"Not only have we been beaten in the decisive battles of this war, but also we lost the communications war. We felt foolishly secure and failed to take adequate measures to protect our own communications on one hand, while on the other hand, we failed to succeed in breaking into the enemy's traffic. This is undoubtedly one of the major reasons for our losing battles and in turn one of the major contributing factors to our losing the war. We failed in communications."

*Books recently published in Japan by former Japanese naval officers come out quite openly with statements attributing their defeat to poor COMSEC on their part and excellent American COMINT and COMSEC. For example, there is Captain Fuchida's book entitled *Midway: The Battle that Doomed Japan*, Chapter VIII, p. 131:

"If Admiral Yamamoto and his staff were vaguely disturbed by persistent bad weather and by lack of information concerning the doings of the enemy, they would have been truly dismayed had they known the actual enemy situation. Post-war American accounts make it clear that the United States Pacific Fleet knew of the Japanese plan to invade Midway even before our forces had started from home waters. As a result of some
amazing achievements of American intelligence, the enemy had succeeded
in breaking the principal code then in use by the Japanese Navy. In this
way the enemy was able to learn of our intentions almost as quickly as
we had determined them ourselves."

(Here as an aside what Wenger told as to disbelief in decrypts.)

Lest you infer that our side didn't meet with any COMSEC accidents, let me
say that we had plenty of them. These were not attributable, however, to serious
weaknesses in our COMSEC devices, machines and procedures, but principally to
human failure to follow the rules implicitly or to weaknesses in the COMSEC
devices, machines and procedures of some of our Allies. Take for instance the
heavy losses that the United States Army Air Corps sustained in their air strikes
on the Ploesti oil fields in southeastern Europe. We lost several hundred big
bombers within a relatively short time because of weaknesses in Russian communi-
cations which let the German fighter commands know exactly when our bombers
left and where they were going. When found out what the trouble was, it was
too late. This incident leads me to say that when you fight a war with allies
their COMSEC weaknesses are bound to affect the security of your own forces;
something must be done to eliminate those weaknesses, even at the risk of
jeopardizing other important things. For instance, you may have to provide
them with some of your own cryptomaterial, in which case you lose control of the
continued secrecy of that material.

It is hardly necessary to tell you that with the advances made in the
what we call Cipher Device/ type M-94. Now, when Major Mauborgne decided to
go ahead with this device, Mrs. Friedman and I were back at Riverbank, after
I had returned from the AEF. We didn't think the device was very secure and
said so, whereupon Mauborgne issued a challenge, which was accepted. He sent
25 messages. We started in with our crew to try to solve the messages by
lining them all up and trying to guess words in them. It was no-go. We spent
a lot of time trying to solve those messages—and so did the crew of crypt-
analysts in G-2. Ten years later I found the plain text of the set of 25
challenge messages amongst some old papers in the Office of the Chief Signal
Officer and then I knew why neither we nor G-2 solved them—look at them! And
we were expecting military text! In defense of Mauborgne I'll say that it was
not he who cooked those test messages up for the challenge—it was one of his
assistants who thought he'd put one over on us, which he did. Mauborgne himself
thought he'd bungled it, but he wanted to make sure his messages couldn't be
solved. When after
some six or so
months nobody had solved his challenge messages Mauborgne went ahead and got
the thing out, and there were thousands of them made. They were used by the Army, the Navy, the Coast
Guard, and the Treasury. [Here's a picture of the thing] A couple of years after
the M-94 was put into service a friend showed me a write-up of something he'd
come across more or less accidentally in the Library of Congress, among
the papers of Thomas Jefferson. Thomas Jefferson was the first to invent the cipher cylinder principle, and he anticipated the Frenchman,
Bazeries, by a century. Here is the first page of his description of his
device, which he called "The Wheel Cypher." Here is the second page. You see his calculations, giving you at the bottom the number of permutations that his particular device affords—a whale of a large number because Jefferson proposed a set of 36 disks.

In studying the degree of security provided by the M-94 both Army and Navy cryptologists soon came to the conclusion that security would be much increased by the use of variable—or changeable—alphabets. Among other versions, I had made one which used metal rings on which we could mount slips of paper and fasten them; thus we could change the alphabets as often as was felt necessary. Navy tried other versions. That was the beginning of the various variant forms of strip cipher devices used by the Armed Forces, and later by the State Department and the Treasury Department. Here is a picture of the final Army type of strip cipher device. You see the channels in which the alphabet strips were inserted according to the daily key, and according to the particular crypto-net to which your command belonged. I mean by this that not all the traffic would be in the same set-up of strips or even used the same strips. The idea was to cut down the amount of interceptible traffic in the same key. The strip ciphers carried an enormous amount of traffic.

Next we come to a machine called the Kryha, invented by a German, in about the year 1925. The Kryha was the last word in the way of mechanical crypto-graphs at the time, and Mr. Kryha tried to interest various governments in his machine. I think I should explain it for those who have never seen it.
which was ever solved in that sort of a machine, and by the way, I hope you
will forgive me if I say that the methods I had to devise at that time for the
solution of rotor machines and rotors in cascade are practically the same today
as they were over thirty-five years ago. Despite my solution we thought that
the Hebern principle was still a good one and Navy went ahead with Mr. Hebern
after he got out of prison. Here's a picture of the last machine built for the
Navy. Hebern wanted to get paid for it naturally, but there was just one hitch--
the machine wouldn't work and when this was pointed out to him he said: "Show
me where it says in the contract it has to work", and when they couldn't, he
was paid off. The Navy then decided that they had had enough of Hebern and
went into research and development themselves. They had a laboratory established
in the Navy Yard, with a very able young man, Seiler, now a Captain in the Navy,
who did some excellent developmental work. Years later the Hebern heirs brought
suit in the United States Court of Claims against the United States for $50,000,000,
which was settled last summer at a considerable discount, $39,000.
The case has been pending for a number of years and the last I knew of it, which was about a month or two ago, a settlement was in prospect for about $30,000. That's quite a discount. I might say that there was very little collaboration between the Army and the Navy cryptologic organizations in those days before Pearl Harbor. Each Service had its own secrets—which was really too bad, but the situation was mended later, as we will have occasion to learn.

Now I'm going to show you a few slides of the Army developments in crypto-machines. This, after the debacle I've told you about, was the first shot that we in the Signal Intelligence Service in the Office of the Chief Signal Officer, in Washington had at developing a machine for the Army. It had a keyboard, a light-bank, 5-rotors, and now an interesting feature—an external keying mechanism. I had come to the conclusion that internal control mechanisms for stepping rotors had a fundamental weakness; I felt that you must not make the rotors depend upon themselves for the stepping, and I conceived the idea of having an external key, for example, a teletype tape, which would step along and control the stepping of the rotors in random fashion. These tapes were composed of a sequence of random characters so that the rotor stepping was quite erratic, and that was our first shot at it. I think the principle is still quite safe, especially if the tapes aren't overburdened in usage. This is another view of the same machine—here is the tape transmitter, the rotors, the keyboard, an electromatic typewriter, etc.
I think this was one of the very early models. We had boxes of about 100 key tapes from which you could make the selection for the day according to the keying document. A perpetual need for

The fatal weakness, of course, was the production and distribution of the tapes. This was quite a headache, even when we used specially heavy paper for the tapes. We used the tapes made in the paper mill in San Francisco, and after the tapes had gone through a number of times, they became quite brittle. We had about 75 of these manufactured by a concern in New Jersey that was not particularly gifted in the typewriter art.

The machines functioned all right but before even ten of them had been produced we had hit upon a new principle for the control of the rotor stepping. I tried my very best to get the Signal Corps to change the development right there and then, and shift to the new type of control. I was practically thrown out of the office of the chief of the division with the remark, "Go back to your den--

you inventors are all alike. A new and better idea every day. I always listen to you, we'd never get anything out." So we put the idea on ice, that is, in secrecy. I will switch now to the Navy MARK I ECM, the electric cipher machine, designed, developed and built by the Navy without any help from Mr. Hebern. It had a new type of control mechanism for rotor stepping, based upon the use of Bowden or flexible cables. They were tricky and gave rise to a lot of difficulty
develop, produce, and use that we had to make an adaptor for this machine so that it could inter-communicate with the British TYPEX and the British had to make an adaptor for their machine to inter-communicate with the ECM-SIGABA. It was a wholly unnecessary expense, I think, but by the end of 1953 we were able to convince the authorities that it would be all right and finally the British were allowed to have our machines until they could complete their developments and be on their own. I think they would be nice if there were time to explain the cryptographic principle of the ECM-SIGABA still have some of our machines but they're supposed to turn them back in due course. I can explain the basic principle of the machine. Here are its essential elements: a set of five ciphering rotors here, and another set of five control rotors here, making a set of ten altogether. Since the rotors are all interchangeable, there can be a great number of permutations from a primary set of ten rotors. It's greater than 10! because the rotors can be inserted right-side up or upside down; in fact, the number is $20 \times 18 \times 16 \ldots \times 2$. And if you have a set of 20 from which you can select 10, as is now the case, the number becomes very much greater. Now there are four inputs in this row of control rotors and their output governs the stepping of the five cryptographic rotors in a very erratic manner. This set of five small rotors permutes the output of the control rotors, adding an additional valuable keying element.

We know of no case of solution of this machine and system throughout the war, and it is still in service as a high-grade off-line machine. During its use in World War II there was one possible compromise-and it raised quite a storm at the time: The 28th Division bivouacked for the night in a small city, the latter carrying all the 28th Division HQ radio machines and materials. But the stuff was soon found where it had been dumped by the Frenchmen-in a nearby river.
in France and the vehicle containing the cryptomaterial and the SIGABAs was
stationed in front of the place where the Signal Officer and his entourage were
quartered for the night. Unfortunately no guard was posted to safeguard the van.
In the morning that vehicle was missing. Warning messages were sent instantly
to Washington and there was a great to-do. The Army blockaded all the roads, the
idea being to make sure that the truck wasn't being carried off by some German
outfit, but nothing turned up. There was a possibility that the van had been
stolen by Frenchmen purely for the vehicle, in which case its contents would be
of no interest to them. Surely they'd get rid of that hot goods at the first
opportunity, which would be to dump them in the nearest river. The Engineer
Corps diverted that river and sure enough all the cipher machines and the crypto-
material had been dumped into the river. The episode was one which caused the
Signal Officer to be tried by court martial, as were several other. We had and
still have very strict rules indeed about safeguarding this gadget, and in
mentioning this point I should say that we weren't worried by the thought that
our messages could be read if the Germans would capture one. We were worried
by the thought that they would learn how good it was and would copy it—thus
cutting off our COMINT. I can hardly refrain from telling you one of the funny
things about our not giving the machine to the British when they needed it so
desperately. I mentioned the strict rules about safeguarding it—who could see
the thing, who could service it, and so on, and we saw to it that these rules
were strictly enforced. But there came a time in North Africa when all our
maintenance men were knocked off and there was nobody to service the machines.
However, a very skillful British Officer, an electrical engineer was pressed into service and he maintained our SIGABAs there for a while. I'm sure you won't be astonished to learn that after VE-Day, when he got back to London he built a machine based upon the ECM-SIGABA principle:

I want to show you next the cipher machine which was used very extensively by all the German Armed Forces in World War II. This was a modification of their commercial Enigma machine but an important modification, introduced when Hitler came into power, at which time the commercial model was withdrawn from the market. I think
using circular key tapes of random characters. This is the way it was done. Here is the keyboard for punching out the plain-text message; here is an ordinary tape transmitter, which took the plain-text tape and put the signals on the telegraph line; but here there were two additional transmitters through which key-tapes were passed. These were composed of random-punched characters, the tapes being joined at their ends to form two circular tapes, and they were of different diameters. To begin with the A.T. & T. started out with one tape 1,000 characters in length and the other 999, so you can see if the tapes start at an initial point, they would not return to the original pair of starting points until the shorter tape had made 999 revolutions, the longer one 1,000, that is, the interaction of the two tapes produced a key that was 999,000 characters in length. So there were three tape transmitters interacting, one for the plain-text tape, two for the key tapes. Great faith was placed in this machine but it was not put into use until the war was over. By that time I had come back from France, rejoined the Riverbank Laboratories and accepted a challenge to solve this kind of cipher system. It's too long a story to go into right now but as a result of the solution the Army dropped the project.

I think it was in a way too bad, and I suppose some of the responsibility lies on my shoulders, because when we had a need for teleprinter ciphering in the early days of 1942 we actually went back to this thing. The big trouble of these key tapes, and it is a course was the production and distribution of which is still with us. Here's an early model
of a machine for making key tapes. We improved such machines very greatly in
the next year or two, so that we could produce hundreds of thousands of good
tapes in a hurry. Our modern key-tape manufacturing apparatus uses a key
generator for producing electronically the random impulses for punching the
tapes.

Next I show another commercial development for teleprinter ciphering, one
by the I. T. & T. Co., who employed Colonel Parker Hitt after he had retired
from the Army in about 1925. The machine presumably was to incorporate a
very secure principle, since Colonel Hitt was well acquainted with cryptology.
But I am sorry to tell you that it wasn't a secure principle that he employed.
A demonstration equipment was installed in the State Department and the Army
cryptanalysts were asked to test its security. Some messages prepared by the
State Department's Chief of Communications were solved in a hurry. I had the
unpleasant task of telling Colonel Hitt that I wasn't at liberty to tell him
what the trouble was. This was our fixed policy in the Office of the Chief
Signal Officer, and I think it was an understandable one. If we undertook to
tell all inventors what the trouble is with their inventions we would never
get anything else done but look into their successive modifications. We would
thus bring them up-to-date in cryptanalysis, too, and this is certainly not
advisable as regards the run-of-mine or would-be inventors of crypto-apparatus.

This is a rotor machine, the SIGCUM, which the Army developed in 1942-43
and used very successfully to encipher teletype communications. It uses not
perforated tapes but rotors which step
in an erratic fashion but not as erratic as in the ECM-SIGABA. The SIGCUM and its successors had weaknesses; every once in a while, when we discovered new cryptanalytic techniques, we found that SIGCUM had weaknesses which could be exploited; whereupon we would proceed to tighten up things by changes in the method of usage or the method of stepping the rotors, and so on. Here's a picture of the entire SIGCUM unit with the teletype signal mixing unit—the more and more improved features in it. Its new designation is KW-2. Here's a most of which was unnecessary. The mixing apparatus takes the signals from here and mixes them with the SIGCUM, then putting the enciphered signals out on the line.

Now we have to say a few words about certain other types of ciphering apparatus. For example, it is necessary to send weather maps, situation maps, and other types of maps important for successful military operations, and so it was desirable to have a machine which would encipher and decipher facsimile. The generic name we gave to machines for ciphering facsimile was cifax. Here is one such machine that was developed by Army for the purpose, called SIGMEW.

We also had need for machines that would impose security protection upon telephone conversations, machines with the generic name ciphony equipments; here's the first shot at it—a development by the Bell Telephone Laboratories, called SIGJIP. It was a gyp in a way—it gave you much more feeling of security than was warranted by the circumstances. Conversations enciphered by means of that thing could be read very readily and we all knew this but it was only an interim piece of equipment. The Telephone Company proceeded with its work, in collaboration with engineers from the Signal Intelligence Service and the Signal Corps,
and a very high-grade ciphony system which became known as SIGSALY was finally and were extremely successful. Each terminal cost over a million dollars and there were a total of seven of them. The two ends of the circuit were kept in synchrony by means of a very-high grade record-playing mechanism. The SIGSALY turned out to be extremely useful.

Now in addition to cifax and ciphony we tried to develop practical cipher machines for other purposes, such as recognition, identification, IFF, callsign machines, etc. This is a war-time callsign machine developed by the U.S. Navy. It was based upon an algebraic principle described in a paper in one of the American mathematical journals; it appealed to me but I could never get the Army to go in for callsign changes in a big way. The Navy did, however, and this principle was incorporated in a call-sign ciphering machine for Navy communications. A good machine was developed and I think it is still in service.

Sooner or later--and I think the sooner the better--we will have to have ciphering apparatus for protecting telemetering signals, television signals, homing beacons, etc.-- anything in the way of a signal is going to have means and mechanisms for security protection.

The professional cryptologist is always amused by the almost invariable reference by the layman to "the German code", "the Japanese code", "the U.S. Navy code", etc. To give an idea as to how fallacious such a notion is, I will say that as I said once before, there are hundreds of systems in simultaneous use in the communication services of all large governments. You will have to have different systems to meet specific types of communications. But you have to divide up the traffic for the best results. First, do not to overlook one system beyond the staff's limit, and second, so that not everybody will read "very to be letter's message", even in the same family. If you read "very to be letter's message", even in the same family. The Midway battle happened primarily because the last principle wasn't in effect at that time in U.S. naval communications. 
and commission. Experience has proved that in the past it has been these
errors and not so much technical weaknesses in the cryptosystems and machines
themselves that have made solution on a regular basis possible. This sort of
practical experience means that the keying procedures should be made simpler,
and, if possible, entirely automatic so far as concerns the human operator and user
of the machine and system. Complexities can be introduced, incorporated, or
applied at NSA, where there are extremely well-trained and experienced crypto-
engineers and their helpers.

You understand, I'm sure, that we depend for crypto-security not on
keeping the construction or design of the machines deep secrets. This means
that the machines must be based upon crypto-principles such that even if copies
of them fall into enemy hands, by capture or otherwise, without possession
of the exact key for the day, the period, or the messages themselves, the enemy
can never learn by cryptanalysis what he can't learn the contents of the messages alone, or at least, for a very large
number of years. By cryptanalysis. At the same time there is a real point in
keeping the machine, apparatus, or system itself in a classified status as long
as possible, because in the case of well-designed crypto-apparatus if you don't
even know what the machine looks like, or its general principles of ciphering,
you can't even make a start at cryptanalysis, or, to be more accurate, it will
take a considerable length of time and more or less involved study to ascertain
what you must know before you can make an attack on the messages with some hope
of success. In a nutshell, then, we keep the machines in a classified status
on-line or off-line

Next we have the KW-9, our tele-type encription machine that uses rotors instead of key tapes and is very much safer than the old SIGCUCY showed you. Here we have the new KW-26, which is fast to becoming the work-horse of fixed tele-type long-range communication systems. It is an on-line synchronous tele-type cipher system with built-in encryption, that is, so far as an enemy intercept is concerned it is impossible to tell when the circuit is idle and when it is carrying a message.
as long as possible in order to delay the enemy's real attack on the traffic enciphered by the machines. But, of course, there's the other reason I've already mentioned: to prevent a potential enemy from copying our machines and turning our own weapons against us.

Now let's see pictures of some of the new apparatus, which will soon be ready for issue.

For field use we now have in place of Converter M-299 a small off-line high security machine designated the AFSAM-7. It has a keyboard and prints the cipher text. For electric power it uses any 24-volt source. This machine is now the work-horse for tactical cryptocommunications, and, by the way, several thousands of them have been issued to our NATO allies.

Here's a machine designated the KW-3. It is an off-line teleprinter cipher machine but it has all the conveniences of an on-line machine and eliminates some of the weaknesses of the latter. The machine generates the key as well as the indicators for messages. All the operator has to do is to type the address, punch a starting key on the machine, and then proceed to type off the plain text of the messages, whereupon a cipher tape is produced, which can be put on any teleprinter circuit for transmission. At the receiving center the operator puts the cipher tape into a reading head, the start button is pushed, the message sets up its indicator and key, and the tape produced is the plain text of the original message. The KW-3 is becoming the real work-horse of our Armed Forces high-command cryptocommunications.
Next I show the KW-37, designed for Navy Fox or broadcast transmissions, a machine which embodies a teletype printer and uses an IBM card for keying purposes. So far as the communication center aboard ship is concerned, the radio operators won't even see the cipher—the messages arrive there in plain language; the ciphering is done elsewhere on the ship. This system is a synchronous one, meaning that both ends of the circuit are constantly and automatically kept in step; also, and related to this fact is the fact that the system is such that the intercepting enemy can't tell when a message is being transmitted and when the circuit is idling, giving what we call "link security", a very important element in communication security.
In what I've just showed you'll notice the emphasis placed on telephone security devices and systems, and on automatic teleprinting systems. The days of hand-operated devices is over, and those of semi-automatic off-line cryptographic machines are drawing to a close. And, last to be mentioned, NSA crypto-engineers are doing development work in civesion systems—enciphered television—which will doubtless come into use within a few years.

But with all these modern improvements I don't think the day has yet dawned when it can be said that the human factors that make for crypto-insecurity have been altogether eliminated. Perhaps it's true that at the moment COMSEC technology can be said to be ahead of COMINT technology; but with ever-increasing speed of electronic analytic apparatus the gap can and perhaps will be closed, unless the COMSEC engineers keep pace with that apparatus. In short, it is the age-old battle between armor and armor-piercing projectiles. In the meantime, communicators must keep their guard up and enforce the rules supplied them for operating their crypto-equipments. In closing this period let me remind you of that introductory slogan: "Don't learn your COMSEC rules by accident."

The establishment and maintenance of communications security is a responsibility of everyone, that there aren't any short-cuts to achieving communications security, and that the rules of COMSEC must be followed to the letter by everybody connected with COMSEC but most especially by crypto-staffing personnel. If these reminders are followed, you won't learn your COMSEC rules by accident!
This and the next slide are a bit out of order, but I didn't have glass slides for them and have to use the small 35-mm. ones. This one showing the KL-36 is KL-36 the one I mentioned before as having been developed for the Marine Corps. The next one is the pneumatic method machine that we think would serve the needs better than the KL-36 and be far safer.