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Learning to Live with Science and Technology

Delivered by
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Learning to Live with Science and Technology

By Professor Jayant Vishnu Narlikar

Ladies and Gentlemen,

It gives me great pleasure to be present here today to deliver the prestigious T.A. Pai Memorial Lecture. I consider this a great honour not only because of the personality of T.A. Pai who had the foresight of starting quality institutions for higher education; but also because of the distinguished speakers in this series who preceded me. I extend my very best wishes for this institution which is translating the vision of T.A. Pai into reality by producing new generations of inspired workers.

When I was asked to suggest a topic for this talk, I felt that rather than choose a purely scientific topic such as one forming part of my own research, I should choose one where the science-society interaction is highlighted. As will become clear from my talk today, I strongly believe that scientists should regularly descend from their ivory towers to share their knowledge and wisdom with the society at large. Why, when and how, I will now proceed to discuss.

The age of science

It is often stated that we live in the age of science: that science and technology are shaping our very existence. No one described the impact of science and technology (S&T in brief) more graphically than Alvin Toffler in his book *'The Future Shock'*. I summarize in my own words his description of the way science and technology have increasingly come to determine the conditions under which we live and why this circumstance has come like something of a shock to human societies the world over.

Let us do some elementary arithmetic! Divide the last 50,000 years or so of known human existence on this planet into some 800 human life spans - each life span comprising of 62.5 years. Take this life span which is typical of that of a human being, as a representative unit of time. Of these 800 time units, for which some historical information is available, the first 650 or so were spent by man in primitive conditions living in caves. The art of writing is not more than 70 life spans old and that of printing only 6 life spans old. The electric motor is two life spans old. In fact most of the things we use in our daily existence involve technology much younger, some of it not more than one life span old. The discovery of atomic energy, use of space technology and the proliferation of computers are all less than a life span old. Today we feel uncomfortable if deprived of electronic mail and

internet; yet these facilities are barely a third life span old.

This indicates how rapidly scientific ideas are being translated into technological inventions and how rapidly we are having to assimilate them in our lives. Yet the rapidity with which this is taking place is not proving entirely beneficial to the society. Rather, the situation resembles that of a human being invited to a buffet dinner where he or she is confronted with a feast of excellent eatables served in rapid succession and tempted to eat them as fast as they come. The banquet may look dazzling but the diner ought to pick and choose keeping in mind the limitations of health and capacity to digest. This the human society has not yet learnt to do.

The diner in the above example may ask : 'How do I know what is good for me - how much of it is good for me - and what items I should avoid?' Who is to tell him? In the case of the citizen of the twentyfirst century, this need for advice can be satisfied by a proper society-science interaction. Science communication in various forms can help inform the citizen about what is happening in S&T, while the development of the scientific temper can help shape the individual's attitude towards this information.

Science communication

Information holds the key towards facing the future shock. Whenever new discoveries in technology take place, it is necessary to understand their full implications. Very often a technology is announced but the science it is based on is not so well publicized. Even leaders in the field sometimes fail to grasp the potential of a discovery. There are famous examples. Thomas Alva Edison, the great inventor, did not believe that alternating currents would play any useful role in the power sector. Lord Rutherford, who demonstrated that the atomic nucleus can be probed and transmuted, did not believe that the discovery had a practical implication. Within three decades, the discovery was put to the highly destructive use in the form of a nuclear holocaust, as well as to peaceful use as an atomic reactor for generating energy. Many distinguished scientists believed after the early rocket experiments that space technology will not play any important role in promoting science and technology.

Examples like these suggest that there needs to be a lot of public discussion between scientists and leaders, decision makers in the society, whenever any new scientific discovery takes place or is in the offing. What are the future implications of the discovery? Is it likely to be harmful to

the society? Does it need to be channeled in a certain direction? In the physical sciences nuclear studies have already shown us, perhaps too late, why one needs to exercise control on the direction of research. The use of the technique enabling the knowledge of the sex of the child still to be born had to be restricted because of its misuse. Evidently these are situations wherein scientists have to come down from their labs or studies to talk practical matters with the society.

Science communication is therefore extremely important today, much more so than appreciated by the common man. Not only do the scientists need to come out to communicate, there can be a whole class of other communicators who are basically good at communication and who read scientific literature or consult with the experts and then tell what they learnt to others. It is possible today to use different media for science communication, including radio, TV, internet, lecturing, movies, etc. A number of voluntary organizations have come up to pursue this objective. But much more needs to be done.

India has a number of such organizations, national as well as in states and towns. The Government of India has supported such activities through *Vigyan Prasar* which is under the umbrella of the Department of Science and Technology. There is a *National Centre for Science Communicators*, headquartered in Mumbai which played a very active role in the nucleation of the International Union of *Science Communicators*. I am happy to say that the IUSC was recently established with headquarters in Mumbai.

But in the last analysis it is not the institutions but the individuals who have to carry the torch forward. I was recently at a felicitation function for Professor Yash Pal, who has turned eighty. He started as a cosmic ray scientist at the Tata Institute of Fundamental Research, but after a series of different avatars as the man who brought satellite television to India, who started the NCSTC, who played a lead role in Bharat Jnan-vijnan jathas, he is seen as a top class science communicator. There is a great need for professional scientists to come down to talk to the masses, sharing with them their excitements and concerns about science and technology.

Science journalism

An important arm of science communication is science journalism. It is sadly much neglected in India. Reporting of scientific events takes up very small percentage of available newspaper space. Very often a science news item is simply taken over from foreign sources, 'by arrangement'.

Clearly science is not a priority subject in the minds of newspaper producers or editors.

Investigative journalism these days covers many cases of corruption, crime, spying, conspiracy and war stories. Once in a while, the scientific world too offers challenging and highly interesting cases. In a typical case, a claim to an important discovery is made but without proper substantiation. In some situations the result is based on fraud while in others it is a genuine mistake. There are also instances of scientific plagiarism. In case it is said that "Good news is no news": perhaps the journalists may at least cover these examples of malpractice in science! I am tempted to give a classic example from the past.

In 1903 the eminent French physicist R. Blondlot claimed to have discovered a new type of radiation called N-rays (N for the town Nancy where the discovery was supposedly made). Coming shortly after the discovery of X-rays in Germany, this discovery of new rays with remarkable properties was hailed widely in France partly because of the competition between the two neighbouring countries in many fields including science. The N-rays became fashionable and a large number of research papers on them began to appear in French journals. Soon Blondlot was awarded the prestigious Lalande Prize by the French Academy for his discovery.

However, a scientific experiment is nothing if it is not repeatable. This was not happening in the case of N-rays. The rays could not be detected in similar experiments in England or Germany. What was wrong? To find out, the British scientists requested R.W. Wood, a distinguished American scientist to visit Blondlot's laboratory and inspect the experiment. (A scientist from a rival country like Britain or Germany would not have been welcome in France for this purpose.) Wood made the trip and found that the claim for N-rays was totally false. His own account of how he detected this fraud makes a very interesting reading even for the layman today.

The temptation to make spectacular but fraudulent claims comes more strongly in the present time than in the relatively placid times a century ago. This is because a scientist is judged by his performance much more stringently today than in the last century. Awards, peer support, promotions, project grants are all linked with performance. Thus if Mr. X has made a stupendous discovery he stands to attract a lot of financial support as well as wield power in the scientific circles. So there is a strong temptation for him to rush out and make premature announcements. In spite of these temptations science has remained relatively clean mainly because a scientific fraud is detected

sooner rather than later. However, such cases as do turn up from time to time need to be widely reported to the public.

Another related area where investigative journalism can do a lot is in testing the claims of UFOs as extra-terrestrial spacecrafts. The so-called unidentified flying objects are reported in the press from time to time. The common man gets excited by the suggestion that these are spaceships from some alien civilizations beyond our Earth. The real explanations may be quite mundane : the object may be Venus, or an optical illusion (like a mirage) or a man-made spy satellite, or simply the figment of a highly fertile imagination. Instead of just publishing the account of some such witness, the journalist should try to probe its credibility.

Philip Klass, a journalist from Washington DC has written a book entitled *'UFOs Explained'* in which he has given absorbing details of investigative journalism which removed the mystery around several such claims. He has also shown how the so-called photographic evidence can be faked. Indeed, in some cases a UFO sighting claim has been turned (fraudulently) to material gains.

Another set of events which generated considerable excitement around twenty five years ago related to the apparently strange events occurring in the so-called 'Bermuda Triangle'. These were debunked by science journalism, although in India they continue to generate a great deal of interest in popular imagination.

Speaking in this vein, there is another topic which offers great scope to a science journalist in India. I will return to it shortly. I now turn to consider the scientific temper.

The scientific temper

What is Scientific temper? Why is its relevance being felt now rather than in the past? Is it an individual trait or does it also extend to societies, cultures, civilizations? To what extent is it prevalent today? What can be done to make it more widespread? These are the questions I shall try to answer. But the bottom line has been stated much more effectively by Pandit Jawaharlal Nehru:

.....The impact of science and the modern world have brought a greater appreciation of facts, a more critical faculty, a weighing of evidence, a refusal to accept tradition merely because it is tradition...

But even today it is strange how we suddenly become overwhelmed by tradition, and the critical faculties of even intelligent men cease to function... Only when we are politically and economically free will the mind function normally and critically.

...(Discovery of India)

This was written during the twilight of the British Raj. Today we live in a free India which is feeling its way towards economic prosperity. Yet we are still a long way away from achieving that scientific outlook which Nehru considered so essential for our future well-being. To appreciate what the scientific outlook is all about, let us first see how science itself works.

There are three steps in the progressive march of science: experiment and observation/ theoretical interpretation/ prediction of new results. This sequence is endless. One performs experiments in the laboratory, or observes some natural phenomenon and then tries to interpret it in terms of a theoretical framework. If the attempt succeeds, then one tries to make new predictions that future experiments or observations will verify. If the success of the theory continues, one keeps believing in the theory. *However, one never accords the theory a blank cheque for being correct.* There is always a possibility that a future experiment may disagree with the predictions of the theory, in which case it may have to be abandoned or modified or replaced by a new and better theoretical framework. Thus Newton's law of gravitation continued successfully until some sophisticated tests in the solar system showed its inadequacies and it was replaced by Einstein's theory of relativity. It was in this connection that Sir Hermann Bondi, the well-known astronomer, remarked:

...The essential thing in science is for the scientist to think up a theory. There is no way of mechanizing this process; there is no way of breaking it down into a science factory. It always requires human imagination, and indeed in science we pay the highest respect to creativity, to originality. It is, of course clear that since every theory must live dangerously, the casualty rate is pretty high. So we do not honour scientists for being right; it is never given to anybody to be always right. We honour scientists for being original, for being stimulating, for having started a whole line of work. Science is the most human of endeavours because it depends on co-operation, it depends on people testing each other's work and it depends on people taking notice of each other.

(Cosmology Now, ed. L.John, 1973, B.B.C. Publications)

Bondi's comment needs one clarification. It does not mean that any Tom, Dick or Harry can propose 'new ideas', claiming to be better than Newton or Einstein. I get such ideas from dozens of people in the post, which are vague flights of imagination with no backing of quantitative facts. Bondi here means ideas carefully worked out with rigorous mathematics and having the benefit of confirmation by at least some physical facts.

The scientific outlook has evolved from this practice of science: it relies on factual evidence and statements that can be checked against established truth. It allows for pragmatism, that is willingness to drop a paradigm if it fails the test of facts and to adopt a better one if it meets all factual checks. However, the scientific outlook need not be the prerogative of the scientist alone. After all, it owes its origin to human curiosity about Nature and as such every one of us, whether a scientist, or not, is entitled to it. Indeed, just as in the case of science, progress could be achieved only when the scientific outlook prevailed over innate conservatism, so in the case of a society of human beings this outlook acts as an antidote to the evils of prejudice and superstitions.

Science and Superstitions

Superstitions are born out of ignorance of how Nature functions. Science is dedicated to the unraveling of the mysteries of nature. As one particular mystery is solved, we should expect the superstitions based on it to disappear. Yet, this does not always happen in practice because of the lack of scientific outlook in the typical human being. I give next one example.

Imagine that you meet a stranger to your town who stops you in the street to ask for some local information. Where can he buy candles and oil lamps to light up his house? Where do they sell huge bronze or copper receptacles to store well water for domestic use? He needs a horse and a carriage for transport...where can he get all these items? No doubt you will be surprised by these queries. You will begin to wonder whether this visitor has sprung from the eighteenth or earlier century through a time-warp. Why is he unaware of electric power, running tap water and motorized transport that are so common to the urban life of today?

I get exactly the same feeling when I am accosted by a stranger and asked this question: "Do planets affect human destiny?" I wonder whether this stranger has come from some remote era in the past, since he seems unaware of the scientific advances that have long debunked beliefs of this kind.

The early human societies ascribed occult powers to planets. This assumption arose from ignorance of what planets are and how they move. Now that astronomy has answered all of the questions raised about planets by the primitive man, we should expect this assumption to be regarded as groundless. Yet this has not happened. Even in the technologically advanced countries this belief persists among sections of educated classes. In the mid-1970s a group of leading

scientists including several Nobel Laureates in the West signed a circular denouncing the very basis of this belief. I give below an extract from their statement:

....It is simply a mistake to imagine that the forces exerted by stars and planets at the moment of birth can in any way shape our futures. Neither is it true that the positions of distant heavenly bodies make certain days or periods more favourable to particular kinds of action, or that the sign under which one was born determines one's compatibility or incompatibility with other people .... In these uncertain times many long for the comfort of having guidance in making decisions. They would like to believe in a destiny predetermined by astral forces beyond their control. However, we must all face the world, and we must realize that our futures lie in ourselves, and not in the stars... (The Humanist, Sept./Oct. 1975).

Do planets influence human destiny? The subject of astrology is based on the answer to this question being 'yes'. How will a scientist go about testing the hypothesis that the answer is 'Yes?' He will not be satisfied by the prediction by a single person based on a single horoscope. First he will require a set of well-defined rules on which such predictions are based. The rules should be unambiguous so that different persons make the same prediction from the same horoscope. Next he will need to be convinced that these rules work in a statistically significant manner to discount the possibility of the prediction being right purely by chance. This will require a systematic study of a large number of such trials under different conditions.

It is then necessary to cast the prediction in a well-focussed form where it can be tested. Statisticians have well defined procedures for tests based on samples collected. Such tests as conducted so far by scientists have yielded negative results. But again, it is not always necessary to call upon a professional scientist to perform such tests. The educated common man can himself sift the evidence provided he adopts an objective outlook. Let me give one illustrative example of experiments of this kind conducted in the United States to test the scientific predictivity of astrology.

A comprehensive test was conducted by Bernie Silverman who sampled the marriage and divorce rates in Michigan in 1967 and 1968. His sample was large, 2978 marriages and 478 divorces. The birth charts of the couples involved were examined by astrologers who were asked to opine on whether the horoscopes matched sufficiently to warrant the conclusion that the couple's marriage would be long lasting and happy. The astrologers (using whatever criteria they had) made out two lots, one with matching and the other with conflicting horoscopes: those in the

former category would have a stable and happy marriage whereas those in the latter wouldn't. These 'predictions' were then compared with the actual state of marriages of these couples, some of whom, as stated earlier, were happily married while others had divorces, broken marriages, etc. It was then a simple matter to test the agreement or otherwise between the actual and the predicted classifications of the sample. Rigorous statistical analyses demonstrated that there was no correlation between predictions and the actual results.

I could go on with other examples, to illustrate that astrology has been tested for the scientific criterion of predictability in numerous ways by numerous research workers on numerous occasions - and has always been found wanting.

Individually or as part of a larger group man has always lived by certain traditional beliefs. These beliefs are inextricably mixed with his cultural and religious heritage. Inevitably conflicts arise whenever the critical appraisal inherent in the scientific temper is applied to these beliefs. Some conflicts arise because the beliefs or the rituals they imply had a rational basis in the olden days but which they no longer possess today. Some rituals may have had a symbolic or even a practical meaning in the social ambience of several centuries ago: today they have become irrelevant. The question arises: what should one do in case such a conflict arises?

On the 'traditional' side we have the traditional virtues of the individual's responsibility to the society, the society's commitment to ensure the well-being of its members and the individual and social commitment to preserve the natural habitat around us. Armed with these virtues man can assess what science has to offer: he can take judicious decision on what to accept and what to reject. This is where the scientific temper comes to the help of the society as a whole.

The technologically advanced nations of the West have been experiencing the ill effects of uncontrolled impact of science and technology on the society. The destructive nuclear arsenal, the excessive industrial pollution, the enforced idleness brought about by automation and the consequent psychological problems of mechanization, etc., are there to see. Does this mean that we must put a stop to all scientific and technological development? Such a response, already advocated by a few from the developing nations, indicates a panic reaction. Given the traditional virtues mentioned above as guiding principles it should be possible to identify a rational path that skirts around the above pitfalls.

The present status

Let me review briefly how we Indians stand today vis-à-vis Nehru's expectation that "... *Only when we are politically and economically free will the mind function normally and critically*".

A dispassionate survey presents a somewhat mixed picture.
On the one hand, as I had mentioned earlier, we have several NGOs devoting their efforts to spreading rationalism and to eradicating superstitions. There are organizations which conduct public awareness programmes through lecture demonstrations, street plays, experiments debunking the so-called miracles, articles and books on the importance of the scientific temper, and so on. The National Council for Science and Technology Communication (NCSTC) in New Delhi has been supporting such programmes in an imaginative fashion.

The NCSTC had been responsible for launching the National Science Day to be celebrated on February 28, commemorating the discovery (on that date in 1928) by C.V. Raman that fetched him the Nobel prize in physics. On this day, (and indeed in the week covering that date) there are several public awareness programmes throughout the country. Scientific institutions keep an open house for the general public, with audio-visuals on their work, exhibitions and lectures, etc. Some institutions organize special quiz programmes and competitions for schoolchildren.

While there are several such laudable efforts in an organized manner both in and out of the government, what is the mindset of the 'person in the street'? Can we confidently assert that in the half century since independence, we have made a significant dent in the wall of superstitions? Astrology is not the only superstition. We remember, for example, the great social reformer Raja Ram Mohan Roy and his crusade against the Suttee-ritual. But there still take place isolated incidents of this ritual and they attract crowds of believers. I will shortly give more examples.

Nor is superstition confined to villages only. The episode of the idols of Lord Ganesha drinking milk drew large crowds in Delhi, Mumbai and other cities in India with some ministers also expressing their wonder and joy at the sight. It did not take long to debunk the phenomenon in terms of known science, but the spontaneity of belief was a give-away that the vaneer of science of technology on the society is very thin indeed.

But perhaps of greater concern is the rising trend towards superstitions. Several symptoms can be cited of this trend.

- More marriages are being arranged today by the criterion of matching of horoscopes than a generation ago. Thus I know of parents whose marriages were not passed through the 'horoscope filter', but whose children feel it necessary to apply this criterion to their marriage.

- With new technology, new superstitions are getting hold of the society. A recent rage is Vastushastra and its Chinese counterpart, the Feng Shui. Influential politicians and leaders of society have been swayed by this new cult. None of the claims of these subjects have passed scientific scrutiny.

- Despite debunking of Godmen's miracles by science, a large section even of the educated urbanites continues to believe in the 'Baba's who demonstrate their superhuman powers through miracles. In fact this is an area where science journalism could bring its investigative aspects to bear. So far it has registered moderate success but much more needs to be done.

- The legitimisation of astrology as a 'science' by the University Grants Commission is another symptom of this unfortunate trend. The UGC used the word 'Vedic Astrology' implying that the subject is of Vedic origin. All historical evidence, however, shows that planetary astrology using horoscopes came from the west, from Greece, Babylone etc.

And so on, and so forth!

Miracles of science benefit all

One could easily enlarge this list. Granted, there are problems with excessive reliance on automation, there are dangers of pollution with indiscriminate uses of technology, there may be serious dangers for the society from continuing certain areas of scientific research, but this does not mean that we turn away from the scientific path and regrasp the age-old superstitions which have been proven to be invalid.

Indeed, at first sight these problems before us appear to be formidable if not insurmountable. Yet, we have only to look at the remarkable progress of science over the last few decades to see that a properly channelled scientific approach holds out hope for the future. The achievements of space technology with such highlights as the manned trips to the Moon, the landing on Mars and the SITE programme in our country, the rapid growth of communications which has dramatically brought the far corners near, the advances in medicine, biology, agriculture are they not scientific miracles happening before

our own eyes and achieved during less than the span of a generation? Unlike the so-called miracles of the so-called godmen, *the miracles of science benefit not one single individual, but a whole class of humanity.* They benefit the poor as well as the rich. The invention of electric power not only runs the gadgets of the rich, it also provides light to the remote villages.

The developed nations have recognized these facts and they not only support science in general but also continue to encourage basic research, which at first sight may appear 'useless' but may lead to useful applications like those just mentioned. For us to ignore basic research at this stage would mean that we will have to keep on importing new ideas from abroad. This would be contrary to our policy of self-reliance. India has plenty of talent for basic research, most of which is untapped. Suitable support for basic research will unearth this talent and bring in its own rewards in the long term if not immediately. Right now I can think of one analogy to illustrate my point of view. Imagine a country which has vast untapped resources of oil, but which will not search for these for reasons of heavy financial outlay. Such a country will forever be dependent on oil imported from abroad. And, finally let me emphasize that basic research does not require heavy financial outlay when compared to its rich potential. We must, however, ensure with adequate safeguards that the research produced is of first class quality.

When Lord Krishna finished telling the Gita to Arjuna, he ended by saying: *"Reflect over what I have said, fully and then do what you wish."* In a sense this is what the scientific temper calls upon us to do: to weigh in all the evidence and then decide what is best. I am confident that if, and only if, we are not blinded by traditions and dazzled by science but keep our visors open and our minds alert, our country will make a triumphant march towards progress in this century.

Professor Jayant Vishnu Narlikar

Jayant Narlikar was born on July 19, 1938 in Kolhapur, Maharashtra and received his early education in the campus of Banaras Hindu University (BHU), where his father Vishnu Vasudeva Narlikar was Professor and Head of the Mathematics Department. His mother Sumati Narlikar was a Sanskrit scholar. After a brilliant career in school and college, Narlikar got his B.Sc. degree in 1957. He went to Cambridge for higher studies, becoming a Wrangler and Tyson Medallist in the Mathematical Tripos. He got his Cambridge degrees in mathematics: B.A.(1960), Ph.D. (1963), M.A. (1964) and Sc.D. (1976), but specialized in astronomy and astrophysics. He distinguished himself at Cambridge with the Smith's Prize in 1962 and the Adams Prize in 1967. He later stayed on at Cambridge till 1972, as Fellow of King's College (1963-72) and Founder Staff Member of the Institute of Theoretical Astronomy (1966-72). During this period he laid the foundations of his research work in cosmology and astrophysics in collaboration with his mentor Fred Hoyle.

Narlikar returned to India to join the Tata Institute of Fundamental Research (1972-1989) where under his charge the Theoretical Astrophysics Group acquired international standing. In 1988 he was invited by the University Grants Commission as Founder Director to set up the proposed Inter-University Centre for Astronomy and Astrophysics (IUCAA). Under his direction IUCAA has acquired a world-wide reputation as a centre for excellence in teaching and research in astronomy and astrophysics. He retired from this position in 2003. He is now Emeritus Professor at IUCAA.

In 1966, Narlikar married Mangala Rajwade, a Ph.D. in mathematics. They have three daughters, Geeta, Girija and Leelavati, all of whom have opted for careers in science.

Narlikar is internationally known for his work in cosmology, in championing models alternative to the popularly believed big bang model. He was President of the Cosmology Commission of the International Astronomical Union from 1994 to 1997. His work has been on the frontiers of gravity and Mach's Principle, quantum cosmology and action at a distance physics. He has received several national and international awards and honorary doctorates. He is a Bhatnagar awardee, as well as recipient of the M.P. Birla award, the Prix Janssen of the French Astronomical Society and an Associate of the Royal Astronomical Society of London. He is Fellow of the three national science academies as well as of the Third World Academy of Sciences. Apart from his scientific research, Narlikar has been well known as a science communicator through his books, articles, and radio/TV programmes. For these efforts, he was honoured by the UNESCO in 1996 with the Kalinga Award.

Narlikar broke new grounds in space research, when during 1999-2003 he headed an international team in a pioneering experiment designed to sample air for microorganisms in the atmosphere at heights of up to 41 km. Biological studies of the samples collected led to the findings of live cells and bacteria, thus opening out the intriguing possibility that the Earth is being bombarded by microorganisms some of which might have seeded life itself here.

Narlikar was decorated Padmabhushan in 1965, at the young age of 26. In 2004 he was awarded Padmavibhushan.

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