From Cybernetics to Systems Theory in the First Space Age: Observations on the Pilot Problem

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Cybernetics is, by name, about piloting, as everyone knows: steering a boat, piloting an aircraft. This question of the steering pilot is as old as antiquity. During World War II, the goal of cybernetics was to automatise piloting, to de-humanise it in a way, if we believe that a carnal pilot invests humanity more than a human-conceived automatic apparatus. Foucault envisioned the historicity of the problem well:

> the idea of piloting as an art, as a theoretical and practical technology necessary for existence, is an idea that I think is rather important and may eventually merit a closer analysis; one can see at least three types of technology regularly attached to this 'piloting' idea: first of all medicine; second of all, political government; third of all self-direction and self-government.[1]

This quote from Foucault appears in the 2014 pamphlet *The Cybernetic Hypothesis*, published by the anonymous Tiqqun collective. The authors add that Foucault refrained from any contemporary digression on the topic, since 'at the end of the twentieth century, the image of piloting, that is to say of management, became the cardinal metaphor for describing not only politics but also all human activity'.[2] For Tiqqun, cybernetics is nothing other than rationalisation pushed to its limits. However, the latent and continuous technophobia spread through Tiqqun's discourse fails to help understand the very nature of technology. Moreover it leaves open no alternate path than a thorough mastering of technology. Technophobia, just like anti-science, fails to understand how it is unreasonable to despise reason, unproductive to put limits on rationalisation, absurd to lament an overdose of rational thinking and acting.

To introduce this article with a violent and ideologically burdened critique of cybernetics is somewhat consistent with the greatest weakness of cybernetics: its having turned into an ideology in less than a decade after its inception. Tiqqun engages in a harsh political critique of cybernetics. They debunk and insult a host of figures of the French intellectual scene such as Edgar Morin, Joël de Rosnay, François Ewald and Antonio Negri, while remaining close to and somewhat critical of Jean-François Lyotard and Gilles Deleuze and Félix Guattari. If provoking established leftist or post-Marxist names is sometimes a healthy anti-dogmatic necessity, it is not rewarding if nothing substantial is delivered after such assaults. We will instead attempt to deal with the non-metaphorical side of piloting and invite into the debate a discipline directly implied or coextensive to cybernetics which became even more powerful than cybernetics itself and was bound to replace it in more than one field: systems theory.

Cybernetics did indeed start with a precise and urgent practical problem where, at least initially, metaphors had almost no place: how to automatise the shooting down of enemy planes with anti-aircraft guns? Norbert Wiener, the mathematician and professor at MIT with uncommon talents for expanding his discipline into a host of other domains, worked hard in 1944–45 to provide

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a practical answer and in doing so invented what he called cybernetics. As is always pointed out, Wiener worked in close partnership with psychologists embracing the behaviourist credo. For, indeed, the pilot problem was mainly one of behaviour: how to anticipate the pilot's behaviour in trying to escape anti-aircraft shots? At the same time, in Great-Britain, another urgent problem arose: how to shoot down pilotless planes? The Germans had invented with the V-1 the very first drone, aimed at destroying London. American and British engineers raced to create smart fuses able to shoot down the V-1 flying at unprecedented speed over the Channel.[3] Note that the 'pilot problem' is still a vivid issue seventy years after the war, with armies around the world flying more and more drones, creating new jet fighters with assisted piloting, and so on. As recently as August 2020 a US jet pilot lost a test dogfight against automated drone jets. It is quite remarkable that the problematic of flight and pilot has stayed so relevant up to the present day. Remember, among many contemporary examples, how Boeing's dramatic 2019 software failure with the 737 Max was a pilot-automation interface flaw; the same company's 2019 Orion spacecraft test was a half-failure.

In any case, there are two different modes of flying objects: piloted and pilotless, the latter divided into two categories, remote-controlled and autopiloted. Elaborating on Wiener's anti-aircraft efforts, Peter Galison's 1991 *The Ontology of the Enemy: Norbert Wiener and the Cybernetic Vision* offers a detailed and valuable analysis on the topic.[4] Galison wisely backtracks from the widest ontological claims of cybernetics. Indeed, so many observers have gotten lost in Wiener's sometimes pseudo-metaphysics that going back to the bare facts is productive. For this essay it will mean relying on some carefully chosen archives that do not often receive attention. It is difficult to ignore or reject the philosophical dimensions carried by cybernetics. If Wiener early on sought to give cybernetics a philosophical prestige, it is mainly in Europe that this drive found fertile ground for further developments, including vigorous critics. For instance, Gilbert Simondon's introduction to *On the Mode of Existence of Technical Objects* (1958) found cybernetics insufficiently universal:

> One need not even found a separate science that would study the mechanisms of regulation and command in automata built to be automata: *technology must deal with the universality of technical objects. In this sense, cybernetics is insufficient*: it has the immense merit of being the first inductive study of technical objects, and of presenting itself as a study of the intermediate domain between the specialized sciences; but it has specialized its domain of investigation too narrowly, because it started from the study of a certain number of technical objects; it accepted as its point of departure that which technology must reject: a classification of technical objects according to criteria established according to genre and species.[5]

In Germany, with the post-war work of Martin Heidegger – a onetime Nazi Party member – cybernetics gained critical interest. Today, for stimulating thoughts on the philosophical destiny of cybernetics, refer to Erich Hörl's article of 2013.[6] Hörl is also a great source for the cybernetics/ecology relation, drawing his concepts, in part, from Félix Guattari's works. Here, a few considerations will suffice before dealing with case studies relating to the first space age (1950–80). Cybernetics grew on the well-prepared ground of American pragmatist philosophy. Wiener's will to expand cybernetics from practical issues such as anti-aircraft weapons to any problem encountered by human societies is the result of ideology taking command of technology. Traumatised, as one should have been, by the invention of the atom bomb, he gave cybernetics an encompassing and unlimited operational space. When the seemingly concurrent systems theory appeared, a shift was made where ideology was somewhat replaced or given a second role by engineers coping with complex new goals such as landing humans on the moon. The pragmatism of systems theory was in a way greater and more efficient than that of cybernetics. This should not be seen as a mere neutral semantic shift from one label to another, from cybernetics to systems theory, even if the latter needed the former. Ideology never quits the scene, however its place is drastically removed from the pragmatic field of operations. Pragmatism was a philosophy and an ideology promoting a paradoxical move against itself in the sense that it thought a retreat from thought in favour of action.[7] Where does ideology find its place if not in the overall social fabric, tightly bonded to politics?

In the meantime, from the 1950s to the 1970s the one-way bridge between cybernetics and systems theory was computation: computation per se, in relation to the ever-growing calculation power of computers. Cybernetics morphed into second-order cybernetics, so the story goes. At some point, Ideology, with a capital 'I', has little or no hold on technologies; when a technique works, it works. The history of luddites is here to prove it. You could hope to counter the wheel, but so long as the wheel is an efficient and working technology it will stay around. Ideology, in the case of the decades 1950–1970 in the USA, was driving engineers and managers, from their education, through their university formation and throughout their careers where they participated in the development of powerful institutions. These men and women, living in a post-World War II and Cold-War era, embraced systems thinking less as an ideology than as an efficient methodology whose first and foremost successful applications were in the military and, sometimes, in the civilian realm. But it evolved into a methodology at the service of an ideology. Systems talk replaced feedback talk. Servomechanisms were used as banal tools and neatly ordered under the control and command of computers. In systems theory, the feedback loop is a given, something already granted, a tool; systems theory is a methodology as well as a strategy, whereas cybernetics becomes a tactic while at the same time it tries to diffuse itself on a philosophical level.

While the links between the cognitive sciences and cybernetics have been underlined by others, I rather insist on how cybernetics gave way to systems theory at large or was somewhat superseded by it.[8] Systems theory was in fact a step sideways more than a shift away from cybernetics. As we will recall, there is a host of applications of systems theory, thus producing dozens of labels with 'systems' as its core noun: systems engineering, -management, -design, -analysis, -dynamics. Some of them share the same parentage, such as systems dynamics invented by Jay Forrester (1969) with the computer as a central tool. Ludwig von Bertalanffy's work is a mandatory step here, since the father of systems theory himself insisted on the difference with cybernetics. Obviously, one can draw various cartographies of the relations between all these fields as well as between them and cybernetics; among the available twenty-first century literature, one can glean all the details from Lars Skyttner's *General Systems Theory: Problems Perspectives Practice.*[9] Bertalanffy phrased the opposition cybernetics/systems theory this way in 1969 in the chapter 'Open Systems and Cybernetics' of his *General System Theory: Foundations, Development, Applications*:

> the important question of the relation of general system theory and cybernetics, of open systems and regulatory mechanisms appears … The basis of the open-system model is the dynamic interaction of its components. The basis of the cybernetic model is the feedback cycle … in which, by way of feedback of information, a desired value (Sollwert) is maintained, a target is reached, etc. The theory of open systems is a generalized kinetics and thermodynamics. Cybernetic theory is based on feedback and information. Both models have, in respective fields, been successfully applied. However, one has to be aware of their differences and limitations. The open-system model in kinetic and thermodynamic formulation does not talk about information. On the other hand, a feedback system is closed thermodynamically and kinetically;

> it has no metabolism. In an open system increase of order and decrease of entropy is thermodynamically possible. The magnitude, 'information' is defined by an expression formally identical with negative entropy. However, in a closed feedback mechanism information can only decrease, never increase, i.e., information can be transformed into 'noise' but not vice versa.[10]

The first part of the introduction was titled 'Systems Everywhere'. In retrospect, Bertalanffy's offspring has greatly outpaced Wiener's. Systems theory encompasses far more than cybernetics and perhaps appeals more on the semantic and linguistic level: less exotic, more mundane and – this is the hidden secret – less metaphoric, or better, not a metaphor at all. Indeed, at the root of cybernetics lies that heavily burdened pilot-metaphor which was instrumental in the success of cybernetics but thereafter became a burden. 'Systems', any way you take it, has no metaphorical connotation. One would qualify it as a concept, if only we could be completely sure of what a concept is and can be (I refer here of course to Deleuze and Guattari's work). Systems engineers discard cybernetics' wrapping (ideology) and do not care for its toppings (metaphysics, ontology, philosophy); they consider that the proof of the pudding is in the eating, to recall an old adage famously quoted by Marx.

The greatest feat of systems theory versus cybernetics was its ability to be, paradoxically, at the same time more general and more specific. This could only happen with the universality (the general) of computation and the utmost exactness of electronically computed calculus (the specific). As we know, Alan Turing's breakthrough and its consequences changed the landscape. Couplings of mathematics, hard science and technology under the banner of research and development were the source from which everything flowed: the military-industry complex, economic growth, social control, down to the overexploitation of the earth's resources, in a word it unleashed capitalism, ready to mutate at the turn of the century into a cognitive post-capitalism. Thus, cybernetics waned and slowly left the scene. What remained in its wake is 'cyber-everything' – mostly confusing catch-words, including, for a short-lived period in the mid-1990s, architectural digital experiments under the so-called cyberspace idiom.[11] The long trail from Wiener to novelist William Gibson (cyberpunk) with a stop-over at the work of William Burroughs is a thin and winding one. Stewart Brand's *Whole Earth Catalog* provided the binding glue for an audience remotely interested in technology while conscious of the information and computation mutation they were witnessing. Among them, some would become the pioneers of Silicon Valley in the 1980s.[12]

Certainly, the notion of the system did not start in the mid-20th century. Since it is impossible to summarise the history of the idea carried by a Greek word – at least for the Occidental world – let us just recall an almost diminutive but truly enlightening anecdote.[13] Auguste Comte, the nineteenth-century philosopher who promoted a positivist philosophy if not positivism itself as such, published his *Système de Politique Positive* in 1851. The fifth edition (1929) publishes an erratum which reads:

> After checking the manuscript, itself kept by Auguste Comte at 10, rue Monsieur-le-Prince, one should read page 539, 2nd line: 'main systematic base' instead of 'main mathematical base.' This error exists in the 1st edition (1851) and consequently in all successive editions.[14]

This mix-up or confusion between mathematics and systems is not without deep meaning if we keep in mind that maths includes calculus, computation; the tethering is constant, unbreakable, working at full power. Further considering mathematics, ironically, its real role in Wiener's work has been judged as 'fairly irrelevant' by a contemporary MIT fellow.[15]

Architect-engineer Richard Buckminster Fuller, contemporary of Wiener, is deservedly often described as a systems theorist. The title of Fuller's *Operating Manual for Spaceship Earth* (1969) has an intriguing double meaning.[16] The manual as a compendium of instructions to be followed for a task is something different from a manual as hands-on process to achieve them. The alternative remains the manned piloting of a spaceship versus automated piloting. This is where computation and the computer come in. In the very same year, NASA's first moon landing was possible through a sophisticated – for the time – man-machine interface. Among the thousands of sub-systems active in the Apollo programme, the Apollo Guidance Computer was crucial.[17] No wonder that the software crux of the computer has, since the early 1960s, been called the operating system (OS). For instance OS/360 was used on most IBM mainframe computers beginning in 1966, including computers used by the Apollo programme.[18] Hence, in a logical semantic move, the idea of 'system' was linked to the fundamental operating software device of a computer.

In short, computation has fully absorbed and integrated the very notion of the system. It is in or with the computer itself that systems theory rises to a universal and inescapable central position. In the meantime, I would argue that cybernetics loses most of its raison d'être apart from a historical oversight: when information theory, with the work of Claude Shannon among others, took pre-eminence over cybernetics. Again, ideology was not left behind or jettisoned, on the contrary. It remained an undercurrent, in the deep strata both of code and other operational-operative functions.

The morphing of cybernetics into systems theory is synchronous with the peak of the Apollo programme. It could be said that the Apollo Guidance Computer was the locus where this took place with the most spectacular force. Some observers have too easily asserted a direct filiation between NASA's glory days of the 1960s and early 1970s and the nascent development of the Silicon Valley in the 1980s. Though the strength of such a bond is evidently impossible to quantify, it is indisputable.[19] Less than two decades after the Second World War, the problem and goal, seen from the US side, was how to land two men on the moon and return them to earth, with piloting an issue once more. In the meantime, another military problem had been resolved: how to have missiles fired from submarines automatically reach their target. The Polaris guidance and navigation unit developed at MIT did the job. MIT would go on to oversee the crucial Apollo Guidance and Navigation computer system. In Great Britain, Alan Turing was deciphering the German-encrypted messages and communications. Automatically guided V-1 and V-2 rockets were bombing London, with Wernher von Braun as the chief designer of the V-2. Thus three parallel technological endeavours were occurring, with automation as a shared element: automated air-defence, automated rockets, and the automated deciphering of secret codes. The US East Coast imagined and developed the scientific and technological base, the West Coast engineered and crafted the artefacts. Automation was the answer and goal, simulation the method, electronic computation the tool. Generated from a weaponry goal, invented to better fight and kill, cybernetics would keep traces of this context. No wonder that the Tiqqun critic can observe that cybernetics carries an unchallenged murderous drive; it would be naïve to argue the contrary.

I would argue, again, that the shift from cybernetics to systems theory in the 1950s and 1960s was strongly articulated with the development of the first space age. It reflects in part the gap between automatically shooting an aircraft pilot (cybernetics) and having pilots traveling safely to the moon and back (systems). For the sake of history, note that the Soviet Union's first space age had no pilot problem: Gagarin, the first man to orbit earth (1961), or Valentina Tereshkova, the first woman (1963), were just passengers of their Vostok spacecraft, like before them the dog Laika, and like other manned Vostok missions. Automation was the leitmotiv of the Soviet engineers. It was, however, automation without cybernetics, without humans in the loop. When automation failed, there was no human backup solution. Cosmonauts were not given piloting capacities, or they were kept at a minimal level, whereas thanks to the combination of cybernetics and systems thinking, US astronauts were wholly integrated – from spacecraft design to fabrication and piloting – in the overall system. Systems theory, analysis, engineering and so forth enabled the achievement of design projects of unknown complexity.[20]

The role given to control appears different in cybernetics and in systems theory: whereas cybernetics control sticks tightly to well-determined operations even if these operations welcome changes, systems control leaves open the possibility of events, of the new and invention. Whereas cybernetics aims at generalising so that it permeates every domain, systems thinking pays attention to minute details, to specifics while keeping operations open to undetermined factors. In systems theory, the definition of requirements is by its very nature open: open to diverse and more than often contradictory requirements. The move from general to specific and specific to general, providing those words with their precise definition, works in a back-and-forth orchestration which could be seen as a mega-feedback loop. Control sometimes has another, softer-sounding name: regulation. Incidentally, the French translation of *Cybernetics: Or Control and Communication in the Animal and the Machine* in fact reads: *La cybernétique: information et régulation dans le vivant et la machine.*[21] In an effort towards increased generalisation 'the animal' is translated by 'the living' ('le vivant') and 'communication' by 'information'.

Because so much can and has been written about cybernetics, so much elaborated on its premises and so many different arguments can be made using the concept of cybernetics, a thorough historical survey is helpful. In place of engaging here in a thorough retrospective, one may observe the downfall of the idea of cybernetics and the inverse prosperity of the idea of systems. Google's Ngram Viewer tool applied to both terms over seven decades starting in 1940 is implacable: the statistical curve of occurrences of 'cybernetics' in the English written corpus climbs steeply to a summit and then enters, in the mid-1970s, a falling slope, while the 'systems' curve starts growing rather slowly up to its apogee in 1990 and then plummets until 2010. Curiously, or not, the peak of cybernetics took place around 1975, at the end of the Apollo programme. Systems catches and crosses the cybernetics curve around 1980. Something happened to cybernetics which is akin to a disgrace. The notion that had lost most of its appeal and was, by the early 2000s, merely paid lip-service, is today encountering a slow recovery. A recent example showing the indolence of this rehabilitation is given by a 2018 conference compendium published under the promising title *Intelligent Systems in Cybernetics and Automation Control Theory.* The order of the sequence of words in the title is noteworthy. The brain-metaphor is dismissed in favour of the notion of intelligence. This book constitutes the refereed proceedings of a *Computational Methods in Systems and Software 2018 Conference* (CoMeSySo 2018). We are told that the:

> CoMeSySo 2018 conference intends to provide an international forum for the discussion of the latest high-quality research results in all areas related to cybernetics and intelligent systems. The addressed topics are the theoretical aspects and applications of software engineering in intelligent systems, cybernetics and automation control theory, econometrics, mathematical statistics in applied sciences, and computational intelligence.[22]

Now, as for cybernetics, out of 342 pages the notion appears a mere five times, including three times on the same page; in other words: never. The conference proceedings are published in a series entitled *Advances in Intelligent Systems and Computing* whose presentation is in itself an exhaustive list of all the specific domains or disciplines and sub-disciplines it encompasses:

> [it] contains publications on theory, applications, and design methods of Intelligent Systems and Intelligent Computing. Virtually all disciplines such as engineering, natural sciences, computer and information science, ICT, economics, business, e-commerce, environment, healthcare, life science are covered. The list of topics spans all the areas of modern intelligent systems and computing such as: computational intelligence, soft computing including neural networks, fuzzy systems, evolutionary computing and the fusion of these paradigms, social intelligence, ambient intelligence, computational neuroscience, artificial life, virtual worlds and society, cognitive science and systems, perception and vision, DNA and immune-based systems, self-organizing and adaptive systems, e-learning and teaching, human-centered and human-centric computing, recommender systems, intelligent control, robotics and mechatronics including human-machine teaming, knowledge-based paradigms, learning paradigms, machine ethics, intelligent data analysis, knowledge management, intelligent agents, intelligent decision making and support, intelligent network security, trust management, interactive entertainment, web intelligence and multimedia.[23]

This makes an impressive list indeed and with a single, thus spectacular, omission: cybernetics. One would be tempted to say that cybernetics is nothing else than the totality of all these fields of work, or even, more fundamentally, the governing paradigm which holds them together. But this is not possible. Moreover, artificial intelligence (AI) is not on the list either, instead of which 'computational intelligence' appears, indeed a wiser label, for computation is neither 'artificial' nor 'natural', it just is. Actually, it crosses the lines between both.

To enhance the tight intertwining of cybernetics, systems theory, complex design-make programme management, as they occurred in the 1960s, I will quote at length from three non-academic sources of interest, representing three cases: one from the military-industrial complex, one from a think-tank working for the military and one from a federal organisation relying heavily on the military-industrial complex. These cases are: TRW Systems, (Thompson Ramo Wooldrige), SDC (System Development Corporation) and NASA. They were interrelated in many ways. The rhetoric used in those documents speaks for itself regarding the place given both to cybernetics and systems – be it systems engineering, management, design, and so on. Chiefly, these documents, which in part aimed at being operational, use a discourse of instructions and orders, command and control. They perfectly mirror the context from which they grew and, significantly, echo each other. In opposition to the tradition of very short and/or truncated quotes, long excerpts will be given here so the reader can immerse themselves in the material used for the argument. This approach is akin to anthropological research where enquiries rely on lengthy exposition of facts, discourses and whatever evidence is found in the field. In doing so, paraphrasing sources is avoided and replaced by the actual documents.

Case 1: TRW

In the US industrial-military complex a major player such as TRW Systems, from Redondo Beach, California, exemplifies with great clarity the paramount role played by systems theory in the mid-sixties. The company described itself thus:

> TRW Systems is one of four operating Groups in TRW Inc., worldwide supplier of aerospace, automotive and electronic products and services … Corporate products, in addition to those of TRW Systems, range from automotive valves, pistons and linkages, through jet engine parts and torpedo propulsion systems, to electronic components for defense, space and consumer applications.[24]

The introduction of a small technical booklet TRW Systems offered as a promotional item in 1967 reads:

THE SYSTEMS APPROACH

The systematic application of computer techniques for solving engineering problems has made possible the handling of the many interrelations necessary to describe complex systems, organisations, and time-variant processes. Prediction as well as increased understanding of system behaviour are the results. These engineering techniques have been extended to the analysis of social and management problems with very beneficial results. The systems approach provides a method of thorough planning and management. Scientists have in the past looked for analogues common to all dynamic systems. The use of feedback loops as a thread common to animal, machine, and organisation was suggested by Norbert Wiener in his book *Cybernetics*. He further suggested simulation as a valuable tool where rigorous, formal, 'optimum' solutions are of less importance than the behaviour of the system as a whole. By linking together feedback loops involving appropriate delay times, amplifications, and structural relationships, it is possible to simulate systems of high complexity with remarkable accuracy. Because the human mind is unable to comprehend the interrelationships of more than four or five feedback loops at a time, it has been found necessary to use the automatic, high speed computer to handle the myriad relationships typically required to describe a large dynamic system in depth. The methodical programming of sequential calculations to be accomplished in a computer run has greatly reduced the mathematical prowess and mental dexterity required, and the resulting (systems approach) solution of problems is amply justified by the significant results obtained. Typically, the equations and procedures are discrete computations at successive intervals of time, to describe levels controlled by rates. Non-linear relationships are easily handled by this approach. Through the use of positive as well as negative feedback loops, growth processes can be simulated in combination with homeostatic processes. By allowing for growth in the model, simulation has become an excellent tool to predict the behaviour and problems of rapidly expanding or newly developing systems, serving to prevent the interpretation of change (per se) as a disease in the system, in contrast to a simple model having a relatively constant state of equilibrium.[25]

All the basics of systems thinking are grouped together in this short text standing as a most thorough abstract of what cybernetics does to industry via systems theory. TRW was contracted by NASA to design and manufacture the Lunar Module's descent stage rocket engine. [Fig. 1] It was the very first rocket engine that could be throttled, its thrust from 15 per cent to 100 per cent being regulated by pilots (astronauts) and the Apollo Guidance Computer in tandem. If we decide, as a heuristic principle, to pay attention to objects or artefacts, considering that they encapsulate a maximum of meaning, the Lunar Module's descent stage rocket engine epitomises an assemblage of cybernetics and systems engineering at its pinnacle.[26] Beyond its TRW descent rocket engine, the whole Lunar Module, designed and made by the general contractor Grumman (Long Island) has the aura of a quasi-fetish object.[27] Examining the photographs, the blueprints and the few still extant Lunar Modules in museums, and taking a step back, yields some uncanny thoughts. We face the difficulty of trying to fully understand the object itself as a material artifact and piece of craftsmanship, condensing not only the technologies of its time but, as crucially, the organisation of the processes which brought it into existence.

The Lunar Module was, from a pilot's point of view, something out of this world, aiming at bringing them to an unknown world. It appears now as an utterly strange product of a by-gone era, impossible either to recreate or grasp comprehensively. The ultimate machine, a man-made and human-controlled machine mediated by the computer, the Lunar Module has sunk into historical oblivion along with other tools from the past, good enough for museums but finally not much else. However, if envisioned as an object intimately connected both to the sphere of cybernetics and systems theory, and to the ideological context which enabled its

Fig. 1: First space age relic: NASA Lunar Module mock-up. Bangkok Science Museum and Planetarium. Photo: author.

development, and when considering any one of its material features or components in the light of cybernetics and systems theory, one could begin to imagine the feelings experienced by the men and women who participated in the Apollo program. The Lunar Module, a 'machine of loving grace'?

In 1967 – note the date – Richard Brautigan wrote: 'I like to think (it has to be!) of a *cybernetic ecology* where we are free of our labors and joined back to nature, returned to our mammal brothers and sisters, and all watched over by *machines of loving grace*'.[28] In a 2015 essay by John Markoff using Brautigan's lines as both its title and epigraph, *Machines of Loving Grace: The Quest for Common Ground Between Humans and Robots,* the opening of Chapter 5 recalls NASA's approach in the 1960s to the pilot/automation dilemma.[29] Here, I cannot resist considering the Lunar Module as a grace machine, if not the grace machine par excellence, thus misinterpreting a superb essay by architect and theorist Lars Spuybroek.[30] For a joint cybernetic-systems induced piloting choreography in an environment bearing from zero to one sixth of the earth's gravity, astronauts were to skilfully manoeuvre their grace machine, combining grace with a gravity-less world. By designing and crafting the Lunar Module's descent engine, TRW made history.

Case 2: SDC

SDC (System Development Corporation) was a spinoff of RAND Corporation, one of the most important American think-tanks, and located on the same premises in Santa Monica. The RAND corporation was, in a way, Wiener's *Predictor* applied to geopolitics, a mega-Predictor.[31] At RAND, thinking was helped, sped-up and enlarged thanks to computer simulation.[32] As its parent institution, SDC had from its inception placed system theory at the heart of its action. Automation, and implicitly, cybernetics, were enlisted in many projects, as for example the improvement of education:

> Research in education at SDC dates back to 1958 when the Automated Teaching Project was initiated in the Human Factors Department. Its major objectives were to determine by experimental research the conditions under which programmed learning materials presented *automatically* provide the most effective instruction to students, and then to develop an *instructional system* which would incorporate these conditions in its operations. Early activities of the project's staff centred around explorations of the possible advantages of a flexible teaching program and display arrangement that would be responsive to individual student differences. The next step in the program was the development of a *system* for literally '*automating'* the presentation of materials. Utilizing a Bendix G-15 computer as the central control unit, the experimental auto-instructional system provided for teaching one student at a time. This was the forerunner and necessary first step in the development of the present facility, CLASS (Computer-Based Laboratory for Automated School Systems), which permits the simultaneous automated instruction of as many as 20 students, each student receiving an individualized sequence of instructional materials adapted to his particular needs.[33]

Education, of course, has always been a major social and political issue; nowadays we marvel at, or complain about, the power gained by the digital in the field of education, vastly increasing its grip since the 2020 pandemic. But as early as the early 1960s, the computerisation of the school and the university was on the move. The SDC's 1962 report *A Computer-Based Laboratory for Automation in School Systems* is a textbook on these matters.[34] The word 'cybernetics' is absent from the report, while 'computer' appears everywhere. The iconography includes photos and architectural perspectives of computerised classrooms where the students are sitting at single tables, reasonably spaced out, bearing cumbersome computer apparatuses. In the 2020–21 pandemic world such spacing resonates strangely, with a less progressive and optimistic tone. The decor of those classrooms bears an indisputable similarity with NASA's Mission Control room in Houston, which was designed at the same time and inaugurated in 1965. The teacher has a small command and control office next to the classroom. Among the eleven sources listed in the bibliography, the link with military's use of systems theory is clear: 'R. L. Chapman, J. L. Kennedy, A. Newell and W. C. Biel, "The Systems Research Laboratory's Air Defense Experiments". *Management Science,* 5:3, 250–69'. Thus, years before Buckminster Fuller promoted with gusto the idea in a 1963 lecture, SDC was already working on education automation.[35] SDC addressed several topics other than education automation and was virtually engaged in most of the large field of systems thinking. Simulation and modelling were also prominent on SDC's agenda.

Case 3: NASA

The *Apollo Program Development Plan* published in January 1965 by NASA captures exceedingly well the paramount importance given to systems thinking in the US space administration:[36]

> 9.9.1 Basic Objective
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> The basic objective of Apollo System Engineering Management is to establish a single reference base for the analysis, definition, trade-off, and synthesis of requirements and design solutions on a total program basis in order to provide clear and concise information flow between the Apollo Program Office, the Field Centers and their contractors. Design trade-off shall be made in terms of time, cost, and performance. Performance considerations shall include the various design constraints imposed on the program such as reliability, maintain ability, safety, human engineering, environmental constraints, transportability, operability, procurability, and producibility. The single reference base shall evolve in consonance with the design process and shall establish the basis for the identification, control, and accounting of the system as it is defined by means of configuration management procedures employing the concept of baseline management (reference Apollo Configuration Management Manual NPC 500-1).
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> 9.9.3.1 Baseline Management
>
> An underlying objective of Apollo System Engineering Management is to establish and maintain a system of control between Apollo Program objectives, design requirements, and design solutions of the various elements of the program at each design level.
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> 9.9.3.2 Engineering Process
>
> The system engineering process represents a systematic approach to engineering – the steps involved in the structured process are identical to those that are involved in any design process. As such, it becomes necessary to ensure that system engineering management becomes an integral part of the design effort rather than a parallel or reporting effort which duplicates the normal design effort. While the discipline necessitated by system engineering may initially require changes in internal procedures, this additional effort will be significantly offset by the advantages accruable through the use of the process. Once implemented, it is anticipated that the documentation and procedures required by Apollo System Engineering Management will become a natural part of everyday design business. Thus, the paper flowing between designers within a contractor's organisation will be the paper required by this system, the review procedures will be a normal part of the everyday management of the program, etc. To summarise, it is the full intent of Apollo System Engineering Management to prescribe and structure a process which is normal to everyday business rather than to establish a superstructure.
>
> 9.9.4 Summary of System Engineering Management Process
>
> *System Engineering requires a form of servo-loop feedback and the initial requirements for facilities*, personnel and procedures depends upon considering an initial equipment design that facilities will have to store and house; personnel will have to use

> and depend on; and procedures will have to describe to personnel for operation and maintenance. The initially predicted facility, personnel and procedure requirements resulting from these initial considerations of equipment are immediately fed back for a trade-off of total program element requirements and a more detailed derivation of equipment, facilities and personnel.[37]

In this NASA document, a ceaseless association, if not sheer fusion, between technical and management issues is accomplished like in no other. The *Apollo Program Development Plan,* dry and meticulous as a legal memo, distributed first to the institution's main leaders and thereafter more largely, stands as a manual we can consider, in its own right, as a genuine monument. It dictates nothing less than good behaviours to be followed at every level by everybody acting in and for the Apollo programme. Behave yourself systematically, if we can say so, with systems in mind. No surprise that during each important space flight sequence, Mission Control (Houston) and astronauts would utter the phrase 'all systems go'.

Chosen among test-pilots with a solid engineering background, astronauts became system engineers, participating in the design of the spacecrafts which would bring them to the moon, regularly meeting the makers in the different labs and factories, testing tirelessly not only the artifacts but, above all, the functioning of the systems they were part of. The three institutions TRW, SDC and NASA were the kind of places where the mingling of cybernetics and systems theory was taken to the highest degree. It is worthwhile studying the individuals who ran them and were instrumental in the achievement of their goals. To name and understand who did what and who invented what is a prerequisite when looking back into history; cybernetics has been well documented on similar grounds.[38] We must complement this knowledge with an enquiry into who was in charge in the realm of the operational field. From concept to action, who was instrumental? This is exactly where systems thinking comes in. A reminder of the careers and backgrounds of a few important figures in leadership positions active in those three sites of operation confirm how close their relations and their interlocking were in the context of the first space age.

For Case 1 (TRW), it makes sense to look at the figure of Simon Ramo. Appointed as a technical adviser to the Strategic Missiles Evaluation Committee (earlier called the Teapot Committee headed by no less than John von Neumann), Ramo was a prime architect of the first intercontinental ballistic missile (ICBM) programme before creating TRW with partners Thompson and Wooldridge:

> Systems engineering … played a prominent role at Hughes Aircraft Company, where Simon Ramo had assembled a skilled team of scientists and engineers to develop electronic gear for military aircraft and the innovative Falcon guided missile … Wondering how best to formulate and pass on the expertise necessary to address the complexities of missiles and electronic systems, Ramo began to promote the idea of an academic discipline of systems engineering. However, his first opportunities to pass along these ideas came not through publication but through his involvement with Schriever's ICBM program.[39]

Incidentally, Ramo was quoted in March 2020 in a feature article of the *Los Angeles Times* casting new light on a rarely treated subject in NASA's history:

> Unlikely partners put man on the moon. At NASA, Jewish and former Nazi engineers and scientists reconciled the past and teamed up to meet a monumental challenge … The German engineers not only helped land Americans on the moon, but played a key role across the nation's defense programs, and there too they collaborated with American Jews. Adolf Thiel was recruited to aerospace giant TRW's Space Park in Redondo Beach by its chief, Simon Ramo, one of the most important Jews in American aerospace. Thiel, a former Nazi Party member, rose up to run all

> of TRW's spacecraft operations, putting him in charge of the nation's most sensitive intelligence and defense satellite programs. During Apollo, TRW developed a revolutionary rocket engine with variable thrust that was critical to the Lunar Module's landing. Thiel and Ramo became friends, recalled Thiel's son, Michael.[40]

This piece highlights a new chapter in the history of first space age: rarely had historical events been so thoroughly live-documented, archived – notwithstanding some unfortunate episodes of lost archives – and professionally treated. NASA, following an old military tradition, founded a history department at its inception in 1958. Here, also, on the specific field of historiography, one is tempted to recognise the imprint of systems thinking allied to a strong political will to educate and to contribute to education. Control and command of the machines and, whenever possible by machines: computers, from design to operation had a parallel in the systematisation of a historical approach to every fact and event encountered during the successive Mercury, Gemini and Apollo programmes. It is true that some aspects were kept in the dark, whether on the ethical-political side – such as the Nazi technical legacy or the relations of Jewish and Nazi engineers as outlined in the *LA Times* enquiry quoted above – or on the more mundane topic of the astronauts' lifestyle, providing the better part of *The Right Stuff*, a 2020 Disney-produced TV series bending Tom Wolfe's famous essay towards private gossip.[41] With Case 2 (SDC), its in-house publications of the 1960s, especially the detailed resumés of prospective new employees, are a gold mine to be explored. As a sample of a career profile, we can quote from that of Stan Rothman:

> Prior to joining SDC, he worked at IBM and at RAND, where as a numerical analyst he was active in the development of a method utilizing Monte Carlo computations for a multidimension search by statistical techniques. He was head of the Operations Research section at General Electric and participated in technical direction activities at Space Technology Laboratories. As a member of the senior staff of Ramo-Wooldridge, he directed the development of the data handling portion of a ground system for 117L and participated in an Air Force-wide system study of intelligence data handling. At SDC, Rothman was among those responsible for the design and development of the Systems Simulation Research Laboratory. He was head of the Development Division's Space Systems Branch and in November, 1961, was appointed manager of the Satellite Control Department. He is a member of the Association for Computing Machinery, Institute of Mathematical Statistics, Operations Research Society of America, and the Society for Industrial and Applied Mathematics.[42]

One could mention many other profiles, all of them providing a faithful portrait of SDC, showing where its expertise, interest and involvement in systems theory came from. Equally informative but less well documented is the fact that, likewise in Santa-Monica, closer to the beach than the RAND/SDC campus, stood SYNANON, a singular commune which thrived in the 1960s and 1970s. Gerald Newmark, an SDC educator, lived there for a few years, putting in practice an idealist goal of sociological reform and progressive thinking.[43] SYNANON dealt with behaviour problems, or problems identified as behavioural, promoting new rules of conduct based on daily collective intro-and exospection meetings they called The Game. Among Newmark's friends were TRW engineers and managers. Thanks to introductions by Newmark I was invited to see a Lunar Module descent engine in the fabrication process at TRW's workshops in July 1968. This personal experience, as a teenager, is undeniably one of my motivations in starting to deal, if possible, critically, with an understanding of the first space age. Writing not only from second or third-hand sources and documents but also from remembered personal experiences provides less a pre-eminence than a forceful incentive.

Finally, with Case 3 (NASA), there are several central figures with published biographies. The curriculum vitae and seminal role of James Webb, NASA's famous head from 1961 to 1968 are well documented. Among other leaders, that of George Mueller is especially relevant to our enquiry.

Mueller was first a Vice President of Space Technology Laboratories (TRW) which aided the Air Force (USAF) missile programme, before becoming the deputy associate administrator of NASA and director of its Office of Manned Space Flight. In his days at NASA, Mueller was already considered 'a highly qualified import into NASA from Space Technology Laboratories, which played such an important role in the Air Force missile program'.[44] More recently, a biographer wrote:

> Mueller had the ability to analyse and understand systems and knew what it took to build complicated space vehicles. In particular, he could visualize a total system – hardware, software, people and processes – and everything necessary to accomplish the task at hand. A system engineer, Mueller knew how to apply it to management, using 'system management'.[45]

Mueller was indeed instrumental in the transition from system engineer to system manager. After his six years as NASA's associate administrator for manned space flight, he served as General Dynamics senior vice president and as chairman and chief executive officer for SDC. Thus, he neatly closed the ring, from TRW (STL, Space Technology Laboratories) to NASA and to SDC (RAND). Moreover, MIT appears at the centre between these three institutions, and even if this is no more than a logical result of a top university producing the best engineers and managers available in the country, an elite of some kind, it still has to be acknowledged. MIT was not only crucial in providing leaders for the whole programme, but even supplied staff to some of its opponents: 'Jerome B. Wiesner of the MIT, who urged that the new administration deemphasise human spaceflight initiatives for practical reasons: spaceflight was dangerous and unlikely to yield valuable scientific results, he argued'.[46] On the astronaut-pilot side, Buzz Aldrin, the second man on the moon, held a PhD from MIT. In summary, an observation to infer from our three cases in addition to MIT is that they operated as a tightly-networked team in the service of a great idea. At one point, something like a nation does coalesce in such a configuration, when precise goals are given, more than often in situations with external threats.

Back to the question of automation and the pilot-astronaut: it is noteworthy that the vast majority of failures in the first space age, and also, it seems, in the new space age, have to do with electricity, and more precisely, with electric interfaces such as sockets, plugs, switches and commutators. Electric flux to control mechanical apparatuses, and how it is managed, has always been a key element. One takes for granted the electrons flowing in copper wires and from there onto boards, printed circuits, then in chips and between chips. Electric and electronic malfunctions come from a very simple fact: the invisibility of the electric flux, the minimum visual presence of the wires and their tiny – micro and now nano – accessories carrying the flux. In this context, the Apollo Guidance Computer we mentioned earlier deserves a closer look. Its read-only memory (ROM) was made with cores (ferrite rings) and threaded wires: 'In the original implementation, the cores were strung out along the wires and not neatly arranged in a grid. Eventually, the design took on the appearance of a long bundle of cores and wire, looking like a rope with cores along its length.'[47] We can consider the core-rope ROM as a paragon of the place taken by copper wires in the system. Carefully woven by seamstresses, the central memory of the Apollo computers seems today both archaic and amazing. While holding the threads they wove in the precise pattern that would encapsulate the crucial software coding to run the Apollo Guidance Computer, these women actually had in their hands the supplest and most resistant computer hardware ever to be. They were crafting neither the heart nor the brain of the machine but weaving during laborious weeks the system itself. Core-rope hand-crafted assemblages were sharing the lead with the astronauts on the lunar missions.

Again, issues typical of the 1960s remain present in the twenty-first century and it appears that the first and the second space ages – also called old and new space – share a greater common ground than assumed. Just consider, in engineering, the sub-discipline of switchology – a well-found label if there was one – dealing with control via switches, push-buttons and triggers. Interestingly, automation in spacecrafts after Apollo followed a seemingly contradictory path on the piloting side. In order to decrease the pervasiveness of switches, the shuttle, designed in the 1970s, did not represent complete progress compared to Apollo: designed more like a mega-747 cockpit, with important computer power and fly-by-wire, it was packed with switches. One had to wait until 2020 and Space X's Crew Dragon manned capsule to introduce a no-switch environment – other than Soviet craft: the fully-automated and non-piloted early Vostoks. Certain contemporary space events show some overlap between historic space age and present day endeavours: think of two failed attempts to automatically land robots on the moon, respectively by Israel and India's space programmes.[48] Both crashes expose the paradoxical nature of sophisticated automatic systems designed to fly objects from earth to the moon with no pilots aboard. It can be seen as quite awkward, with all of today's computer means, to fail in 2019, at something that was first achieved by the Soviet Luna 9 on 3 February 1966, and four months later by NASA's Jet Propulsion Laboratory Surveyor 1.

Does the slowdown and falling curve of systems thinking since the 1990s have to do with the apparent loss of knowhow or, more precisely, of command and control? Is the deep cause a lack of cybernetics, systems engineering, AI, or all of them together? And 'who' is in charge now of the 'together', if not AI? The loop is once more closing back on the rather common question of governance and piloting, metaphorically and non-metaphorically. Always observe the pilot to understand what is going on, even if it is a fully automated pilot working on cybernetic feedbacks encapsulated in systems. Whatever the gap between old and new space, a direct link between them is exemplified by the recruitments made to create Space X: TRW veterans were instrumental in founding the company. In fact, to have the boldness to imagine bringing back a rocket's first stage smoothly to its launch pad, you need bold, ageing experts who were instrumental in the successes of the first space age. And, I would argue, one of the paths to those successes was a dedicated devotion to systems engineering and systems management. Impossible feats ask for a sense of possible extreme control and command, backed with up-to-date technoscientific knowledge.

Cybernetics gave way to systems theory at the very moment the Apollo programme was at its peak; systems theory gave way to AI and, finally, only one guiding watchword remained unchanged from 1945 to the present: automation. Thus, to deal with cybernetics now can only take place on a historical level. From Norbert Wiener to our own time, the very idea of cybernetics has evolved more than once. Wiener went from solving the pilot problem to solving everything, from a precise goal to an all-encompassing ideology, if not a metaphysics. But NASA, for instance, had no use for metaphysics when asked to land men on the moon, even if, ironically, such a feat did produce a few metaphysical questions. The truth is that when you focus on the operational quality, you discard ideology and keep going without the word, name, label of cybernetics. This is when systems enter the scene. The pilot problem, whether it is to kill an enemy pilot or to land a pilot on the moon, is a technical problem with technical solutions. The process of achievement relies, in the last example, on a systematic use of systems theory. No metaphor is involved here; the organic/machinic bind, so fundamental to Wiener's cybernetics, is of little use here. The power of cybernetics was the way it shifted back and forth from metaphor to non-metaphor, at a very fast pace, like an alternating electric current, to stick with metaphorical language. It was also its main weakness.[49] Ideology, however is never far away; impossible to erase, it stays in the background as a rumble, a white noise. It is noteworthy that Bertalanffy, who claimed to be the first inventor of cybernetics, at the same time avoided Wiener's label in order to promote systems theory instead. Ultimately, his success exceeded even his own dreams. What do we do, then, with this history of the paradoxical mingling and divergence of cybernetics and systems theory? Are there echoes or surviving effects in the twenty-first century's combined developments of AI, deep learning, algorithms, and big data? Observing the differences and similarities between the first and second space age offers clues as to what persists and what is gone. For instance, the pilot problem stays around despite the almost exponential build-up of automation at the end of twentieth century, not only in the field of actual flight or space flight, but in so many other domains. It persists in the background like a feeble rumour and the metaphorical figure of the pilot has not lost its strength.

The far-left and/or self-declared revolutionary – if such a label helps to locate this political and theoretical school of thought – while quite accurate in its harsh critique of the post-Marxists' positions on economics and capitalism (Negri and Hardt) reveals its technophobia when finally claiming the motto: to fight cybernetics instead of being a critical cybernetician.[50] By insisting that the greatest asset – and at the same time, failure – of cybernetics is its outrageous rationalisation, the far-left anti-cybernetics thinkers miss the main point: to shoot the moving target is a practical problem with no ideological rationalisation behind it. If a mathematical and computational rationalisation is needed to achieve the goal, then let it be. Landing humans on the moon was possible thanks to systems thinking plus a heavy dose of cybernetics and cybernetics-inspired technics, where it was never a question of too little or too much rationalisation. Succeeding in crafting a near-perfect weld on a piece of rocket or spacecraft depended heavily on talented gestures by an ingenious craftsman featuring a rational mind.

Half a century after the glorious years of NASA, the ambition to land men and women on the moon encounters similar issues. It finds most of its answers in techno-science inherited from cybernetics and systems theory: AI plus outstanding computation power. 'Shoot the pilot' triggered cybernetics; 'shoot to the stars' did so for systems engineering; 'shoot cybernetics' is of no avail. Cyberneticians reconfigured what piloting a plane meant, systems engineers what piloting a spacecraft meant. Wiener saw the pilot functioning as a servomechanism. From there on systems engineers carried the flight task up to the moon, where the man-machine interface anticipated what we are living now. As is often recalled, the origin of the word cyborg had to do with the concern about how astronauts' bodies and health could be enhanced in order to endure the hazardous and arduous constraints of spaceflight.[51] It is important to underscore the strength of the anthropological assemblage between what can roughly be called a strict method (systems theory) seen as a 'usage of the world' in part linked to cybernetics, and design and built artefacts under some precise global political wills and goals. In short, every single object produced in the course of the Apollo programme was submitted and integrated in this assemblage, including, needless to say, the pilots themselves. The pilot problem, redefined by Wiener, was reshaped under new anthropological parameters mixing things of different orders, scales and natures, put together, or more exactly, handcrafted together.

Cybernetics was not dissolved into systems thinking but taken to another operational level under the pressure of computation's compelling exponential progress. The so-called Cold War following 'plain' war offered the stimulus, and the 1960s space race was the new site of operation, the new battlefield long before the coming institution of space armies in the twenty-first century. If to disentangle the relations between cybernetics and systems theory seems a lost cause, paradoxically, the need to draw a dividing line between them still makes sense today. Whether this irregular borderline mirrors an ideological ground or follows more concrete predicaments, it is traced on a historical map of events, which as with any human matter, relies both on collective social factors and on specific actors holding key positions of knowledge and power. Now, since I am in part writing from the perspective of the architectural discipline, what lessons from this story can be drawn for our trade? In short, architecture seems to have missed a step or two during the last four or five decades. The works of Nicholas Negroponte, Gordon Pask, Cedric Price and other 1970s pioneers of architecture and computation were largely ignored by the profession. The digital turn of the early 1990s took at least twenty years to really integrate AEC (Architecture Engineering Construction)**.** Doesn't BIM (Building Information Modelling) appear as an extremely late integration of systems thinking into the architecture field? Everything, day after day, becomes semi-automatised and progressively automated from the design to the construction site.[52] Notwithstanding the limits of the pilot metaphor applied to architecture, we are today in a situation where the architect, technically, culturally and historically, seems to be sitting on an ejection seat.

Notes

This article is dedicated to the memory of Gerald Newmark (1926–2018).

1. Tiqqun, *The Cybernetic Hypothesis*, trans. anonymous (2014 [2001]), 11, https://theanarchistlibrary.org/library/tiqqun-the-cybernetic-hypothesis from *L'hypothèse cybernétique,* in: *Tiqqun* no.2, 'Zone d'opacité offensive' (2001). The Foucault quote comes, according to Tiqqun, from his 1981–82 courses.
2. Ibid.
3. Jamie Holmes, *12 Seconds of Silence: How a Team of Inventors, Tinkerers, and Spies Took Down a Nazi Superweapon* (Boston: Houghton Mifflin Harcourt, 2020).
4. Peter Galison, 'The Ontology of the Enemy: Norbert Wiener and the Cybernetic Vision', *Critical Inquiry* 21, no. 1. (Autumn 1994): 228–66.
5. Gilbert Simondon, *On the Mode of Existence of Technical Objects,* trans. Cécile Malaspina and John Rogove (Minneapolis,Univocal Publishing, 2017 [1958]), 51; my emphasis.
6. Erich Hörl, 'A Thousand Ecologies: The Process of Cyberneticization and General Ecology', trans. James Kirkwood, Jeffrey Burton and Maria Vlotides, in *The Whole Earth: California and the Disappearance of the Outside*, ed. Diedrich Diederichsen and Anselm Franke (Berlin: Sternberg Press, 2013), 121–30; cf. Erich Hörl, 'Knowledge in the Age of Simulation: Metatechnical Reflections', in *Simulation: Presentation Technique and Cognitive Method*, ed. Andrea Gleiniger and Georg Vrachliotis (Bâle: Birkhäuser, 2008), 93–105.
7. For an efficient recent introduction to pragmatist philosophy in relation to architecture, see *Footprint* 20, 'Analytic Philosophy and Architecture: Approaching Things from the Other Side' (Spring / Summer 2017) and, in particular, David Macarthur, 'Reflections on Pragmatism as a Philosophy of Architecture', 105–20.
8. This position is held by Jean-Pierre Dupuy in *The Mechanization of the Mind: On the Origins of Cognitive Science,* trans. M. B. DeBevoise (Cambridge, MA: MIT Press, 2000 [1994]). His 'Introduction: The Self-Mechanized Mind' (3–26) offers a valuable account of Heideggers' relation to cybernetics and of the French structuralist reinterpretation of cybernetics.
9. Lars Skyttner, *General Systems Theory Problems Perspectives Practice,* second edition (Singapore,World Scientific Publishing Co., 2005).
10. Ludwig von Bertalanffy, *General System Theory: Foundations, Development, Applications* (New York: George Braziller, 1969), 149–50.
11. To borrow from Ronan Le Roux's foreword to the French translation: Norbert Wiener, *La Cybernétique Information et régulation dans le vivant et la machine,* ed. R. Le Roux, trans. R. Le Roux, R.Vallée and N.Vallée-Lévi (Paris: Éditions du Seuil, 2014).
12. Cf. Fred Turner, *From Counterculture to Cyberculture: Stewart Brand, the Whole Earth Network, and the*

Rise of Digital Utopianism (Chicago and London: The University of Chicago Press, 2006). 'Even as they set out for the rural frontier, the communards of the back- to-the-land movement often embraced the collaborative social practices, the celebration of technology, and the cybernetic rhetoric of mainstream military-industrial-academic research.' Ibid., 33.

13. Today, Wikipedia remains the best source of synthetic, and fairly reliable knowledge one can have immediately access to for free. On its reliability, cf. it's own warnings at : *https://en.wikipedia.org/wiki/Wikipedia: Wikipedia_is_not_a reliable_source*, accessed December 2020.
14. Auguste Comte, *Système de Politique Positive* (Paris: self-published, 1929 [1815]), my translation. The full title of this four-volume work is *Système de Politique Positive de Traité de Sociologie Instituant la Religion de l'Humanité.* Comte (1798–1857), credited for the 'invention' of sociology, created at his home address the *Société Positiviste,* which published his work, available in two bookstores listed on the front page.
15. David Mindell, *Cybernetics Knowledge domains in Engineering systems* (Fall 2000, MIT), academic on-line paper. 'The original *Cybernetics* was filled with obscure and fairly irrelevant mathematics, which intimidated lay readers, so he (Wiener) followed the book with a popularized account, *The Human Use of Human Beings*. Ibid., 3. Mindell is Dibner Professor of the History of Engineering and Manufacturing at MIT, Professor of Aeronautics and Astronautics, and from 2005 to 2011, Mindell was director of MIT's programme in Science, Technology, and Society.
16. R. Buckminster Fuller, *Operating Manual For Spaceship Earth* (Carbondale: Southern Illinois University Press, 1969). Note that for the first printing in 1967, no publisher was identified. In our 2020 pandemic world one may doubt whether we are still on a 'spaceship', and if this stands for a closed system of precisely and well-controlled environment where humans can live in good health. Bucky's elegant metaphor of the 1960s has been turned upside down. Spaceships of the present second space age are explicitly becoming rescue rafts designed to let humanity escape for ever its derelict earth.
17. David Mindell, *Digital Apollo: Human and Machine in Spaceflight* (Cambridge, MA: The MIT Press, 2008); *Memoir* (Boston: Fort Point Press, 2018). This undisputed reference must be complemented with Don Eyles's *Sunburst and Luminary: An Apollo Memoir* (Boston: Fort Point Press, 2018), a remarkable account of his experience as a computer programmer for the AGC. Written in 2002, with no publishing company interested, Eyles created his own. Don Eyles presented a paper to the 27th annual Guidance and Control Conference of the American Astronautical Society in Breckenridge, Colorado (2004) entitled *Tales From The Lunar Module Guidance Computer.*
18. Cf. https://en.wikipedia.org/wiki/Operating_system (retrieved November 2020).
19. For a broader view of the interactions of mainstream technology with the radical and underground movements in the 1960s, see Diedrich Diedrichsen and Anslem Franke, eds., *The Whole Earth: California and the Disappearance of the Outside* (Berlin: Sternberg Press, 2013); see also: Felicity D. Scott, *Architecture of Techno-Utopia Politics after Modernism* (Cambridge, MA: The MIT Press, 2007).
20. Cf. Matthew Hersch, '"Capsules Are Swallowed": The Mythology of the Pilot in American Spaceflight', in Michael J. Neufeld, ed., *Spacefarers: Images of Astronauts and Cosmonauts in the Heroic Era of Spaceflight* (Washington DC: Smithsonian Institution Scholarly Press, 2013), 72–114.
21. Wiener, *La cybernétique.*
22. Zdenka Prokopova, Petr Silhavy and Radek Silhavy, eds., *Intelligent Systems in Cybernetics and Automation Control Theory*, (Cham, Switzerland: Springer, 2019), V.
23. Ibid., I.
24. J. B. Kendrick, ed., *TRW Space Data*, third edition (Redondo Beach: TRW Systems, 1967).
25. Ibid., 4.
26. To examine how Simondon's concept of objective concretization could be applied here would require an in-depth investigation.
27. Grumman company was a jet maker with sound experience in jets designed for aircraft carriers; landing on

a moving strip at sea is still one of the most testing pilot experiences. Fetish-wise, note that provided they have sufficient assets, space geeks can participate in the museumification of used or lost spacescraft: the owner of a major New Space company, Blue Origin – made billionaire by delivering books anywhere within a few days – financed the retrieval of Gus Grissom's sunken Mercury Liberty Bell 7 capsule in July 1999.

28. Richard Brautigan, *All Watched Over by Machines of Loving Grace* (San Francisco: The Communication Company,1967). The short poem was published in the collection of the same title, written during Brautigan's poet's residency at the California Institute of Technology in Pasadena, California, 17–26 January 1967. Cf. http://www.brautigan.net/index.html. My emphasis.
29. John Markoff, *Machines of Loving Grace: The Quest for Common Ground Between Humans and Robots* (New York: HarperCollins, 2015).
30. Lars Spuybroek, 'The Grace Machine: Of Turns, Wheels and Limbs', *Footprint* 22 (Spring/Summer 2018): 7–32; cf. his essay *Grace and Gravity: Architectures of the Figure* (London: Bloomsbury, 2020).
31. '[Wiener's] early efforts at computation and antiaircraft fire coalesced in a remarkably ambitious calculating device that he called the "antiaircraft (AA) predictor", designed to characterize an enemy pilot's zigzagging flight, anticipate his future position, and launch an anti-aircraft shell to down his plane.' Galison, 'Ontology of the Enemy', 229.
32. Architecture-wise, the nondescript office building of its headquarters in Santa Monica was analysed by Michael Kubo, 'Network Building: The RAND Corporation, Santa Monica', *VERB Connection* 3 (2004): 72–81; followed by Michael Kubo, *Constructing The Cold War Environment: The Strategic Architecture of RAND* (self-published, 2009), available for print on www.lulu.com.
33. *SDC Monthly* 6 no. 3 (March 1963): 1; my emphasis.
34. David G. Ryans, Don D. Bushnell and John F. Cogswell, *A Computer-Based Laboratory for Automation in School Systems* (Santa Monica: System Development Corporation, 12 March 1962), nineteen-page memo prepared for the United Nations Educational Scientific and Cultural Organisation's Conference on Development End Use of New Methods and Techniques in Education, Paris, March 1962. SP-256/000/01c.
35. R. Buckminster Fuller, *Education Automation* (New York: Doubleday, 1963); Claude Baum, *The System Builders: The Story of SDC* (Santa Monica: System Development Corp,1981).
36. NASA's Office of Manned Spacecraft, *Apollo Program Development Plan* (Burlington: Apogee Books, 2017 [1965]). This NASA document was originally prepared by Samuel Philipps, Apollo Program Director, and published on 15 January 1965.
37. Ibid., pages 9-22 and 9-23, sub-section 9.9, 'Apollo System Engineering Management' of Section 9, 'Technical Description & System Engineering'; my emphasis for excerpt 9.9.4.
38. For example, cf. Andrew Pickering, *The Cybernetic Brain: Sketches of Another Future* (Chicago: University of Chicago Press, 2011).
39. Stephen B. Johnson, *The Secret of Apollo Systems Management in American and European Space Programs* (Baltimore and London: The Johns Hopkins University Press, 2002), 50–51.
40. Ralph Vartabedian, 'Unlikely Partners Put Man On The Moon', *The Los Angeles Times* (1 March 2020), A1, A12, A13. Quote from page A13.
41. Walt Disney had, from before the start of the space race, teamed up with von Braun to promote his visions and projects for manned space exploration, and it is no surprise if, more than half a century later, Disney keeps banking on the topic. The novelty is the focus on the less-advertised human behaviour of the astronaut heroes, revealing in such a move an ironical involuntary insistence on pilots' behaviour on the ground, while cybernetics dealt with their in-flight behaviour. The overlap of the two is a classical trope of every astronaut's biography, culminating in the melodramatic film *First Man* (2019) based on Neil Armstrong's biography.
42. *SDC Monthly*, 21.

43. Gerald Newmark, human factors scientist at RAND Corp. from 1956–57 and System Development Corp. from 1958–1970, was involved in research and development activities related to the design, development and evaluation of innovative training and instructional systems for public schools and military programs. Cf. dedication above, before Note 1. On Synanon, see Christian Girard, 'Synanon: une "communauté" géante', *Le Monde* (10–11 November 1974), 10.
44. William Leavitt, 'The USAF Missile Program: Helping the Nation off the Pad', in Ernest Schwiebert, *A History of the US Air Force Ballistic Missiles* (New York: Praeger,1965), 201.
45. Arthur L. Slotkin, *Doing the Impossible: George E. Mueller and the Management of NASA's Human Spaceflight Program* (New York: Springer-Praxis, 2012), xviii and xix. A standard biography overloaded with redundant quotes by Mueller on the post-Apollo project he tried to continue at NASA.
46. Roger Launius, *Apollo's Legacy Perspectives on the Apollo Moon Landings* (Washington DC: Smithsonian Books, 2019), 36.
47. Frank O'Brien, *The Apollo Guidance Computer Architecture and Operation* (New York: Springer-Praxis, 2010), 37.
48. Israel's Beresheet lunar lander from Israel Aerospace Industries crashed on the moon in April 2019, as did India's Chandrayaan-2, developed by the Indian Space Research Organisation in September 2019.
49. Peter Galison, 'The Ontology of the Enemy', 249, relates how philosopher Richard Taylor accused Wiener of being too metaphoric.
50. Tiqqun, *The Cybernetic Hypothesis,* part. VI. This mostly rhetorical formula sets the limit of the manifesto.
51. The original first source on this topic is Manfred E. Clynes and Nathan S. Kline, 'Cyborgs and Space', *Astronautics* (September 1960): 26–27 and 74–77.
52. Christian Girard, 'Robots Don't Care: Why Bots Won't Reboot Architecture', in *Critical and Clinical Cartographies Architecture, Robotics, Medicine, Philosophy*, ed. Andrej Radman and Heidi Sohn (Edinburgh: Edinburgh University Press, 2017), 123–42.

Biography

Christian Girard, architect, PhD in philosophy, is Emeritus Professor of Architecture (Paris). His interests cover design automation, digital architecture, aesthetics and epistemology. Co-founder of the *Digital Knowledge* department at Ecole d'Architecture Paris-Malaquais, he has published numerous texts of architecture theory and lectured at international conferences. He contributed to the *Archilab* platform as a critic and moderator and served as external examiner at the Bartlett and at the AA in London. With his experience as a practicing architect, Girard works on a wide range of topics where technics meet epistemology. A Paris native, he relocated to the Corsican landscape, combining critical thinking and writing with stargazing. He currently writes on issues of control and design, especially related to space exploration, from the 1960s to the present day.