PDV as a Diagnostic Tool for Separation Mechanisms, Particle Impact, and Hypervelocity Testing

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Outline

- Purpose
- WSTF Capabilities
- WSTF PDV Development
- NASA Applications of PDV
- Lessons Learned
- Questions

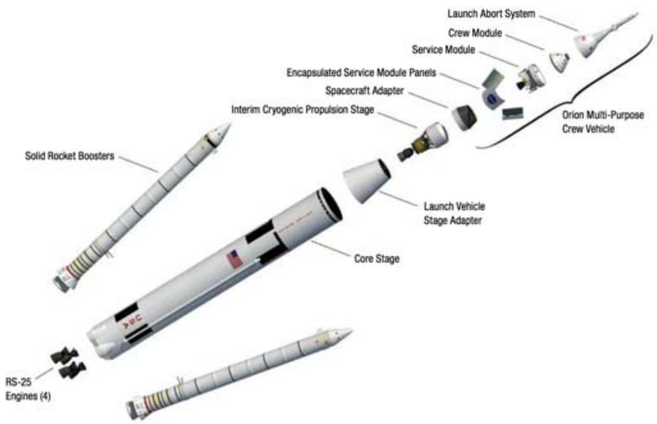
Acknowledgements

- Tim Gallus
- Brandon Maese
- Chris Keddy
- Sonny Gallegos
- Adam Iverson
- Ted Strand
- David Holtkamp
- Dan Dolan
- NKT Photonics
- Brook Jilek
- Steve Morra Third Millennium Engineering

Purpose

Past

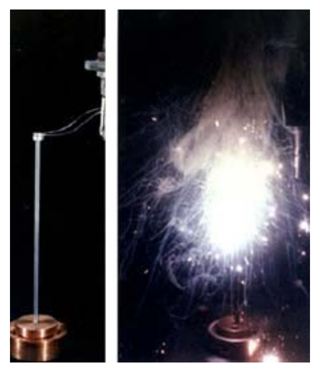
Present
and Future



What WSTF Does

Our mission is to provide the expertise and infrastructure to test and evaluate materials, components, and propulsion systems to enable the safe exploration and use of space

- Rocket Propulsion Testing and Evaluation
- Oxygen Systems Testing and Analysis
- Propellants and Aerospace Fluids Testing and Analysis
- Hypervelocity Impact Testing
- Composite Pressure Systems Testing and Analysis



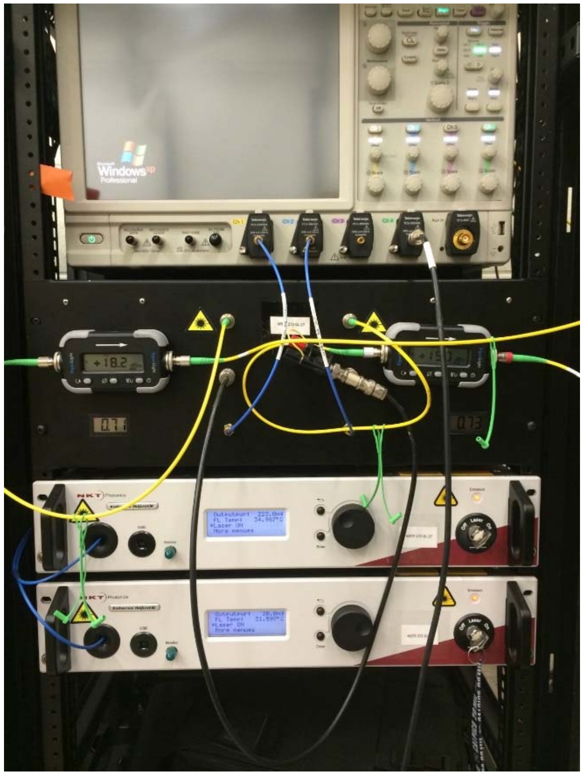
http://www.nasa.gov/centers/wstf/home/index.html

PDV Development

- 4-channel system
  - Capable of up to 10 km/s
- 8-channel/20-channel system
  - Capable of lower speed measurements (300 m/s)
  - Modular
  - Multiplexed Data

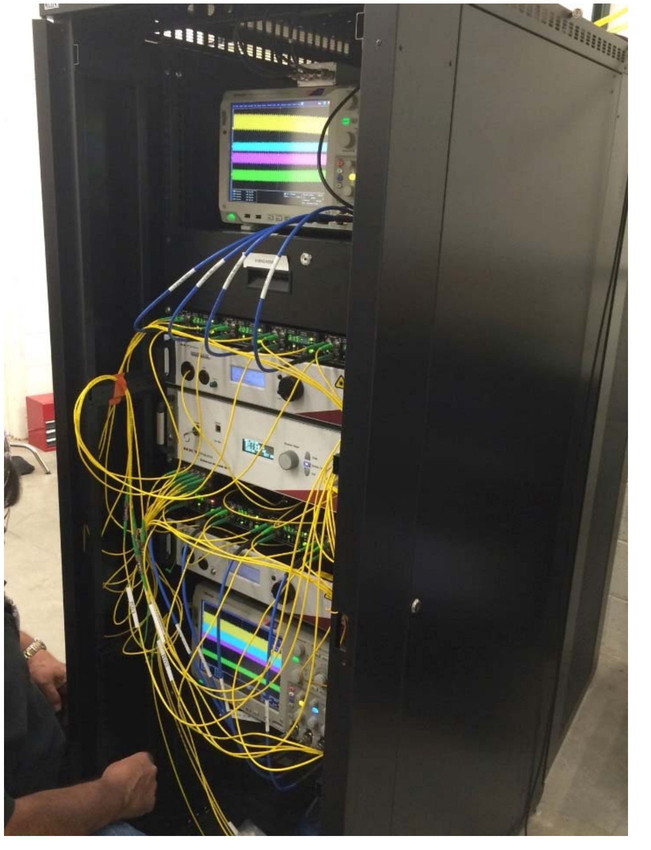
4-Channel Heterodyne System

- NKT Photonics Koheras Adjustik™ Lasers
- EigenLight OPMs
- Thorlabs Fiber Components
- Discovery Semiconductor Lab Buddy photo-detectors
- Tektronix Oscilloscope



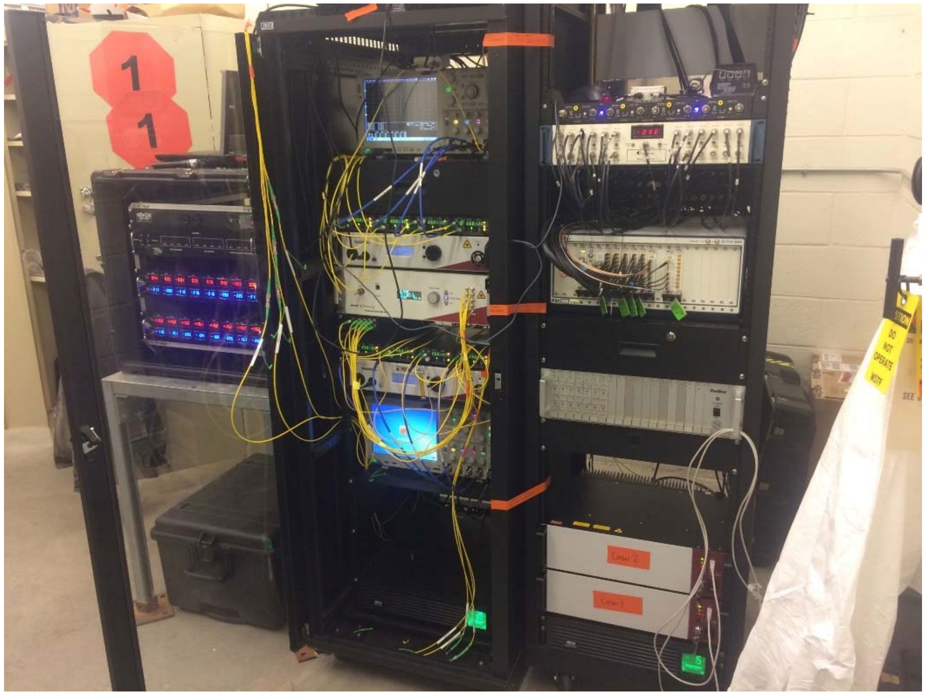
8-Channel Heterodyne System

- NKT Photonics Koheras Adjustik™ Lasers
- NKT Photonics Amplifier
- TME Receivers (Discovery Semiconductors PIN)
- Thorlabs Fiber Components
- OZ Optics Probes
- Tektronix Oscilloscopes



20-Channel Heterodyne System

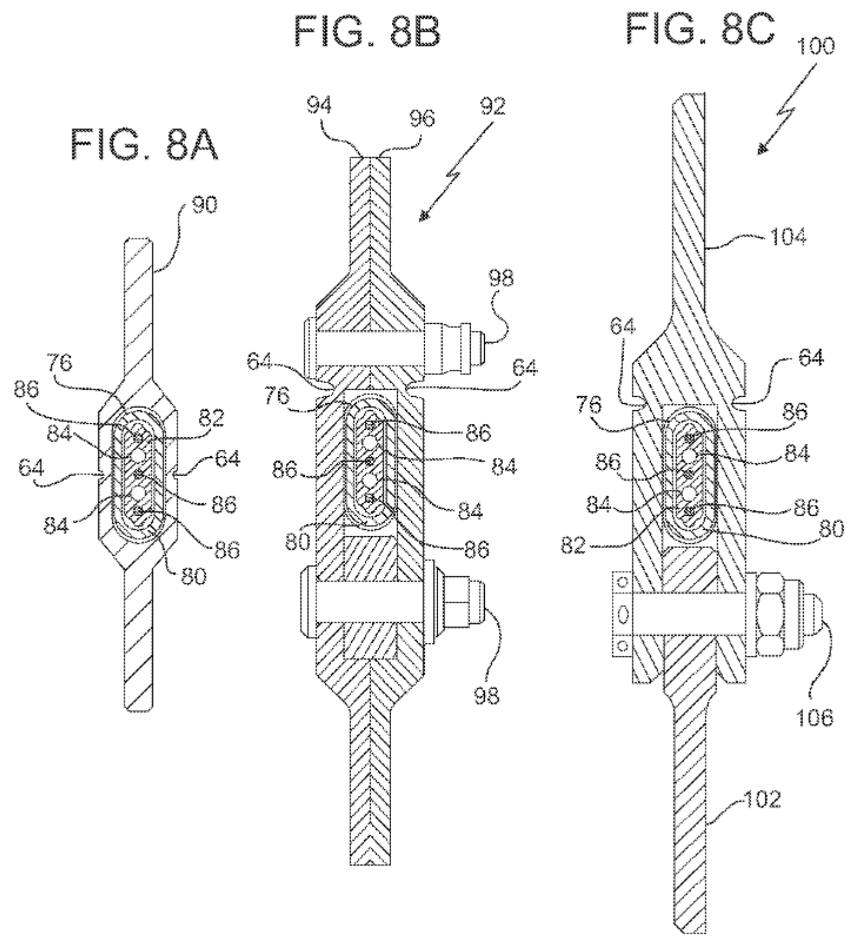
- NKT Photonics ACOUTIK Mux
  - Modular Koheras BASIK™ lasers
  - Multiple matched ITU Bands (30, 32, 34, 36)
- NKT Photonics Amplifier
- NSTec Muliplexing Unit
- TME Receivers (Discovery Semiconductors PIN)
- Thorlabs Fiber Components
- OZ Optics Probes
- Tektronix Oscilloscopes

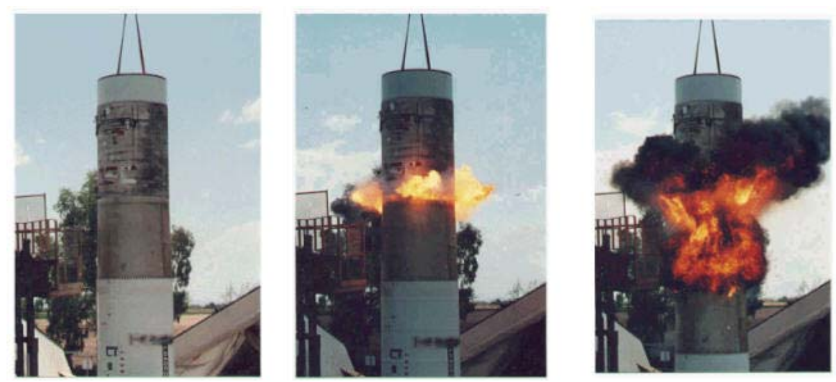


Applications For PDV

- Separation Mechanisms
- Particle Impact
- Hypervelocity Impact Testing

What Are Frangible Joints

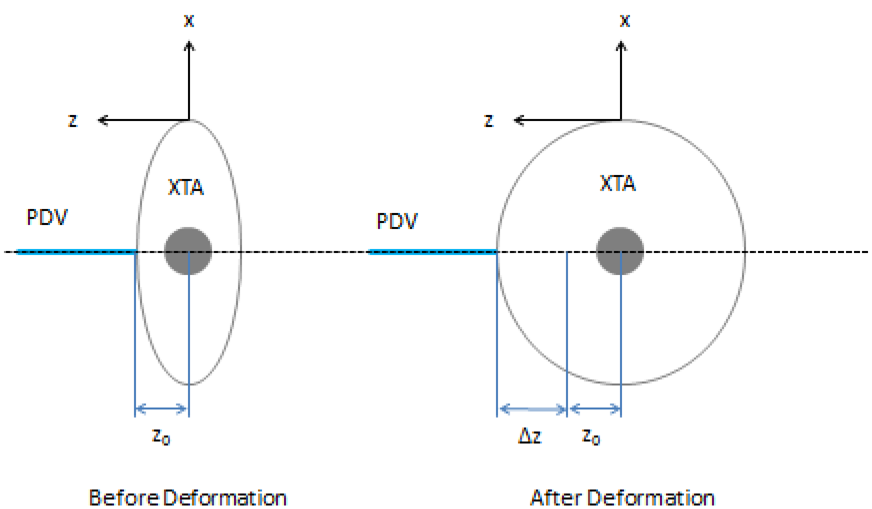


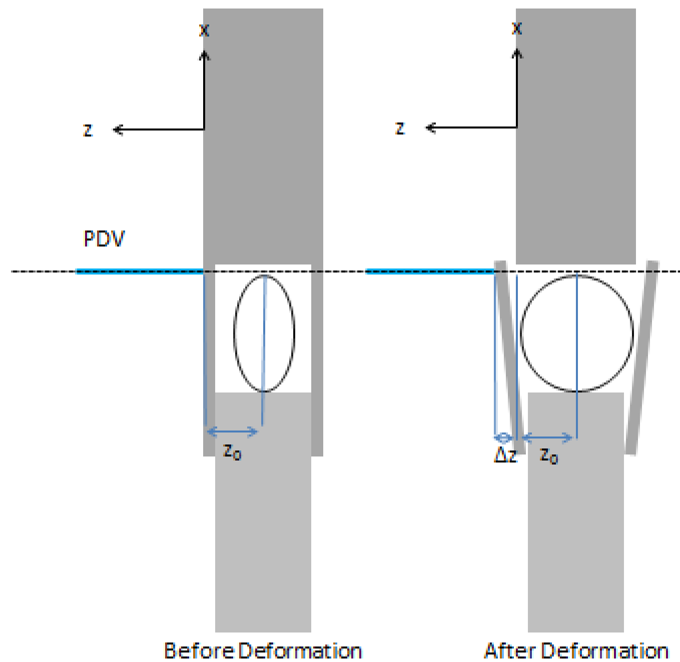


https://vibrationdata.wordpress.com/2012/09/04/pyrotechnic-shock-characterization-testing/

Patient US8695473 B2 also published as US20130233161 A1

Deformation Process





These events result in several centimeters of deflection and several milliseconds of movement; however, information is needed on the sub-microsecond level

Why Understand Frangible Joints

- February 24, 2009
  - The Orbiting Carbon Observatory satellite mission
  - Loss of Mission
- March 4, 2011
  - The Glory spacecraft satellite mission
  - Loss of Mission
- As a result of these failures the reliability and functionality of frangible joints have been called into question and an investigate by the NASA Engineering and Safety Center (NESC) has been initiated.
- Frangible Joints are in the designs proposals for manned space flight missions.

Frangible Joints

- Test program was designed to be both empirical and computational
  - How well do models predict the physics of a frangible joint?
- Multi-factor designed experiment
  - Defensible data that shows statistical significance in findings.
- What Effect Joints Performance/Reliability

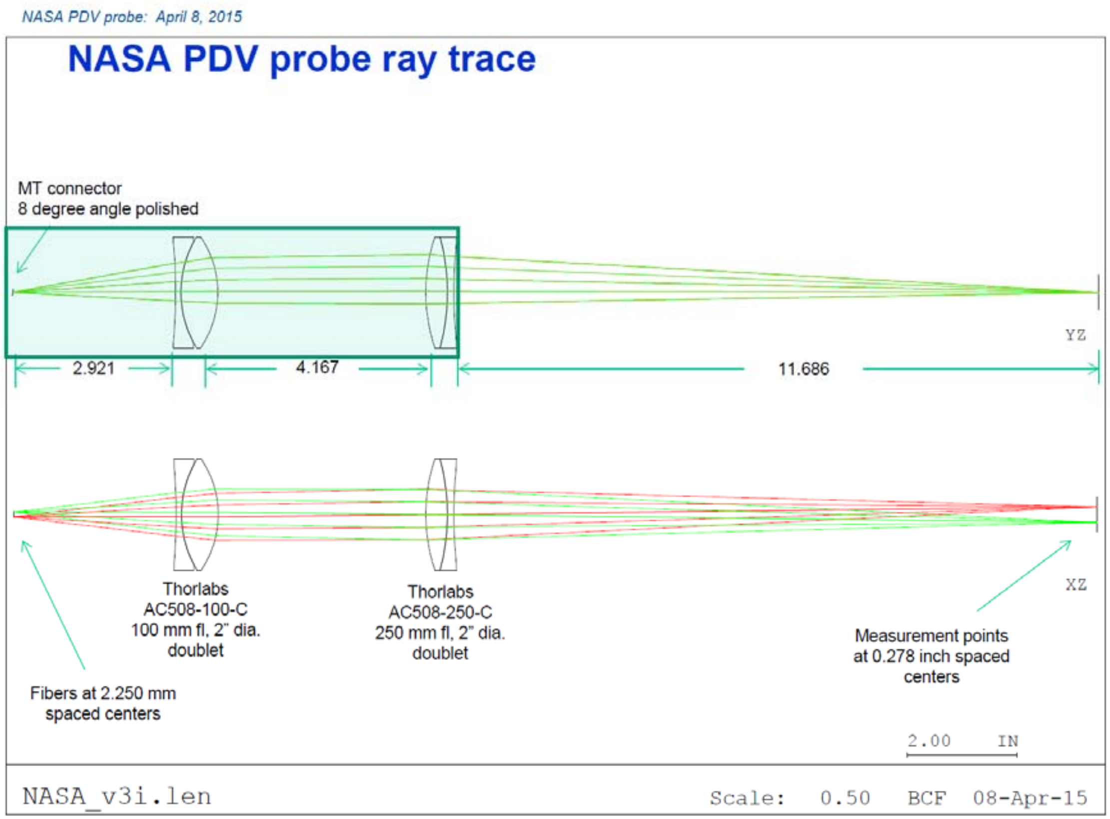
Frangible Joints

- Potential Factors Affecting Performance
  - Design Features (Tolerance and Choice)
  - Core Load
  - Symmetry
  - Boundary Conditions
  - Environment
  - Joint Type

Probe Locations

- Locations of PDV probes were very important
  - Physical Reasons (Computational Understanding)
  - Statistical Reasons (Empirical Understanding)
- Locations were chosen just below the notch of the frangible joint and along the mid-line of the mild detonating fuse (MDF)
- Certain channels were held constant throughout the program as design of experiment channels.
- We had very good luck with OZ Optics probes.
- Locations were held constant for approximately 50% of the channels.

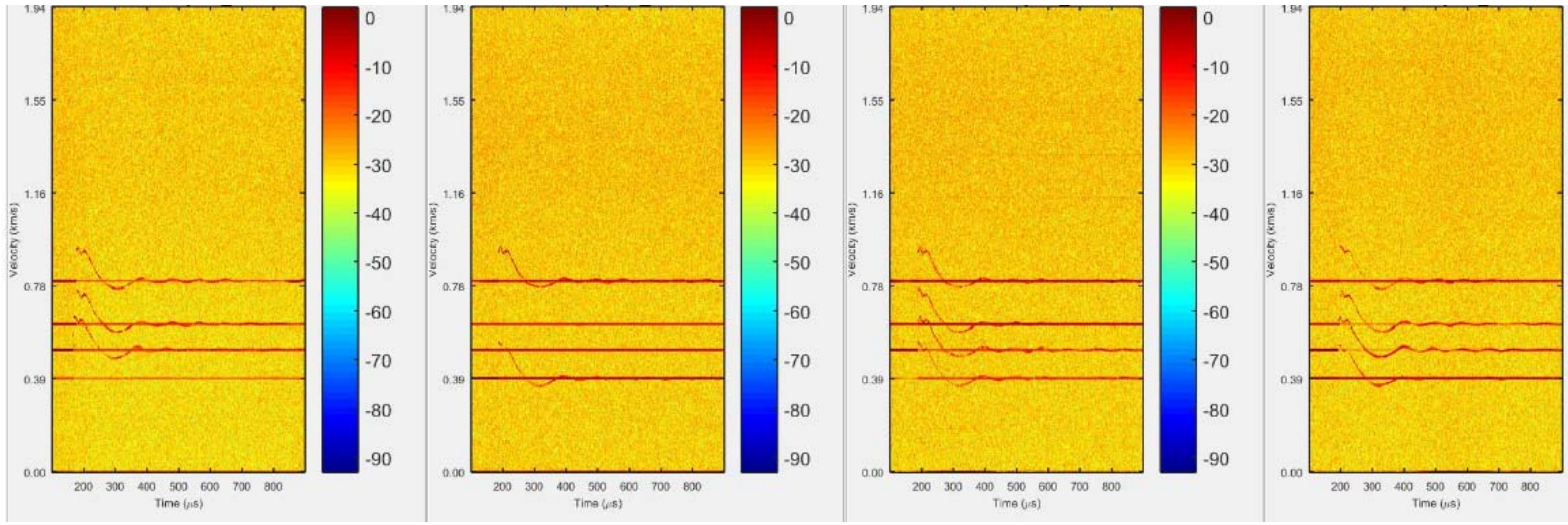
Custom Probe



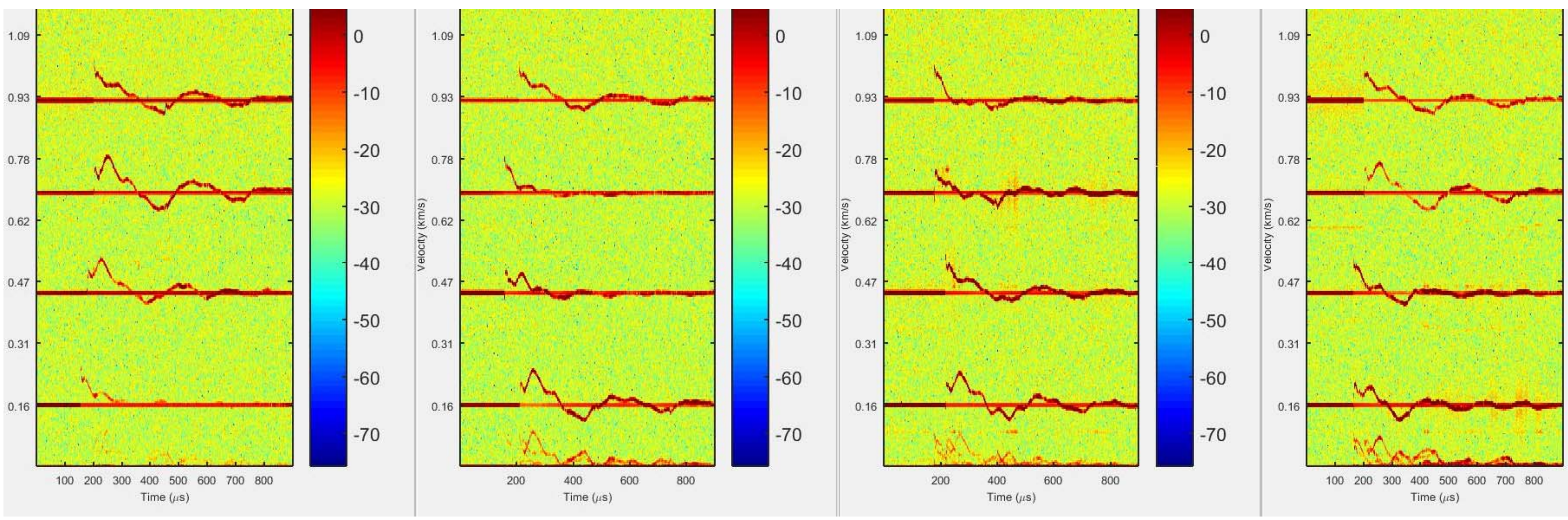
Spots	inches	mm
1-2	0.031	0.785
1-3	0.062	1.569
1-4	0.093	2.354
1-5	0.124	3.138
1-6	0.154	3.923
1-7	0.185	4.707
1-8	0.216	5.492
1-9	0.247	6.277
1-10	0.278	7.061
1-11	0.309	7.846
1-12	0.340	8.630

Probe design was by NSTec

Data Examples



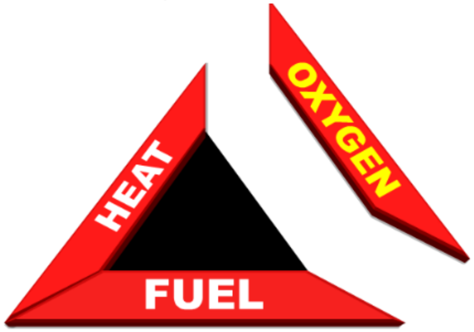
First Multiplexed Data



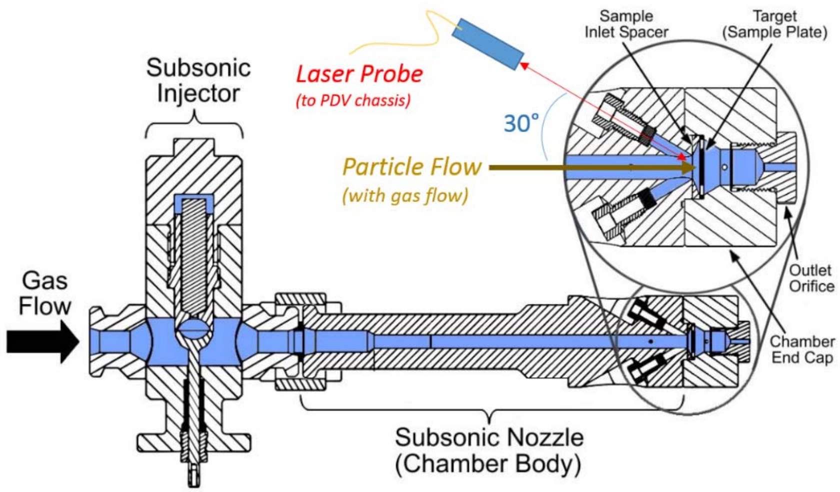
We got better with practice

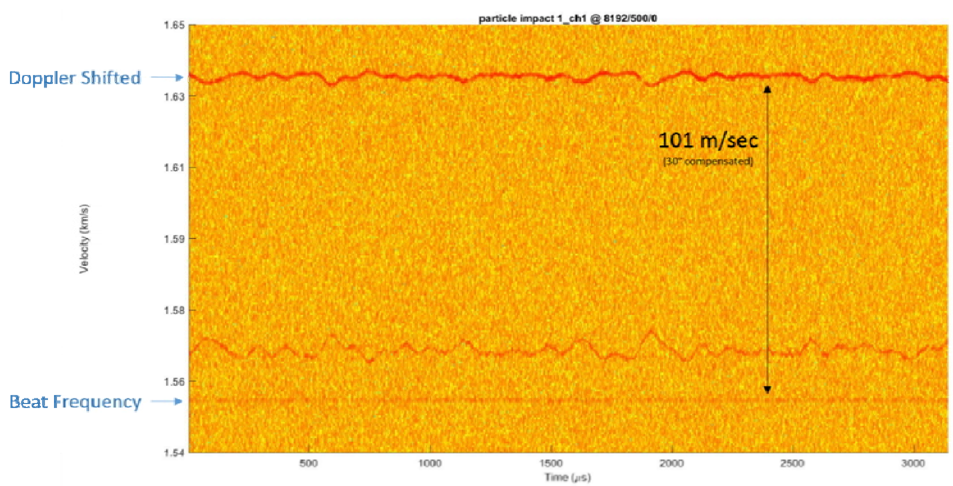
Particle Impact

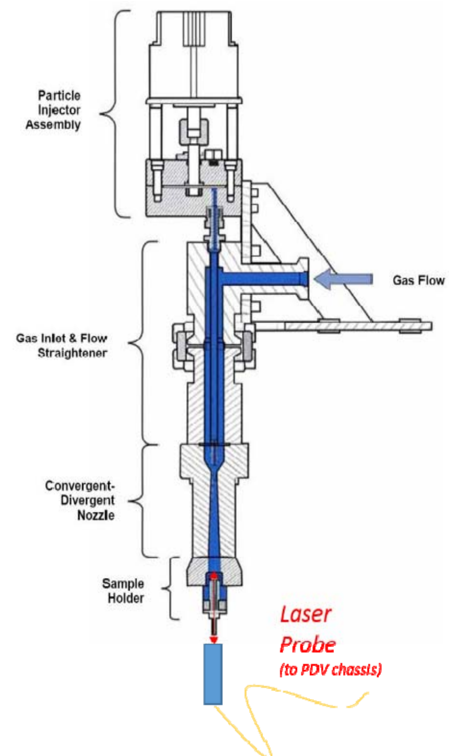
- In oxygen environments of elevated concentration, temperature, and pressure
  - Materials are easier to ignite and burn
  - Burn more vigorously
- Reduce risk by removing/reducing a leg of the fire triangle which is often heat sources
- Particle impact is a common ignition mechanism source of metals in oxygen systems.



Particle Impact

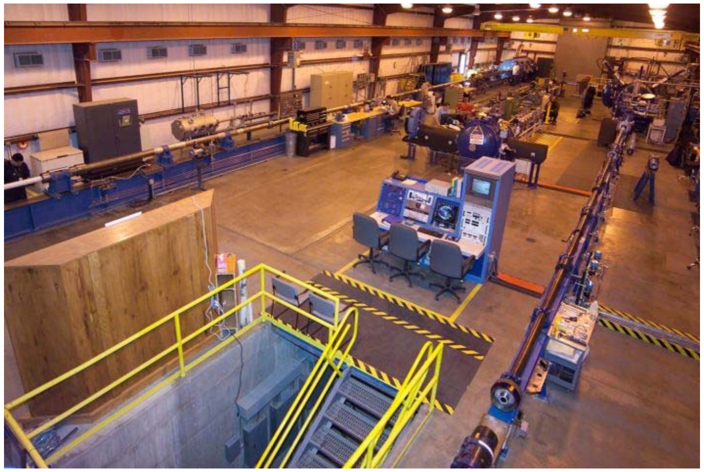




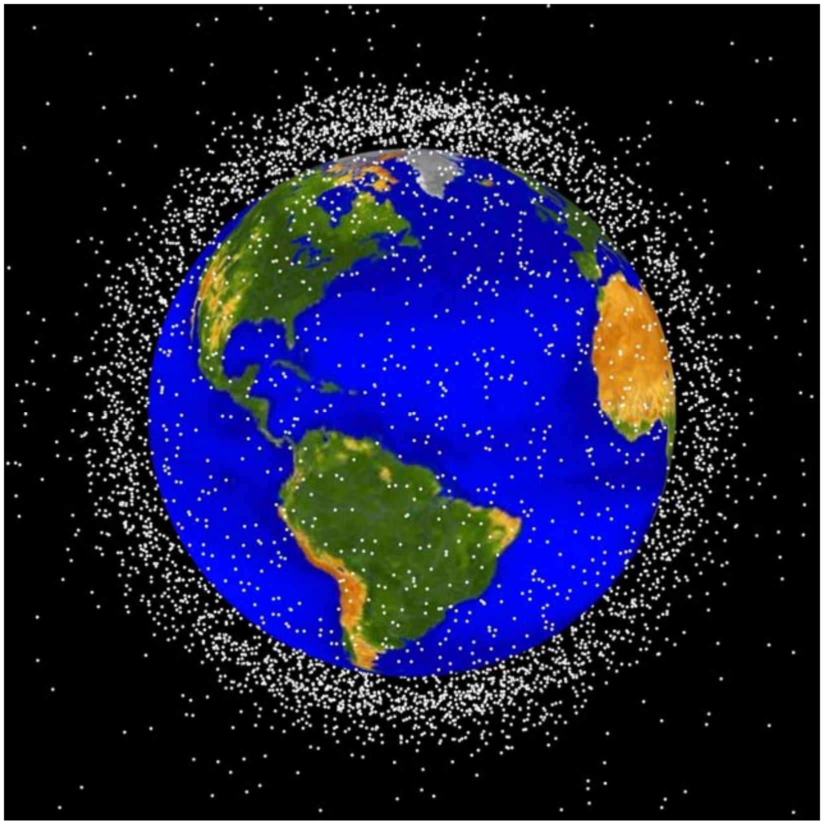


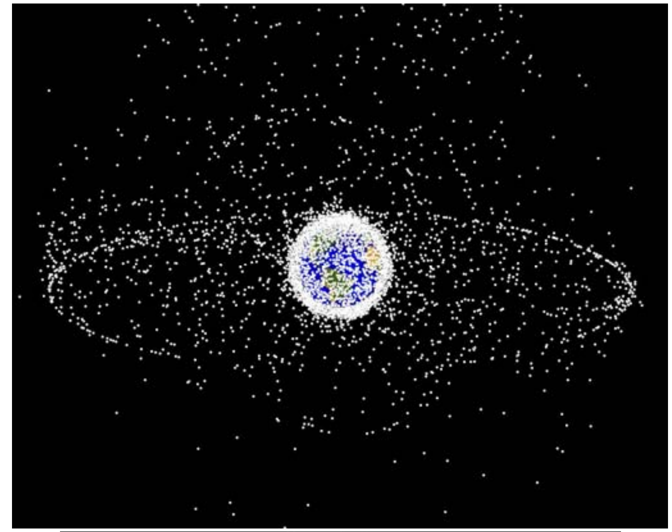
Hypervelocity

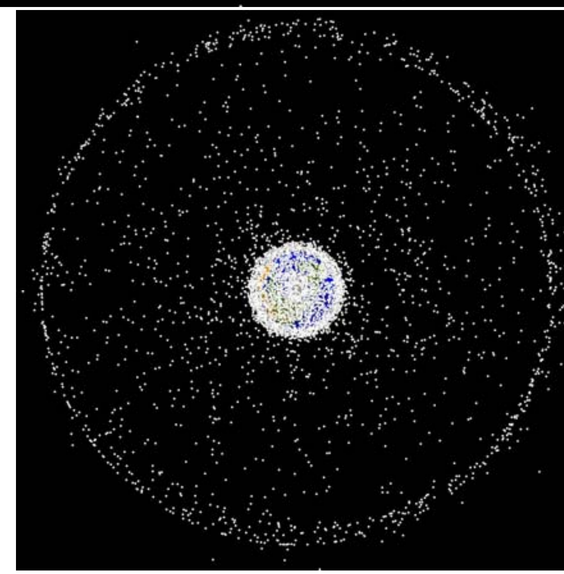
- How do materials respond to impact from space debris?
- How do you validate gun codes?



Hypervelocity



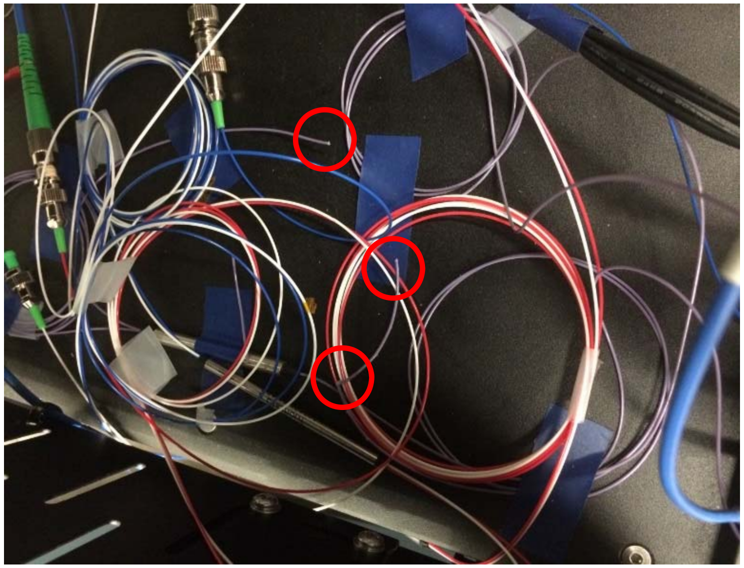




http://orbitaldebris.jsc.nasa.gov/photogallery/beehives.html

Lessons Learned

- Rodents Like fiber (not the dietary kind either)



Lessons Learned

- Unknowns can be painful when they lead to lost data like, laser amplifiers do not like low input power

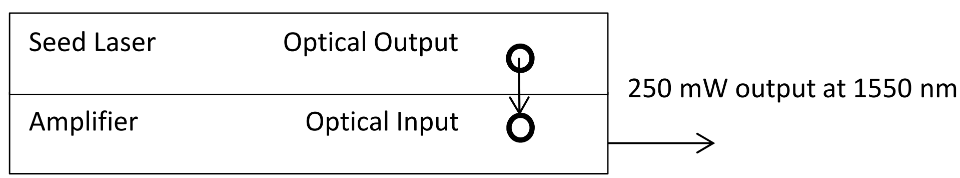


Figure 1 (Diagram of Koheras BOOSTIK™)

Lessons Learned

- System uncertainty can be difficult to quantify
  – Stacked probes may not be parallel
  – Center of probes are not necessarily the center of the housing
  – Small angle error becomes larger linear error at long probe stand off distances

Lessons Learned

- Multiplexing is not trivial
  - Multiple ITU bands into an EDFA lead to preferential amplification.
  - Drifting baseline caused by tunable cavity

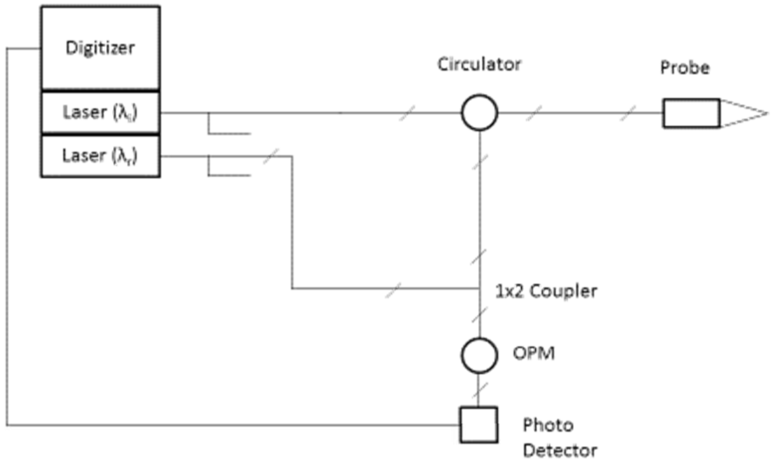
- Cleanliness, Cleanliness, Cleanliness

PDV's Future at NASA

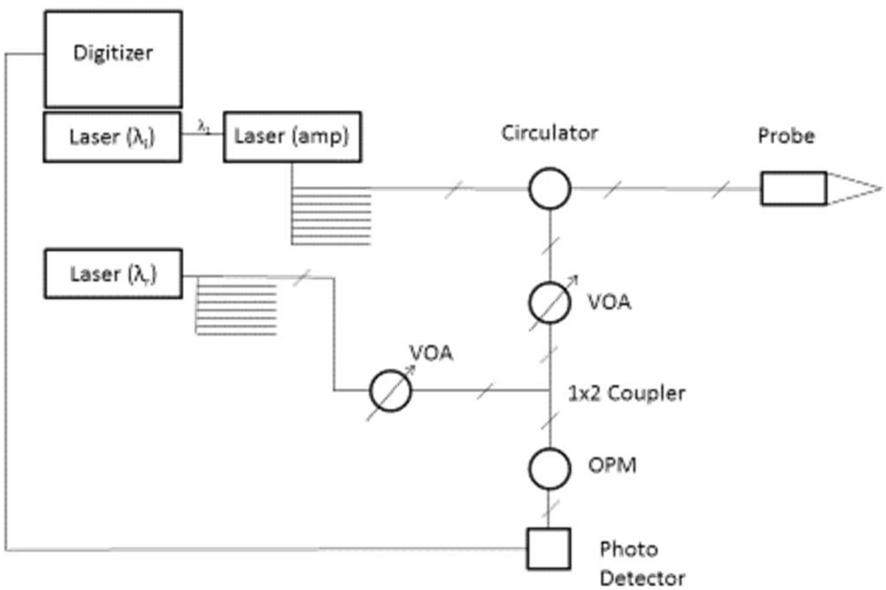
- Other Pyrotechnic Devices
  - Frangible Nuts
  - Pyro-shock testing
- Opportunities to further develop the technique through collaboration

Questions

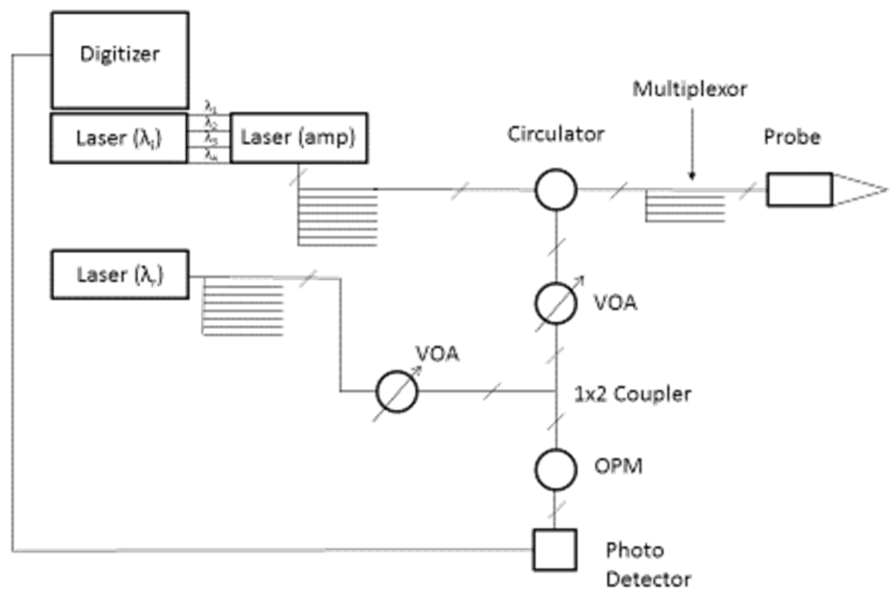
Back Up



Digitizer
Laser (λ_i)
Laser (λ_r)
Circulator
Probe
1x2 Coupler
OPM
Photo
Detector



Digitizer
Laser (λ_i)
λ_1
Laser (amp)
Circulator
Probe
Laser (λ_r)
VOA
VOA
1x2 Coupler
OPM
Photo
Detector



Digitizer
Laser (λ_i)
λ_1
λ_2
λ_3
λ_4
Laser (amp)
Circulator
Multiplexor
Probe
Laser (λ_r)
VOA
VOA
1x2 Coupler
OPM
Photo
Detector

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