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History of The Bombe Project

MEMORANDUM FOR THE DIRECTOR OF NAVAL COMMUNICATIONS

Subj: History of the Bombe Project.

1. The following history of the Bombe project has been prepared in accordance with your request. To insure an accurate presentation of this history, it has been prepared by the three officers who were most intimately concerned with the project from inception to completion. It should be pointed out, however, that, while the work of directing, planning, organizing, and deciding the multitude of questions involved was accomplished by the three undersigned officers, working as a committee, the ultimate results have been achieved by the combined efforts of a number of persons.

2. Early in 1941, Op-20-G, under Capt. Safford, began work on German Naval ciphers. In March 1941, Comdr. Denniston, then head of G.C. & C.S., reported that we had been informed of British progress on the German Enigma problem and that complete cooperation on this problem was now possible. The technical difficulties of the problem were appreciated, and some of our best cryptanalytic talent was assigned to it. A certain amount of information on the Enigma solution had been divulged to Lieut. Weeks and Lieut. Currier at G.C. & C.S. under a pledge that the information was to be disclosed only under a pledge that the information was to be disclosed only to the Director of Naval Communications. Results of the work under this arrangement were extremely meager. Prior to this time the British were apparently attempting to withhold their knowledge and discoveries with regard to the Enigma because of dissatisfaction with American security standards and also possibly as a bargaining element for obtaining more intimate knowledge of our superior Japanese information. Between March and October of 1941 very little information on the German Enigma was forthcoming. On 1 October 1941 Comdr. Denniston supplied to Capt. Safford some details of German Naval Enigma traffic. In November 1941 the Director of Naval Communications complained that the British had not carried out the bargain made in March 1941 for complete cooperation. By way of reply, the British stated categorically that (a) "everything asked for in conjunction with the German Naval Enigma problem had been supplied" and (b) that "Admiralty would pass German Naval intelligence to Navy Department when U.S.A. was affected." The difficulties were thus temporarily cleared up in the middle of December 1941. We were apparently left, however, in the position of not getting anything unless we asked for it.

3. The situation rested thus at the time of the reorganization of Op-20-G in February 1942. At the time of this reorganization, two parties in Op-20-G, comprising the most experienced cryptanalysts, were engaged in research on the

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History of The Bombe Project

Enigma problem. Sporadic information was received from British sources. In view of the pressing situation in the Pacific, it was decided to devote at least part of this effort to Japanese cryptanalysis and obtain necessary assistance in the German field from the British. Accordingly, the situation was brought to the attention of the Director of Naval Communications at the end of February 1942. As a result, two communications requesting further information on German cryptographic systems were sent to the British: first, a dispatch to the Admiralty from the Vice Chief of Naval Operations and, second, a letter to the First Sea Lord from Admiral Stark. During this period Comdr. Travis replaced Comdr. Denniston as Director of the British Code and Cipher Section. Col. John Tiltman of G.C. & C.S. visited the Navy Department in April 1942 and we had further discussions concerning the German Enigma problem with him in order that our position might be improved. As a result of these discussions, Col. Tiltman sent the following dispatch to Comdr. Travis, with the approval of the Director of Naval Communications:

"a. Officers controlling Y at the Navy Department agree in principle that the solution and exploitation of "E" can best be carried out by the British but I agree with them the following considerations must be taken into account.

"b. In view of the fact that they are now at war and have a vital interest in submarine traffic, they are entitled to results or a detailed statement as to why this traffic cannot be read at present and what are prospects for future.

"c. Unless a rapid and satisfactory solution is found to (b) the high command will insist on their naval cryptanalysts attempting to duplicate our work on E ."

The basis for this proposal was the belief that only by devoting its entire attention to Japanese communications could Op-20-G achieve any results in the Pacific with the meager facilities then available. It was felt, moreover, that this proposal represented a proper division of labor, under the circumstances, between the British and U.S. radio intelligence activities. In connection with the proposal it was pointed out that we had suggestions to make on electronic lines which might speed up existing machinery for the Enigma solution. The reply from Comdr. Travis contained a statement that the 4-wheel submarine traffic was, for the time at least, unreadable. It also disagreed with any idea of forming a skeleton party in the U.S.A., since "if any real danger arose of the present facilities being lost we would certainly send experts to the other side." Col. Tiltman replied to Comdr. Travis on 21 April 1942 that he felt the British answer would be unacceptable to

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History of The Bombe Project

the Navy Department and, unless full details of the machine solution were made available to the Navy Department, officers controlling "Y" would certainly seek aid of higher authority to press their point of view. On 13 May 1942, a dispatch from Comdr. Travis indicated approval by higher authority of American machine investigations. It also contained a promise of a machine for solution in August or September, as well as a mechanic to instruct in the maintenance and operation.

4. During Col. Tiltman s visit to Op-20-G in April 1942, he was asked for frank criticism of our organization. Col. Tiltman expressed the view that our outstanding weakness was the lack of a well trained and experienced research group. We informed him that we had created a research group under Comdr. Engstrom and asked if it would be possible to send two or three officers to G.C. & C.S. to study the functioning of the British research group. Col. Tiltman agreed and, with the approval of Admiral Redman, two officers, Lieut. R. B. Ely and Lieut. (jg) J. J. Eachus, were sent to England in July of 1942 for the primary purpose of studying British cryptanalytical research methods but with additional instructions to find out all the details possible concerning the British "E" problem. Under the impetus of the presence of these two officers, considerable detailed information was forthcoming concerning the British Bombe and wiring diagrams. The preliminary studies on problems of high-speed Bombes led American opinion to the conclusion that achievement of success in the high-speed problem would be more probable along somewhat different lines from those of the British three wheel machines for which wiring diagrams had been sent. During August 1942 the material shortages and power requirements for the electronic approach made it advisable to an electro-mechanical Bombe of independent design. Investigations along these lines had gone on simultaneously with the electronic procedures.

5. Meanwhile, it became more and more obvious from reports received from our representatives in England that the British would be unable to supply us a machine by the promised date. It became evident, furthermore, that the British were having considerable difficulty in building any workable high-speed machine. Accordingly, late in August, after continuous conferences, we reached the conclusion that American methods and design showed sufficient probability of success to inaugurate the Bombe program. Comdr. Wenger then held a conference with Capt. Hastings, British representative of G.C. & C.S., in which he pointed out that the British ahd [had] shown no evidence of being able to live up to their promises. Capt. Hastings was informed that, in view of this fact, we felt obliged to recommend to higher authority that we take the matter in our own hands and proceed as we considered proper. Capt. Hastings protested that the British had lived up to their agreement and, referring to Col. Tiltman s dispatch, quoted above, pointed out that the British had consented to give us results or a detailed

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History of The Bombe Project

statement as to why the traffic could not be read. As this detailed statement had been given, Capt. Hastings consented that British obligations had been fulfilled. In reply he was advised that such a stand would not be acceptable to the Navy Department and that we proposed to ask for authority to undertake a U.S. Bombe program. Accordingly, on 3 September 1942, Comdr. Wenger submitted a memorandum to the Director of Naval Communications requesting authority and funds to initiate the Bombe program. With the complete backing of Admiral Redman, approval of the Bombe project was granted by Vice Admiral Horne on 4 September 1942. In the request for authorization it was stated that the general British approach would be taken but that the project must be understood to be a gamble. It was pointed out that the project was not only a gamble from the point of view of possible enemy changes of procedure but also from the technical side. Although theoretical calculations indicated that the proposed high-speed Bombe would work, these calculations were based on engineering design of extremely questionable practical achievement and at variance with British experience and recommendations. Following the announcement of our intentions, Comdr. Travis visited Op-20-G, and on 2 October 1942 a formal agreement was drawn up providing for full collaboration on the German submarine and naval problems. While by this agreement we accepted in effect a subordinate position in the Atlantic Theater, we exacted in return the dominating position in the Pacific.

6. Until February 1942 the German services had made almost universal use of the 3-wheel Enigma machine for enciphering. In February 1942 the German Navy introduced a 4-wheel cipher machine for all submarine circuits. The British machine solution for the Enigma problem was based on the 3-wheel Enigma machine and their 3-wheel Bombes had been successfully used in solving the problem. The use of the fourth wheel inorduced [introduced] a factor of twenty-six in the time required for solution. This necessitated either twenty-six times as many Bombes or a Bombe which would go twenty-six times as fast. Thus American thought during the early part of 1942 had been directed to high-speed approaches to the problem. Information and intelligence from the British on the German problem was meager and slow in arriving. Meanwhile, the submarine situation in the Atlantic was becoming more and more critical, and we discussed at great length the entire problem and the possibilities of building high-speed equipment of our own design to meet it. Failure to receive anything assuring from the British and the urgency of the situation finally led to the establishment of a development contract at the National Cash Register Company for the investigation of an extremely high-speed cipher machine of the Enigma type. In the meantime, efforts were renewed along different lines to obtain more information from

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History of The Bombe Project

the British. Reports from the British during September and October of 1942 indicated definitely that attempts to construct a high-speed Bombe were not proceeding satisfactorily.

7. On 11 November 1942 the U.S. Naval Computing Machine Laboratory was established by letter from the Vice Chief of Naval Operations to the Chief of Naval Personnel via the Chief of the Bureau of Ships, and by letter from the Vice Chief of Naval Operations to the Commandant, Ninth Naval District, for the purpose of assisting the contractor in the production of these Bombes and in the training of maintenance and operation personnel.

8. In the original concept of the problem it appeared that 336 units were desirable since there are 336 possible wheel orders. In forming preliminary notions of the size and power requirements for the equipment, the British 3-wheel Bombe was in mind. The British three-wheel Bombes have three levels in each physical piece of equipment. Thus the concept of 336 Bombes led to the notion of 112 separate pieces of equipment. The early decision to build 336 units was predicated upon the belief that we should have to provide for running all 336 wheel orders. As study of the problem progressed, it became evident that there were analytical ways of ruling out many of the wheel orders, thus reducing the Bombe requirements. The possibilities of making this reduction were given very serious study for the reason that materials at the time were exceedingly critical. Discussions with the Head of the Radio Division of the Bureau of Ships indicated that serious difficulties were being experienced in getting certain critical materials necessary in radio manufacture. As this equipment would use considerable quantities of these materials, it was felt essential that every effort be made to reduce the needs to the absolute minimum. Meanwhile, certain changes in German communications which affected cross-cribbing and indications of procedure changes involving the use of the fourth wheel arose. These changes made it impossible to arrive at a definite decision on the number of machines required before it became necessary to proceed with designs for housing and equipment.

9. Preliminary discussions on the operation of the equipment indicated that optimum operations could be obtained if facilities were provided in Dayton, since proximity to the factory was considered a strong element in successful maintenance. However, the Vice Chief of Naval Operations, on the recommendation of the Director of Naval communications, Capt. Holden, ruled that the equipment must be operated in Washington. The problem of designing a building to house equipment which was only on drawing boards and in extremely tentative form was difficult, particularly since the total number of machines to be build was also

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History of The Bombe Project

undermined. Plans for the building, which had to be completed in January 1943, were made on the basis of 112 separate pieces of equipment. The problem of providing space was largely a matter of guesswork, since the details of the method were unknown, the problem of stowing communicators had not been solved, and operational techniques undeveloped.

10. In December 1942, Dr. Turing from G.C. & C.S., an expert on the British "E" solution, visited Op-20-G and the U.S. Naval Computing Machine Laboratory at Dayton. His reaction to the American Bombe design was far from enthusiastic. Extracts from his report on his visit (shown to us by Capt. Hasings) are as follows:

> "It seems a pity for them to go out of their way to build a machine to do al this stopping if it is not necessary[.] I am now converted to the extent of thinking that starting from scratch on the design of a Bombe, this method is about as good as our own. The American Bombe program was to produce 336 Bombes, one for each wheel order. I used to smile inwardly at the conception of test (of commutators) can hardly be considered conclusive as they were not testing for the bounce with electronic stop finding devices. Nobody seems to be told about rods or officers or banburismus unless they are really going to do something about it.

These quotations and other comments in the report indicate the considerable extent to which our design was at variance with British ideas and experience.

11. The original directive for the Bombe project did not specify the number of Bombes to be built. In the first six months of 1943 considerable thought was expended concerning the number of Bombes to be built to deal effectively with the naval problem. The British opinion in March 1943 indicated a total of ninety (90) 4-wheel Bombes adequate for the naval problem under the worst conditions that might reasonably be expected . Many factors entered the American decision in reaching the number ninety-six (96) as the optimum number of Bombes for the German Naval problem. During the summer of 1943 optimistic opinion concerning the duration of the Atlantic war tended to revise the preliminary figure of ninety-six (96) in a downward direction rather than back to the original 336. However, after discussing the question with the British we decided against any reduction.

12. The first two experimental models of the 4-wheel Bombes were put into operation at the U.S. Naval Computing Machine Laboratory in May 1943 and

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History of The Bombe Project

were immediately successful. Secure means of communications were established between Washington and Dayton and the machines were operated there in order to be under observation by the maintenance and design engineers. Designs for the production models were completed in April 1943, and production models started to be put into operation in early June. In order to insure practical operation, we insisted on the inclusion of several features in the production model, contrary to advice by the engineers. The principal difficulty we had was in connection with the design of the commutator. Nothing available would serve the purpose, and a tremendous amount of research had to be undertaken to arrive at a satisfactory solution. The engineers finally decided that only the use of small commutators could we attain the necessary speed. The two test models built had these two small wheels, and designs proceeded along those lines. However, after much consideration, we decided that the use of the two small wheels would result in doubling the total number of wheels to be employed (approximately 40,000 in all) and would present extreme difficulties in maintenance and in rewiring in the event of any change by the Germans. We therefore decided that to make the machines workable it was imperative that we use a single size wheel for all four positions in the machine. Meantime, the procurement of the materials for the production models had been extremely difficult because of the structure of the priority system. To obtain proper priority and precedence ratings without having to reveal widely the complete nature and purpose of the project, as required under normal procedure, it was finally necessary to request an appeal from Admiral King to Admiral Leahy. It was also necessary to request the personal intercession of Admiral Redman to obtain the requisite manufacturing facilities from the National Cash Register Company. Because of the resulting delays, we found ourselves
facing the difficult choice of going ahead with the production on the chance that we could meanwhile develop a satisfactory high speed commutator, or holding up the entire project until this vital element in the machine could be proven. In view of the critical submarine situation, we decided to take a chance on being able to develop a commutator and went ahead with production against the advice of the engineers.

13. The first production models of the machine were operated at Dayton until September 1943 when the Laboratory Building at the Annex was ready for occupancy. The machines were shipped from Dayton to the Laboratory starting in September at the rate of four (4) a week and operations carried on continuously from that time. At present there are ninety-six (96) machines in the Laboratory Building. Two (2) of these machines have been combined to a double unit. In order to provide for maintenance, the usual ten percent (10%) supply of spare parts for replacements has been made available. This supply includes three

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History of The Bombe Project

assembled machines and complete parts for seven others which are being used in maintenance.

14. The decryption of German Naval traffic has been very successful during the past six months. At present all units are used on naval jobs until the daily keys are out; then the machines are used on non naval research. During the six-month period about forty-five (45%) of the Bombe time has been devoted to non-naval research problems carried out at the request of the British. The successful operation of this project has confirmed the correctness of decisions both as to the number of machines necessary for the naval problem as well as space provisions in the Laboratory Building.

15. Recent pressure from the British, which led to the request for construction of fifty (50) additional units, was not the result of need in the naval problem; it was motivated principally by the need for Army and Air Force keys, resulting from the British failure to carry through their obligation in building 4-wheel Bombes. According to latest information, only eighteen (18) have been produced by them, and continued operation of three (3) of these is the average performance. In the original discussions of this project with the British, the U.S. Navy was to assist G.C. & C.S. in the German Naval problem. At present practically the entire burden of the naval problem is carried by the U.S. Navy Bombes. To confirm the figure of ninety-six (96) Bombes, the following quotation from 24 March 1944 should serve:

> "Performance of our machine is still poor and likely to remain so.
> In view of your 4-wheel capacity being more than adequate, priority is being given here to the production of new 3-wheel machines."

16. In our opinion there is serious question as to the necessity for building all of the additional Bombes. Certain important changes are apparently underway in the German Enigma machine, which if carried through as expected, will require use of a different type of machine, designed by the Research Group of Op-20-G. The extent to which the Bombes will be useful if these expected changes become extensive, is questionable. We are taking all reasonable steps to provide for eventualities. In order to insure meeting the problem when it arises, we are proceeding with the design and construction of ten (10) of these new units, and may find it desirable to build, at most, only a portion of the additional Bombes. While the position as far as the Germans are concerned is not clear at the present time, we expect some clarification prior to the completion of the Bombes; and should it appear advisable, we shall recommend a reduction in the number to be built.

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History of The Bombe Project

17. From a position of domination, the British have, by their failures, fallen behind in the submarine problem. The part played by the British in the success of our work should not, however, be minimized. While it is possible that we might have been able to proceed independently, they have supplied the elements, such as wheel wirings, absolutely essential to an early solution of the problem. Their coverage of the entire Enigma field and their resulting strong position with regard to cross-cribbing, as well as their ability to obtain physical possession of German cryptographic equipment and documents, make it highly advisable that we endeavor to maintain our present relations in this problem, despite their failure to carry out their obligations along certain lines.

[SIGNED]

J. N. Wenger,
Commander, U.S.N.

[SIGNED]

H. T. Engstrom,
Commander, U.S.N.R.

[SIGNED]

R. I. Meader,
Lieut. Comdr., U.S.N.R.