



# MINIMALLY INTRUSIVE VERIFICATION OF DEEP NUCLEAR WARHEAD REDUCTIONS A FRESH LOOK AT THE BUDDY-TAG CONCEPT

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Revision 2

# BACKGROUND

## VERIFICATION CHALLENGES OF DEEP(ER) REDUCTIONS

# WHAT IS TO BE VERIFIED?

## VERIFICATION CHALLENGES FOR NUCLEAR ARMS CONTROL AT LOW NUMBERS



### 1. VERIFY NUMERICAL LIMITS OF DECLARED WARHEADS

Requires techniques to account for (and identify) nuclear warheads in storage  
*for example, using (hashed) declarations and/or unique identifiers (UIDs)*



### 2. CONFIRM AUTHENTICITY OF NUCLEAR WARHEADS

Requires dedicated inspection systems  
*for example, based on radiation-detection techniques (passive/active, neutron/gamma)*



### 3. ESTABLISH CONFIDENCE IN ABSENCE OF UNDECLARED ITEMS OR MATERIALS

How to make sure that no covert warheads / materials exist outside the verification regime?  
No silver bullet; not much different from NPT verification challenges

Source: Paul Shambroom (top), U.S. Department of Energy (middle), and Google Earth (bottom)

# VERIFYING NUMERICAL LIMITS

# TAGGING

TRANSFORMING A “NUMERICAL LIMIT” INTO A “BAN ON UNTAGGED ITEMS”

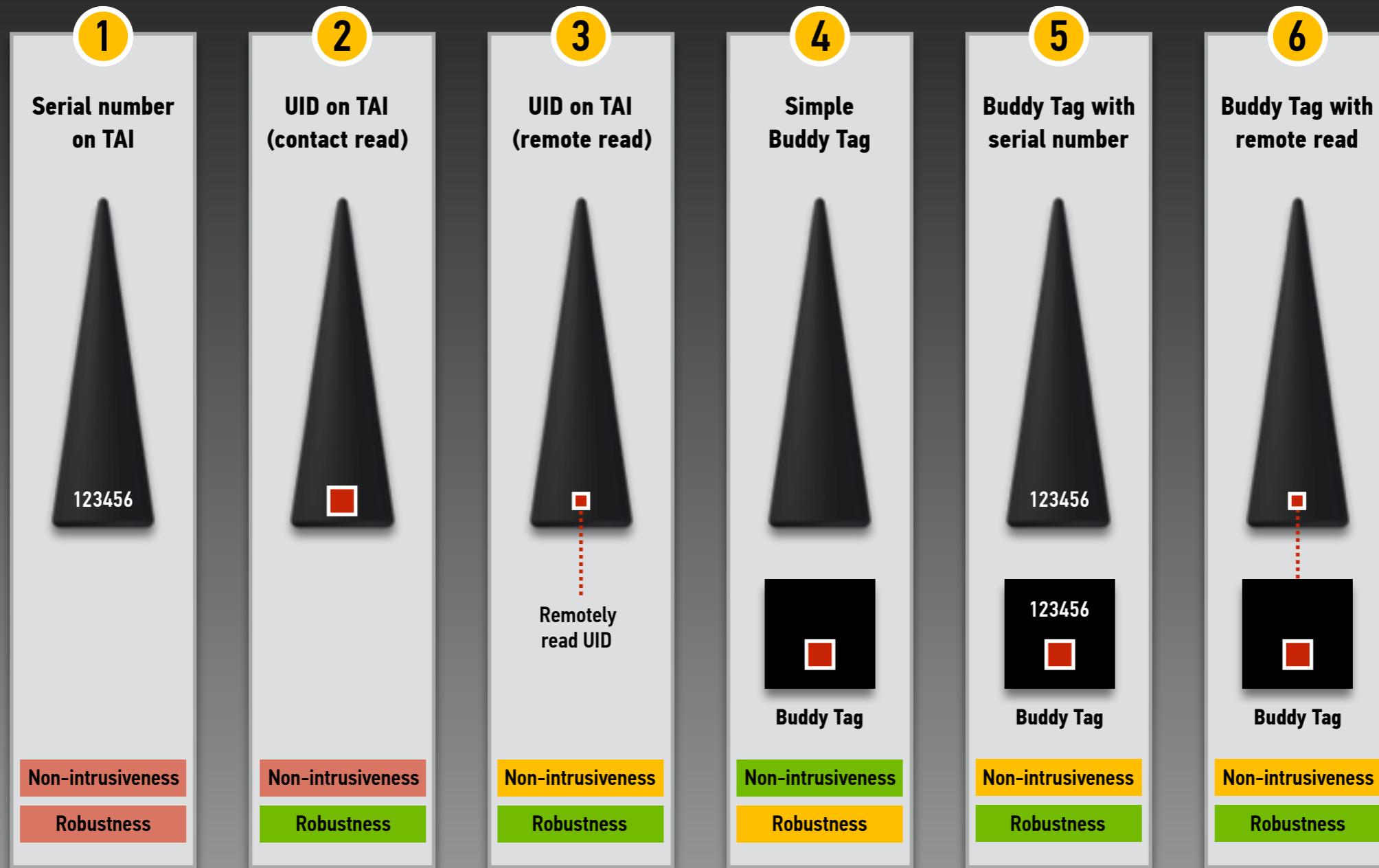


Source: [www.automoblog.net](http://www.automoblog.net)

*Steve Fetter and Thomas Garwin, “Using Tags to Monitor Numerical Limits in Arms Control Agreements”  
in Barry M. Blechman, ed., *Technology and the Limitation of International Conflict*, Washington, DC, 1989, pp. 33–54*

# WARHEAD COUNTING OPTIONS

## WITH VARIOUS LEVELS OF INTRUSIVENESS AND ROBUSTNESS



# THE BUDDY TAG CONCEPT

# WHAT THE BUDDY TAG IS NOT

The image is a composite of three parts. The top left shows a woman in a blue shirt in a kitchen. The top right shows a screenshot of the Tile app interface with a green banner that says 'Find your phone, keys, anything.' The bottom right shows a yellow advertisement for 'My Buddy Tag' with text 'A Lost Child is a Parent's Worst Nightmare' and 'Keep Kids Safe'.

**tile**

BUY TILE FOR \$25 ▶ MENU

Find your phone, keys, anything.

*My*  
**BuddyTag**

- Out-of-Range Alert**  
Helps Prevent Lost Child
- Water Safety Alert**  
Helps Prevent Drowning
- Panic Button**  
Alert When Child is in Fear
- Last Seen Location**  
E-Mail Alert When Child is Lost

0:31 / 0:36

**A Lost Child is a Parent's Worst Nightmare**

**My**  
**BuddyTag**<sup>TM</sup>

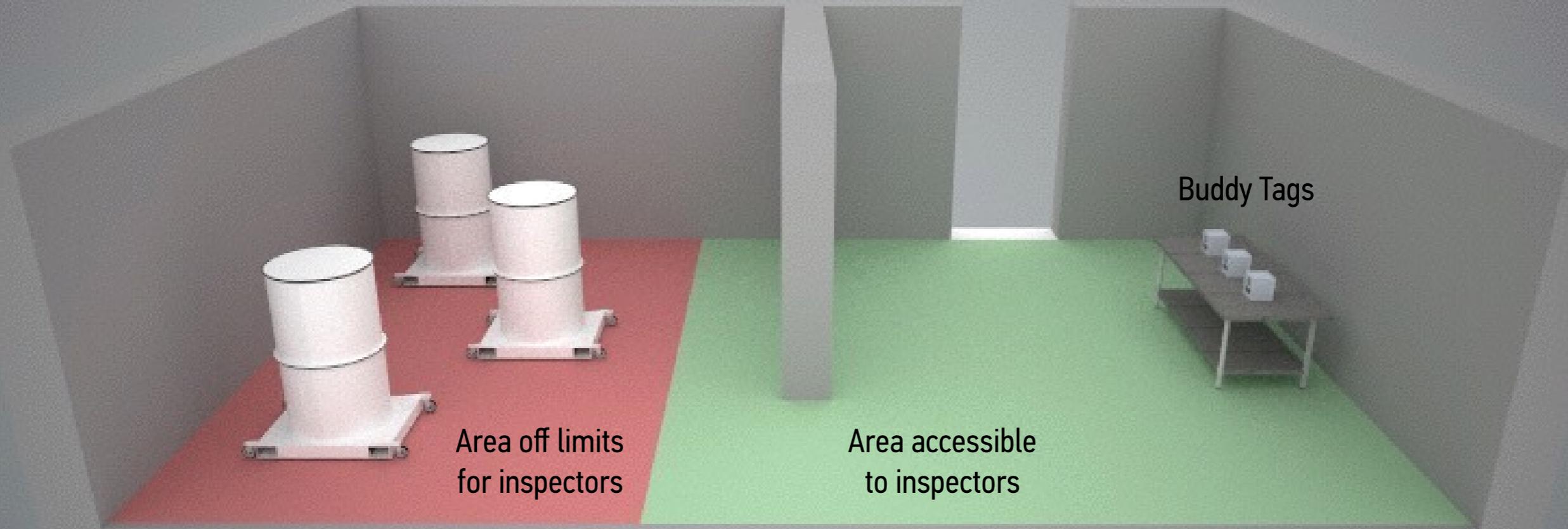
Keep Kids Safe

Shop Now

Source: [www.thetileapp.com](http://www.thetileapp.com) and [www.mybuddytag.com](http://www.mybuddytag.com)

# OPTION FOR A MINIMALLY INTRUSIVE ONSITE INSPECTION

USING BUDDY TAGS WITHOUT DIRECT ACCESS TO TREATY ACCOUNTABLE ITEMS



*Image: Tamara Patton*

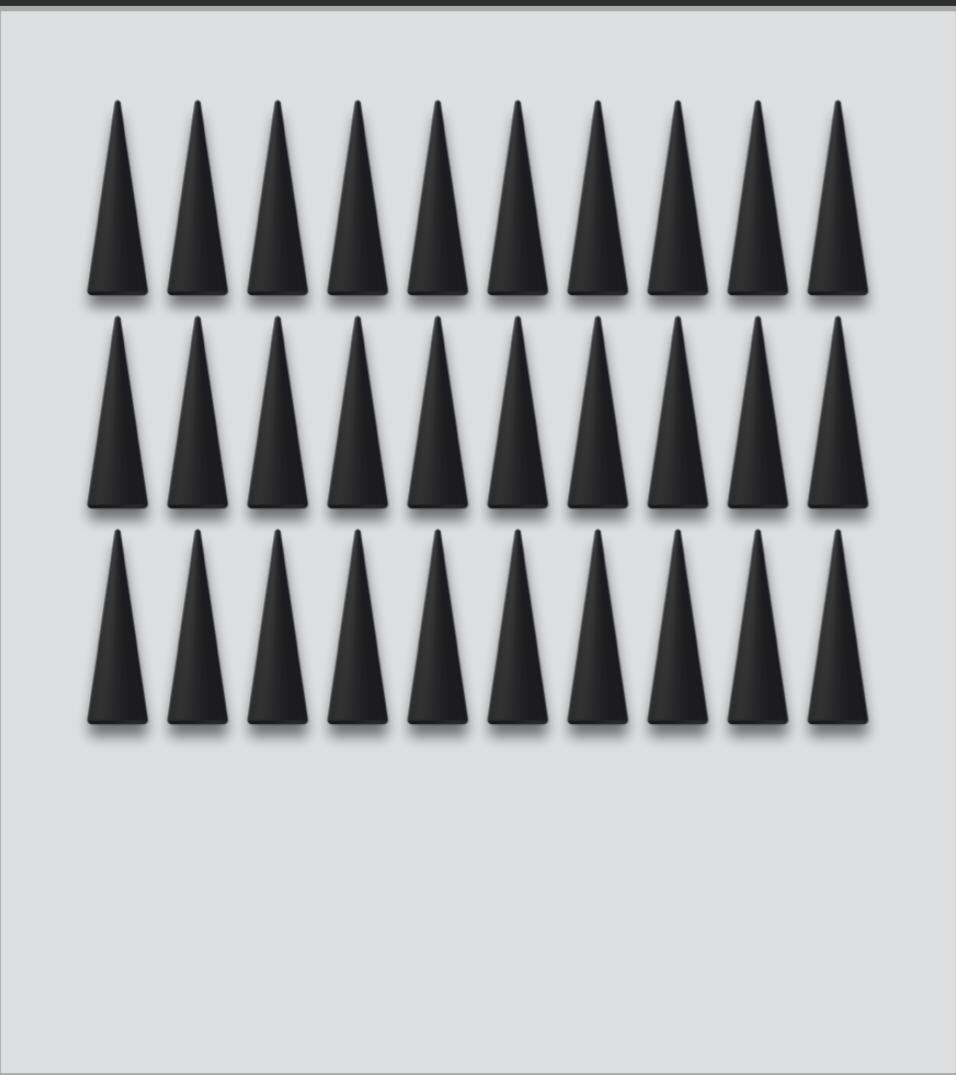
# SCENARIO 1

**(“DISHONEST HOST”)**

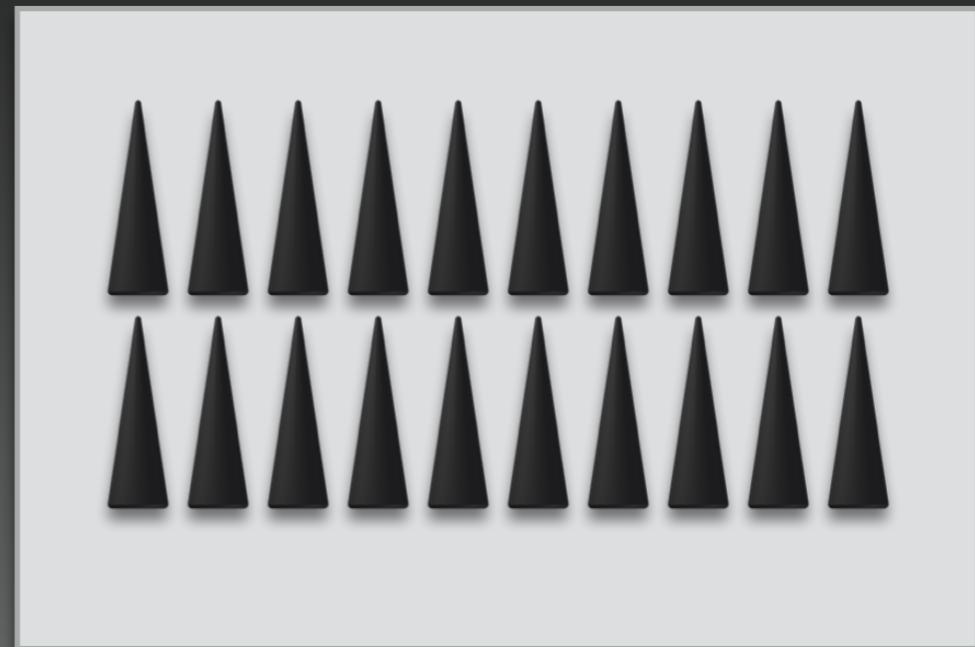
# SCENARIO 1

PARTY HAS DECLARED 50 WARHEADS; THEY ARE STORED AT TWO (DECLARED) SITES

SITE A



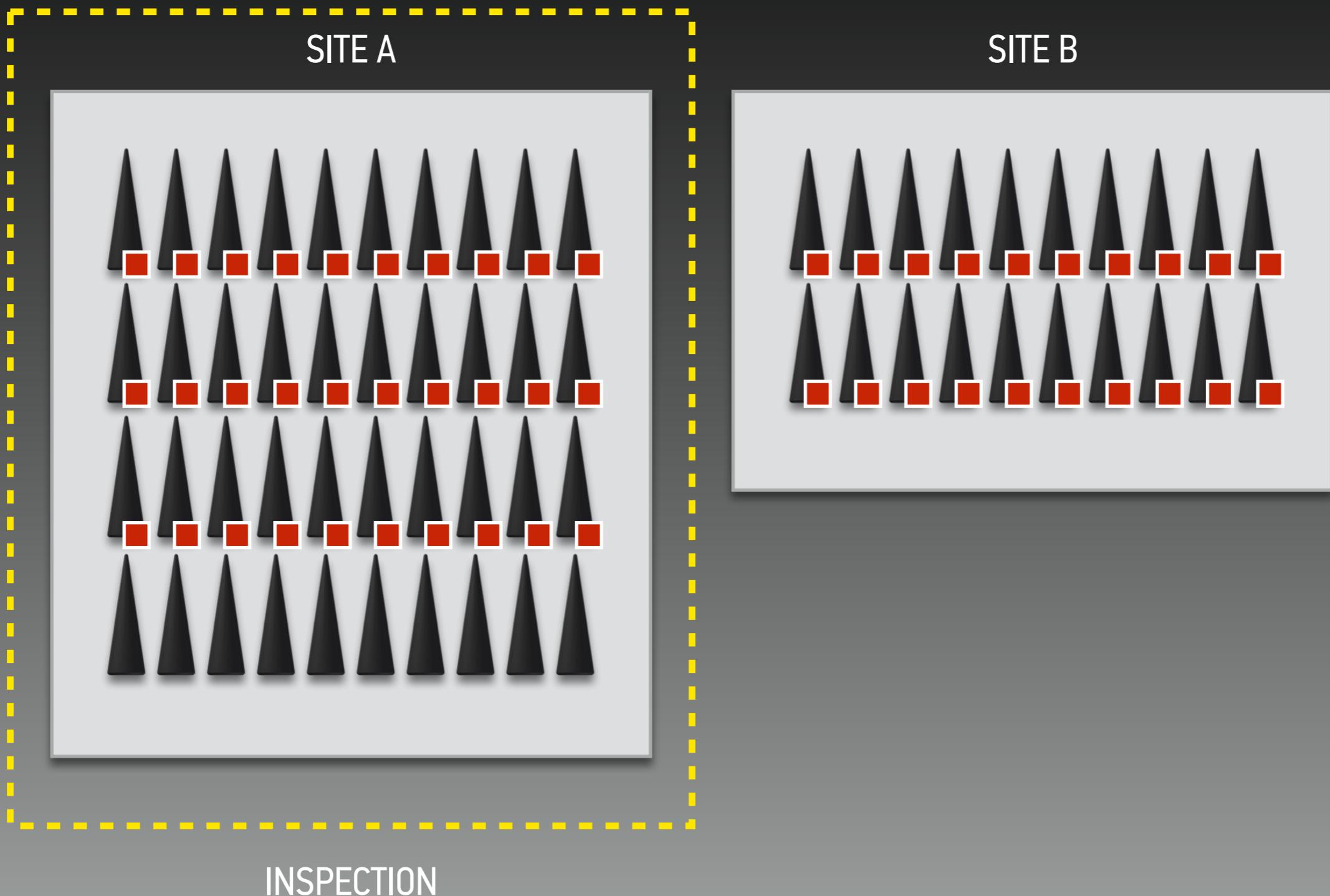
SITE B



In reality, there are 60 warheads

# SCENARIO 1

PARTY HAS DECLARED 50 WARHEADS; THEY ARE STORED AT TWO (DECLARED) SITES



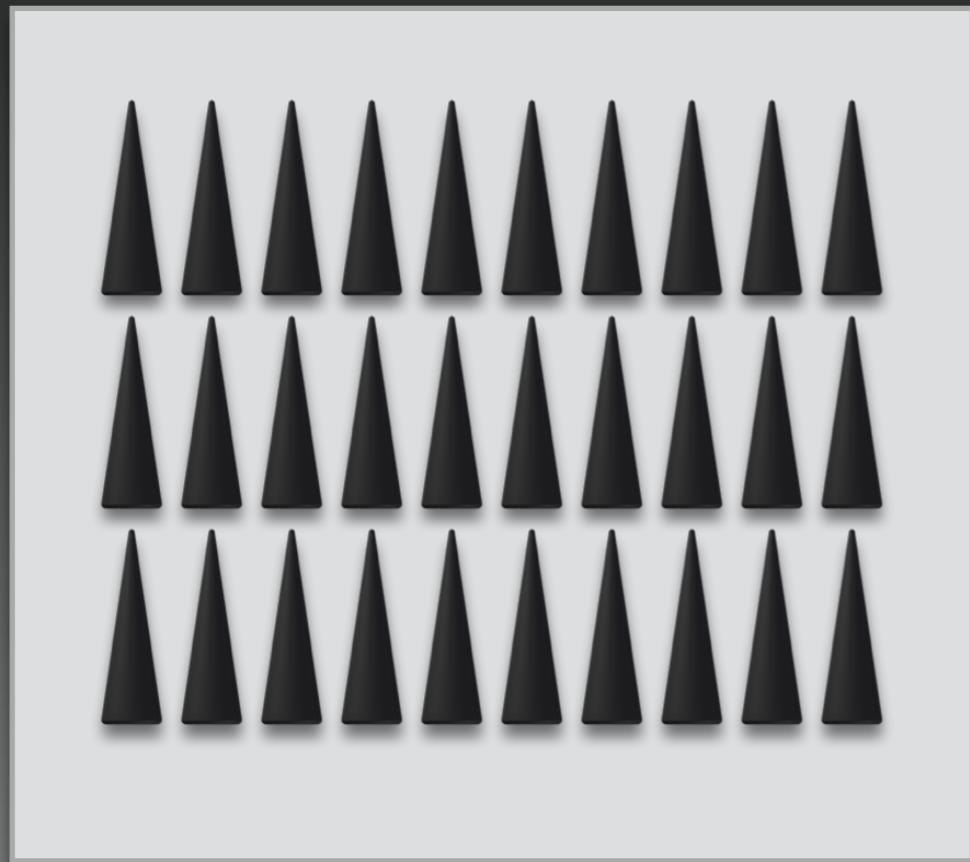
# SCENARIO 2

(“HONEST HOST”)

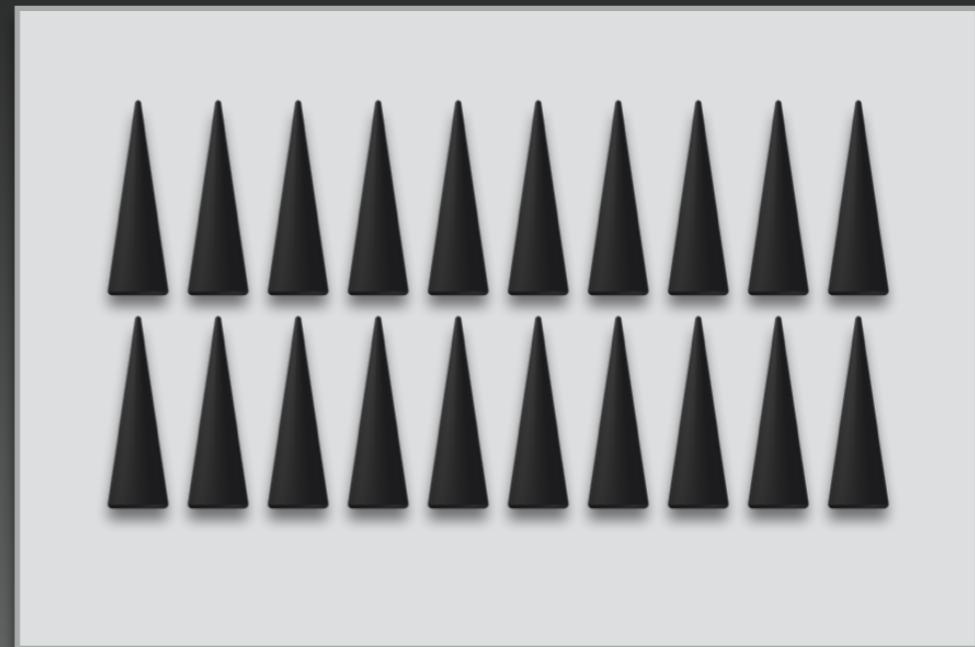
# SCENARIO 2

PARTY HAS DECLARED 50 WARHEADS; THEY ARE STORED AT TWO (DECLARED) SITES

SITE A



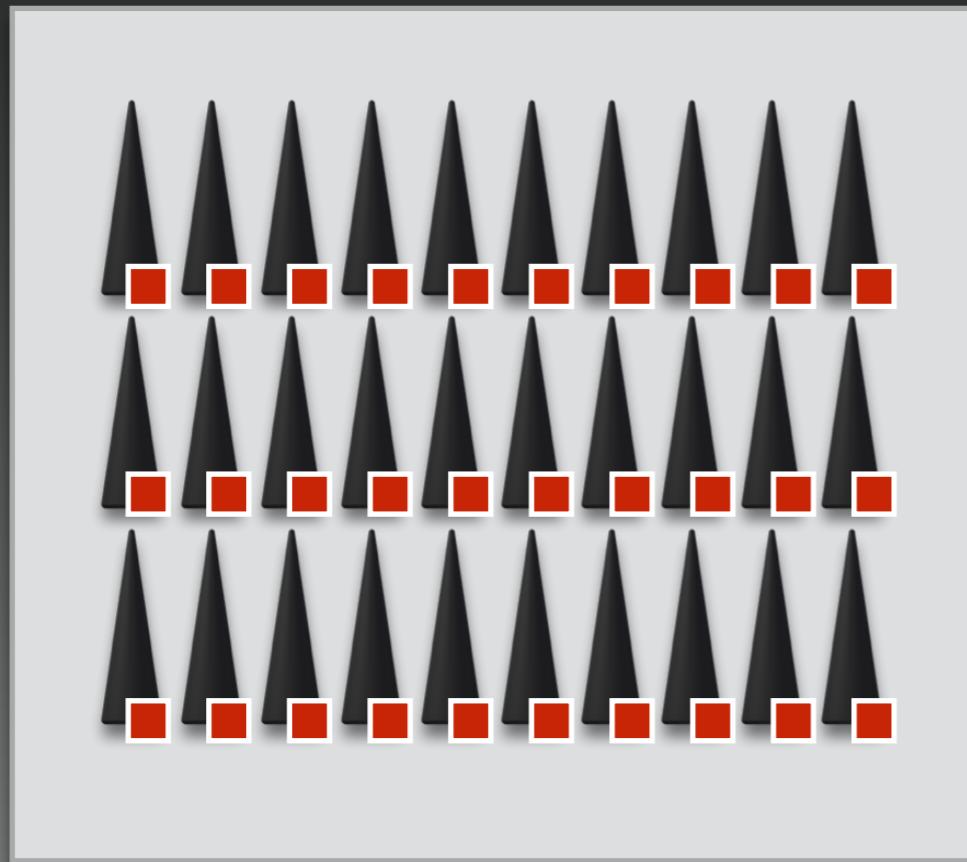
SITE B



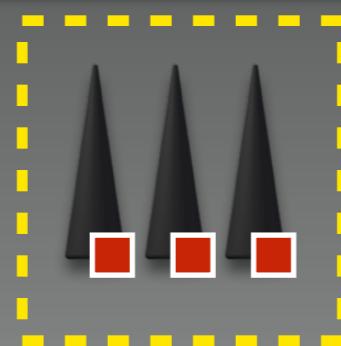
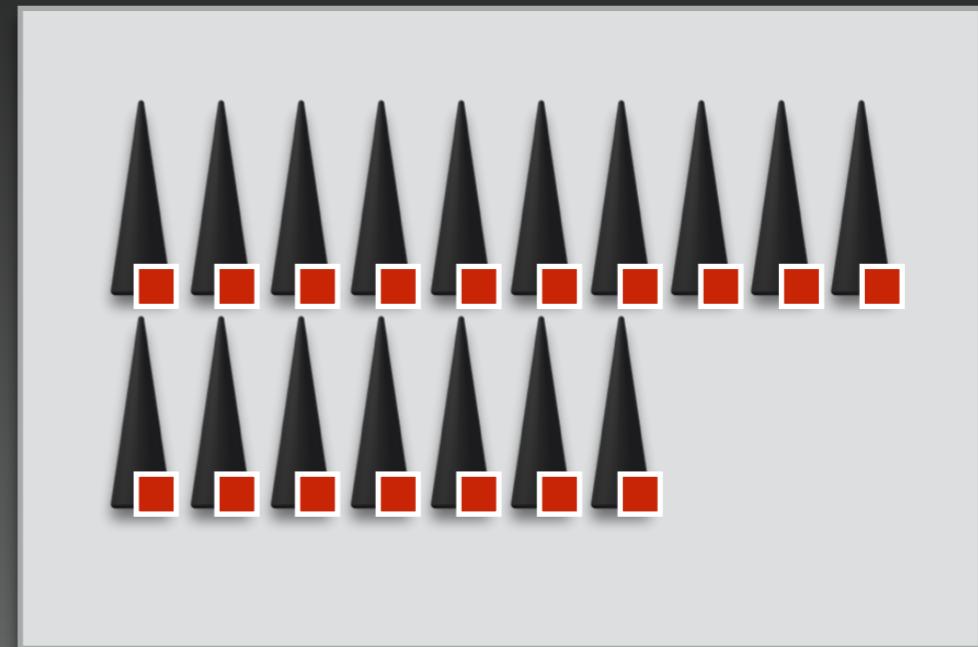
# SCENARIO 2

PARTY HAS DECLARED 50 WARHEADS; THEY ARE STORED AT TWO (DECLARED) SITES

SITE A



SITE B



Some items are moved to a previously unknown  
third site (perhaps for maintenance)

Without buddy tags, the presence of these items  
may be considered suspect

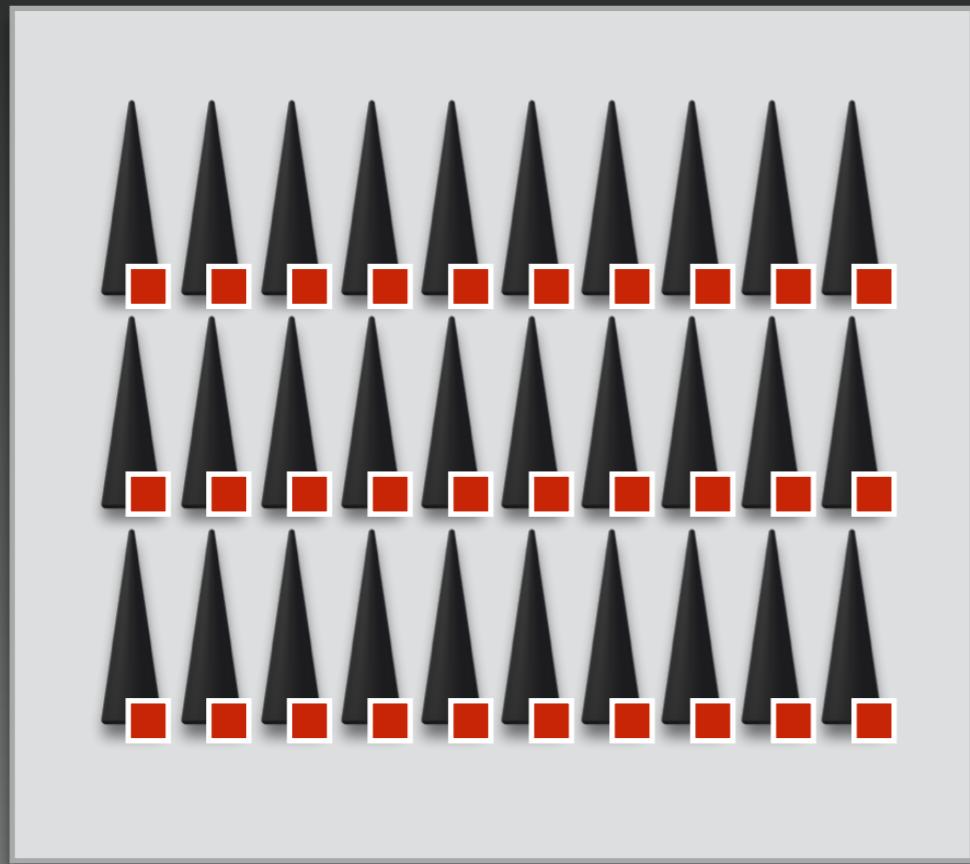
# SCENARIO 3

(“DISHONEST HOST REVISITED”)

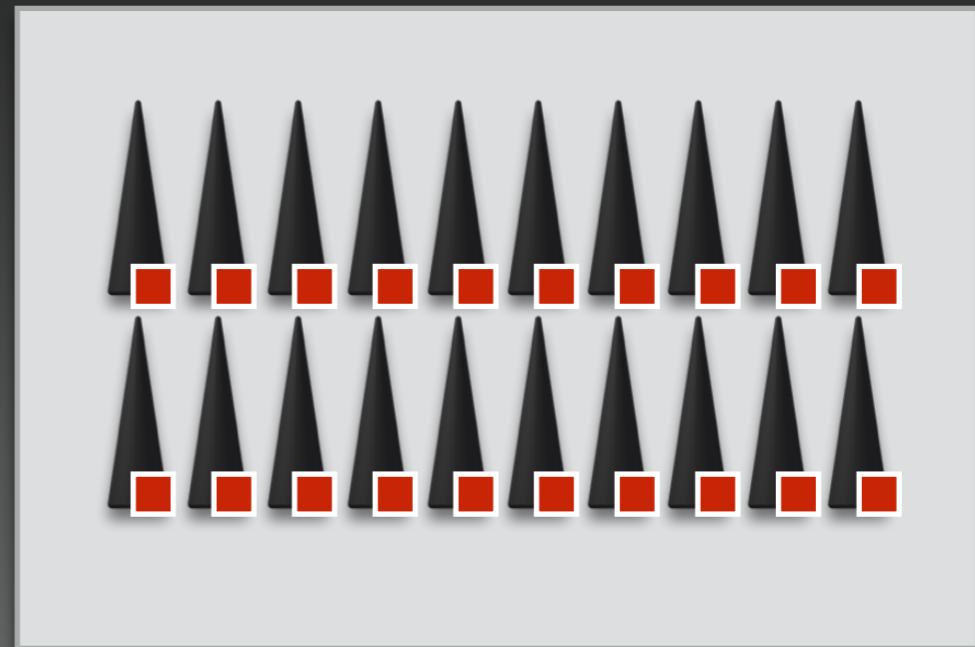
# SCENARIO 3

PARTY HAS DECLARED 50 WARHEADS; THEY ARE STORED AT TWO (DECLARED) SITES

SITE A



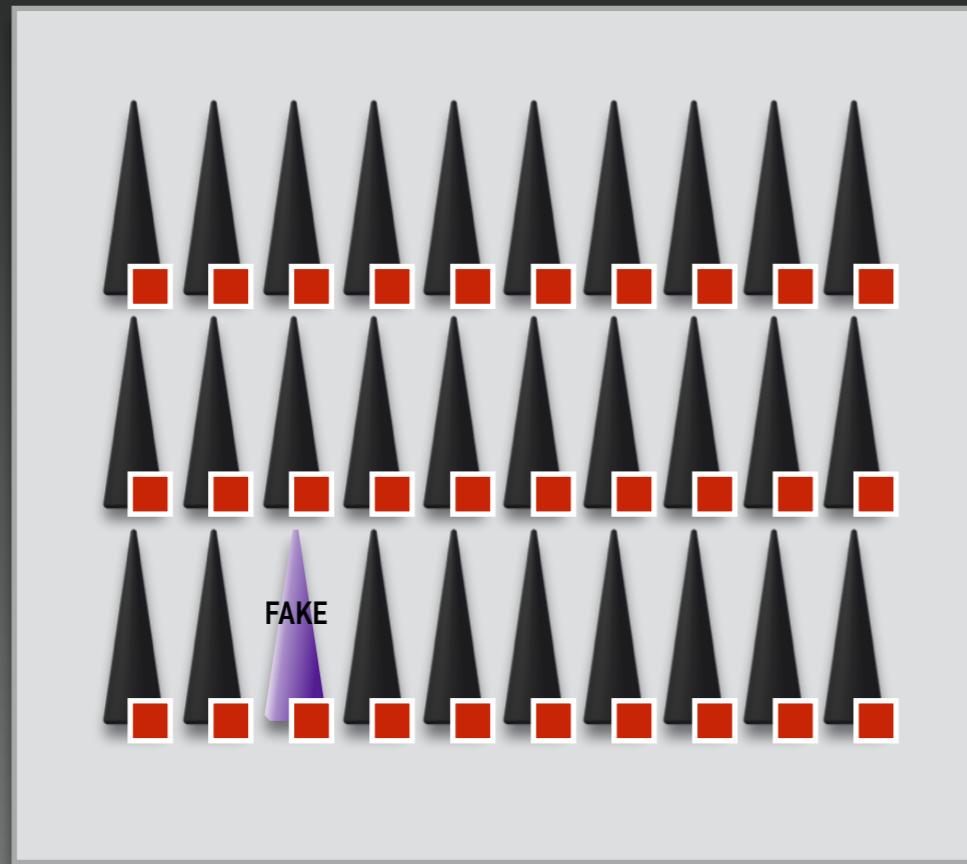
SITE B



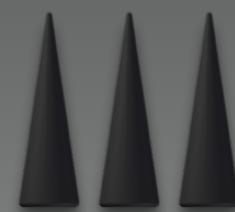
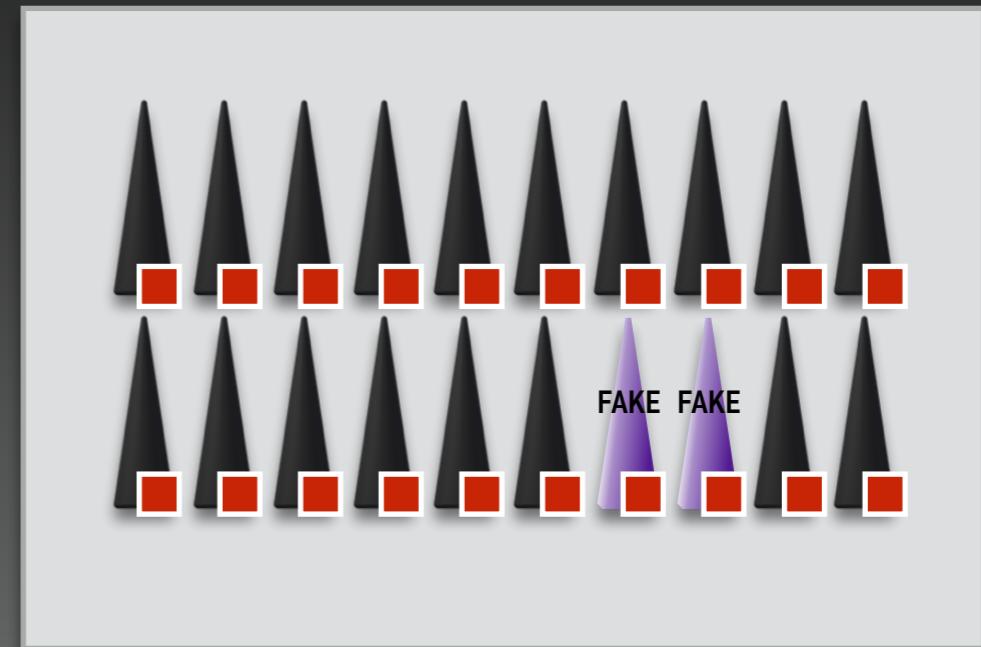
# SCENARIO 3

PARTY HAS DECLARED 50 WARHEADS; THEY ARE STORED AT TWO (DECLARED) SITES

SITE A



SITE B



Essentially at any time, the host  
could swap genuine warheads for mockups

This scenario is not captured with the basic buddy-tag concept  
(but it introduces several complications for the host down the road)

# HOW DOES A BUDDY TAG LOOK LIKE?

# ELEMENTS OF THE BUDDY TAG

Tamper Indicating Enclosure

Unique Identifier

LED Display

State of health

Movement detected

Battery status

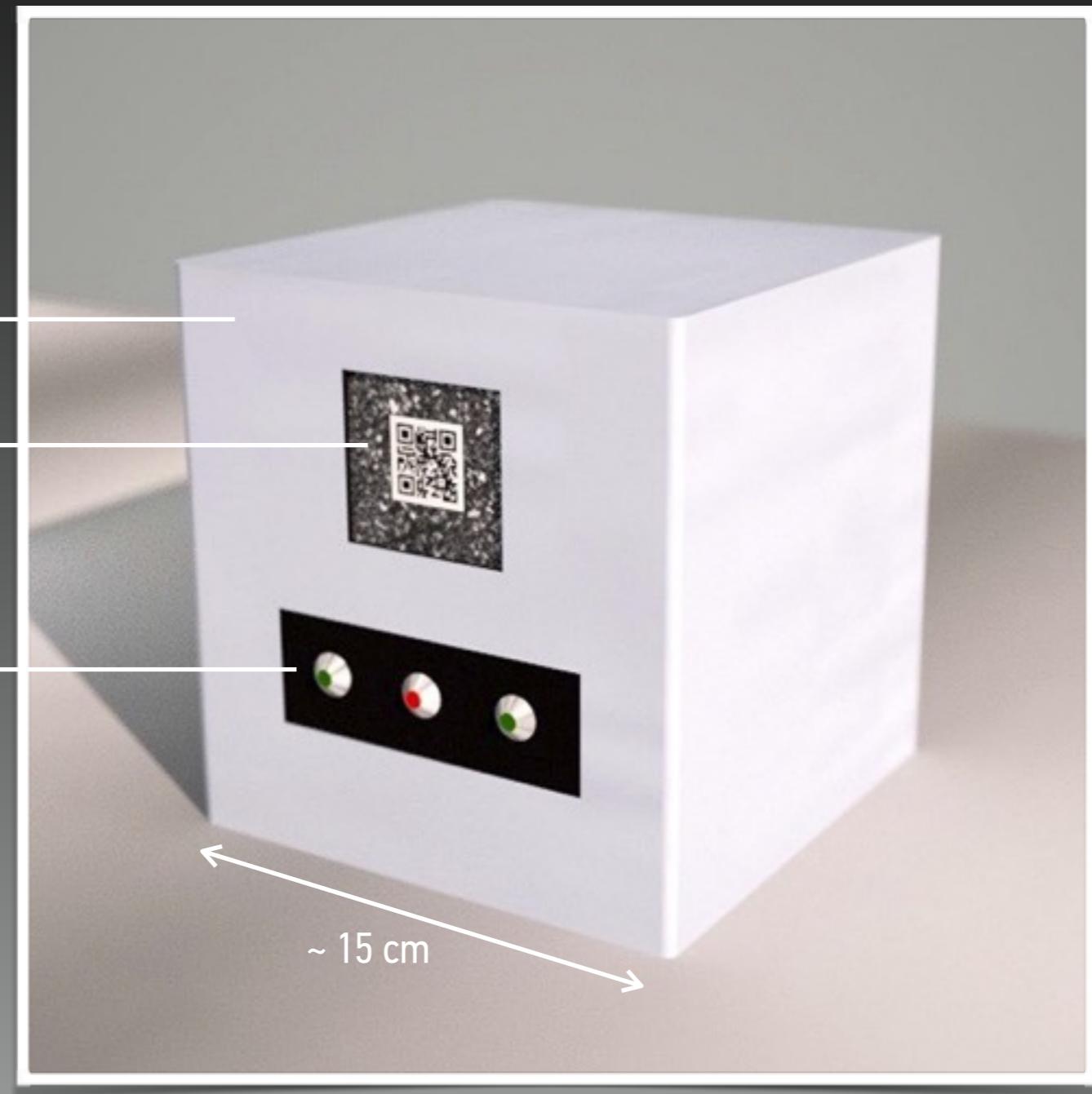


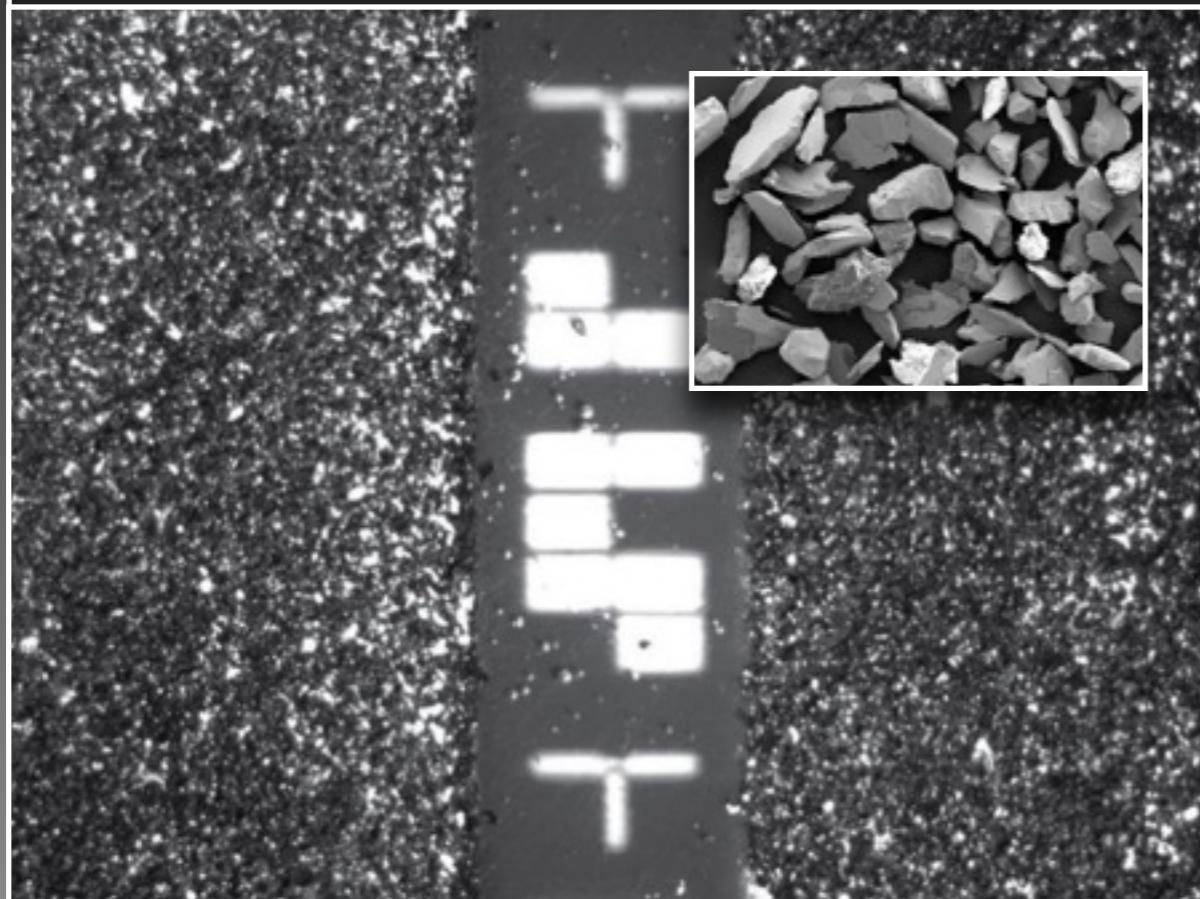
Image: Tamara Patton

# TAGGING THE TAG

## TREATY ACCOUNTABLE ITEMS WITH UNIQUE IDENTIFIERS

### UNIQUE TAGS

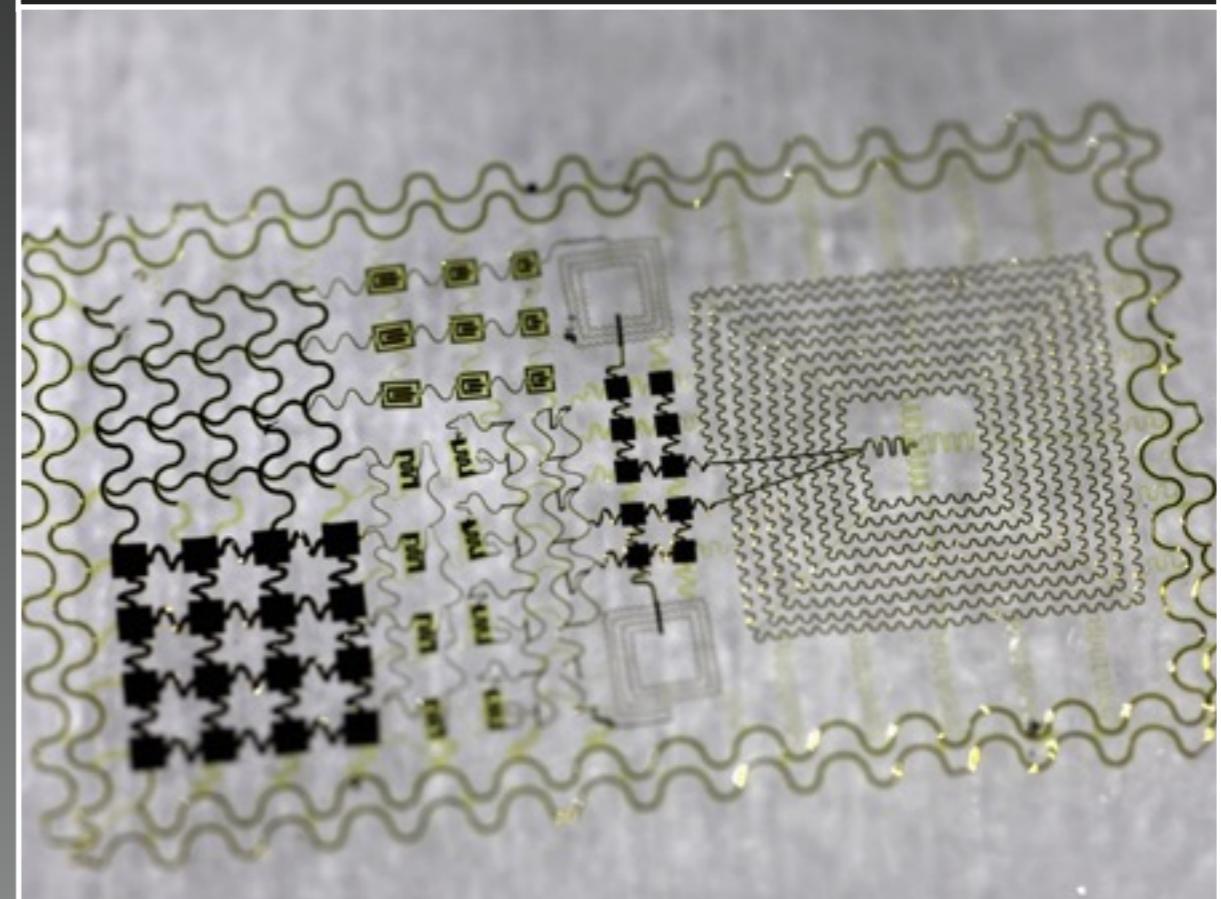
Physically unique, i.e., very hard to duplicate



Reflective Particle Tag  
using microscopic particles randomly suspended in matrix  
*Source: Sandia National Laboratory*

### IDENTICAL TAGS

Physically non-unique, but input/output unique



Electronic Tattoo  
using printed circuits, miniature sensors, and solar collectors  
*Source: John Rogers, University of Illinois*

# MOTION-DETECTION SUBSYSTEM

# CANDIDATE COMPONENTS FOR USE IN THE MOTION-DETECTION SUBSYSTEM



## ADXL362

Triple-axis accelerometer

Sensitivity: 1 mg/LSB

Price: \$15

*Source: Sparkfun*



## ITG3200/ADXL345

Inertial measurement unit

Sensitivity: 4 mg/LSB

Price: \$40

*Source: Sparkfun*



## STIM300

Inertial measurement unit

Sensitivity: 2  $\mu$ g/LSB

Price: \$8600

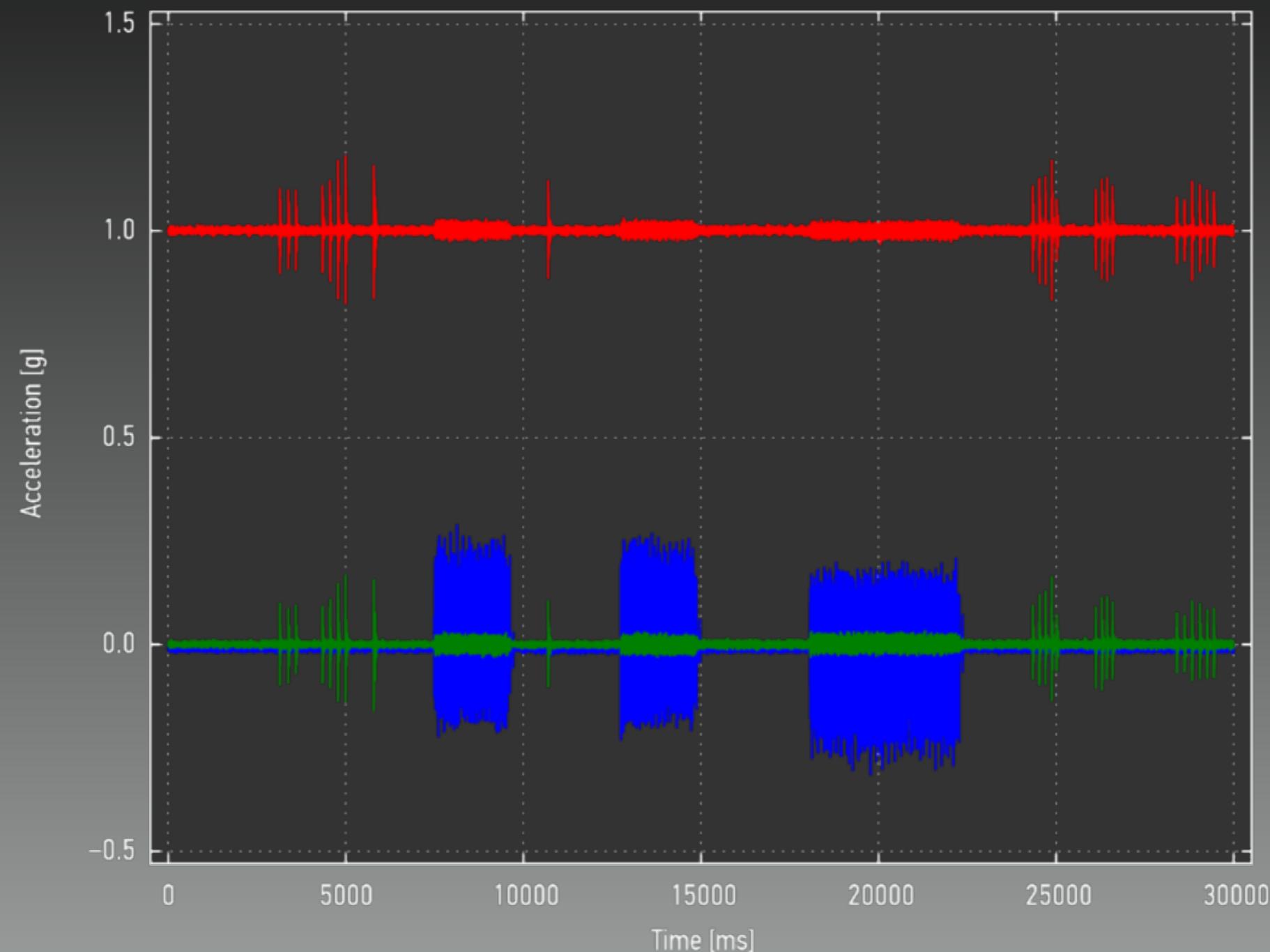
*Source: Senonor*

All systems are strap-down systems based on micro-machined electromechanical systems (MEMS) technology

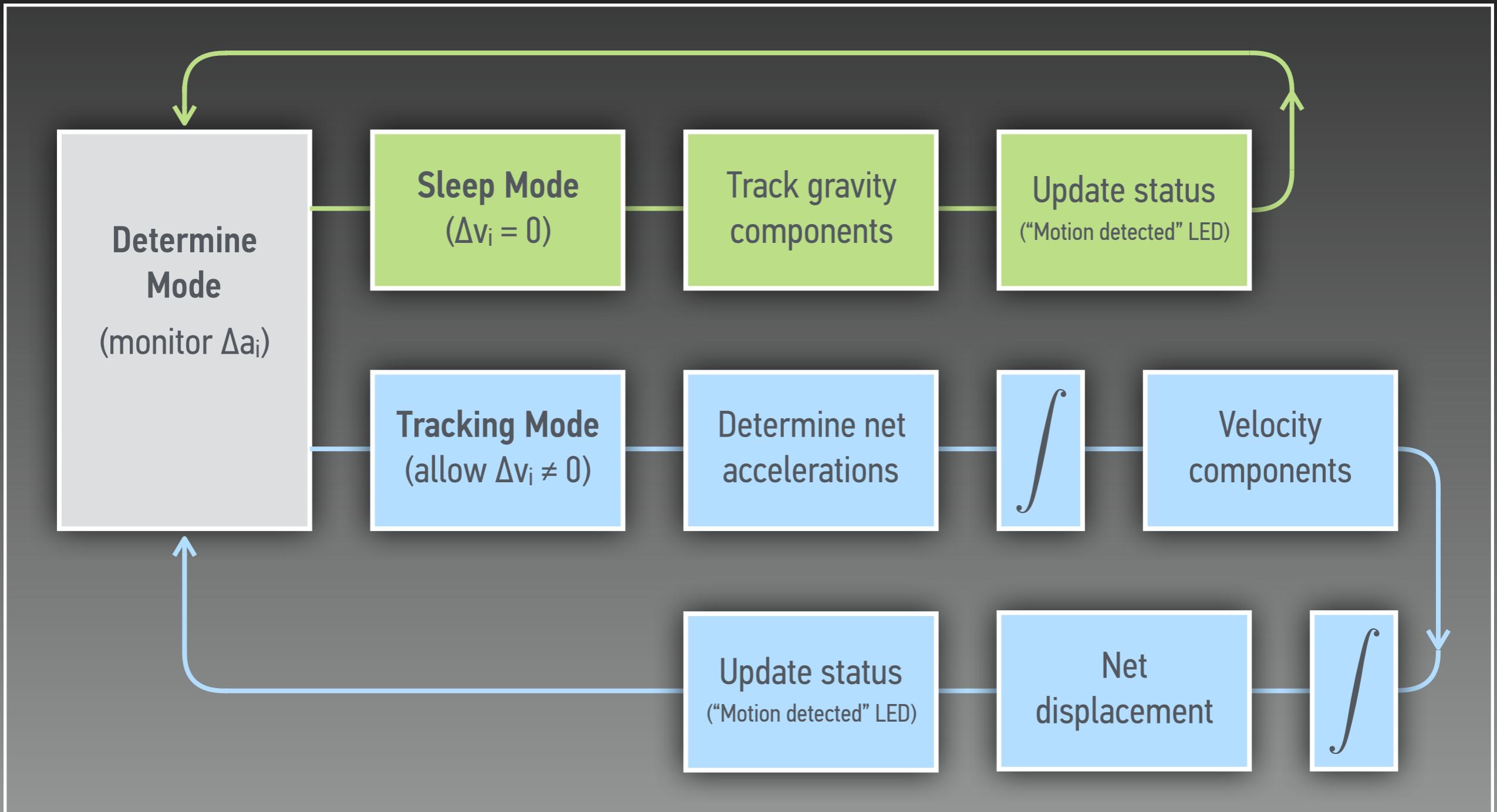
See [damien.douxchamps.net/research/imu](http://damien.douxchamps.net/research/imu) for a list of currently available units

# STIM300 RAW DATA

6000 DATA POINTS PER SECOND FROM ACCELEROMETERS AND GYROSCOPES

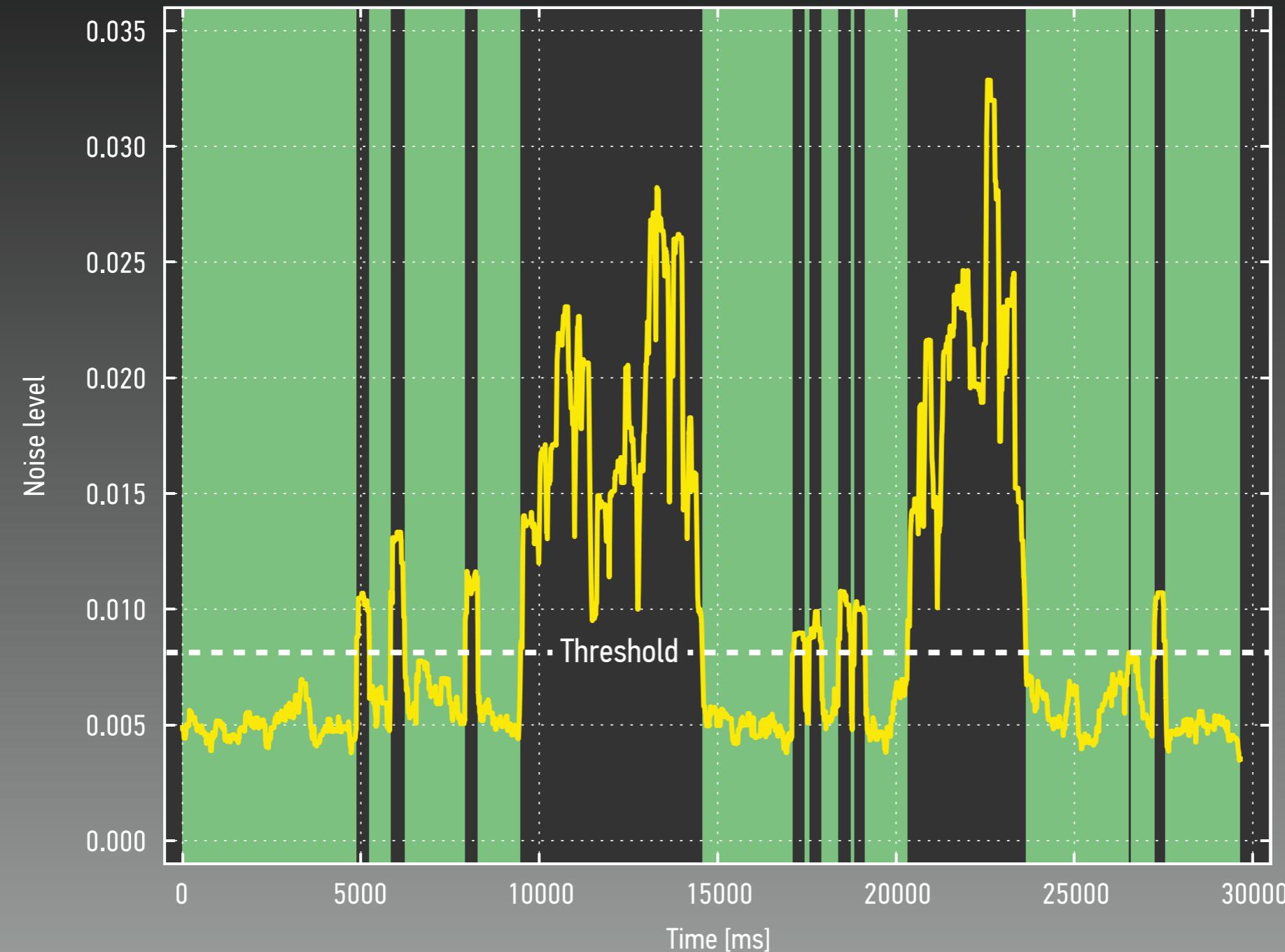


# MODE OF OPERATION



# SAMPLE DATA SET AND BUDDY TAG'S RESPONSE

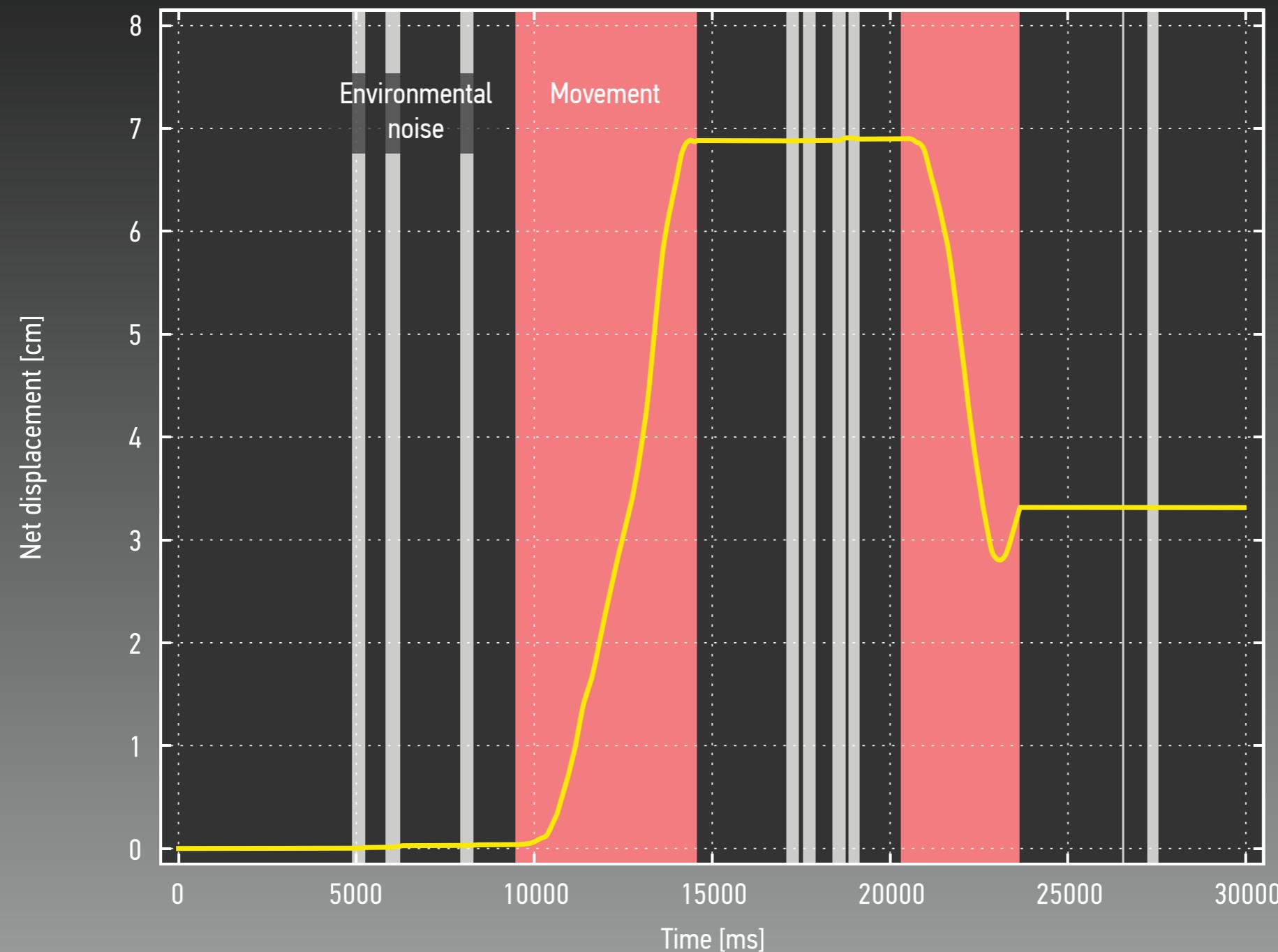
TAG “WAKES UP” IF ACCELERATIONS EXCEED THRESHOLD VALUE



(Data acquired and analyzed with preliminary methods and algorithms)

# SAMPLE DATA SET AND BUDDY TAG'S RESPONSE

## IN TRACKING MODE, ALGORITHM IDENTIFIES TRANSLATIONS



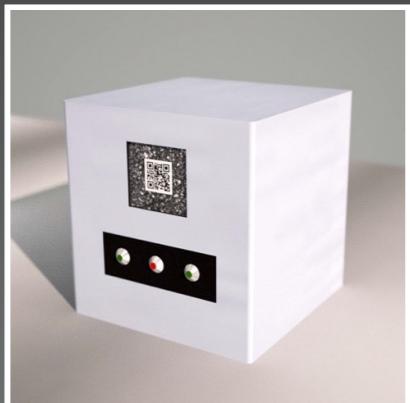
(Data acquired and analyzed with preliminary methods and algorithms)

# SUMMARY AND NEXT STEPS



## VERIFYING NUMERICAL LIMITS

Buddy Tag provides a method to non-intrusively verify numerical limits on sensitive items (by separating the tag from the item) with opportunities for gradual enhancements



## NEXT STEPS: REVIEWING THE CONCEPT

Joint construction of a number of full-up prototypes for review by independent experts to assess selected features and potential vulnerabilities



## BUDDY TAG AS A PLATFORM FOR TECHNOLOGY DEMONSTRATION

Relevant technologies include unique identifiers, tamper indicating enclosures, secure electronics, secure software, and advanced algorithms

*Source: Paul Shambroom (top) and U.S. Department of Energy (bottom)*

# ACKNOWLEDGEMENTS



Bureau of Arms Control, Verification and Compliance (AVC)  
U.S. Department of State

Consortium for Verification Technology  
National Nuclear Security Administration  
U.S. Department of Energy