Hydrodynamics at AWE

David Chambers – Head of Hydrodynamics

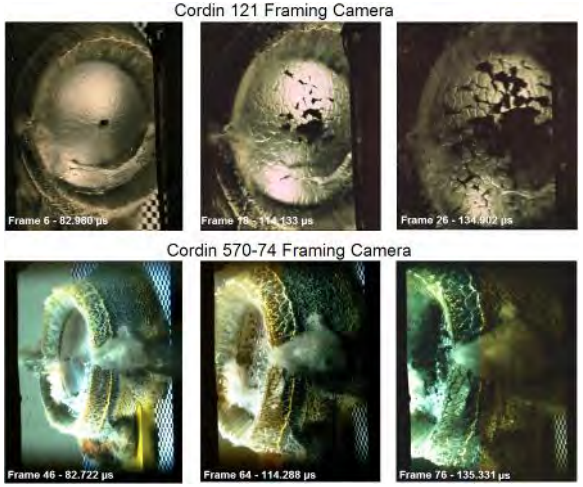
Outline

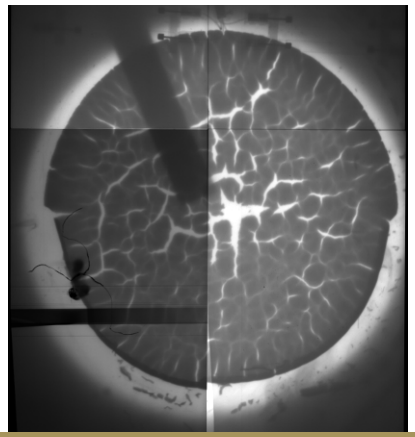
- Size and Structure of Hydrodynamics Department (HD)
- Facilities we operate
- Radiographic Diagnostics
- Analysis Techniques
- Pulse Power Research

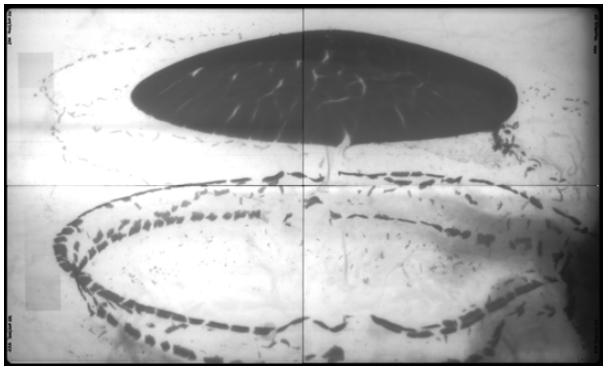
Hydrodynamics is the science of forces acting on or exerted by fluids.

When explosively compressed nuclear warheads behave like fluids

Experiments are conducted using explosives to drive metals. Data collected and analysed using a range of diagnostics





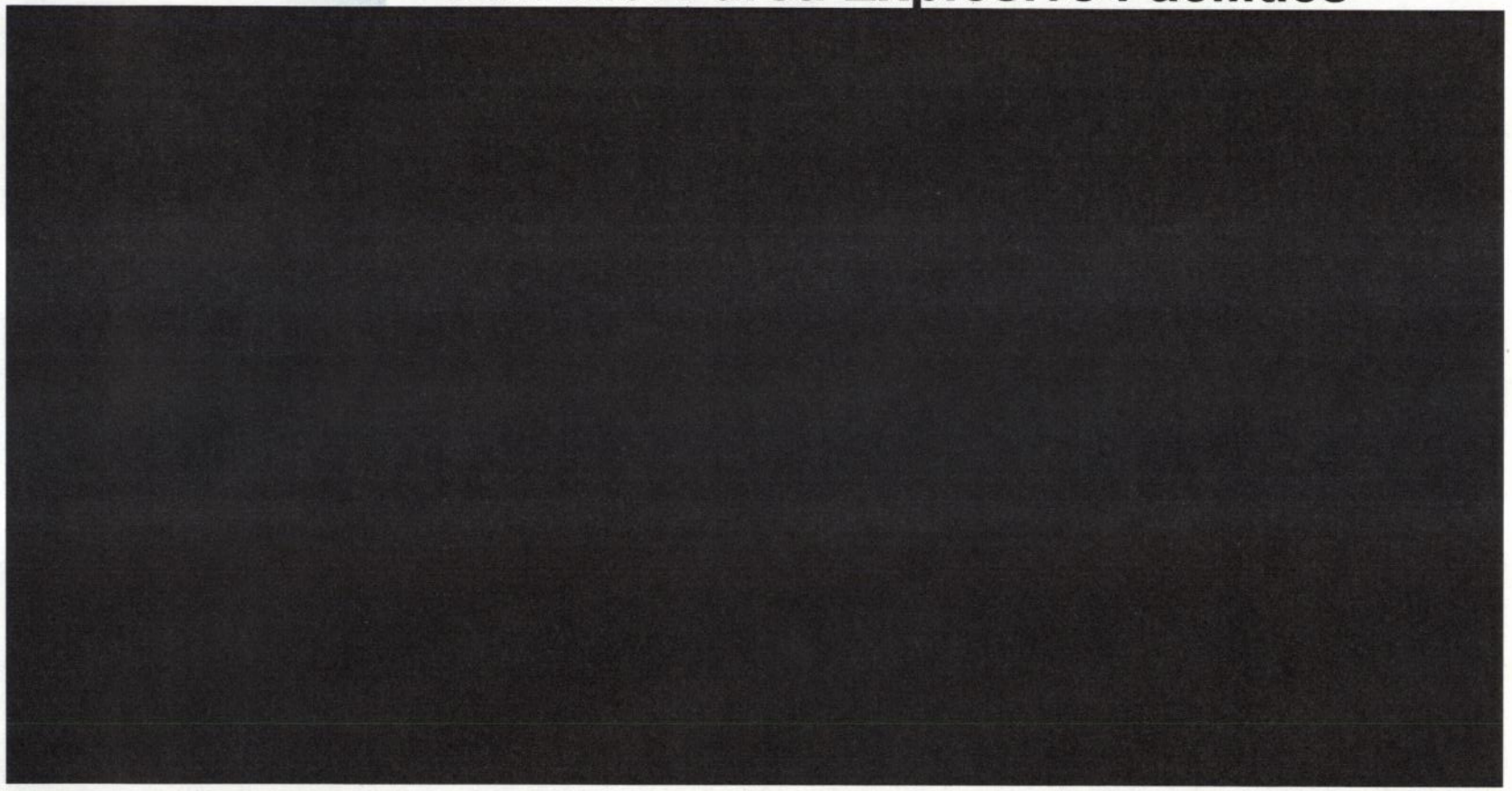


AWE core capability that delivers its primary mission through the provision and analysis of data

Hydrodynamics Division

- ~200 personnel
  - 50% science, engineering & technology
  - 30% facilities engineering and enabling functions
  - 20% management and overhead
- ~150 trials conducted/yr
  - 8 “major” trials
  - 25 “minor” or “physics” trials
  - 120 non-explosive trials

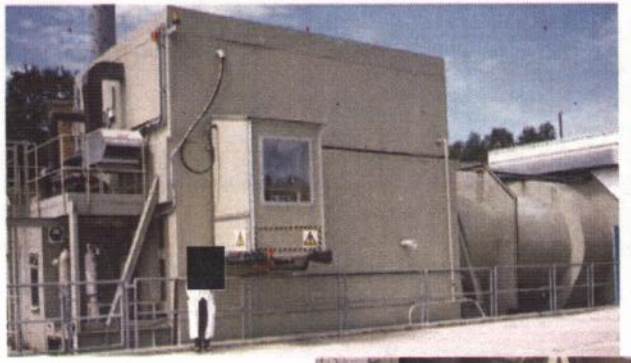
Current H-area Explosive Facilities



- Circa 1950s construction
- Requiring regular – and deep – maintenance to remain compliant

Chamber Set-up Before and After

Diagnostics - Radiographic Facilities

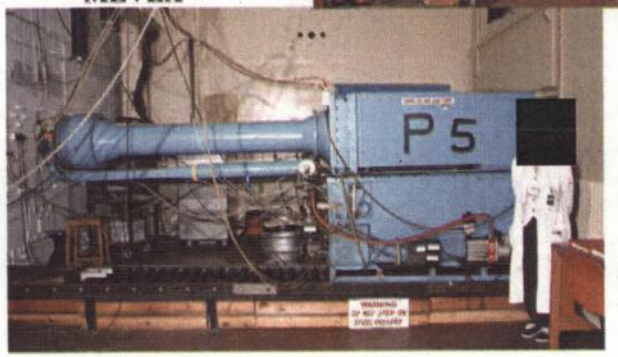


MOGUL E
400R
10million volts
5mm spot

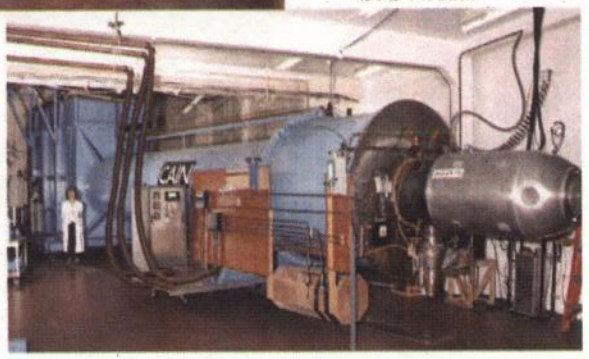
MOGUL D
150R
4mm spot

MINI B
12R
2.5mm spot

MEVEX
1R
0.8 MV
2.5mm spot

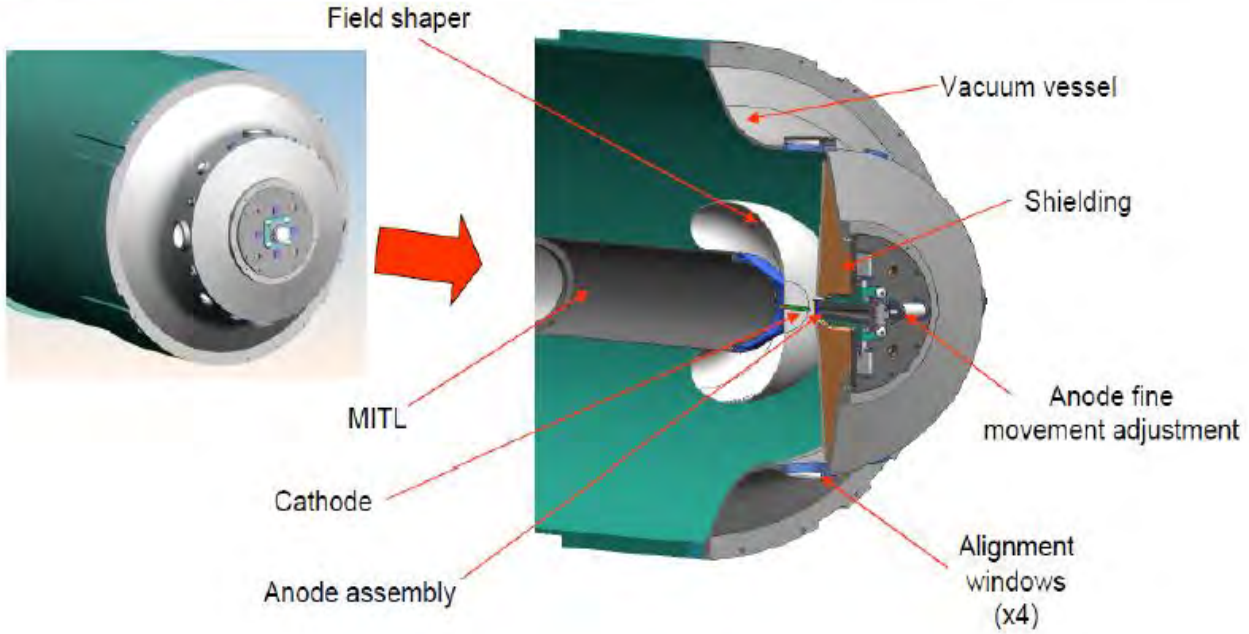


S. SWARF
60R
4mm spot



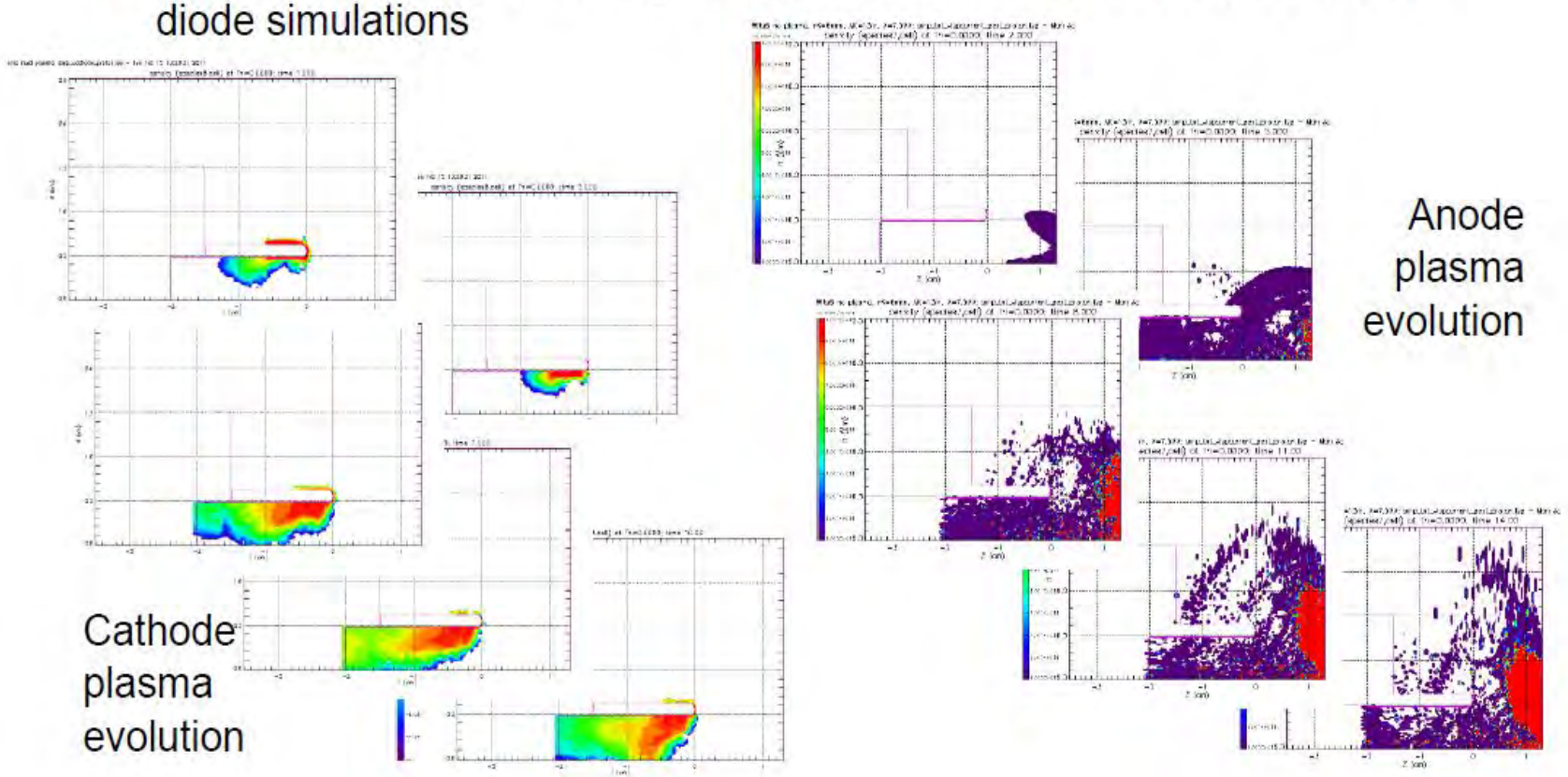
Pulse Power Research and Development

- **Self Magnetic Pinch (SMP) selected as the source for the IVA in 2006**
- Since 2006, an engineering design has been developed for the diode on the IVA driver.
  - Much of the development work was carried out on RITS6 at SNL as this is a very similar driver to the **IVA**



Pulse Power Research and Development

- We have been implementing new plasma modelling techniques into SMP diode simulations



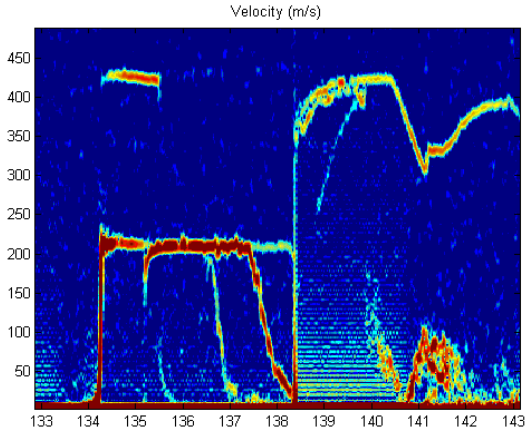
AWE 70mm gas gun

The AWE gas gun is used to produce dynamic data and develop experimental techniques in support of the development and validation of material models.

Research areas include: *Equation of State, Strength, Friction, Ejecta.*

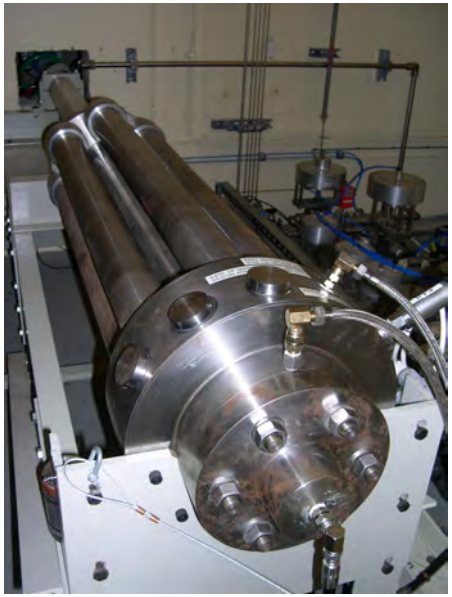
Single stage Helium gas gun

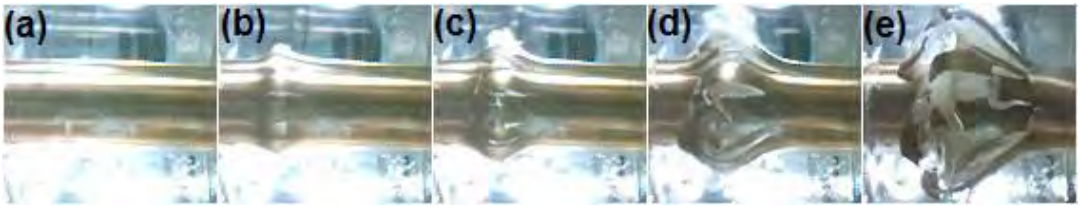
- 3m bore, 70mm diameter barrel
- Capable of impact velocities 150-900 m/s
- 1D plate impact experiments
- ISP 4kg - ~860m/s



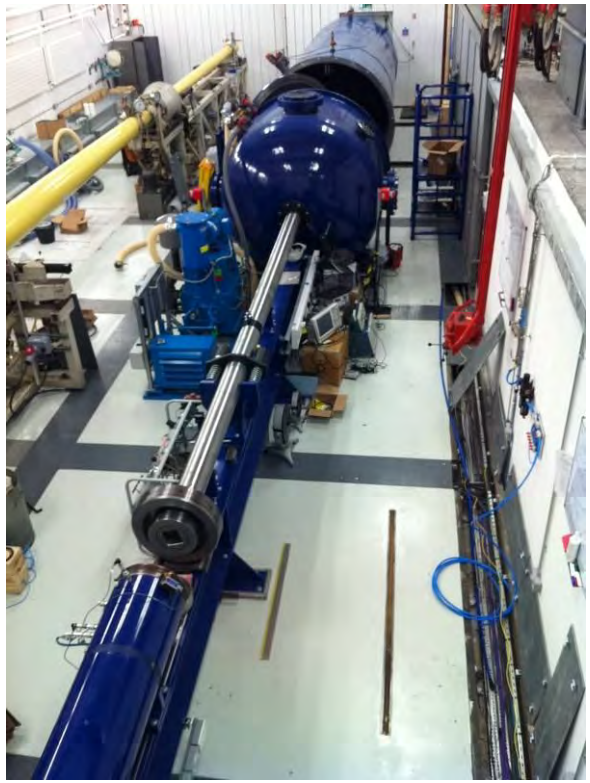
Diagnostics

- Velocimetry - HetV,
- Timing - electrical pins, ionisation pins, piezo pins
- Stress - Manganin stress gauges
- Ductility/Fracture – High speed photography



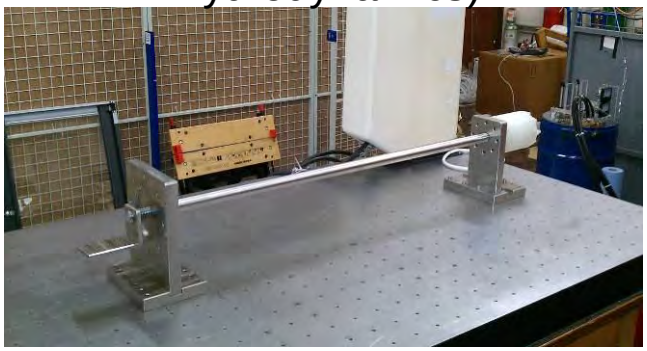


Institute of Shock Physics (ISP) Capabilities



100mm Gas Gun

MACH (Mega Ampere Compression & Hydrodynamics)

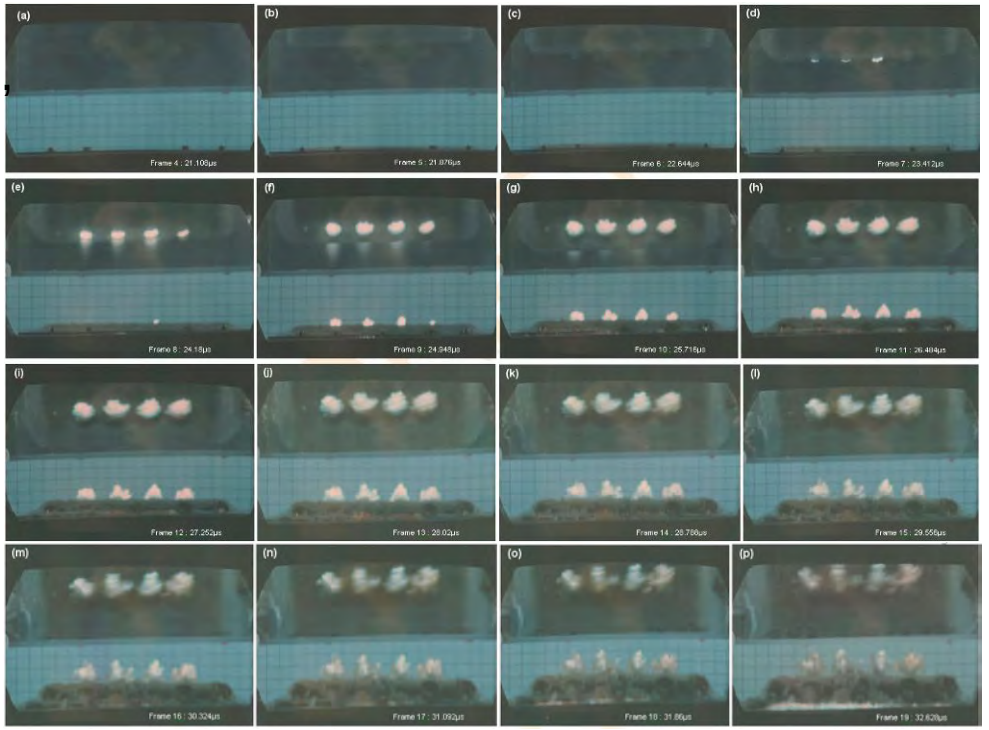


Electrothermal launcher

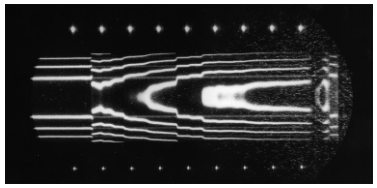
Gas loader for DAC

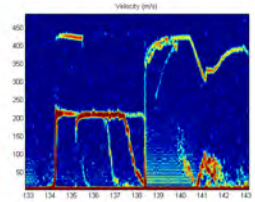
High Speed Photography

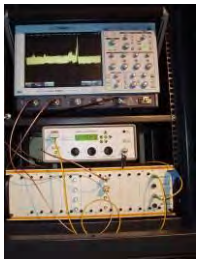
- Cordin Digital camera 570-74
- Cordin 121 max camera speed, Framing 7.5 x 10^6 fps, 30mm/µs



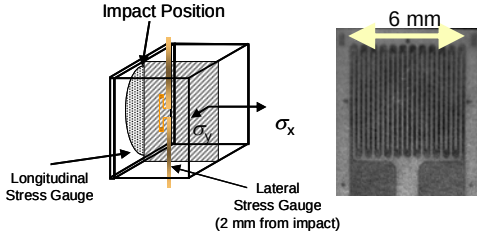
Non-Radiographic Diagnostics



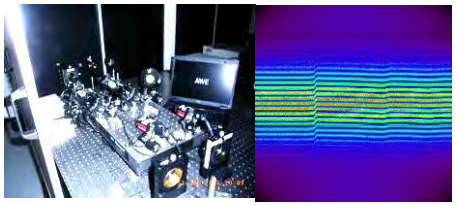




Optical Velocimetry: Capability Well established
HetV technique beginning to replace F-P

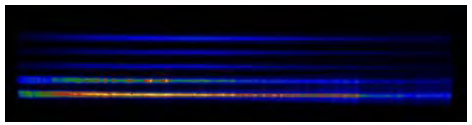


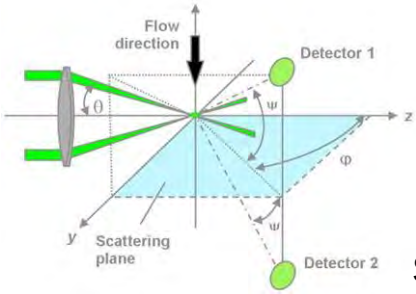
Stress Gauges: Regularly deployed
On Gas Gun experiments

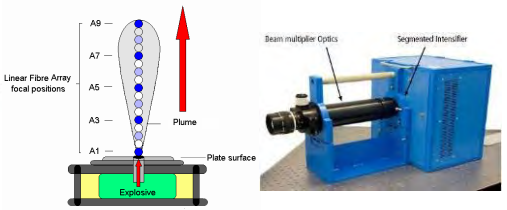


Line VISAR (spatially resolved velocity)
Under development (Engaged with Academia/ISP)

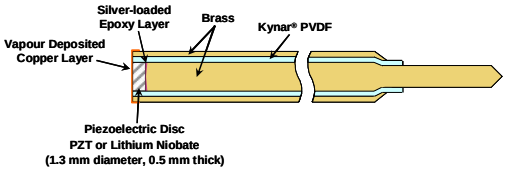
PDA: Under development
for particle size measurement



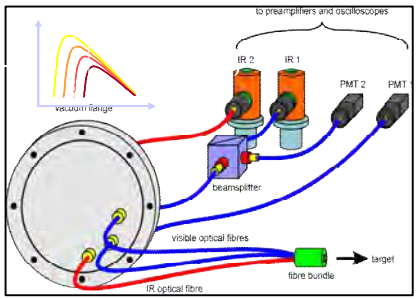




Spectroscopy: Established to study
diode performance

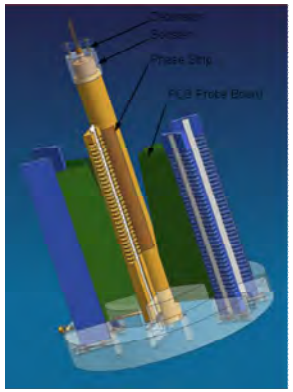


Piezo-electric Gauges: Routinely
fielded on ejecta experiments



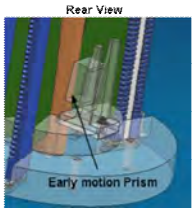
Pyrometry: Newly established
capability (Gas Gun Experiments)

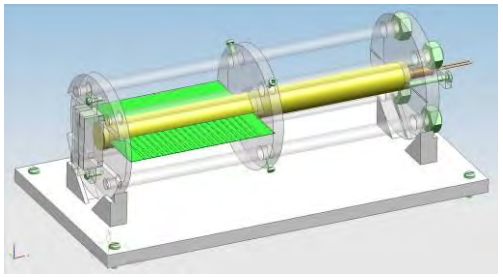
HE Performance Experiments



Cylinder tests:
- Investigation EoS Detonation products

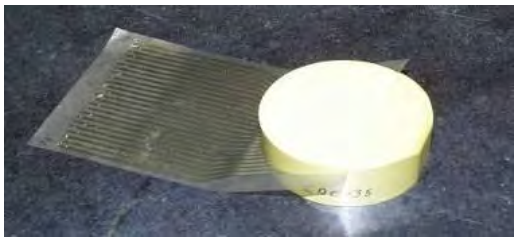
Investigation into next generation diagnostics ongoing

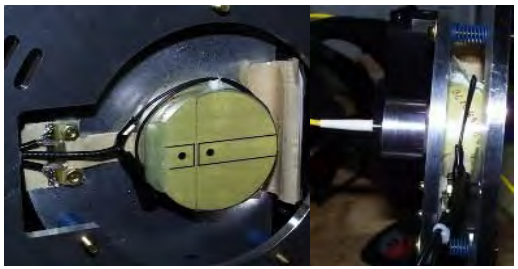




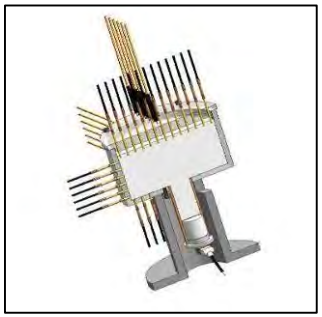
Rate stick tests:
- HE performance (V-o-D / Wave curvature)

Shock to detonation:
-Magnetic gauge technique
- To be deployed on ISP HE gas gun (PhD)

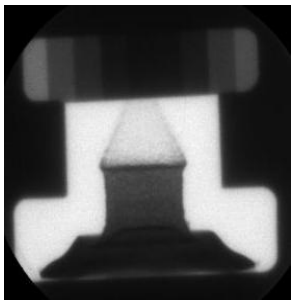




Corner Turning:
Study of non-Ideal Explosives

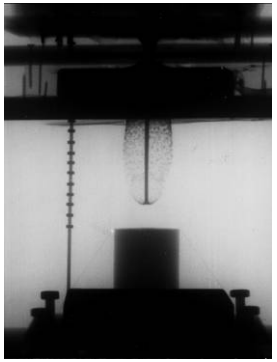


HE Driven Damage / Physics experiments

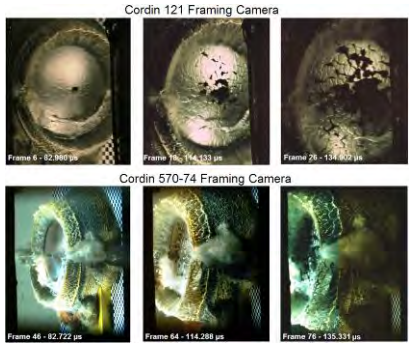


HE driven coupon experiments
-Strength/spall investigation
-Radiography
-Velocimetry

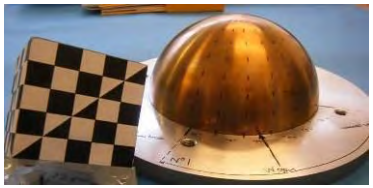
Jet Penetration studies:
Jet characterisation
-Radiography
-Jet stopper techniques

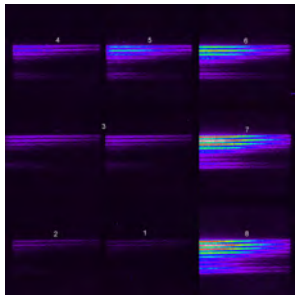


HE driven coupon experiments
-Ejecta production
-Velocimetry
-Piezo-electric probes
-Foil probes
High speed imaging
-Spectroscopy
-radiography

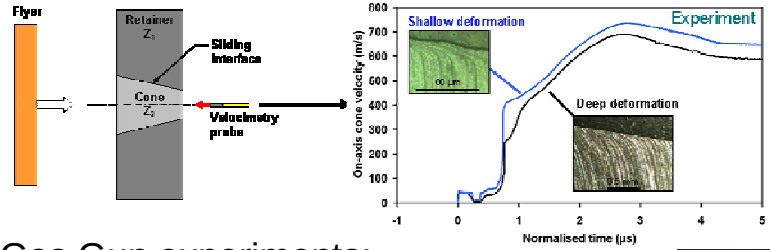


Fracture code validation experiments
-Radiography
-High speed imaging
-Newly established CCD Imaging system

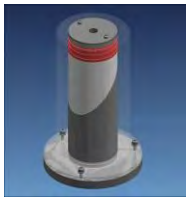


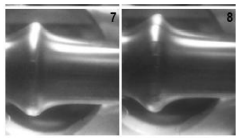


Non-HE Physics Experiments

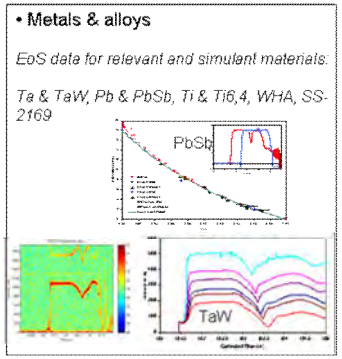


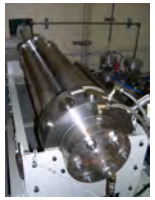
Gas Gun experiments:
Study of friction at metal interface



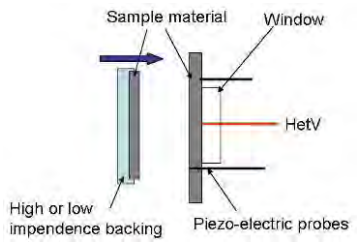


Gas Gun experiments: EoS Data
Currently use D16 SS Gun (0.9km/s: 70mm Bore)
Limited in pressure range required
Future: ISP SSG (1.3km/s: 100mm Bore)
and ELC 2SG later

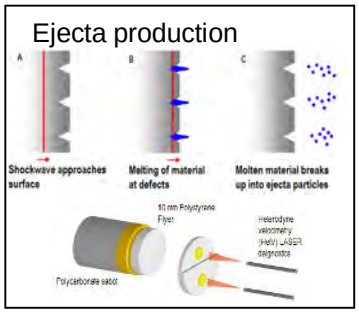




Gas Gun experiments:
Wave Profile Experiments
HetV and Piezo experiments



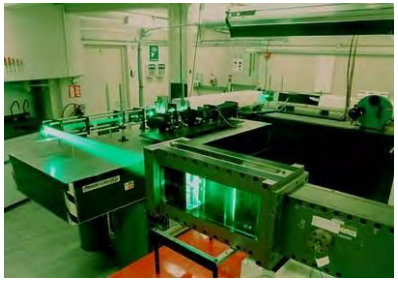
Gas Gun experiments:
Ejecta Production studies

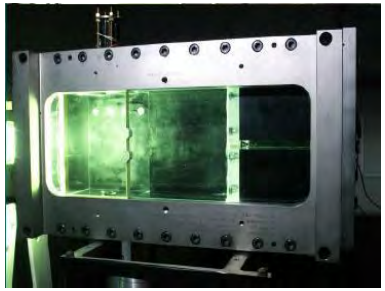


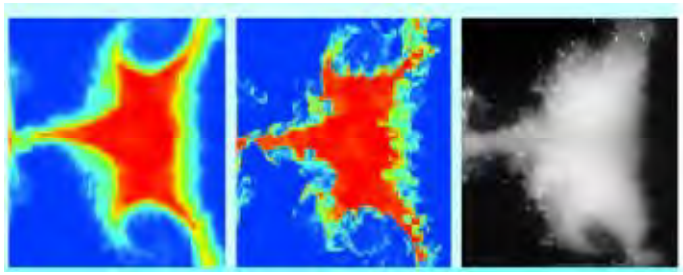
Gas Gun Experiments:
Shear strength studies using lateral manganin stress gauges
Polycrystalline studies

Employing Line Visar

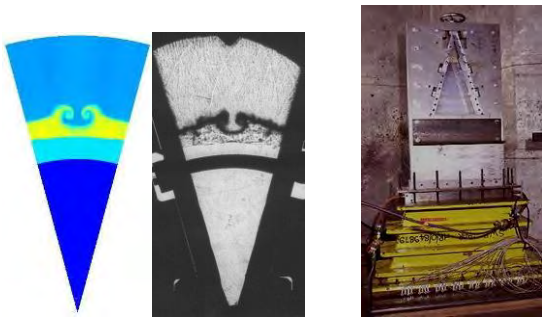
Non-HE Physics Experiments



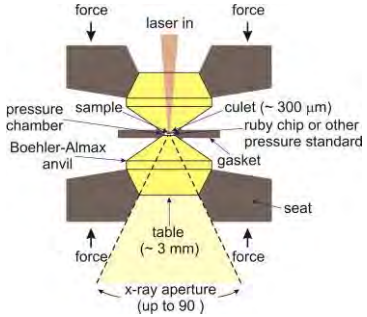


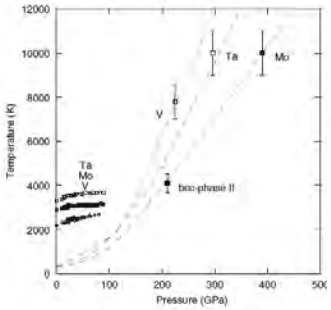


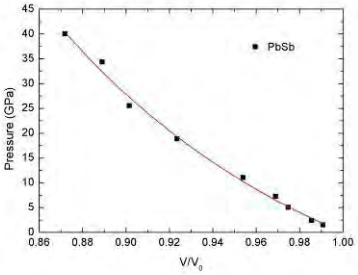
Linear Shock Tube: Operation re-established – Mix experiments
Use as R&D tool for quantitative turbulent mixing diagnostics



Convergent Shock Tube: Operational system Imminent. Capability to conduct shadowgraphy on turbulent mixing.



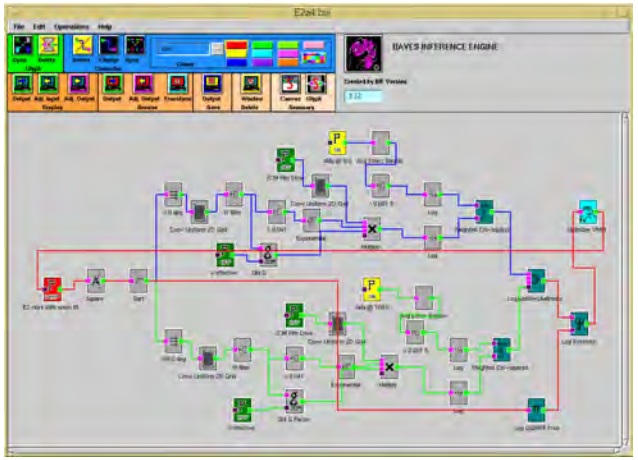


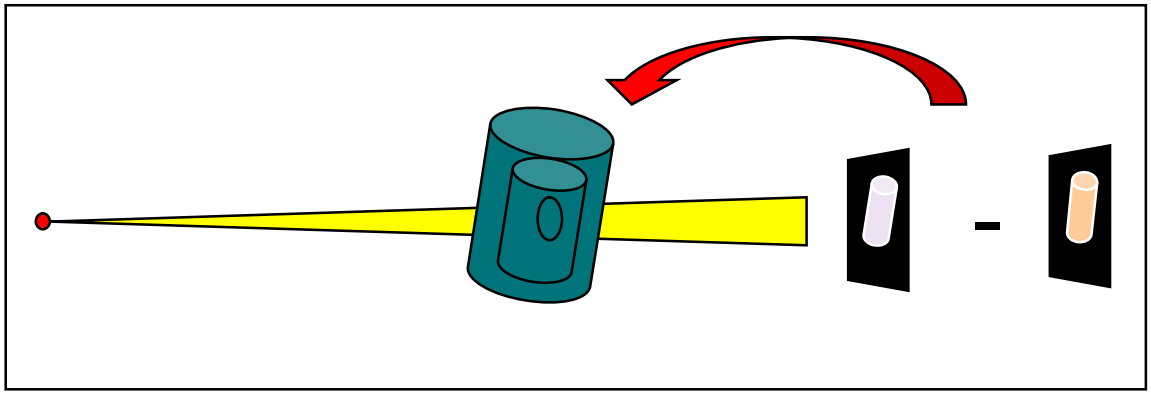


High pressure compression data on metals
P,T melt curve for metals at high pressure (laser heating)
Pu, U, Ta, Ti, V, PbSb, Ti64, Etc…
Pressure up to 1 Mbar +
Joint collaborations with LLNL, Edinburgh, UCL
Synchrotron beam time through collaborations

Image Analysis - Forward Modelling

- Make an estimate of the object
- Simulate the radiograph that would result from this object
- Iteratively change the object until the calculated dose agrees with the experimental dose





Due to experimental uncertainties solution non unique

Image Analysis aims to find the most probable solution

Using ‘prior knowledge’ to reject unlikely solutions

Summary

Essential capability to support AWE Mission

- Clear & Enduring UK need for Hydro data
- Unique UK testing facilities
- Unique ultra-high speed diagnostics
- Wide range of different types of Hydrodynamic Experiment carried out
- Strong & active area of international collaboration