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Aggregation Machines—A Political Science of Science Approach to the Future of the Peer Review System

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Peer Review of Proposals and Funding Agencies as Aggregation Machines

Peer review of project or program proposals must somehow assess research that has not yet been done, but still must be judged. This task is given by funding agencies to their referees, positioning them as unwilling futurologists. Some fifteen years ago, the British physicist and science analyst John Ziman captured their quandary in his phrase about peer review of proposals being "a higher form of nonsense." (Ziman, 1983)

Ziman then went on to argue that funding of science should not be based on project and program proposals judged by a version of peer review, but on track record. Past performance would make scientists eligible for further funding, and there would be additional ways to support "young blood." Peer review would remain important to interpret performance indicators and translate them into an overall judgement. His proposal has in fact been implemented for the funding of university research in the UK and the Netherlands, but not for funding agencies like the UK research councils, Dutch NWO, and the U.S. National Science Foundation and National Institutes of Health. A system based on track record or formula funding, while it has been advocated by critics of peer review of proposals (e.g., Roy, 1985), would have undermined the raison d'être of fund-

ing agencies as an intermediary sponsor of research between the state and individuals and institutions at the research performance level.

It is possible to criticize Ziman's proposal for judgement on the basis of track record in terms of his own analysis. It does not do away with the nonsense: when scientists judge the value of a piece of research or the track record of a scientist or a research group, they always relate this to ongoing developments in relevant areas of science and the potential of the work in this respect. In other words, there is already some futurology involved in assessing past performance.

Rather than criticize attempts at futurology, however, one should inquire how funding agencies and their referees have been able to manage the nonsense. I start from the other side, as it were. Over time, practical competencies have developed to handle the appraisal of proposals, and it is such competencies which keep the nonsense within bounds.

This development is bound up with sponsors and their need to get advice from competent and trusted people before deciding to spend resources on a promising proposal. From Galileo at the court of the Medici in Florence, to publishers of books and journals from the seventeenth century onward, and to U.S. scientists trying to get the Mohole project funded in the 1960s, there have been princely and other patrons of science who needed such advice.[2] A tradition developed where such advice could and should be asked of the "peers"—i.e., the colleagues of the applicant (who often compete with him/her for resources)—and through experience and education, peers became competent to give advice (the one more than the other).

I am not saying that these competencies are perfect and everything is going well in the best of all possible worlds, only that workable practices have evolved. In particular, the sponsor's risk of getting entangled in a promising but not feasible and/or not relevant proposal is reduced. In fact, many of the criteria and practices of appraisal of research proposals are geared to reduction of this risk for the sponsor: Is the proposal, with its plan of work and institutional context, worth the risk of funding it? Is the proposal credible, does it deserve some credit? The various aspects involved must then be combined in one overall rating, a letter (A, B, or C) or a number on some scale.

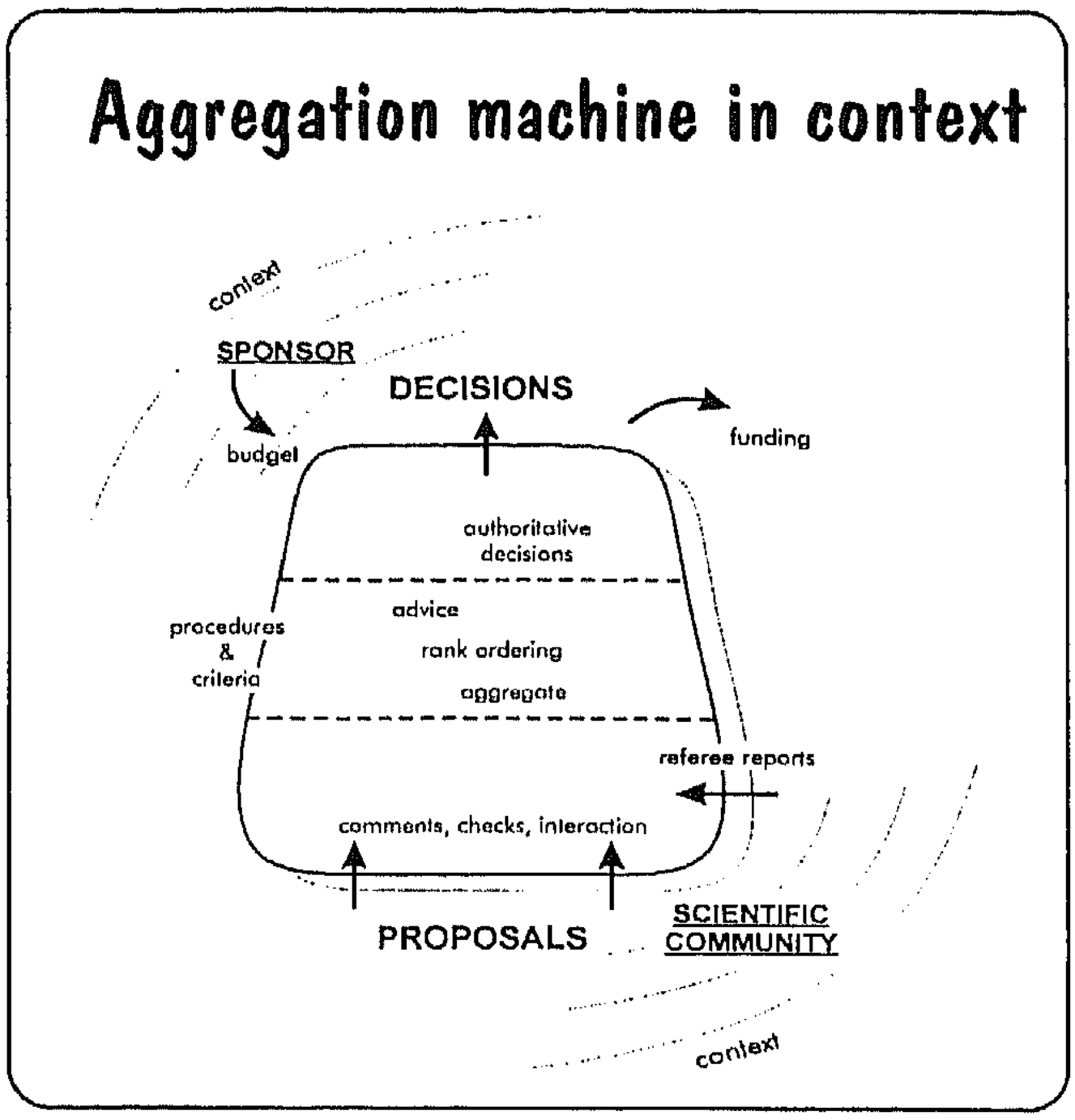
For funding agencies, research councils, and charitable foundations, there is a second problem. Given their limited resources and the multitude of claims made upon them, how to rank project or program proposals so as to prepare for eventual authoritative allocation of funds. Since the proposals may come from different areas, or be difficult to compare in still other ways, this is a daunting task. It requires even higher forms of nonsense. Again, ways of handling this have been developed, up to the "talking up and talking down" of proposals that occurs in panels, study sections, or other meetings of experts (Travis and Collins, 1991).

Here, it becomes clear that to keep the nonsense within bounds, more is needed than the right competencies of scientists. For refereeing, criteria are supplied by the funding agency, and there is some selection of the "right" referees by staff of the agency. After refereeing, the proposals, review reports, and other documents are put together and ranked, and authoritative decisions eventually lead to allocation of funds. To put it briefly, the business of a funding agency is: proposals in, money out. There is more to it, of course: the funding agency is not an independent sponsor with its own resources, but has to manage its relations with its own sponsor, the nation state, and remain legitimate to its clients, scientific communities. But these additional tasks depend for their success on the functioning of the basic "business process" of the funding agency.

What transforms inputs into outputs is a machine, in the generalized sense, in which an organizational structure and practice is a machine (Crozier and Friedberg, 1980:115–116). The machine doing the funding agency's work is an aggregation machine. Ranking proposals within a section or panel is one example of aggregation work, the comparison across scientific domains which is often necessary to formulate final priorities another.

Figure 17.1 visualizes the aggregation machine and some of its context. It has a three-layered structure, and the different activities are indicated with a few keywords. These activities and their connections can be recognized easily in actual funding agencies; clearly, these are recurrent features. However, there is no ideal, optimal machine because what "works" also depends on context. The concept of "aggregation machine" derives its importance from the possibility to compare across funding agencies at the level of processes and mechanisms, and to extrapolate to changed contexts.

Figure 17.1



One example is the issue of keeping the three layers of the machine separate, not mixing the refereeing of individual proposals according to quality (and perhaps relevance) and the ranking of proposals to prepare for decision making. While there are good reasons to do so, there is always need for repair work across layers, what with referees scoring strategically, and rankers interpreting the judgements of referees.[3]

Another recurrent issue is how to aggregate the disciplinary domains in terms of which the scientific community is organized, into a unitary top-level construct (organization or committee) which can negotiate with sponsors. In the Netherlands, as in some other countries, there is one overarching organization with internal vertical divisions. The United States has its National Science Foundation (NSF), but the National Institutes of Health (NIH) are very important in funding basic biomedical research. In the UK there are five (now six) separate organizations, each covering a particular domain of science and scholarship; for a time, there was a joint Advisory Board for the Research Councils. Norway is an example of a country go-

ing from separate organizations to a unitary one. Whatever the specific structure, there clearly is an Andreas fault in the lay of the land of funding agencies: the gap between the structure of the scientific community and that of the sponsor must be bridged, but this is always precarious, and when the deeper layers of the earth move, the bridges may collapse.

Detailed practical questions, like the number of referees to be asked, or the kind of scale to be used for scoring proposals, are sometimes discussed as if these could be answered in general, but they must be located in the actual aggregation machine of the concrete funding agency (Wood, 1997).

A general implication of these considerations is that questions about productive future practices have to be discussed in terms of whatever aggregation machine is projected to be in place then. This is how I will discuss the future of peer review: not by focusing on peer review, but by drawing up scenarios for future aggregation machines, and drawing out implications for peer review (and other) practices. Before I can do this, however, one further important point must be made: funding agencies have their histories, and present practices depend on how the agencies, and more generally, the relation between science and governments, have evolved.

Changing Regimes of Science in Society

Funding agencies, with their aggregation machines, function in a particular historical context, and translate contextual changes, though often with some delay, into changes in their inner workings. One can see this happen now, for example when the UK Research Councils take thematic priorities derived from the Foresight Exercise on board. But it has happened all the time. In other words, what we now consider to be key characteristics of the nature and work of funding agencies are the effects of earlier, context-related changes. The notion that peer review of proposals is necessary to maintain the quality of the work of the funding agency derives from post-1945 changes in the relationship between governments and science. In fact, there continue to be other practices of sponsorship (especially with the charitable foundations). In other words, the notion of peer review to be kept as it is for fear the working of science would break down is an ideology. Which is not to say that there are no achievements, only that there is no essence to be cherished.

The dominance of this particular way of managing sponsorship of science is linked to a historical phase in the development of science in its contexts, a particular regime or social contract between science and society which can aptly be called "Science, The Endless Frontier," after the title of the Vannevar Bush Report of 1945 that was the starting point for the creation of the US National Science Foundation (Bush, 1990). The social contract of "Science, The Endless Frontier," has strongly affected the institutions, practices, and expectations of science and scientists. While it has been under pressure since the 1970s, and a new social contract appears to emerge, that of "Strategic Science," responses to changes are shaped by, and cannot avoid being shaped, by the earlier contract and its achievements.

Under the regime of "Science, The Endless Frontier," the state, as final sponsor, delegated most of its tasks to the funding agency as an intermediary sponsor, and the funding agency delegated refereeing and ranking to the scientists. Competent referees were equated with scientific peers. In a sense, the funding agency, while formally part of the government, became captured by the scientific community. The need for accountability to the final sponsor, important for politicians and government officials (as was clear in their original reluctance to delegate), was short-circuited by the argument that peer review was selecting the best research, and this was what the final sponsor wanted, or at least should want. In a cynical mood, one might also call it the division of spoils by the scientific establishment.

Scientists definitely acquired an entitlement attitude: it was their right to be funded, and to be funded on their own terms. Similarly, the debate about fairness of peer review became important: what is a fair distribution of the "spoils"? Especially in the United States, there was additional political pressure for equitable distribution, linked to pork barreling and suspicions about old-boys' networks biasing against the selection of the best research.[4]

Life on the Endless Frontier was competitive, but competition was kept within bounds by new traditions of patronage, now from the intermediary sponsor and its peer reviewers. Scientific establishments, being influential with the intermediary sponsor, could reproduce themselves, and did so (up to reproduction of gender asymmetries). The incestuous element in such a set-up reinforces the risk-aversive tendencies of the funding agency as a bureaucracy. Careful judgements and due procedure limit the nonsense, at the cost of limiting some of the novelty as well. In general, without external stimuli,

awarding decisions tend to be conservative. The importance of novelty is recognized, and enshrined in the criterion of "originality." But to actually get scarce resources awarded to far-out proposals is not easy in the multi-layered systems, where scientific establishments as well as bureaucratic accountability must be honored. Risk taking requires Zivilcourage, by peers as well as by staff of funding agencies and their boards, because the system is not geared to it.

The closure of the system had its advantages as well. The relative autonomy of the funding agency, legitimated through its being linked to the scientific community, mitigates the arbitrariness of the final sponsor, who might follow political or individual whims. Government ministers of science or the U.S. Congress may assert themselves vis-à-vis the world of science, up to unexpected budget cuts and increases, and Golden Fleece Awards for seemingly ridiculous research (Greenberg, 1969). But the full force of their discretionary power is buffered by the funding agencies (and sometimes other actors in the intermediary layer between final sponsors and research performers).

This brief discussion of the regime of "Science, The Endless Frontier," and the aggregation machines evolving under it, indicates that such aggregation machines do two things at the same time: they handle the business of appraisal of proposals, ranking and allocation of funds; and they manage the translation from scientific communities and fields to sponsor's needs and priorities, and vice versa. Any attempt at business process re-engineering—to use a presently fashionable term—must thus take into account that there are two business processes to be improved at the same time. For example, a funding agency wants to get many submissions of proposals, to be able to select as well as to justify its existence and budget. Its internal work processes are geared to handle many submissions and come up with aggregate rankings and final decisions. But with more submissions, and a constant budget, the success rate goes down and scientists will be less inclined to submit the next time. Some balance will be reached, but it is an uneasy balance (Wood, 1997).

The particular shape of the aggregation machine in context, and the simultaneous but uneasy optimization of the two business processes, is heavily influenced by its coming of age under the social contract of "Science, The Endless Frontier." For example, communities and fields of knowledge production were automatically equated with disciplinary communities and fields, and the sponsor's need is

positioned as an interest in the progress of science and national excellence, which (together with national security) were the dominant political goals in the first twenty years after World War Two.

Particularly important is how actual sponsor's needs were backgrounded by the work of the aggregation machine being oriented toward scientific quality, which was deemed sufficient to deliver everything society would wish. Such a sentiment (rather than argument) was voiced already by Von Helmholtz, in 1862:

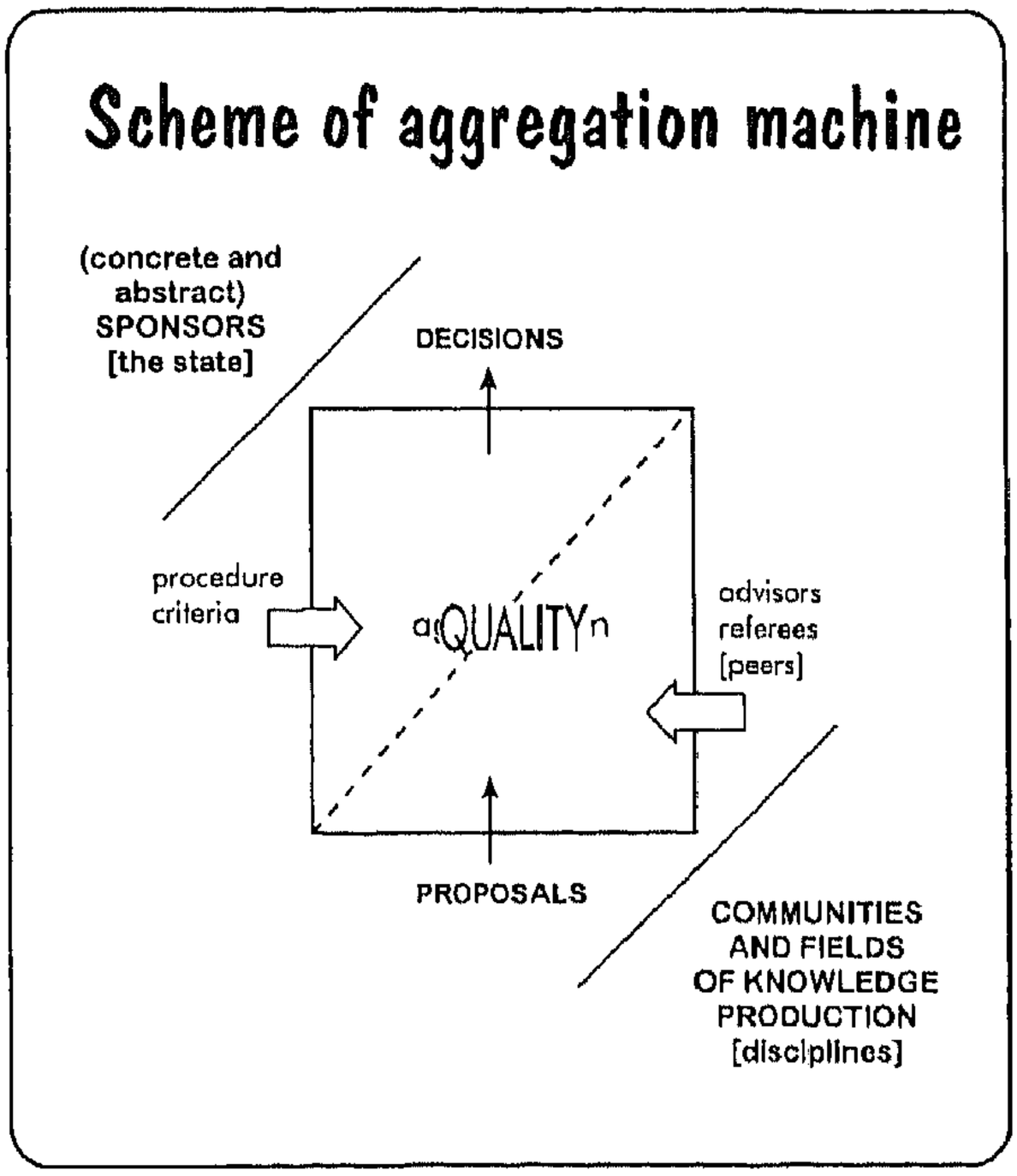
> The scientists—for the benefit of the entire nation and almost always at its request and expense—are seeking to multiply the knowledge which can serve the increase of industry, wealth, and the beauty of life, the improvement of the political organisation and the moral development. Yet, not immediate utility must be looked for, as is so often done by the uninformed. Everything that informs us about the natural forces or the forces of the human spirit is valuable and in time may prove useful, normally in a place where one had least expected this.

The difference between the 1860s and the 1960s is that the sentiment has been transformed from a programmatic call to an institutionalized practice.

By the 1970s, the sentiment as well as its institutionalization was challenged, and "relevance" of science was called for. In the meantime, however, the procedures and practices of funding agencies had become able to provide an assurance of quality. This institutional competence, based on the productive functioning of aggregation machines, was oriented toward scientific quality. The notion of 'quality' is not limited to scientific quality, however, and while there may not yet be institutional competencies to address broader aspects, the possibility might well be explored and exploited in the new context.[5]

Figure 17.2 gives a second sketch of the aggregation machine, but with less detail of its inner workings. Only the shift, from the lower to the upper level, in the balance of inputs from scientific community to sponsor is indicated. The guarantee of "quality" eclipses the aggregation work to the outside. The way the contexts are described uses more general terms than in figure 17.1, in order to accommodate other linkages than the focus on scientific disciplines under the regime of "Science, The Endless Frontier," and its complementary focus on national governments as sponsors. The label "knowledge production" is chosen because it is a more general concept than science (cf. Gibbons et al., 1994). The concept of "abstract sponsors" is introduced to take into account that there is more

Figure 17.2



than the generalized sponsorship of the state. For example the idea of "sustainability" moves researchers and concrete sponsors and in that sense is a source of symbolic and financial resources. Research proposals can orient themselves to this abstract sponsor, while being submitted to a variety of concrete sponsors (Rip 1997).

Five Scenarios

The general sketch in figure 17.2 is applicable under the earlier and present regimes, and under eventual future ones as well. Thus, it can be used to speculate about the future of intermediary sponsors (funding agencies, research councils, and the like), under conditions of rapid change. I shall sketch five scenarios, each one highlighting a particular modality of intermediary sponsorship in relation to changing contexts, and specify implications for aggregation machines and peer review. Each scenario has some immediate plausibility in the sense that examples of its modality can be given. The scenarios are more than interesting thought experiments because they are positioned with regard to longer-term dynamics.

The scenarios were constructed in two steps. In the first step, dynamical change of institutions in their context is seen as taking place at three levels, each of which produces "drivers" (as they are called in the scenario literature). First, inertia: attitudes and the trajectories of institutions, shaped in older regimes, cannot be changed easily because of sunk investments. Second, responsiveness: institutions (often through specific segments within them) respond to changing contexts in order to survive, and adapt themselves, more or less consciously and with trial-and-error learning. Third, ecology: the overall system and modes of knowledge production are changing all the time, which creates pressures and new opportunities for the various species of institutions.

The scenarios must present possible routes of response and adaptation. There must be at least one conservative scenario, where the first type of driver is dominant, and contextual changes are to be brought in line with the continuation of the trajectory and its achievements. There must also be at least one alternative scenario, where the third type of driver is dominant, and the institution may well become transformed beyond recognition. Dominance of the second type of driver leads to an adaptive and more or less pro-active scenario. In fact, I will develop three such scenarios, each of which takes up one feature in the present situation and expands on it, transforming it into the dominant trend.

The spectrum of possibilities for institutional change of funding agencies is not unlimited. In particular, the shift toward relevance of science, and the partial lock-in into the regime of "Strategic Science" must be taken into account. In scenario jargon: it is a TINA (There Is No Alternative). Claims on science to become relevant, and increasingly pro-active science policy since the 1970s, were combined with hopes for the potential to overcome the economic and environmental problems evident in the 1980s, and crystallized out in a new regime in the late 1980s and early 1990s. Why call this the regime of "Strategic Science"?

As a concept, strategic science was (and is) used to classify certain kinds of research and its organization. Irvine and Martin's (1984) definition has become authoritative: "Strategic research: Basic research carried out with the expectation that it will produce a broad base of knowledge likely to form the background to the solution of recognized current or future practical problems." By now, strategic research, with its emphasis on expectation and potential, rather than

actual application, is the core of the new regime, organizing activities of various actors and defining their roles. Scientists, for example, have internalized the pressure for relevance, but at the same time have captured it for their own purposes by claiming a division of labor, where their mandate is to work for long-term relevance and the freedom to explore a variety of options (Rip, 1997). Thus, all parties get something out of the regime.

There are other components in the present situation that must be taken into account even if they are less standardized: science and its organizations, including funding agencies, are orienting themselves to a variety of sponsors, and not just because of the need to mobilize resources. There is an interest in addressing issues (for example, climate change) where uncertainties are so great that they appear to fall outside the traditional bounds of science. Ravetz (Chapter 20, this volume) has analyzed the challenges of such "post-normal science." And public scrutiny of science has become more intense and more specific, partly because scientists themselves are going public. Such interactions with the outside world increase in number and intensity, as well as become more legitimate. Publishing by press conference, once frowned upon, has become almost the rule in some fields—and even funding agencies are now using this ploy to attract attention.

The division of labor typical for the regime of "Strategic Science," however, emphasizes a supply-side dynamic. It is its supply-side aspect which has enabled existing institutions of science to adapt to the new regime, and this, together with the actual and symbolic importance of new science and technology on the political and societal agendas, has led to a lock-in in the 1990s into a potentially stable regime.

The second step in scenario construction is to choose a time horizon, elaborate on the chosen features, and think through their possible effects. One must be able to tell plausible stories, and capture the essence of the scenario in a few keywords or a phrase. The five scenarios below are still somewhat limited, but for a time horizon of about five years they do a good job already.

Scenario 1: Maintaining the Endless Frontier

Key characteristic: The achievements of funding agencies are defended, together with their responsibility for good science to be done.

Because of this responsibility, funding agencies seek ways to maintain some space for themselves: some autonomy vis-à-vis *the*

government, and a budget which will allow sufficient responsive-mode funding to maintain the commitment of scientists. Within such a protected space, there is no need to change the approaches that were settled in the 1960s and 1970s. Strategic science may be important, but if new institutional arrangements are necessary, these have to be located outside the world of the funding agencies.[6]

The Deutsche Forschungsgemeinschaft (DFG), with its relatively ample budget and special legal status, exemplifies this scenario. In other countries one can see elements, and typically concern about how little this scenario can be realized. Sometimes alliances are sought and found with charitable foundations that fund scientific research. In medical research this has been an established feature for decades, and involvement of the peers in all relevant organizations ensures coordination (as well as closure).

In this scenario, the organization of the funding agency has to reflect the organization of the scientific community, and disciplinary representation is important. Bodies responsible for areas of science play an important role in the aggregation machine. They are strongholds for disciplines. Occasionally, special programs leaven their effect.

Peer review continues to take the form of refereeing as a good citizen's chore (Chubin and Hackett, 1990) in a Republic of Science, which is overseen by benevolent elites. *The Comité National* of the French *Centre National de la Recherche Scientifique*, even if it does not oversee responsive funding, is a good example of a Republic of Science. The "College of Peers" set up recently by the UK Engineering and Physical Sciences Research Council is an attempt to emphasize peer review as a collective responsibility of the scientific community, but it is not functioning satisfactorily.

Scenario 2: Grafting on Existing "Machines"

Key characteristic: Survival requires adaptation by differentiation of existing practices.

The shape and structure of the intermediary sponsor is retained, while the new pressures for relevance which enter at the top of the aggregation machine introduce additional criteria in the working of the machine. The sponsor may then get more opportunities to exert its discretionary power,[7] but peer review is expanded through a broader notion of quality, and thus a buffer is introduced again.

One route, already visible, is to ask current referees to consider additional criteria when judging proposals, and if necessary offer support to their judgement by providing (or asking proposal writer to provide) indications of relevance, or societal quality, of the proposed research. The other route is to seek new competencies by involving new actors who are expected to be knowledgeable and/or can be spokespersons for the new icons of relevance like "industry" or "sustainability." Such extended peer review is used in other situations, for example in regulatory peer review and other assessments of the scientific basis for decision making. Learning processes occur over time, and practices with recognizable competencies may evolve. A case in point is how appraisal of proposals in technical sciences (in the Netherlands) at first just needed letters from users applauding the project, but now require substantial demonstration of relevance, and often some actual commitment from intended users.

The structure of the aggregation machines will not change very much, and area panels or councils will remain important. Special programs, in response to external, political, and societal agendas, are instituted, and sometimes have their own type of review. Thus, a variety of funding modes is available to the scientist; differentiation leads to diversification.

Review of proposals now follows a "dual ladder."[8] Scores for scientific quality and for relevance are given separately, and an algorithm is developed to aggregate the scores. Examples range from the U.S. NSF's merit review, to the European Union's Marie Curie fellowships and the procedure followed by Dutch NWO Medical Sciences. In some cases, different referees or advisors are responsible for judging scientific and societal quality.

In "dual ladder" review, a space for discretionary action is left open for the sponsor, who can position and combine judgements on the two dimensions in different ways, and choose whatever fits his goals best. If the final sponsor is exploiting this space for discretion, the funding agency may want to close off such openings for intervention by merging the various judgements at an earlier stage, for example by establishing hybrid panels or juries. Their aggregation work becomes more difficult, but if successful, a closure is achieved which allows the funding agency to buffer the whims of political actors.

Scenario 3: Becoming a Distributed Research Center

Key characteristic: Intermediary sponsors arrange themselves to serve strategic themes.

Strategic themes are partly defined in the political realm, but often with inputs from the scientific community, as in the recent foresight exercises. The UK research councils are prime examples at the moment. The "workforce" of scientists in relevant areas is their human capital to achieve results enabling them to continue getting funds from the state. Their core business is to get strategic programs done—but they still depend on scientists' willingness to participate. Institutes and research centers also work with strategic programs, but have a captive workforce. Funding agencies in this scenario can then be seen as distributed research centers, with an interest in capacity building and maintenance of their human capital, but also flexible in the sense that they can move from one set of research performers to another.

Playing the role of a distributed research center is difficult for a general research council. Area-specific intermediary sponsors like the UK research councils can shift easily into this role .[9]

Indicators for this modality in the structure of the funding agency are a shift to managed rather than responsive modes, and an interest in larger units of funding. Area panels or councils disappear, unless they transform themselves into a management team for the distributed research center in their area. Capacity building (rather than exploiting the science base) is a concern, and is taken up by introducing developmental criteria in the assessment of proposals.

Peer review has to address strategic themes and developmental potential, in addition to evaluating scientific quality of proposals.[10] In this scenario, a second function of peer review appears: to advise on the implicit or explicit strategic program of the funding agency or its sub-section. In regular research institutes and centers, such a function is often performed by board members or by standing advisory committees. Funding agencies may institute rolling review procedures, as some of the UK research councils do, or turn their evaluations into strategic evaluation.

Scenario 4: Operating on a Market of Strategic Science

Key characteristic: Funding agency becomes a broker.

As intermediary sponsors, funding agencies need not limit themselves to dispensing state money (scenario 2), nor commit themselves to thematic missions (scenario 3). They can function as a broker between research performers and clients wishing (or being persuaded to wish) for certain research results. In fact, funding agencies increasingly go for consortium funding, with quality assessment as their distinctive asset, and thus responsibility.

With the opening up of science to a variety of sponsors, and the interest of such sponsors in long-term relevant research, a market for strategic science is established. Regular research institutes, as well as consultancies and non-traditional knowledge producers (for example environmental organizations) move on this market. Funding agencies have a competitive advantage because of the assurance of scientific quality they can provide, but must learn to offer packaged products. One can see funding agencies like Dutch NWO putting an effort in realizing this scenario, primarily in order to be less dependent on its main sponsor, the Minister of Education, Culture, and Sciences. Interestingly, there is also a risk involved: the minister might decide that NWO did not need him any more as a sponsor, and limit himself to paying for particular packages of strategic research. The risk is real in the present situation, but for scenario 4 it is only a transitional effect. But the observation highlights the change in status of a funding agency: it is now an independent actor, earning its keep and with little or no prospect of patronage.

The internal structure of the funding agency will be affected. Area panels or councils become business units, and these might start to compete among themselves. This is a real possibility because the multi-disciplinary or non-disciplinary, problem-solving research required by the market can be offered by various suppliers.

In deciding about proposals, leverage or multiplier potential of a project will now be an important additional criterion. It is not necessary to ask peers for advice on this point, but a new kind of advisor might be called in, the strategic–scientific market consultant.[11] Since contracting and submission of tenders will be important, review by peers is mobilized to assess track record rather than to judge the proposals as such.

Compared with other scenarios, the traditional shared responsibility for final decisions between the scientific advisors and the au-

thoritative decision maker at the top, bound by the need for legitimization, becomes a hindrance rather than a help. Thus, executive responsibilities will be strengthened, and rapid decision making in response to opportunities is more important than due process.

Scenario 5: Grabbing Floating Proposals

Key characteristic: State patronage has become one source of funds among many others, and funding agencies cannot count on scientists submitting proposals to them.

In areas of science like biotechnology, funding agencies may be marginalized. Other sponsors and arrangements may have limitations. This can be a response to decreasing success rates for grant applications, but it also heralds a brave new world where modes of knowledge production have changed, and non-traditional locations of research are on a par with the traditional sites in universities and academic institutes.

With the variety of sponsors, research performers become less dependent on subventions from any particular one, and funding agencies, as intermediary sponsors, cannot continue to see themselves as exclusively or primarily responsible for funding the science base. Conversely, scientists have lost their entitlement attitude. Research groups and centers, while most often linked to a research performance organization, actively seek opportunities for funding, provided by the variety of sponsors, and become somewhat independent of their umbrella organization. New arrangements emerge in which funding agencies become independent operators, offering services to final sponsors, and competing with other such operators for a share of research proposals.

Two developments stand out. One was the break-up of traditional research institutions, which became holding companies of research groups and centers behaving as quasi-firms. In the U.S. research system, with its separation of teaching and research funding, this only required the abolishment of the individual principal investigator rule in submitting proposals for funding. In Europe, there was more debate, but boards of universities and research institutes resigned themselves to the new arrangement to avoid losing their best research groups. Then they found out they could profit from new linkages with new research units, including devolved industrial research laboratories.

In parallel, intermediary organizations were transformed. The UK Higher Education Funding Councils were split in two, one organization to cater to higher education (through formula funding), the other for research funding, based on assessment exercises and special programs. Thus, they competed with the research councils for a share in interesting research. In the Netherlands, a new research funding organization was created along the same lines to resolve the ambiguity in the position of the Association of Dutch Cooperating Universities VSNU, which could now focus on interest promotion. In these two countries, and with some delays elsewhere, a miraculous multiplication of intermediary sponsors occurred, which implied a shift in their role: no single one was the exclusive or primary intermediary between ongoing research and the state.

The second key development was related to the status of research proposals. A funding agency tended to assume that the proposals it received were designed specifically for them, while in fact, each proposal was part of the resource mobilization strategy of a research group or center, and reflected the need for ongoing work rather than the goals of the agency. The possibility of relabeling had been a vexing question for agencies (funding agencies, program committees, government departments) which wanted their own priorities to be implemented. But the dynamics of the research system are different. Proposals have a life of their own: They will be re-submitted in somewhat modified form, and not necessarily to the same sponsor as before. They can be arranged and recombined, as long as they serve the continuation of the work of the research group or center. Thus, there is a sea of stories about interesting research and its promise for a variety of sponsors: floating proposals, and sponsors can grab some of them to fund them.

Track record had been important all along, but now became the responsibility of the research group or center, which produced relevant documentation, as well as the outcomes of independent assessments and certifications. In addition, proposers (rather than sponsors) arranged for reviews, which would then be added to the "floating" proposal to support its status. Reviews should be authoritative, but need not be limited to traditional scientific peer review. In the new situation, this is not a problem, because traditional differences in funding streams (government block funding, indirect, funding-agency mediated funding, third-party funding) have disappeared, or at least become less relevant.

Compared with earlier aggregation machines of funding agencies, which work on articulated proposals for identifiable sponsors, the boundary between the machine and the sea of floating proposals is drawn differently. There will be "horizontal" aggregation processes outside the funding agency, initiated by the research groups or centers themselves. For each sponsor, the bottom part of its aggregation machine is then reduced to staff "grabbing" proposals.

The internal organization of funding agencies must still bridge the gap between ongoing knowledge production and the agenda of sponsors, but there are major differences with the traditional set-up. At the bottom right in figure 17.2, there are now groups and centers, with little allegiance to traditional disciplines, and sometimes located in "contexts of application." At the top left, there is no privileged link with a general government sponsor, but the need to show valuable service to whatever sponsor can be enrolled. Instead of disciplinary-defined area councils and panels, there will changing clusters of spokespersons, gathered together by agency staff on the basis of their monitoring of ongoing knowledge production and needs of sponsors. Quality, the traditional competitive advantage of funding agencies, is redefined as alignment between supply and demand. Substantial considerations of quality are now relegated to the research actors.

Peer review continues to be important for the entrepreneurial funding agencies, but now as a marginal check on the assessments offered by the proposers of projects or programs. The problem of finding independent reviewers had been there all along, and with globalization and increasing demands for reviewers, it is often impossible to resolve the need for independent review satisfactorily. When proposals come with reviews attached, it is easier to check for independence—but there is no guarantee that there will be any independent and knowledgeable reviewers left.

For the proposers of projects and programs, two routes are available to obtain peer review. One route is open, and in a sense democratic: assemble reviews from whoever wants to comment (for example, via the Internet). The other route anticipates on decision contexts, and seeks reviewers that will make a difference with intended sponsors. Authoritative reviewers will become sought after (as is the case already, as agency staff know). They become a scarce resource, and when they do not set a price, their discretionary power to provide a review or not will turn them into patrons who can dispense favors.

Conclusion

The scenario exercise offers controlled speculation about the future of the peer-review system. It also gives us a better view of possible developments at the science–society interface.

An immediate point to be made derives from the dominance of the scientific community which becomes less from scenario 1 to scenario 5. In other words, the vertical business process will dominate the diagonal process (figure 17.2). While the funding agency and its government sponsor may welcome the freedom to do their (vertical) business well, there is a price. "Desertion," that is, scientists stopping to give their research proposals to the funding agency, becomes a real risk. Since access to (good) research proposals is important in each of the scenarios, the funding agency has to do something to maintain its access, especially if it cannot keep the scientists dependent on its selective support. Its quality assurance system (actual and symbolical) is an asset to be exploited here, provided the stamp of approval of the funding agency remains part of the reward system that moves scientists and decision makers about science.

Five different futures were discussed as possibilities, but are they also desirabilities? The answer depends on the dimensions along one wants to assess the system. One dimension is the advance of science, as such and in relation to society. Innovativeness is an issue here, because institutionalized practices generally, and also in science, tend to repress novelty (unless it is in their immediate interest). How to accommodate "*recherche sauvage*"? This is a matter of a workable balance between discretion (and the Zivilcourage to use it) and due process.

Another dimension is the efficiency of the system, as such and in relation to its effectiveness in achieving system goals. Transaction costs are important to consider. Some agencies pride themselves in spending only a few percent of their budget on agency costs. In scenario 1, their pride is justified, but in scenarios 3 and 4, agency costs must be at a reasonably high level to do the job well. It is interesting to consider an additional mini-scenario, by way of contrast: Do away with peer review altogether and have funds allocated by lottery (after agency staff has checked for minimum eligibility). This minimizes transaction costs—at what price? It has been suggested that this will undermine legitimacy with the scientific com-

munity, but the scientists may well, after a first outcry, accommodate to the new situation.

A third dimension is about the peers and their competence. The traditional meaning of "peer" will be lost. Under the regime of "Science, The Endless Frontier," "peers" were important symbolically: they represented the mutual commitment of funding agency and scientific community, as much as that their specific competence was sought. When the scientific community and its work sites become more heterogeneous, there is less need to secure the links through having a unitary category of "peer." There will be a variety of knowledge professionals who can serve as referee or adviser.

Under the present regime of Strategic Science, and certainly in the further evolution of the regime, competence will take precedence: its utilization as well as ways to build and improve relevant competence. There is a real competence involved in handling the higher forms of nonsense: the craft skills of experts in handling (assessing, judging) promising stories. The challenge is to exploit such skills, to set up learning processes to build and increase such skills, and to design productive aggregation machines.

The focus on competencies and learning processes makes it possible to have a further, and productive, take on the vexing question of citizen input in the sponsorship and orientation ("steering") of science. Experts have skills which citizens do not have. But in all but the conservative scenarios, experts have to learn new skills and competencies. If they can do so, why not citizens? In other words, citizens can become experts.

This is not an argument about democracy, or about the right to participate. That would be the mirror image of the entitlement attitude of scientists. Citizens, as well as scientists, have to earn their ticket by developing relevant competencies and showing that they can use them. This depends on the aggregation machines that are in place. Or, as this paper has shown, might emerge, and perhaps be actively pursued.

Notes

1. For technology, an interesting venture is De La Bruhlize's attempt (1992) to replace the popular SCOT (Social Construction of Technology) approach by PCOT (Political Construction of Technology).
2. For princely patrons and scholars like Galileo, see Biagioli (1993). The pre-history of the Mohole project (deep ocean drilling) is recounted in Greenberg (1969).

3. An interesting mixed case is the evaluation of fellowship proposals to the European Commission's Human Capital and Mobility Program and its successor, the Transfer and Mobility through Research Program. The same experts do the refereeing and the ranking, but separated in time, and with attempts at separation of communication (through procedure and availability of data). As member and chair of the Economics and Social Sciences panel, I could observe strategic interaction and repair work, as well as doing so myself. Competencies were built over time, and one effect was that substantial discussion was pushed into the background, while procedural rules took precedence. With the need to handle up to 300 or 400 proposals in two days, industrialization of peer review was necessary, and became accepted by the experts.
4. The study by Stephen Cole and Jonathan R. Cole of peer review in the National Science Foundation, reported in 1978 and 1981, was a response to such concerns, and has been discussed widely, from the pages of *Science Magazine* to meetings of scholars in science studies (see Chubin and Hackett, 1990). In 1988, NSF published the results of a survey of proposal review among principal investigators; see McCullough (1989) and commentaries following his paper.
5. In the Netherlands, the concept of "societal quality" has become an entrance point for the introduction of societal considerations, relevance, and potential impact in judging research (Spaapen and Sylvain, 1994; van der Meulen and Rip, 1997). This will stimulate extensions of the aggregation machine, even if the attempt at assessing societal relevance and potential implies more, and more uncertain futurology—even higher forms of nonsense.
6. At the same time, funding agencies can do exercises to show that the research they fund is relevant to strategic themes. The U.S. National Science Foundation did so when Senator Mikulsky was pressing for more strategic research funding, and the UK Economic and Social Research Council conducted a similarly defensive exercise. In both cases, about 60 percent of the research they funded fitted the strategic themes set by policy. Science, the endless frontier, is shown to be cornucopian indeed. The 60 percent outcomes can be explained from the open-ended character of scientific research, which can be linked to a variety of goals and themes.
7. This happens in any case, cf. the way the U.S. Congress tends to increase NIH budgets unilaterally.
8. Originally, the name for the system instituted by ICI and some other UK research organizations, where researchers could be rewarded and promoted for their research achievements, and not only for their management responsibilities (Ziman, 1984).
9. Especially in the late 1940s and the 1950s, the Dutch Foundation for Fundamental Studies of Matter, formally a subdivision of ZWO/NWO, was a distributed research center *avant la lettre*, and ZWO/NWO has had trouble accommodating FOM, exactly for this reason. The Dutch effort in materials research, from the Foundation for Advanced Materials Research to the present Special Program of NWO, comes close to being an example of an ad hoc distributed research center.
10. It will be difficult to aggregate these three distinct dimensions. Brave attempts in the first rounds of the European Union's Human Capital and Mobility program, for example, have over time been reduced to a focus on scientific quality, with preference given to proposals from less-privileged regions when other things are equal.
11. The competencies required are based on experience, and are available already, since research performers ask for advice from knowledgeable persons to help shape their research and resource mobilization strategy.

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