Author Kyuheun Ko
Source *NJP Reader #7 Coevolution: Cybernetics to Posthuman*, pp.231-277
Publisher Nam June Paik Art Center, Yongin

NAM JUNE PAIK ART CENTER

Cybernetics and Later, the History of the Integration and Simulation for Processing Human Elements in Circuits

Colophon

Editor Sooyoung Lee
Translation Seong Eun Kim, Eunjoo Sung, Sangeun Lee, Sohye Lee, Hyungju Woo, Semin Choi
Designer Ahju Kwon
Published on 27 December 2017

NAM JUNE PAIK ART CENTER
백남준아트센터

CYBERNETICS AND LATER, THE HISTORY OF THE INTEGRATION AND SIMULATION FOR PROCESSING HUMAN ELEMENTS IN CIRCUITS

—

From the Anti-Aircraft Predictor of 'Control and Communication' Until the Screens of 'Man–Machine symbiosis', or in Reverse Order around the Wars

KYUHEUN KO

Kyuheun Ko
Adjunct Professor of Sung Kyun Kwan University

His major is science of arts but he wrote his doctoral dissertation under the title of *A Study on Man–Machine Convergence Drive Since the Second World War*, which is quite irrelevant with his study area. He is now working on the interactive relationship between humans and machines in terms of 'the historiography of interface.' While interface can be considered as time and space where humans and machines integrate, merge and become one with each other, his tentative conclusion is that all interface in our everyday lives exist in order to shoot all information inside and outside the body out into networks. Among his publications are A study on *W. R. Ashby's Artificial Brain, Homeostat: Focusing on His Position in the History of Cybernetics* (2016), *A Brain Related to the Early History of the Internet, and the Problems with DARPA–Supported Neuro-Engineering Projects referencing* '*Mind Wars*' (2014) and *The Shortest Times when Machines that Solve Complex Problems were the Most Transparent: the Story just Before the Computer was Sealed with a Black Box* (2014).

> We can make a machine that will do almost anything, given enough time and enough engineers. But man has limits to his development, at least as far as we can see it. Machines that demand superhuman performance will fail, and jobs that push man beyond the limits of his skill, speed, sensitivity, and endurance will not be done.
> — Chapanis, A., Garner, W. R., & Morgan[1]

> Violence, especially in war, is a confused and uncertain activity, highly unpredictable depending on decisions made by fallible human beings organized into imperfect governments depending on fallible communications and warning systems and on the untested performance of people and equipment. It is furthermore a hotheaded activity, in which commitments and reputations can develop a momentum of their own.
> — Thomas Schelling[2]

To reveal aesthetic severance between high-tech devices and traditional technological ones, designer Chaput mentioned 'breakdown of continuity between structure and style.'[3] High-tech devices are full of integrated circuits consisting of billions of electronic elements on the inside, and the shape of their exterior is almost unrelated to their interior structure and operation of the parts. Thus, the advent of these devices sounded the knell of the era that materials and process constrained forms or the interior determined the surface. Now is the time when the organic integration of inside and outside has been broken. Has style, then, broadened its range since it was liberated from physical restriction?

In fact, this is not what really happened. The obsession from modernism that functional design should be achieved by removing

1 Chapanis, A., Garner, W. R., & Morgan, C. T., *Applied Experimental Psychology: Human Factors in Engineering Design* (New York, John Wiley & Sons, Inc., 1949), p.7.

2 Schelling, T., *Arms and Influence* (New Haven: Yale Univ. Press, 1966), p.93 | Lawrence, F., The Evolution of Nuclear Strategy (New York: St. Martin's Press, 1989), requoted from p.220.

3 Chaput, T., "From Socrates To Intel: the Chaos of Micro-Aesthetics," in J. Thackara(ed.), *Design After Modernism* (London: Thames and Hudson, 1988), pp.183-86.

any excess even drives the technological style of the postmodern era, according to Rutsky. However, because practical projects of machine civilization for efficiency and standardization by simplification had been completed, geometric simplicity is now working only as a signifier of 'cutting edge,' and, for achieving the signifier, style has moved forward to be "abstracted into a purely formal rationality."[4] Decorations have been totally eliminated and even minimum switches or physical buttons have been replaced by a touchscreen. This current trend of design meets the subtle correlation in which cutting-edge sense is satisfied with minimalism. And by consuming this minimalism, users savor 'state-of-the-art.'[5]

Through the miniaturization caused by increased chip density to the display swallowing all the control buttons, now what is remained for users is black flat glass plates, as significantly indicated in the title of a British television series, *Black Mirror*, a show that has unfolded a futuristic society of technological progress in its several seasons. As predicted by a futurologist in Intel, who said that the boundaries of information devices would break down and converge into a form of a screen in the near future[6], the term black mirror refers to the dark screen covering the whole device when the power is off, implying universal types of human-machine interfaces that are molding daily experiences in this era of ours. In a world of near future where micro intelligent machine and the nervous system are commonly linked, the catastrophic scenarios of *Black Mirror* establish a certain association between those black screens and the general attributes of the users (or viewers) that are reflected on the surfaces. Although today's users hardly know of principles or procedures of operation inside the devices, they are able to make up

4 Rutsky, R. L., *High Techne: Art and Technology from the Machine Aesthetic to the Posthuman* (Menneapolis: Univerisity of Minnesota Press, 1999), p.87.

5 The problem is that this high-tech sense would be gone just by fine scratches or slight traces of use. To desperately prevent this loss, users stick a protective film to the screen and cover the device with a case. Although this addition would erase the sense of state-of-the-art, users cannot help protecting the outer senses, facing a dilemma. This approach to high-tech design is quite different from that to the devices in the past — typewriters and film cameras — on which the users do not have to be afraid of see traces of time.

6 MBN World Economic and Future Forum, the interview with B D. Johnson. Park In-hye, "TV, smartphone, PC disappear only the screens remain", *Maeil Business*, March 4, 2011, page A4.

for the ignorance from the prompt sense of their fingertips, a sense that something seems to be realized just with a few touches on the surface. The above-mentioned minimalist sense of state-of-the-art accompanies this type of feeling. The screen, implementing the paradox of 'omnipotence of ignorance' or 'asymmetric interaction,' might be the characteristic line from which all kinds of relations between human and machine will be derived in the future.

Manuel de Landa had traced back the genealogy of the screen to put the relations into shape of two models derived from military origins.[7] Military commands had keenly realized the necessity of real-time systems to cope with immediately visualizing the patterns found in crypto communication of enemy or grasping progress of battle from enormous data transmitted by radar bases.[8] The solutions they found out was to directly visualize the data inside the computers and to condense the usual working process to use the display space itself as an input/output interface. However, working through the screens opened two paths, or models, to the relevant human operators. In one model they could respond to patterns of flickering signals on the screens while gradually delegating right of decision-making to the computers. The other model was a synergistic integration one: the operators could collaborate with the computers closely and with vigor, merging their abilities to achieve a novel level of problem-solving.

When attempting to merge human into the data circuits of command and control system, the military commands from the start had no intention to permanently assign human to the place. The formidable potential of computers had already been revealed in ballistic calculation and development of hydrogen bombs: then, if the computation power of computers could be maximized, could the computers submit reasonable judgment and prediction that surpass those of the elite? The US Air Force Intelligence Command in the early 60's actually anticipated that a giant mainframe might

7 De Landa, M., *War in the Age of Intelligent Machines* (New York: Zone Books, 1991), pp.192–94.

8 Batch programming in those days was to program a problem on perforated cards and send them to system administrators, who input them to the computer and performed debugging to get the desired results. Because it took several hours, the method could not catch up with the speed of modern warfare in case of an emergency.

analyze behavior patterns of military brains of the Soviet Union to automatically detect military trends behind the Iron Curtain.

> (···) you take this powerful computer and feed it all this qualitative information, such as 'The air force chief drank two Martinis,' or 'Khrushchev isn't reading Pravda on Mondays' (···) and the computer would play Sherlock Holmes and conclude that the Russians must be building an MX-72 missile or something like that.[9]

The background from which the idea came was this: immediately after the Second World War, when the operational considerations became increasingly complex, the military could no longer rely solely on experience or intuition of the officers, hiring a great number of scientist of several field. Collaboration with the scientists steered the tactical judgments of the command to be close to finding a solution of an equation in numerical analysis. Consequently, improving computer performance that controlled these calculations directly enhanced ability to solve military problems. Encouraged by the reliability of the method, the military tried to embody their idea. The idea was not fully groundless to them, because computers the U.S. military aspired to develop at that time were like state-of-the-art brain machine, in which a war game simulation activated with a large amount of data automatically generate trends based on several conditions to infer future circumstances. Moreover, if there is intelligence that could predict war situation, could the computer itself find a way to cope with a state of emergency such as a preemptive attack of enemy? At the base of this desire was not only an expectation of ruling out inaccurate intervention swayed by prejudice or emotion but also a picture that roles of human beings would be ended immediately before completion of system for future prediction and automated strategic weapons.

J. C. R. Licklider pointed out how unrealistic this anticipation

9 Hafner, K & Lyon, M., *Where Wizards Stay Up Late: The Origin of the Internet* (New York: Touchstone, 1996), p.37.

was, seeking to turn the evolution direction of computers from the route that the military had planned to follow. When appointed as head of a ARPA (DARPA)[10]— affiliated organization in 1962, Licklider argued that computers are necessary to establish symbiotic partnership with humans as a system not replacing decision-making ability of humans but intervening in problem solving process in real time, and that tightly coupling the electronic power of computers and the biological capabilities of the cerebral cortex would handle problems to face in future on a totally innovative level. According to him, the way that all capabilities are tucked into an automation system and human beings assist the working process of the computers is vulnerable to a number of accidents that were not (or, could not be) formulated in advance, not to mention its doubtful practicality. Rather, he thought that a flexible flow of interactions generated by simultaneous commitment of intuition and logic to close relations between human and computer could cope with the speed, complexity, and unpredictability of modern warfare. What was urgent to him, thus, was not an advanced calculation but computers that could cooperate with human operators, cooperation that first required interfaces developed to promote the combination between human and machine. In an article written in 1960, Licklider already stated:

> It seems likely that the contributions of human operators and equipment will blend together so completely in many operations that it will be difficult to separate them neatly in analysis. That would be the case if, in gathering data on which to base a decision, for example, both the man and the computer came up with relevant precedents from experience and if the computer then suggested a course of action that agreed with the man's intuitive judgment.[11]

10 The Defense Advanced Research Projects Agency was established in 1977 to respond to requests of researching military technology and developing advanced weaponry to gain the upper hand in the military competitiveness against the Soviet Union. Its first name was the ARPA, which was renamed to the DARPA in 1972 and then returned to the ARPA in 1993 by the Clinton Administration. Since 1996, it has been renamed back to the DARPA.

11 Licklider, J. C. R., "Man – Computer Symbiosis," *IRE Transactions on Human Factors in Electronics HFE-1* (1960), p.6.

And an ideal display for this blending was the following:

> Many computers plot graphs on oscilloscope screens, and a few take advantage of the remarkable capabilities, graphical and symbolic, of the charactron display tube. Nowhere, to my knowledge, however, is there anything approaching the flexibility and convenience of the pencil and doodle pad or the chalk and blackboard used by men in technical discussion. (···) Certainly, for effective man-computer interaction, it will be necessary for the man and the computer to draw graph and pictures and to write notes and equations to each other on the same display surface.[12]

In the early stage of the Cold War, the US military had expected that the screen would serve as territory where calculation and judgment of computers could be quickly monitored while becoming the starting point where human share would be cut down efficiently. Licklider, on the other hand, had anticipated that the visual interface would be the driving force to promote a strong coupling between human and machine, an anticipation that turned out to be realized. The current users, who combine themselves with remote servers by equipping and manipulating small-sized machines, pointing devices, touch screens, and numerous applications to exchange necessary information and deal with tasks with speed, have already gone beyond the symbolism of 'symbiotic' and 'couple tightly,' a rhetoric that Licklider had presented. At the point of time that screen has emerged as overwhelmingly dominant interface, however, there might be an optical illusion over the general frame overlooking the combination of human and machine, because the relations between the two are somewhat differently seen from the position of human in the genealogy of screen and from the history of man-machine systems.

Officially declaring that the basis of issues related to command and control was directly combined with human-computer interactions, Licklider changed the title the Command and Control Research Office into the Information Processing Techniques Office

12 Licklider(1960), p.9.

(IPTO) immediately when he was appointed to head of the office.[13] What he did was to express his intention that the office would cover a wide range of issues related to computer operation and information processing rather than do research on only military projects. With the approval and huge amount of fund from the ARPA headquarters, he organized a research collaboration network to run several projects. He and his research partners opened up core fields of computer engineering of next generations, "interactive" and "networking," including time-sharing in which multiple users share computer resources at the same time, applications developed from several engineering fields and graphic-based display linked to the applications, online systems accessed via remote terminals.

However, there is one thing to note in a historical overview: how to deal with the greatest emergency was different from the interested parties. Jack Ruina, who was the chief of the ARPA and personally appointed Licklider to head of the office to push forward computerization of command systems, predicted in his testimony in Congress in 1963 that missile defense systems would be operated completely without human intervention, emphasizing necessity of immediate reaction. As told by him, because an intercontinental ballistic missile attack by the Soviet Union would be 'really a surprise attack,' the nuclear-warhead antimissile missiles of Nike–Zeus must be launched right away without approval by the President. With this vision of fully automated — "all up to computers" system presented —, the software field, which had served as a foundation of human –computer interactions, was split up from missile defense.[14] The area of speed where every second counts was not likely to need the early-stage, unreliable software and the not-yet-verified human–computer interaction. Computers at least used in the missile defense system should be able to go all out for numerical analysis based on highly powerful calculation. Although carrying out an attack might be a matter of life and death for the nation, there was no previous data about nuclear missile war. Thus, trusting rather computers than humans seemed to be more reasonable in order to square

13 O'Neil, J. E., "The Role of ARPA in the Development of the ARPANET, 1961–1972", *IEEE Annals of the History of Computing 17:4* (1995), p.76–77.

14 Slayton, R., *Arguments that Count: Physics, Computing, and Missile Defense, 1949–2012* (Cambridge: The MIT Press, 2013), pp.63–84.

unpredictable future with war scenarios that was proven in terms of computational physics.

> No matter how complex a hardware system, except for NIKE-ZEUS, a man is always there.[15]

The policies of the ARPA in the early 1960s was self-contradictory: the agency supported $14 million to Licklider's IPTO every year[16] and made the Representatives known the appropriateness of the fund, while excluding his research from missile defense. This inconsistency demonstrated not only the dilemma that the US military had experienced during the Cold War but also a symbolic example how the main worries that they had suffered since the Second World War were transferred to the Cold War era. Licklider's vision of the future of symbiosis was actually conceived at the intersection of two areas of research — computer science and human factor engineering (or, engineering psychology),[17] two fields that had been born from the historical background of the Second World War. The Second World War was a period of frenzy, seeking for maximized physical speed of movement and strike, efficiency of firepower and decimation projected to the enemy, accuracy of intelligence, and agility of handling crises. To satisfy these demands, war fighting machines of the time always took the cutting edge of technology, overwhelming the counterparts of the past. Contrary to this technological advancement that seemed to have no bounds, however, human beings could exert their abilities only within the limits of their physiological conditions, the asymmetry of advancement unavoidable until newly-evolved human beings such as "Newtype" emerged. This was where the roles of human beings and whether they were suitable within systems were raised as an important issue. Or, this was where a rupture was noticed from the systems that had

15 Extracted from Jack Ruina's testimony in Congress in May 1963. Slayton(2013), p.80.

16 Licklider's IPTO in those days received more money than the total amount of the US government funding for other computer research institutions. Newman, N., *Net Loss: Internet Prophets, Private Profits, and the Costs to Community* (Pennsylvania: Pennsylvania Univ. Press, 2002), p.49.

17 Hookway, B., *Interface* (Cambridge: The MIT Press, 2014), p. 135.

been designed by human beings but so advanced that were almost unmanageable by human beings.

Then, how the rupture was handled? Winning a war needs infinite improvement in system and precise prediction of future. Human beings committed to these technological battles are not up to scratch in many ways; they are always degraded to a dubious component because engineering control is not able to neatly sock its way into them. While launching an ultimate plan to completely exclude the inappropriate element from war, they had to continue a long, uncomfortable journey through the period of the late Second World War and the Cold War, during which they struggled themselves to try to suture the rupture. But the common cue to complete the task of the exclusion and suture lay in a hypothesis that both humans and machines process 'information' and implement exquisite behaviors through maintaining communication patterns and circulating messages.

This paper focused on the history borrowing interchangeable metaphors between humans and war-fighting machines on a common foundation of information processing, dealing with engineering attempts and scientific research in which humans and machines were merged into a single system by diluting the concentration of specific heterogeneity. These discussion and analysis methods, named by science historian Andy Pickering in the mid-90s as 'cyborg science',[18] had widespread ramifications over dominant principles in operating the nuclear power-based command and control system in the Cold War era, over preparation against catastrophic scenarios that could be realized by a military provocation of the socialist camp, and over approaches to mediate issues in economic and social organizations. The research of war and science of the 1940s and 1950s was later generalized to permeate from battlefield into everyday life, from the command and control level into collective behaviors, personal habits, and even inner tastes as of today. The purpose of this study was to examine the generalization on a historical basis, determining

18 Pickering combined scientific methods of cybernetics, operations research, system dynamics, and game theory into cyborg science, in which the classical boundaries between humans, machines, and objects are broken down to move toward general integration. Pickering, A., "Cyborg History and the World War II Regime," *Perspectives On Science 3:1* (1995), pp.1–48.

a point where the origin of the human-technology combination, a combination that we now rely on, meet.

01.

The combination between human and machine in the past had been a way that can be described by a metaphor of a Procrustean bed or survival of the fittest.[19] For tank drivers, soldiers with small statures were chosen because they could move easily within the confined compartment; those who were shorter but stronger than normal people were selected to be submarine crew. The deployed soldiers had to take the full responsibility for adapting to their specific environments through training. The extended war, however, made these approaches come to the limit.[20] When the Cold War began, problems that could not be solved without changes in perspectives and systematic preparation emerged as significant tasks of psychology. This flow was largely due to the facts that both attack and defensive systems required much greater amount of cognitive labor than did those in the past and that enhanced complexity and speed of such systems increased mental fatigue and put body reaction to the limit.[21]

For instance, in a fighter or a bomber flying at a speed that is incomparably faster than that of a propeller-driven aircraft, is it possible for the pilot to maintain sound judgment by enduing the noise of the jet engine and the centrifugal force at rapid revolving? As air objectives move faster, can manual intervention by humans be allowed in calculating ballistics for firing from warships? When the radar system processes what happens on the airspace to output data moment by moment, how long is the concentration of operators able to handle the amount of information and processing speed? All these questions could not be dealt with by the conventional ways of

19 For the metaphor of Procustean bed, see: Taylor, F. V., "Psychology and the Design of Machines," American Psychologist 12:5 (1957), p.249. For survival of the fittest, seeMeister, D., *The History of Human Factors and Ergonomics* (London: LEA, 1999), pp.147–151.

20 A machine that did not take account of human beings in its operation was hard to find a human who could connect with it when a war was extended. In addition, as weapon systems became modernized, the equipmenets got complicated, inducing frequent mistakes of the operators.

21 Wickens, C. D., *Engineering Psychology and Human Performance* (2nd edition) (New York: HarperCollins, 1992), Preface.

rigidly adhering to guidelines and regulations. In response to these problems, engineering psychology had been expanding explosively in the United States in 1950 to 60′s.[22]

Because human beings are not possible to adapt to those hostile environments only through training and being fully aware of manuals, the burden of adaptation should be assigned to both humans and machines. This is what researchers of engineering psychology have to do—improve interaction environments by engraving parts of specificity of muscular movements, perception, and cognition of humans on the surface of systems. Through these studies was a new concept of "man-machine unit (or man-machine system)"[23] running. The concept was not that operators as separate elements were tied to the already-completed machines; it was an approach of integrating and coordinating all the components including humans in the whole system from design, a system that humans could be interlocked with other components smoothly.[24] In this picture, the stability of the combination was improved, and the entire components could be merged into a single unit. Exploring effects of the Cold War discourses on space design, Hookway pointed out cockpits as spaces where post-war man-machine interactions were realized with the most avant-garde way:

> The growing complexity of flight instrumentation would lead to the systematic design of the cockpit instrument panel. For combat aircraft in particular, the flow of information within the cockpit is a critical factor in a pilot's decision-making process. Yet at the same time that the cockpit-as-interface served to mediate the information flow between pilot and plane, the cockpit-as-environment would have to address the physiological and psychological needs of pilot and aircrew.[25]

22 Grether, W. F., "Engineering psychology in the United States," *American Psychologist 23:10* (1968), p.745.

23 This term may be mentioned for the first time in W.S. Hunter's "Psychology in the War," *American Psychologist 1:11* (1946), pp.479–92.

24 From this point of view, an operation mistake is dealt with as rather an error induded by design of the machine than the operator's carelessness, for a mistake is not from a human's fault but from interaction between human and system.

25 Hookway, B. "Cockpit," in B. Colomina, A. Brennan & J. Kim (eds.), *Cold War Hothouses* (New York: Princeton Architectural Press, 2004). pp. 41–42.

If information flows within a cockpit, then there may be no essential difference between a pilot, who combines with the aircraft through the space, and electro-mechanical devices in charge of certain section of the information circuit. From decoding complicated signs on the instrument panel and immediately taking appropriate actions to capturing the moment when the enemy aircraft is placed in the line of sight and pressing the fire button — the entire process conducted by a human pilot could be appropriately substituted by the role of an information processing device, or a servo mechanism. In fact, Enoch Ferrell, one of engineers at the Bell Laboratories during World War II who participated in developing directors of anti-aircraft guns,[26] had equated a process of perception and behaviors of operators in charge of aiming with a negative feedback system, a system that was described as “The difference in azimuth between the output shaft, as marked by the telescope cross-hairs, and the target azimuth is detected by a human eye and brain, amplified by human muscle, and passed through a handwheel and gear-train to the output shaft in such a polarity as to reduce the observed difference” in his report in 1942.[27] And this analogy between human and machine components was inherited to post-war research in a highly similar way.

What Franklin V. Taylor studied is one good example. In 1947 he joined in designing systems of controlling naval guns and missiles at the Naval Research Laboratory, a project that contained evaluation and development of military training simulators enabling the same functions and psychological research on the coordination of the eyes and the hands when aiming a target.[28] The ultimate goals of the project were to design systems overcome the complexity of mechanism with precise operation according to rules of the field and to develop training devices with more usefulness than ever before. After exactly ten years from outlining his research, Taylor wrote on the

26 The roles of gun directors in antiaircraft defense can be summarized as prediction of target movement and calculation of trajectory. After measuring the speed, direction, and distance of the target, they calculate the azimuth and altitude for aiming and the estimated time between discharging and detonation.

27 Ferrell, E. B., “Automatic Tracking as a Feedback Problem,” 20 May 1942, OSRD 7 GP, Box 2 | Mindell, D. A., *Between Human and Machine* (Baltimore: The Johns Hopkins Univ. Press, 2002), requoted from p.285.

28 Taylor, F. V., “Psychology at the Naval Research Laboratory,” *American Psychologist 2:3* (1947), pp.87–92.

correlation between psychology and designing machine in his paper:

> One system may require the operator to act analogously to a complex differential equation-solver, while another may require of him nothing more than proportional responding. One radar warning system may require the operator to calculate the threat of each target and to indicate the most threatening; another may compute the threat automatically and place a marker around the target to be signaled.[29]

In this paper published in 1957, humans were described as their local functions of mind and action were transplanted into the system and most of the totality of their existence was reduced. The representative type is the coordination of the eyes and the hands as mentioned above; human operators were regarded as "an input-output system" that handles buttons and switches in response to display information, or as "an organic data transmission and processing link." Five years later the already-canon paper was quoted by psychologist Robert M. Gagne, who suggested that, when certain mental functions are activated to meet what a system needs, other functional circuits should be shut down appropriately. For these selective coordination, Gagne argued that the internal systems of human had to be figured out by experiments.[30] The purpose of the experiments in engineering psychology was to measure limitations of motor ability based on situations, threshold of responses, and sensitivity of boundaries to mathematically model mechanisms of such changes. The digitized data would be used to optimize the contact between human and machine. The engineering psychology reflected an approach that logically designed interfaces could adjust human senses and perceptions to fit to certain goals, while the series of process indicated the cold-war struggles to complement the weakest link in system with minimal physiological disqualification.

The paradox that human had to be substituted by machine in order for machine to combine with human was noticeable when

29 Taylor, F. V., "Psychology and the Design of Machines," *American Psychologist 12:5* (1957), p.254.

30 Gagne, R. M., "Human Functions in Systems," in R. M. Gagne & A. W. Melton(eds.), *Psychological Principles in System Development* (New York: Rinehart & Winston, 1962), pp.35–74.

quantitative data was obtained on perception and cognitive activities. Psychologists began to use the terms of telecommunication engineering, such as bandwidth, channel capacity, gain, filtering, in explaining mental activities, determining capacities and limitations of human in information processing in the same way used for machine. While bandwidth referred to the incidence (Hz) of information that the nervous system could handle during a unit of time, visual and auditory organs were considered to have different channel capacities as separate communication channels. Thus, how much information could be received and processed replied on the nature of the information and which channel was used. This is the point where they came in, however. If each piece of mental activities such as perceptions, responses, attention, boundaries that were inserted into systems could be mathematically measured and these internal mechanisms could be rationalized as a principle of telecommunication engineering, then it might be possible for these processes to be implemented by mechanical devices. Of course, much higher-level problems are involved here: one is that the subtlety and complexity of decision-making is not able to be fully covered by input/output terminals or data transmission link. The key part is whether a mechanical process can be developed to cope with those problems.

Suppose that a radar operator identified a faint blip on the plan position indicator (PPI).[31] They could judge the blip as an enemy aircraft or just an error signal, a choice that is a completely different matter from just seeing the signal or identifying that it can be ignored.[32] The thoughts of the operator become overlapped and entangled when they try to choose between reporting to the superior authority or ignoring the blip because they have to calculate risks in and gains and losses of either side and predict the indefinite future. "This blip is so faint that it may be OK to be ignored. But what if this is the real signal of the enemy's air strike?"[33] Thus, it is not possible to quantify how an operator makes a decision without adding a cognitive model that copes with the practical problems in

31 The most common type of display that shows the airspace detected by a radar.

32 Lachman, R. & Butterfield, E. C., "Psychology's Contribution to the information-Processing Paradigm," in *Cognitive Psychology and Information Processing: An Introduction* (Hillsdale: LEA, 1979), pp.58–59.

the field. While the existing engineering psychology had focused on estimating how quickly the operator could detect a light spot on the PPI or how bright and how frequently flickering the spot should be to be easily identified, now a new approach was needed to simulate a complex process by grouping the signal detection process into a system of "perception-plus-decision." This is where an access route of cognitive psychology could be built. And it was the metaphor of "digital computer" that filled the ambiguous vacuum between the stimulus and the reaction.

Cognitive psychology attempted to establish this unknown internal process in a regular form by presupposing that decision-making and judging of humans are not from a chain of stimuli and reactions but from logical operations according to sequential rules and then by implementing the operations with computer programs. From a military point of view, in particular, computers were perfectly appropriate for elaborate reasoning and decision-making, thus immediately being accepted as a substance that represented the inner side of human. On this natural alliance between the military and the computer, Van Creveld, specialist in military science, said that computers operated with binary on–off logic were ideal substances to the military because "in order to counter the inherent confusion and danger of war," it had been "forever seeking ways to make communications as terse and unambiguous as humanly possible."[34] Owing to the cohesive alliance, these cognitive approaches went through activity from the late 50s and 60s and beyond.

One of the leading roles in the cognitive boom was the Center for Cognitive Studies (CCS), founded in 1960 by George A. Miller and Jerome S. Bruner. Miller had participated in the Psycho-Acoustic Laboratory (PAL) of Harvard University, an institute that was supported by the National Defense Research Committee

33 When they do not report to the superior authority because they judged the blip as an error and it turns out to be an enemy aircraft, they will face a deadly risk of being defenseless for a considerable amount of time by the enemy's air strike that has already crossed the border. On the other hand, reporting every time they see a faint blip increases the task fatigue, and the operator may avoid reporting because their reputation of job performance could be lowered when the blip is revealed to be just an error.

34 Van Creveld, M., Technology and War: *From 2000 B.C. To the Present* (New York: The Free Press, 1991), p.239.

(NDRC) during the war and to which the greatest funds were invested in the field of psychology, concentrating on scientific quantification of perceived discrimination or memory threshold. What was most emphasized in the projects they promoted in the CCS was "mechanical implementation quantified inner side," or how to implement the cognitive processes of human by using computer programs. Because cognitive theory for them was a principle that could be applied not only to mind but to information-processing machine, they utilized mental activities as an analogy with computer operation or in verifying operational principles of programs. This keynote was displayed in the following introduction that delivered the aims of the CCS.

> (Questions about the nature of thought and knowledge) have application not only to the study of man but also to the devices man uses to amplify his cognitive control over his environment. (⋯) the study of memory systems and devices now extends far beyond any philosophical formulations. (⋯) The Center for Cognitive Studies is concerned with how information is stored, processed, and communicated — both by human beings and by the devices human beings invent in order to cope with information.[35]

When the metaphor was progressed from a model based on communications devices to computers, terms such as buffer, gate, and central processing unit were widely accepted by cognitive psychologists; mental activities began to be regarded as "the appropriately programmed computer."[36] It was the Dartmouth Summer Workshop in 1956 that served as a symbolic event from which these academic trends became the stream of times. Eleven experts from psychology, mathematics, computer science, neurophysiology had interdisciplinary discussions at Dartmouth College, New Hampshire, focusing on how machine could be

35 Miller, G. & Bruner J., "Center for Cognitive Studies: General Description," (Harvard Univ. Archives, April 1960) | Edwards, P. N., *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge: The MIT Press, 1996), requoted from p.234.

36 Searle, J. R., "Minds, Brains, and Programs," *Behavioral and Brain Sciences 3:3* (1980), p.417.

constructed to reproduce intact intellectual activities, based on an expectant presupposition that machine could describe "every aspect of learning or any other feature of intelligence" with precision. The experts had the confidence to think of intellectual machines that could use language, symbols, and meaning concepts not only to solve problems but to improve themselves. Mathematician John McCarthy, the organizer of the conference, revealed an expectation boldly ambitious then, saying: "We think that a significant advance can be made in one or more of these problems if a carefully selected group of scientists work on it together for a summer."[37] And "artificial intelligence," the notion McCarthy proposed and obtained unanimous agreement of the participants, heralded the official birth of cognitive science[38] in the 1960s, making a tide of "computer = brain = mind."

From here on, how the selected relations between integration and simulation, frequently mediated by interface and artificial intelligence, had to be maintained side by side can be tracked down. Marvin Minsky,[39] who led the Dartmouth Summer Workshop and developed the field of artificial intelligence with McCarthy, predicted in his article contributed to Life magazine in 1970 that intelligence of computer would develop to be at a level similar to that of human three to at most eight years later and that it could understand Shakespeare's works and make political decisions.[40] His prospects were quite optimistic; now it is not difficult to see how far-off and ridiculous the prospects were. However, the ARPA at the time provided enormous financial support for artificial intelligence,[41] and the media in the mid-1980s cynically commented on the absurdly

37 McCarthy, J., Minsky, M., Rochester, N., & Shannon, C. E., "A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence," (August 1955) https://goo.gl/HP9DoY (last access: 2017. 11. 7).

38 Although the title "cognitive science" was settled in 1976, this interdisciplinary field of study had already been in full bloom as several names such as cognitive research, information processing psychology, and cognitive science in many university and research institute in the 1960s.

39 He and McCarthy founded the MIT AI Lab., a basis of this field of study.

40 Roszak, T., *The Cult of Information* (Berkeley: Univ. of California Press, 1994), p.122.

41 By the mid-1960s, the funds invested to the MIT's research team by Marvin Minsky had already exceeded $ 10 million. Keller, E. F., "Organisms, Machines, and Thunderstorms: A History of Self-Organization, Part One," *Historical Studies in the Natural Sciences 38:1* (2008), p.72.

high expectations on it: "artificial intelligence is a two-word phrase which makes US Department of Defense Officials salivate when they hear it."[42] Expectations that maximum performance could be realized by eliminating factors of disqualification in system, plans that detection, response, and even prediction of changes in situations would be delegated to machine — these were the future not to be relinquished when the tension of the Cold War was at its peak, but humans had to be remained in their place for a long time since then.

Yet it is worthwhile to notice that this ultimate scenario came from the projects attempting to draw the inner side of human into the territory of measurement and unfold it on an engineering diagram with machine, in order to strengthen the integration of the two. It was an ironic flow in which reasons of elimination were secured by seeking integration, but, on the other side, this paradox might reveal that the contrary approaches of both sides were established on a certain shared ground. Both the attempt to buffer heterogeneity in interaction and the premise that machine could imitate thinking and reasoning can be rationalized by building a universal principle that penetrates the barrier separating human from machine. Let's take a look what Miller described the situations of 1956:

> In short, 1956 was a good year for those interested in theories of the mind, but it was only slightly better than the years just preceding and following. Many were riding the waves that began during World War II: those of servo theory, information theory, signal-detection theory, computer theory and computers themselves.[43]

Miller had already listed outstanding works of 1956 that induced the cognitive revolution as a paradigm of the times, including the Dartmouth workshop; he in the above paragraph mentioned that study of engineering developed by the war had flowed through the works. The aspects of the flow referred to by Miller had already been involved in key issues of from the second half of World War II such

42 An article on Observer of the London eidition of November 1985: Re-quoted from Rozak (1994), p.123.

43 Miller, G. A., "The Cognitive Revolution: A Historical Perspective," *Trends in Cognitive Sciences 7:3* (2003), p.142.

as strategic bombing, winning the air superiority, and establishment of a defense system against the enemy's air strike: more precisely, the flow originated from the scientific research led by the military – industrial – academic complex in order to urgently solve relevant issues. And tracing a little back in this flow, there was a research of developing anti-aircraft predictors by Nobert Wiener. Also under the general control of the NDRC, the research was instituted around Christmas in 1940 when the D-2, the fire control section of the NDRC, adopted the proposal of Wiener, and was wrapped up when a report of applied mathematics was submitted in January 1942, titled "Extrapolation, Interpolation, and Smoothing of Stationary Time Series, with Engineering Applications."[44] The project was in fact failed, but the report was passed around for experts in radar and anti-air defense when it was declassified in 1946, attracting academic attention as what had triggered broad interdisciplinary discussions of cybernetics.

02.

In those days, researching how to improve accuracy of bombardment was the top priority of several nations.[45] The United Kingdom consumed more than 10,000 shells to shoot down one enemy aircraft in the early 1940s, when it suffered from German air raids, indicating that the English antiaircraft guns were not able to respond to the speed of the aircrafts of the time. The United States, of course, was no exception to this problem. The NDRC undertook a number of support projects to increase accuracy of aiming and shelling, some of which was delegated to Wiener in MIT.[46] Wiener, with a graduate student Julian Bigelow who majored in electrical engineering and mathematics,[47] firstly started researching how to estimate future

44 The report was then given access only to some scientists and engineers who were involved in the war projects, and it was nicknamed "Yellow Peril" because of its yellow cover and abstruse text.

45 Rogers, R. M., *Communication Technology: The New Media in Society* (Korean version, translated by Kim Yong Suk, 1988, p.126).

46 During the years 1940 – 45, the NDRC's D-2 had supported around 80 projects related to anti-air defense, of which 29 were assigned to universities. The largest amount of support was $1.5 million given to Bell Laboratories, while the amount funded to MIT's Winner was little more than $2,000.

47 As an amateur pilot, Bigelow used his flight experience to design devices that realized senses of flight control.

flight patterns of enemy aircrafts. Their approach was different from that of other researchers of the time in that they selected statistical reasoning according to accumulated past data as the basis of learning on which those estimations were performed.[48, 49]

The system automatically detects an enemy aircraft to measure the moving direction, speed, and distance from the antiaircraft gun and has to designate a spot on the coming path of the enemy as the point of impact because it considers the time the shell reaches the target. If so, the gun has to aim at the air, which accomplished by predicting movements of the enemy aircraft that will be displayed in the section between firing and striking and filling the unknown vacuum. How is it possible? First, it is possible to extrapolate the path of the target to estimate its coming position as a straight line or a smooth curve. As soon as the first attempt to shoot down fails, however, this method becomes ineffective and the situation becomes complicated. The enemy pilot, realizing that he is being attacked, will take a zig-zag evasive action rather than a gentle route to avoid attacks, an irregularity that will makes prediction more difficult.

Fortunately, the evasive action the pilot could do is confined to narrowed range of selection. They must keep in mind that a quick turning at high speed flying mode can make them fall into unconsciousness. Limit requirements caused by the control surface and the air flow and the psychological pressures to be endured in the battle force the pilot to follow patterns already imbued with drill rather than choose improvised, instantaneous flight skills. These limitations ultimately give the evasive action some kind of regularity rather than randomness, leading to statistical bias. It is this statistical data that Wiener pointed out:

48 See the following texts: Wiener, N., *Cybernetics: or Control and Communication in the Animal and the Machine* (Cambridge: The MIT Press, 1948/1961), pp.5–6, 8–10; Wiener, N., *The Human Use of Human Beings: Cybernetics and Society* (Boston: Da Capo Press, 1950/1954), pp.61–63; Conway, F. & Siegelman, J., *Dark Hero of the Information Age* (New York: Basic Books, 2005), pp. 110–11.

49 While the established aiming method was operated by maintaining fixed rules, what he conceived was a machine that would improve its operating principle by learning. Hayles, N. K., *How We Became Posthuman: Virtual Bodies in Cybernetics,. Literature, and Informatics* (Chicago: Univ. of Chicago Press, 1999), p.106.

All the figuring must be built into the gun control itself. This figuring must include data which depend on our past statistical experience of airplanes of a given type under varying flight conditions.[50]

What he had conceived was a system capable of automatically responding to the constantly-changing direction and speed of the enemy aircraft by compiling statistics that matched the observed movement of a target and feeding them back to the control unit, and then moving the gun barrels quickly according to the command organized from the unit. During his research, however, Wiener transformed the battlefield where human and machine are jumbled into a territory of pure telecommunication engineering by integrating the entire process from raiding, tracking, aiming, to shooting into a single information circuit and replacing the human components of pilots and gunners with a servo mechanism inserted in this feedback loop. When the field was established as a communication circuit in this way, issues of stabilizing the transmission and reception of the electrical signals took charge of the entire control, intervention of noises became the biggest threat, and applied mathematical approaches to this system indiscriminately penetrated into humans and machines to be mobilized as a system of across-the-board analysis.[51]

As soon as the problem of how to control anti-aircraft guns control was unfolded on communication networks, all procedures are clearly abbreviated as the analogies: Identifying the enemy from the impure signals that intruded into the radar system to locate it is similar to deciphering transmitting messages modulated as background noises into their original state; predicting a target's future location is not different from assigning the most probable message in a mathematically feasible repertoire by analyzing the accumulated signal patterns. In addition, information on how close each of the fired shells is to the target or whether it hit the target is flowed back to the control unit and then controls the subsequent aiming and firing.[52]

50 Wiener(1950/1954), p.62.
51 Ko Kyu-heun, A Study on W. R. Ashby's Artificial Brain, Homeostat: Focusing on His Position in the History of Cybernetics, *Journal of the Korean History of Science Society, 38:3* (2016), p.407.

This telecommunication-engineering based negative feedback was where the premise of cybernetics was founded, a premise that human, animal, and machine are mixed within one frame.[53]

It was the principle of negative feedback from the first that Wiener could depend on when he replaced a pilot in a cockpit with a mechanical part by describing the pilot "behaves like a servo-mechanism."[54] When a pilot handles a control stick or a lever, the response of the weighty aircraft accompanies a slight temporal delay according to physical inertia. The pilot tends to make up for this delay by instinctively calculating the error from the delay and performing additional operations in advance. This was an unusual result from the different responses of the human's kinaesthesia system, contrary to other sensory organs that naturally cooperate with movements of the aircraft. The temporary severance between visual sense and kinaesthesia generally enabled exquisite art of flying. Wiener confirmed that some of these actions of pilots were repeatedly conducted by anti-aircraft gunners in a similar pattern, matching the roles of these human components — which had not been mathematically explained till then — to the feedback mechanism that automatically starts attenuation when an error is detected. Furthermore, each of the integrated units in which aircrafts & pilots and anti-aircraft guns & gunners were combined repeated disturbance, chase, and evasion to frustrate the opposite's aim, joining the feedback circuit governed by this circular causality.

According to historian Peter Galison, Wiener, while deepening his research, persuaded himself that this automatic system was a prototype of an intellectual system in which intentions and responses of both parties — enemy pilots and friendly gunners — were entangled simultaneously and a mixed feedback system

52 Conway & Siegelman (2005), pp.110–17; Rheingold, H., *Tools for Thought: The History and Future of Mind-Expanding Technology* (Cambridge: The MIT Press, 2000), pp.103–105.

53 For the significance of Wiener's study of anti-aircraft predictor in the entire history of cybernetics, see Ko Kyu-heun (2016), pp.381–424.

54 Wiener, N., report to D. I. C. 5980 A. A. Directors, "Summary Report for Demonstration," p.6 (10 June 1942, Record Group 227, OSRD, NDRC Contractors' Technical Reports, Division 7, MIT, NDCrc-83, NA_LC) | Galison, P., "The Ontology of the Enemy: Norbert Wiener and the Cybernetic Vision," *Critical Inquiry 23:1* (1994), requoted from p.236.

in which an electronic system and a "proprioceptive" physiological system were engaged.[55] Wiener in the end designed a conceptual circuit based on the similarity of both sides, in order to merge biological human beings in battle and machines that exert actual combat power and draw their actions into a domain of prediction. He wrote in his memoirs:

> (it became possible to couple directly to the gun the radar apparatus by which the plane is localized, and thus to eliminate the human element in gun pointing.) However, it does not seem even remotely possible to eliminate the human element as far as it shows itself in enemy behavior. Therefore, in order to obtain as complete a mathematical treatment as possible of the over-all control problem, it is necessary to assimilate the different parts of system to a single basis, either human or mechanical. Since our understanding of the mechanical elements of gun pointing appeared to us to be far ahead of our psychological understanding, we chose to try to find a mechanical analogue of the gun pointer and the airplane pilot.[56]

In the first chapter of his *The Human Use of Human Beings* (1950), a book contributed to the dissemination of cybernetics' views and thoughts into the public, Wiener clarified that the fundamentals of communication and control were integrated. According to him, message go through human and machine as the separated entities with indifference, and, in the theory of control in engineering, it is irrelevant whether the messages are from human or machine.[57] He later argued that the rotating information combined human and machine and the exclusive boundary severing the two was neutralized in a territory where feedbacks of information flow. Conditions in which each of the components were bound to a single circuit and in charge of sections of information circulation, processes of approaching all the belonged entities to an aim by striving for repetitively correcting

55 Galison(1994), pp.228–33; Ko Kyu-heun , (2016), p.406.
56 Wiener, N., I am a Mathematician (Cambridge: The MIT Press, 1964), pp.251–52.
57 Wiener(1950/1954), pp.16–17.

errors based on feedback input information updated moment by moment with thorough consistency, and efforts to firmly maintain these patterns of information against the chaotic outer attacks that attempted to destroy what had been organized—all these referred to the teleology of cybernetics established by Wiener,[58] or the results of modeling struggles to survive in the catastrophe of war.

George R. Stibitz, who was chairman of the D-2 under the NDRC was present to evaluate the devices developed by Wiener, commented that those devices displayed a mechanical access to physiological behaviors to the maximum than others in any previous attempt, complimenting that his prediction of future behaviors as analogy was exceptional because he tried to do it not by understanding inner structures but by analyzing the data of past behaviors.[59] However, it is difficult to say that all these achievements owed to Winner's originality. Attempts to neutralize the heterogeneity of substances by combining control and communication or conceptions to encompass all the objects in computable classes were also shown in projects of developing anti-aircraft directors, projects that were conducted at the same time as Wiener's research. The NDRC assigned tasks of gun pointing and prediction to Bell Laboratories too. The lab developed the T-10 (M-9 later) gun directors, which achieved brilliant success in battle by shooting down the Nazi's V-1 cruise missiles in the final part of the Second World War.[60] What the lab selected in the development was a method that several servo mechanisms were connected and actual calculations were performed within the chains.[61]

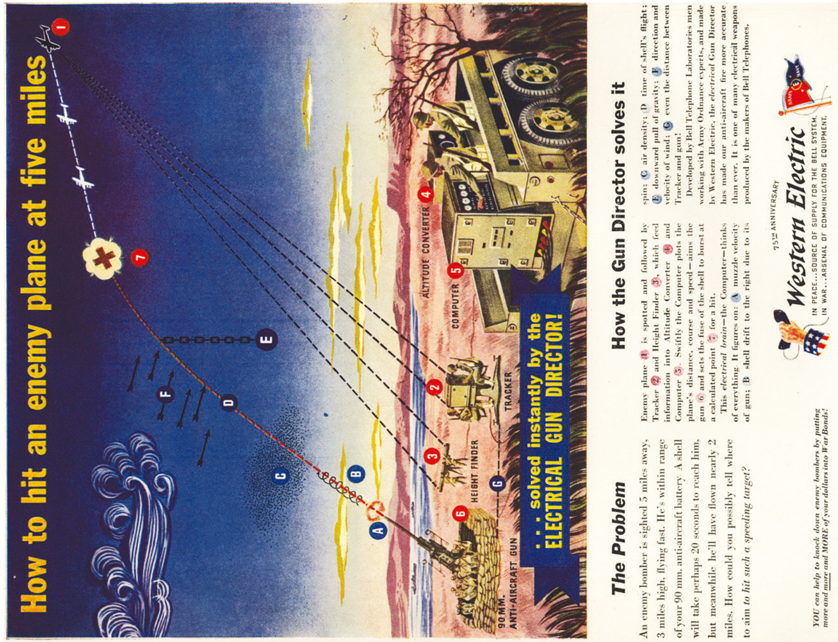
58 The definition and contents of teleological behaviors are established in the following article: Rosenblueth, A., Wiener, N., & Bigelow, J., "Behavior, Purpose and Teleology," *Philosophy of Science 10:1* (1943), pp.18–24.

59 Stivitz, G. R., Section 2 of Division D, Diary of Chairman (1 July 1942, Boston, Project no.6, Record Group 227, OSRD, Division 7, General Project Files, 1940-46) | Galison(1994), requoted from p.243. Given that discussions of analogy between human and machine have been linked to anatomy since the Renaissance, Winner's analysis was quite different from that of the past.

60 The T–10 was the name at the development, while the M–9 was the name for its mass production model. The directors performed remarkable exploits in the air raids for London and Antwerp (in Belgium) in 1944, blocking more than 50% of the enemy air attacks.

61 The prediction method presented by Wiener-bigelow could not establish effects enough to be deployed for actual battles; thus, the gun directors of Bell Lab were chosen because of the facilitation of mass production and rapid deployment.

[1] The T-10 gun directors were mass-produced by Western Electric Co., Inc. after being improved as the M-9. The above image is an advertisement of the company on Life, displaying factors that were considered in terms of aiming target and calculation of the aiming. When (1) an enemy aircraft (1) is spotted, (2) the tracker locates it and (3) the height finder measures the altitude. This information is transferred to (4) the altitude converter and then to (5) the computer. The computer (6) plots the enemy's range of movement, course, and speed, (7) calculates time of shell's burst, and sends the information to the anti-aircraft gun with an aiming signal. The computer should figure on several variables in calculating the hit, including (A) muzzle velocity of gun, (B) shell drift to the right due to its spin; (C) air density; (D) time of shell's flight; (E) downward pull of gravity; (F) direction and velocity of wind, (G) the distance between Tracker and gun.
Source: Duke University Libraries Digital Collections, https://goo.gl/DrQxD1 (Last access: 2017. 11. 7



T-10 was operated as follows: First, two operators sat on a rotating tracking head ((2) in Figure [1]) with a telescope mounted, sending data on location, movement, and distance of the enemy aircraft from the gun to the computer within a trailer. The four servo mechanisms inserted into sections from the computer to the gun aiming input and output data of shooting with a sylsin,[62] solving equations to reduce errors in input/output. All numerical values generated in the T-10 system were expressed with DC voltage. The numerical errors occurring in transmission and reception were minimized through feedbacks in each servo section. In short, all the responses based on sudden disorders such as delay by inertia and physical vibration, as well as aiming at a moving target, were unified into the flow of the entire calculation, by referring signal amplification and numerical calculation to the entire feedback circuits. This design, in addition, gave immunity against unexpected variables such as problems caused by worn-out equipment or sudden climate change.[63]

It should be noted that this project was based on the engineering foundations that had already been completed 15 years before, such as the principle of negative feedback amplification applied to reduce signal distortion in long-distance telecommunication networks and the servo control theory derived from development and application of analog computers. Ferrell, who was involved in the project, recalled the unfamiliarity at the intersection of the principles from different systems:

> Normally, as communications engineers, they had dealt with current and inductance and band width and distortion. Suddenly they found themselves worrying about velocity and mass and lag and error. Instead of the problems of speech transmission, they had the problems of gun-pointing and

62 It is a device that electrically connects two or more axes that are difficult to mechanically interlock to synchronously operate at the same or constant speed ratio. Consisting of a transmitter and a receiver, it is used for telemetry and signal transmission. The Naver Dictionary: https://goo.gl/gMQSd9 (Last access: 2017. 11. 7).

63 Mindell, D. A., "Automation's Finest Hour: Bell Labs and Automatic Control in World War II," *IEEE Control System Magazine 15:6* (1995), pp.72–80.

bomb-sighting. Different quantities, different units, different equations, different methods of analysis and investigation. Or are They?[64]

If a telecommunications engineering principle dealing with the invisible world of voice signals could serve as a universal formula defining the world of massive volume and mass, then would it be possible to apply the same principle to human operators embedded in the circuit? Ferrell in his report in 1942 used the Nyquist stability criterion[65] as a criterion to verify stability of human–machine combination in a system or explained an operator's nervous system when aiming to a target by precisely matching it to the principle of negative feedback.[66]

Back to the above-mentioned discussion: this trend was directly linked to what Miller referred to the flow of the Second World War, on which the outcomes of research was during the revolution of cognitivism in 1956. The engineering in the 1940s and 1950s was dominated by integration and homogenization; the battlefield controlled by human–machine systems was being transformed into a place where indiscriminate quantification and prediction were realized by means of applied mathematics and statistics owing to integration of control and communication. Cybernetics received attention in that it became systematized as an academic research field by encompassing achievements of several fields that had arisen out of the war to establish mathematical proofs, general theories, and more abstract forms. In this trend, the faint boundary was not necessarily put between human and machine. Since World War II, wars had been markedly transferred to an area of symbols and representations; systems of analysis for situation diagnosis and prediction of future had been reduced to mathematical algorithms. At this very moment did (digital) computers emerge as a reliever that handled ever-increasing variables and complex equations. The more

64 Ferrell, E., "Electrical and Mechanical Analogies," Bell Laboratories Record, October 1946 | Mindell(2002), Re-quoted from p.258.

65 Harry Nyquist announced the Nyquist criterion after studying causes of self-oscillation in feedback circuits and conditions of the stability. His study became a foundation on which reliable feedback circuits were developed.

66 Refer to the paragraph related to footnote 24.

the machines were able to cope with almost everything of war by skillfully handling formulas and symbols, the more the trust of the military on computers was soaring up.

When computers controlled war, a war was no longer a place of chaos. As real-time situation data were transmitted and received remotely through densely-organized computer networks, the conceptual circuit of Wiener, in which pilots of enemy aircrafts, aircrafts, anti-aircraft guns and gunners were engaged, began to be extended as omnidirectional networks in which all the elements of war sent and received feedback data at various geographical distances. This was also an initial foundation of the Network-Centric Warfare (NCW), a military doctrine argued by the US Department of Defense in the mid-1990s. According to Donna Haraway as feedback-controlled cybernetics translated the world in general into issues of computer coding, it has encompassed a number of issues including telephone technology, computer design, weapons deployment, or database construction and maintenance, while the entire basis of the various technologies has been condensed into a military symbol titled C^3I.[67] This concept connoted early warning systems for survival, analysis and prediction of enemy's strength via intelligence, and various tactical responses in order to secure prompt decisions in battles by rapid rotation of information during the Cold War, a period of opposing to the enemy based on nuclear power. However, it also contained a reverse side that had to be coped with in order to fight back the uncertainties of the future during an operation — an issue of complexity added to overall systems.[68]

03.

Here, it is worthwhile to recall that the conceptions implying the basis of modern war and components of C^3I — command, control, communication, and intelligence — had been repeated in the articles and books dealing with cybernetics. Physicist Freeman Dyson briefly defined cybernetics as "a theory of messiness, a theory that

67 Haraway, D. J., Simians, *Cyborgs, and Women: The Reinvention of Nature* (New York: Routledge, 1991), p.164.

68 For correlations between C^3I and complexity, see: Cooper, C., "Complexity in C^3I Systems," in D. Green & T. Bossomaier(eds.), *Complex Systems: From Biology To Computation* (Amsterdam: IOS Press, 1993), pp.226–231.

allowed people to find an optimum way to deal with a world full of poorly known agents and unpredictable events."[69] It may not be a coincidence that his definition can be precisely compatible with the concept of operations research, which has been systematized at a time similar to cybernetics. In the chaos of the Second World War where several operations were carried out simultaneously with a number of intricate variables, it was urgent to develop techniques to find the optimal solution to minimize mutual friction and loss or the optimal combination of multiple factors including troops, weapons, and other military equipment. A result of accumulation and systematization of the know-how was operations research, a research that was practically applied to the British convoys in order to minimize damage from the German U-boats and the discovery of submarine routes of the enemy. Operations research at the time had to face messiness as follows:

> Consider the overall problem of convoying troops and supplies across the Atlantic. Take into account the number and effectiveness of the naval vessels available, the character of submarine attacks, and a multitude of other factors, including such an imponderable as the dependability of visual watch when men are tired, sick, or bored. Considering a whole mass of factors, some measurable and some elusive, what procedure would lead to the best over-all plan, that is, best from the combined point of view of speed, safety, cost, and so on? Should the convoys be large or small, fast or slow? Should they zigzag and expose themselves longer to possible attack, or dash in a speedy straight line? How are they to be organized, what defenses are best, and what organization and instruments should be used for watch and attack?[70]

Warren Weaver, who had directed the D–2 of the NDRC and later led a mathematically based science of warfare as an applied mathematician,[71] wrote in his 1947 essay that "mixed teams" had to

69 Dyson, F., *The Scientist as Rebel* (New York: New York Review of Books, 2006), p.257.

70 Weaver, W.,"Science and Complexity," *American Scientist 36* (1948), p.541.

be preestablished in order to solve the complicated issues requiring concurrent processing and that a fusion of merging several fields and scopes was realized on the basis of the operations research. According to Weaver, it was the first time in history to mobilize mathematicians, physicists, engineers, and even physiologists and psychologists to solve military problems such as execution of operations and logistics, and the decision-making from cooperation and concentration was the progressive accomplishments of the time. When experts in different fields were collected to analyze and compare massive data, by the way, decisions that were against human intuition sometimes, a decision that showed unexpected effects later.

The first example of close cooperation between military and private sectors for a military action was the B-29 bombing project. In 1944, the US Air Force stationed in the Mariana islands had to improve performance of the strategic bomber B-29 as much as possible before bombing the Japanese mainland. The results of operations research by Curtis LeMay, Commander of Strategic Bombing Command 21, Arthur E. Raymond, engineer of Douglas Airways, and Franklin Collbohm and Edward Bowles, researchers at the MIT's Radiation Laboratory suggested that most of the armor of the B–29s should be removed, except for the tail guns for minimal defense. Reducing the armor would lighten the fuselage to increase the flying range and the carrying capacity of bombs, lowering chances of being shot down because the bombers could fly faster than Japanese fighters. The pilots were greatly reluctant to select armor reduction because it meant going into the battlefield without any protection against enemy attacks and was also a decision that violated most of their intuition. However, after reducing the armors of B–29s for the last few weeks of the Pacific War, LeMay reported to the headquarters that the reduction established effects, saying that the bombing was unprecedented in history in terms of precision.[72]

71 Jardini, D. R., "Out of the Blue Yonder: The Transfer of Systems Thinking from the Pentagon to the Great Society, 1961–1965," in A. C. Hughes & T. P. Hughes(eds.), *Systems, Experts, and Computers* (Cambridge: The MIT Press, 2000), pp.315–16.

72 Kaplan, F., *The Wizards of Armageddon* (Stanford: Stanford Univ. Press, 1983), p.57; Abella, A., *Soldiers of Reason* (Boston: Mariner Books, 2009), pp.16–17.

This success suggested that the intuitive actions taken by pilots, captains, or commanders facing battles might be inappropriate from a scientific point of view, making cracks in the traditional view of conducting a war.

After the Second World War, the entire quantitative analysis on wars was more keenly required due to the Cold War. Because nuclear weapons had been selected to be one of the major strategic assets of the Soviet Union and the United States, it was obvious that the outbreak of war would bring about extinction of both in which precedents of battles were totally meaningless. In this future, there would be no accumulated data and most of the tactical abilities in the past were of no use. A considerable amount of national military investment to prepare for this future unpredictability was based on mathematical modeling or computer simulations, while analyses of war preparation and acceptance of battle around the nuclear strategies naturally began to be inclined to "atmosphere of intense unreality."[73]

The RAND Corporation,[74] which played a leading role in development of the situation, had already established in the late 1940s a basis or a new system of analysis that policy decision-makers could use as at least superficially reasonable and objective criteria. This technique, called systems analysis, was a form in which possibilities of operations research of the past maximized. While operations research is used to explore the most efficient way of performing a specific task within an already-established system, systems analysis provides several concrete assumptions when an access to a goal is still uncertain and then selects and analyzes a number of incomplete alternatives based on these assumptions. Thus, systems analysis begins with original questions such as what

73 Edwards (1996), p.120.

74 The title RAND stands for Research ANd Development, an organization founded by Franklin Collbohm, who participated in the above-mentioned B-29 project. It was initially Douglas Aircraft's internal research organization and later became independent as research commissioned from the US Air Force continued to increase. According to Scientific writer William Poundstone, "Legally, Rand was a chimera, not quite a business concern and not quite a government agency," due to its double-sidedness; it was a private organization, but its most research projects were from research contracts with the government. Poundstone, W., *Prisoner's Dilemma* (New York: Anchor Books, 1992), p.86

to do or how to do it, drawing the answers as forms of stripped-down formalism such as game theory, numerical analysis as the basis of simulation, or mathematical modeling.[75] Despite its high degrees of uncertainty and freedom with no empirical measurement data, systems analysis is a technique in which complexity can be increased when a large number of parameters are entangled. This is why the history of systems analysis is naturally accompanied with the technical development of computers. Although computers had not created systems analysis, "the computer has put muscles on its techniques," according to Joseph Weizenbaum as a computer scientist.[76] The more the computation of computers was enhanced, the more systems analysis gained abilities to deal with complicated problems; the complexity that had to be dealt with by research of systems analysis, in turn, promoted improvement in efficiency of computers. In this way, both were involved in a spiral of symbiotic ascension.

Owing to the systems analysis as their specialty[77] and the robust computation of IBM models, the researchers of the RAND, who were well known for "thinking about the unthinkable,"[78] could create all types of supposititious scenarios describing "if⋯ then⋯" and review applicability of the scenarios, taking advantage of the Cold War crisis. The research of the RAND accorded rationality and scientific justification to the policies of the American military and the conservative hardliners. Overwhelmed by the thoughts that solutions to the threats against national security should be sought from science rather than diplomacy, the faults of those quantitative and numerical methodologies were not considered serious. Edward Barlow, a RAND researcher, gave a critical view of this blindness in his report on improvement in air defense systems in 1950:

75 The RAND Corporation, *The RAND Corporation: The First Fifteen Years* (Santa monica, 1963), pp.27–28; Edwards(1996), p.120; Kaplan(2009), pp.87–88; Van Creveld, M., *Command in War*, (Campridge: Harvard Univ. Press,1985), pp. 239–41.

76 Weizenbaum, J., *Computer Power and Human Reason: From Judgement To Calculation* (San Francisco: W. H. Freeman and Company, 1976), p.34.

77 Poundstone(1992), pp.90–92.

78 Amadae, S. M., *Rationalizing Capitalist Democracy: The Cold War Origins of Rational Choice Liberalism* (Chicago: The Univ. of Chicago Press, 2003), p.40.

The great dangers inherent in the systems analysis approach, however, are that factors which we aren't yet in a position to treat quantitatively tend to be omitted from serious consideration. Even some factors we can be quantitative about are omitted because of limits on the complexity of structure we have learned to handle. Finally a system analysis is fairly rigid, so that we have to decide six months in advance what the USAF problem is we are trying to answer — frequently the question has changed or disappeared by the time the analysis is finished.[79]

Edward Paxon, who had created the term systems analysis and elaborated the techniques for overall quantification of battles, also emphasized that analysis of a single weapon system must encompass every factor from soldiers and civilians, geographical features such as lands and structures, food supply, medical system, even to entertainment programs offered to soldiers.[80] Although it was obvious that factors such as confidence of individual soldiers, collective morale, anxiety, and stress should be considered major parameters that affected warfighting, it was extremely difficult or even impossible to handle the factors numerically. However, over three years between 1952 and 1954, the RAND had experimented these problems in earnest, focusing on subjects related to the construction of air defense systems.

When psychologists who consulted the RAND had a meeting in the summer of 1950 to discuss human factors in man–machine systems, John L. Kennedy was performing a commissioned research on improving the design of radar equipment as well as crew message-handling procedures on the basis of human engineering and physiological psychology. He forcefully suggested to the RAND a series of research projects based on what was debated in the meeting — group behaviors of human when job stress increased

79 Barlow, E. J., "Preliminary Proposal for Air Defense Study," RAND Limited Document D(L)–816, 2 October 1950, RAND Classified Library | Jardini, D. R., *Thinking Through the Cold War: RAND, National Security and Domestic Policy, 1945–1975* (Meadowlands: Smashwords, 2013), requoted from ebook: https://goo.gl/9Ja3P2 (Last access: 2017. 11. 7).

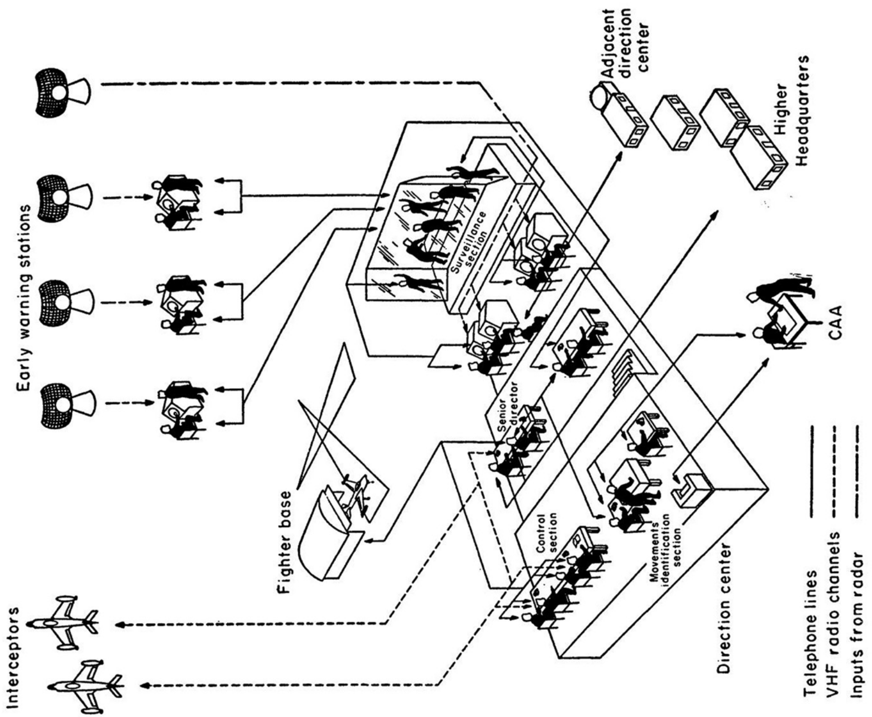
80 Novick, D., "The Meaning of Cost Analysis" (Santa Monica: The RAND Corporation, 1983), p.3.

under certain conditions.[81] What he suggested, simulating perception and judgment within a workplace and overall communication of human–machine and human–human, was highly likely to be connected with the most pressing military issue of those days. Since the Soviet Union was confirmed to possess nuclear weapons about a year ago, the United States had increasingly been threatened by the asymmetric dominance of nuclear power. As soon as the White House announced this confirmation to the public, American society was overwhelmed by a gloomy assumption that Soviet bombers equipped with nuclear bombs could simultaneously fly to the US mainland at any time. Now it was not possible for the United States to monopolize nuclear weapons; if one launched a preemptive attack, the other could attack of revenge with nuclear weapons. It was urgent to prepare multilateral provisions considering all types of enemy air strikes.

When a nuclear war breaks out, the most urgent information is primarily exchanged in the Air Defense Direction Center (ADDC). If communication was delayed or an error is included in a report to the superior authority due to misidentification of signals at a desperately dangerous situation, it would be immediately fatal to national defense. Then, how can communication in an emergency be efficient? How can the information processing procedures be optimized within a command center? Kennedy, who was skillful in linking his field of study to military projects, suggested a simulation training: all possible situations would be simulated in a site reenacting the ADDC, and the measurement data of human behaviors in the simulation could be applied to cases at an actual direction center. The US Air Force and the RAND accepted what Kennedy suggested, remodeling a billiard building in Santa Monica where the RAND was located then to recreate the interior and facilities of the McChord Field Air Force Command Post in Tacoma, Washington, in May of the following year.[82] This was the beginning of the Systems Research Laboratory (SRL), a dress rehearsal that reproduced the “first 8 hours of World War III”[83] and a testing ground that displayed organized collective

81 Farish, M., *The Contours of America's Cold War* (Minneapolis: Univ. of Minnesota Press, 2010), p.169.
82 It was not possible to use the facilities of the actual command centers for this reseach because the centers always had to handle heavy workloads even in performing operations in peace time.

[2] The flow of information within the ADDC. The CAA indicates the Civil Aeronautics Authority. Source: Chapman, R. L., Kennedy, J. L., Newell, A. and Biel, W. C., "The Systems Research Laboratory's Air Defense Experiments," Management Science 5:3 (1959), p.255.



behaviors of the human when a crisis was heightened.

Figure [2] shows how the information is exchanged within the ADDC. The operators of the surveillance section watch the PPI to obverse the flight patterns of aircrafts. Although most of the patterns do not deviate the courses of civil or friendly aircrafts registered on the basis of the data by the civil aeronautics authority (CAA), signals going off course or an unidentifiable signal on the PPI are instantly classified as unknown and the data is transferred to the movements identification section. The section makes calls to the CAA to identify the unidentifiable aircraft or whether the spotted movement was notified in advance, for some airplanes can fly back or veer of their courses because of lack of fuel or mechanical problems. If the veering-off aircraft is unidentifiable, the control section immediately dispatches interceptors. When the interceptors can identify the type and the serial number of the aircraft and communicate with it, the situation is terminated. When the pilot of the unidentifiable airplane does not reply to the communication or show a hostile behavior, the interceptors engage in a fight immediately upon receiving a firing command from the senior director. Then this situation is conveyed to command centers all over the country, a state of emergency is proclaimed, and the outbreak of war is declared.

Although these processes seem highly articulate, the operators have to fight a fierce battle against uncertain and embarrassing signals. Even the waves caused by flocks of birds, vessels on the sea, and weather factors such as clouds or typhoons will frequently be detected as carrier frequency and rushed into the radar as the valid signals. Screening to find out critical data from these intruded noises is always troublesome, tedious, and distracting. Thus, the soldiers of the ADDC should barely establish patterns of order by minimizing amount of information poured from the full-of-entropy airspace, through information processing tasks such as "men plotting information on a visual display board, men transmitting over a communications network, men reading off ranges and bearings from a radar presentation, men operating as trackers

83 Ghamari-Tabrizi, S., "Cognitive and Perceptual Training in the Cold War Man-Machine System" in J. Isaac & D. Bell(eds.), *Uncertain Empire* (Oxford: Oxford Univ. Press, 2012), p.279.

in a gun-control system."[84] What SRL wanted to simulate was the torturous labor conducted by those who were involved in (the possibility of) engagement only with their mental functions, as well as the entire information process of the ADDC that was formed on such labor.

In addition to Kennedy, the team of the organizers of the simulation—two experimental psychologists William C. Biel and Robert L. Chapman and mathematician Allen Newell—wanted to accomplish quantification of the human components, a component that had been pointed out as a limitation in systems analysis. How can human keep concentration on analyzing signals without making a mistake in an emergency? At what point is the boundary immediately before human attention is collapsed? What conditions stimulate improvements in job performance? Many of the proposed questions were connected to ways of determining where the awareness of the group was exhausted to increase the threshold to the maximum. From the collected data the SRL tried to recognize conditions that all members of an organization quickly adapted to an ever-changing situation to make a resilient decision in an emergency.[85] What was focused on was to coordinate the performance of human components to maintain balance with the high performance of mechanical systems, for the errors in operations were caused not by the hardware but occurred "in the way the hardware was used."[86] In this regard Chapman determined what the SRL intended.

> Operations analysis and system analysis often need to consider the effect of the human factor on system performance. Usually a "degradation factor" is used to qualify the predicted effectiveness. In an effort to better understand the human element in systems, RAND set up the Systems Research Laboratory to study man's performance in complex man-machine systems.[87]

84 Ghamari-Tabrizi, S., "Simulating the Unthinkable: Gaming Future War in the 1950s and 1960s," *Social Studies of Science 30:2* (2000), p.184.

85 Chapman, R. L., Kennedy, R. L., Newell, A. & Biel, W. C., "The Systems Research Laboratory's Air Defense Experiments," *Management Science 5:3* (1959), p.251.

86 Sweetland, A. & Haythorn, W. W., "An Analysis of the Decision-Making Functions of a Simulated Air Defense Direction Center" P-1988 (Santa Monica: The RAND Corporation, 11 May 1960), p. ii.

The RAND had hypothesized that high-level learning could be achieved by integrated training in groups rather than individual training if the goal was to improve system performance and that the entire group could enter a higher level through the systematization learning in which a human group and mechanical devices were entangled. Thus, each experiment was collectively performed by all the agents in the simulated ADDC, selecting a metaphor of "organism"[88] for the subjects in order to determine a process of "biological adaptation" in which the heterogeneous components of "metal, flesh, and blood" bonded to each other with high intensity were not lowered but improved in terms of performance in spite of the burden of increasing amount of information and the pressure of acceleration of processing.[89] And the principle supporting this adaptation was again, negative feedback.

> The underlying notion behind this research was that it might be possible to obtain the predictable feature of a "closed" system by exploiting man's capacity to seek and find problem solutions. That is, if man could be motivated to seek the system's goal, and if he were provided knowledge of operational results, a disparity between actual and desired performance might serve as an error feedback to trigger adaptation of operating practices to improve effectiveness.[90]

The key of the negative feedback was to continually induce stress and obsession by instantly informing the agents even during a military operation about a level of contribution of their job to the entire system, transparent evaluation of success or failure as a result of their job performance, and the difference between ideal and actual outcome. This was what was emphasized throughout the report: the report insisted that it was a "stress-based training" and that deadly pressure applied to the entire system could be an extremely effective

87 Chapman, R. L. , "Simulation in Rand's System Research Laboratory," P–1074 (Santa Monica: The RAND Corporation, 30 April 1957), p.1.

88 Chapman, R. L., Biel, W. C., Kennedy, J. L., & Newell, A., "The Systems Research Laboratory and its Program," RM–890 (Santa Monica: The RAND Corporation, 7 January 1952), pp.10–11, 20–21.

89 Chapman et al.(1952), pp.1–25.

90 Chapman(1957), p.1.

means in "making the full potential of a system available before an emergency occurs."[91] The agents undertook the experiment with a strong motivation that "the fate of the United States depends on how I will perform in this training."[92] Each session ended with open assessment from investigators and peers followed by arguments. Above all things, their jobs became more and more intensified.

According to the results of the report, however, the mental capacity of the agents had never been exhausted by any high-level pressure. The agents seemed overwhelmed by the cognitive overload but kept the steady flow of performance after a certain period of time.[93] When the target signals poured in, all the agents were even more decisive in filtering unnecessary signals, instinctively utilizing the strategy to reduce ever-increasing cognitive burden without losing precision of reading. Like an organism that survives by maintaining homeostasis in an ever-worsening environment, the entire group continuously renewed the cognitive threshold that they had to endure, letting steadiness of information process be persistent. This was the kernel of "adaptation" mentioned in the report.

00.

Philip Mirowski, a historian and philosopher of economic thought, commented that the SRL experiment was analyzed on the basis of an attempt to complement with empirical research what was omitted in the strategic omniscience like in game theory presuming complete rationality.[94] According to him, the RAND tried to improve military strategies established from mathematical formal logic, by practically analyzing ways of humans' coping with threat from the enemy, psychological anxiety, and collective crises within the frames of varying levels of stress, new procedures of learning, and alternative management structures. However, the investigators in the report admitted that they failed to acquire individuality of existence through the concept of "organism"; they tried to equate the prediction problem

91 Chapman, R. L. & Kennedy, J. L., "The Background and Implications of the Systems Research Laboratory Studies," P–740 (Santa Monica: The RAND Corporation, 21 September 1955), pp.10–14.

92 Chapman et al.(1959), p.259.

93 Chapman et al.(1959), pp.266–67.

94 Mirowski, P., *Machine Dreams: Economics Becomes a Cyborg Science* (New York: Cambridge Univ. Press), p.350.

of group performance with the prediction of individual human behavior but could not solve the inner enigma.[95] This conclusion can be considered from two aspects. First, the experimental tasks were intentionally designed to exclude privateness; the past affairs, social perception, and personal value system of an individual had no effects on job performance[96] so that the human behaviors in the experiment was confined to an extremely limited frame.

Another aspect to be considered is that the RAND investigators were not capable of analyzing the large collected data at the time. As above-mentioned, much of the information processing within the ADDC was conducted through verbal communication among the agents. Because the investigators thought that understanding the oral information was essential to comprehend properties of the organization or how the agents adapted to situations, they gave headsets to the agents to record almost every moment of their phone or face-to-face communications. From the second experiment,[97] they tried to understand patterns of information exchange by coding which telephone line was being used with the IBM card perforators every 15 seconds. In the third and fourth experiments, almost all the linguistic messages were recorded on the cards through keyboards. Job attitudes and types of behaviors were also observed to be recorded every 30 seconds, while the bulletin display was photographed every two minutes during a session.[98] As a result, the total amount of data gathered was enormous: voice recording was 12,000 hours long and the collected cards and typed documents filled 60 or more drawers. As the RAND had confessed, the problem was that only a small fraction of the collected data could be significantly analyzed. In the end, they had to incinerate all the data just because they could not afford to cope with it.

The RAND adhered to collect data not because they wanted to test the already-established hypotheses but because they had expected that a meaningful analysis system could be found.[99] Thus,

95 Chapman et al.(1959), p.268.

96 Chapman et al.(1952), p.20.

97 A total of four experiments (with the code names Casey, Cowboy, Cobra, and Cogwheel) were conducted from 1952 to 1954, with varied numbers of people, hours, and sessions.

98 For the types of records collected in the experiments, see: Parsons, H. M., *Man–Machine System Experiments* (Baltimore: The Johns Hopkins Press, 1972), pp.168–169.

discarding the data meant that it was no more possible to draw assumptions from the data. If these two aspects could be solved, how close could the RAND's experiment approach toward human psychology and behavioral prediction? As Chapman hoped and Mirowski commented, could the SRL be a more definite complement to systems analysis and game theory?

In *The Control Revolution*, historian Beniger pointed out "preprocessing" as the most important control mode among those that were selected by modern management systems to expand self-regulating capacity.[100] According to him, administers needed to reduce the amount of data by eliminating minor elements in order to control the highly-developed, large-scale social system with stability. When the processing capacity is very limited, the control of the entire system can be roughly established by manipulating and managing only the minimal elements that are needed to approach toward target values. Preprocessing, in short, is a basic requirement to reduce the amount of information by ignoring trivial data and details for the efficiency of control. With excluding personal factors, the SRL could make a remarkable achievement in integrating and controlling the entire experimental space that the experiment team had planned — "a single information processing unit"[101] which produced accurate calculations through elaborate interactions of "human and hardware" or "human and human" based on information input. However, the RAND failed to achieve meaningful discovery from the vast volume of voice messages poured from the beginning of the operation and the detailed information about subtle attitudes, movements, and expressions of emotions of the subjects, because analyses of the RAND and approaches used by experimental psychology at the time were systems specialized in objective and quantified data.

Zuckerman, who established operations research in England during World War II, confessed its defects in his book in 1966.

99 Chapman et al.(1959), p.263.

100 It is a term borrowed from computer science. Beniger, J. R., The Control Revolution: Technological and Economic Origins of the Information Society (Cambridge: Harvard Univ. Press, 1986), pp.15–16.

101 Or, 'information processing center.' Chapman et al.(1952), pp.1, 3–4.

> operational analysis (···) is a search for exact information as a foundation for extrapolation and prediction. It is not so much a science in the sense of a corpus of exact knowledge, as it is the attempted application of rigorous methods of scientific method and action to new and apparently unique situations. The less exact the information available for analysis, the less it is founded on experience, the more imprecise are its conclusions, however sophisticated and glamorous the mathematics with which the analysis is done.[102]

Techniques that can be reduced to neat mathematical symbol contain risks in its abstract processing: a fatal error could occur when the rules or assumptions of a question for an answer are not elaborate. However, what if such mathematical approaches could deal with a vast amount of data? Now is the time when reducing minor data such as preprocessing is no more necessary; all the data collected can be processed and integrated to display significant correlations. Such powerful capabilities of information gathering and processing of the present have brought the control and prediction of the past into an entirely different stage. This is what Chris Anderson pointed out in his article "The End of Theory: The Data Deluge Makes the Scientific Method Obsolete" in *Wired* about ten years ago:

> This is a world where massive amounts of data and applied mathematics replace every other tool that might be brought to bear. Out with every theory of human behavior, from linguistics to sociology. Forget taxonomy, ontology, and psychology. Who knows why people do what they do? The point is they do it, and we can track and measure it with unprecedented fidelity. With enough data, the numbers speak for themselves.[103]

102 Zuckerman, S., *Scientist and War: The Impact of Science on Military and Civil Affairs* (London, 1966), p.18 | Perry, R. L., "Commentary," in M. D. Wright & L. J. Paszek(eds.) *Science, Technology, and Warfare: The Proceedings of the Third Military History Symposium* (United States Air Force Academy, 8–9 May 1969), re-quoted from p.117.

103 Anderson, C., "The End of Theory: The Data Deluge Makes the Scientific Method Obsolete", *Wired* (June 2008) https://goo.gl/nUXqPU (Last access: 2017. 11. 7).

To sum it up, this paper has discussed what humans had to give in and up in order to control all the factors in an operation at a level similar to that of the advanced machines, and to turn the war into a field of prediction. On securing clues that the material world of a battlefield full of violent, heavy machines could be controlled by patterns of non-visible signals across the board, the scientific research of wars had had no hesitation about bringing humans as the living things into the communication circuits. Propensities, habits, entangled desires, and changeable emotions were excluded from the system as being heretical. The humans within the system were considered servo-mechanisms inserted into the feedback loop of information, shafts of data transmission, or information processing units. When these pseudo-machines with their specificity reduced were fully merged within the system, the war machines seemed to secure abilities to react to sudden confusion, adaptation to circumstances unique to organisms, and even resilient adjustment.

However, let's think of News Feed of Facebook, search engine of Google, and recommendation algorithm of Amazon.com. These machines do not replace humans with any other beings; on the contrary, they resemble the intelligence of organism by absorbing all activity patterns, individual propensities, and internal factors. Users are not bound to machines. Instead, they can expect more reliable machine intelligence and more accurate prediction algorithm as they emit more signals of taste and desire to flood circuits with heavy traffic. The asymmetry of the senses created on the above-mentioned black glass plates, then, could be reconfirmed on a totally different stratum. While we thoughtlessly repeat mindless touches and unconscious clicks, irregular and non-quantitative data that could not be dealt with by systems analysis in the past flow into the frame of mathematical analysis. These random traces of chaotic interaction events are not only neatly patterned by data mining or machine learning algorithms, but are also updated in real time by rules and parameters that we cannot predict.

The difficulties of the operations research and systems analysis in the past — inaccurate samples and missing data undermining the entire framework of analysis — are not a big problem anymore. Data is now collected not by terabytes but by petabytes. The supercomputers, whose computation is far superior to those of the past, can quickly visualize ambiguous correlations of nonlinear regions and the reliability of these correlations, without hypotheses or modeling. When the samples are vast, the result is usually beyond coincidence or randomness. The reality is originally more often involved in nonlinear complexity than what can be explained by linear causality. This is truer to private tastes and preferences of humans. The expectations of the US military on computers in the early 60′s as mentioned above may not have been so absurd. Who knows? The liquor that a military chief drank yesterday, the newspaper he reads, or whether he read a certain article or not—these data might have linked to the direction of strategies that the Soviet military chose. According to records, the office of the U.S. Department of Defense in charge of systems analysis at the time even tried to determine theoretical implications between problems of national security and the skirt lengths of women who worked in the department.[104] Just because the data was too insufficient, however, they could not find any significance.

Interfaces are making artificial intelligence even more complete; selection and prediction of artificial intelligence are performing an ensemble of collaboration that keeps users logged-in to induce chain interactions. Thus, exclusive boundaries in integration become extinct. Humans, transformed into continuous streams of data, unreservedly permeate electronic networks to let their patterns be statistically analyzed. Have human beings ever experienced a more completed human-machine integration system than this?

The integration has recently been accelerated for a few years. Netflix recommends movies and American shows to a person considering their preference. More than 25% of the academic books filling a scholar's library are recommended by Amazon.com site. In return, a person's taste awakened by the recommendation algorithm engenders new patterns of streaming. A researcher's academic tendencies are determined by their inquiring mind promoted by Amazon. Aspects of everyday life are being absorbed into the sphere of prediction owing to omnidirectional collection, processing, and statistical analysis of data. These current trends can be connected to the feedback circuits of complete control and prediction via calculation and simulation, a circuit that the military command system

104 Van Creveld(1985), p. 240.

of the Cold War had dreamed of. Then, the concept for defining the present time of post-Cold War may have to be adjusted at least in terms of the specificity of human-technology relationship. The current situations in which mobile devices, touchscreens, big data, and learning algorithms are densely intertwined to create every corner of everyday life may be expanded from the Cold War technology system or linked from the era of extra technology Cold War.

Perhaps this world is what the Cold War dreamed of.