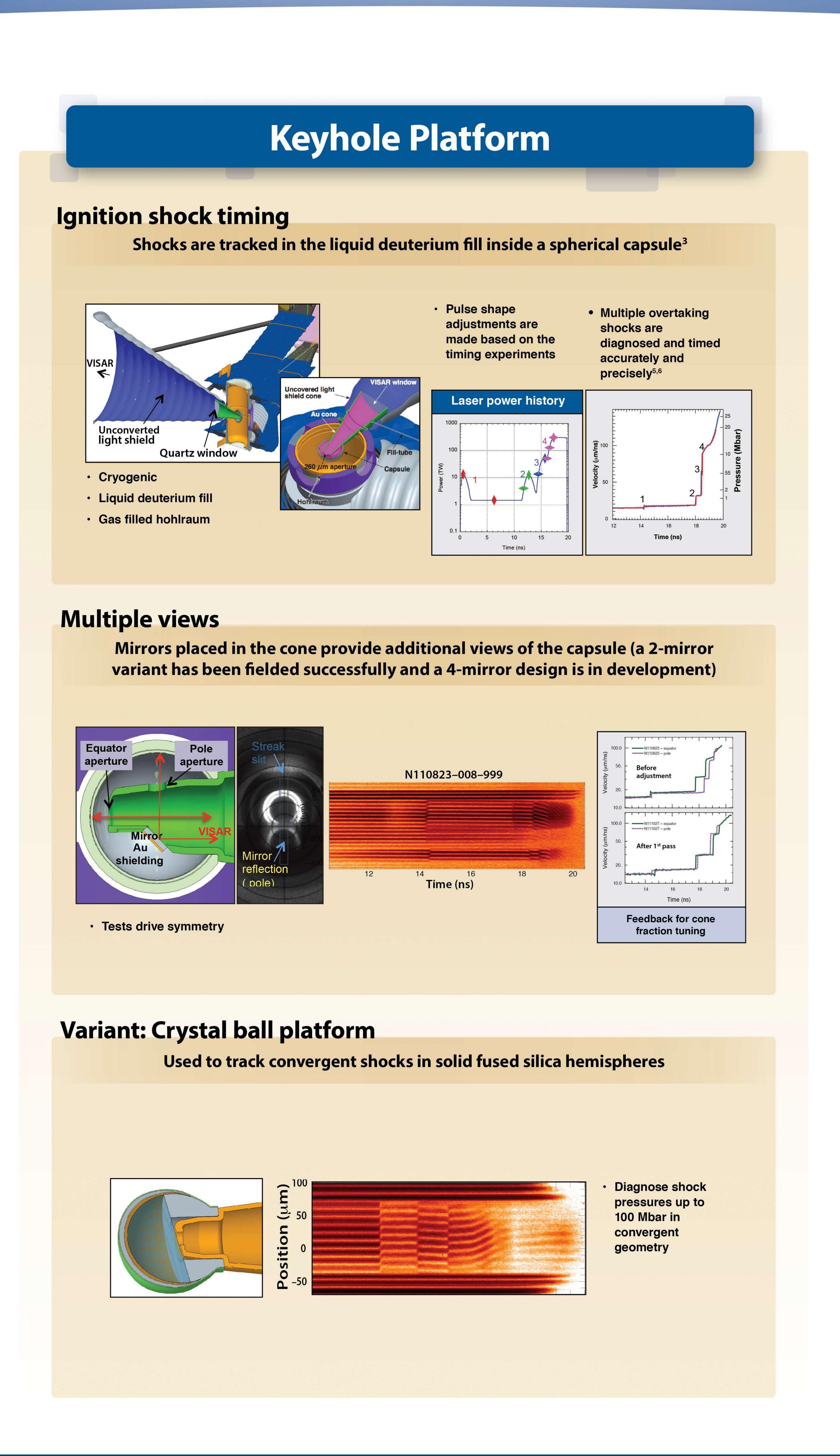# Shock Timing and Equation of State Platforms on the National Ignition Facility
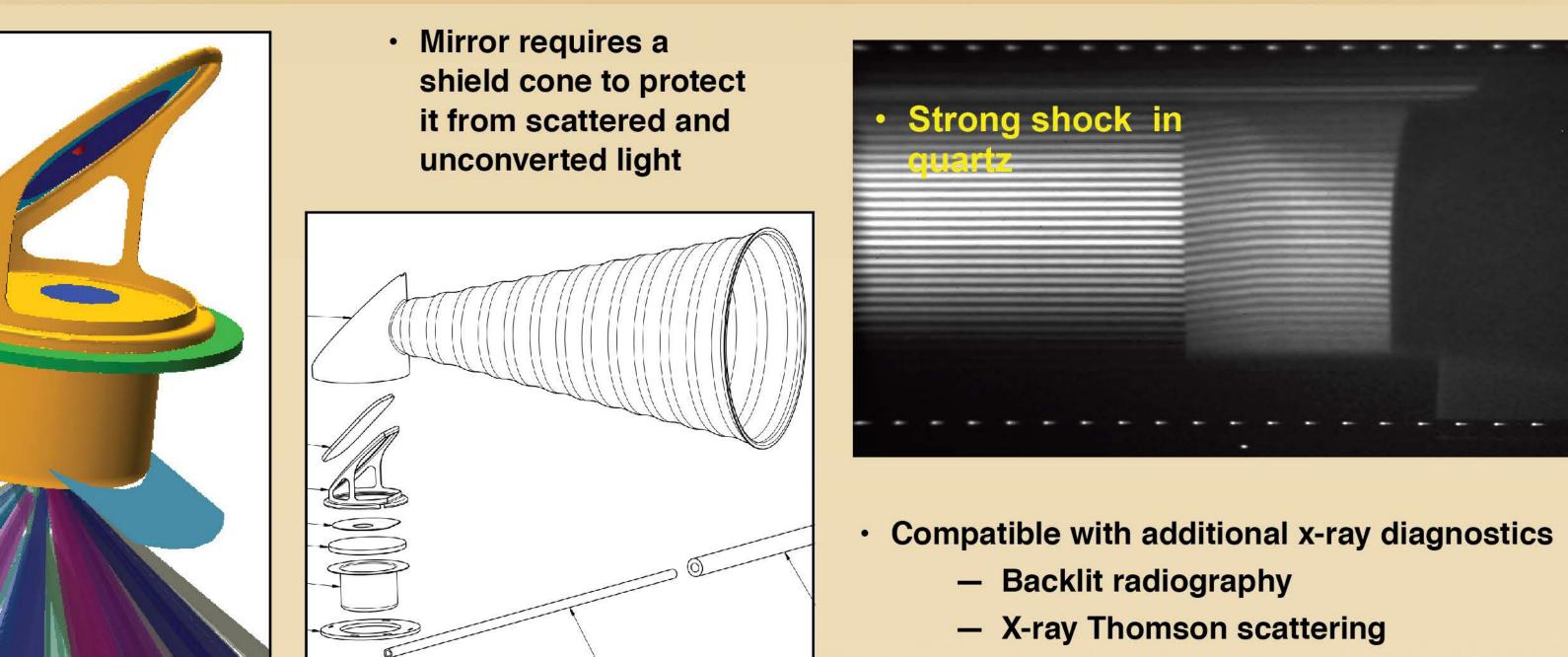
## VISAR Diagnostic

### VISAR: Velocity Interferometer System for Any Reflector

**The VISAR is an optical probing diagnostic that tracks target motion through Doppler shifts in a reflected probe beam[1,2]**



Shock front in a transparent sample

Shock front

DRIVER

Reflection originates at shock front

- Coherent laser beam directed onto target
- Reflected beam collected and imaged onto a streak camera line-imaging
- Interferometer placed in relay path imposes fringes onto recorded signal
- Velocity is proportional to fringe shift
- The moving reflector can be[1,2,3]:
  — A free surface
  — A reflecting shock front
  — A moving interface behind a transparent window



Target
Probe laser
Etalon: delay = $\tau$ ~10 to 300 ps
$\Phi_{t+\tau}$
$\Phi_t$   Image plane
Streak camera

Image relay from target to detector

- NIF VISAR features[4]:
  — Velocity accuracy approximately 1%
  — Time resolution 0.5% of the data window
  — Spatial resolution < 20 $\mu$m
- Two streak detectors record phase information simultaneously with different sensitivities
- Available fields of view: 1 mm and 2 mm
- Arbitrary orientation of streak slit relative to target image for each channel

VISAR: Velocity Interferometer System for Any Reflector

velocity
time
time

Doppler shift ⇔ fringe phase ⇔ velocity

### Phase space of material states probed by VISAR

**VISAR can diagnose single and multiple strong shocks in transparent media, as well as the motion of free surfaces. Velocities up to 150 km/s demonstrated**



Pressure (Mbar)
$SiO_2$
Atomic Fluid
Hugoniot (Quartz)
Hugoniot (Stishovite)
Polymeric Fluid
Accessible on NIF
Pyrite-type
???
Hicks, 2006
Pressure (GPa)
Temperature (K)

Trajectory for plastic ablator ($CH_{1.5}$) in ICF implosion
Ablation
Cold curve
Hugoniot
Plastic ablator
Cold curve
◆ shock
▲ shock + release (DD)
● shock + reshock (quartz)
Pressure (Mbar)
Density (g/cc)

**Appropriately designed experiments can probe a wide phase space between the principal Hugoniot and principal isentrope of many materials using VISAR as the means to determine the thermodynamic state.**
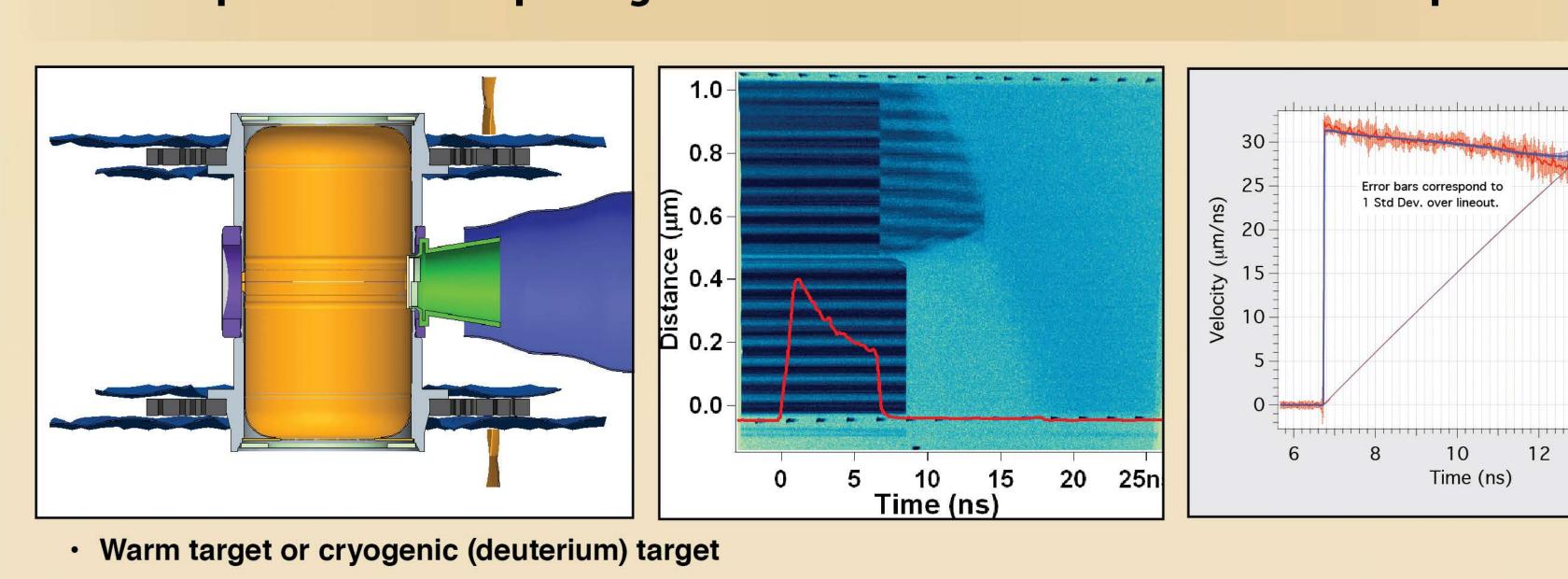
## Keyhole Platform

### Ignition shock timing

**Shocks are tracked in the liquid deuterium fill inside a spherical capsule[3]**



VISAR
Unconverted light shield
Quartz window
Unconverted light shield cone
Au cone
VISAR window
Pit-tube
Capsule
Hohlraum

- Cryogenic
- Liquid deuterium fill
- Gas filled hohlraum

- Pulse shape adjustments are made based on the timing experiments
- Multiple overtaking shocks are diagnosed and timed accurately and precisely[5,6]

Laser power history
Power (TW)
Time (ns)
Velocity (km/s)
Pressure (Mbar)
Time (ns)

### Multiple views

**Mirrors placed in the cone provide additional views of the capsule (a 2-mirror variant has been fielded successfully and a 4-mirror design is in development)**



Equator aperture
Pole aperture
Mirror Au shielding
VISAR
Streak slit
Mirror reflection (pole)
N110823-008-999
Time (ns)
Velocity (km/s)
Before adjustment
After 1st pass
Time (ns)
Feedback for cone fraction tuning

- Tests drive symmetry

### Variant: Crystal ball platform

**Used to track convergent shocks in solid fused silica hemispheres**



Position ($\mu$m)

- Diagnose shock pressures up to 100 Mbar in convergent geometry

## Planar Geometry Platforms

### Planar x-ray drive with half-hohlraum geometry

**VISAR view of the target is achieved with a fold mirror mounted on the target**



- Mirror requires a shield cone to protect it from scattered and unconverted light

Strong shock in quartz

- Warm target
- Vacuum hohlraum

- Compatible with additional x-ray diagnostics
  — Backlit radiography
  — X-ray Thomson scattering

### Planar x-ray drive with full hohlraum geometry

**Equation of state packages can be driven with >100 Mbar of drive pressure**



Distance ($\mu$m)
Time (ns)
Velocity (km/s)
Thickness ($\mu$m)
Time (ns)

- Warm target or cryogenic (deuterium) target
- Utilizes full NIF drive for maximum shock pressure
- Shock states >100 Mbar can be achieved

### Ramp compression

**"Coming soon"
Publication pending**

Lawrence Livermore National Laboratory

NIF