Background Data:
Naval Warfare, Battle of the Atlantic, Cryptography, and the Code Game

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Battle of the Atlantic
Allied Convoys vs. German U-Boats

- Germans on the Offensive, Allies on the Defensive
  - Choosing Targets
  - Assembling Forces
  - Finding the Enemy
  - Attacking with Precision or Causing As Much Damage as Possible
  - Avoiding/Surviving Defenders
  - Determining the Effects of Naval Combat

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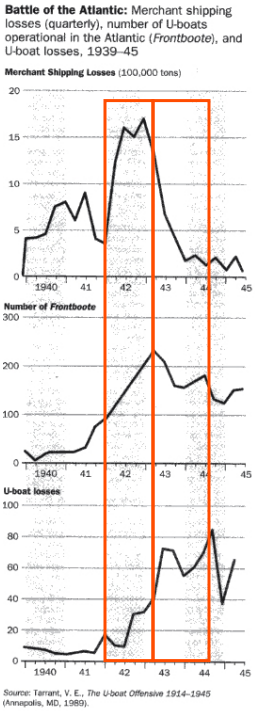
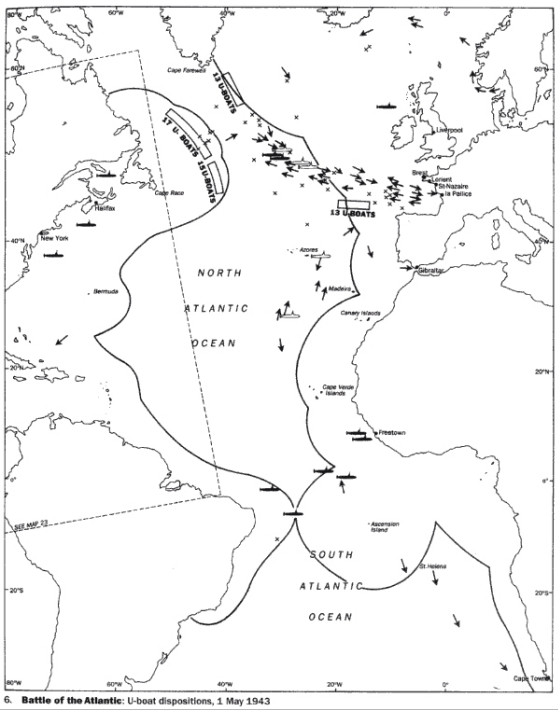


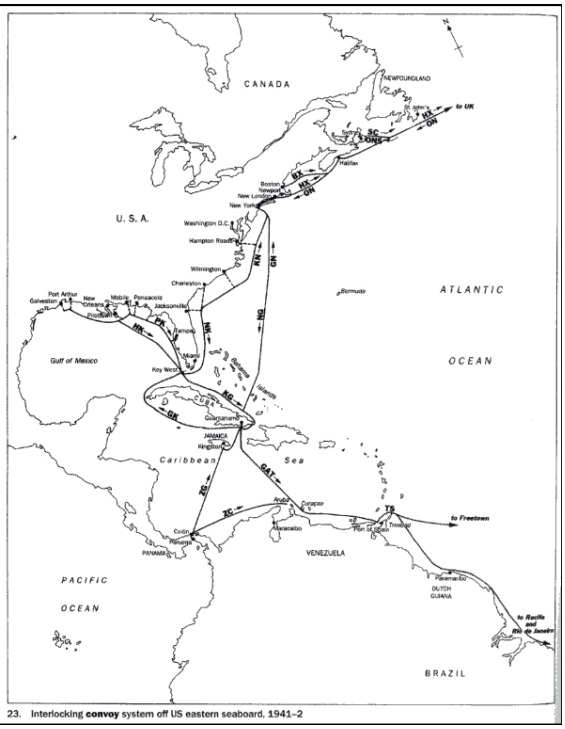
Battle of the Atlantic: Merchant shipping losses (quarterly), number of U-boats operational in the Atlantic (*Frontboote*), and U-boat losses, 1939–45

Source: Tarrant, V. E., *The U-boat Offensive 1914–1945* (Annapolis, MD, 1989).



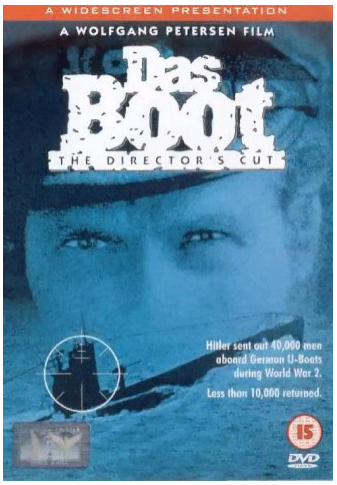
6. **Battle of the Atlantic**: U-boat dispositions, 1 May 1943

Convoys



23. Interlocking **convoy** system off US eastern seaboard, 1941–2

"Das Boot"



Naval Intelligence
Finding the Enemy, Hiding Your Forces

- Is an "unbreakable" code possible?
- Is it possible to "hide" coded transmissions?
- How do you balance the need to communicate with the need to be invisible to easedropping?
- Cryptography, Cryptanalysis
  - Heroic Codebreaking: Enigma, the Battle of the Atlantic, and the Development of the Computer
  - Codebreaking in the Pacific: Intelligence successes at Midway
- Technology and the Battle of the Atlantic
  - Airborne Radars, High Frequency Direction Finding

Signals Intelligence

- Collecting information about a (potential) foe's capabilities (economic, military) and intentions (political, military) as old as nations themselves!
- New about the late 19th and 20th Centuries:
  - Rise of far-flung empires, increasing use of technologies for communications, need for command and control

Development of Communications Technology

- Commercial = Militarily Relevant Technologies
  - Electric Telegraph (1837)
  - Undersea Cables (1842); transatlantic cable (1866)
  - Transcontinental Telegraph (1861); crucial role in American Civil War
  - Marconi, Radio (1895): first customer--the Royal Navy!
- Counter measures: cut foe's undersea cables, message interception, message deception;
- Counter counter measure: radio communications
- Counter counter counter measure: jamming, direction finding
- Every measure has a counter measure, and in turn, a counter-counter measure!

To Communicate is to Reveal

- Communication methods lead to detection
  - Can the detector be detected? identified as to individual and location?
  - Can the interceptor be fooled? traffic analysis and deception?
  - Can the communicator be stopped from successfully communicating? jamming?
  - Can the communicator hide his/her communications? stealth?

Intelligence Collection

- Spying, reconnaissance, spy satellites, code breaking
- Human intelligence (HUMINT) aka spies
- Signal intelligence (SIGINT)/Communications intelligence (COMINT) often used interchangeable, especially up through WWII
  - Modern militaries use many forms of electromagnetic radiation that don't involve communications, but are used for detection (e.g., RADAR)
  - Information derived from the monitoring, interception, decryption and evaluation of enemy radio communications
  - Naval intelligence particularly important, as until the development of recon satellites, the ability to put "eyes" at sea was very limited!

Codebreaking

- Before the Age of Radio, much more difficult to intercept cable traffic
- Radio potentially places large numbers of encrypted messages in the hands of the cryptanalysts
  - Key to breaking the code!
  - British Admiralty Room 40: Codebreaking Room

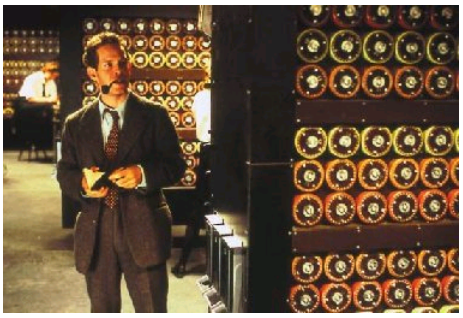
Enigma Machine

- Existence of ULTRA ("Very Special Intelligence") first revealed in 1974! Changed completely the way we view the history of WW II
- Combined encoding/decoding machine
  - Five rotor system, three in use at any time
  - How it worked and why it was hard to crack
    - Use of per message keys makes analysis difficult
    - But patterns provide the way in: doubly encrypted message keys
    - Poles reverse engineer a stolen Enigma machine
    - Invention of the Bombe: mechanical device to exhaust all enumerations
    - New Enigma stumps the Poles who turn to the British (1939)

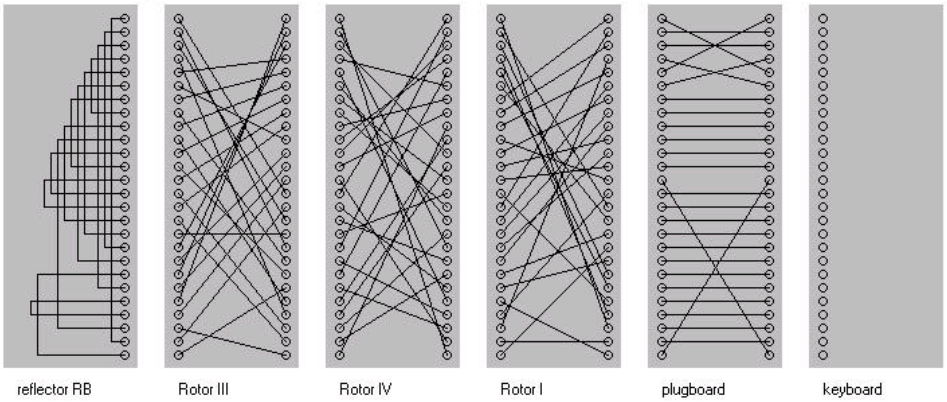
Bletchley Park

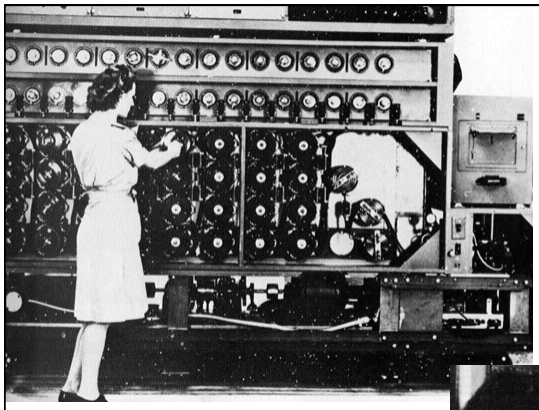
- Guessing the day key: cillies—common three letter sequences
- Human operator weakness!
- Rules of usage also limit the alternatives
- Stereotypical message structure helps too
- Turing's idea: the crib--<common plain text, encrypted text>
- If found, then could determine Enigma settings
- Compute the transformation in parallel: Turing's Bombe
- 10 May 40: Germans change their message key scheme
- Naval codes hardest to break—more sophisticated Enigma used
- Battle of Atlantic was being lost! Solution: pinch the codebooks!

"Enigma"

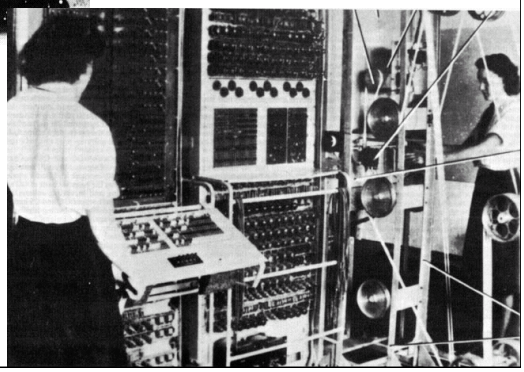


Enigma Deciphered





The Bombe



Colossus

The Code Game

% Letter Occurrence in English Text

a	7.49	n	6.74
b	1.29	o	7.37
c	3.54	p	2.43
d	3.62	q	0.26
e	14.00	r	6.14
f	2.18	s	6.95
g	1.74	t	9.85
h	4.22	u	3.00
i	6.65	v	1.16
j	0.27	w	1.69
k	0.47	x	0.28
l	3.57	y	1.64
m	3.39	z	0.04

The Code Game
More Text Analysis

- Common Digrams:
  - th he at st an in ea nd er en re nt to es on ed is ti
- Common Trigrams:
  - the and tha hat ent ion for tio has edt tis ers res ter con ing men tho
- Double Letters:
  - ll tt ss ee pp oo rr ff cc dd nn
- Common word ending letters:
  - e t s d n r y
- Most common words:
  - the of are I and you a can to he her that in was is has it him his