Progress in Fielding a Zero-Focus Shadowgraph System for Ablation Measurement During Arc Jet Testing

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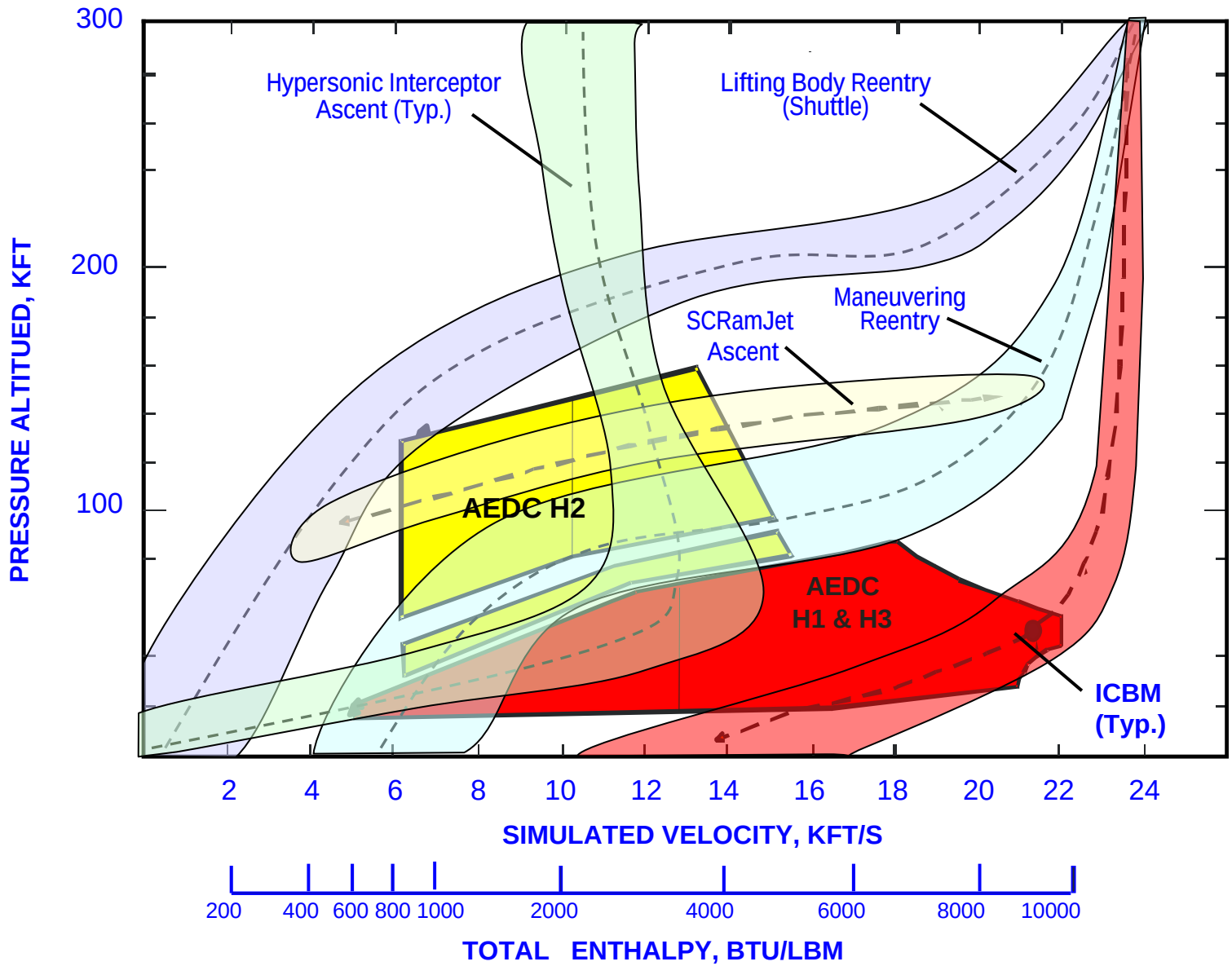
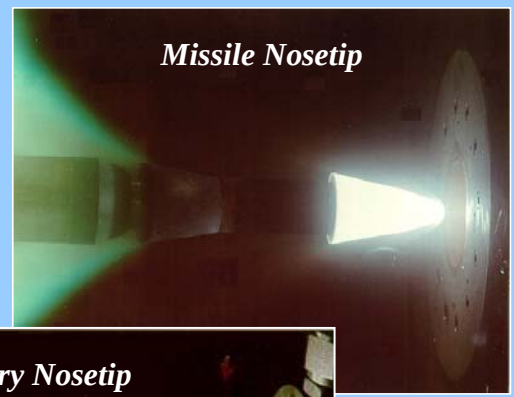
Outline

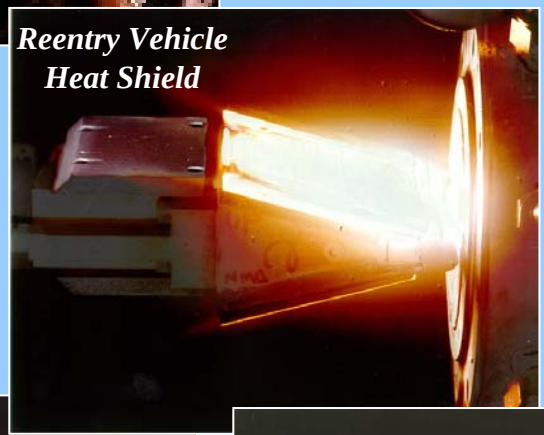
- Materials Testing in Arc Heated Tunnels
- Facility Description
- Issues - Motivation for New Technique
- Shadowgraph Technique
- Shadowgraph Images
- Image Reduction Method
- Conclusions

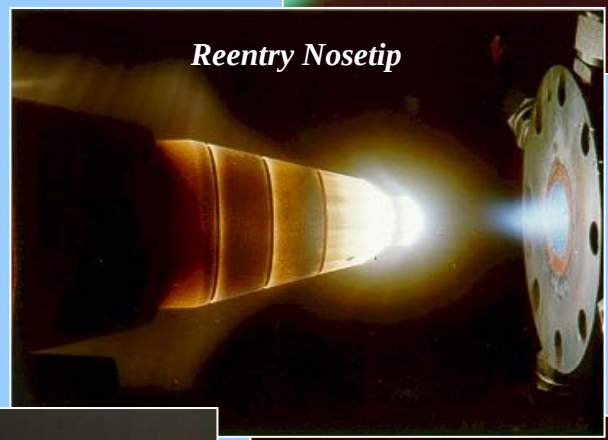
DOD Arc Heater Flight Simulation Envelope



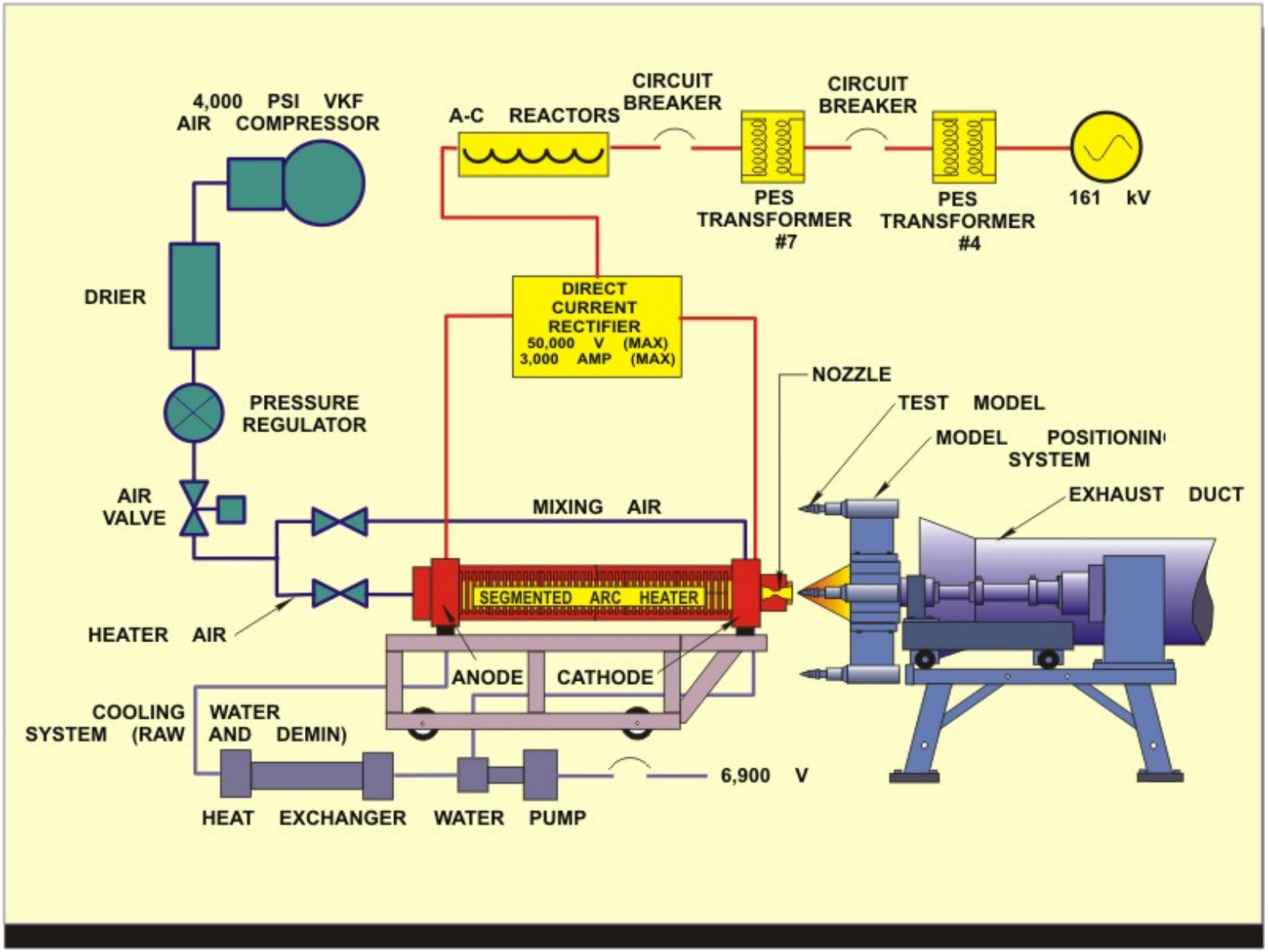
Typical Tests Performed







Schematic of HEAT H1 Facility



Film Reading

Technique

- Test article filmed during a run using split ND Filter
- Film developed, lengths determined manually
- Results typically available overnight

Issues

- Exposure, filtering, variances in test article brightness
- Little feedback soon after test, difficult to make adjustments
- Environmental issues

CCD/Image Analysis

Technique

- Record digital images using a CCD Camera
- Use image analysis software to determine profiles and ablation rates immediately after test

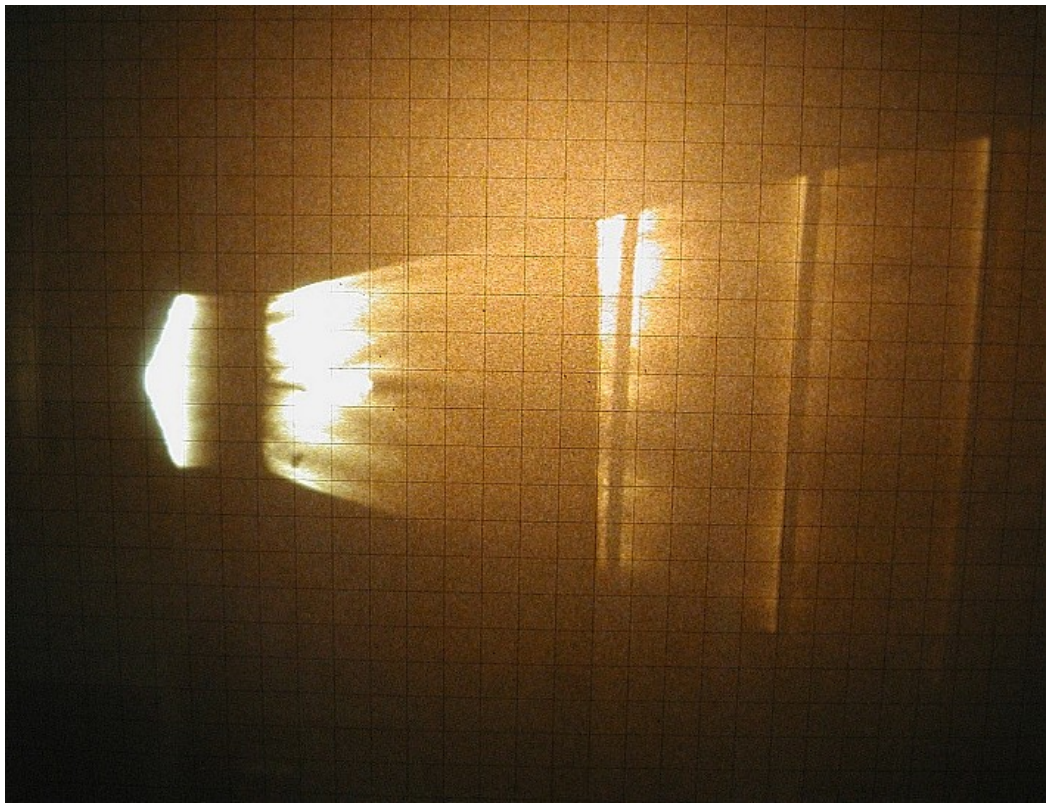
Advantages

- Immediate feedback
- Less labor intensive
- No chemicals

Difficulties in Using Images/Self-Luminosity

- Test article stagnation region extremely bright, washing out edges
- Split ND filter, natural brightness variations cause many edges
- Still have filtering issues due to variations in test article brightness

Standard Film Image of a Nosetip Test in H1



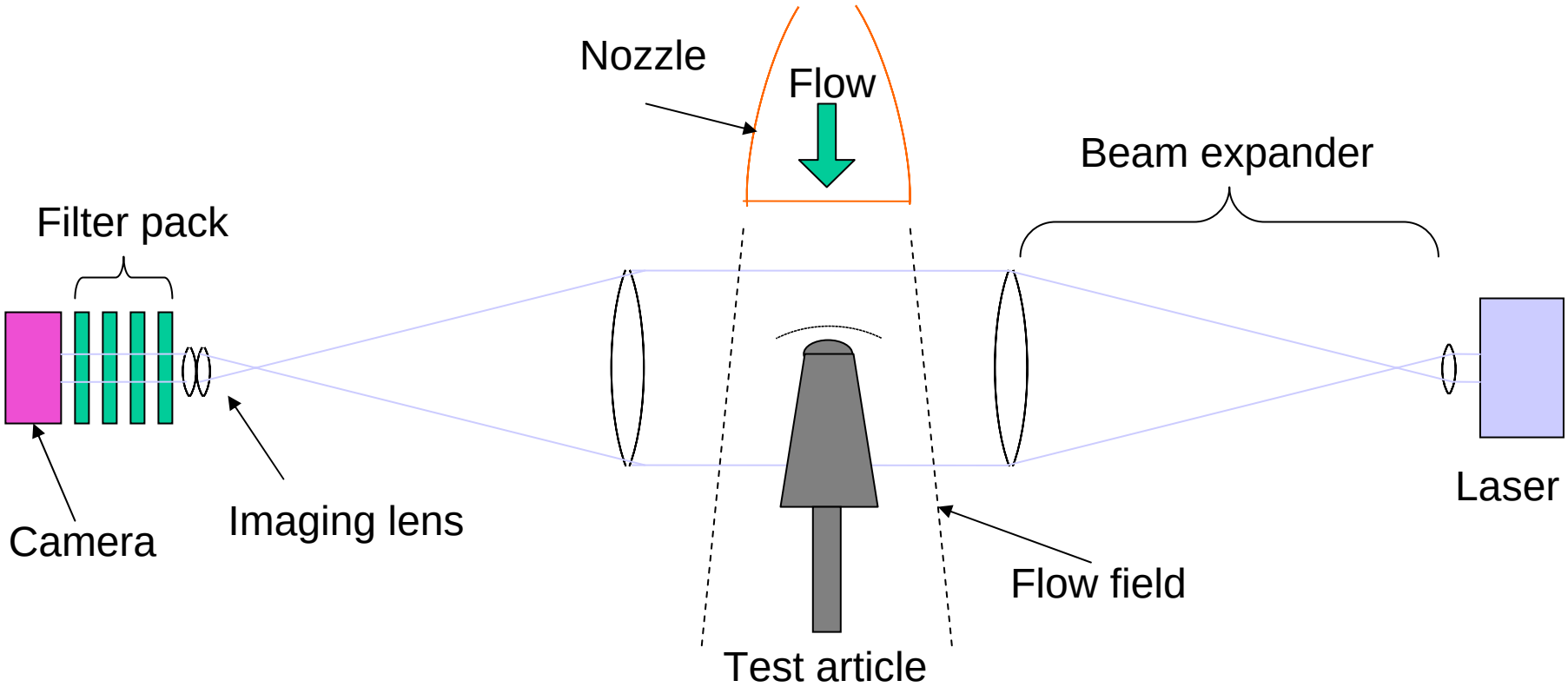
Proposed Solution:
Zero Focus Shadowgraph

- **Laser backlighting creates silhouette of test article**
- **Laser line filtered to eliminate self luminance**
- **Resultant image has high contrast test article edges**
- **Ideal for computer automated edge detection and tracking**

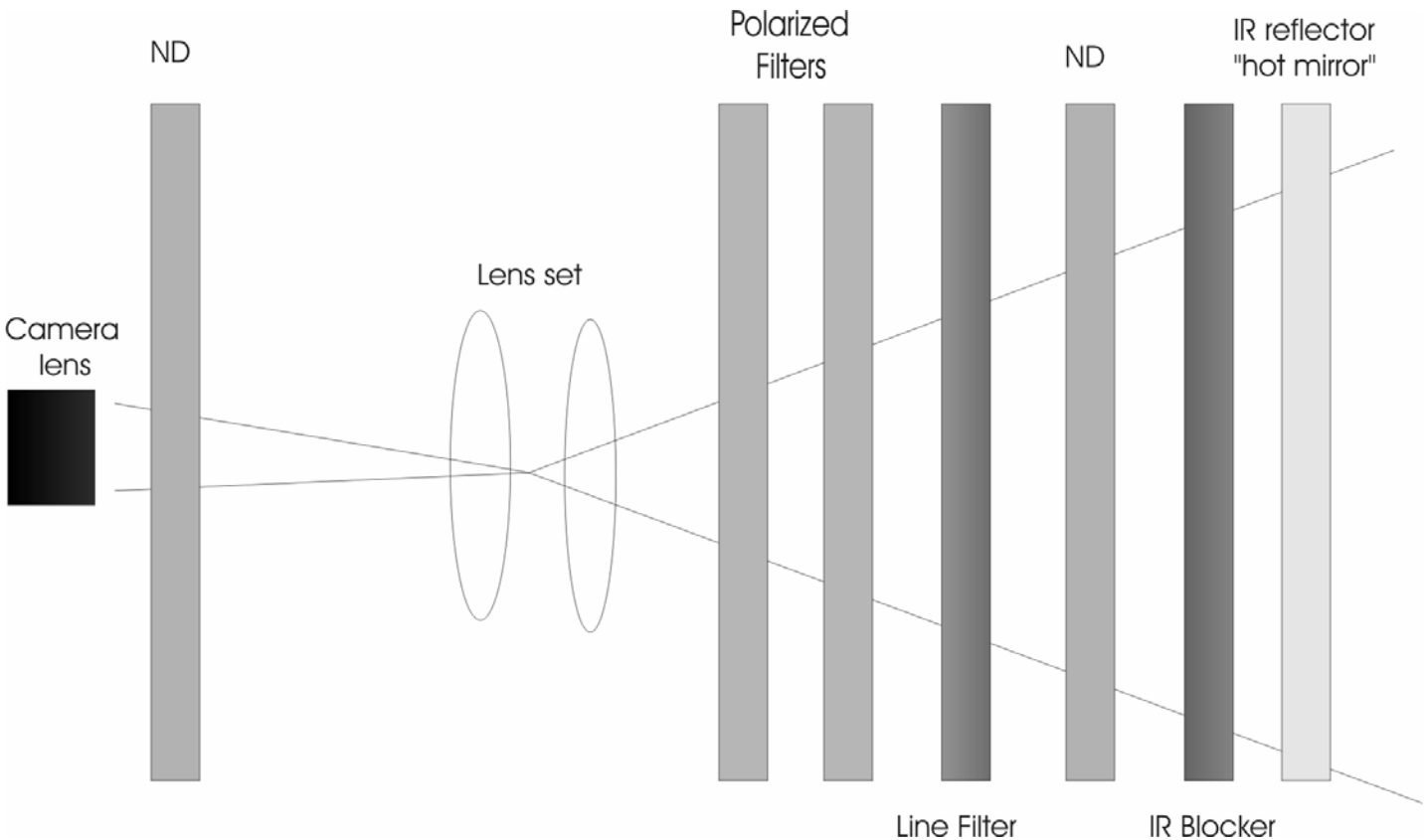
Arc-Specific Issues
- *Solutions*

- **Blocking of extreme test article incandescence**
  - *wavelength selection & "robust" filter design*
- **Flow density gradients create severe vignetting**
  - *Large aperture system & reduced vignetting design*
- **Radiant heat induced drift of filters**
  - *Front end IR blockers*
- "**Facility Smoke and Fire Tolerance**"
  - *Facility hardened system design*

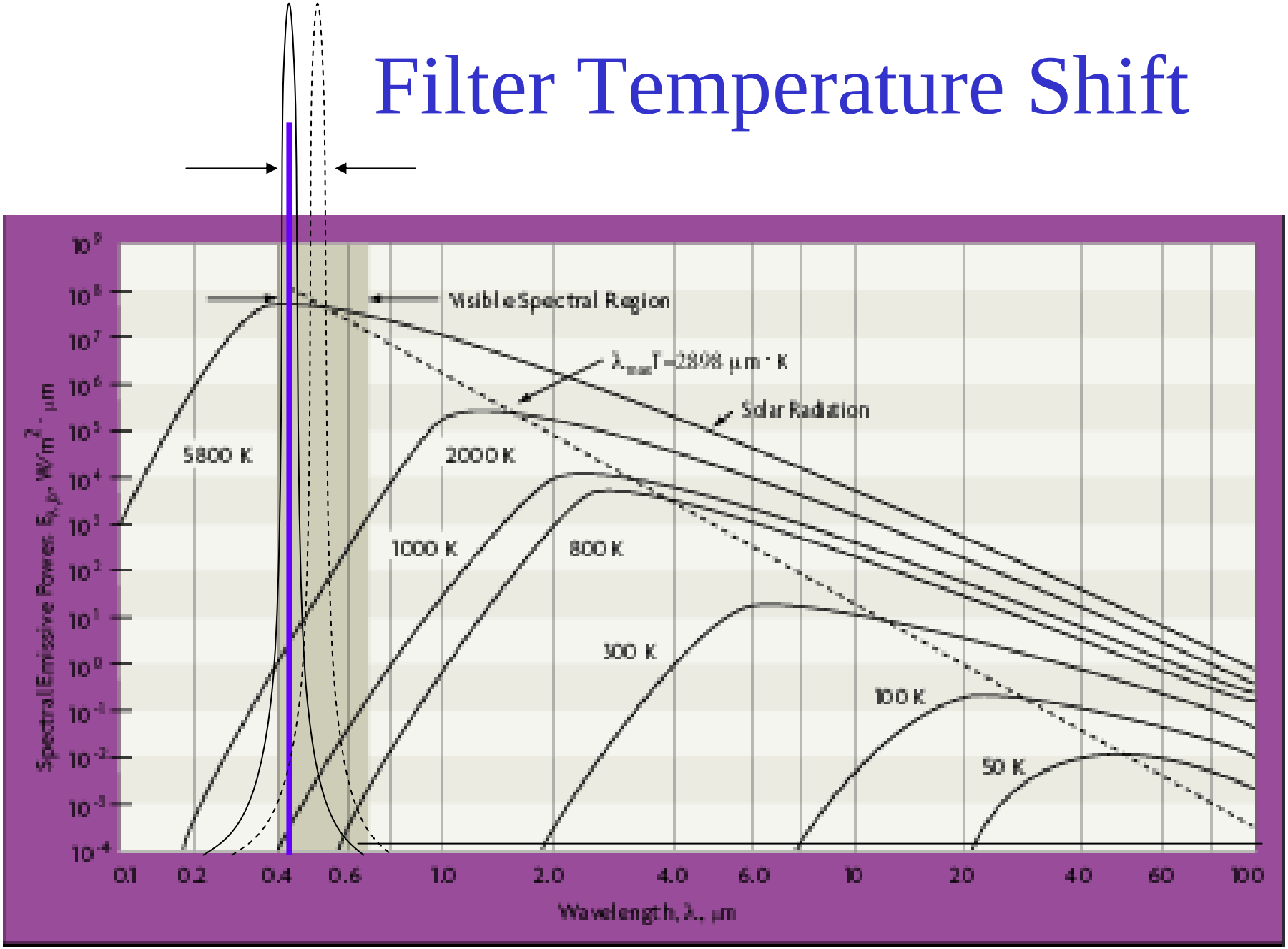
Zero-focus Shadowgraph Configuration



Receiver Assembly



Filter Temperature Shift



Zero-focus Shadowgraph of Nose-tip Test

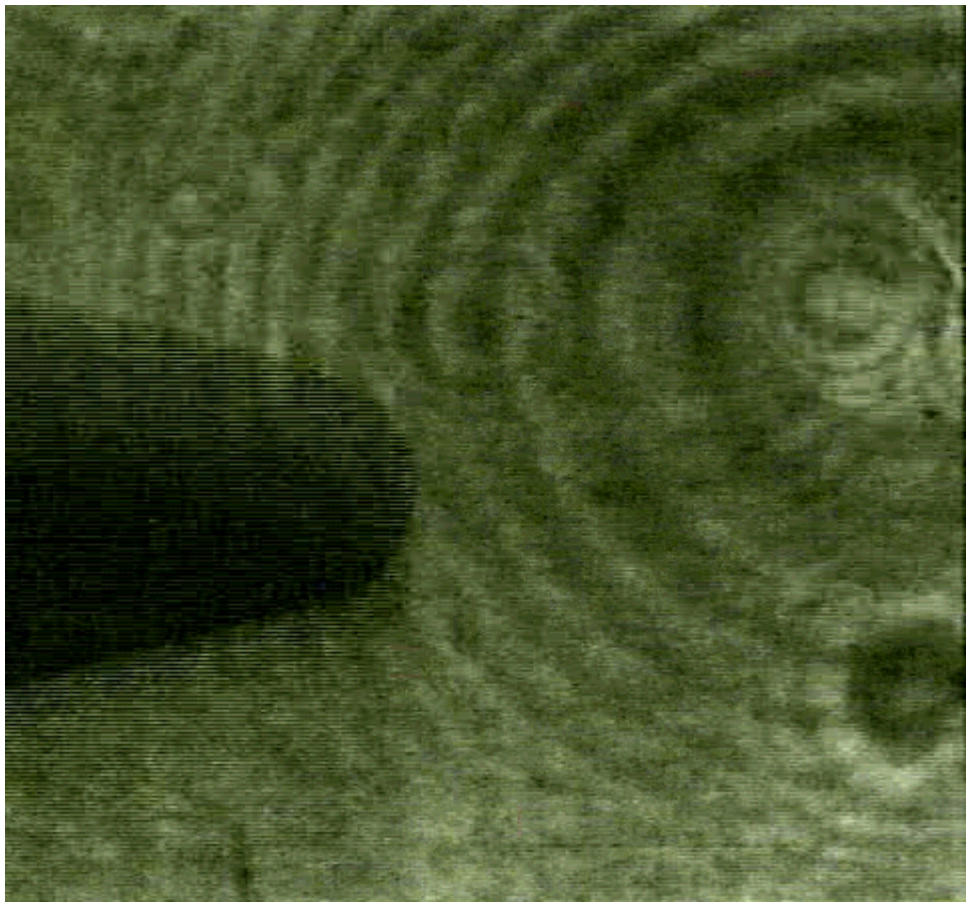
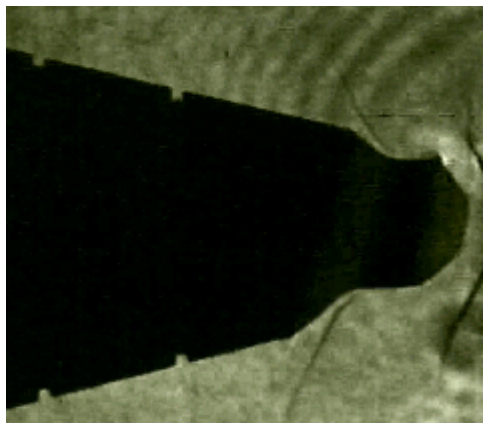
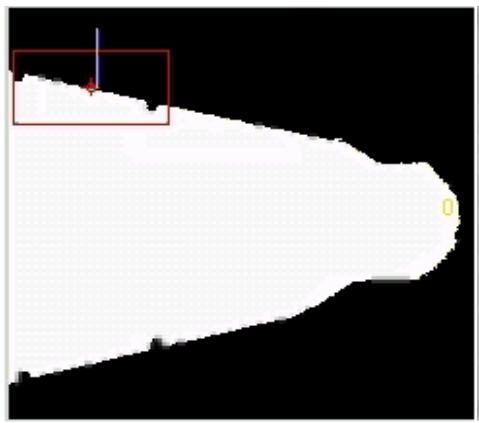


Image Processing on Zero Focus Shadowgraph

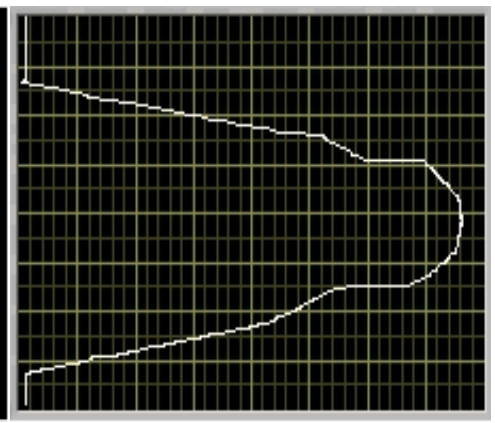
- Processing steps:
  - Setup the Image characteristics
    - Threshold levels
    - Area of interest
    - Process loop extremes
    - Image Inversion
  - Locate target pattern and determine leading edge
  - Calculate edge distance for each row and create shape



Original Image



Inverse with target



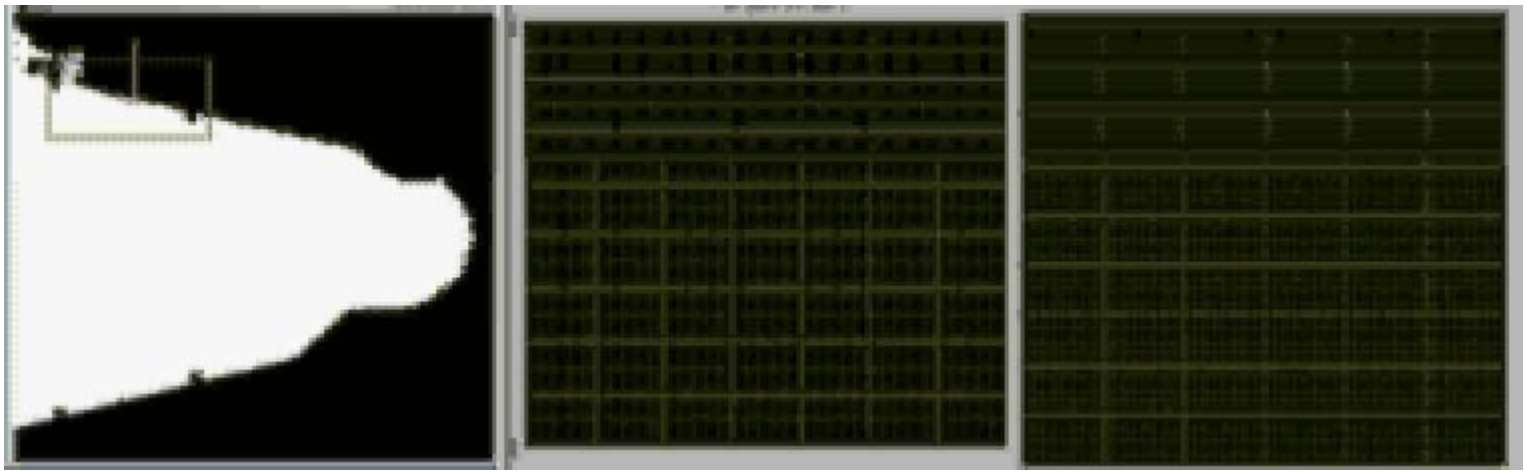
Target Shape

Image Processing on Zero Focus Shadowgraph

- Processing Complications
  - File Conversion
    - File had to be converted from the original AVI to a binary array in order to use standard programming techniques. Software based on LabVIEW™ from National Instruments™ (IMAQ image processing add-on toolkit)
    - LabVIEW™ conversion utilities were used to convert bitmap to data array
  - Non-Uniformity of Background
    - Optical artifacts in addition to bow-shock imagery caused problems setting a well defined target .vs. background threshold level.
    - An image inversion was performed prior to application of a Multi level threshold in order to convert original image to single bit image
  - Target Shape Definition
    - LabVIEW™ IMAQ toolkit provides a very useful pattern recognition tool.
    - Pattern recognition “highly” dependent on quality of imagery
    - Optimized optics on imager are needed in order to provide more defined target .vs. background contrast.

Image Processing on Zero Focus Shadowgraph

- Sample movie showing image processing of typical test article.



Conclusions

- Images of significant contrast were produced, suitable for image analysis
- Preliminary image analysis has been applied
- Capability to determine test article shape via automated analysis has been demonstrated
- Technique has the potential to reduce turn-around time to support decisions during test matrix execution