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A Bridge Too Far ?

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Abstract

In our book "Surviving 1,000 centuries; can we do it?", published by Springer (NY), Roger Bonnet and I have addressed the question of longevity of our society and very briefly also of the future of science. Here I examine the latter question from an economic and from a cultural point of view. I express doubts as to whether science can really be an "Endless Frontier" as proclaimed in the title of the Report to the US President by Vannevar Bush in 1945 which was at the origin of the science enterprise as we know it today. While we are uncertain about the development of science following the coming half century, this in no way diminishes our enthusiasm for SKA as a project for several decades to come.

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In 1944 the allied forces tried to arrive at a rapid end of the war by getting hold of the bridges over the river Rhine near Arnhem and so cutting off the German army. As described in a book and a movie with the above title, lack of knowledge of the terrain and unrealistic planning, the result was a catastrophic lengthening of the war. Of course, this is not a unique case. Lack of realism frequently not only makes a project unrealizable, but the end result may be very negative for other projects as well.

Lack of understanding of the financial limits led to the termination of the US super accelerator under construction in Texas after some four billion dollars had been spent. This affected the field in the US negatively and ultimately allowed the Europeans to take the lead in particle physics. This is certainly not the only example in scientific projects of the danger of trying to do more than is realistically possible. At ESO, around the year 2000, plans were developed for OWL, a 100-meter optical telescope, to be constructed at a cost of around a billion euros. Fortunately before too large investments had been made cooler heads prevailed and now ESO has tied its future to a more reasonable 39-meter telescope which is supposed to cost still a billion euros! A somewhat similar situation in space has played out with NASA's infrared space telescope JWST. It was planned as an 8-m instrument at a cost of a billion dollars and by now has become a telescope with half the collecting area and a reduced wavelength range at 7 billion. The US Congress voted to terminate it, though for the moment it seems still to survive, though with much delay. Moreover, it negatively affected many other projects. As *Nature* wrote: "The telescope that ate astronomy".

These examples show that cost projections should receive much more attention than astronomers have been used to. Perhaps it also could raise questions about the realism of the projected cost of the two-continent version of SKA. Before addressing these, let us go back a bit and turn to the broader issue of why Society supports astronomy at all.

Why Support Astronomy ?

At the time the Antikythera mechanism was constructed, Lucretius (De Rerum Natura I, 146) might have answered that the study of astronomy and other sciences leads to the elimination of superstitious beliefs, thereby freeing humanity from many fears, including even the fear of death. As he wrote "This dread and darkness of the mind cannot be dispelled by the sunbeams, the shining shafts of day, but only by an understanding of the outward form and inner workings of nature". And Pliny the Elder (Historia Naturalis II, 54) gives examples of the catastrophic consequences that irrational fears induced by eclipses of the Sun and the Moon have had : "through such fears and ignorance of the underlying cause the Athenian general Nicias was afraid to lead his fleet from harbor and so destroyed the Athenians' greatness". If Nicias had had the Antikythera mechanism he could have foreseen the eclipse rather than being panicked by it. So it is plausible that the mechanism was an object of great value, well worth transporting to Rome.

Of course in the meantime other aspects of the Universe have been understood which have a philosophical impact. Among these one could mention :
that our Universe is very large, very old and full of stars and planets
that our Universe is likely to have had some kind of an origin
that the Universe evolves along with all its contents : stars and life
that most of the matter and energy in the Universe is non-luminous

that our presence in the Universe results from some very delicate numerical coincidences in its characteristic parameters.

When the Royal Society in the UK looked for funds for the Cook expedition to observe the Venus transit, the motivation given was that it would :

(1) Advance knowledge
(2) Provide the solution to an important practical problem
(3) Enhance national prestige.

Somewhat schematically item (1) was the more philosophical aspect and item (2) the utilitarian one.

Examples of the latter in which astronomy has played a role include

- The development of accurate clocks
- The determination of systems of coordinates on Earth, with most recently the GPS
- The development of imaging instruments over the whole electromagnetic spectrum
- Communication technologies
- Technologies of Earth observation (atmosphere, pollution, water, agriculture, forests, etc.)
- Evaluation of solar variability and its impact on the Earth's atmosphere, including climate
- Evaluation of the risk of asteroid and other bodies' impact on Earth
- The prospects for mining of asteroids for rare elements, though these seem quite remote.

Cost of Contemporary Astronomical Projects

The costs of the big projects in astronomy have been inching up towards the one billion euro mark. Whether this was because the science required this or whether one designed up to such a sum as being the largest amount obtainable is an interesting question for discussion. The EU spends annually some 1.5 G€, or 0.013 % of GDP, on astronomy; one third of that passes through ESA and ESO.

The ESO VLT came in at some 0.5 G€, while ESO's next project, the 39-m E-ELT, has been approved at 1 G€. ALMA, the EU-US-Japan sub-mm, currently being completed is supposed to have cost perhaps some 0.7 G€. All of these figures are elastic in the sense that it is not always clear what is included of instrumentation and personnel cost. To put these figures in perspective, the most expensive ones which may perhaps be classified as scientific include the world plasma physics experiment ITER which is climbing beyond 18 G€ and the aforementioned JWST.

Considering then SKA, we see that its projected cost is not entirely out of line of other projects in astronomy. However, it seems somewhat surprising that the two continent (Africa/Australia) decision seems to have been made without great clarity of the financial implications. In fact, it appears for the moment at least not evident how the relative contributions of the participating countries are to be determined. With billion euro sums being involved, one can no longer afford to shift to the future the difficult decision on how to apportion the costs between countries of very unequal economical development.

Assuming for a moment that all practical problems can be dealt with, we can see that there is much that is attractive in SKA. Scientifically there is no doubt that the unprecedented combination of sensitivity and resolution allows many discoveries to be made. At least equally important is the involvement of many African countries which are still in the early stages of development. Most development agencies and charities try to feed the undernourished masses – uncontestably a most worthy goal. But development is not just about growing food; the aim should be that every country should be able to control its own destiny. This implies that everyone should have a certain understanding of how the contemporary world functions and this requires some idea of the concepts of science and technology. If SKA can contribute to this significantly, it will provide the project with a raison d'être as important as its anticipated scientific results.

The Future

The end of the second world war demonstrated the essential importance of science in the management of the world. So the promotion of science became a task for governments in the developed countries. The consequence was that almost any project judged to be "good science" could gain financial support. As the sums involved got bigger – also as a fraction of GNP – this could no longer continue. Scientific investments could no longer be justified just from the inside perspective of science. Pure science was no longer enough and other factors had to be included in decisions about funding. These included utilitarian considerations involving applications, but also the interests of a broader public of non scientists.

So, are we going to build ever more powerful telescopes after completion of the ones now under construction or in the planning stage? Roger Bonnet and I have very briefly touched on the question in our book "Surviving 1,000 centuries; can we do it?". While we came to relatively optimistic conclusions about the adequacy of food, water, etc. we are less sure about the long term future of science. Will there be the interest and the capacity in Society to continue providing ever larger sums? For a few centuries in the European and even more in the American mind set there has remained a brilliant future on the horizon with vistas of scientific discovery, technological development and economic growth. Characteristic was the influential 1945 report by Vannevar Bush to the US President "Science: The Endless Frontier". This report indicated that for the US and Europe scientific development largely sponsored by the governments was needed as a driver of the economy and led to the science establishment as we know it today and that has served us all so well. But can this last? After all the idea of continuing progress is a relatively recent one and most past societies have lived without it. Surely no one living in Europe a thousand years after the Antikythera mechanism had been constructed could have duplicated the complex machinery.

Even apart from issues of affordability, the question may be asked if every next step in the performance of our instruments will be equally productive. Will the future developments have as large an impact on our image of the world as those of an earlier generation? We may doubt it.

Taking a step back to the early days of quantum mechanics, these were so exciting because it fundamentally changed not just a specialized part of physics but much of

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science, including chemistry, earth science, astronomy and biology. A similar situation in the future seems rather unlikely. As science becomes more and more narrowly specialized, it may remain very interesting to its practitioners, but a disconnect to society at large seems probable.

So while I see a bright future for astronomy in the next half century or even somewhat beyond that, I believe that thereafter we may look back to a past golden age, irremediably lost. If so, it might be well if we would plan for a less favorable situation. Of course one may argue about the precise time scale on which future events will unfold. But it seems difficult to avoid the suspicion that science may not be an infinite frontier after all.

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