Flight Hardware Logistics Group at the Jet Propulsion Laboratory
Pilot Testing Innovative Auto ID Technologies

By Jim Bagley
Code Corporation
February 28, 2003

It's all about keeping track of things.

Driven by the need to keep track of a myriad of items ranging from chairs and desks to spacecraft payloads, the government-industry partnership in the field of aerospace has lead the way in the implementation of new Auto ID technologies.

The Flight Hardware Logistics Program (FHLP) at the Jet Propulsion Laboratory in Pasadena, California is currently developing and piloting several new technologies to upgrade their inventory management and tracking systems. The goal of the pilot is to improve the configuration management process. The scope of the pilot program includes:

- Identify parts through labeling and permanent marking
- Upgrade to smaller, two-dimensional symbol
- Upgrade reader hardware – wireless
- Improve database connectivity internally and with vendor and subcontractors

Fortunately, the aerospace industry, the automatic identification industry (makers of bar code equipment and the like, including radio frequency data transmission and identification equipment), and vendors from all product related areas have been working on standards and technologies which make this daunting task feasible. The Internet provides a highly efficient transport medium for the data, and Internet-related standards for high-level program and computer independent programming languages to facilitate the process.

The following technology components are being researched or implemented within the FHLP system:

- Bar Codes and 2-D Codes
- Data Collection Hardware
- Data Management Software
- Radios and RFID

The system can be implemented in a stepwise manner, which is a new concept. Historically, major system upgrades have required all-or-nothing leaps with substantial integration of hardware and software essential before the plug can be pulled on an old system and a new method put into operation.

Good, Old-Fashioned Bar Codes

1 23456 78901 2

UPC CODE – Typically used on consumer goods purchased in retail stores

Also known as "one dimensional" or "linear" codes, carry data using a method called "bar width modulation" – an easy way for machines to determine binary information using the analog input methods which were prevalent thirty years ago. These simple wide-and-narrow striped symbols, which carry between ten and twenty bytes of data, exist on many items, ranging from consumer products to fixed assets such as chairs and PC's, to doorways (location codes), to automotive vehicles (VIN numbers). Here's the rub: the method of encoding data varies and, depending on where and when the code originated, it may or may not be unique, or even fall into a recognizable category. Fortunately, standards have been in place for nearly three decades which describe the method of encoding the information, and modern bar code readers can quickly decide which method of encoding was used and the content of the data encoded. This is referred to, by the bar code crowd, as "automatic discrimination." Bar Codes have a capacity to carry a "license plate" or key to a database, but need additional information from another source to fully identify the item, and often, the appropriate data base to go find the information.

Advanced Two-Dimensional Bar Codes

Using matrix codes, components can carry a large amount of information in a small area, including data identifiers specifying each field of encoded data.

Also known as "matrix symbols," this relatively new addition to the machine-readable arsenal uses the vertical, as well as horizontal dimension, to encode information. The result is a symbol that looks like a miniature checkerboard, and can encode an order of magnitude more information in the same area as a linear bar code. As a result, more information can be carried with an item. Designed to be read by more modern digital imaging technology, the "2D" marks are rapidly showing up on everything from postage machine stamps to computer chip packages. Standards have been developed over the past decade which include data identifiers encoded along with data content, making these symbols, literally, miniature databases which travel along with an item, with from sixty to several hundred bytes of data typically encoded. Along with the advantages of this plethora of information, however, come some major integration issues with computer systems needing to access this information. The standards for encoding this information have been driven by the industries that need better ways to interchange data. These have included the electronics industry, represented by the EIA, *(Electronics Industry Alliance*), the automotive industry, represented by the AIAG (*Automotive Industry Action Group),* the Telecommunications Industry represented by the TCIF (*Telecommunications Industry Forum),* the transportation industry, which has coordinated activities through ANSI (*American National Standards Institute*), and which represents all of the above, and others, to the international community via ISO (*International Standards Organization*).

Critical to these activities have been the creation of the aforementioned data identifiers, which are collected, and numbered, and identified by the ANSI MH10.8.2 standard. While this creates a reference point for data identifiers, it also is continually being updated. Here are some examples. If two trading partners wish to send each other information on shipping cartons, they can do so using ANSI MH10.8.2 standard matrix codes. Within the matrix codes, part numbers carry a data identifier, followed by the actual part number. Additional data elements, such as production date, purchase order, etc., carry their own unique data identifiers. Each label on a shipping carton becomes its own data base, providing the receiver with all or much of the information needed to receive the shipment and keep track of it. The creation of new data identifiers is an on-going process, and synchronizing systems with new data is a daunting, ongoing maintenance activity.

These matrix codes use field separation sentinels in order to handle variable length data encoding, and have built-in forward error correction using Reed-Solomon principles, named after the MIT scientists who developed them about forty years ago, and first published in a five-page paper that appeared in 1960 in the Journal of the Society for Industrial and Applied Mathematics. The paper, "Polynomial Codes over Certain Finite Fields," by Irving S. Reed and Gustave Solomon, then staff members at MIT's Lincoln Laboratory, established the principles for forward error correction that have since been deployed in everything from disc drives to deep space probe radio transmissions. In basic terms, in addition to the data, additional information is sent with the data in order to detect any errors and correct the data errors by mathematically reconstructing the information. This is an important feature due to the high probability of partial damage to labels and permanently marked symbols in the shipping, construction, mission, and recovery processes. Reed, later a professor at California's U.S.C., consulted for the Jet Propulsion Laboratory on projects to insure of the receipt of correct data in transmissions involving space exploration, as related in the Society for Industrial and Applied Mathematics Newsletter in January 1993.

Bar Code Readers Have Become Miniature Digital Cameras

The latest generation of bar code readers are small, hand held, devices that use digital photography and cordless data transmission. Shown: Code Corporation's Code Reader 2.0.

There are many types of bar code readers deployed in millions of locations around the world. The technologies used for reading bar codes always involve the use of light, since bar codes are an optical technology. Machines must be able to "see" the codes in order to derive the data from them. The sensing equipment always involves a light source, a method of interrogating the light reflected from the object with the bar code on it, and an electrical circuit that translates the light-and-dark patterns into digital information for a receiving computer. As bar codes have become more diverse and complex, the automatic identification industry has responded with more complex systems, which have deployed moving laser beams, Charged-Coupled Devices (CCD's), microprocessor chips, and most recently, Complimentary Metal Oxide Semiconductor (CMOS) camera sensors controlled by powerful micro computers with tremendous calculation processing capacity. The industry has benefited by the consumer products which have driven the costs of these components downward, including compact disc players, digital cameras, and Internet-capable home computers. Cellular telephones have added cheap and reliable miniature rechargeable batteries and low cost digital radios. The overall electronics industry supplies memories, keyboards, switches, displays, and connectors. The latest generation of bar code readers includes palm-sized devices which can read and decode any matrix or linear symbol and transmit the information over a local radio connection to a host computer, which is typically a client operating within a broader LAN or WAN. The host uses the Internet to communicate transactions over the World Wide Web to other trading partners, and all can be controlled by high level, open platform programs written in XML.

Data Routers Send the Right Stuff to the Right Place

The routing of data between host computers has been a core element in the rapid deployment of the Internet into every aspect of modern business communications. A similar component is used in the software of client systems which accept the input from the bar code reader, and then determines the proper recipient of the data elements. This is fairly simple in a rigid, linear bar code system, such as the type which exists in every modern grocery store. The bar code reader at checkout sees the code on the item as it is moved over the reader in the checkout lane. The reader in the checkout lane sends the information to a computer which uses it as a key to look up the price of the item in a database, and totals the price of all items being purchased. When the buyer swipes a credit or ATM card to pay for the goods, the Point-of-Sale computer is smart enough to route that information to a different network which does the money transaction.

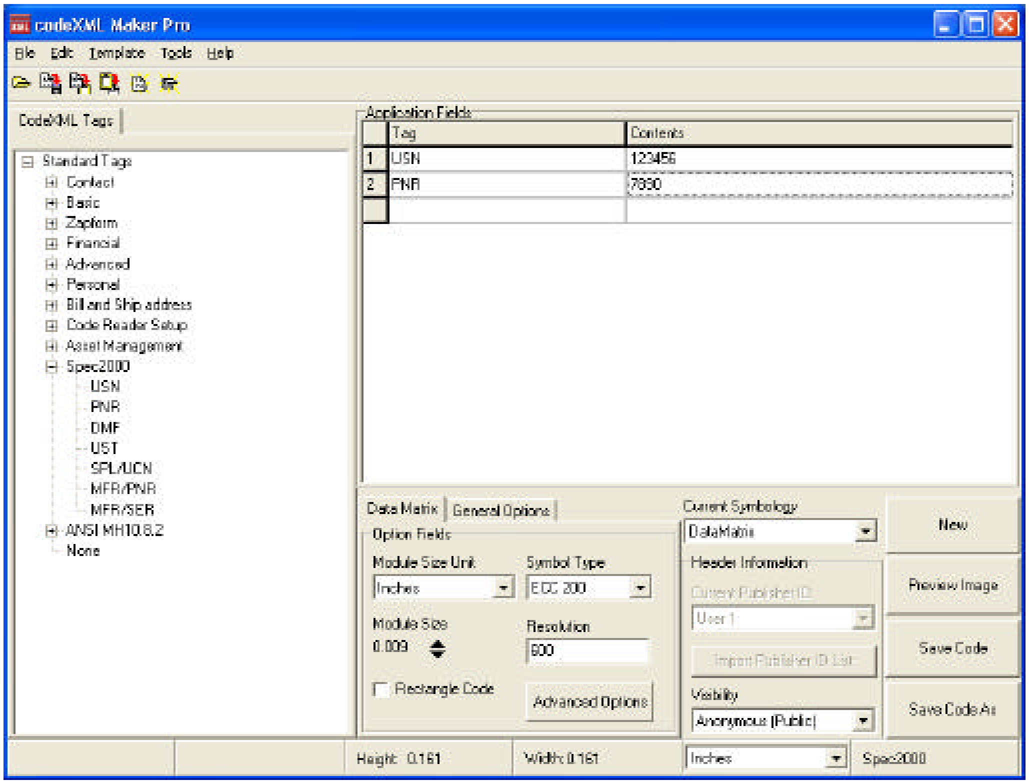
Now, imagine a palm-top computer that receives a 100-character record from a matrix bar code, including twelve different data elements, followed by a six digit location number which the bar code reader derives from a linear code on a storage bin. The palm top computer routes the information from the matrix code to a receiving system which generates inventory update transactions, another computer which generates an electronic data interchange closure transaction to the supplier that shipped the system, and another transaction to the local warehouse computer which keeps track of the location of the item just received. Now multiply these transactions by the activities involved in the logistics support of a space payload, and the original problem, of keeping track of things, is solved.

On Going Maintenance is Mission Critical

Most systems involving commerce require a substantial continuing maintenance effort. This maintenance effort has certainly been improved with a variety of Internet tools and the establishment of XML as an open standard for applications development. This allows Auto ID system developers the ability to pool resources to define data identifier lexicon standards.

Further tools are being developed which will analyze a matrix code, determine the data identifiers used, and then analyze a web interface program, in order to automatically match the data elements, requiring only the exceptions to involve further programming. What this means is that new applications can be quickly implemented in parallel to legacy operations, which can exist without being disturbed, thanks to the intelligence contained in the data router nodes.

Among the early adopters of the matrix codes and data identifiers is the Aerospace Industries SPEC 2000, which contains a system roadmap for applying intelligent data identifiers to information exchange between trading partners.



In the above computer display, a developer selects Spec2000 elements for encoding and intelligent routing from a matrix bar code.

Keeping the Systems in Synch

As new data elements get incorporated into Spec2000 and ANSI MH10.8.2, the requirement for periodic updates to the systems becomes evident. This is another important feature of the intelligent data routing capability. As new data elements enter the system, a simple update of the rules from a subscription service, similar to those deployed to prevent the spread of new computer viruses, keeps the new data flowing.

Radios – from Sputnik to Bluetooth

The Compaq iPAQ H5450 includes a 400MHz CPU, 64MB RAM, and supports both IEEE 802.11 and Bluetooth wireless communications.

Data always needs a method for movement. Many components involved in the aerospace technology are not conveniently brought to a bar code reader. So the reader must be carried to the bar code. It was this application characteristic that created the need for small, portable data radios. While we currently take the digital radios in our pocket cell phones for granted, it was not too many years ago that this was merely a dream for applications developers. Ten years ago, the majority of data radios used a part of the radio band which required an FCC site license for each using location. Data rates averaged about a hundred characters per second, and the batteries necessary to operate these radios were the size and weight of a brick. The first step towards modern cordless data transmissions was when the FCC declared several radio bands free of the need for site licensing. Deemed "ISM" – Industry, Science, Medical – these radio bands created an instant area of development for the automatic identification industry. They also attracted a number of other gadgets, ranging from cordless phones to cordless loudspeaker systems. With many gadgets deploying into these bands, the need for standards became paramount. The first standard, IEEE 802.11, was developed as a relatively high speed (millions of bytes per second) communications scheme for use in wireless local area networks. Now deployed worldwide in millions of locations, the IEEE 802.11standards-based products represent an excellent example of industrial competitors achieving a consensus standard for complex equipment interoperability. While ten years ago it was discussed as a remote possibility, today, people go to the local electronics mega-store and buy IEEE 802.11 components from multiple vendors, then go home and plug-and-play wireless, nearly as simply as plugging a DVD player into a new TV set.

While the IEEE 802.11standard works well for full-time local area networks, its requirement of session maintenance creates a tremendous drain on the batteries of portable devices. Recognizing the need for a cable replacement strategy, a new standard, designed to operate within the same radio band and coexistent with the 802.11 networks, began about six years ago. Dubbed "Bluetooth", the new standard promised lower cordless device costs due to a number of factors, including smaller batteries. Bluetooth now is becoming the de facto standard for cordless digital products, with literally thousands of devices available, ranging from cellular telephone headsets to industrial computer links. According to an article in the December 31, 2002 issue of *Computerworld*, United Parcel Service recently announced that, beginning in June of 2003, over 50,000 Bluetooth-equipped bar code reading devices will be deployed throughout its world wide network of computerized parcel handling systems. Bar code readers without Bluetooth as an option will soon be relegated to the "has-been" pile.

Direct Identification through "RFID"

As useful as the bar code technologies are, they are still an optical technology, meaning, simply, that the item must be "seen" by the reader in order to be decoded. Another relatively new technology offers an alternative, albeit far more expensive, a method for cases where in item that is embedded in another item, or covered with a coat of paint, or is encased in rubber inside of a tire, can still identify itself to the outside world. This method is called Radio Frequency Identification, and involves a miniature radio transmitter attached to, or embedded into the item being identified. While still very early in its evolution – there is no standard in place for interoperability of RFID systems – the technology is promising and will be deployed in future systems. While far from achieving interoperability, and therefore, far from mass deployment, the ANSI committees involved with the MH10.8.2 standard are already planning for RFID within the world of data interchange. This means that existing systems with intelligent data routers will easily be adapted to these components when they begin to overcome the manufacturing standards and cost problems currently confounding the promise of this technology.

Putting It All Together, and Bringing It All Back Home

The benefits of these technologies will be available for scientists and aerospace designers for many years to come. The Jet Propulsion Laboratory, managed by the California Institute of Technology, is NASA's lead center for robotic exploration of the solar system. To support continued exploration, JPL is making advances in technology with new instruments and computer programs to help spaceships travel further and telescopes see farther than ever before.

James E. Bagley is Vice President of Sales and Marketing for Code Corporation. He has held senior management positions with Metanetics Corporation, Symbol Technologies, Norand, and Radix Corporation. Code Corporation designs, develops and manufactures automatic identification implementation and data collection platforms. Its worldwide headquarters are located in the Salt Lake City, Utah metropolitan area.