



# *Passive RFID Sensing for Harsh Environments*

Lawrence Livermore National Laboratory

Faranak Nekoogar, Ph.D.  
Farid Dowla, Ph.D.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

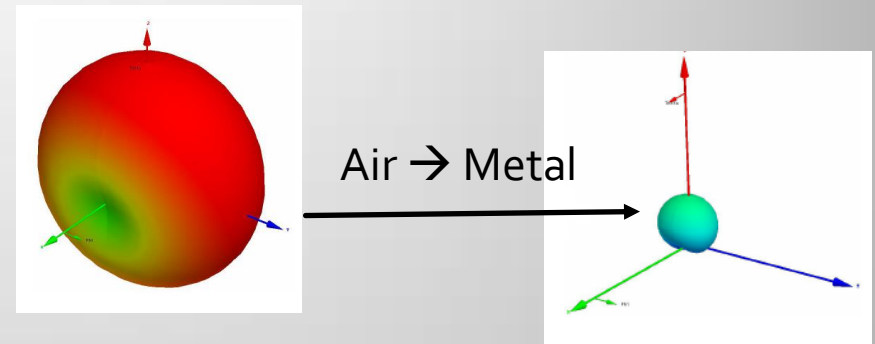
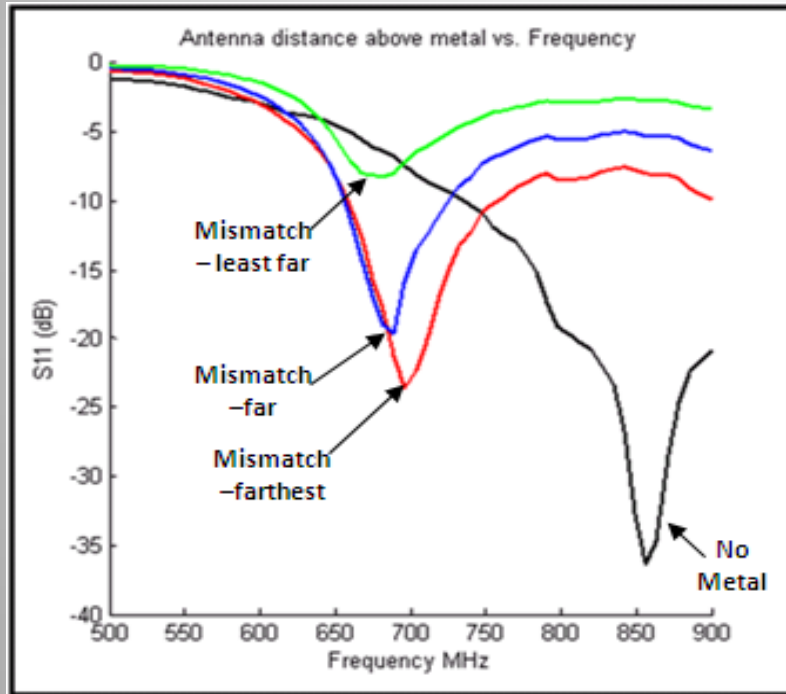
LLNL-PRES-680285



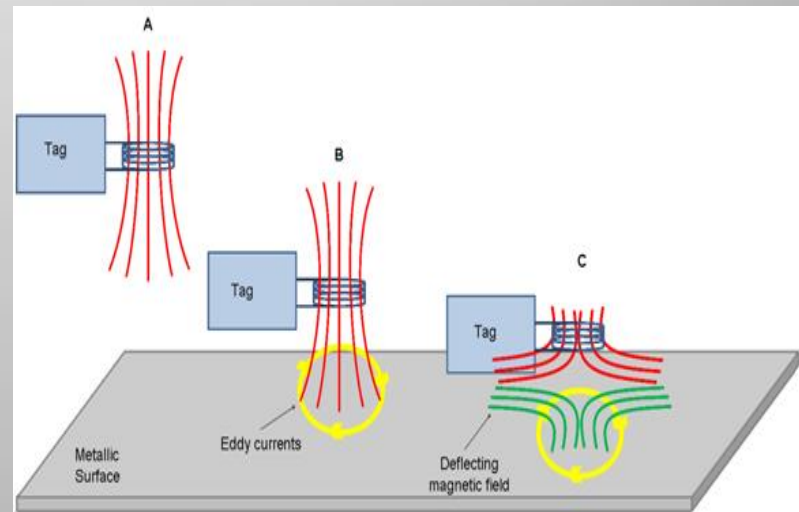
# Asset monitoring and remote sensing in hostile environments is an important need and a daunting technical challenge



# Performance of conventional tags degrades significantly when placed on metallic objects



Communication (remote powering and Back-scattering) is a technical challenge that requires a comprehensive system design.





# Why active tags are not ideal?

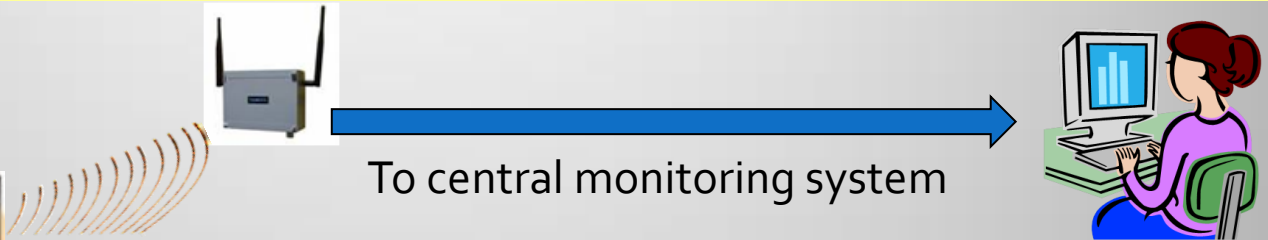
- ❑ Operational lifetime is limited by fixed capacity of battery.
- ❑ Depletion of battery is dependent on both transmission, computation, and usage.
- ❑ Computational requirement is increased with the need for data security.
- ❑ Unpredictability of life expectancy.
- ❑ Battery health status is difficult to predict and monitor.
- ❑ Battery maintenance, shipping, and disposal.
- ❑ Active RF transmission is undesirable in nuclear facilities
  - ❑ Constant transmission can lead to security issues
  - ❑ Active transmission by 1000's of tags can increase the noise level



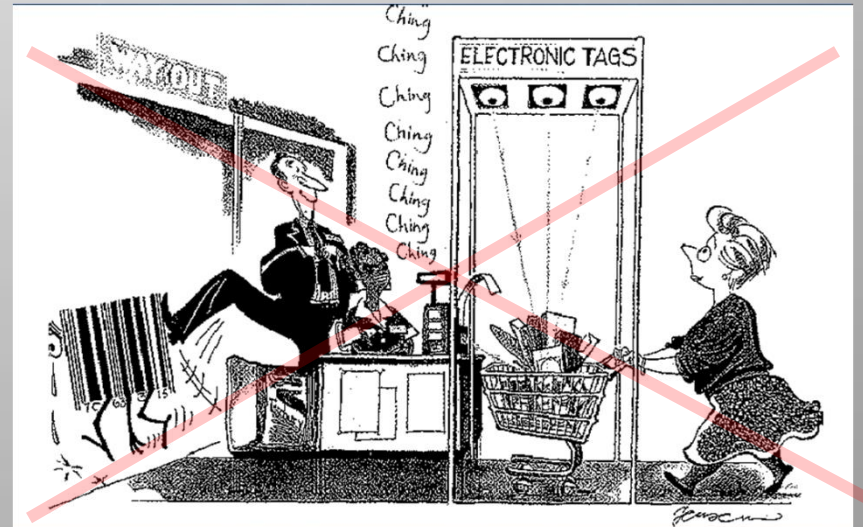
**Reducing the number of critical components in a system, always increases its reliability over a long period of time**

# Conventional RFIDs do not meet the requirements for monitoring of some valuable assets

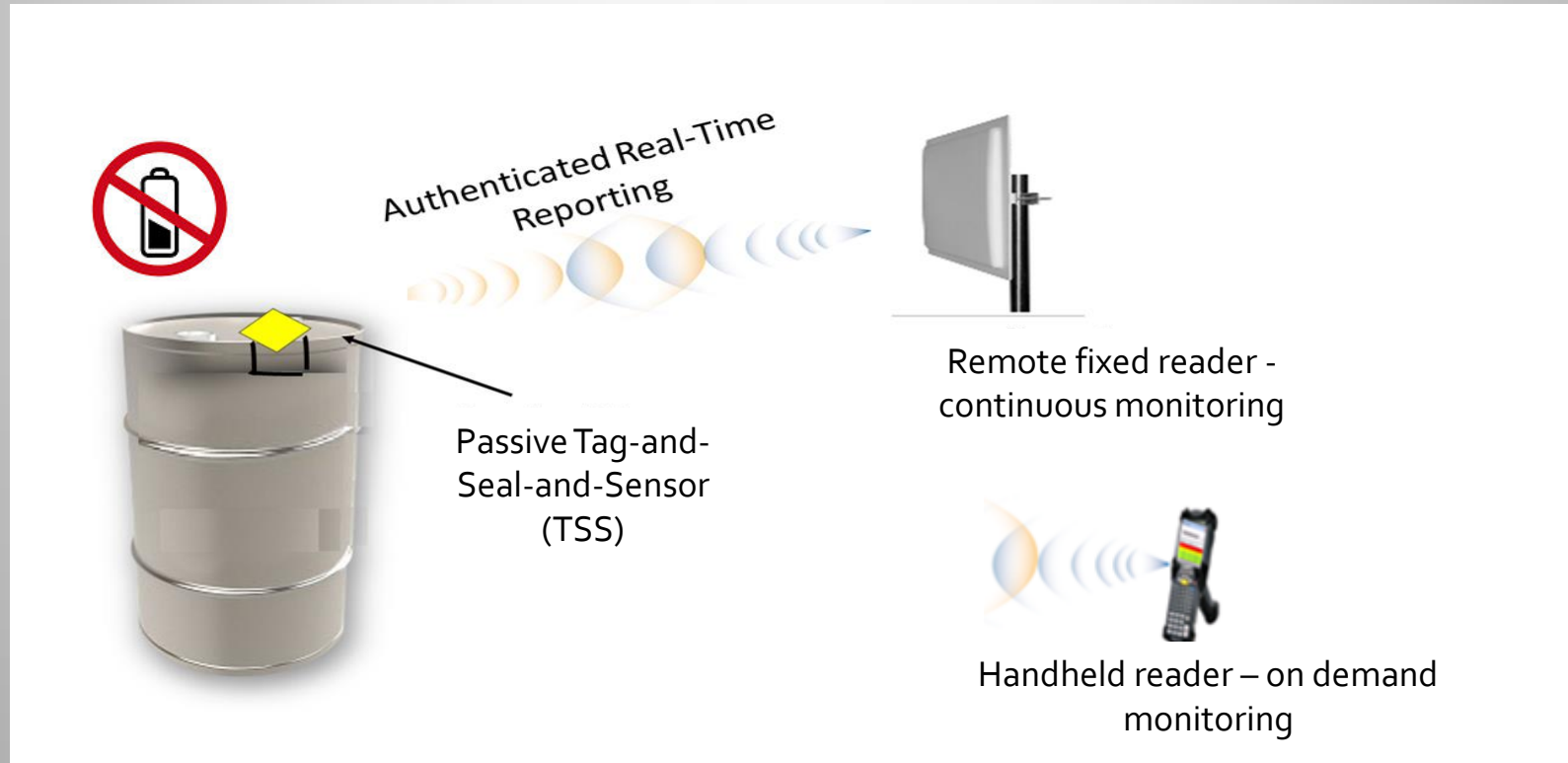
NNSA/DOE RFID systems need to be designed to address unique challenges of tags on metal, reflections, NLOS, passive, data security, physical security, multiple sensors...



The requirements and capabilities of commercial RFID systems are different and do NOT meet the requirements of most DOE applications.



# Remote Monitoring of Items with Ultra Secure, Long-Range, Passive (Battery-Free) Tag-and-Seal-and-Sensors (TSS)



TSS provides the following features ***without the need for any batteries***:

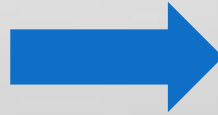
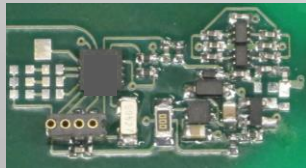
- Unique ID, seal tampering state, temperature and accelerometer data, and time stamps
- Secure communications with AES encryption and dynamic authentication
- Self-destruction upon removal
- No active transmission (backscattering technology)

## Authenticated reporting of ID, sensor data, seal status, and location without the need for batteries is a new paradigm that can revolutionize Safeguards monitoring

Characteristics	Benefit
Totally Passive (battery-free)	Indefinite lifetime
Designed for metallic assets	Reliable communications on metallic objects
Dynamic Authentication	defeats tag cloning threat
Strong Encryption (AES)	Secure wireless channel
Conformable tags	Adapts to the curvature of the container
Tamper resistant base, self-destruction upon removal	Physical security, could act as a seal
Multiple tags detection (1000's)	Automated monitoring
Long-range (>15 ft with encryption, 200 ft without encryption)	Standoff monitoring
Integrated temperature, accelerometer, radiation sensor	Both sensor and tag are powered remotely by RFID reader antenna
Standalone customized reader with single board computer	Easy deployment to various facilities
Networking through TCP/IP protocol	Remote end-to-end monitoring
Multiple antennas provide longer read range	Large area monitoring
TRL level 7	Mature technology
ASIC implementation will further improve range	Longer range standoff monitoring



Passive, secure TSS is being miniaturized by ASIC design for lower cost, mass manufacturing at DSI



ASIC allows for optimal performance of either longer range or smaller size



# LLNL- DSI Harsh Environment Tag (HET) system is uniquely designed for remote monitoring applications in hostile environments without the need for batteries.

Unique characteristics of the HET system include:

- Passive (battery-free) tags with indefinite lifetime and no maintenance designed for harsh environments such as:
  - Reflective (Metals)
  - Absorptive (Liquids)
  - Attenuating (Clutter)
- Portal standalone readers with distributed antennas, on-board battery, and processing platform for continuous monitoring
- Customized handheld readers reporting to tablets and smart phones for on-demand monitoring
- Multi-layer relational database and customized application specific business logic



Customized  
Handheld Reader



HET Passive Tags

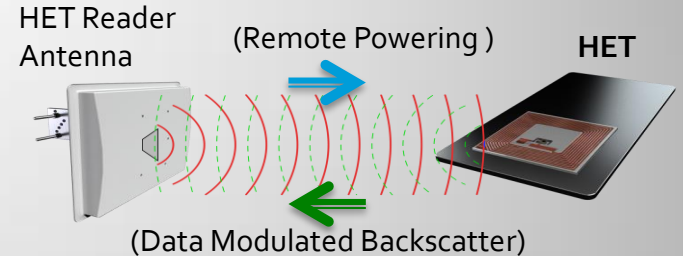


HET Portal Reader

# The HET system consists of three important key innovations

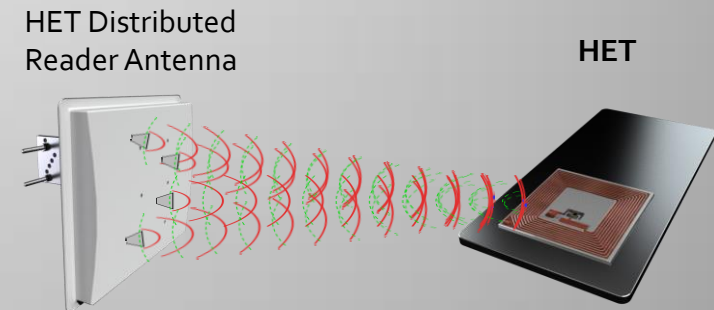
- long-range, power-harvesting passive RF tags to overcome harsh environment RF challenges

- Using novel antenna and advanced material substrate design, The HET tag is able to harvest over 200 micro-watts of power from the receiving EM field, compared to 20 micro-watts in a typical passive tags.



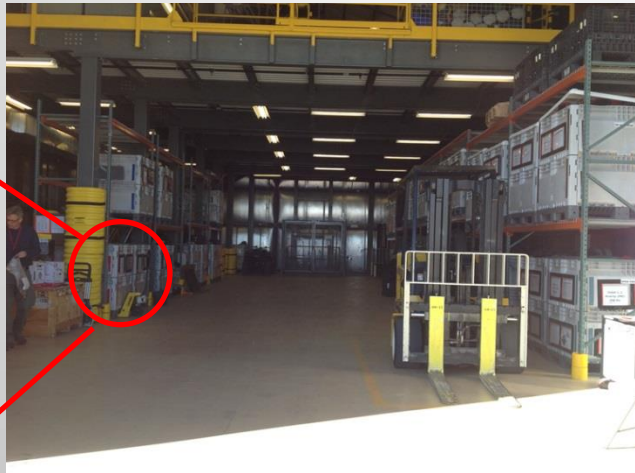
- A set of distributed reader antennas to focus low-power RF signals onto confined monitoring areas and complete coverage of tags

- The multi-static antenna design allows for the focusing of the reader signals
- Advanced signal processing in readers computing platform allows for detection of low SNR backscattered signals.



- Readers are integrated with a highly intelligent database with proper business logic, and reporting to a cloud network for real-time inventory

# Harsh Environment 1: Currently in use: Inventory Automation for Time-Critical Missions, Large number of Assets, Time- Consuming manual database operations



Each pelican case (parent asset) contain many equipment (children assets)





## Assets are monitored by various size passive tags

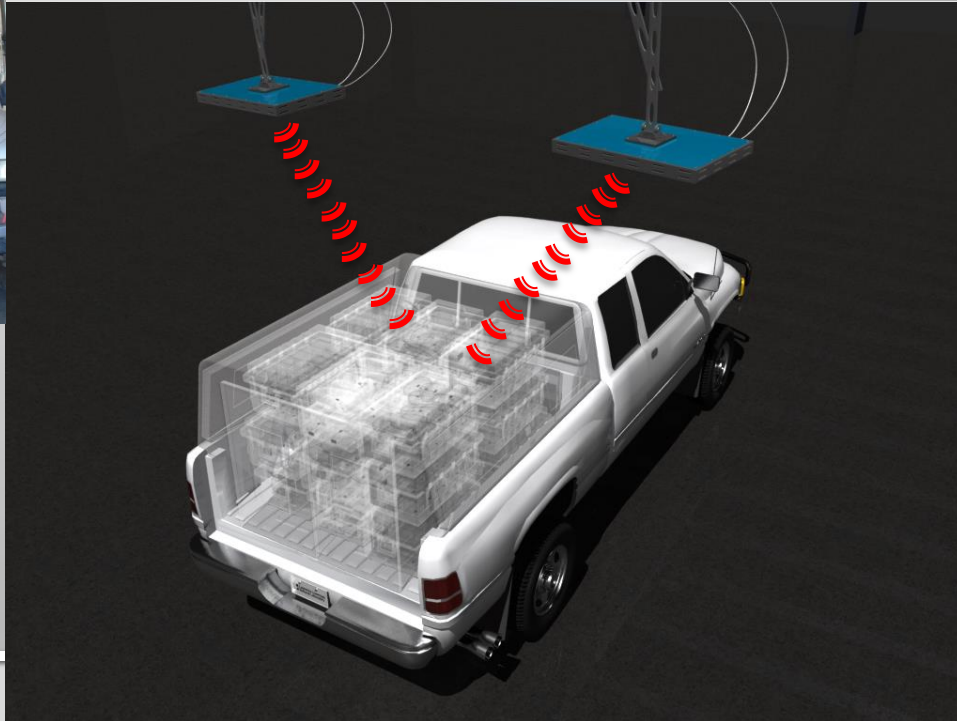




Individual assets inside the pelican cases are monitored with a handheld reader, displaying contents in a relational database on iPad without the need for opening the case.



**Portal readers monitor and report the vehicle, pelican cases inside and individual assets inside the cases, in real-time**



## Harsh Environment 2: LLNL-DSI passive tags respond reliably from inside of metallic containers with mm gaps





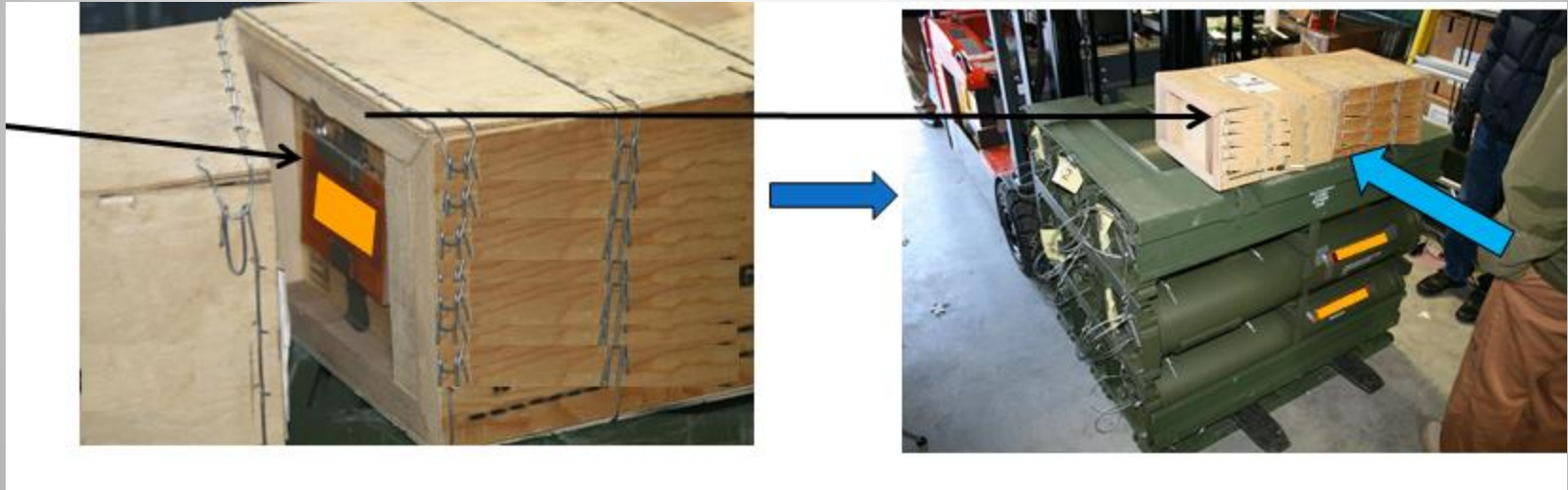
# Harsh Environment 3: Demonstration for Army's Ammunition inventory

- LLNL's RFID system characteristics:
  - ✓ Passive RF tags (no battery required)
  - ✓ Low power reader (1 Watt EIRP)
  - ✓ Minimum of 6 ft read range in several container scenarios
  - ✓ Reliable operation on metallic objects
  - ✓ EPC Global compliant
  - ✓ Reliable operations on standard range of military environment of -60F to 160F.





## Test case: Passive tags, sandwiched between wooden containers of metal contents (NLOS)



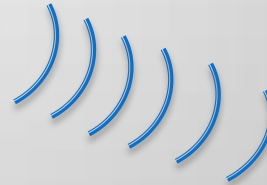
- ☐ Tag was reliably detected at 6 ft in direction of blue arrow
- ☐ This is a remarkable result as no other tags showed success in this configuration

## Harsh Environment 4: LLNL Safeguards tags can be used for Biological agent monitoring

- Integrated tag-seal provides security and confidence in monitoring bio samples
- Tags inside the freezer were read reliably at the opening of the door
- No performance degradation of tags in -80°C



*Passive (batteryless)  
authenticated real-  
time reporting*



## Harsh Environment 5: HET were placed on various parts of a rotorhead and detected by remote reader



DSI Passive Tags





From 18ft, ALL tags were read despite their challenging positions, from 30 ft tags on one side of rotorhead were detected





# Summary

- ❑ Integration of RFID tags and a suite sensors solves many important problems.
- ❑ Eliminating the batteries and operating in harsh environments addresses many real-life application requirements.
- ❑ LLNL-DSI tags address the widespread user needs in harsh environments, provide data and physical security, and allow sensor integration without the need for batteries.



# Acknowledgements

Special thanks to:

- ❑ DOE NNSA HQ
- ❑ Dirac Solutions Inc.
- ❑ TDA Systems
- ❑ WISEE workshop committee