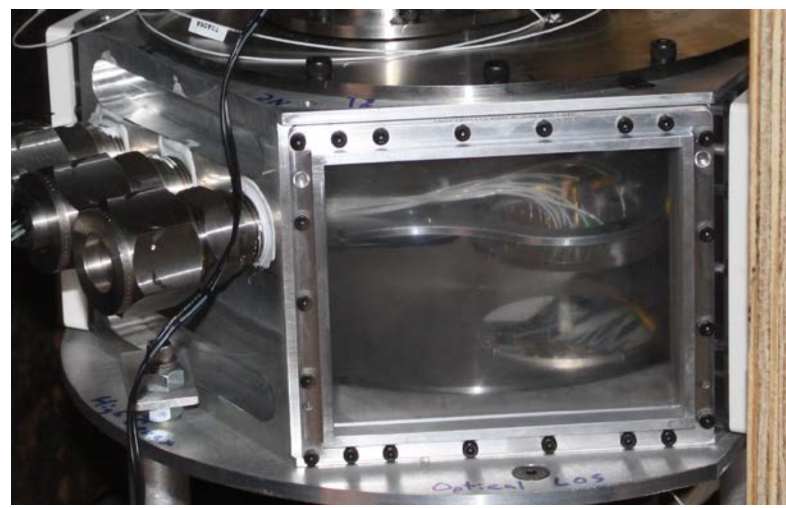






The Silverleaf diagnostic suite incorporates all primary Nightshade diagnostics, as well as some additional measurements





Momentum diagnostics:

- Lithium niobate pins
- Asay foils

Mass-density diagnostics:

- Soft radiography (2 pulses)

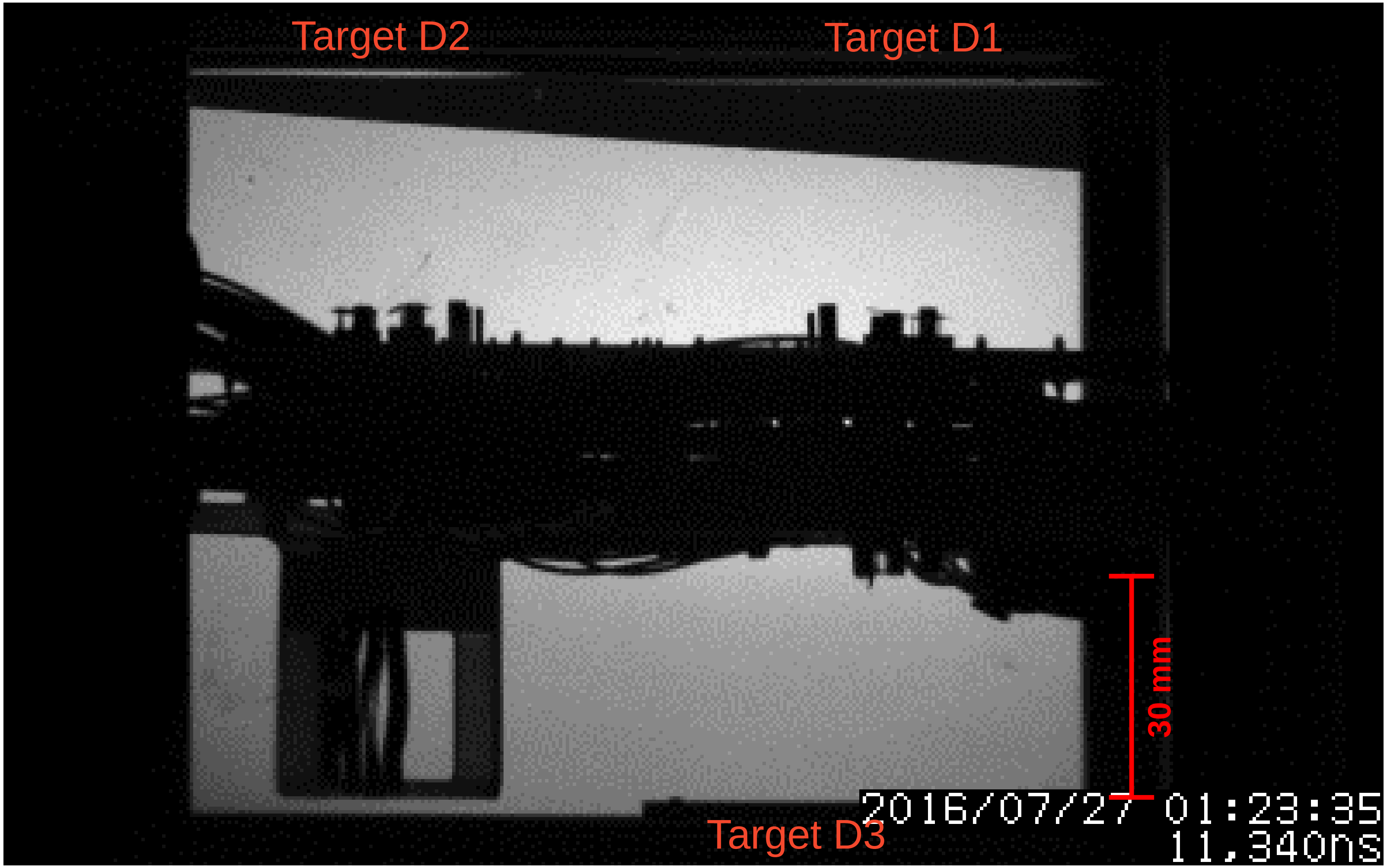
Drive Diagnostics:

- PDV
- Broadband laser ranging
- HE burn diagnostic (TOAD)

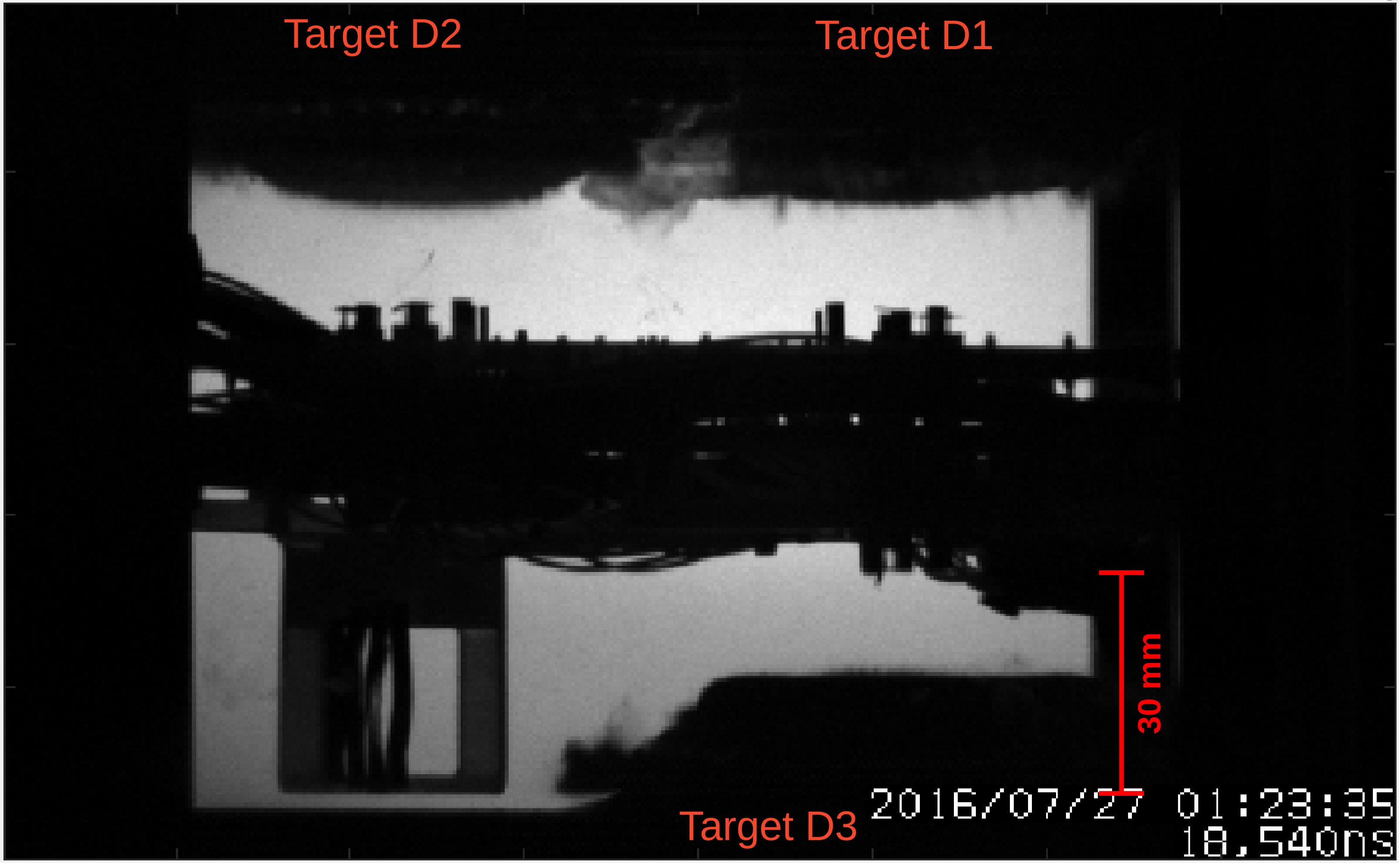
Package Assessment:

- High-speed video (through package)
- Slower video of outside of package
- Witness plates to examine fragmentation pattern
- Armored port for X-ray source

Silverleaf high speed video shows package performance and late-time interferences

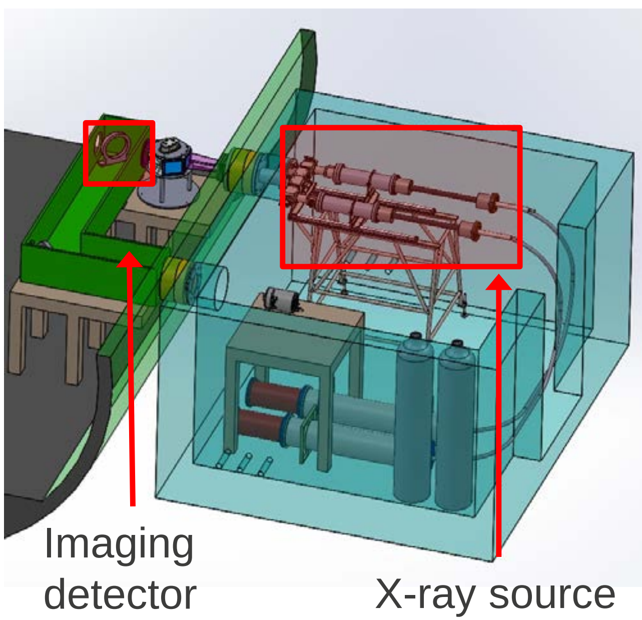


Silverleaf high speed video reveals package performance and late-time interferences

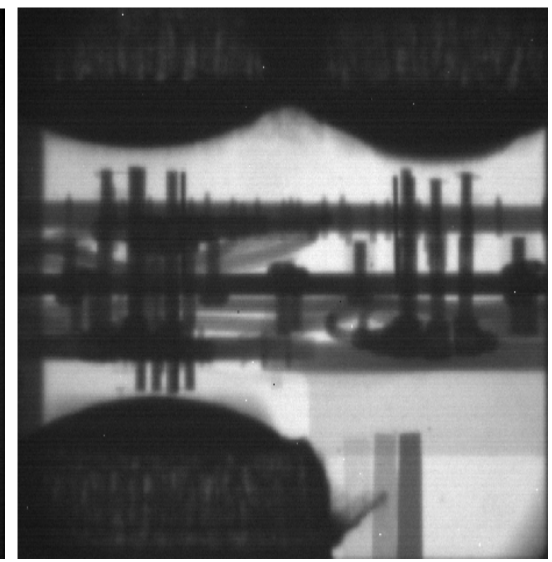


We fielded 2-pulse radiography in an 'in-vessel' configuration

- The radiographic system used a CsI scintillator.
- Two Platts-flash X-ray heads with molybdenum and tungsten anodes were used to make two frames. On each shot, the two radiographs were taken 5 μs apart.
- The heads and scintillator were placed at the correct conjugates, assuming modifications to the vessel port.
- We used the opportunity to test a new material for the X-ray port, a Spectra™ composite designed to withstand penetration but transmit more X-rays.

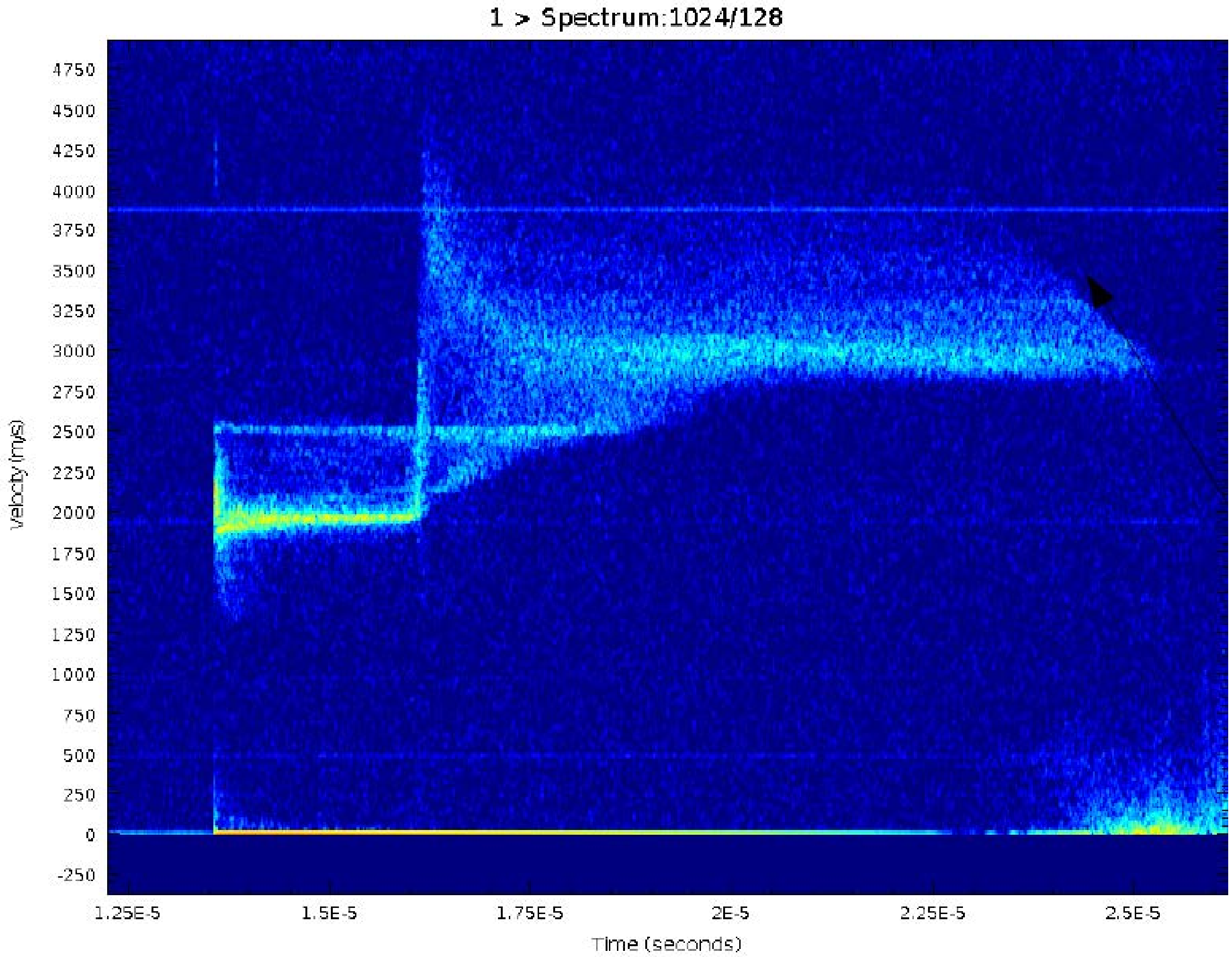


18 μs



23 μs

PDV on Silverleaf reveals the drive and qualitative ejecta information



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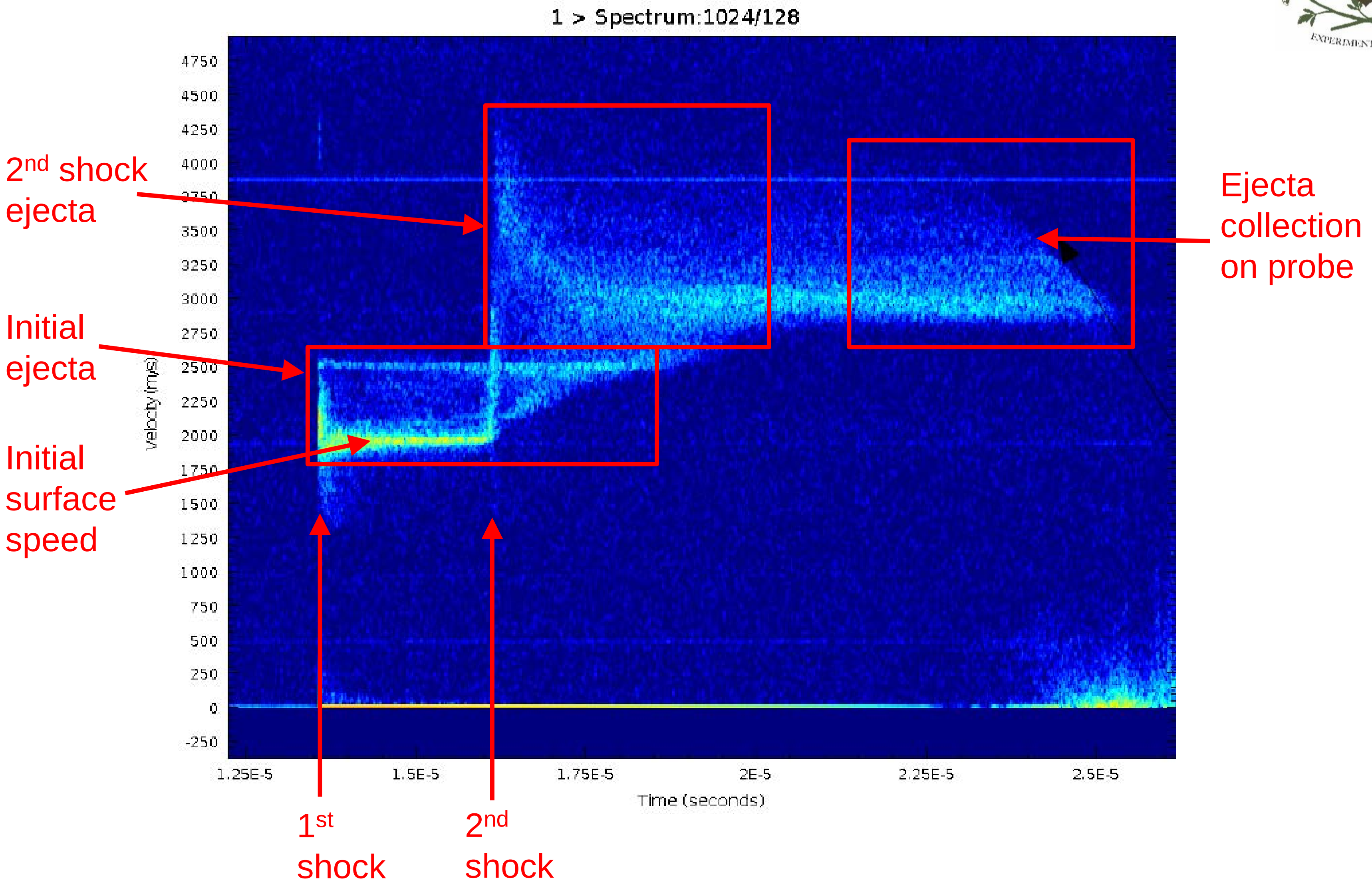
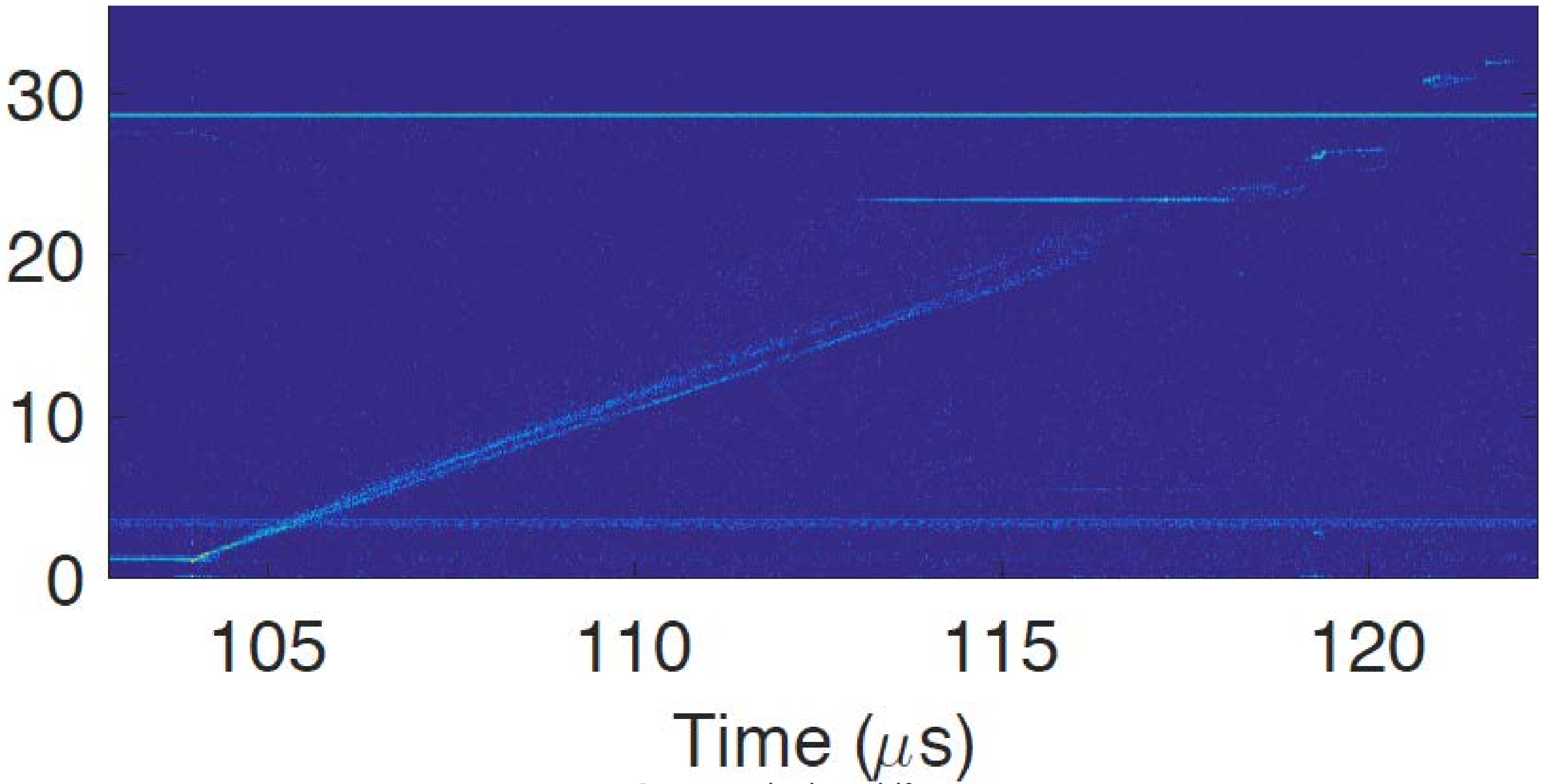


BLR on Silverleaf shows many of the same features



*Systematic timeshift

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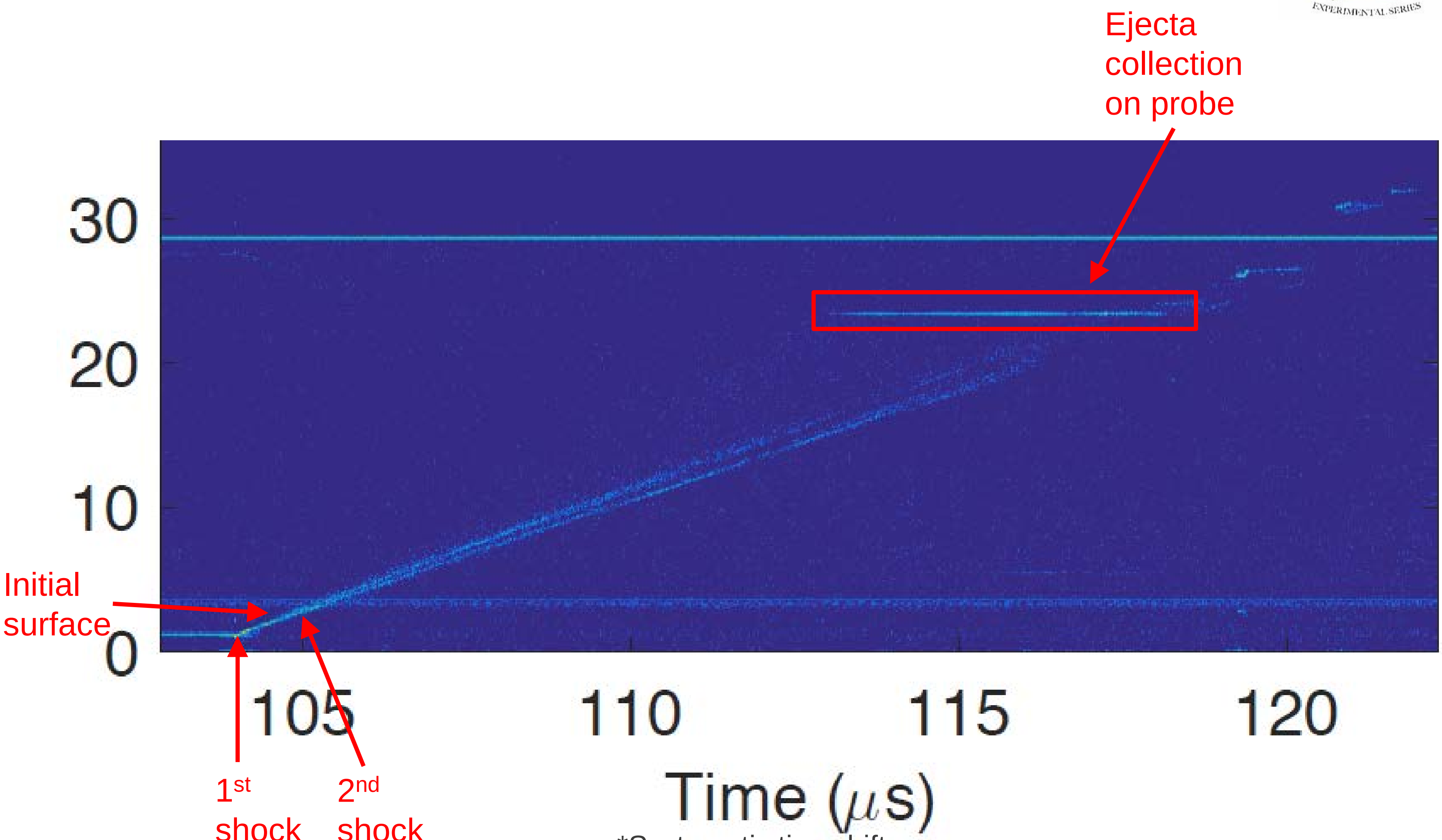
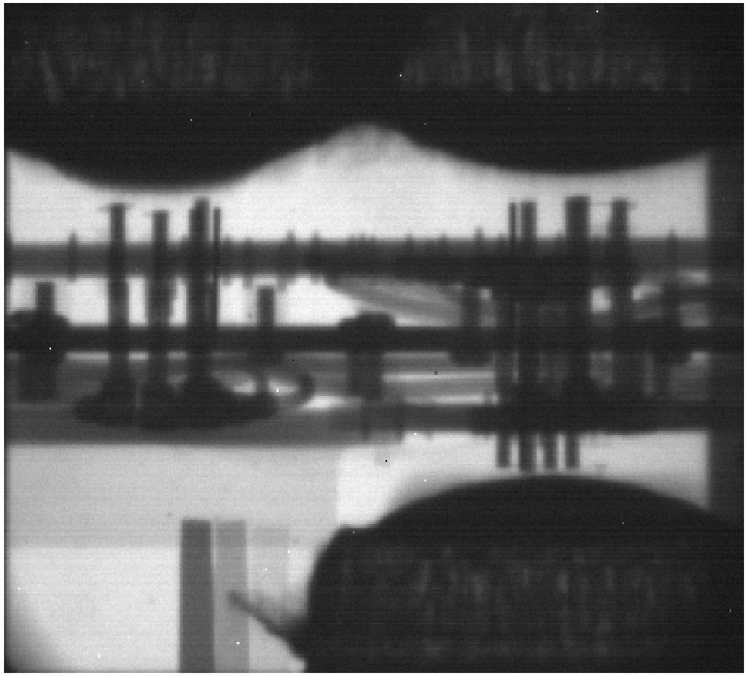


*Systematic timeshift

Radiography and optical video show the drives didn't interfere

Both radiography and optical images show spray from the edges of the targets.
The center regions of the packages appear uncontaminated.



Second radiograph, 23 μs

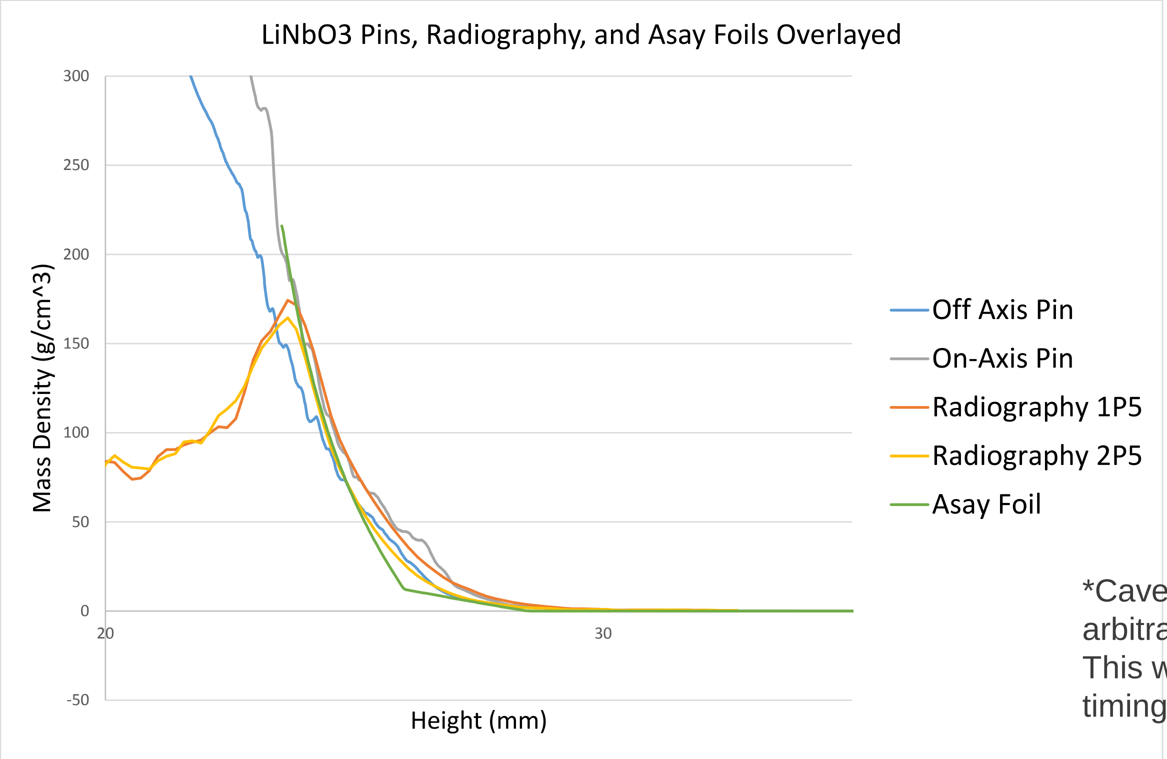
Optical image ~23 μs

A preliminary comparison of momentum diagnostics and radiography infer agreement

Both Asay foils and piezoelectric pins returned data. The radiography also consistently returned data.

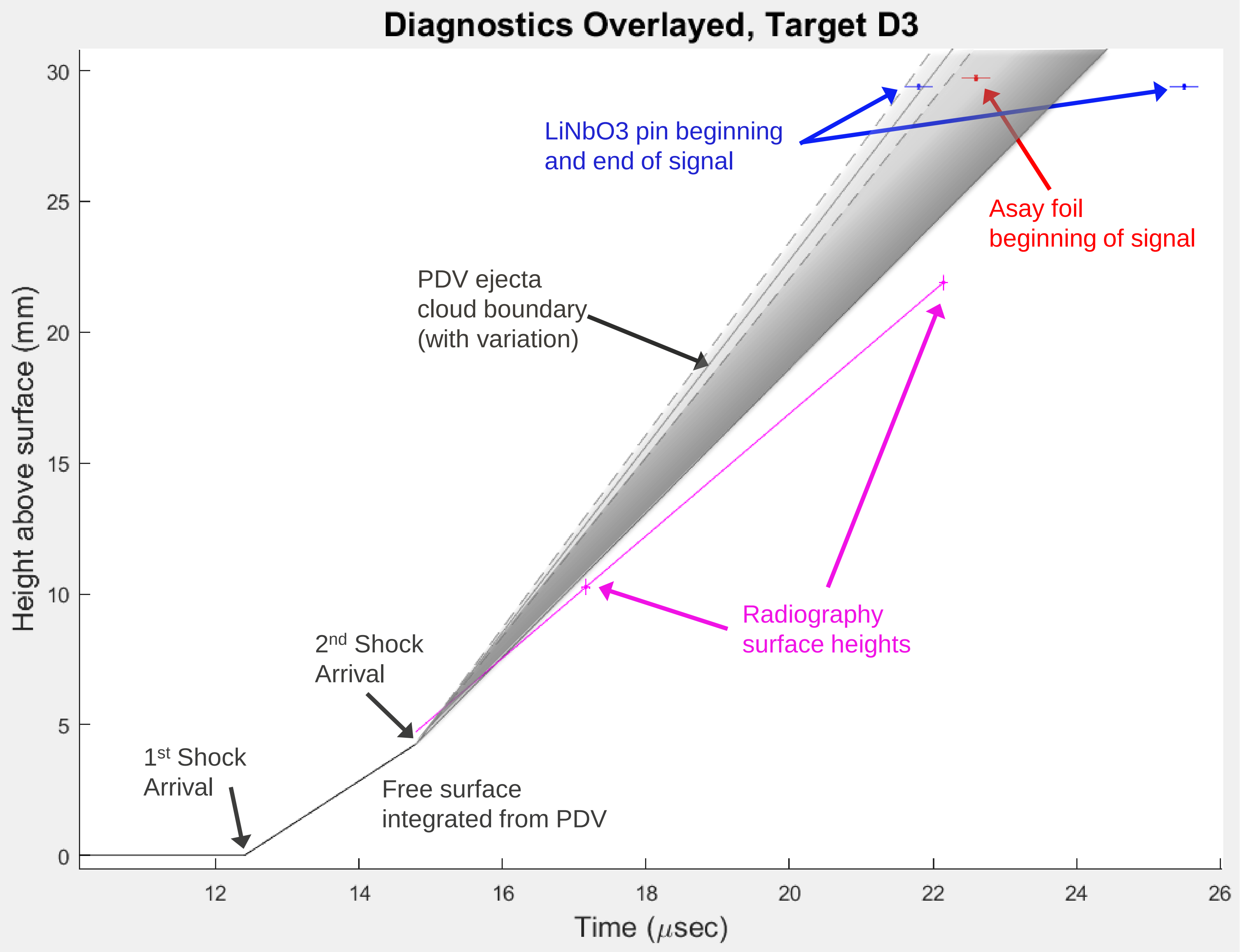
Data comparisons are underway but unfinished. We will have this prepared for the report at the end of September.

Silverleaf D3 Preliminary Data



*Caveat: The data have been arbitrarily shifted in location. This will be fixed as we correct timing

An overlay of locations and timing of the data show consistency



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BACKUP SLIDES

Nightshade Milestone - Diagnostic/Vessel Integration Tests

Milestone:

Validate the preliminary Nightshade in-vessel fielding geometry by demonstrating inter-diagnostic agreement with the relevant geometries, stand-off distances, and conjugates.

Action:

Complete and provide NNSA a test report comparing radiographic and momentum-transfer ejecta mass-velocity diagnostics on double-shock ejecta packages in geometries representative of the Nightshade in-vessel design.

This milestone addresses a major technical risk – This is a complex package with a lot of possible interference between drives and diagnostics.

Also, the assembly of the package requires practice and proofing. This series is an opportunity to find ways to improve efficiency and data quality.

Nightshade Diagnostics – Radiography systems

It is worth contrasting the two radiographic systems for Red Sage

Cygnus

Has a sensitivity range of <1 mg/cm^2 to 100s of mg/cm^2.

Has been operating reliably for years and carries little vessel and mitigation risk.

The source is far enough from the package to minimize parallax problems.

Can see through and measure the spall and material layer behind the ejecta field.

Takes 1 image per axis.

Soft X-ray head

Has a sensitivity range of <50 μg/cm^2 to ~ 100 mg/cm^2.

Ports and mitigation need to be designed and qualified to allow X-rays in and images out.

Will suffer from parallax if the source is as close as the vessel wall.

Cannot see through the spall layer.

Takes 4 images per axis, potentially allowing separation of the 1st and 2nd shock ejecta distributions.

Silverleaf – Drive / Target Matrix

Sample Class	Description	kh	h (μm)	p-p ampllitude (μm)	wavelength (μm)
0	Polished/Diamond Turned	0	0	XX	XX
1(a)	Moderate Surface Roughness - Solid Target	0.2	3.2	6.4	100
1(b)	Moderate Surface Roughness - Momentum Ring	0.2	3.2	6.4	100
2	High Surface Roughness	0.4	4.8	9.5	150

Package	State after first shock	State after second shock	Target	Direction	Notes
Sliverleaf A					
1	Liquid	Liquid	1(a)	down	Tests severely different timing
7	Solid	Solid	2	down	Tests severely different timing
2	Liquid	N/A	1(a)	up	
Silverleaf B					
3	Liquid	Liquid	2	down	Tests severely different timing
8	Solid	N/A	2	down	Tests severely different timing
4	Liquid	N/A	2	up	
Silverleaf C					
9	Solid	Solid	0	down	
12	Mixed	N/A	1(a)	down	
11	Liquid	N/A	1(a)	up	
Silverleaf D					
5	Liquid	Liquid	1(b)	down	Momentum Trapping Ring
6	Liquid	N/A	1(b)	down	Momentum Trapping Ring
10	Solid	N/A	0	up	

Targets and Drives are arranged to:

Explore diagnostic failure regions
Test lens fratricide
Examine effect of momentum trap
Have both upwards and downwards directed lenses

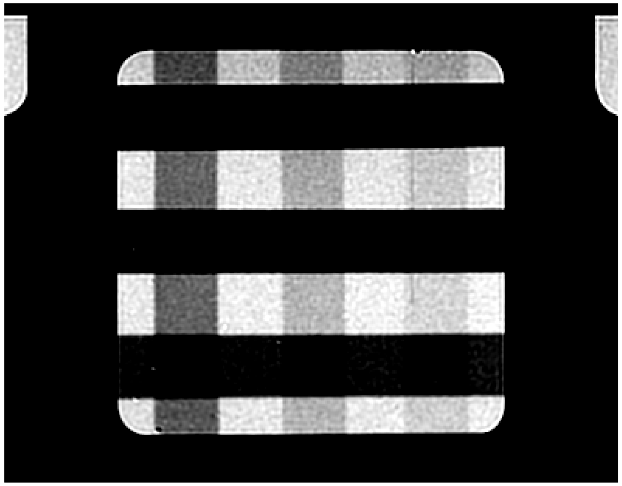
We believe the packages in Silverleaf A and B are sufficient to meet the milestone.

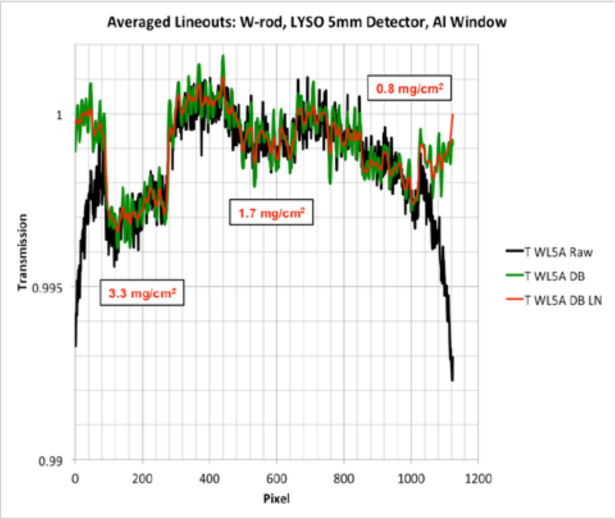
Red Sage Diagnostics – Radiography (Cygnus)

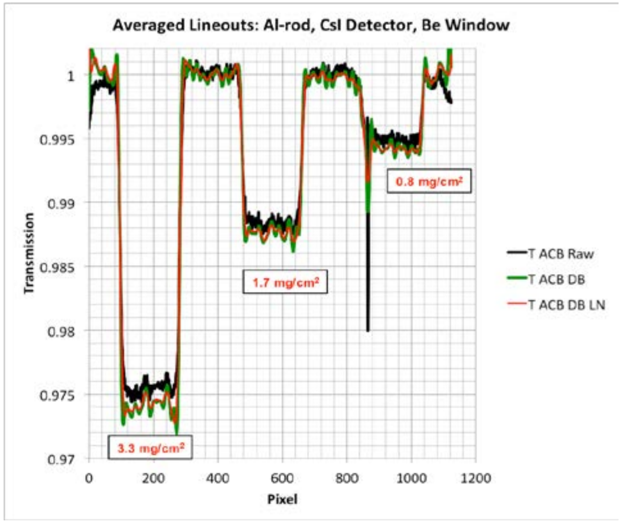
Cygnus has been operated reliably at U1a since Armando. The principle of the measurement is similar to that of the Platt's flash, but has traditionally had a much higher energy endpoint (2.2 MeV rather than 100's of KeV)

By modifying the cathode, window and scintillator materials, Cygnus has demonstrated a sensitivity of <1mg/cm^2. It also has enough punch to see through 100 of g/cm^2, giving a measurement of the spall layer behind the ejecta field.

NRL is developing a Plasma-filled rod pinch diode. This is a modification to the standard rod pinch that gives a soft spectrum (good ejecta measurement) and a lot of dose (better noise characteristics).







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