CONCEPT FOR AN IN-FIELD INVENTORY ASSISTANT TO STRENGTHEN IAEA INVENTORY ACTIVITIES

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ABSTRACT

Oak Ridge National Laboratory has developed the concept and user experience for an in-field software assistant to support a variety of nuclear item inventory activities at nuclear fuel cycle facilities. The concept was modeled after the International Atomic Energy Agency's (IAEA's) paper-based item counting and tag checking of uranium hexafluoride cylinders at fuel fabrication and enrichment plants, which may have thousands of cylinders. The proposed inventory assistant was designed to significantly reduce the number of person-days of inspection (PDIs) currently expended by the IAEA, and it could be integrated into the IAEA's existing workflow to enhance their ability to conduct inventory activities more quickly, accurately, and reliably. The assistant provides capabilities to digitally record field observations, quickly display discrepancies between provided listings and actual observations, and maintain records of actions to resolve discrepancies. The authors suggest that significant PDI savings can be achieved, and the IAEA can apply these savings to conduct other more impactful on-site verification activities. The proposed assistant consists of two software components: (1) a tool for inventory teams to record observations in the field and (2) a tool for the inventory lead to (a) distribute the inventory list to each team, (b) integrate the observations from each team, and (c) reconcile the inventory list with observations. This paper discusses the concept and proposed workflow, illustrates key conceptual screens, and describes the anticipated PDI savings.

INTRODUCTION

A team at Oak Ridge National Laboratory (ORNL) has developed proof-of-concept software to empower users to reconcile inventory-related observations more accurately, reliably, and quickly. Inventory activities at nuclear facilities are typically conducted using pen and paper, which can be time-consuming, tedious, and susceptible to reading or transcription errors. The proposed inventory assistant would be a replacement for this paper-based process currently used by International Atomic Energy Agency (IAEA) inspectors, nuclear facility operators, regulatory authorities, or treaty verification monitors to inventory nuclear and nonnuclear items. The inventory assistant consists of two software components—one that is loaded onto a portable device like a Windows-enabled tablet (mobile app) and one that is loaded onto a desktop or laptop computer in an on-site office (desktop application). The concept, user experience, and functionality for the mobile app and the desktop application are introduced in the ORNL reports *A Conceptual Design for a Mobile Application to Support Infield Inventory Activities* (ORNL/TM-2020/1646) and *A Conceptual Design for a Desktop Application to Support Inventory Reconciliation Activities* (ORNL/TM-2020/1790), respectively [1], [2].

In general, the inventory assistant would ingest an inventory list, distribute assigned items from the inventory list to one or more portable devices, enable inventory teams to record their observations in the field, and then enable an inventory lead to integrate and reconcile the observations to produce a final report. The inventory teams would use the mobile app to record their inventory-related observations in the field, while the

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inventory lead would use the desktop application to (a) distribute the inventory list to each team, (b) integrate the observations from each team, and (c) reconcile the inventory list with recorded observations.

This paper discusses the concept and presents the workflow for the inventory assistant, using IAEA inspectors conducting item counting and tag checking activities of uranium hexafluoride (UF_6) cylinders at a gas centrifuge enrichment plant (GCEP) as a representative use case. Additionally, this paper reports on ORNL's progress to date on developing the inventory assistant proof of concept.

BACKGROUND

Many industries use commercial systems to inventory individually identified items on a regular basis. However, the commercial off-the-shelf inventory software typically requires the items to be barcoded, which is not always the case for items at nuclear facilities. For example, UF_6 cylinders commonly found at conversion, enrichment, and fuel fabrication facilities may not be barcoded or even use a consistent naming convention [3]. The ANSI [4] and ISO [5] specifications only require cylinders to have a debossed (stamped) serial number on the stainless-steel nameplate. To improve inventory procedures and practices, some operators affix a vinyl label with their own identification number and a one-dimensional (1D) barcode [6]. Recently, new cylinders are being produced with a larger laser-etched global identification number and a two-dimensional (2D) barcode.[1] However, considering that cylinders can be in service for 40 years or longer, there will likely be a mixture of barcoded cylinders and legacy cylinders with difficult-to-read serial numbers for the foreseeable future [7], [8]. To accurately and quickly perform inventory activities for a wide variety of items at nuclear facilities, an inventory assistant should be able to efficiently inventory items with only a serial number as well as those with 1D or 2D barcodes.

IAEA inspection activities at GCEPs can currently require 30–40 person-days of inspection (PDIs) to complete. The authors believe an inventory assistant could allow the IAEA to complete item counting and tag checking in 8–10 PDIs.[2] Other users (e.g., facility operators, regulatory authorities, or treaty verification monitors) are also expected to be able to benefit from significant time savings using the inventory assistant. For example, nuclear facility operators may be interested in using the tool to inventory nuclear items or other equipment that may or may not have an affixed barcode, as well items that may have more than one identification number. For verification monitors, an inventory assistant may be used to inventory equipment or items (e.g., B-25 boxes, drums, cylinders) or to create inventory listings for previously unreported items at fuel cycle facilities.

REPRESENTATIVE IAEA USE CASE

A large commercial GCEP may have thousands of UF_6 cylinders on-site, and depending upon the facility, it is jointly inspected by the IAEA and a regulatory authority (e.g., Euratom). Its annual physical inventory verification could take approximately two weeks for a team of four to six IAEA inspectors to complete item

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[1] In 2017, the World Nuclear Transport Institute (WNTI) issued a voluntary, global standard for identification of UF_6 cylinders; this standard provides for a larger laser-etched global identification number and a 2D barcode representation of the cylinder's identification number [3]. Several of the major UF_6 cylinder owners have begun ordering new cylinders produced in compliance with this standard.

[2] Based on exercises performed at the IAEA by the ORNL team in 2016, a user familiar with the software and the exercise could complete an inventory of 50 cylinders in approximately 40 minutes using a pen and paper method, 30 minutes when assisted with software on a tablet, and about 10 minutes when most cylinders included a barcode. Note that PDI savings can be achieved without widespread adoption of the WNTI standard.

counting and tag checking activities on those cylinders. This can require up to 30–40 IAEA PDIs[3], with a similar burden on Euratom and proportional burden on the facility operator.

Currently, IAEA item counting and tag checking activities are paper-based and do not leverage the value of existing barcodes on UF_6 cylinders. The facility operator may provide the IAEA inventory lead with a paper or electronic inventory list. The inventory lead then distributes the list to their teams of inspectors. Often, each team will consist of an IAEA inspector, a Euratom inspector, and a facility escort. As shown in Figure 1, each team is tasked with matching the identification number on its assigned portion of the paper inventory list to a debossed (stamped) serial number on the stainless-steel nameplate or to the operator's identification number printed on a vinyl label [9]. This process is time-intensive, requiring the inventory teams to laboriously find and read the identification number as marked on the cylinder, find the corresponding identification number on the paper list, and then manually mark it off the list.[4] This process is also prone to reading or character transposition errors. When a UF_6 cylinder cannot be found in its listed location, the inspectors may need to extensively search the facility, which may contain thousands of cylinders (Figure 2).

Figure 1. An inspector matches an identification number on a paper inventory list with the identification number on a cylinder observed in the field.[5]

[3] According to the IAEA, a PDI is a day during which a single inspector has access to a facility at any time for a total of no more than 8 hours [10]. While the team may be as large as four IAEA inspectors for some activities, the full team does not participate in all inspection days. For example, four inspectors may be present for the tag checking and item counting activities which benefit from additional teams; other activities may only require one to two IAEA inspectors on additional days during the physical inventory verification period.

[4] The following link shows typical activities that occur during an IAEA inspection at a nuclear fuel cycle facility: https://www.youtube.com/watch?v=Pf1MtMxnEEc.

[5] Reprinted from https://www.flickr.com/photos/iaea_imagebank/22166534096/in/album-72157659464420989/. Some rights reserved. Distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs 2.0 Generic [CC BY-NC-ND 2.0] license.

Figure 2. Finding all the items listed on paper-based inventory listings can be time-consuming and challenging, as illustrated by the two inspectors searching a large storage room for a cylinder of interest.[6]

Once the inventory teams have completed their portion of the inventory list, the inventory lead then collects and merges the handwritten forms and manually identifies and tabulates any differences. Irregularities are common, including cylinders on the inventory list that were not observed in the field, cylinders observed in the field that are not on the inventory list, or separate teams that report observing the same cylinder [9]. The inventory lead must then reconcile these irregularities with the operator before producing a final report.

CONCEPTUAL WORKFLOW

The ORNL team envisions that the inventory assistant would have a component for activities conducted in an office at the facility and a component that would be used in the field at the facility (cylinder yard, feed and withdrawal area, and so forth). In the on-site office, the desktop application could be used on a desktop or laptop computer to ingest the inventory list and distribute the assigned items to the inventory teams. In the field, each inventory team would use the mobile app loaded on a portable device to record observations about the items on their assigned portion of the inventory list or about other items that they observe in their assigned area. Once the inventory teams complete their portion of the inventory list, the inventory lead would use the desktop application to integrate the observations from each team, then reconcile any irregularities between the operator-provided inventory list and the recorded observations before producing the final inventory report. The overall workflow of the inventory assistant is given in the following steps.

1. The facility operator uses the operator's computer to
    - Step 1. Upload the inventory list to a shared location on the datastore[7, 8] (Figure 3)
2. The inventory lead uses the desktop application on the office computer to

[6] Reprinted from https://www.flickr.com/photos/iaea_imagebank/22192664675/in/album-72157659464420989/. Some rights reserved. Distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs 2.0 Generic [CC BY-NC-ND 2.0] license.
[7] One implementation approach may be to use a web server (e.g., Internet Information Services, Apache, or Tomcat) to provide an accessible location to store data files from the various components.
[8] Another option to investigate involves creating a capability for the inventory lead to scan and convert a paper copy of the inventory list.

- Step 2. Download the inventory list from the shared location on the datastore (Figure 3)
- Step 3. Assign portions of the inventory list to multiple inventory teams (Figure 3)
- Step 4. Upload the assigned inventory lists to the inspectorate-controlled portion of the datastore (Figure 3)

3. Each inventory team uses the mobile app on the portable device to

- Step 5. Download the assigned inventory list from the inspectorate-controlled portion of the datastore (Figure 3)
- Step 6. Record observations in the field. Each observation is time-stamped to create an observations log (Figure 4)
- Step 7. Upload their observations log to the inspectorate-controlled portion of the datastore (Figure 4)

4. The inventory lead uses the desktop application on the office computer to

- Step 8. Download the observations logs submitted by the individual inventory teams from the inspectorate-controlled portion of the datastore (Figure 4)
- Step 9. Integrate the observations logs with the inventory list and reconcile any irregularities with the inventory teams or operator (Figure 4)
- Step 10. Generate a summary report (Figure 4)

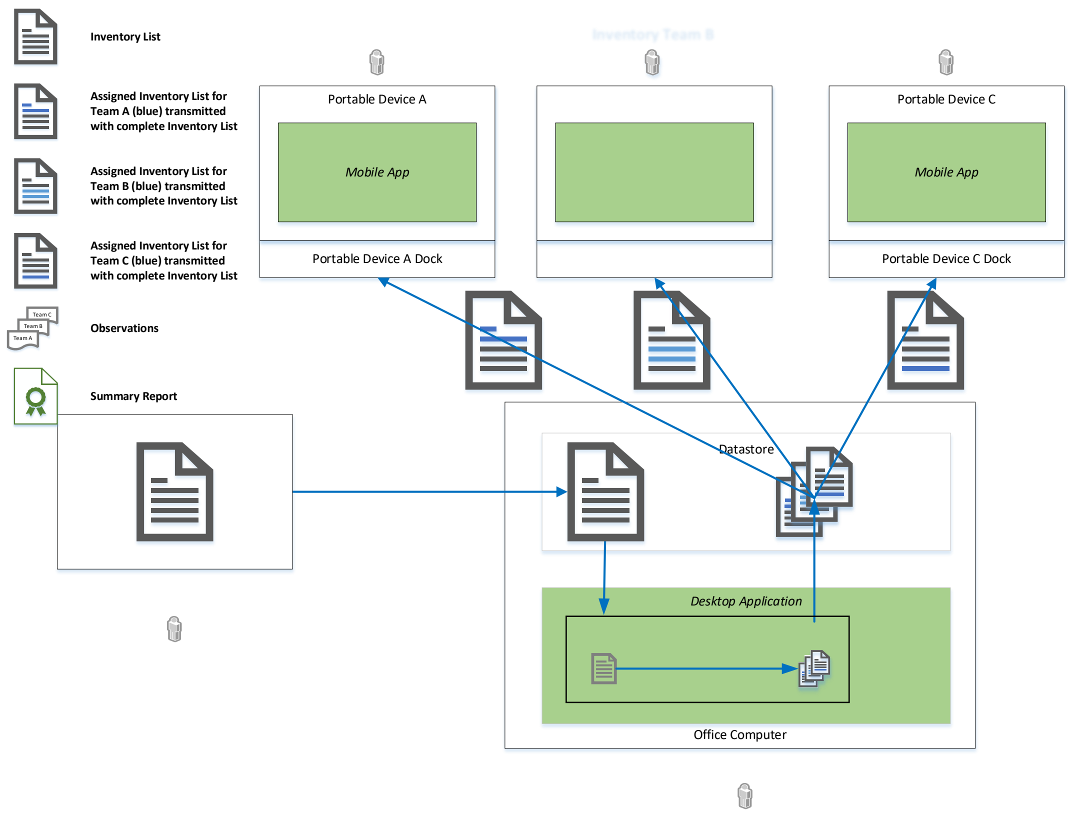

Figure 3. Inventory assistant workflow, Steps 1–5. The inventory lead downloads the inventory list on the office computer and then distributes the assigned inventory lists to the portable devices.

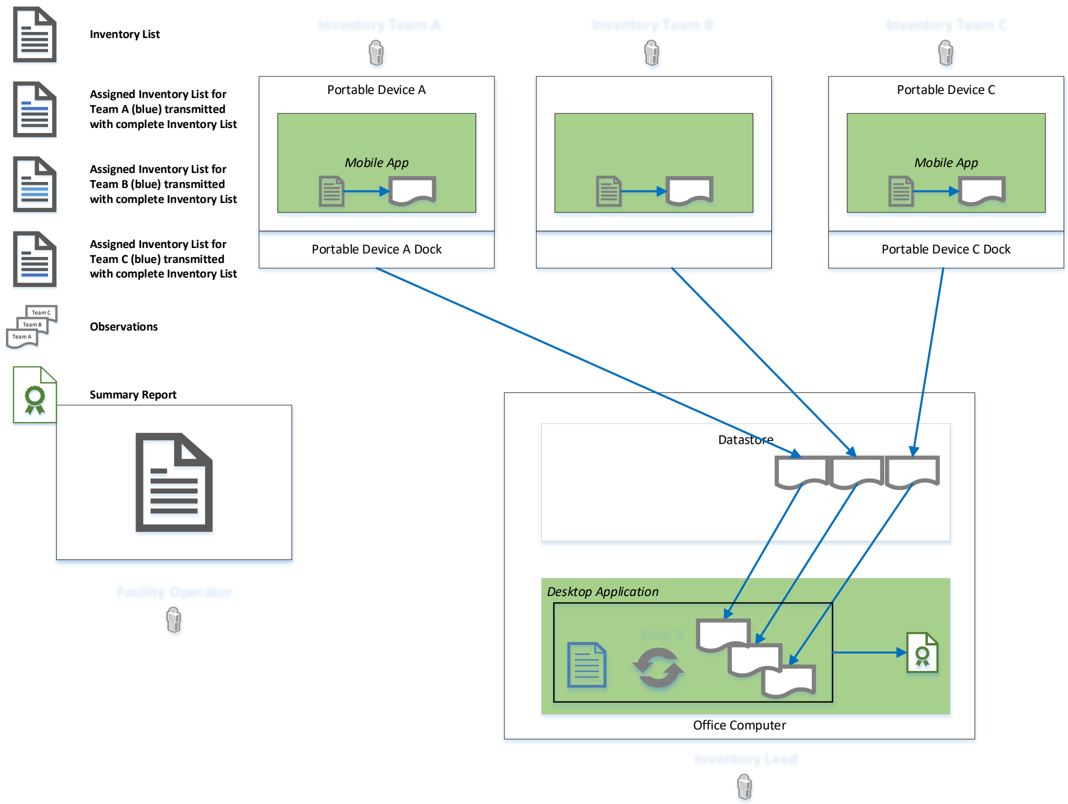

Figure 4. Inventory assistant workflow, Steps 6–10. Inventory teams using the portable devices record time-stamped observations. The inventory lead uses the desktop application on the office computer to integrate observations with the inventory list, reconcile any irregularities, and generate a summary report.

PROGRESS

To date, significant progress has been achieved in developing the inventory assistant concept. The conceptual design and user experience for both the mobile and desktop applications have been developed in [1] and [2]. Additionally, a limited functionality, proof-of-concept mobile app was developed for an Android Smartphone with a best-in-class barcode scanner. With this proof-of-concept app, a user can search for an identification number, as well as scan barcodes, and swipe right on listed identification numbers to record observations. The functionality to handle irregularities such as adding items to the list, noting duplicated items, or adding comments was not included in this proof of concept. Representative screenshots from the proof-of-concept app in Figure 5 show from left to right: the initial splash screen after the assigned inventory list is downloaded, the assigned inventory list consisting of primary identification numbers, and a confirmation pop-up after an observation is recorded for an identification number. Although the Android proof-of-concept app was useful to refine the concept and user experience, the authors believe future work should target a ruggedized tablet running Windows. A Windows tablet like the Panasonic CF-33 can be purchased without wireless cards, which may permit it to be more easily brought into sensitive fuel cycle facilities. While the initial mobile app was developed using Xamarin to permit cross-platform (iOS, Android, Windows) compatibility, the larger screen and expectation to use the app with a landscape screen orientation will require additional development effort.

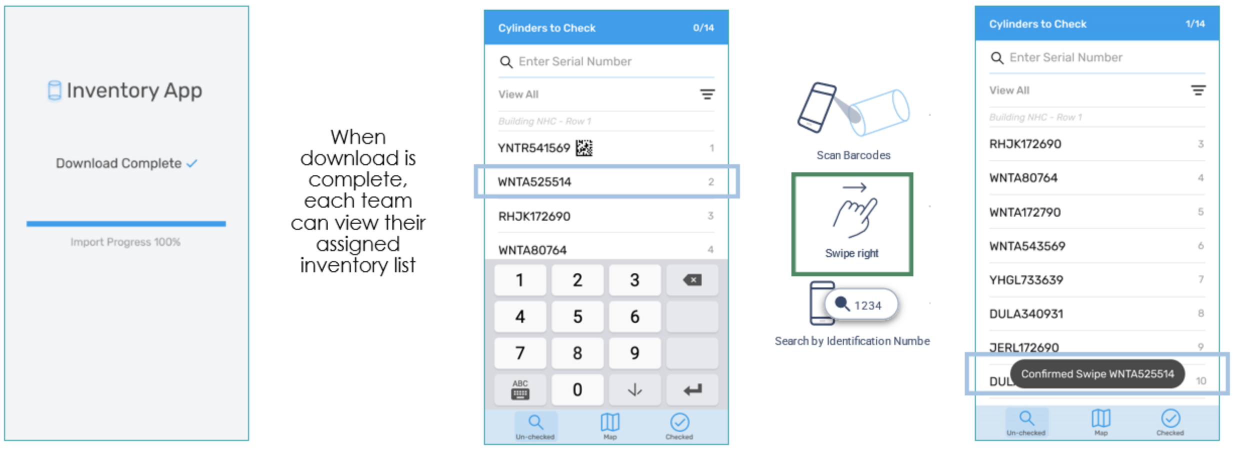

Figure 5. Screenshots from proof-of-concept mobile app software.

Additionally, a proof-of-concept desktop application was developed in Windows Presentation Foundation (WPF) and written in C#. With this proof-of-concept application, a user can start a new inventory, resume an in-progress inventory, or view a completed inventory. For a new inventory, the user can load the appropriate inventory files, assign and distribute the items to different inventory teams, and import observations from the teams. Finally, the user has the ability to reconcile irregularities between the imported observations and the operator-provided inventory list. Reference [2] provides the full description of possible reconciliation actions. Some functionality, like the ability to create teams, was not included in the initial proof of concept. Further refinement of features associated with the data import, initialization activities, and assignment process is likely necessary before the proof of concept could be utilized by others. Figure 6 shows how a user can assign items to different teams by selecting the checkboxes on the right side of the screen. Figure 7 shows how the desktop application sorts items into different categories after all field observations have been imported. For each item in the "Needs Action" category, users can acknowledge or resolve the observations depending upon the composite observation.

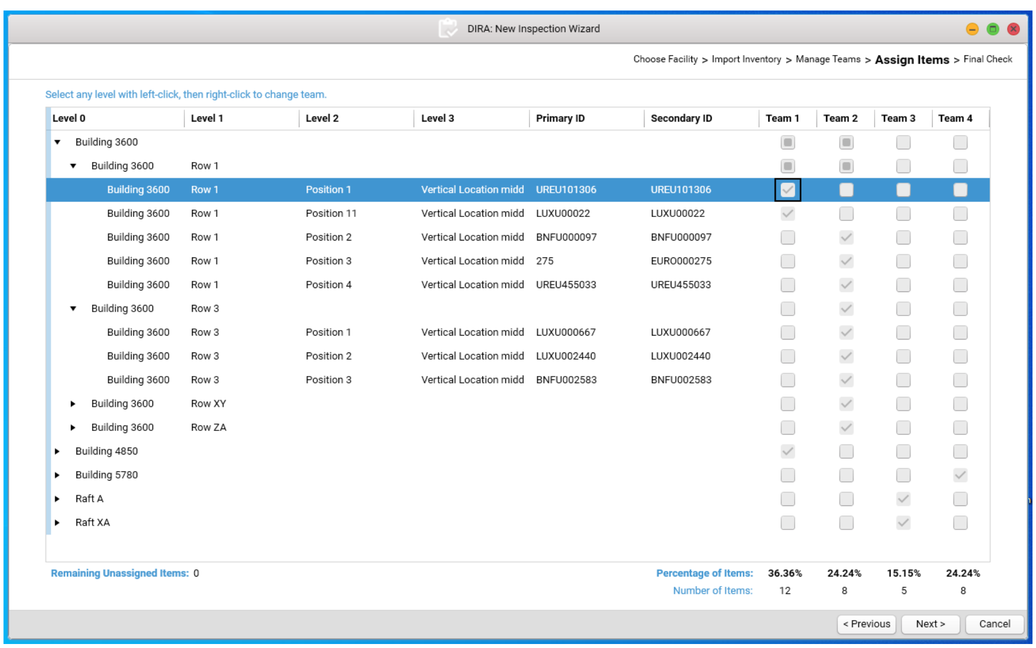

Figure 6. Screenshot of assignment screen from proof-of-concept desktop application software.

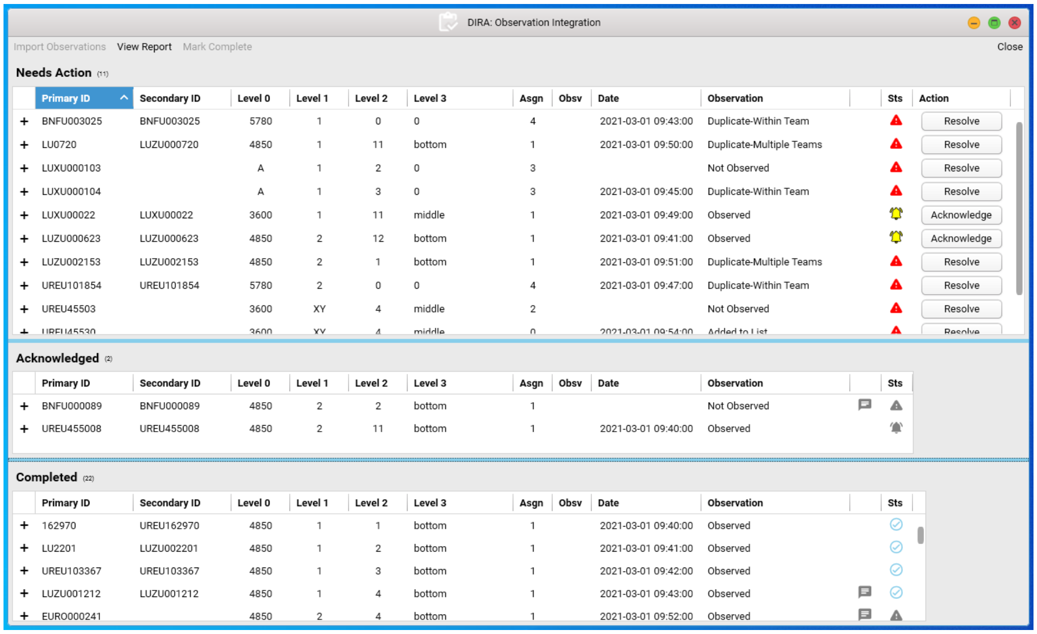

Figure 7. Screenshot of reconciliation screen from proof-of-concept desktop application software.

The existing software includes the basic functionality of the system but would need some minor changes to facilitate end-to-end testing and demonstration in a controlled laboratory environment or at a partner facility. As described previously, the ORNL team would like to refine the mobile software for a Windows tablet, implement the additional functionality and software modifications, and implement the data exchange process between the mobile and desktop software systems.

CONCLUSION

Because of its versatility compared with current paper-based approaches, the discussed inventory assistant could be used by IAEA inspectors, nuclear facility operators, regulatory authorities, or treaty verification monitors to complete an inventory of nuclear and nonnuclear items in a more timely and accurate manner. A mobile app installed on a portable device will allow an inventory team to search and record observations for items through a variety of methods, including scanning a barcode, swiping right on an identification number that is immediately visible on the assigned inventory list, and searching the list for an identification number. A desktop application installed on a laptop or desktop computer in an on-site office will allow an inventory lead to (1) assign and distribute the inventory list to each team, (2) integrate the observations from each team, and (3) reconcile any irregularities between the operator-provided inventory list and the recorded observations before producing the final inventory report. The inventory assistant can be integrated into the IAEA's existing workflow, provide them with time-stamped and electronic records, and allow them to reallocate a significant number of PDIs from item counting and tag checking activities to other, more challenging, on-site work such as investigating discrepancies or evaluating indicators of potential misuse scenarios.

Overall, the inventory assistant can be adapted for use with other uniquely identified items, can accommodate items with two or more identification numbers, and can be used for items with and without affixed barcodes. The inventory assistant would ease the creation and maintenance of more accurate and complete inventory listings and can provide sufficient flexibility to accommodate local operator practices. Future work for the inventory assistant includes building in the ability to handle irregularities on the mobile app, refining existing features on the desktop application, and implementing a data exchange process between the two software systems. After completion of the next development phase, a field test for the inventory system at an operating nuclear facility is desired.

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