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Status of Non-Contact Handheld Imager for Reflective Particle Tags

Heidi A. Smartt, PhD

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Outline

- Introduction
  - Tags
  - "Contact" Reflective Particle Tag (RPT) System
- Non-Contact Handheld Tag Reader: Current Embodiment
- Security Considerations
- Next steps

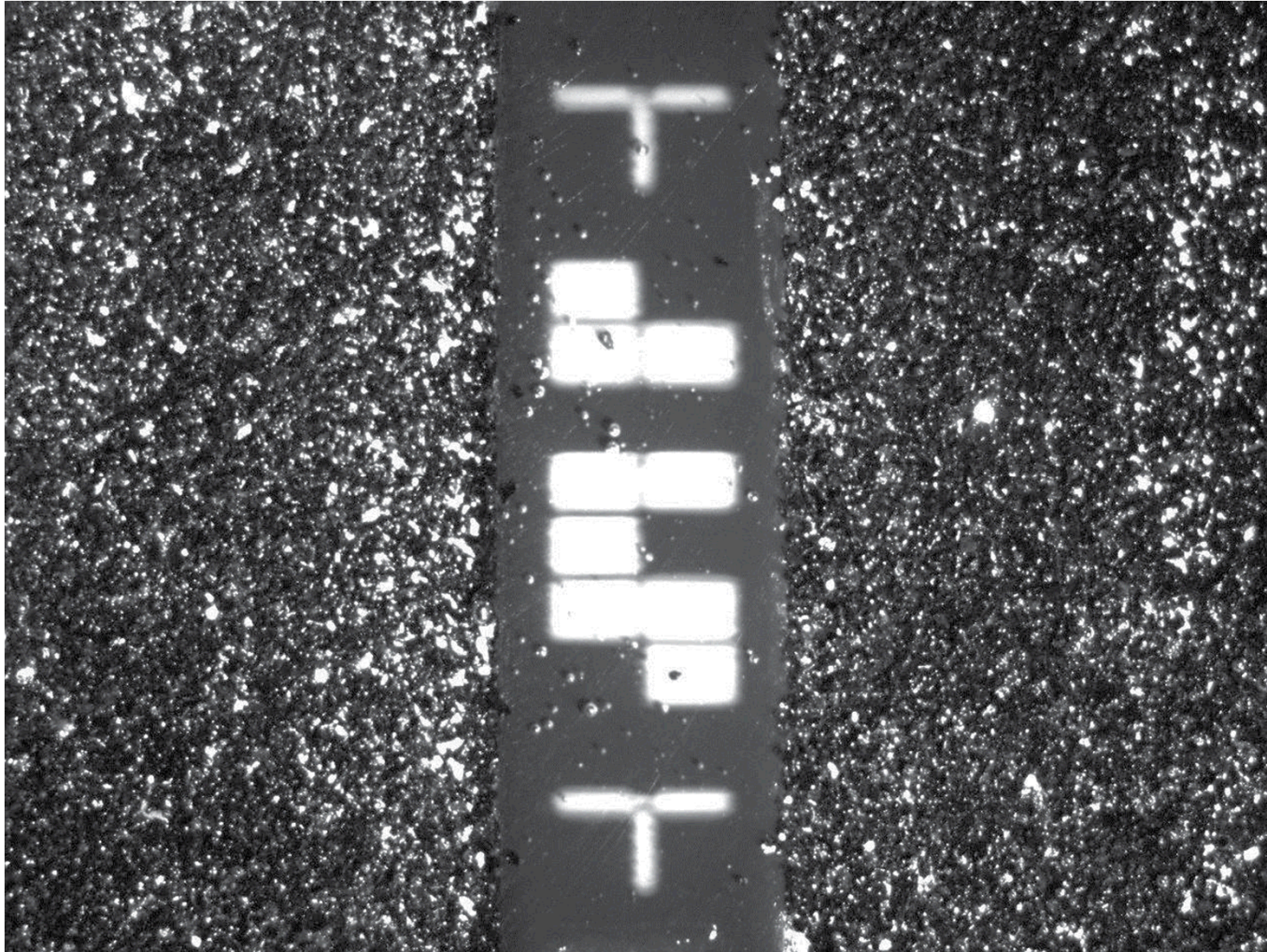# Tags in treaty verification

- Tags
  - Establish identity of item as accountable
  - Maintain Continuity of Knowledge (CoK) of item over time
  - Provide evidence of tampering
    - Either with item if applied appropriately
    - With tag itself
- Require continuous improvement
  - To counteract technical advances of potential adversaries
  - To respond to changing requirements
  - To incorporate technological advances that provide
    - Efficiency gains
    - Deployment in new application spaces
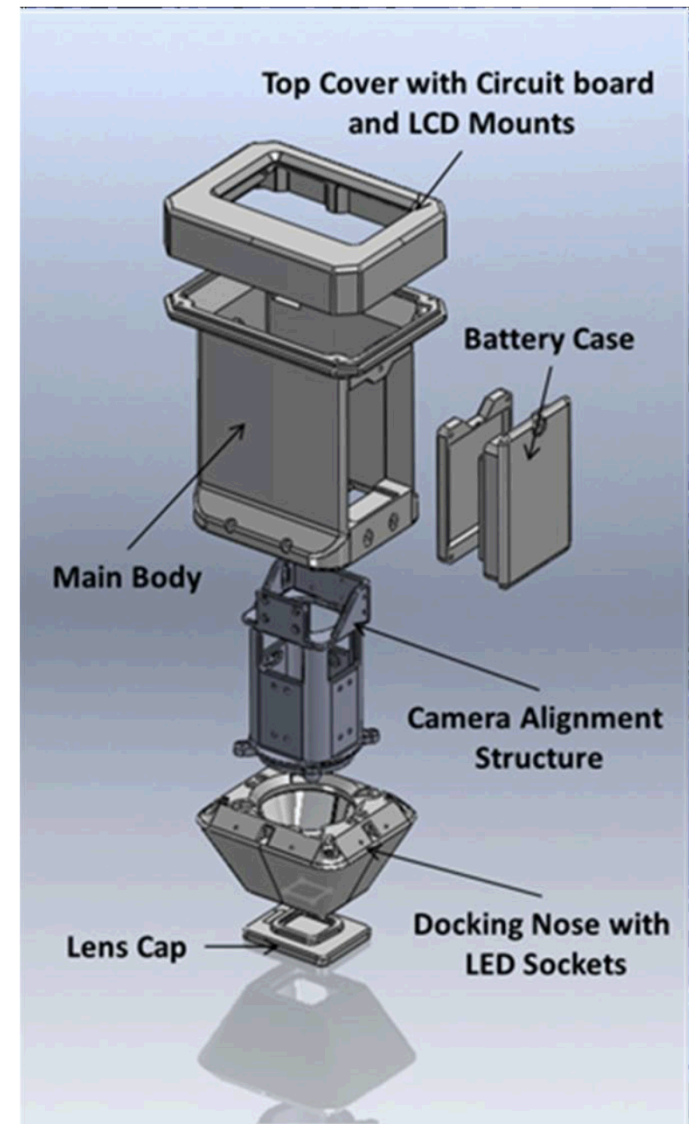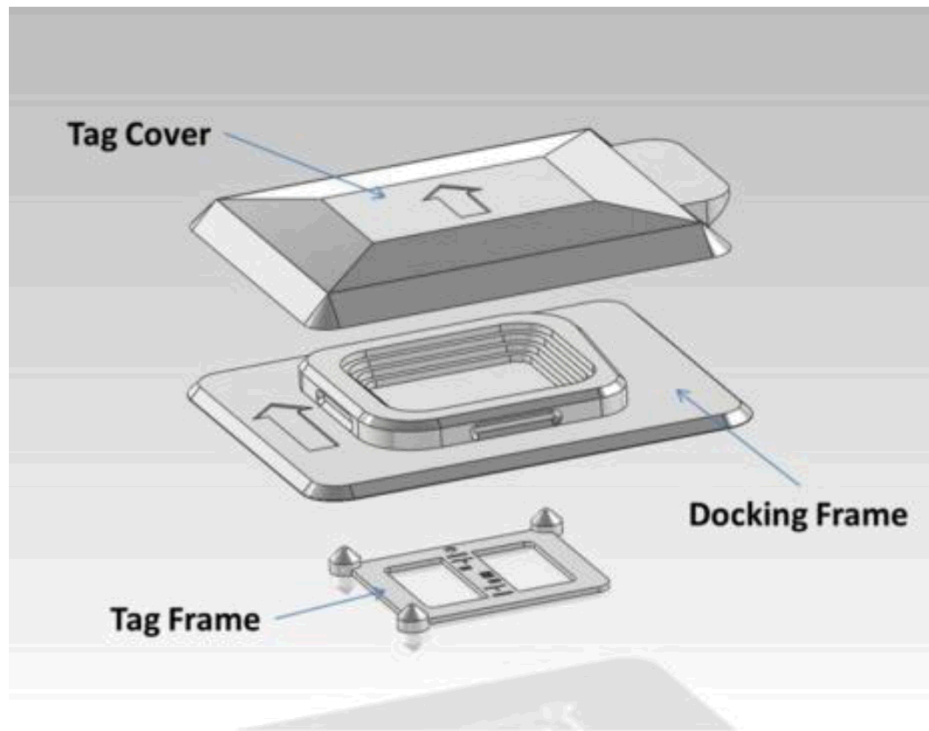
Contact Reflective Particle Tag (RPT) System

- Developed by Sandia in 1990s to tag treaty-accountable items

- Hematite particles in clear adhesive polymer matrix

- Reader (camera and illuminators)
  - Attaches to tag frame for alignment
  - Illuminates tag from 4 angles

- Each tag presents complex patterns of light reflections unique to tag

- Reader acquires 4 images and ID at midline of tag

- Inspector returns to item, attaches reader, compares ID and reflective patterns and verifies or rejects tag

Reflective Particle Tag (RPT)

Contact RPT frame, cover, reader

Tag Cover

Docking Frame

Tag Frame

Top Cover with Circuit board and LCD Mounts

Battery Case

Main Body

Camera Alignment Structure

Docking Nose with LED Sockets

Lens Cap

Contact RPT benefits and potential improvements

- Benefits
  - Resistant to counterfeiting and removal without detection
  - Environmentally robust
  - Passive
  - Low cost
- Improvements can be made by
  - Option to remove frame
    - Allows application to curved surfaces
  - Non-contact readout
    - Minimize inspector time in harsh environments
    - Allows automation
    - Host policy

Project goal

- Develop system:
  - With tag that can be applied to complex geometries
  - Read with non-contact handheld system
  - Maintains
    - High security
    - Durability
    - Low cost
    - Easy application

New design philosophy

- Borrow from previous system where appropriate
    - Illumination from multiple angles
    - Central camera and optics
    - Hematite particles in matrix
- Reduce emphasis on *precise* registration of imager with tag
    - Allows non-contact handheld format
- Recognize when acceptable alignment momentarily achieved
- Current embodiment relies on "read head" tethered to desktop to assess approach
- Next version moves from desktop to tablet for true non-contact handheld system

Illumination and Imaging System

4 megapixel CMOS camera, 90 frames/sec

High-power LED

High-power LED

Tag
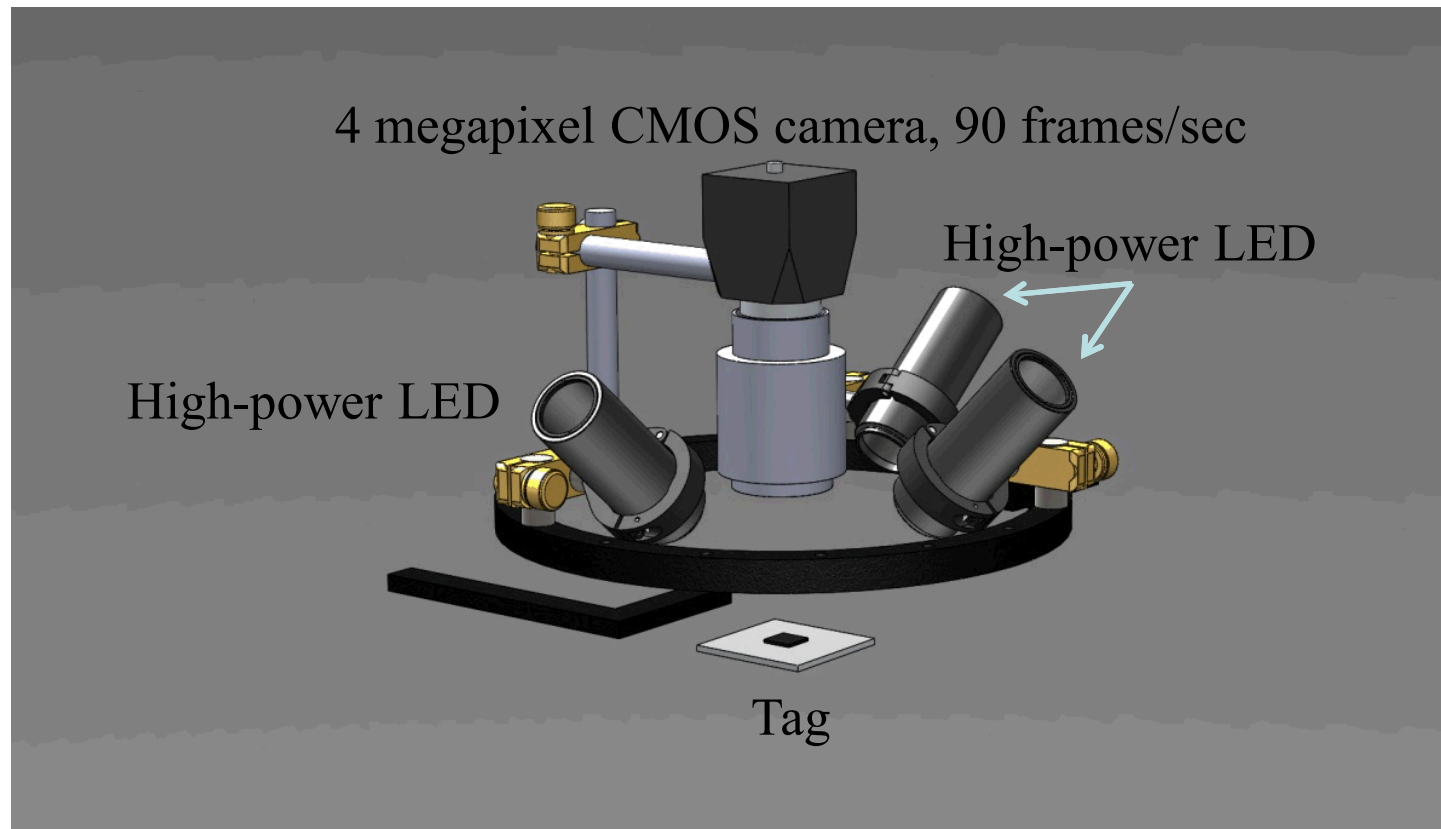
- Illuminators project ~F/2 beams
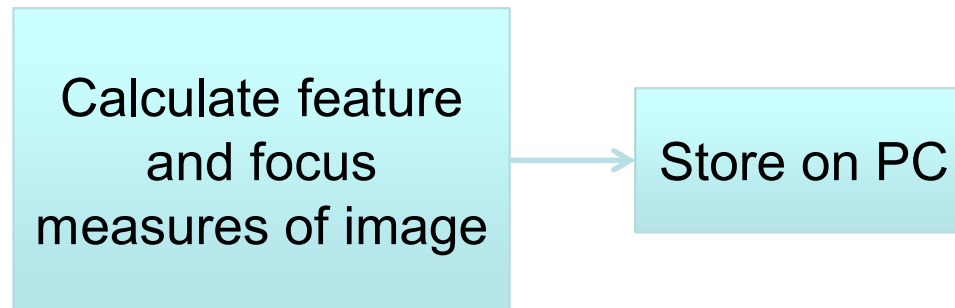- Object space f-number of camera lens ~F/5.6

Computer Vision System

- 2 main steps – alignment and verification
- Alignment allows inspector to re-image tag at relatively same position as when tag was initially placed and imaged
    - Occurs in real time on desktop/tablet
    - Provides feedback to inspector for improvement
- Verification determines if image sets match
    - Offline processing
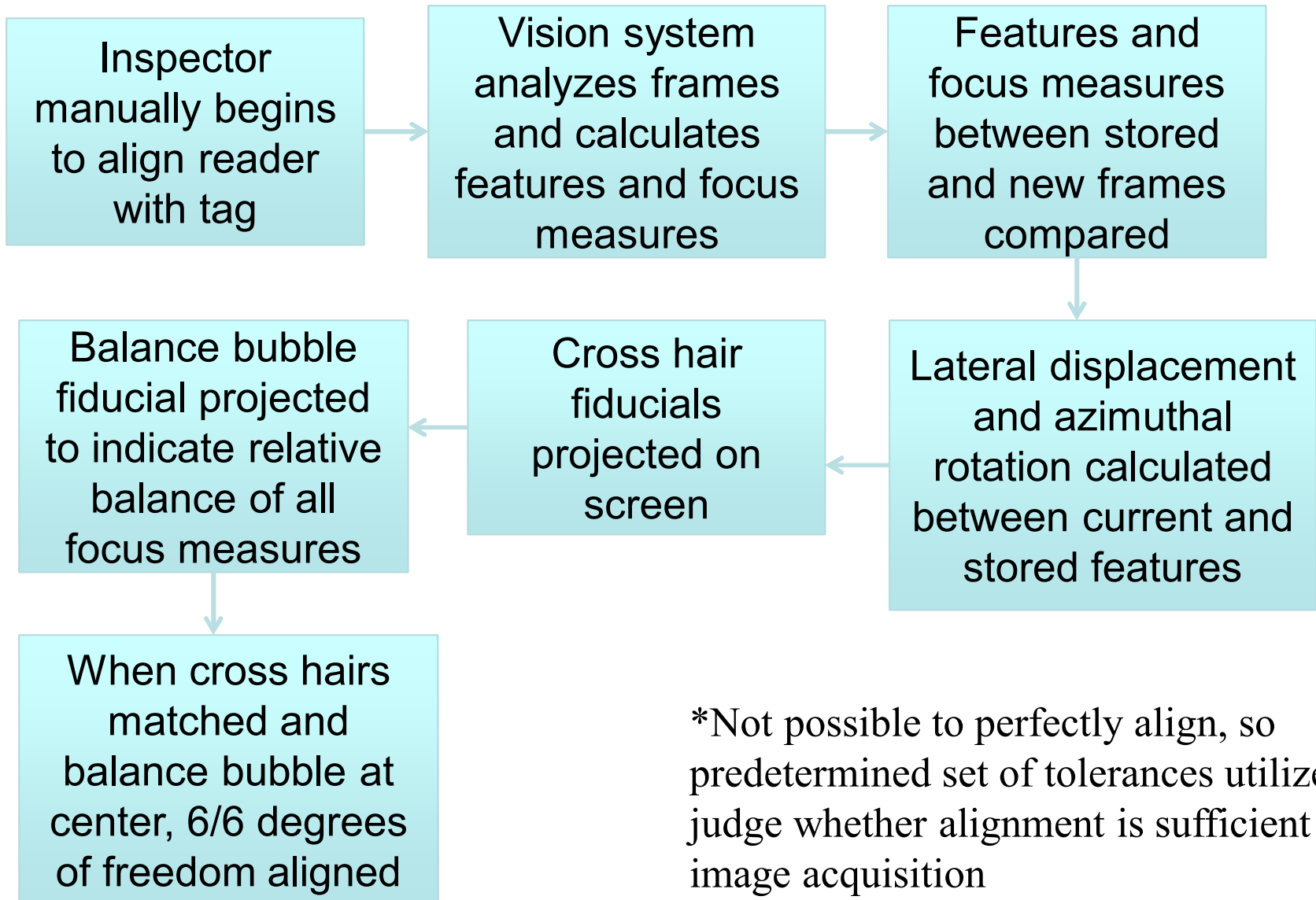   - Image sets are from initial tag placement and subsequent image acquisition

Alignment, initial tag set

- Rely on "image features" and "focus measures" recorded at time tag initially set
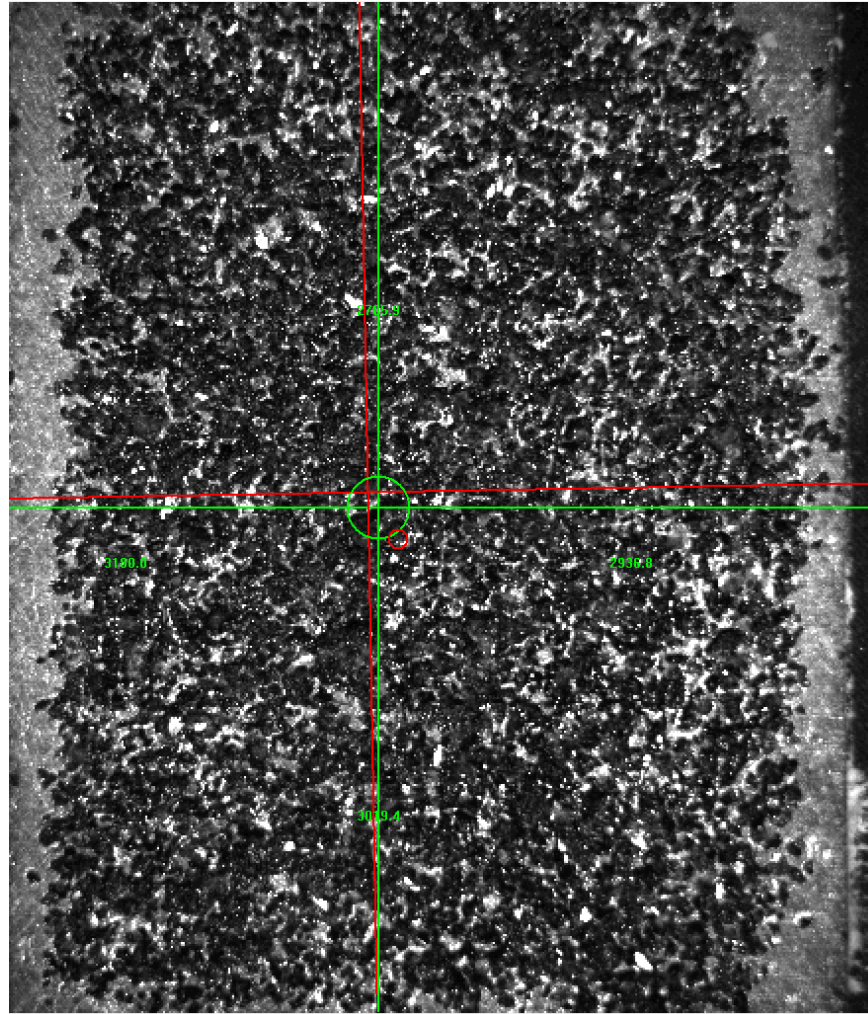
Initial tag image acquisition

Calculate feature and focus measures of image → Store on PC

Inspector returns to verify tag

Inspector manually begins to align reader with tag

Vision system analyzes frames and calculates features and focus measures

Features and focus measures between stored and new frames compared

Lateral displacement and azimuthal rotation calculated between current and stored features

Cross hair fiducials projected on screen

Balance bubble fiducial projected to indicate relative balance of all focus measures

When cross hairs matched and balance bubble at center, 6/6 degrees of freedom aligned

*Not possible to perfectly align, so predetermined set of tolerances utilized to judge whether alignment is sufficient for image acquisition

Alignment fiducials

Verification

- Once alignment is achieved, burst of images acquired
  - ~100 full resolution frames
  - 90 frames/second
- During image acquisition
  - Illuminators sequentially strobed
  - Focus is dithered to allow in-focus images of all regions of potentially non-flat tag
- Image features compared to determine "match"

Security Considerations

- Important to ensure that design changes have not negatively impacted system security

- Defined security figure of merit and compared contact and non-contact systems

- Calculated security figure of merit for non-contact handheld reader larger than contact RPT system by factor of 3

Next steps

- Test impact of human motion on alignment precision and image quality

- Perform tests using existing RPT tags to demonstrate non-contact handheld system feasibility

- Replace desktop computer with tablet computer and custom circuit boards