The Securities Technology Institute for Counterfeit Deterrence

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The Applied Physics Laboratory is involved in a program sponsored by the U.S. Bureau of Engraving and Printing to increase the security of this nation's currency against counterfeiting. The program seeks to develop new security features for the currency and to monitor developments in reprographic technology. Some features are intended to allow visual identification of counterfeits by the general public; others are to be machine readable and are designed for cash transfer machines and governmental inspection.
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INTRODUCTION

The Securities Technology Institute (STI) was founded at APL in late 1994 by the U.S. Department of the Treasury Bureau of Engraving and Printing (BEP) with the charter of developing advanced counterfeit deterrence technologies for future versions of U.S. currency. The need for such a program arose in response to advances in reprographic technology and computer graphics[1] (notably color copiers, scanners, and color laser printers attached to personal computers), which have greatly increased the tools available to traditional counterfeiters and have created a new class of "casual" counterfeiters. These developments have increased the threat counterfeiting poses to the integrity of the dollar and to the security of the United States.

The new technology increases the counterfeiting threat in several ways. First, professional counterfeiters and, potentially, state-supported counterfeiters, now have the tools to design and produce very high-quality banknotes easily and quickly. Second, the number of people worldwide with access to this new technology has increased dramatically. The threat posed by these casual counterfeiters is large, even assuming that each person who counterfeits makes only a small number of notes per year, simply because the number of potential offenders is very large.[1]

Counterfeiting as a form of fraud is not a new problem. The barter system used in early societies (which involved the direct exchange of goods) was subject to substitution of merchandise of inferior quality or quantity for good products. In later monetary systems using gold or silver, shaving of metal from a coin, hence reducing its value, was commonplace.

Counterfeiting became widespread in the United States around the time of the Civil War. The result was a general loss of confidence in the currencies in circulation (some issued by private banks) and a concomitant negative impact on the economy. The counterfeiting problem led to the formation of the Secret Service by President Abraham Lincoln under the direction of James Pinkerton. New engraving and printing techniques were developed and implemented under governmental control (a high-tech solution in the 1880s), and an aggressive enforcement campaign was instituted by the Secret Service. These steps made counterfeiting a marginal problem for many years, and it appears to remain so today. Still at issue, however, is the level of the future counterfeiting threat.

The counterfeit problem also has an international component because of the dollar's status as the *de facto* world currency. Today, about 65% of all U.S. paper money is in circulation abroad, and a substantial portion of the counterfeit currency in circulation is thought to be produced overseas. The United States reaps significant benefits from the dollar's international presence. As a direct benefit, the overseas currency pool effectively functions as an interest-free loan to the U.S. Treasury with an estimated annual value of $14 billion. As an indirect benefit, our economic health, and hence the value of our currency, is important to many people overseas who use the dollar as a medium of exchange and a store of value. The latter factor implies political as well as economic advantage. Conversely, its widespread acceptance outside the United States makes the dollar an important target currency for counterfeiting worldwide, thereby increasing the scope of the counterfeiting threat. In addition, the international nature of the threat makes defense of the dollar more difficult, since data collection channels in place within the United States are not generally available abroad. Thus, the ability of the Secret Service and other governmental agencies to identify and prosecute illegal activities is lessened.

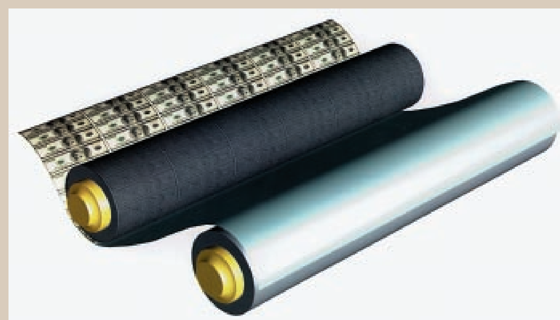
Other aspects of counterfeiting affect national security. One important issue is that paper currency has no intrinsic value. Its value rests solely on public confidence in the credit of the United States and on the belief that the dollar can be used as a medium of exchange and a store of value, now and in the future. Loss of public confidence in the dollar would have direct effects on the economy through higher transactional costs and possibly reduced savings and investment as well as generally lower levels of business activity. A final issue is the direct monetary loss suffered by those who accept a counterfeit note. Such notes, by law, cannot be exchanged, and must be surrendered to the government without compensation.

CURRENCY SECURITY TODAY

Our country has historically used a variety of approaches to foil counterfeiting, particularly intaglio printing and a special cotton–linen currency paper containing colored fibers. These combine to produce a Federal Reserve note with a unique feel. It is widely believed that this is the primary defense in person-to-person transfer, since the feel of the currency is one of the first things a person notices when deciding if the note is real or counterfeit. This tactile response originates in the intaglio printing process described in the boxed insert. The security provided by these two features is based on controlled access to printing equipment and paper, linked with the high cost of acquiring comparable materiel.

INTAGLIO PRINTING

Intaglio printing is a kind of three-dimensional printing. As shown in the figure, the paper is forced into etched depressions on a large-diameter printing roller. The depressions are initially filled with ink, and, through the intaglio process, the ink is deposited not just two-dimensionally on the top surface of the paper but also on the sides of the raised regions of paper formed by the depressions. The result is a relatively stiff, textured paper currency. The intaglio presses and the special paper have been available only to select printers, including national governments and some banknote printers.



Two other important approaches have historically been used to protect the currency. One is the fine engraving seen around the portrait and along the edges of the note. Engravers for the BEP are skilled artisans (it takes at least 12 years to become a journeyman engraver), and it takes a long time to produce a note having the quality of U.S. currency. Again, security is based on limited access to and the high cost of obtaining the equipment and expertise needed to produce counterfeits. The second security feature is the overprinting on the treasury seal. In overprinting, a second distinct pattern (i.e., the seal) is printed above the intaglio. Green ink is overprinted in the seal region, and both the overprint and intaglio patterns can be seen. The overprinted ink is somewhat transparent, and it is difficult to photocopy the numbers intaglio-printed below the seal.

In the past, these features have been adequate to protect the currency. Recently, however, with advances in technology, concern has risen over security, and in response the BEP has developed new security features. Figure 1 summarizes the overt features of the $100 note released last year. Intaglio printing, special currency paper, and high-resolution engraving are still in evidence. In addition, a security thread, first added in the 1990 series, is seen. Other features include a larger portrait, a watermark, ink that changes color with viewing angle, and microprinting throughout the note and in the thread. The thread also contains a fluorescent phosphor that emits red light under ultraviolet illumination. Although the features in the new $100 note, and similar features in other denominations to be issued in the future, are thought to be effective security measures, counterfeiters are expected to try to reproduce the new notes, making it necessary to continue development of advanced security features.

WHO DESIGNS THE CURRENCY?

By law, a new note is designed by the BEP, which considers such factors as aesthetics, cost, and durability in addition to security. The design is submitted to the secretary of the treasury for approval. The approved design is then printed by the BEP and sold to the Federal Reserve bank system (hereafter the Fed)—hence the name Federal Reserve note. The Fed issues the notes to banks and to the public.

In practice, the approval process involves at least all of the groups identified in Fig. 2. Some, such as the Secret Service and the Fed, as well as suppliers of the specialty papers, inks, printing equipment, and inspection equipment used to produce the currency, are obvious. However, many other groups play an important role, such as the cash handling and vending industries, including metropolitan transportation systems using automated fare machines. The public is consulted using a variety of focus groups since it must accept the new design (does anyone remember Susan B. Anthony dollar coins?), as is the Congress and a list of advocacy groups for people with special needs. Part of STI's initial work was to establish working relationships with many of these organizations to provide a basis for the development of new counterfeit deterrence features.

THE SECURITIES TECHNOLOGY INSTITUTE

STI's charter is to identify advanced counterfeit detection techniques, develop new counterfeit deterrence features, and monitor developments in reprographic and other technological areas that might threaten the future security of U.S. currency. As such, the Institute is intended to serve as a national focal point for the science and advanced technology of currency security. The STI program takes a systems engineering approach that includes interaction with experts from industry (e.g., printing, reprographic, cash transaction), universities, advocacy groups, and the federal government (including other technology centers with government ties). Technical expertise is supplied by APL and other divisions of The Johns Hopkins

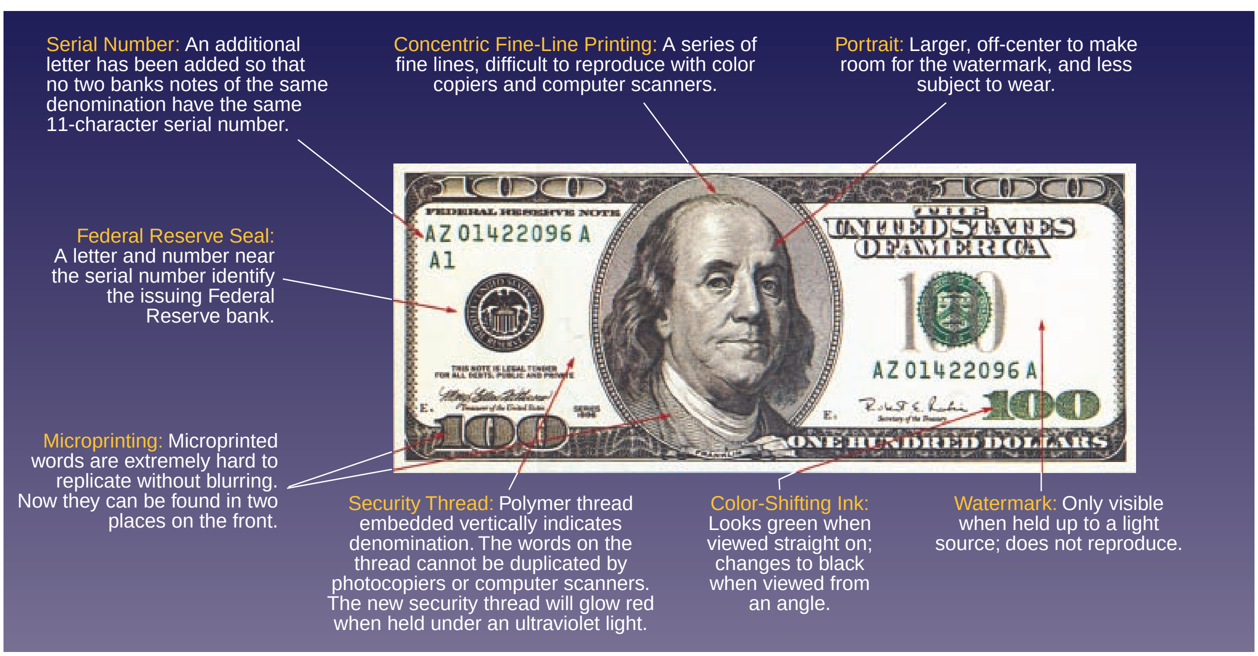


Figure 1. Special features of the new $100 note released in 1996.

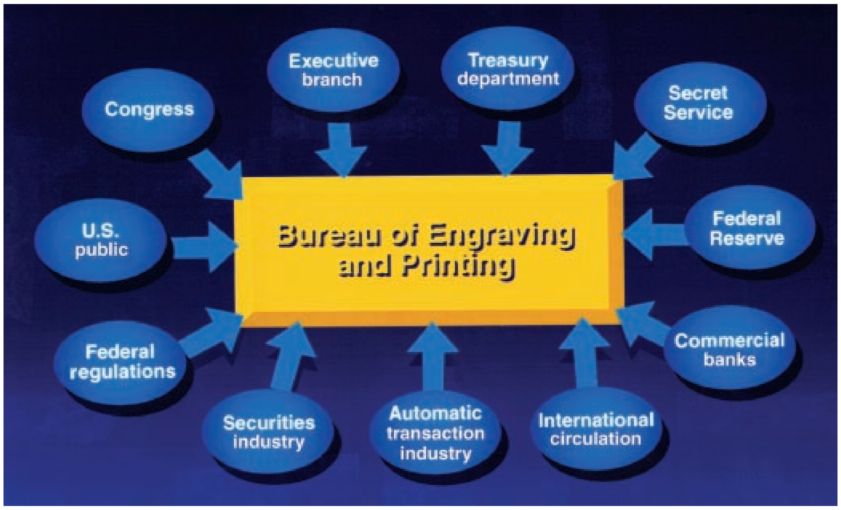


Figure 2. The Bureau of Engraving and Printing receives input from many sources when designing currency.

University. Although the goal of the STI is to develop practical methods to identify counterfeit notes and protect the currency, implementation of any method developed will be the responsibility of the BEP and the Fed.

The process of combating counterfeiters begins with the first exchange of a counterfeit note. The transfer can occur person-to-person or through a bank cash machine, for example. Verification that a particular note is valid is based on so-called overt security features, including those described previously. Most of today's features are visual or tactile in nature and are useful mainly for person-to-person exchange. For machine verification, the BEP does not identify covert security features. Private sector groups may use any parameters of valid notes to identify counterfeits. Since the economic stakes are high, machine-readable features are often closely held secrets of the highly competitive vending and cash-transfer machine industries.

Banks, especially the regional Fed banks, play a key role later in the counterfeit detection process, i.e., after first exchange. They must transfer cash they collect during normal business operations to the local Fed bank for counting and inspection. Notes are denominated, counted, and checked for authenticity. Notes torn or otherwise damaged are withdrawn from circulation and destroyed.

The scale of the process is illustrated by the number of notes that pass through the Fed branch in Baltimore near Camden Yards. The Baltimore branch is only a sub-bank of the district centered in Richmond, yet it regularly processes more than 70,000 notes per hour and has, at peak, reached almost 100,000 notes per hour! Such throughput requires machine processing and hence features that can be used for machine authentication. Both overt and covert features are used for this inspection. The authentication process removes counterfeits from circulation, provides estimates of the level of counterfeit activity, and supports the forensic and investigative activities of the Secret Service.

The STI program today focuses on developing covert features or "tags" for incorporation into the currency (overt feature development is also planned). The criteria for such tags include high security with low false positives and false negatives, support for high-speed decision making, and stability of the tagging agent over the life of the note under harsh environmental conditions. Another consideration is the nontoxic composition of the note: notes must be disposed of safely, but disposal of inks containing heavy metal, which were used in early series of U.S. currency, is no longer permitted. Cost per note is also important. For reference, a note costs the Fed about 3.5 cents to produce (the 1996 series $100 bills were slightly more expensive). Given the volume of notes printed annually, money is always a factor and new features should only marginally increase the cost per note.

The general approach taken by the STI to the development of tags is to incorporate special materials whose response can be stimulated and "interrogated" (to elicit a response) at high speed under conditions found in the inspection machines used by the Fed. The overall program includes development of secure sensor systems to be linked to the Fed authentication machines, including hardware, software, and signal analysis techniques. Many materials-based approaches have been developed. Some of the potentially interesting technologies entail electromagnetic induction effects, active and passive optical effects, active and passive acoustic effects, odorants, structural effects of the substrate, and materials that exhibit specific interactions with energetic probes. A brief discussion of a few specific concepts follows to give a flavor for the considerations underlying both overt and covert tag development. Some discussion of their potential for implementation in the currency is included as well.

CONCEPTUAL EXAMPLES OF TAGGING AGENTS

Figure 3 illustrates the use of a probe to interrogate a note and "read" the tag. In the following paragraphs, two general concepts of a tag are presented: the first is based on a fluorescent compound placed in the security

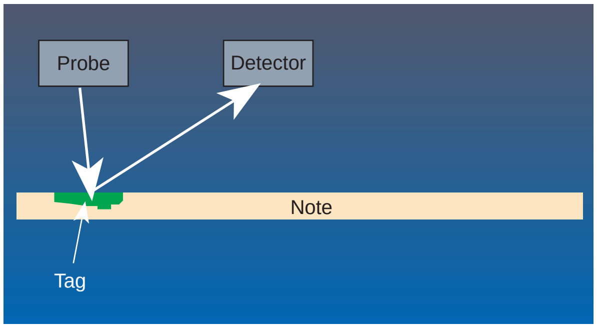


Figure 3. A probe is used to interrogate the note and read the tag (the feature that interacts with the probe). Reading a tag, in effect, is the equivalent of reading a message.

thread, which is excited and monitored optically, and the second is based on acoustic probing and monitoring of features within the substrate.

Some materials fluoresce when illuminated with light; such materials are used in the new $100 notes. Figure 4 represents schematically how fluorescence might be used in note inspection. The STI program has identified a wide range of optical methods and materials including conventional fluorophores as well as a range of materials exhibiting modulated responses (e.g., second-harmonic generation, Raman scattering, electro- and magneto-optical modulation).

Studies indicate that acoustic techniques have potential in counterfeit deterrence since they offer rapid, noncontact interaction with the note and a response that can be tailored to the use of special materials. Figure 5 shows a conceptual view of the generation and detection of acoustic waves in a note. One detection method uses the photoacoustic effect (conversion of heat produced by light absorption into sound). A second method uses direct coupling of sound generated by an external acoustic source into the note with detection of the acoustic response. Note that two approaches to coupling the acoustic waves in and out of the note are shown, one (Fig. 5b) using a roller system already present in the inspection machine and the second (Fig. 5c) using noncontact coupling through air. The paper industry already uses acoustic methods for

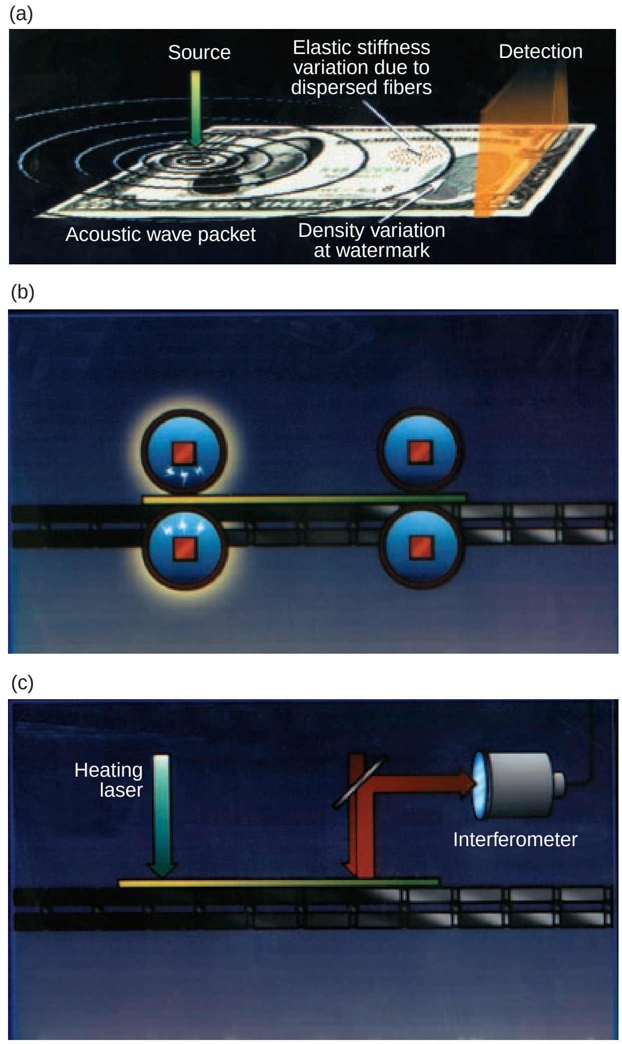


Figure 5. Probing paper with ultrasound. (a) The velocity of the acoustic waves is determined by the density and elastic stiffness coefficient of the paper. (b) Contact generation and detection using transducers inside fluid-filled rubber wheels. (c) Noncontact thermoelastic generation (laser, microwave) interferometric detection.

on-line quality control of their products. In our case, the particular interactions of acoustic waves with specific materials would be the key to tag selection.

Figure 5a shows a wave propagating along the long axis of the note. From the data in Fig. 5c, the acoustic velocity can be determined. Typical acoustic velocities for paper are in the range of 200 to 500 m/s, which means that the propagation time through a 100-μm-thick note would be about 0.3 μs, and the acoustic propagation time from end to end (15.6 cm) would be about 450 μs. One concept based on special materials involves embedding

Figure 4. Probing currency using phosphor embedded in security thread.

localized materials that can act as generators of acoustic waves in the paper or ink. Certain shape-memory materials (i.e., materials that return to an initial shape after heating, etc.) have this property. Moreover, if the sound generators are spatially coded, it might even be possible to produce a note that emits a perceptible sound (an overt tag), e.g., the $100 note might say "I'm a hundred!" when scratched along its length.

Another acoustical concept is the use of piezoelectric powders distributed across the note. The orientation of individual powder grains can be modified by an initial acoustic wave passing through the powder. When a subsequent acoustic pulse is injected, it interacts with the spatial pattern (possibly a diffraction grating) produced by the first wave and creates a backward-propagating acoustic echo that can be detected at the source end. A variable code might be written into the powder and detected with a matched interrogating acoustic signal.

SUMMARY

The STI offers an exciting opportunity for the Laboratory to contribute to a significant problem affecting national security in the nondefense arena. The problem includes issues of systems definition, technology development, and security planning. It draws on APL's expertise in technological threat assessment gained through its Submarine Security Program in the Submarine Technology Department and through an extensive background in advanced materials and sensors developed in the Milton S. Eisenhower Research and Technology Development Center.

The STI program also offers the prospect of applying our knowledge to other counterfeiting problems. Many governmental documents (e.g., passports, visas, green cards, and Social Security cards) must be secure. Industrial and economic security areas needing protection from counterfeiting include security documents, software, electronics, and manufactured parts. The counterfeiting problem as a whole is enormous; billions of dollars are lost worldwide each year to bogus products. Some of the technologies developed in the STI can eventually be applied to this broader market, thus having a significant impact on the U.S. economy.

REFERENCE

[1] *Counterfeit Deterrent Features for the Next-Generation Currency Design*, NMAB-472, National Research Council, Washington, DC (1993).

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