Results from a "Proof-of-Concept" Demonstration of RF-Based Tracking of UF_6 Cylinders during a Processing Operation at a Uranium Enrichment Plant

C. A. Pickett
J. R. Hines
D. N. Kovacic
M. D. Laughter
J. R. Younkin
Oak Ridge National Laboratory

Bernie Carrick, Ken Whittle
USEC

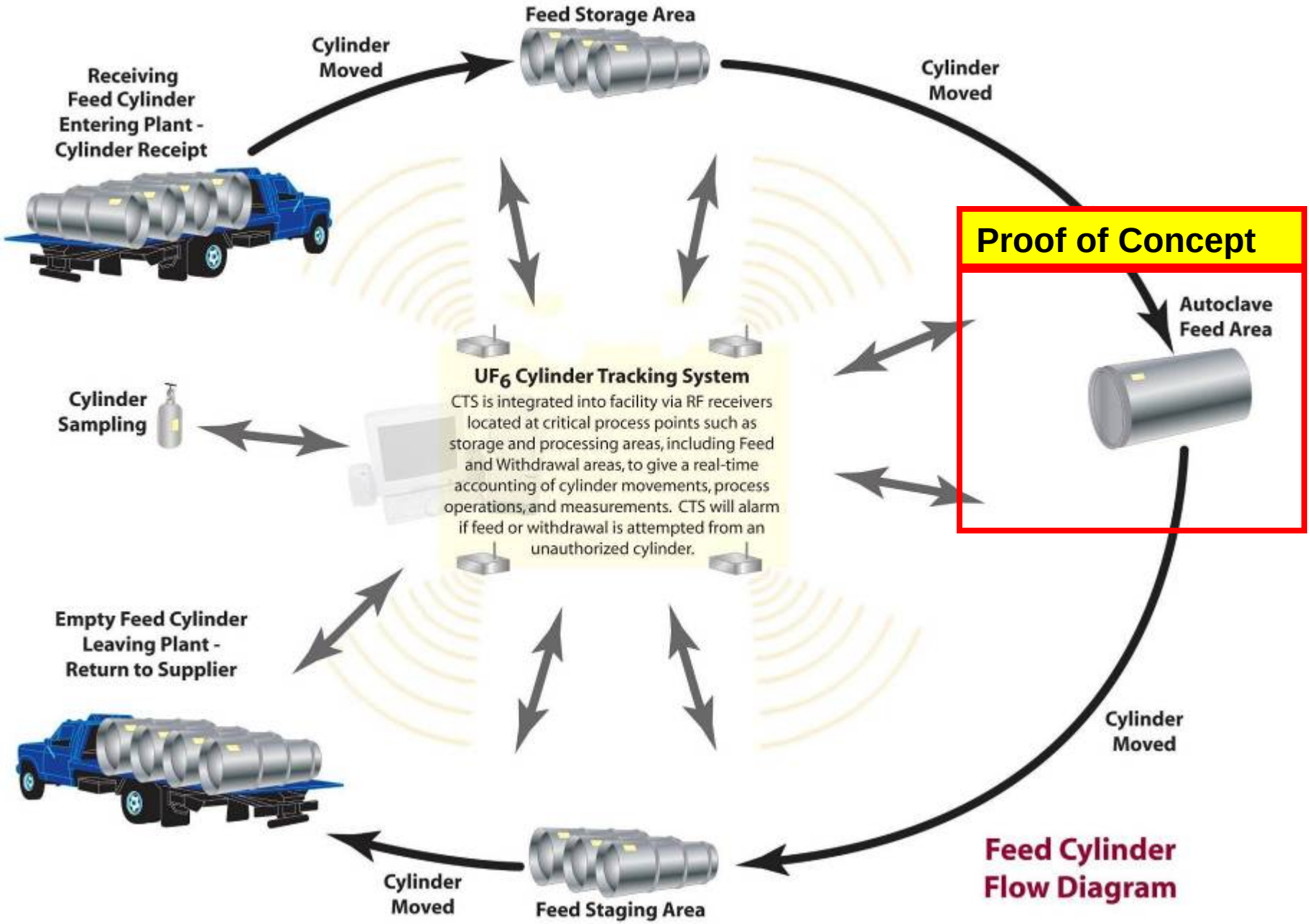
B. D. Boyer
Los Alamos National Laboratory

INMM 49th Annual Meeting
Nashville, Tennessee
July 13 – July 17, 2008

Agenda

- **“Proof-of-Concept” demonstration**
- **System installation at Portsmouth**
- **Radio frequency (RF) tags**
- **Results & Lessons Learned**
- **Some next steps**

Real-Time UF_6 Cylinder Tracking System (CTS)



UF_6 Cylinder Accountability and Tracking System (CATS) Proof-of-Concept Demo

- **What it IS**
  - **Proof of the feasibility of using RF technology for tracking UF6 cylinders and how it can be applied to a safeguards system**
  - **Operational understanding of system needs**
  - **How rules-based tracking can be implemented**
- **What it IS NOT**
  - **Ready to be critiqued as a safeguards application**
  - **Endorsement of any specific type of RF frequency or technology**

System Layout at Autoclave Facility

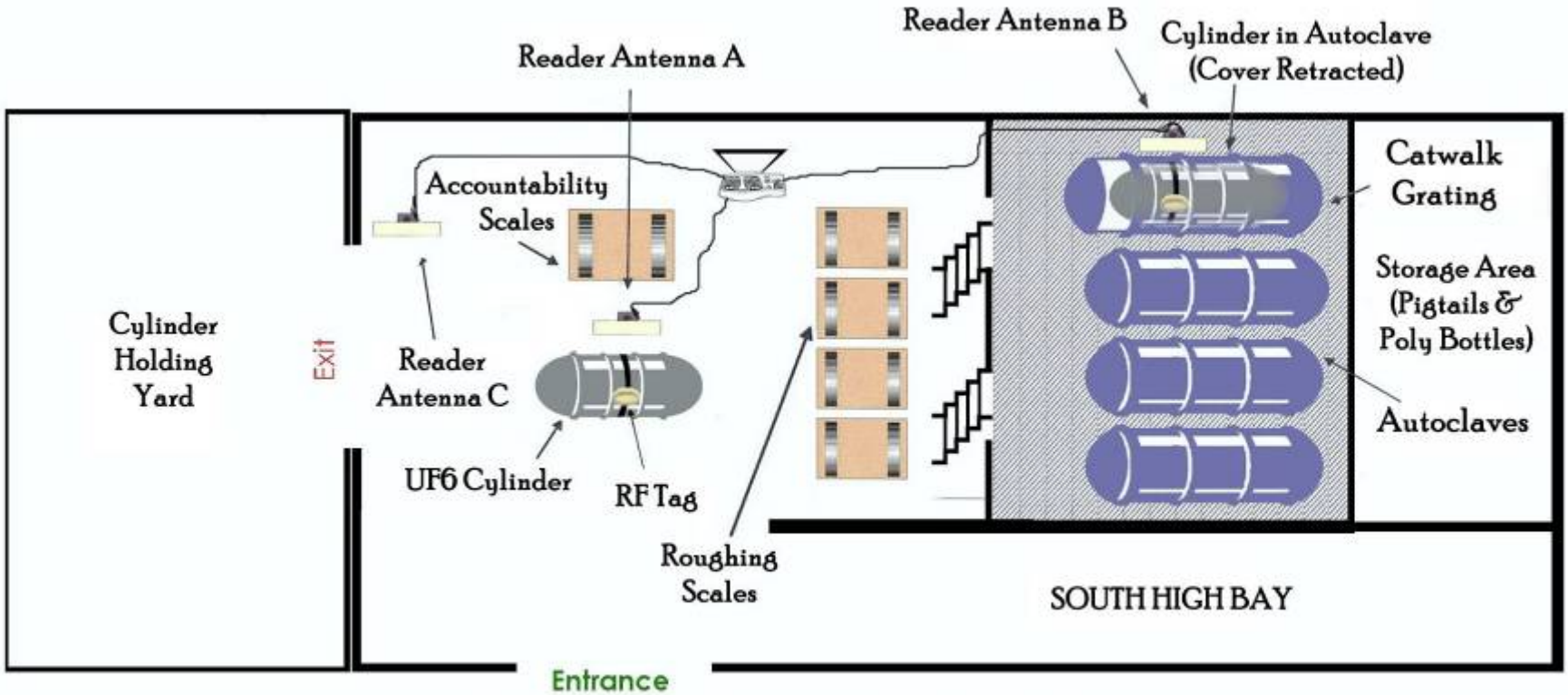
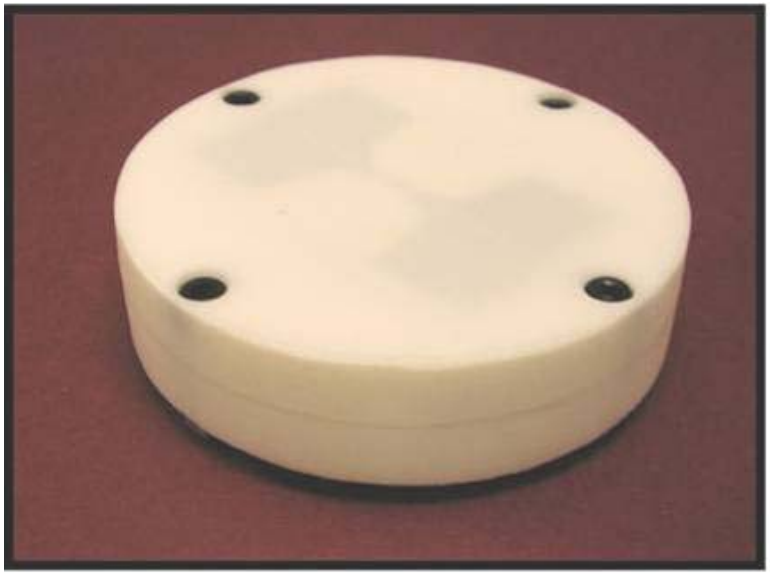


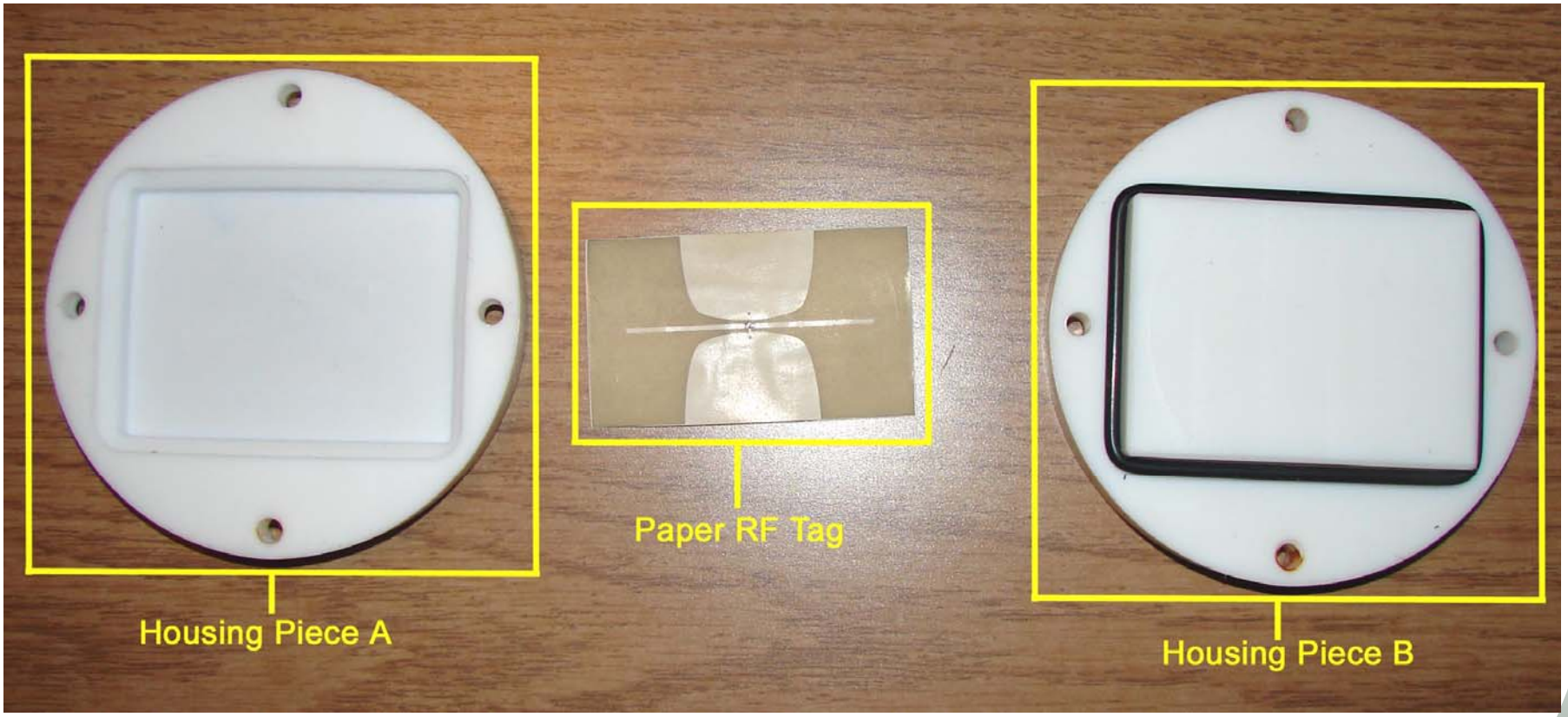
Fig. 1 Proposed Field Test Set-up at the X-344 Transfer Facility

"Hockey Puck" Tag

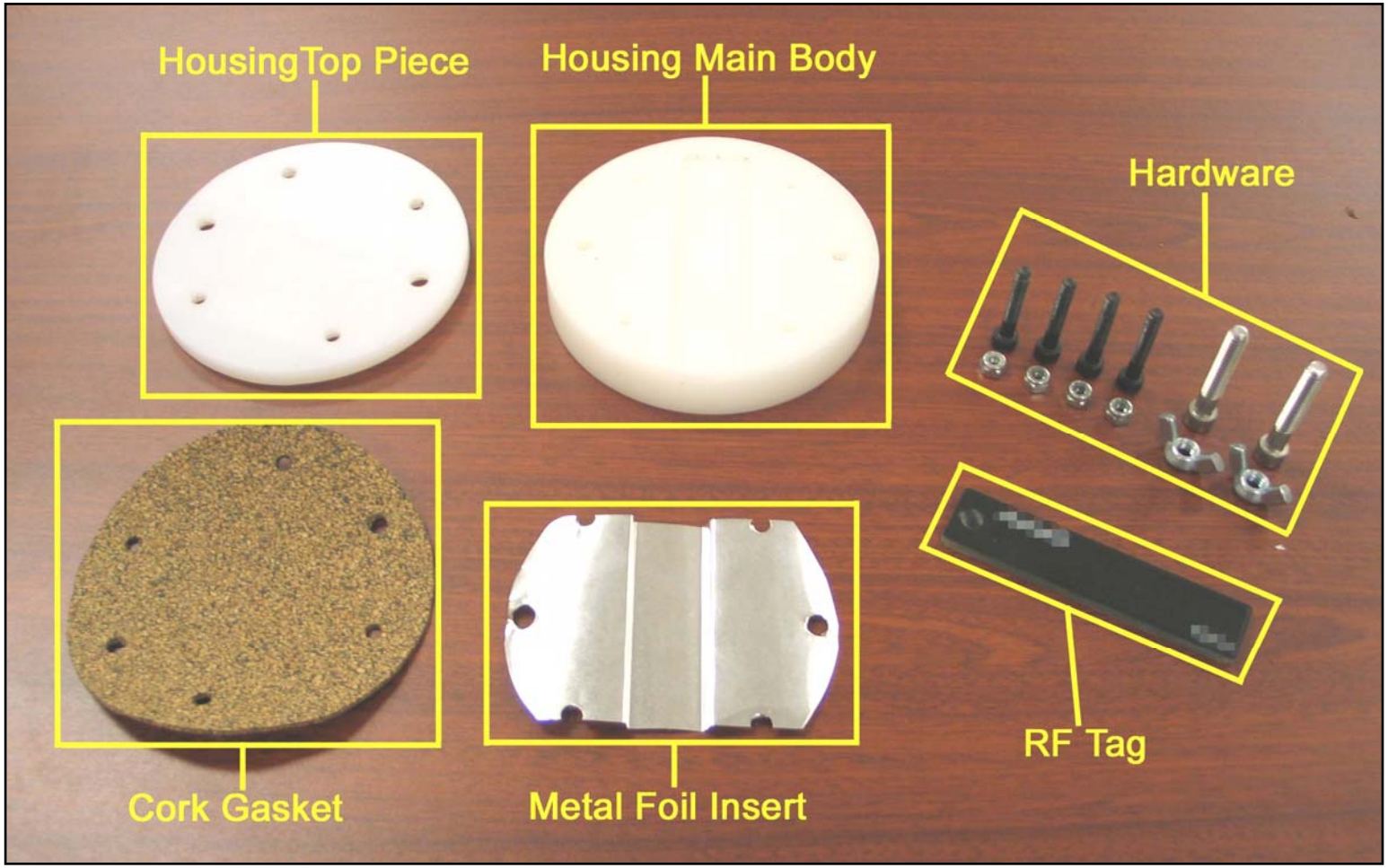
- **Custom designed**
  - **Four-in. diameter by one-in.-thick machined polyethylene**
  - **Designed to provide standoff height for paper tag**
  - **Accommodation for mounting bolts and band type attachment**



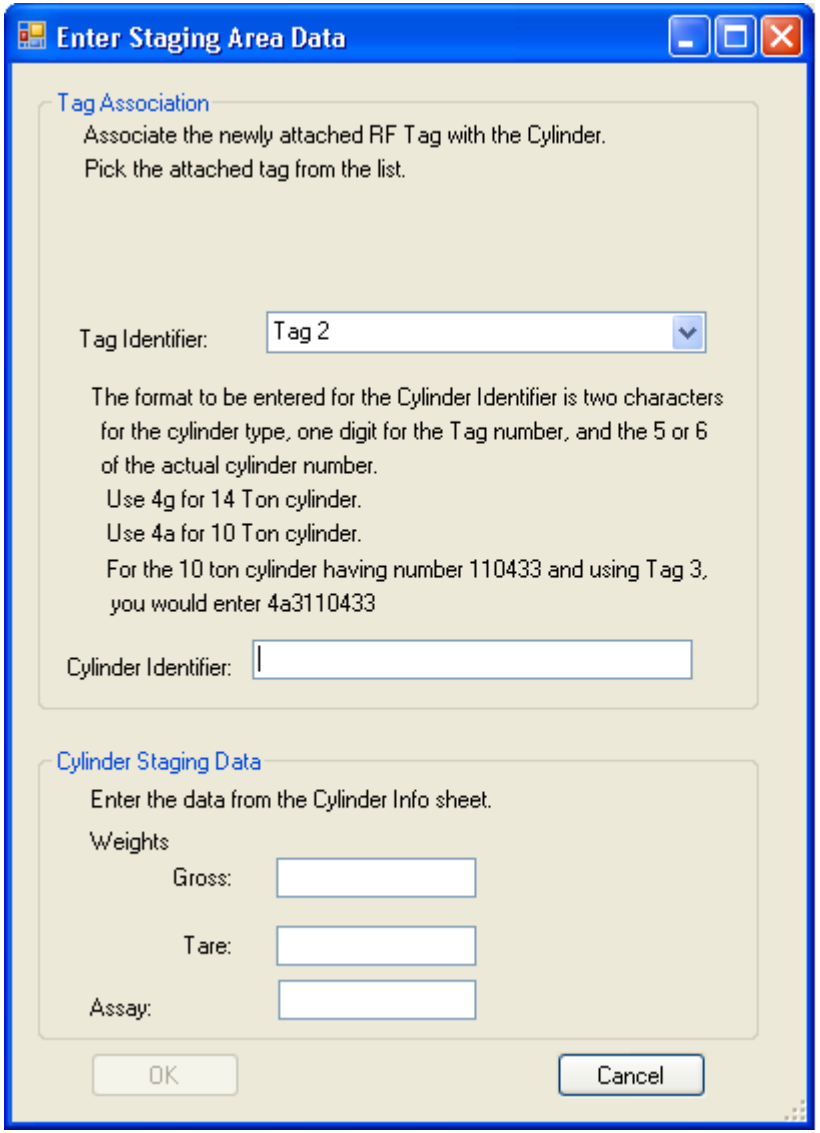
Tag Type 1 – Internal Components



Tag Type 2 – Internal Components

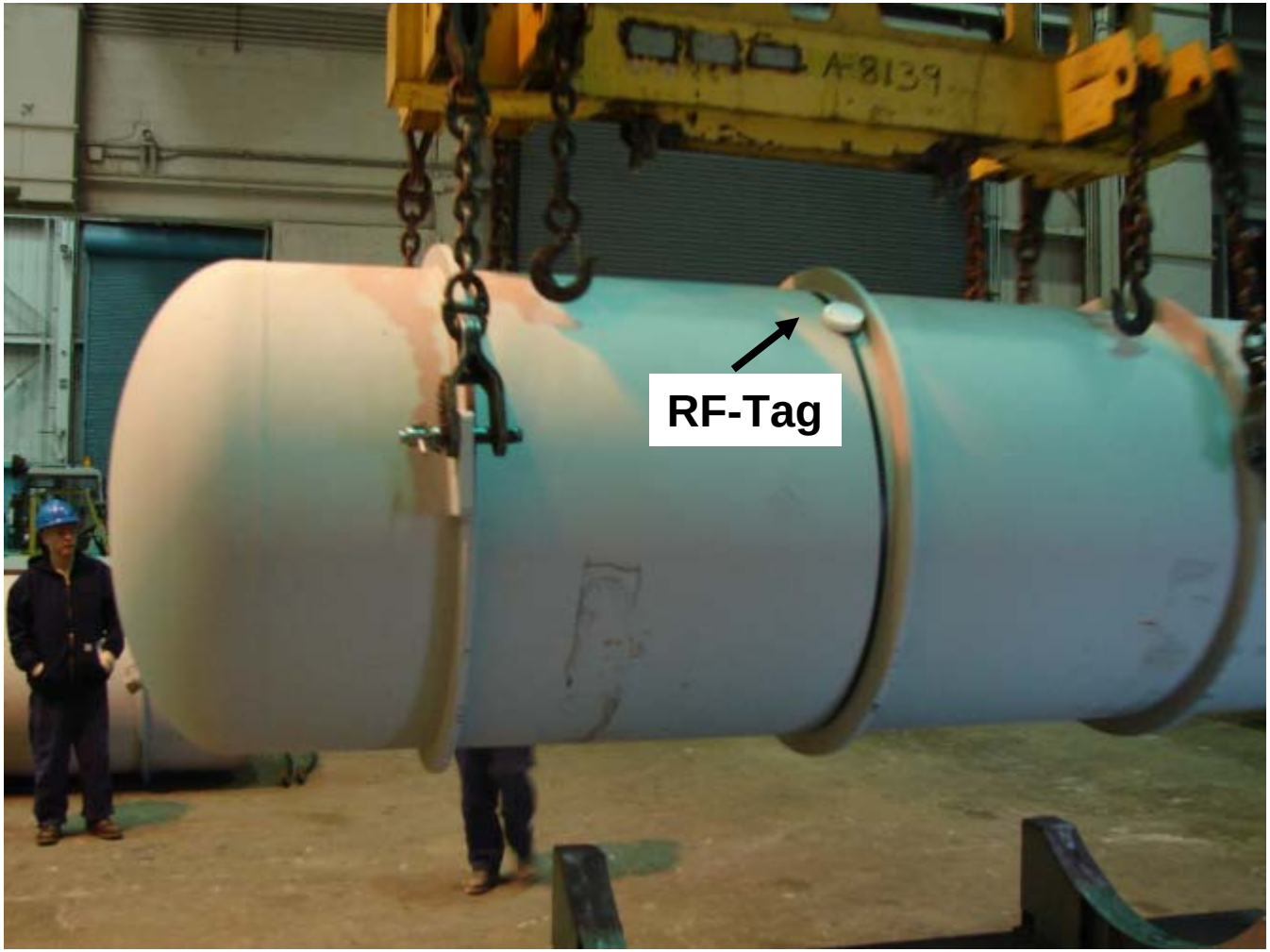


Tag Registration Dialog Box



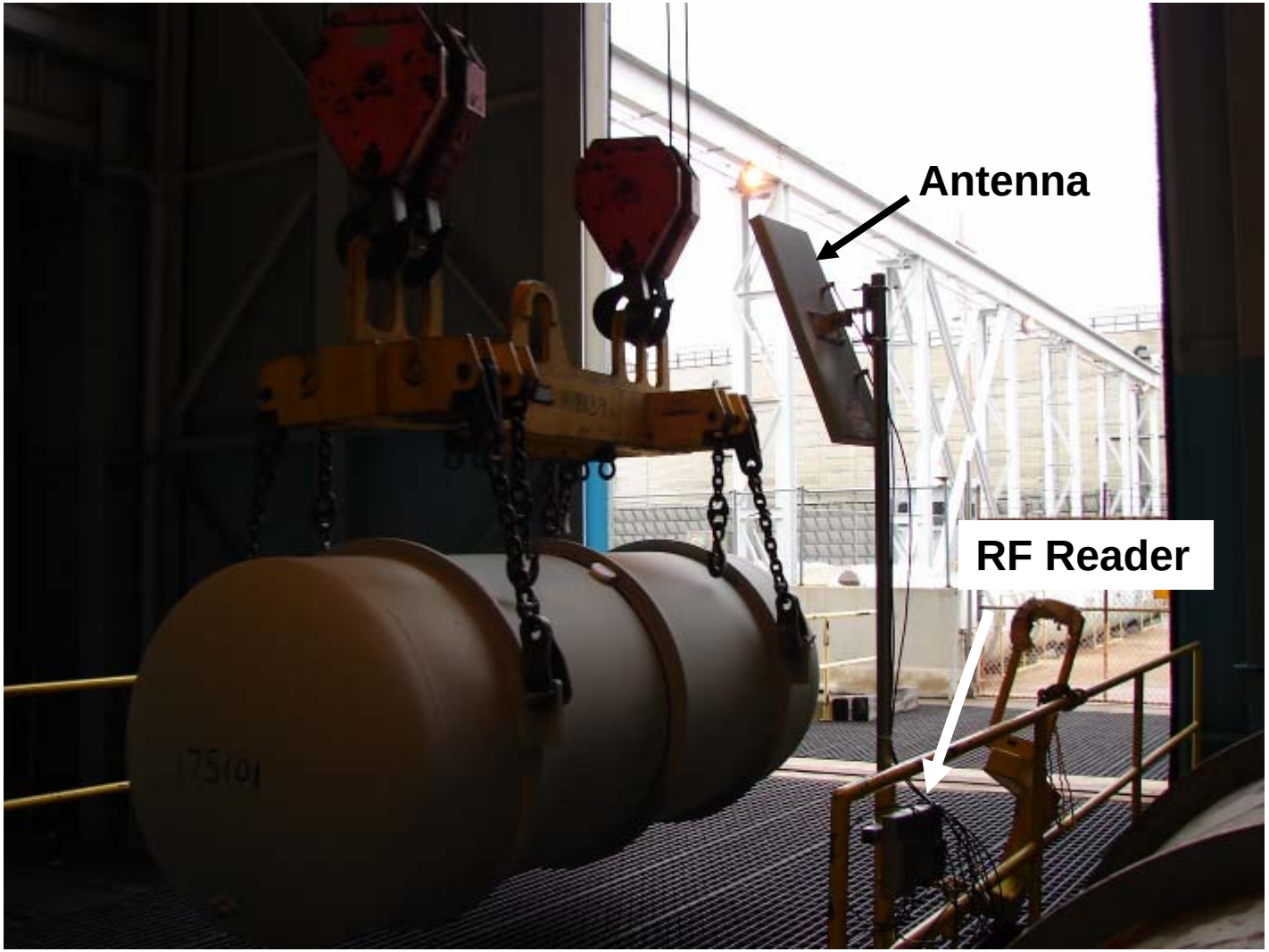
Tag registration ensures that a specific protocol is followed and verified to ensure appropriate cylinder-tag association

RF-Tagged Cylinder



RF Monitoring as Cylinder is Moved to Scale for Post-Process Weighing

Detection of Cylinder Exiting Facility



Cylinders and Tags Processing Log

Date	Cylinder #	Tag #	Comment
1/17/2008	175101	Tag 4	Empty test cylinder to check out system/optimize tag placement on Cylinder at Autoclave reader.
1/18/2008	174995	Tag 2	
1/18/2008	001879	Tag 4	11 Hours
1/19/2008	002476	Tag 1	Last seen at Autoclave - died
1/20/2008	002222	Tag 4	
1/24/2008	174017	Tag 4	15 Hours
1/25/2008	001551	Tag 2	22 Hours
1/26/2008	002463	Tag 4	26 Hours
1/27/2008	005031	Tag 2	20 Hours
1/28/2008	173624	Tag 2	9 Hours
1/29/2008	002161	Tag 4	3.5 Hours
1/30/2008	001988	Tag 2	26 Hours
2/2/2008	174661	Tag 4	7 Hours

Results to Date

- **Two UHF tag types were tested**
- **Total 8 Tags Tested (4 of Each Type)**
- **37 Cylinders Cycled (as of February 2008)**
- **Two of paper type tags failed on first run due to leaking seal**
- **All four of Type 2 tags either failed completely or suffered diminished read range (Results for this tag are inconclusive)**
- **Two of paper tags had 20 successful runs through autoclave before seal failed**
- **All tags surviving the autoclave (through February) had a 100% successful read rate with all antennas.**
- **Final system testing on re-worked tags concluded in late June and this data has not yet been compiled.**
- **These results indicate that it is possible to construct survivable passive RF tags.**

Lessons Learned (Preliminary)

- **RF tags can be designed and manufactured to survive autoclave and processing environment**
- **Have (to date) experienced 100% read accuracy**
- **Operator has indicated that using such a system for internal tracking of UF6 cylinders could be extremely beneficial provided that cylinder attributes are linked with cylinder ID (such as maintenance histories, certification info, etc.)**
- **RF tags will need a quality assurance effort to ensure they are manufactured to specification**

More Lessons Learned

- **RF interference must be tested and observed (may be mitigated)**
  - **Three RF interference issues were evaluated for this test**
    - RF-controlled Gantry crane (not a problem, different frequency)
    - Electronic dosimeters (affected old version, but not new ones)
    - NDA equipment (affected older model, but not newer one)
- **Operational evaluations via field tests are absolutely necessary to determine real-world performance and to gather valuable input from operators (this will be site specific to a certain degree)**

Equipment in the Autoclave Facility that was susceptible to RF-interference

(a) **(b)**

(a) RF-based dosimetry and
(b) nondestructive assay measurement cart.

Future Efforts and System Design Issues to Addressed

- **A team of RF technologists and safeguards professionals met in Oak Ridge, Tennessee, during May of 2008 to discuss vulnerability issues and functional requirements for a next generation RF-based CTS. The following are some of the near-term steps that were identified.**
- **Engaging stakeholders (operators, IAEA, etc.) in developing full system requirements.**
- **Integration of system with continuous load cell (weighing) measurements.**
- **Working with Los Alamos National Laboratory on supporting global positioning system tracking of cylinders from a shipping site to a receiving site.**
- **Evaluating other RF technologies.**
- **Developing some tamper-resistant attachment options.**

Vulnerability Issues: include spoofing, counterfeiting, transfer, and cloning.

• **Tag attachment**	**Solutions: Embedded technologies**
• **Tag Packaging**	**Solutions: Tamper indicating packaging, smart tags**
• **Battery lifetime**	**Solutions: Passive tags, low power circuitry, batteries with extended life**
• **Environmental**	**Solutions: Improved packaging technologies**
• **RF interference**	**Solutions: Site and route survey, ultrawide band and spread spectrum**
• **Shielding**	**Solutions: Low frequencies, heart-beat (for an active tag), multiple antennas**
• **Spoofing/authentication**	**Solutions: Advanced cyber security techniques**
• **Data security/integrity**	**Solutions: Advanced cyber security techniques**
• **Orientation and range**	**Solutions: Distributed readers, ultra-wide-band antenna design**
• **Location of Readers**	**Solutions: Tamper-resistant packaging and location sealing**

The extent to which the system design can mitigate these concerns will be an important aspect of this work.

RF Interference: RF signals can interfere with existing systems and equipment. This interference can be a site-specific or a state-specific issue.

- **Must work in international radio frequencies**
- **Must not interfere with other equipment frequencies**
- **Must be resistant to jamming detection/denial of service**
- **May need to be resistant to shielding**
- **May need to include watchdog heart beat for active tags**
- **Must be resistant to spoofing/amenable to authentication**
- **Must include transport layer of security**
- **Must ensure data security and integrity**
- **Must be insensitive to orientation**
- **Must have adequate location accuracy and read range**

Layered Technologies-
A number of technologies that may improve system effectiveness have been identified.

- **Load cells**
- **Reusable tamper indicating devices**
- **Radiation detection sensors**
- **Integrated Tamper technologies (such as reflective particle tag)**

Some Future issues that need to be addressed for system acceptance include:

- **Operator and state or IAEA acceptance,**
- **International standards,**
- **Export control, and**
- **System costs.**

Current Near Term Activities

- **Engaging stakeholders (operators, IAEA, etc.) on developing full system requirements**
- **Integration of system with load cells**
- **Working with Los Alamos National Laboratory on supporting GPS tracking of cylinders from shipping site to receiving site**
- **Evaluating other RF technologies**
- **Developing some tamper resistant attachment options**
- **Some near term testing in a fuel assembly facility later this year.**