7   Science and Technology in South Africa: A New Society in the Making[1]

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Dr Franz-Joseph von Leinsdorf is [a scientist] absorbed in his work; wrapped up in it, as the saying goes, year after year the experience of this work enfolds him, swaddling him away from the landscapes, the cities and the people . . . .
    The shortage of skilled manpower brought about his recruitment here [in South Africa]. He has no interest in the politics of the country he works in (Nadine Gordimer, *City lovers*).

South Africa is in a period of transition[2] between two states of society: one obsolete and on the way out, the other under construction and on the way in. With the dismantling of the former regime and the difficult assembly of a new one, this intermediary period is proving decisive. Socio-political analysis shows how the discarding of the institutional rules of apartheid is also wiping out the reference points, values and norms that used to be the Draconian gel of a certain collective order (Darbon, 1992; Darbon and Faure, 1992). Decomposition, decay and disintegration are among the terms used to describe this situation.

    South Africa is not solely in the grip of *centrifugal* forces. This period of transition is also being propelled by centripetal movements or, to put it more precisely and in a less mechanistic manner, 'decomposition-reconstruction' dynamics with the involvement of fully-fledged actors (Copans et al., 1992). Cultural groups, trade union organizations or civil rights associations, for example, are becoming attached to establishing new cohesive bonds; through the associations they implement and the emerging 'social networks', they are progressively weaving a new societal fabric.

    This article intends to do its part towards the description of the reconstruction efforts by drawing attention to the ongoing action in a still unexplored yet vital sector—science and technology—which should be studied as cultural constructions closely related to the society producing them and whose sense of meaning they influence. They actually translate social conditions, while at the same time creating them too. S&T proceeds, in fact, from negotiations and the balance of power between entities—in

short, from associations of people and materials. Yet, they also shape the intellectual and physical world that constitutes, and is indissociable from, society.[3] This 'constructivist'[4] approach fittingly accounts for the current changes in South Africa. In revealing the actors-builders' blueprint, it above all enables us to outline the main themes of the reconstruction.

This chapter is divided into three sections. The first highlights the importance and characteristics of South African S&T research. The second shows its place in a social plan and how it is laying the foundations for the future. The third introduces its effects on pan-African industrial innovation and socio-economic development—levels where the very identity of South Africa is being redefined.

A Historic Turning Point for South African Research

It would be illusory to try and present an exhaustive report on the S&T system of South Africa. Just as with the country itself, the transitional and much debated situation characterizing it cannot be captured in a supposedly objectivizing portrait. Respecting this relative and temporary state of affairs, our adopted methodology deliberately works from two separate standpoints: one bringing out the sturdiness of the system and the other, its weaknesses. Together, they will produce a picture highlighting the contrasts of the S&T landscape. This blended vision will help relocate the system with regard to its economic, political and other stakes—in short, contextualizing it, like any other social and historical phenomenon.

An African Giant

There is no common measure between the research machinery of South Africa and that of other countries on the continent. For instance, it is often hard to know whether South Africa belongs to the category of developing countries or not: looking at its GDP one would be inclined to say no; yet, its structure and arrangement firmly suggest that it does. On the basis of scientific indicators,[5] the Republic of South Africa (RSA) would unquestionably figure as an industrialized country. In terms of contributions to world scientific production, as recorded in major American databases, it is ranked twenty-second, which is entirely respectable considering the country's size (Pouris, 1989). The local scientific establishment underlines this fact, comparing its research capacity with big Western countries rather than its African neighbours. True enough, the RSA alone produces a quarter of all the African scientific publications registered by the bibliographical databases. And the proportion is even greater in the area of hard sciences. Its many abilities cover a whole range of areas from all the natural and social

sciences through to aeronautics, telecommunications, science of materials and genetic engineering. The indicators show a considerable gap between the RSA and the next biggest country in Africa: Nigeria has five times fewer engineer-researchers and invests three times less of its GDP in research. And the configuration for Kenya, the third biggest country on the continent in this respect, is comparable to that of Nigeria (Pouris, 1991; Gaillard and Waast, 1992).

The scientific dividing line between the RSA and the rest of Africa is drawn on the basis of indicators that, somewhat ambiguously, reflect a particular form of research activity rather than a universal and homogeneous science. Some of the leanings of the international publication databases are now well-known: they implicitly record references more to do with a mainstream, mainly Anglo-Saxon, science while under-rating the locally edited production characterizing research in the Third World (Gaillard, 1989). Also, in describing Third World research on the basis of such indicators, South African research managers are in fact endorsing the criteria prevailing during their construction. They are not describing an absolute position for a system which is measurable and naturally commensurable to others; they are emphasizing a significant inter-comparability between mainstream science and their own. The phenomenon is indeed worth pointing out. It illustrates the socio-cultural nature of scientific activity whose 'modes of circulation', 'visibility' and 'style'[6] in the RSA bring it closer to that practised in big Western countries. Explanations for this can doubtless be found in the history of the South African scientific community. The fact that young researchers have frequently trained at British, Flemish or American universities, for example, most certainly has something to do with it. But we do not need to delve into the past. Determining the extent to which racial divisions still underlie the make-up of research staff today is convincing enough evidence of the meaningful social moorings of local science (see Figure 7.1).

The graph shows the overall magnitude of the gap between researcher-engineer racial populations as well as the recent trend to close it, which has amplified since the period considered here.

The institutional configuration of the South African S&T machinery is modelled on the traditional British pattern. Statutory councils manage and carry out research along the lines of divisions in large, very distinct sectors (see Figure 7.2). They employ a good many researchers in work that they lead for themselves. A significant part of their budgets nonetheless serves to finance outside (private or university) individuals or groups brought into their broadly selected and coordinated projects. So they deal with two branches of activity at the same time: one purely investigative, and the other administrative and tied in with science policy (see Figure 7.2).

Even before the recent political change, the machinery had been undergoing change for some years with the government instructing the councils

FIGURE 7.1
Number of White Research Staff Members and Others
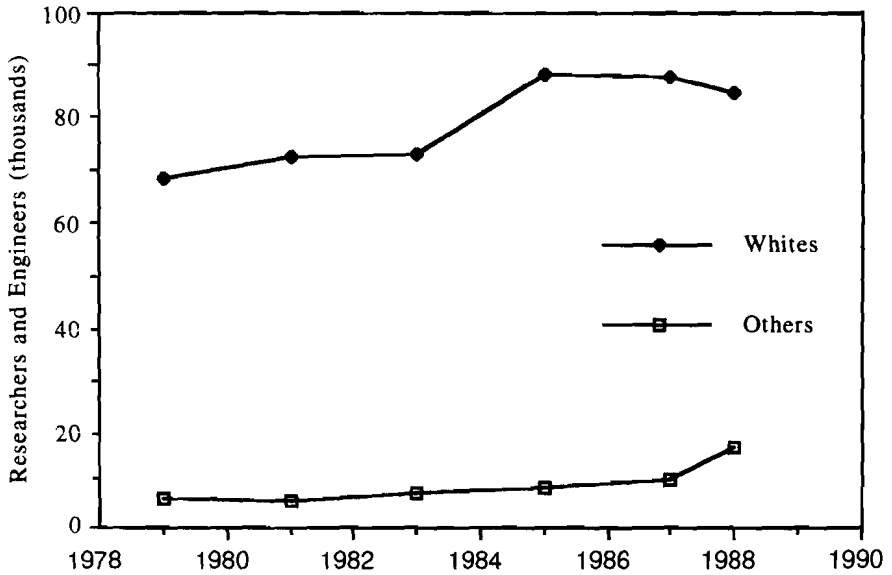
Source: Central Statistical Service, Manpower survey[7]

to take on greater financial autonomy since 1988. This was the 'framework of autonomy': a planned, yet rapid, state disengagement from the funding of activities of national scientific bodies.

Research policy had always previously been subject to voluntarist state-led action, managed by an 'interventionist' bureaucracy and organized with massive public investment. So why such a change? There is much more to it than just economic reasons or the need to relieve the pressure on state budgets in a period of economic crisis. On one side, the former regime's vital requirement to keep close and exclusive control over the basic power source disappeared as soon as the democracy process got underway. Elsewhere, the independence prepared by the 'framework of autonomy' was a way to protect its institutions from being called into question with the change of government; and there were people who were keen on keeping

FIGURE 7.2
Organization Chart of South African Research
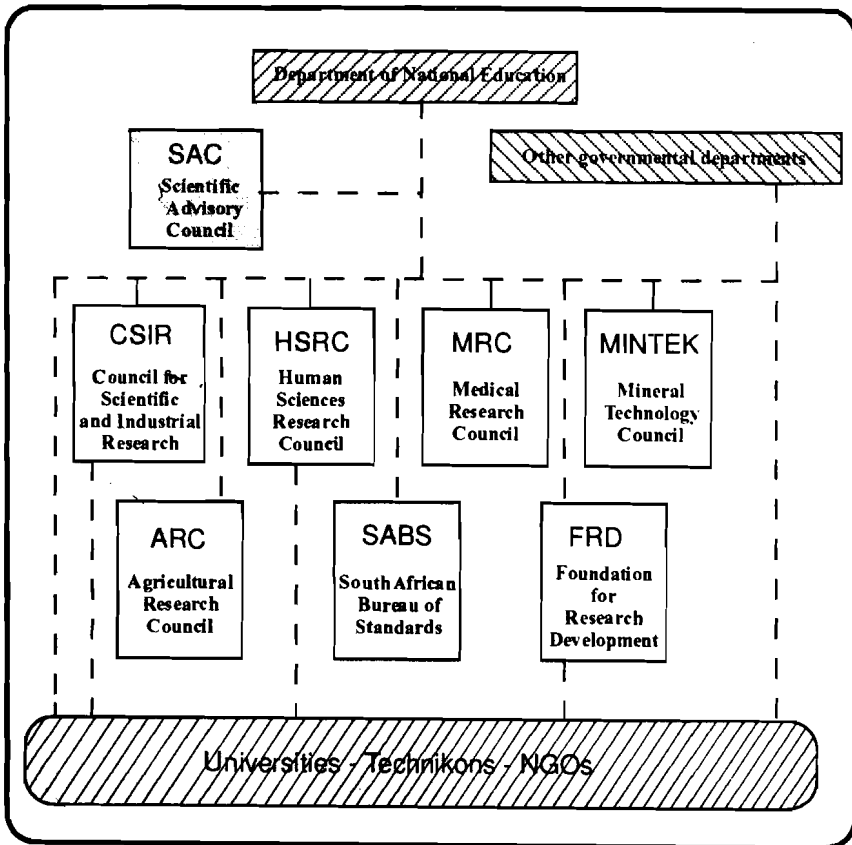
an outstanding, yet fragile instrument (that is, the South African research machinery), from falling into 'unsafe hands'.[8]

The Fragility of R&D

The research system's weaknesses can be seen not so much in its rather complete and diversified internal architecture as in its linkages with economic production and education in schools, colleges and universities.

First, we see the pronounced division between public research done by both the earlier-mentioned bodies and the universities, and the equally important research accomplished by private firms. The public sector contributed very little to the R&D of companies (see Figure 7.3) and they, in turn, hardly played any part at all in the investigative activities of

FIGURE 7.3
Company R&D Funding Sources
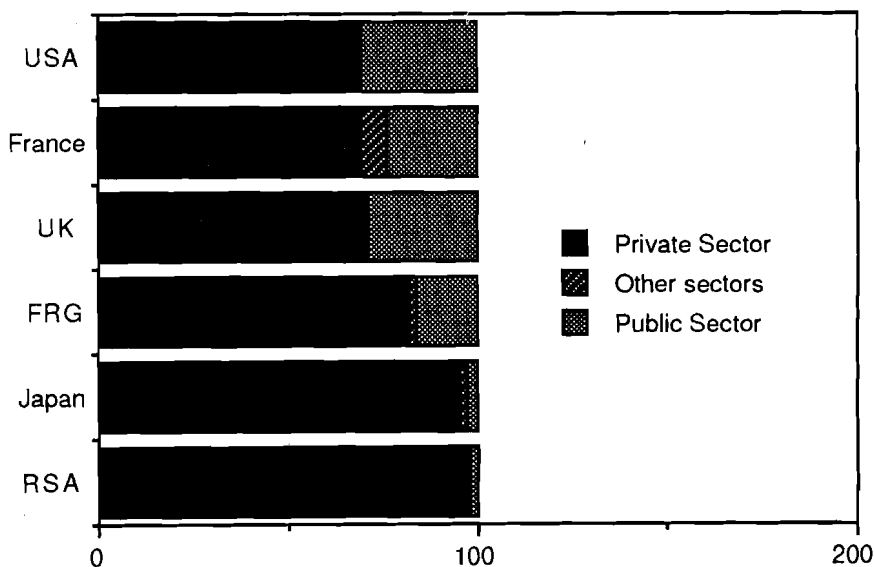
Source: OCDE, 1986[12]

public bodies prior to the recent age of autonomization. The fact that the two sectors are so completely out of joint is highly detrimental to the revival of the industrial system and, consequently, to economic growth. What the strategists of innovation in the RSA currently deplore is the absence of a technology policy and the difficulties involved in transferring science on to the market.

Over the past few years, an unfavourable economic trend has been setting in. The causes of the decline are many and much debated. Sanctions may be the more familiar of them, but they chiefly seem to have interacted with other phenomena, both circumstantial (e.g., droughts, falling gold prices) and structural (especially industrial obsolescence).[9] One identified factor is the drop in industrial productivity. Some studies point out that the apartheid system has left the work force deskilled and demoralized; others

refer more to the run-down equipment, antiquated manufacturing structures and the collapse of competitiveness (Harary and Beaty, 1989). In fact, the causes appear to be combined, often indistinct, cumulative and reciprocal—the crisis might be more precisely of a 'socio-technical' order (Gelb, 1991).[10] The production system's failure to generate the innovations it needs to remain competitive is especially due to the apparent shortcomings of the techno-economic networks. There is a 'technology' pole missing between the poles of 'science' and 'the market',[11] that is, the capacity, abilities, organizations and equipment able to design, test and develop artefacts in a collective and repeated process of innovation. The make-up of the South African R&D work force ostensibly confirms this fact: there are comparatively fewer engineers than researchers and their proportion has significantly diminished throughout the last decade, which saw a coinciding fall in the country's industrial production. It is a telling correlation which has drawn attention to some of the weaknesses of the South African education system.

Two avenues of technological training exist in South Africa, in two different types of institutions: universities and technikons. Technikons are colleges of higher education that aim to produce technicians specialized in various branches of industry and the service sector. Graduates should, in theory, eventually become the vital, highly-qualified employees that a highly technology-intensive production system on the lookout for planners has long been awaiting. Until now, technikons have, in reality, been considered as the poor relations of higher education: their teaching staff, resources, student numbers and the status of their diplomas are traditionally regarded as being of a lower quality and level than the universities. The universities, for their part, are unable to compensate for the lack of intermediary training in the education system. In fact, they themselves have to face their own shortcomings in terms of low numbers of engineering students. Exactly how low they have fallen and the manifest asymmetry between training in engineering and in the natural sciences can be seen in the graph in Figure 7.4. The imbalance is all the more striking when the socio-racial characteristics of student bodies are taken into consideration. Extremely few coloured teachers would be in a position to take charge of sophisticated technical activities, if there were no marked and rapid shifts in the trend.

The very low level of education in majority of the population seems to be a crucial problem for the development of South Africa (NEPI, 1993). And it has an effect on the numbers of researcher-engineers per social group. If the country wants its research system to be representative of the population and concerned with its development, its S&T staff has to be diversified. Yet, the pool of brains trained to undertake this is still very much dominated by a single colour: it is impossible to enrol fewer people from the Black, Mixed Race and Indian groups. Efforts in their school

FIGURE 7.4
Distribution of Students Per Sector and the Proportion of Whites, Indians, Blacks and Mixed Races in 1988
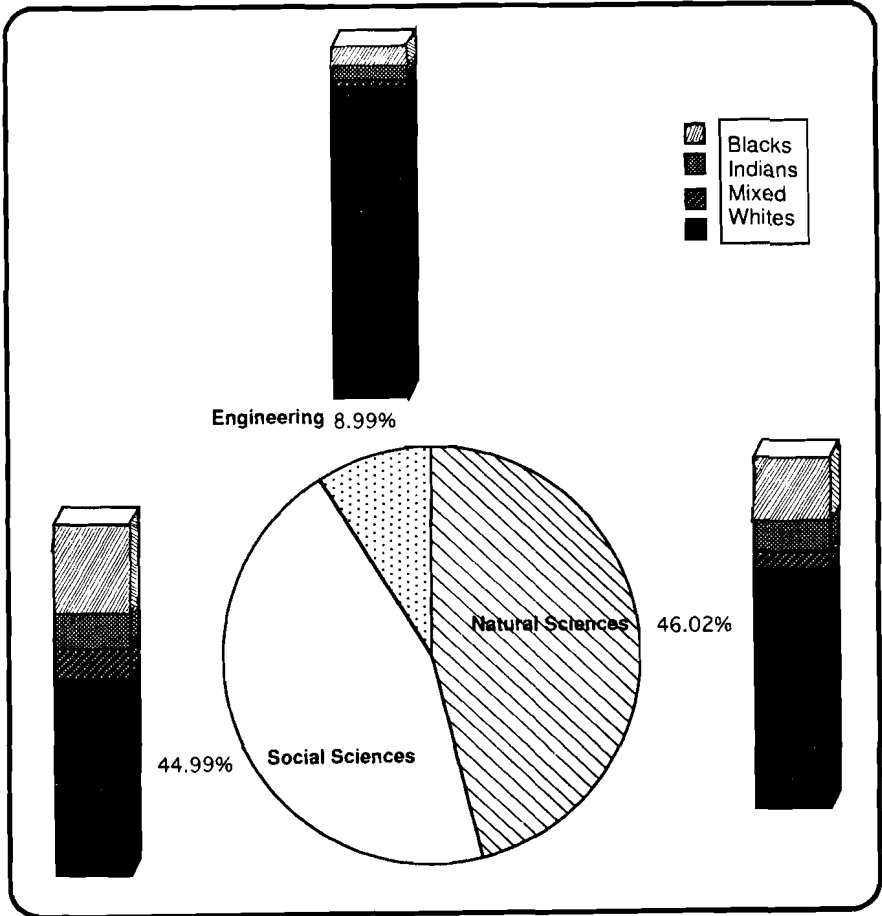
Source: Department of Education[3]

environments to raise awareness of the natural sciences and encourage familiarity with technology are embryonic.

The machinery of South African S&T is indissociable from the social, political, economic, educational and cultural challenges, many of which it also brings to light. Aware of its robustness and size, as well as the weakness of its training capacities, some actors have introduced it into the reconstruction debate and their social plan for a new South Africa.

Science and Technology Enter the Debate

In South Africa today, S&T creates a space where positions are taken up, interests are vested and stakes defined. Research is not just instrumental in the establishing of a new society. It is also fundamental or foundational insofar as it is where future solutions are tried out, and active forces express themselves and are tested. In such a climate of strategic positioning, some inspired actors are themselves creating the events that will enable them to acquire and consolidate their positions.

Strategic Deployment and Tactical Initiative

Research in South Africa is currently effervescent. One of the underlying reasons is the application of the earlier-mentioned 'framework of autonomy' which has caused great changes in the institutional and financial structures. Yet, there is also the fact that research is deeply affected and concerned by the ongoing transformation. Better still, because it draws up scenarios for the future, it plays a lead role in offering propositions. The preoccupation for research in the political debate grew alongside the feeling that the regime was about to change. A variety of different initiatives saw the light of day before F.W. de Klerk took office, and have proliferated since.[14] One of the initiatives that emerged was a complete mobilization of the research system through the unprecedented politicization of S&T issues.

   The democratic movement, a three-headed actor made up of the African National Congress (ANC), the COSATU group of affiliated trade unions and the South African National Council (SANCO) civil rights association, has sparked off a procedure subjecting the research system to constructive in-depth review. The initiative first consisted of assessing the institutional and organizational machinery of S&T, and then discussing its results with the people involved. The idea of an in-depth examination followed-up by an exchange with the people in-charge was put into practice with consummate diplomatic skill. Instead of directly opposing the upholders of the South African scientific establishment, the democratic movement brought in an initially fully credible third party—a panel of British, Canadian, Kenyan, Swazi and Jamaican experts—who did the assessment in line with an OECD-applied methodology ratified on the basis of a good number of earlier exercises in other countries and clarified at the outset. The operation received funding and support from the IDRC. The self-regulating, independent assessment mission lasted for fifteen days in December 1992. It visited all the main scientific and research organizing institutions, interviewed their managers and went through descriptive documentation. Its members then went on to analyze the data and write up a report entitled 'Science and Technology for a Democratic South Africa' in February 1993,[15] copies of

which were sent out to all the institutions they had visited. Their managers then had the chance to present to the panel their reactions for its advice at a one-day meeting held at the beginning of March. This top-level meeting constituted a truly historic event: it opened the first genuine forum for first-rate dialogue on research.

Before going into what the experts actually said, it is important to stress the effectiveness and reach of the method used. First of all, the evaluation exercise came off perfectly, with as full a review of the whole system as had been planned within the allotted time. Second, not a single institution nor South African research actor evaded or excluded themselves from the process at any time. Finally, following this first effort, the ins and outs of the system underwent a wholesale return to the drawing board. Research organization and its vocation came to form the subject of broadened and formalized public discussion. None of this had been sure-fire in advance; far from it. It was the first time that the managers of S&T had assembled (collectively and before witnesses) to consider the future role their fields should play in a democratic society. This consequently expressed a politicization of the field, enacted in a cool-headed, well-mediated fashion via a technical/managerial assessment exercise by an actor expected to bypass ideological meaning and personal interests and still get to grips with the most sensitive strategic issues. This assessment–discussion constitutes a really historic event that has had three effects:

- Research is no longer considered as an extra-social activity or one that transcends policy. On the contrary, it is recognized as being crucial and central to the development of the community in which it plays a part.
- Scientists are being called down from their 'ivory towers' to enter the social arena; although they undergo questioning there, they also negotiate their roles and acquire a formerly eclipsed dimension.
- The director staging this scenario becomes an unavoidable actor, an obligatory passage point in the emerging situation.

This last point deserves some attention, for it helps us to grasp the ongoing action and understand it without having to resort to outside explanatory factors. With this initiative, the democratic movement did in fact take on the role and status of a near-official interlocutor for South African research operators. Is this simply the conversion of symbolic capital acquired elsewhere and carefully reinvested here, just as S&T takes on fresh importance? Might it be a pure extension of the political field into a space naturally reinterpreted according to the new deal of the cards?[16] In reality, it is a more subtle phenomenon than that. There is far more to it than porosity between compartments of a multiple social reality or *political* overdetermination vis-à-vis the rest. The actors' genius in creating events and making history is what is at work here. Before them, science received no official

recognition whatsoever from the powers that were; it existed, of course, but only for itself, disconnected from the social issues to which it could never manage to make any more than a marginal contribution. Prior to the democratic movement initiative, though, could a scientist accept a politician as an able judge of research—especially anyone from precisely that militant movement? Actually, in this unprecedented relationship, it is politics and science that are being altogether reinvented through the mediation of the panel. For the process to succeed, the actors too have an interest in this redefinition, this new plan for sharing out status, abilities and attributes. The democratic movement is imposing itself on the scientific community as an unavoidable, skilled, de facto representative; indeed, not a single top-level manager withdrew from the assessment exercise or contested its good grounding. Conversely, the democratic movement has implicitly given institutions (issuing from the former regime) a central role and an ability to take part in working out the new South Africa.

This outline picture does not portray an irenic landscape, a consensual situation. One of the people involved, as it happens, has perfectly summed up this meeting as a 'marriage of convenience, not love'. The negotiations are indeed bitter and the legitimacies unstable, even hotly disputed. Research institute managers, for example, are calling for private sector speakers and representatives from other political movements to be brought into an 'inclusive dialogue process'. Meanwhile, the ANC laid the blame for the current crisis on the scientific managers so as to incite their obedience. In short, while there may be mutual recognition between the two parties, there is also continual bargaining over the bases of that recognition and the sense of authority.

Denunciation and Construction

Launching a public debate about research based on an assessment of the existing machinery is far from just a symbolic gesture; it has opened up a path to a critical, well-documented and argued report on the state of the system and its vocation. At the same time, this review work has been backed up by an effort to make concrete proposals; here again concerning both organizational and institutional layouts, and the deep-seated scientific and technical orientations of the programmes.[17]

The assessment brings one of the South African scientific community's old-fashioned attitudes right up-to-date. The community used to like to represent the world of research as a 'republic of science',[18] governed by purely intellectual and apolitical laws, and totally foreign to social life. The ANC refuses such an exoneration of responsibilities in contemporary historical phenomena and, on the contrary, urges research officials to assume them entirely. In so doing, it is paradoxically reassuring the scientific community by expressing all the respect it has for their activities. Indeed,

the ANC maintains it will give research a central place in the very areas where scientists feared it might tragically lose out to socio-economic priorities (teaching, basic healthcare, employment, etc.). It has stated that rather than the question of a choice between healthcare and research, for example, the latter will be used in the development of the former. In fact, if the citizens of the 'republic of science' had been 'waiting for the barbarians',[19] they have found to their relief that the people they are dealing with intend to safeguard many of their treasures. The democratic movement recognizes the quality and consistency of the country's S&T machinery; there is nothing like it anywhere else in Africa. It maintains a wish to thoroughly transform it, yet also to keep what is good. While this (cautious) discourse is clearly not without ideology, it is above all else the pragmatics of action that clearly show through.

One major point of discussion has been the power to decide in science policy matters. The assessment mission denounces the 'policy vacuum', the dissolving of responsibilities and the absence of strategic perspectives in matters to do with the country's research. Many opinions converge on this. This opaqueness, the vagueness, and the inconsistency and incoherence in decision making are forever cropping up in comments describing the current situation. Simply a problem of bureaucratic management? That is not the way the ANC, for example, sees it. Their analysis explains the state of affairs historically. The 'policy vacuum' is a recent phenomoenon, stemming from the socio-political transformation of the South African state. With the abandoning of apartheid, the systematic security policy would become useless and drained of one of the major secret components of its vocation: the techno-scientific apparatus. Deprived of its centre, the backbone linking it unofficially yet effectively to a coherent policy, it would lose its sense of direction. The democratic movement tends to counter this by reallotting it a very strong social meaning—this time official and in response to the needs of the majority of the population.

The democratic movement's analysis stands as a shining example of the problematization of a situation.[20] Starting with a well-constructed report and formulation—the 'policy vacuum'—one ends up reconsidering the very foundations of the system. This approach does not meet with the automatic approval of all the actors. Some judge the 'policy vacuum' to be a rhetorical formula describing a situation they consider to be far less alarming in reality. Others recognize the vacuum, yet put it down to different origins: the 'framework of autonomy'. They go on to attribute inoffensive consequences to it: this decentralization plan would mean flexibility and independence more than indecision or incoherence. Finally, still others express doubts about whether it is possible or relevant to align science with a population's needs; it would appear to be an unnatural marriage likely to destroy the performance of the South African system.

Despite the alternative visions, the majority of actors converged to the democratic movement's general option. Most top-level managers of public

research institutes subscribed to the idea of re-orienting the research system towards matters concerning society as a whole. This was no magical convergence; rather, it was the result of careful groundwork on the part of the democratic movement: the assessment exercise, the public nature of the meeting, its very title and the preparatory documents defining the main lines of discussion—all points that both created and contained the area of debate. The fact that S&T and its problematization with regard to socio-political issues are now subject to discussion is well and truly the fruit of constructive work.

In the end, the collective negotiation exercise instituted the needs of the majority of the population as a fundamental priority in reconsidering a system. The whole matter then became one of identifying those needs and the ways to meet them. On the organizational and macro-social level, the required changes would seem clear. First, there was no avoiding a change in resource allocation. The highly research-intensive, sophisticated military technologies (the pride of the South African 'military-industrial complex') will have to have their scientific and economic facilities partially turned over to more constructive ends. So, the symbolic shift from security to development options is thus plain to see. Yet, for all that, the practical difficulties have not been eclipsed: many actors present the reconversion as requiring time and a well worked-out strategic definition. Another sector closely related to this has also been put on the hot seat— the nuclear sector. The Atomic Energy Commission, which manages the South African nuclear programme, appears to be an efficient institution; yet it is expensive. Although its reactors are running well and giving full satisfaction, it costs the government 700 million Rands a year to produce nuclear fuel or goòds that will be worth no more than 220 million within a matter of four years.[21] It has to be reassessed according to technical, economic and political variables that hardly make a very favourable case: availability of coal reserves, the hydroelectric potential, and the disappearance of the security argument and force-related legitimacy. Orienting a system adapted to serve the minority is discussed with just as much severity. The assessment mission cast doubts on whether the upkeep of costly equipment, such as the particle accelerator—the finest jewel of a luxury techno-science rather than a public utility—is appropriate. In most cases, unbearably high-cost end applications, like nuclear cancer treatment using the accelerator, concern a proportionally small, privileged section of the population. Meanwhile, developing more primary medicine for categories of people deprived of healthcare structures would constitute a more judicious use of the same resources. Therefore, at the very heart of the systems being planned, there are highly political priorities at stake where the choices clearly involve a vision of society.

Whereas re-orienting the system towards the needs of the majority appears to be a concrete and syncretic objective, identifying them is proving complex. Some researchers say they need to be translated into an

understandable demand. So who is best fit to do the translating? Which actors represent the majority? Who can set forth the needs calling for an element of research, according to individual cases and in various fields?[22] Everyone, in fact, agrees that the population's living conditions appear so heterogeneous and misunderstood that the demand can only come to light via credible intermediaries. Here again, introducing legitimate represent-atives is most easily accomplished at the institutional level. Suggestions with regard to this have been issued by the democratic movement. With the statutory overhaul of their boards of governors, the councils should be able to quickly open up and reflect racial and social plurality at this level. Affirmative action to recruit non-white researchers at the research operator level already seems more problematic. Systematic application in fields, where exceptional rather than interchangeable actors are by definition crucial for building and retaining ability, is not helped by the difference in training levels between Blacks and Whites. Consequently, it has become an essential objective to reform the education system, and both the teaching and widespread cultural dissemination of S&T among the population. This involves long-term change; science here is no longer in the unilateral service of society: the latter has to meet the demands of the former—a reciprocal arrangement. This two-way movement is also expressed in attempts to define the representation of demand. As such, in think-tanks, actors from civilian society, the unions and associations often emerge as the most credible representatives of majority needs and the intermediaries between those needs and the science producing the innovations intended to meet them. Now the sphere of association and union is showing itself to be indulging in intense training and research activity, and clearly anxious to understand and manage S&T developments.[23] These are plainly central to the development perspectives now being freely considered with regard to Africa as a whole.

An African Avenue of Development

'New South Africa' intends to take up a totally different position in the international community. Rather than just a matter of an inevitable opening up with the lifting of sanctions, or a blind belief in doing so, this is a matter of South Africa genuinely redefining its status and role within that com-munity. S&T innovations allow one to put forward an explanatory hypo-thesis on the ongoing changes, bringing them into a long-term historical perspective.

A Policy of Innovation for a New Identity

South Africa is changing references: it sees itself less as a real industrialized country and more in a state of development. This is patent in both the discourse and strategies induced by that change of reference. In finally recognizing the 'African' majority of its population, the country is also reconsidering its enrollment into world society. In reducing its 'European' ancestry to a minimum, South Africa is partly identifying with other Third World countries and with its African neighbours. Its ongoing internal reassessment is coupled with external repositioning in the international networks. In the scientific and technological fields, this phenomenon is being expressed in a particularly acute fashion.

The public bodies, chiefly HSRC, Medical Research Council (MRC) and CSIR, are drawing up programmes with an emphasis on 'community problems'. Their referent for naming, designing and organizing programmes thus becomes the Black population, in the generally perceived and accepted sense of the term. This designation is accompanied by a cognitive change of which the bodies are aware: many community-related problems need new categories of learning, new methods of work and new conceptual tools. Research bodies are increasingly opening up to the international sphere, chiefly with a view to equipping themselves or perfecting their abilities in those areas where tropical and *tropicalist* institutes operate.

In considering the problems of illiteracy, agricultural food production, hygiene and the environment, the public institutes are picking up on experiments conducted elsewhere in Africa and issuing proposals for the continent as a whole. The case of CSIR speaks for itself; it has been developing an authentic African sector of activities, coordinated by an 'African business development' director. This is essentially a matter of a programme applying South African expertise to development projects. Chiefly financed by multilateral agencies, these are already stretching well beyond southern Africa to the fringes of French-speaking Africa. There is obviously a higher concentration of efforts in the former though. For example, the electronic network starting in Pretoria with international connections via the Cape, has linked the country's academic community with its counterparts in the big OECD countries and also its immediate neighbours, who were actively encouraged to plug in. Regional cooperation in the actual managing of research is intensifying at a very fast rate. In June 1993, the FRD held a conference in Pretoria in conjunction with the United Nations African Economic Commission and the Organization of African Unity (OAU) under the title 'Development of a Sub-Regional Science and Technology Policy in South Africa'. All these initiatives go hand-in-hand with, and very often precede, the growing attempts at regional reconciliation, be they commercial or otherwise.[24]

The rest of Africa expresses a firm interest in seeing the country extend the benefits of its abilities throughout the continent. The panel of the reassessment mission, by the way, recommended that South African researchers become more involved in the continental scientific community. In January 1993, the first round table of scientific advisors for 'science-led development in Africa' was held in Nairobi. Its theme was 'Managing Science and Technology for the Rapid and Sustainable Development of Africa'. South African representatives, from non-governmental academia, received their first ever invitations to attend. Their colleagues showed how keen they were on seeing South Africa play an active part in the endogenous continental constitution of the science-led development base, without excessive interference on the part of non-Africans. Considering the call for a repeat of the exercise, even at the governmental level, this kind of approach has every chance of being developed in time. The country's research capacity is consequently acting as a real catalyst for the African scientific community.

The Africanization of the mode of development is particularly strong in the linkages between S&T policy and industrial growth policy. In the face of the structural problems confronting the South African economy, there is agreement on the need for industrial redeployment. The whole question is to determine the branch, subjects and methods to adopt. Two possible strategies have been put forward: one favours industrialization based on internal markets or 'inward industrialization'; the other, on the contrary, is 'export-oriented', recommending the production of goods and services for export.[25] Actually, a synthesis of the two options is emerging with a judicious international arrangement in the bargain. This involves identifying the sectors where goods satisfying an internal demand are also suitable for the international market. This is especially likely with regard to the demand of developing countries—African countries to be precise. Their demand has some characteristics in common with that of the population of 'New South Africa'. An industrial system might also be designed to choose to invest in market gaps untouched by big industrialized countries.

In the telecommunications sector, for instance, telephone equipment is in very short supply among African populations (Kaplan, 1990). Their needs and purchasing power scarcely correspond with the models of big international firms. There would thus be very promising work in artefact design, mass production and distribution networks. Yet, to be worthwhile, items should be manufactured in anticipation of resulting markets in Africa as a whole. Rather than intermediary technologies, as these are obviously very sophisticated, we are talking about a median position where technological creation is considered in terms of the demand. South Africa is moving its capacity down from a very fundamental 'uphill' position where it excels, to bring it closer to the preoccupations of the population (Erwin, 1992). For all that, it seems vital to the country's powers of creation and

even technology transfer to maintain the scientific resources.[26] With constant inputs from an active and partially finalized science, technology transfer is what will enable the RSA to immediately set about gaining successive footholds in every African market, from the south through to the north.

Conclusion: Long-term Prospects

The earlier sections emphasize the actors' work and the radical changes incurred by it. While leaving its historical authenticity, singularity and specificity apart, a broader understanding of it can be gained by reinscribing it into the long-term movements that it extends and expresses. This way, we can grasp a deeper meaning of contemporary phenomena without impairing their uniqueness.

The paradigm notion appears very useful for understanding current developments from an historical viewpoint, associating S&T with society and the economy. Without causal determinism, it takes regularity, conformity, equivalence and interdependency into account along with sociotechnical changes, and enables an account of the way current events are interrelated. The technological paradigm is a sum of all the equipment, procedures, know-how, training methods, industrial organizations and work management, which together coordinate production and innovation activities.[27]

The paradigm constitutes a material, organizational and institutional cognitive framework within which action is deployed. But it is temporary: paradigmatic revolution occurs when the existing paradigm proves incapable of responding to a situation, at which point a new framework is then required. The techno-economic paradigm is an extension of the concept, superimposed on economic development cycles.[28] Generally speaking, the twentieth century can thus be seen as a succession of paradigmatic phases: industrialization with heavy infrastructure, followed by *Fordism* and mass production and, finally, the advent of information and communication. Each sequence has its corresponding generic technologies (e.g., electricity, the automobile and computers respectively), working methods and individual levels of qualification. These cycles can be applied to the history of South African industrial development. During the first-half of the century, a mining paradigm prevailed with a whole sophisticated organization to exploit cheap immigrant labour, which chiefly enabled technical innovation to be delayed in various sectors. The period opened with the decision to exclude Blacks from skilled labour and the building of a single national state established under the aegis of the British crown and integrated into its exchange channels. The subsequent sequence of 'Racial Fordism'[29] corresponds to the advent of the Republic, the arrival of apartheid, authorizing of an exclusively 'White' mass market, the oligopolistic structuring of the

South African economy, its industrial diversification with recourse to varied manufacturing techniques, etc. The present-day, socio-technical changes could correspond to a paradigmatic revolution where the internationalization of the economy, the highly science-intensive technologies, the importance of qualifications and industrial flexibility could no longer fit in with the alignment of socio-professional and cultural relations upon racial divisions. This is a simple hypothesis and the temporal correlation definitely deserves in-depth observation and detailing. Yet, it opens up a line of explanation which affords a fuller understanding of contemporary phenomena in South Africa. With it, we can reconstitute the sequences of a basic evolution with the mutual effects of the events. Beyond a univocal logic of successive phases of capitalist development (Morris, 1991), however, it explains the socio-economic transformations through technical and social convergences, the most accomplished combinations of which scan the course of the country's history.

S&T in South Africa really does appear to be a major element in the broadened social reconstruction underway in this country. It is an entity sometimes mobilized by the actors and sometimes itself producer of society, though definitely never disconnected from the ongoing changes. South Africa presents a totally unique situation. Nonetheless, the analysis presented here could enable one to look at it alongside many other changing countries where dominating secular relationships are in play under conditions of extreme tension. In this sense, the social study of S&T takes its place in a 'comparative sociology of the transformations',[30] renewing development approaches for the better.

Notes

1. This text was written prior to the change of government in South Africa and Mr Mandela's administration's takeover; as such, the new policy may have begun resolving some of the problems presented here. Having said that, the basic S&T issues at stake in the social recomposition as stated here remain as relevant in the current context of this country. A slightly different version of this text in French has been published under the title, 'Science et Technique en Afrique du Sud'. *Afrique Contemporaine*, 172 (October–December), 1994, 186–99.
2. The 'L'Afrique du Sud en Transition' conference was held in Paris in January 1993. The proceedings were published in 'Les cahiers du DEFAP', March 1993.
3. The new sociology of science has opened up an avenue of analysis in terms of associations between entities and heterogeneous actors which create 'worlds' (see Callon and Latour, 1985; Callon, 1990).
4. Two constructivist approaches can be distinguished in the sociology of S&T: the first considers that determinations between science, technology and society are symmetrical, neither having pre-eminence over the other in building worlds (cf. the authors cited in note 3); the second approach gives priority to the human social actors who are building structures that reflects and satisfy their pre-existing group interests (cf. in particular, Pinch and Bijker, 1987). Both approaches nonetheless have the same basic characteristic, that is,

showing the interdependence between social content and the content of S&T; they contest the classic epistemological vision completely isolating these contents, attributing a neutrality to scientific activity and to those doing it, as Nadine Gordimer's opening quotation marvellously illustrates.

5. Quantitative data on the size of its resources and facilities or its production figures, e.g., publications or patents. For a discussion on the scope and relevance of these indicators see Arvanitis and Gaillard (1992); see also Chatelin and Arvanitis (1992).

6. On styles of science, see Botelho (1995).

7. Figures supplied by the Foundation for Research Development (1991).

8. Take the telling example of the nuclear debate prior to the recent change of government. Before announcing that the RSA had for some time been in possession of the atomic weapon, F.W. de Klerk chose to dramatize the fact by first convening a surprise session of the three chambers with a view to informing them. There could not have been a better way to underscore the public and socio-political nature of the ongoing techno-scientific debate. It was also a shrewd way of laying out the three points of the 'framework of autonomy' programme: showing, through an a posteriori openness, that the political powers were no longer playing the role of the sorcerer's apprentice and thus reducing the 'Armageddon syndrome' affecting South Africa; nipping likely attacks on a system with a marked military calling in the bud, purging it of its most hotly debated elements; finally, ensuring these paragons of power and sovereignty did not fall into the hands of a state whose behaviour might (at that time) have been considered dubious.

9. See in particular Coll (1992).

10. On socio-technical hybridization, see Latour (1991).

11. On the science—technology—market networks, see Boyer et al. (1991).

12. Figures supplied by the Foundation for Research Development (1991).

13. Ibid.

14. Although it is impossible to describe all these initiatives, many of which were localized and spontaneous, some can be mentioned. First, the statutory councils (especially the Council of Scientific and Industrial Research [CSIR] and Human Sciences Research Council [HSRC]) have undertaken extensive restructuring since the mid- or late eighties. Second, at the beginning of the nineties, universities (Cape Town, Durban) have organized major meetings with the participation of foreign specialists or institutions such as the International Development Research Centre (IDRC) to discuss the S&T issues in the reconstruction process. At the same time, the then new Policy and Assessment Centre of the Foundation for Research Development (FRD) carried out a comparative and critical analysis of the South African research system with those of certain OECD countries. Among others, see Coll (1992); Foundation for Research Development (1991).

15. The mission wrote its 'Science and Technology Policy for a Democratic South Africa' report under the supervision of James Mullin.

16. The notions of 'symbolic capital' and 'field' have obviously been borrowed from Bourdieu; for an introduction to them see Bourdieu (1980).

17. In the sociology of science, this is where we see all the difference between two approaches: first, the institution approach analyses the relationships between groups or individuals acting in the scientific sphere, yet refrains from exploring the social content of the science itself (see Merton, 1973); after the pioneering work of the sociology of knowledge or the history of science (see Needham, 1956; Kuhn, 1962), the second approach enters the 'hard core' of scientific activity to discover the social factors at work there under various forms (see, among others, Bloor, 1976).

18. An expression by Polanyis, quoted in the report prepared by James Mullin (see footnote 15).

19. A metaphorical use of the title of J.M. Coetzee's famous 1981 novel, *Waiting for the Barbarians*, which describes the ignorance and fear in the face of approaching otherness and interactions with it.

20. On the problematization and the performative as much as resolvent translation operations, see Callon (1986).
21. See the report prepared by James Mullin (refer footnote 15); and for further details on the South African nuclear programme, its international implications and associations, see Lory (1990).
22. Beyond the distinctive features of the South African situation, the question of demand, accounting for and, therefore, representing it, is at the heart of the innovation process; see Meyer (1992).
23. See Bird (1992). The notion of a 'labour-based approach' with technological development being compatible to the employment of an abundant work force, is coming mainly from these actors; on this approach see McCutcheon et al. (1992).
24. On the dynamics of regional integration and its implications, see Maasdorp (1992).
25. For a detailed description of the terms of the debate and a synthetic approach, see Freund (1992) and Kaplan (1991).
26. The existence of a research-specific capacity is vital for absorbing the fruits of research carried out in other countries and adapted to local conditions (see Gaillard, 1991). Conceiving an applied research and banking solely on it at the expense of basic research completely sterilizes a national science system (see Arvanitis, 1990).
27. Evolutionary economists have borrowed the paradigm concept from the science historian Thomas Kuhn. The prime example is Dosi (1982).
28. Kondratieff's economic cycles have been tied in with major technical innovations by Schumpeter (1939) and extended to a globalizing socio-economic approach by Freeman and Perez (1988).
29. See Gelb (1991).
30. On the 'comparative sociology of the transformations' see Schlemmer and Waast (1992).

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