Retooling Collections Management:

Tagging and Tracking Singapore's National Collection with Radio Frequency Identification (RFID) Tags

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This paper details how a Radio Frequency Identification (RFID) tracking system was implemented to improve collections management at the Heritage Conservation Centre (HCC) in Singapore. The HCC is the repository and conservation facility that manages, cares for and facilitates access to the National Collection in the custody of the National Heritage Board (NHB).

The project consisted of three phases: development of a suitable software system, installation of the required infrastructure and hardware, and execution of an extensive exercise to tag over 275,000 artefacts and artworks in the National Collection. The introduction of this new capability has yielded several benefits which include helping to resolve many legacy registration issues, putting in place a systematic process for handling high volumes of collections access, and enabling more efficient work processes. But first, we will outline the context and operational challenges that led to the HCC's development of a customised RFID tracking system.

The imperative for change

Electronic database management systems have already been used globally to manage collections data and increase productivity for more than a decade. The NHB too has introduced its own collections database management system since 2005. However, the use of these systems is often confined to content management with only a limited emphasis on workflow optimisation and automation of key business processes like registration of new acquisitions and tracking of collections movements. Manual registration of new acquisitions in physical ledger books and tracking of collections movements using cards and logbooks are still common practices at many museums all over the world.

The largely manual collections management processes used at the HCC had become severely overwhelmed and strained as the size of the National Collection had grown significantly over time from around 25,000 items in the 1990s to over 275,000 items currently. In particular, the manual process of inputting, updating and retrieving artefact location information was time-consuming, labourintensive and prone to human error. As a result, the accessioning of new acquisitions took a long time, and the tracking of artefacts and artworks movements for retrieval or stocktaking was frustrating and onerous.

Even though our Registrars and Collections Officers were already assisted by contracted art-handlers and temporary staff in less sophisticated functions and laborious tasks, they were still inundated by the heavy workload due to the rapidly growing National Collection and increasing frequency of exhibitions, rotations and loans. With only a small pool of staff to manage a large collection involving voluminous requests to retrieve and move items under constant deadline pressures, it was inevitable that less-pressing but nonetheless necessary tasks, for example, updating of location records, verification of collections data, photography documentation, etc., were often helplessly postponed and inadvertently snowballed.

This status quo was assessed to be untenable. This was even more so as the multiyear acquisition plans of the museums and heritage institutions were projected to continue to increase the size of the National Collection substantially in the coming years. The number of museums and heritage institutions supported by HCC has also expanded rapidly from just two in the late 1990s to eight today, namely: the National Museum of Singapore, Asian Civilisations Museum, the Peranakan Museum, Singapore Art Museum, National Gallery Singapore, Malay Heritage Centre, Indian Heritage Centre and Sun Yat Sen Nanyang Memorial Hall. Consequently, the number and frequency of exhibitions, rotations, and loans have also increased noticeably in the recent years. The need to improve the status quo was strong and urgent.

<u>Customising a</u> <u>technology-based solution</u>

After a process review by the HCC in 2011, a project to improve collections management, specifically, in the areas of tracking, updating and monitoring of artefacts and artworks, was prioritised to be critical. The central idea was to use suitable tagging and data capture technology to automate the work processes.

The technological options for tagging and automatic data capturing are many, namely, 1D barcode, 2D barcode, colour coding, passive High Frequency (HF) Radio Frequency Identification (RFID), passive Ultra High Frequency (UHF) RFID, active RFID, semiactive RFID, Near Field Communication (NFC), and Contactless Smartcard. Amongst these, passive UHF RFID held the most promise as the most versatile technology for large-scale implementation.

Although passive UHF RFID technology had been found to be suitable, there were no readily available and cost-efficient solutions to RFID-tag the whole spectrum of artefacts and artworks in the National Collection and monitor their movements according to NHB's operational processes. Cultural heritage materials are difficult to tag as each item is unique and comes in a different material, condition, shape and size, Stringent handling and preventive conservation practices are also enforced in order to avoid damage and to preserve these precious heritage materials for future generations. This means that the affixing of permanent fixtures of any kind, for example, gluing tamper-proof security devices onto the artefacts and artworks, is not permitted.

The size of our National Collection is considered relatively modest with around 275,000 items (parts included). Nevertheless, given that each item is unique, devising a standardised solution with economies of scale to tag these 275,000 items was a tall order. Effectively, all the known commercial examples for reaping productivity gains in non-heritage asset management were not directly applicable.

Customised solutions were needed. The HCC took about two years to study the problem, conduct research on relevant technologies, and met with various industry players to finally formulate a proposal for an Automated Collections Tagging System (ACTS). The executive decision to invest in the ACTS was made in 2013 by NHB's Senior Management. The ACTS project aimed to develop an automated tracking system using passive UHF RFID tagging technology on all the heritage materials belonging to the State that have been entrusted to the custody of the National Heritage Board.

It was recognised that the project would have to be implemented without disrupting the HCC's operational commitments to the museums in the many major events planned to celebrate Singapore's Golden Jubilee in 2015. Given the inherent difficulty, complexity and scale of the project, the time and effort spent on careful and deliberate preparation work was warranted. The time and effort expended had allowed the operational requirements and technical specifications to be prepared properly, which resulted in a detailed tender document that was published in the Singapore Government Procurement Website - the GeBIZ. Consultations with NHB's Information Technology & Knowledge Management (ITKM) and Procurement Divisions were invaluable in achieving a successful tendering outcome.

Objectives of the ACTS project

The ACTS project is probably one of the world's largest deployments of RFID technology on a wide spectrum and range of artefacts and artworks. The project is expected to yield significant productivity gains in the management of the National Collection. The four objectives for the project are:

I: to automate existing manual work processes such as the issuing of receipts and updating of item movements on physical store logbooks. This includes eliminating the need to manually keep track of collections data such as the size of collections, breakdown of acquisition types, and number of items on display, which is currently tracked in spreadsheets.

2: to improve the ease and efficiency of managing item movements. This would allow fast and accurate retrieval and updating of location records through portable handheld devices. It involves

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implementing standardised location naming and allowing instantaneous updating and tracking of item movements.

3: to facilitate stocktakes through the use of handheld devices. The aim is to allow stocktakes to be carried out accurately and efficiently to ensure better accountability of the National Collection. It seeks to eliminate the current cumbersome and tedious stocktaking process that involves manual generation and preparation of stocktake lists, manual tracking and reconciliation of stocktake results. and manual compilation of stocktake reports. It also has to cater for different modes of stocktakes, such as rapid scanning, individual item authentication, and authentication with and through external witnesses.

4: to improve data collection for management reporting. This allows for important data for management reporting such as collections display rate, storage space utilisation, time spent on work activities, and Entity Capacity Management (ECM) utilisation to be captured and tracked through the ACTS system. The ECM system is used to manage the allocation of HCC resources to support museum acquisitions, exhibitions, rotations and loans.

Retooling collections management

The ACTS project consisted of three main tracks: software development, infrastructure and hardware, and physical tagging. The project also had a training and orientation component to complete its implementation. Waterfall project management¹ was largely employed to manage the whole project. However, agile project management² was also utilised to address a portion of the project, namely software development, which had frequent changes and where requirements were incremental and interrelated with completed requirements. Despite the scale and complexity, the project was completed within an acceptable timeline of fifteen months.

Track 1: Software development

The software development track involved developing a system that delivers near realtime updates of multiple and simultaneous data exchanges for daily operational uses as well as customisable dashboards for management decision-making. The ACTS software largely captures the business processes of collections management, digitalises it, and provides timely, accurate and consistent data synchronisation that allows fast and accurate generation of reports and statistics. Part of the software development required integration with the new Singapore Collections Management System (SCMS) database³.

Following the general principles of agile project management, the software development took on an iterative and incremental design and build model. Each software module was treated as a mini-project of its own with the following stages:



As much as the software development team wanted to "do it right the first time" as assumed under the waterfall project management method, the importance of finding a balance between efficiency and effectiveness of complex requirements was recognised. Although more effort was required in managing the multiple modules, the agile process was worth the additional effort as it ensured that each module is useful for the HCC users. The end result was an effective software that meets the needs of users. Table 1 provides a summary of the software modules developed and new functions and capabilities achieved.

Table	1.	Software	Modules	and	their	Functions	and	Capabilities
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Modules	Functions and Capabilities
Collections	Dynamic collections search and export; issue of receipts and delivery receipts from system; tracking of new acquisitions registration and accessioning; storage capacity management; electronic store logbooks; RFID tags request
Project Management	Management of exhibitions, rotations and loans as projects; tracking of ECM utilisation; collection of project data such as artefacts and artworks displayed and time spent on different support activities (e.g., retrieval, viewing, packing, etc.)
Investigation	Documentation of legacy registration and accessioning issues for follow-up; documentation of long-term loans and non-National Collection items (e.g., props, frames, mounts, etc.)
Stocktake	Dynamic generation of stocktake list based on user input criteria; tracking of stocktake progress through system; options for various modes of stocktake (e.g., item-by-item authentication, rapid scanning, etc.)
Reports	Management reports on total items tagged and verified, projects supported, new acquisitions received pending Artefact Justification Forms (AJFs), total items moved out for loan or display, etc.
User Management	Management of user accounts with role based access rights control

Track 2: Infrastructure and hardware

The choice of infrastructure and hardware for passive UHF RFID technology was another significant part of the project upon which the necessary platform for the software and physical tagging was based. The advantages of passive UHF RFID technology for collections management are compelling. Every tag has a unique ID assigned from its production source. It is thus not easy to counterfeit. It does not require a line of sight when reading so long as reading is not attempted through metallic objects/material. A RFID reader can read multiple tags per scan. The reading range can be adjusted according to the choice of readers used.

Due to mass-market adoption of the technology, the tags and reader hardware are cost effective. There are also peripheral support items such as RFID printers and encoders, which can programme and print the tag at the same time, thus facilitating the use of this technology. The different types of reader functionalities, namely, handheld, portable or fixed mount, provide a good range for users to choose the reader hardware best suited for their operations. The tag's form factor for passive RFID is also versatile and easy to package to suit the different types of artefacts and artworks and the materials that they are made from, such as wood, stone, textiles, metal, ceramic, etc. The customised RFID tags created, handheld readers and scanners, and specialised RFID tag printing machine can be seen in Figure 1.

On top of the RFID readers and tags, the infrastructure for the project also included the computer server and wireless components that make up the "communications backbone" of the entire ACTS. A major consideration in the infrastructure set up was how to innovatively install, test and phase it in without affecting ongoing daily operations.

Track 3: Physical Tagging

The third and most difficult part of the ACTS project was the physical tagging exercise. This task covered all stores and all items in the HCC. Physical tagging of the artefacts and artworks consists of five subprocesses: surveying of artefacts to check physical accession numbers; verification of the survey results; preparation of RFID tags and association to database records; physical tagging on the artefacts and artworks; and verifying that the tag is attached on the correct item. Figure 2 illustrates the steps of the physical tagging process.

The physical tagging exercise was much more extensive than expected. The tedious and time-consuming process was further challenged by the need to find experienced personnel with know-how in artefacts handling before tagging activities could even commence. Physical tagging is an area which requires four types of expertise: art handling, tag production, sorting, and verification. Four teams are thus required: art handlers who can competently handle the artefacts and artworks according to HCC's practices and standards: a production team who prepares and produces the RFID tags according to the approved form and format: a sorting team who has to meticulously sort the printed tags according to their location to facilitate the tagging process; and a verification team who knows how to handle the RFID devices and tablets so as to make updates in the application properly. The competency of these four teams was critical to the seamless process



From left: Customised RFID tags, handheld readers/scanners, and RFID printing machine. Images courtesy of Heritage Conservation Centre, National Heritage Board.

Figure 2. Five-step process of physical tagging



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of tagging. The whole spectrum of collections tagged is illustrated in Figure 3.

Training and orientation

When the project was nearing completion, a training-cum-orientation programme (see figure 4) was conducted to transit the HCC personnel from their former manual mode of operations to the new technology-assisted operations. The objective was to allow HCC staff to be familiar with the ACTS system before the cut-over period. This programme lasted several weeks. HCC staff were equipped with the necessary skills and given opportunities to practice during the training programme. Oneto-one consultations were also made available so that users were given further opportunities to clarify doubts as well as to raise areas for improvement after using the system.

Figure 3. Tagging of the whole spectrum of collections such as 2-D archival documents, 3-D objects, textiles, etc.



Figure 4. Group and individual training orientation to prepare HCC staff for system cut-over. Images courtesy of Heritage Conservation Centre, National Heritage Board.





Project duration

From commencement to completion, the ACTS project took about twelve months. This was followed by another three months of runin and stabilisation. The infrastructure and hardware are now fully in place, the software modules are functional and the RFID readers are deployed to users. More than 275,000 items have been tagged with customised RFID tags. HCC personnel have been trained and are comfortable with the new technology and method of operation.

Improvements in productivity and morale

ACTS delivers the following key improvements: automation of the previously manual work processes, with the need to manually update logbooks completely eliminated;, improved ease and efficiency of managing artefact movements, with fast and accurate retrieval and updating of location records; facilitated stocktaking through use of handheld devices; and streamlined tracking and data collection data for management reporting, such as collections size, display rate, and staff time spent. The improvements derived from the ACTS project implementation are summarised in Table 2. The implementation of ACTS has improved productivity at the HCC. With the increased productivity, the ease of use of the ACTS system and the convenience resulting from the automation of previously mundane and manual work processes, staff morale has also improved.

Table 2. Summary of improvements accrued from ACTS project implementation	Table 2. S	Summary	of improvements	accrued	from	ACTS	project	implementation
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<u>Improvement</u>	Elaborations				
100% tagging of collections stored at the HCC	Allows rigorous checks to be made to locate misplaced or missing items: every item at the HCC has been physically checked and those with unclear identities have been flagged out and documented for follow-up.				
	Improved accountability of the National Collection: every item at the HCC has now been checked, tagged and accounted for; previously missing or inaccurate storage locations are now updated; the collections database can now be data-cleansed to reflect only live, unique and verified records.				
	Improved storage conditions and housekeeping: during tagging implementation, the tagging team made many improvements to storage conditions (e.g., by changing old acid-free paper, re-housing and re-organising items to optimise storage space, re-sorting items to improve ease of retrieval, etc.) to enhance the long-term preservation of the National Collection.				
Standardised location naming system and automatic update of locations through	Resolved problem of inaccurate location records in database by making location updates automatic through the use of handheld devices.				
handheld devices using RFID tags	Resolved problem of inconsistent location naming which made data search and retrieval unreliable; a standardised location naming system controlled by a system administrator is now in place.				
	Improved data accuracy and accountability of collections: the risk of items becoming misplaced, especially at stores with high volume of movements, has been greatly reduced as the new system and workflow forces and helps users to update location automatically using handheld devices; locations are now also further distinguished as permanent or temporary, and the system can trigger alerts for follow-up actions (e.g., when new acquisitions or items returned from exhibitions are kept at temporary locations for an extended period).				
	Improved productively: staff no longer have to perform the previously tedious and time-consuming work of manually updating location changes in MCS and manually updating physical store logbooks; time spent on locating and retrieving items for viewings is also reduced with more accurate locations records available.				

Improvement	Elaborations
	Improved management reporting and planning capabilities: storage capacity and utilisation can now be tracked and managed through the system which facilitates planning for future improvements (e.g., re-organizing items to increase capacity and re-grouping items to better meet environmental requirements); reports can also be generated to retrieve information on how many and what types of locations are in the system and the specific list of items at every single location.
Improved stocktake efficiency and capabilities	Elimination of various manual processes in performing stocktake: previously a large amount of manpower and time were spent on carrying out stocktake as there were many manual processes involved, such as the manual generation of the list of items to stocktake, the manual preparation of daily stocktake lists for verification with witnesses, the manual reconciliation of stocktake results, and the manual preparation of stocktake reports; these manual processes are now completely eliminated as the system is able to generate stocktake lists automatically based on a variety of criteria such as specific collections stores, specific locations, percentage of total collection, etc. Stocktake is now carried out using handheld readers and the system automatically keeps track of stocktake progress and generates management reports.
	Improved accountability and productivity: productivity is greatly improved with the elimination of manual processes that are tedious, time-consuming and susceptible to human error; accountability is also greatly increased as the confirmation of items sighted and stocktaken can only be done through matching images retrieved onto the handheld device, scanning the RFID tag, and confirming through an authentication card held by an external witness; the possibility of fraud or errors in stocktake has been greatly reduced.
Improved data collection for management reporting with enhanced software functions and	Collections statistics are now more accurate and can be retrieved directly from the system for management reporting as compared to manually compiled data; these statistics include size of collection, breakdown of acquisitions by types and museums, number of items on display, number of items on loan, etc.
features	Registration of new acquisitions and generation of receipts through the system: registration of new acquisitions and issuing of receipts are now done and tracked through the system instead of manually; accessioning of new acquisitions and backlogs can now be better tracked and managed; receipts (both receiving and delivery receipts) are now generated through the system instead of manually issued which will allow for better tracking and data retrieval in future.

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Improvement	Elaborations
	Project management features have also been implemented to manage exhibitions, rotations and loans support for museums: project leads and members can be defined, artefact lists can be imported and maintained within projects, movement forms generated and tracked within projects, and time spent on various work activities (e.g., museum support, new acquisition accessioning, etc.) can be recorded and tracked by the system; ECM allocation and utilisation can now be better tracked and managed using these new project management features.

<u>Automation for greater</u> <u>accuracy and accountability</u>

The two key achievements of the ACTS project are in the areas of improved work productivity and accountability for the National Collection. Many manual work processes have been eliminated, so precious time can be now directed to more added-value work activities. The HCC is now better able to manage and collect accurate collections and operations data for work planning and management reporting. New features and capabilities developed for stocktake, together with 100% RFID tagging of the collections at the HCC, has greatly enhanced our ability to conduct regular stocktakes to ensure accountability for the National Collection. Other new system features and work processes developed in areas such as project management, time-tracking on work activities, and storage capacity management

have also laid the foundation for further improvements in resource management, work efficiency, and operations excellence.

In conclusion, the ACTS project has proven to be an important step in modernising and leveraging on technology to automate work processes in collections management. It facilitates the handling of high volume transactions with greater accuracy and reliability. The RFID tagging implementation, which entailed a 100% survey of the collection, has allowed us to gain better clarity on the status of all the items stored at the HCC. With every single item now tagged, there is a basis for systematically resolving registrations issues of the past and rectifying accessioning errors and anomalies. Retooling our collections management system has thus allowed many legacy issues to be resolved and laid the foundation for a better and sustainable way of doing things in the HCC.

<u>Notes</u>

- I. The waterfall project management system is a sequential design process in which progress is seen as flowing steadily down like a waterfall through the phases of conception, initiation, analysis, design, construction, testing, production/implementation and maintenance.
- 2. Used in software development processes and known as agile software development, it is a set of principles for software development in which requirements and solutions evolve through collaboration between self-organizing, cross-functional teams. It promotes adaptive planning, evolutionary development, early delivery, and continuous improvement, and it encourages rapid and flexibile response to change.
- 3. Singapore Collections Management System (SCMS) is NHB's collections management system to manage national collection information. It supports various business functions, including acquisition process, conservation and exhibition documentation.