



Minimally-Intrusive Verification: A Fresh Look at the Buddy-Tag Concept

Ben Reimold, Alexander Glaser, Andrew Kim, Dan Steingart

Department of Mechanical & Aerospace Engineering, Princeton University, Princeton, NJ

Consortium for Verification Technology (CVT)

Director: Sara Pozzi, University of Michigan



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Motivation and Introduction

Verification of a limit of number of nuclear weapons will require the ability for inspectors to count individual warheads, both deployed and non-deployed. This can be accomplished by “tagging” treaty-accountable items with unique identifiers (UIDs), which transforms a numerical limit into a ban on untagged items.

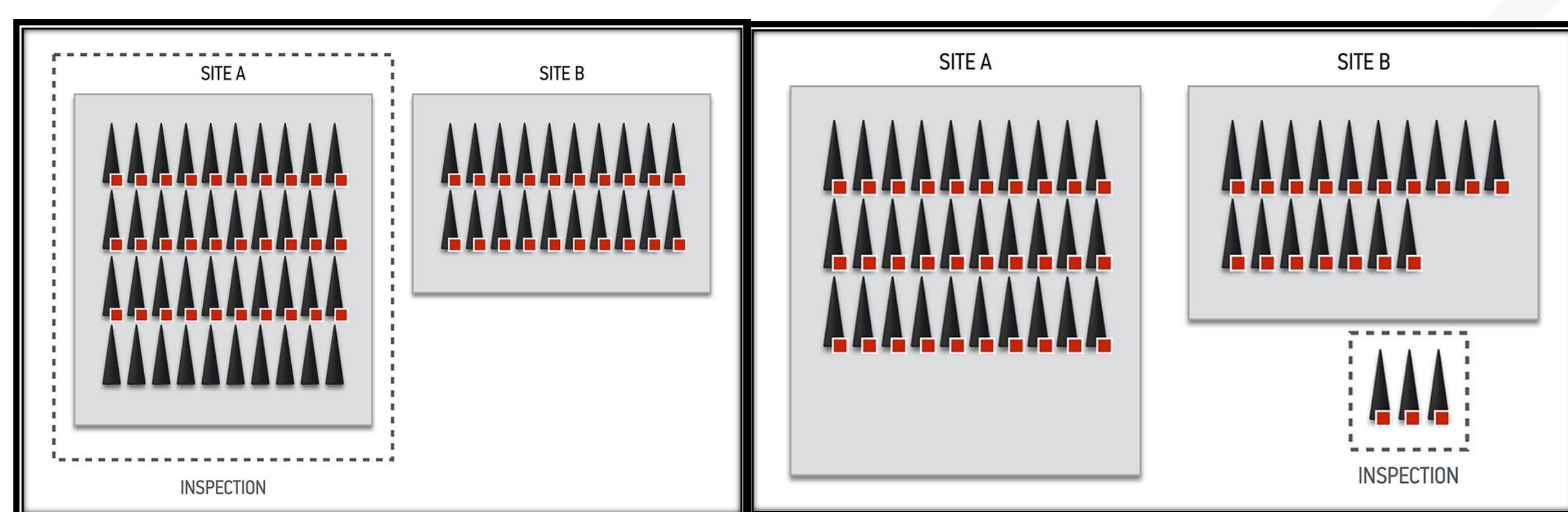


Figure 1: In the first scenario, a dishonest host retains an additional 10 warheads beyond their declaration of 50 warheads. With only 40 warheads at Site A, an inspection would not reveal the cheating attempt without buddy tags. In the second scenario, an honest host has removed some items to a unknown third site for maintenance, but because the warheads are tagged, the activity is within the bounds of the agreement. A. Glaser, PVTS-SGS Workshop, Beijing, June 2015

The buddy tag acts as a token, proving ownership of an treaty accountable item (TAI) without having to present the item itself. Treaty signatories would receive one tag per TAI. Numerical declarations would be verified through short notice inspections with 24 hour advance notice. Once an inspection has been called for a particular site, the host would not be allowed to move TAIs to or from the site, verified by the on-board sensing data from the tags.

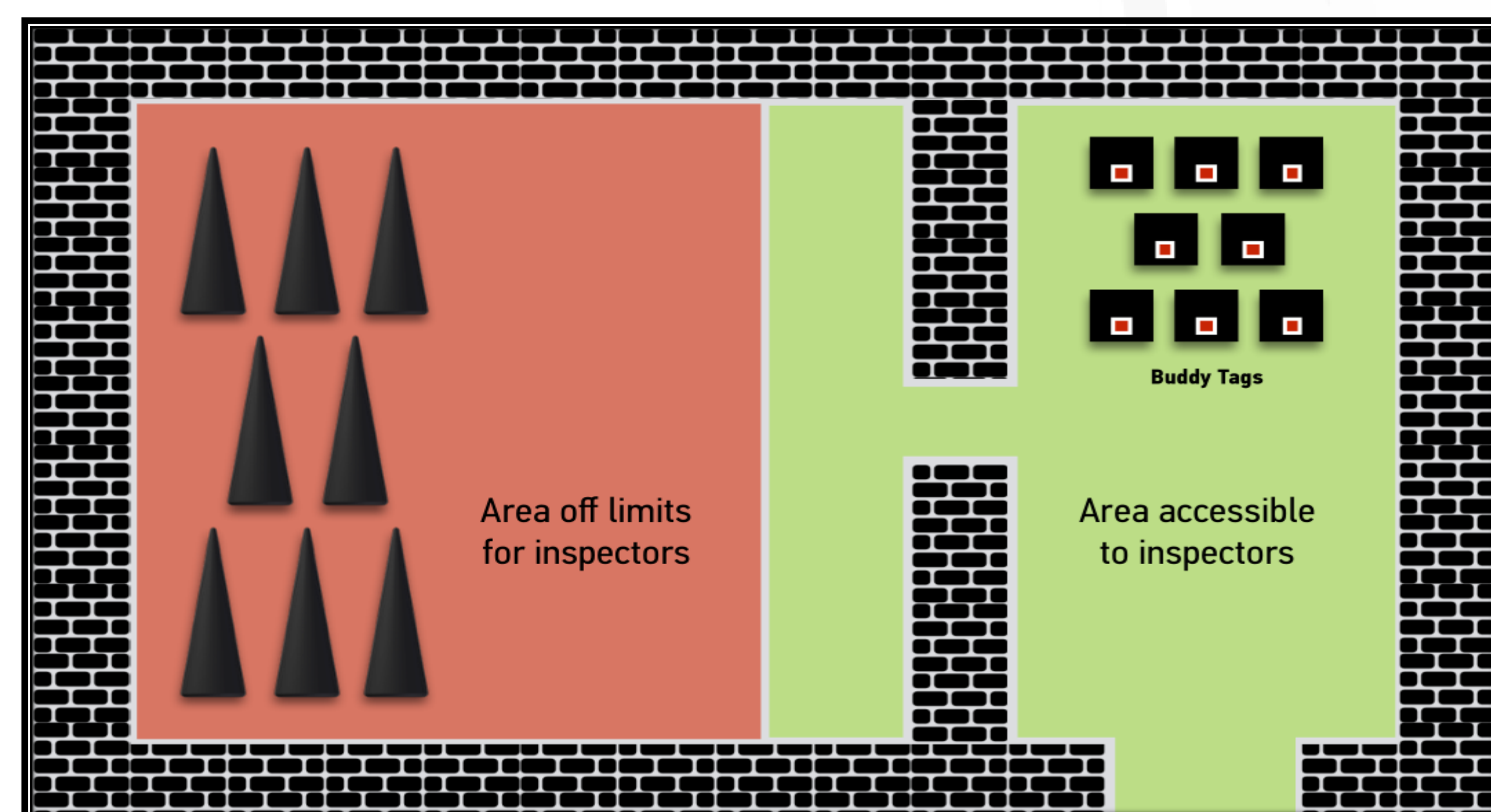
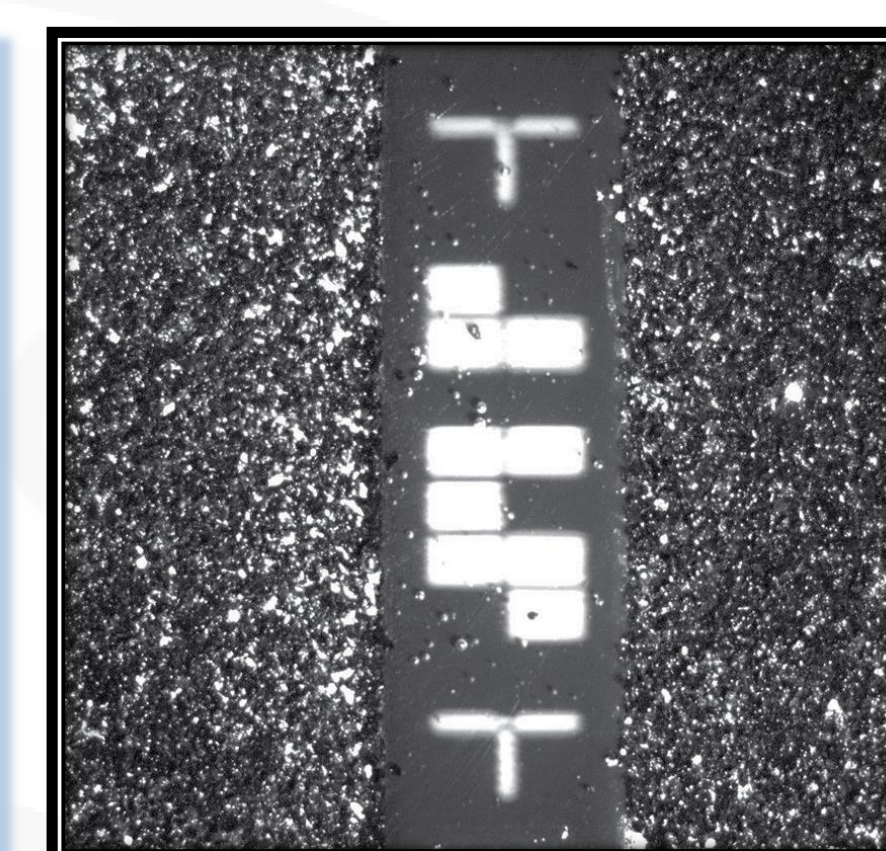


Figure 2: A hypothetical warhead storage facility, illustrating the inspection concept
A. Glaser, Information Security in Nuclear Warhead Verification, Vienna, December 12, 2014

Tag Subsystems

Unique Identifier: The buddy tag must be proven to be unique and authentic. We propose using a reflective particle ID tag developed by Sandia National Labs. Reflective particles are imbedded in a transparent adhesive, forming random patterns. A reader shines light on the particles from a variety of angles and captures images of the unique reflection patterns. These patterns can be compared with images taken when the tag was applied to the item, authenticating the tag.



A. Gonzales, Reflective Particle Tag for Arms Control and Safeguards Authentication, Sandia National Laboratories, 2004

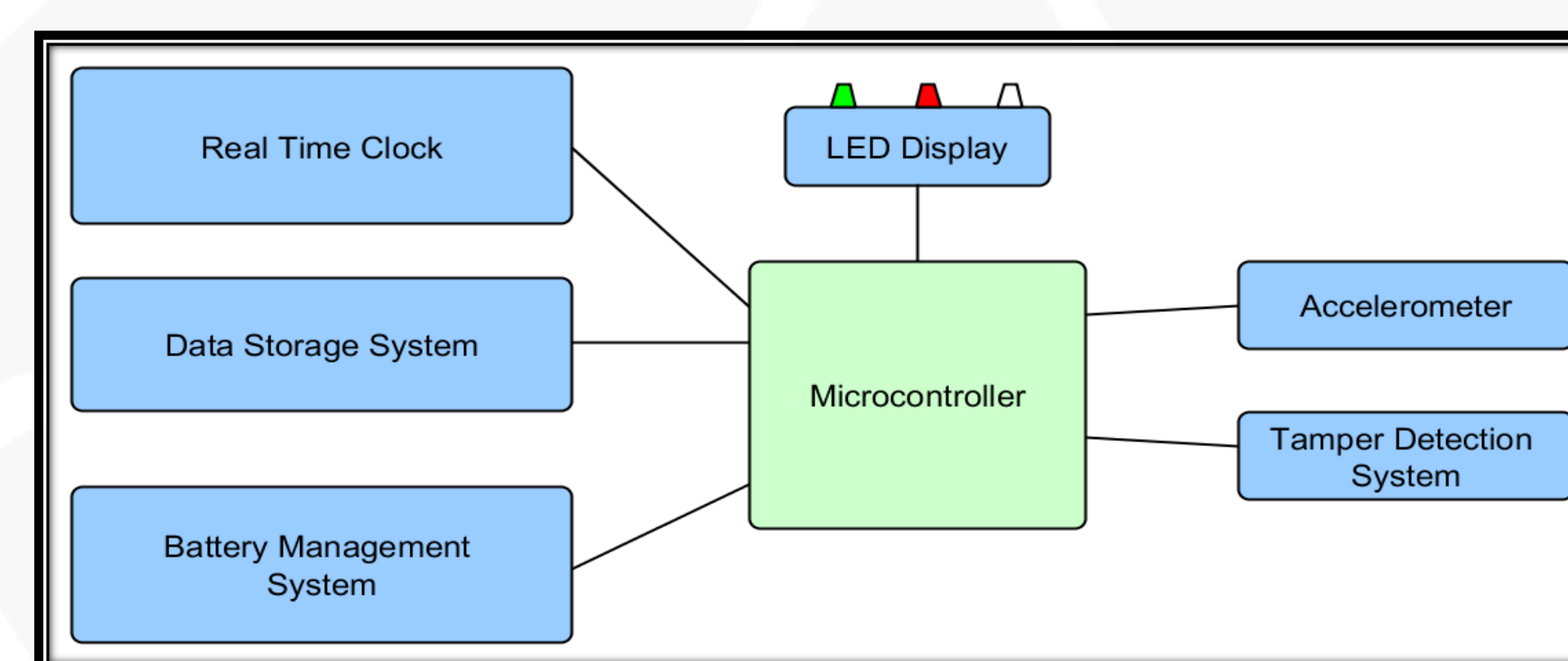


Figure 3: Block Diagram of buddy tag system components

Motion Detection: Buddy tag must be able to distinguish translative movement from environmental vibrations, and indicate this illegal motion to the inspector during the short notice inspection period. We have selected the STIM 300, a MEMS-based, ITAR-free inertial measurement unit package with tri-axial accelerometers, gyroscopes, and inclinometers to detect movement of the tag.

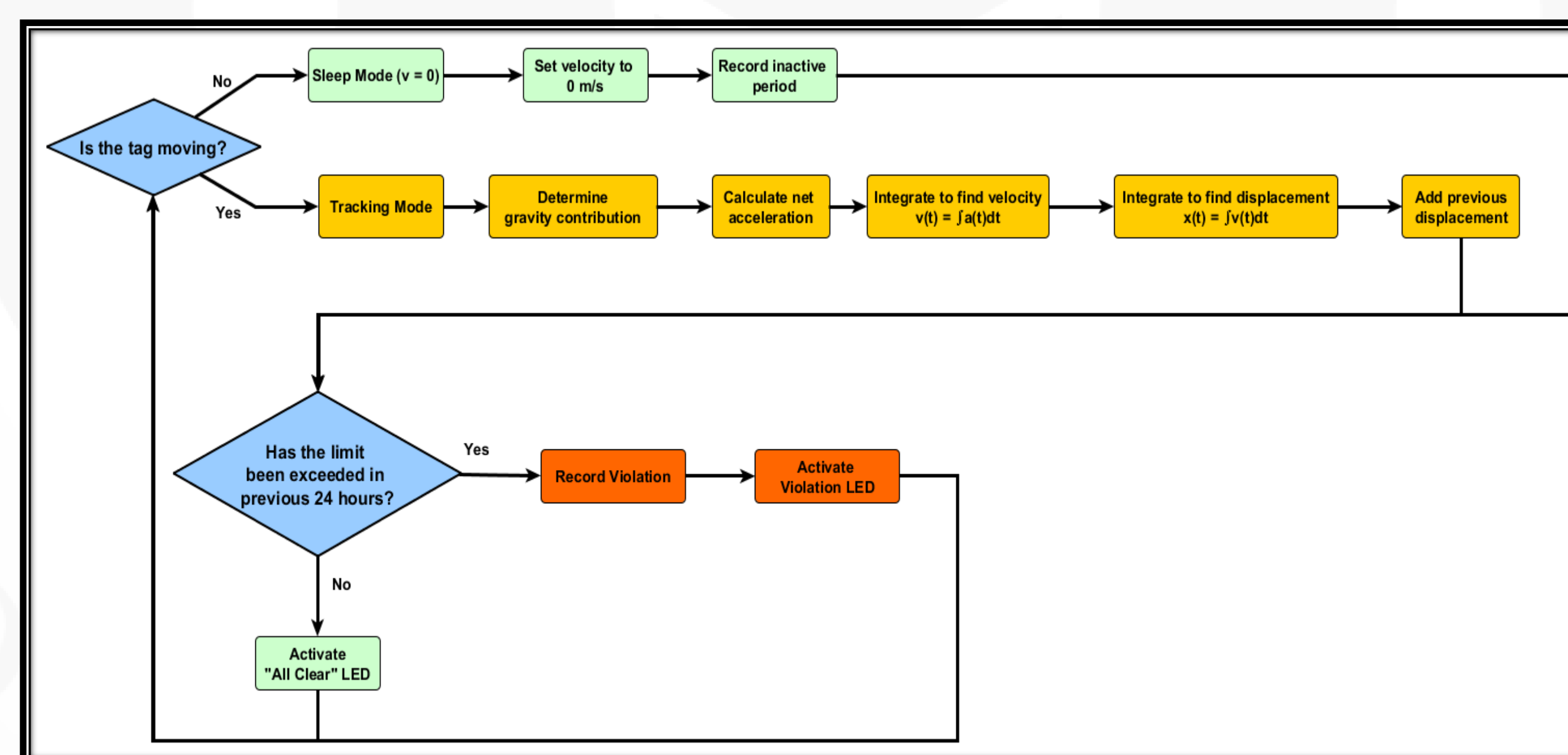


Figure 4: Block Diagram of buddy tag algorithm flow

Tamper Indication: A combination of passive barriers and active monitoring systems will ensure that any intrusions of the tag enclosure are indicated to the inspector. Nefarious intrusion can be hampered by the use of a double enclosure made of material that is difficult to repair if penetrated. External vulnerabilities can be reduced by minimizing the number of seams in the enclosure design.

Preliminary Results

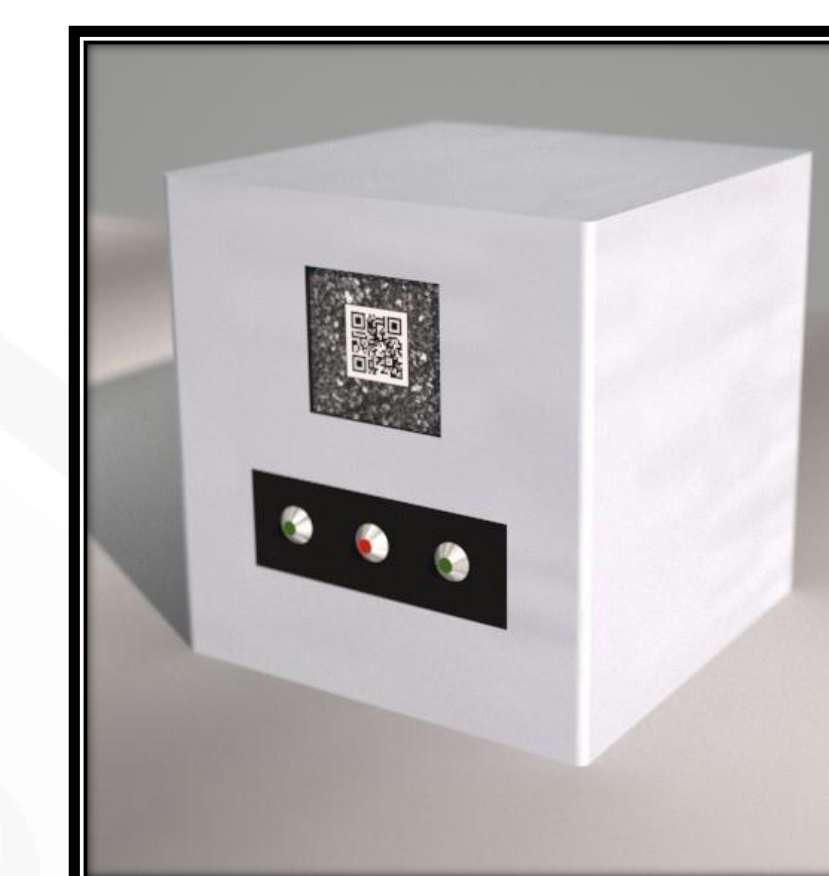


Figure 5: VR model of Buddy Tag
Image courtesy Tamara Patton

We have built a initial prototype, focusing on the motion detection subsystem. The accelerometer data is processed using an Arduino-based “Teensy” microcontroller. We are currently working on a next-generation prototype using a powerful ITAR-free inertial measurement unit (STIM-300). Other tag systems, such as the outer enclosure, power supply, data storage, and inspector interface are also under development.

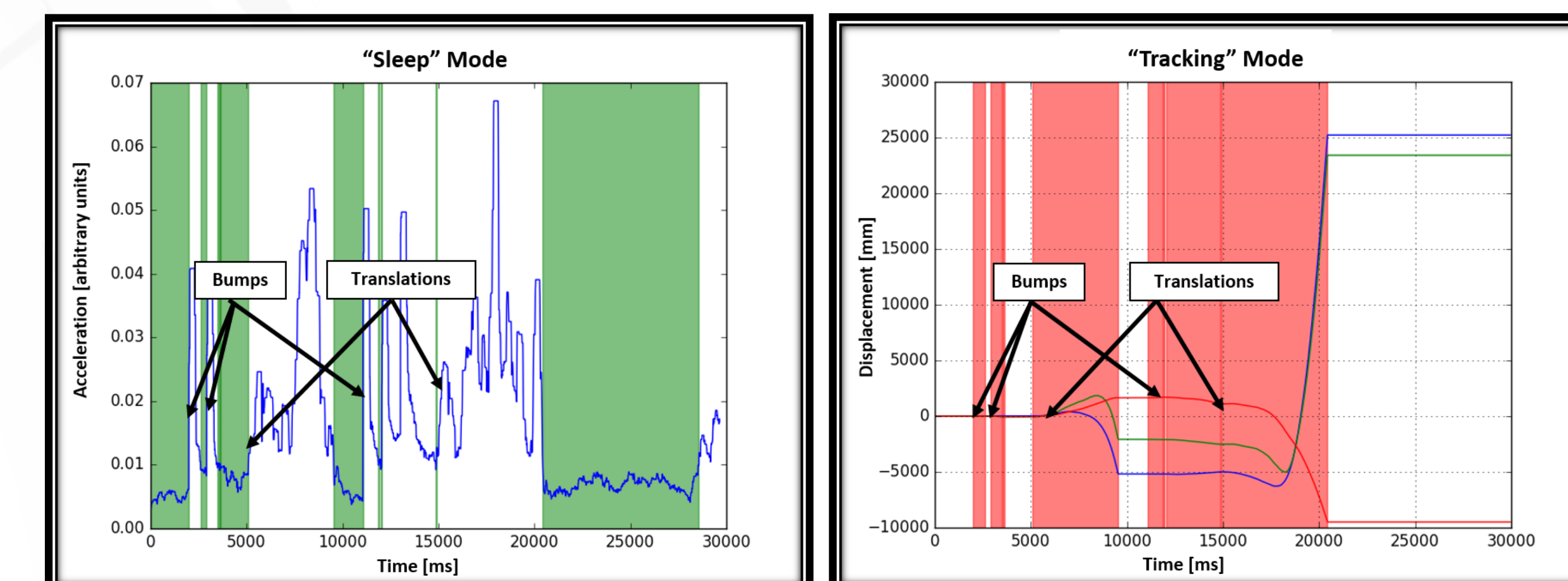


Figure 6: Demonstration of the tag's “Sleep” and “Tracking” modes on a dataset containing both bumps and translations

We propose an algorithm for the tag which consists of two monitoring modes: “Sleep” and “Tracking”. After an initialization phase, where the tag determines its orientation with respect to the gravity vector, the data are run through a moving average filter. The tag then compares the difference between the max and min of a window of datapoints with a preset threshold value. If this is below the threshold, the tag enters Sleep Mode, which fixes the velocity at zero. If the threshold has been exceeded, then the tag enters Tracking Mode, determines its offset from gravity, and begins integrating to calculate its displacement. If the displacement limit has been exceeded in the past 24 hours, a violation is recorded and indicated to the inspector.

Conclusion / Next Steps

- We continue to improve our prototype and add features to the tag systems, including a powerful ITAR-free accelerometer (STIM-300).
- Work continues on improving the sensitivity of the algorithm, including incorporating adaptive orientation sensing using on-board gyroscopes.
- We envision buddy tag as a platform for demonstrating innovative safeguards technologies such as unique identifiers, tamper-indicating enclosures, secure electronics, and machine learning algorithms.

