From the Editor

A highlight of this issue is an article by our latest Burton award winner, Galileo “Leo” Violini. We owe him many thanks for all the work that he has done for Physics over many years, and I am very grateful to him for the contribution. This continues our policy of soliciting and publishing articles by Szilard and Burton Forum award winners.

There are two more articles all by recent Forum invited speakers: Richard Taylor on running, Arjun Makijani on the biological consequences of the Bikini explosions. I plan to continue asking Forum invited speakers to write for this newsletter. In the next issue I expect to have an article by our own Anna Quider. As the current Forum chair Anna has been very supportive of the newsletter. Myself and the entire Board of Editors have to thank her and other members of the Forum elected leadership for invaluable help with recent difficulties with some people in the APS staff (not with any APS members) that found the book reviews in the last issue as possibly “not aligned with its [APS] values”. Please readers, look up these reviews if you need to refresh your memory and let me know what you think.

We have also in this issue book reviews as organized by Quinn Campagna, our Reviews Editor. As you know, Quinn is a graduate student and is doing a great job in a situation that would tax much more experienced people.

We are still looking for a Media Editor. This is a great opportunity for somebody up to date on everything related to social media, and who wants to get more involved in Forum activities. Please apply or get somebody to apply. Just send me an email.

This newsletter and its contents are mostly reader driven. All topics related to Physics and Society are acceptable, excluding only pure politics and anything containing ad hominem invective. Manuscripts should be sent to me, preferably in .docx format, except Book Reviews which should be sent directly to book reviews editor Quinn Campagna (qcampagn@go.olemiss.edu).

Content is not peer reviewed and opinions given are the author’s only, not necessarily mine, nor the Forum’s nor, a fortiori, the APS’s either. But subject to the mild restrictions mentioned above no pertinent subject needs to be avoided on the grounds that it might be controversial. On the contrary, controversy is welcome.

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Challenges to foster science in developing countries. Learning from lost opportunities.

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ABSTRACT

The limited successes that have been recognized with the Joseph A. Burton Award contrasts with several initiatives which, in different contexts, unfortunately, did not achieve the same level of success, despite their social and scientific impact on scientific advancement, regional integration, economic development or peace. Quoting a poetry of Guido Gozzano, a 19th-century Italian poet the title of this reflection might have been "I love only the roses I did not pick. that could have been and were not been." Actually, it sheds light on the formidable obstacles one faces when advocating science in developing countries or navigating complex political situations, and, optimistically, proposes an agenda for future work aimed to rescue those initiatives, learning from the reasons that made them lost opportunities.

The purpose of these reflections is to extract the lessons from a 45-year experience of activity as testimonial of the role that science, and physics, play to make more equitable the world at large and the society.

The opportunity for this reflection has been offered by the decision of the APS Forum on Physics and Society of honoring me with the prestigious Joseph A. Burton Forum Award.

The activities that have allowed me to join the impressive, fifty-years long, list of previous awardees have a common bottom line, a long-term vision. Often, and it happened also in some of those activities, external conditions may suggest that a goal has little, if any, chance of being achieved. However, the seeds can bear fruits for future harvest. The pessimism of the reason should never prevent the optimism of the will to be the compass. This Gramsci statement well applies to the complex reality of developing countries, that share the burden of historical delays in science and higher education policies, often accompanied by social and economic inequalities which demand vigorous and difficult decisions.

Fifty years ago, to talk about high-energy physics in the Andean region could have seemed crazy. It was a delicate and difficult task to advocate, with Marcello Cini, the right of young Colombian scientists to follow their vocation in the country, without being forced to migrate or to make research in few areas, supposedly relevant in the national context. A few years later, at CIF, the International Center of Physics, that I founded with a Colombian friend and colleague, Eduardo Posada, and with the support of a dozen of colleagues, the crop of that seed was a small group of young physicists. Some of them would become University rectors, dean of faculties, head of departments or lead important scientific programs. And, as a second fruit, CIF promoted, with the collaboration of Leon Lederman and José Antonio Rubio among others, a broad regional commitment in Fundamental Physics. This, also thanks to the broad HELEN program, promoted by Luciano Maiani, Veronica Riquer, and, again, Rubio, paved the way of Andean groups to Fermilab and CERN. Now, decades later, Ecuadorians, Colombians, Peruvians are regular active participants in LHC experiments.
When I first advocated African-Latin American collaboration, at the end of last century, it could have seemed to be a non-sense dream. Few weeks ago, it was exciting to hear Brazilian President, Luís Inácio Lula da Silva, speaking at the African Union Summit, a confirmation that now interregional scientific collaboration is in the agenda. It was not considered a strange curiosity by the Dominican Government, when, last year, I decided to include it in a two-day Symposium program, looking at Gulf and Maghreb countries. Actually, such kind of collaboration is being put in place, with the beautiful example of the synergy between the African Light Source and the Greater Caribbean Light Source Initiative.

I had the fortune of being involved in a program of reconstruction of the University of El Salvador, after the civil war, and of being UNESCO’s representative to Islamic Republic of Iran, and director of the Tehran’s Office of the Organization. In El Salvador, I could, with another friend and colleague, James Vary, convene a meeting to design a Science Development Plan for Central America. Among the participants there was a young Guatemalan, Fernando Quevedo. Twenty years later, the direct, unpredictable crop of that seed was a needed and ambitious program of regional doctorates in Central America, but who knows how that experience was instrumental to make him a future extraordinary and visionary director of ICTP? In Iran, with Reza Mansouri, we could contribute to make possible the long-awaited participation of Iranian scientists in CERN.

These experiences were not part of my duties. This allows me to dare to suggest to whom may have in the future similar responsibilities: “Don’t be bureaucrats. Always interpret duties extensively. Be confident that your supervisors will understand. Never look at why something may appear to be impossible. Find how it can be made possible.”

However, looking back to those achievements, it is impossible to be satisfied.

The needs of the countries and the Andean-Caribbean region where I have been working for about 45 years would have required much more, and the sad side of the story is that, 45 years later, most of those needs are still there. It looks like if the out-of-time Macondo atmosphere of Garcia Marquez’s One hundred years of solitude pervades science policy. It is a scandal, not an amazing curiosity, that the talk I gave thirty years ago, for the John Wheatley Award ceremony is still actual. And it is more than anecdotic that, a few months ago, I could write an article for a Dominican Republic online newspaper, which was a plagiarism of something I had said with Marta Lucia Guardiola and José Luis Villavecches, thirty-five years earlier, at a TWAS Conference.

Too many problems are structural. Too many Latin American countries have an economic matrix based on volatile items, tourism, services, remittances. High tech is imported, not produced nationally, even less is it object of advanced applied research, despite the popularity of a magic word: innovation. This reflects and is rooted on their scientific and education system.

Science is Cinderella. It is mentioned in electoral campaigns, but rapidly forgotten the day after the election, when the attention shifts to everyday urgent problems. The average Latin American investment in science is, now as decades ago, of the order of 0.6% of the GNP, but differences between countries are huge. The mantra goal of the mythical 2% is transmitted from a generation of politicians to another. And there are the differences within the country, social, geographical, sometimes ethnic, those between capital and small towns and villages. This makes the 2017 unanimous recognition by UNESCO of the human right to access and use Science as fundamental, remain one of those wishful decisions of United Nations, applauded in the Summit speeches, but not reflected in actions.

Science and Education are entangled. Not only in UNESCO acronym. They require harmonious policies. However, their national plans do not use to be entangled. Little is done to assess their implementation. The illusion of innovation and technological development without facing structural problems is cultivated. Nobel Prize Houssay’s warning against the pitfall of research of immediate application and (supposedly, I add) useful to the society is not part of common politician education. Short-time actions are often politically more rewarding than creating infrastructure, be it a center of science be it an important facility. New Meliboei, many politicians are terrified of the idea that a “brutal alien master” from an opposite political party may enjoy the benefits of their policy.

Sometimes the return of the investment is harvested decades later. Brazil entered High Energy Physics forty years ago. I remember Tiomno at Fermilab, proposing to two brilliant theorists, Escobar and Santoro to make the brave decision of moving to experimental physics. Brazil has just joined CERN as first American non-member state. Among the possible benefits, let me just mention that, yearly, against a duty of 11 M$, it will have access to a 500M$ portfolio of tenders.

Perhaps, this may explain, at least in part, why certain proposals did not succeed, despite their goal should have been recognized as a must for a country or a region. Therefore, I prefer to talk about what could not materialize. This, not because, as an Italian XIX century poet, Guido Gozzano, wrote “I love only the roses I did not pick, that could have been and were not been”, but because understanding why those roses could not be picked, lessons are learned, and, hopefully, this will help me, or whoever may be, to pick those that still deserve it.

The successful creation of CIF in Colombia was due to several fortunate time and space coincidences. A visionary president, Belisario Betancur, excellent science administrators in Colciencias, the Colombian Research Council, Efraim Otero and Fernando Chaparro, a scientific community that supported the project without looking at petty individual or institutional interests. There was a generous regional vision, that led to establishing offices in Peru and Ecuador, anticipating what ICTP would have made decades later, when it created four satellite Centers in Mexico, Brazil, Rwanda and China.
There were also other fortunate circumstances. UNESCO’s support through Antonio De Veciana, Siegbert Raither at Headquarters and Gunther Trapp in Caracas, and that of OAS with Athos Giachetti.

Research Centers are useful. The best assessment of ICTP impact is provided by the South scientific development during its 60 years of existence and by the centers established having it as a model. Unfortunately, the circumstances that made possible the creation of CIF are rare and there were also failures. This happened in advanced as well as in developing countries. In Spain, Gregorio Medrano promoted an intercultural center that, in some way, recalled the universal idea of XIV Century Toledo\textsuperscript{22}. It never took off. After a local election, the new majority did not understand the strength of the idea. Nor was it understood when Medrano received a few years ago the Spirit of Abdus Salam Award, rare, perhaps unique, case of recognizing an unrealized idea\textsuperscript{24}. In the US, the extraordinary experience of the Iowa Institute of Theoretical and Applied Physics, promoted by James Vary\textsuperscript{24}, lived the space of a morning, only few years, because of cuts in the State support. Among its important lines of activity, not only science. It was pioneer in gender capacity building. In Peru, Multiciencias, promoted by Victor Latorre, could not resist the strain of the economic changes introduced by Fujimori government\textsuperscript{25}.

I witnessed those cases as a spectator and advisor of these visionary friends. In other cases, again sadly too many, I was instead the promoter. It has been impossible to convince the Andean countries that a Trieste-like Center for the region is necessary, to complement those In Mexico and Brazil. Twice, I was close to succeed. In Colombia\textsuperscript{26}, few days before starting to realize the project, first there was a change of rector in the University where it was going to arise, then the following rector showed an alternating (weak) interest that did not allow to rescue the project. It remains a mystery how the political importance of such a Center in one of the most vigorously developing regions of the country, the Atlantic Coast, did not receive more than a generic attention by the local politicians. Few years later the same project was considered and supported by Ecuadorian government. The feasibility study\textsuperscript{27} was not implemented because the realization was delegated to a university, whose rector suddenly changed his mind and stopped the project, despite a diffused interest inside the institution. Also in this case, the social and economic impact in one of the less developed provinces of the country transcended the scientific value of the project, which should have deserved a more vigorous political support. These Centers belong to UNESCO’s C2C, category 2 centers. There are some twenty worldwide. In Latin America only the two I mentioned.

Something similar happened in Dominican Republic. For a project of a regional center on materials science\textsuperscript{28}, the support by at least two important private universities, and its fit with one of the most developed areas of national research was not sufficient. Personal interests, or worse jealousies? Different priorities of the Government? Consequence of a higher education system in which much advanced research is made in private universities, which limits their capacity? A mixture of all of this?

Certainly, a basic problem is that limited 0.6% of average GNP investment in science, a percentage that in several Central American countries is much above reality, more than one order of magnitude. Nine years ago, during a meeting of the regional Central American doctorates, I launched a proposal, to create a regional fund for Science and Technology. It would have remained an academic pronouncement, had not been for the lucky circumstance that the Government of Guatemala, and its vice president, Juan Alfonso Fuentes Soria, endorsed it\textsuperscript{29}. More or less approved, nine years after, it has not yet been brought to the attention of the Central American Head of State Summit.

What is missing? Diagnostic may provide different answers. First of all, the Society support. Of the whole civil society, not only of scientists. Often, scientists are biased by the (wrong) idea that science funding is rigid and that new projects mean less money for theirs.

Structures open to the society, such as a regional Association for the Advancement of Science may be more effective than the scientific societies, that, in some cases, as I had an unpleasant first-hand experience, may be dominated by small groups of mutual admiration and interest.

Moreover, not necessarily, good scientists have the vision of promoting other sectors. I had the fortune of studying in Rome. After the WWII, Edoardo Amaldi could have made Physics at University of Rome be focused only on High Energy Physics. He did not. However, promoting diversification is not always successful. An emblematic case of lost opportunity for Latin America is that of gravitational waves. They were the subject of the first CIF’s workshop, forty years ago\textsuperscript{30}. The key opening speaker was Amaldi. Audience from all the region. There was no follow up. Latin American presence in their discovery has been minimal, even if very important. Nor a better fate had a second attempt, when the Italian spokesperson of the experiment, Fulvio Ricci, participated few years ago in a Dominican Republic Symposium\textsuperscript{31}.

Differentiation is the only way by which developing countries science agenda may be autonomous. And the collaboration with advanced countries will not be as if they were Pygmalion’s professor Higgins or colonel Pickering. However, to make them behave as new Eliza Doolittle is not trivial\textsuperscript{22}.

It is not easy to convince policymakers that by differentiating the lines of scientific development, opportunities open for that industrial and hi-tech development that only can make their country be, in the next decades, more than a tourist destination, a market and a service provider. And the same holds for the authorities of the universities, especially if private, who rarely understand that the first beneficiary of cultivating some new niche will be their institution.

\textsuperscript{22} Amaldi, E. (1964). A new idea for international cooperation: the International Center for Theoretical Physics. Nature, 201(4910), 939-940. doi:10.1038/201939a0


\textsuperscript{31} Ricci, F. (1976). The potential of Latin America in the field of science and technology. Revista de Educación, 10(1), 111-120.
Science scope is more than scientific or economic development. It includes a better society and peaceful international relations. Responsible scientists must assume a holistic civil commitment, not limited to their specialty. Often, they will be ignored or have little chance of impact. It is a fact. It is necessary to have scientific journalists, possibly with access to TV popular channels. Unfortunately, for this, I do not have marvelous results to present as evidence, but I am proud of the little support I could give, advocating, on non-scientific press, the equitable availability of vaccines and the liberalization of the patents during the COVID pandemic.

I conclude with two more experiences, based on education and science, but of a much broader scope. They could have been important. They still are. Thus, let me make a call for the tremendous challenge of their rescuing.

My first contact with Haiti was after the catastrophic 2010 earthquake. In the following years, with ICTP support, we were very close to achieve the goal of launching an integrated national plan of Education and Science. The crisis of the last few years has stopped this initiative. I am not so naïve to be not aware of the many Haiti problems, but among the conditions for any solution, a vigorous Education program is a must.

Moving to another region on which worldwide attention is concentrated, the Middle East, after October 7, the hostages tragedy, the civilian deaths in Gaza, the destruction of scientific, education and health infrastructure, it is difficult and embarrassing to imagine what science can do. Nevertheless, let me end with a word of hope.

Some thirty years ago, I met two magnificent scientists, Reyad Sawafta, from Palestine, and Avivi Yavin, from Israel. They had made a visionary proposal, a Center of Science or a University in the region of Eilat-Aqaba, where scientists of the region could work together. I was an enthusiast supporter of that proposal. Two milestones were my participation in a UNESCO Conference in Jerusalem, and a mission for UNESCO, together with two American colleagues, again James Vary, and Hildegard Vary. This, and the experience of ICTP being instrumental for the development of the tertiary sector in Trieste, even led me to suggest that Gaza could instead be the ideal location for such a Center.

Obviously, this is unthinkable today. However, also the Hundred Years War had an end. My experience at UNESCO, the lesson of a great director general of that organization, Federico Mayor Zaragoza, make me a convinced ambassador of the Preamble to UNESCO Statutes: “since wars begin in the minds of men, it is in the minds of men that the defences of peace must be constructed”.

Our hope must be, and are, the young generations. I have a dream. That I can see at least the launching of a minor initiative, such as that suggested together two colleagues of Iowa State University, Joe Shinar and again James Vary - a kind of periodical Conferences, where young scientists from the Middle East may meet, know each other, perhaps work or at least create the conditions for future work, jointly. An experience of this kind has already been possible and successful in that same region. SESAME synchrotron shows that through Science historical barriers can be overcome.

The main raison d'être of the recognition like Joseph Burton Forum Award, so intimately related to societal development, is to motivate young people, who pursuing the same goals, may be successful where the previous generation was not. As a Latin American by adoption, I want therefore to conclude dedicating this talk to young Latin American scientists, and wish that many others join me and the 1992 awardees, those who were honored “For laying the groundwork for the agreement between Argentina and Brazil to abstain from building any explosive nuclear device”.

I cannot conclude without expressing once again my deepest gratitude to all the colleagues, of whom only few I mentioned, without whom I would not have been here. However, there is one special acknowledgment and commitment I cannot miss. My model has been Abdus Salam, and his ideal of promoting science in the developing world, in a holistic vision, encompassing science, education and peace.

I took the commitment, thirty years ago, receiving the John Wheatley Award, of pursuing further that ideal. Today, this recognition that I kept that word with APS and the Forum on International Physics makes me excited, and makes me renew that commitment.

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Legacy of U.S. Nuclear Testing in the Marshall Islands

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1. Overview

The United States carried out 67 nuclear weapons tests in the Marshall Islands between 1946 and 1958: 23 at Bikini Atoll totaling 76.8 megatons and 44 at Enewetak Atoll with a total explosive power of 31.7 megatons. The total power of tests in the Marshall Islands of 108.5 megatons, was over one hundred times that of all surface, tower, and atmospheric tests conducted at the Nevada Test Site. The largest single test, named Bravo, was a 15-megaton thermonuclear bomb, one thousand times the power of the bomb that destroyed Hiroshima. The testing yield in the Marshall Islands was equivalent to exploding one Nagasaki-size bomb there every day for about 14 years.

Before considering the devastating impacts of nuclear testing in quantitative terms, it is important to consider what the United States knew about test site locations at the time, both in general and specifically about the Marshall Islands. Surveys had already shown that the very first test, Trinity, on July 16, 1945 sprayed radioactive fallout for days as far as 200 miles from ground zero; it had created intense hot spots, including one documented 20 miles away from the site and one at a house where the cumulative dose was estimated at 57 to 60 roentgen – or roughly 50 rads, which is 5,000 times the allowable annual dose for the members of the general public today. Having led the team that measured the Trinity test fallout, Colonel Stafford L. Warren, the Chief of Radiological Safety recommended that if “a similar test” (21 kilotons) were done, it should be at a site “preferably with a radius of at least 150 miles without population.”

The Bravo test was about 700 times larger than the Trinity test; Rongelap Atoll, which was devastated by that test, is less than 100 miles as the crow flies from Bikini. Other tests were scores of times larger than Trinity. Thus, Bikini, where the very first tests after World War II were done (as part of Operation Crossroads in 1946), was selected in blatant violation of the general recommendation about test sites by Col. Warren, a medical doctor, who was also in charge of radiological safety at Bikini. The two Operation Crossroad tests were the same size as Trinity. The second, Test Baker, who was suspended from a barge in the lagoon and exploded underwater. It rained two million tons of radioactive water back down and enveloped the area with tsunamis and radioactive mists (Figure 1).

The Navy, which led the operation, had no idea how to decontaminate the ships. It set sailors to scrubbing the decks without protective gear; meat was washed with water from the lagoon, laden with fission products and more than four kilograms of unfissioned plutonium. The daily dose limit of 0.1 roentgen could be exceeded in 45 seconds at hot spots unpredictably scattered on the ships. The operation was such a debacle that the third test was cancelled. Safety officials complained about the “hairy-chested” attitude of some officers which led to a “disdain for the unseen hazard” of radiation. Things were so bad that Col. Warren said “I never want to go through the experience of the last three weeks of August [1946] again.” The operation had been a widely publicized coming out party for the bomb. The radioactive hangover not only left Bikini uninhabitable but extended to contamination of parts of Honolulu harbor and San Francisco Bay, where efforts to decontaminate the ships continued.

The Marshall Islands were soon understood to be unsuitable for nuclear testing shortly after it began. Two years after the disastrous 1946 “Operation Crossroads” at Bikini, the U.S. military made the following assessment of the Marshall Islands sites as test locations:

From a meteorological standpoint, there are three basic requirements for a suitable site for atomic bomb experiments. These are:

a. There should be a reasonable frequency of occurrence of cloud or weather conditions to meet the operational requirements for the experiment....

b. Wind conditions from the surface to stratospheric levels should be such that there can be no possibil-
ity of subjecting personnel to radiological hazards or surrounding land or water area to unintentional radioactive contamination.

c. The mechanism of meteorological processes for the site should be adequately understood and the weather predictions for the site demonstrated to be of a high and reliable accuracy.

The Marshall Islands in the main do not meet these meteorological requirements.5

At the time of this assessment 0.15 megatons of explosions, just 0.14 percent of the eventual total of 108.5 megatons, had been conducted at Bikini and Enewetak at the time of this assessment; the tests continued anyway.

2. Radiologically impacted area and radiation doses

The United States has recognized only four of the northern atolls as being radiologically impacted. But reasonable radiological metrics, including those implied by U.S. government policies, show that the entire country was impacted.

Thyroid doses are a good proxy for estimating the health impact and risk created by fallout. Radiation dose to the organ is primarily due to short-lived iodine radioisotopes, including iodine-131 with a half-life of about 8 days. In addition to thyroid-related health impacts, whole-body radiation doses can be roughly estimated from thyroid doses. The thyroid-dose metric also allows a comparison with the impact of atmospheric testing at the Nevada Test Site, since the doses have been estimated for both situations. A good reference metric is to note that the exposure to the thyroid to any member of the public from commercial nuclear power-related exposures is limited to 0.75 millisievert (mSv) per year; this is generally considered as equivalent to 0.75 milligray (mGy) in case of exposure to gamma and beta radiation; this would be the case for radiiodine-related thyroid doses. The corresponding whole-body limit is 0.25 mSv/year.6 Exposure at the latter limit for a lifetime of 70 years yields an excess cancer risk (all cancers) of about 1 in 500.

The 1954 Castle test series, consisting of six tests carried out between 1 March 1954 to 14 May 1954,7 had the most serious radiological impacts of U.S. tests anywhere. The United States conducted aerial and ground-based measurements of fallout which provides clear evidence that the entire country was impacted.8 Cumulative external doses were also estimated at the time. The highest doses, about 2 gray, were estimated for Rongelap and Rongerik. Cumulative external doses in the southern atolls were in the range of a few milligray, going down to about 2 milligray in the southern-most atolls.9 The near lethal levels of fallout from the Bravo test can be seen in U.S. government constructed dose isopleths (Figure 2).

Independent studies have generally estimated doses to be significantly higher than government estimates. For instance, an independent evaluation by Sanford Cohen & Associates (SC&A),10 presented to a congressional committee in 2005, estimated that whole-body doses were at least double the U.S. government’s values and that blood counts and other data supported the higher numbers.11

A similar picture emerges from consideration of thyroid doses, which are age-dependent; doses to three-month-old infants and five-year-old children are estimated to be roughly 30 to 100 times the average external dose.12 On this basis, the

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Figure 2: Dose isopleths (in rads) due to the 1 March 1954 Bravo test. A Japanese fishing vessel, the Lucky Dragon Number 5, was also affected.

Source: Department of Energy figure downloaded from Wikimedia Commons at https://commons.wikimedia.org/wiki/File:Bravo_fallout2.png
average inferred infant thyroid doses in the southern atolls would be on the order of 100 to 200 milligray due to the 1954 Castle test series. In the northern atolls, the corresponding values would be one gray to tens of grays. The exposure from other tests would have to be added to this amount.

A comparison to the National Cancer Institute’s estimates for thyroid exposures due to the tests at the Nevada Test Site is revealing. In the most affected countries (four in Idaho and one in Montana), average thyroid doses ranged from 120 to 160 milligray. Three-month old infants would have received on the order of 1 gray.

People in the highest exposed counties in the United States, as measured by average thyroid dose, have not yet been compensated under the 1990 Radiation Exposure Compensation Act (RECA). The counties included in RECA had average doses in the 10 to 120 milligray range; inferred infant thyroid doses would be in the 70 to 800 milligray range (rounded). The lower end of this range is smaller than thyroid exposures in the southern atolls of the Marshall Islands. Thyroid doses were far higher in northern latitude atolls like Ailuk, Mejit, Likiep, Wotho, Wotje, and Ujelang that have not been recognized by the U.S. government as radiologically impacted. As a result, they have not been provided with medical care or even health screenings.

There is, of course, a distribution of doses around the average for each age group. According to the National Cancer Institute “[a]ny specific person could have received a dose many times lower or higher than the estimated [average] doses.” This would apply people in the Marshall Islands as well as the United States.

The 1954 Castle test series also produced hotspots around the world, as measured by U.S. monitoring at the time of the tests. Figure 3 shows a map of cumulative fallout from these series, decay-corrected to July 1, 1954, prepared from data gathered at the time. Note the hot spots in Mexico City and in Colombo, Sri Lanka.

3. Health impacts estimates

a. Cancers

Several estimates of excess cancers due to U.S. nuclear testing in the Marshall Islands have been made. A 2004 National Cancer Institute study, presented at the same 2005 congressional hearing discussed above, estimated that cancer incidence in the Marshallese population of the time would increase by about 9%—amounting to about 500 excess cancers. Eighty-seven percent of the cancers were estimated to occur in the Northern atolls (44% in Rongelap, Ailinginae, and Utrik; 43% in the still unrecognized atolls of Ailuk, Mejit, Likiep, Wotho, Wotje, and Ujelang). The other 13% were estimated to occur in the southern atolls, also unrecognized as radiologically affected by the U.S. government. The independent cumulative doses cited at the same hearing would indicate a cancer increase substantially larger than that. The U.S. government lowered its dose estimates by about a factor of 3 in a subsequent 2010 reassessment—still equivalent to 2 million excess cancers in the United States had the doses been similar.

b. Non-cancer impacts

Serious non-cancer impacts would also be expected in the northern atolls, especially Rongelap, Utrik, and Ailinginae. The high thyroid doses in these atolls would be expected to destroy thyroid tissue (which is why iodine-131 is used in thyroid cancer treatment), creating a risk of hypothyroidism. Thyroid hormone deficiency can cause serious health problems, especially in children. The potential impacts include Hashimoto’s disease, an auto-immune disorder, and physical and mental growth deficiencies in children. Women would have been at risk of early failed pregnancies and their children at risk of organ malformations and “severe

Figure 3: 1954 Castle test series fallout map, created from data in List 1955, by Yunus Kinkhabwala (Senior Data Scientist, PSE Healthy Energy). Note the hot spots in Mexico City and in Colombo, Sri Lanka. Cumulative radioactivity deposition, decay-corrected to July 1, 1954. Measurements in list 1955 were converted to Standard International Units.

Figure 4 shows a photograph of the Bravo test. Source: U.S. Department of Energy photograph downloaded from Wikimedia Commons at https://commons.wikimedia.org/wiki/File:Castle_Bravo_nuclear_test.jpg
mental retardation” which was defined, in the radiation exposure context, by International Commission on Radiological Protection (ICRP) as “an individual unable to form simple sentences, to solve simple problems in arithmetic, to care for himself or herself, or is (was) unmanageable or institutionalized.”24 This ICRP conclusion derived from an epidemiological analysis of children who were in utero during the Hiroshima and Nagasaki bombings who survived. Like solid cancers, this impact was found to be proportional to dose with no threshold below which there was zero risk. The risk coefficient was estimated at 0.4 occurrences per gray; this means that a cumulative population dose of roughly 2.5 gray experienced in a short time would be expected to produce one such case with high probability in that population.22

4. Long-term impacts and residual radioactivity

There is significant residual radioactivity in the highly impacted atolls. Bikini remains uninhabitable; the people of Rongelap are in exile, their atoll contaminated and the habitability of their home atoll the subject of considerable controversy. Even the radiation protection norm has been the subject of disagreement. The Marshall Islands have asked for residual radioactivity to be reduced to levels that would keep the maximum dose below 0.15 mSv/year – the EPA derived standard for U.S. Superfund sites. The United States uses a level almost seven times as high: 1 mSv/year; this is the NRC standard for exposure from all anthropogenic sources except medical radiation.

The amounts of residual radioactivity, decay-corrected to 2022 are estimated to be as follows:21

- Cesium-137 (half-life, 30.1 years) – a potassium analog: 90,000 terabecquerels.
- Strontium-90 (half-life, 28.8 years) – a calcium analog: 50,000 terabecquerels; strontium mimics calcium in the body and goes to the bone.
- Plutonium-239 (half-life, 24,110 years): 160 kilograms of unexploded plutonium-239.

Smaller amounts of very long-lived radionuclides will remain in the environment essentially permanently, including technetium-99 (half-life: 211,000 years); cesium-135 (half-life: 2.3 million years); and iodine-129 (half-life: 15.7 million years).24

Typical individual doses from the very dilute global presence would be very small; however, the cumulative population doses over hundreds or thousands of generations could become large. The Marshall Islands would be most impacted; but, as with fallout from all atmospheric testing, no area of the world was spared (see Figure 3 above).

5. Remediation

Bikini and Eniwetak atolls, where the tests were done, and Rongelap, Ailinginae, and Utrik, the locations of the heaviest fallout, have significant amounts of residual radioactivity. For instance, food produced in contaminated areas would have elevated levels of cesium-137 (half-life 30.1 years); this is one of the main lasting impacts in terms of habitability. The risks of cancer and of the teratogenic harm that has no threshold will persist. These risks can be reduced by remediation programs, including remediation of land and lagoon ecosystems. For instance, real-time monitoring and fertilization with potassium can reduce cesium-137 uptake by plants. But it requires systematic investment in the local people and local infrastructure as well as a high level of confidence and trust between the Marshallese and the United States on radiation issues that does yet exist.

The Runit Dome constructed by the United States in Eniwetok to promote the return of its people provides a negative object lesson in remediation. Residual plutonium remains on the inhabited Islands. Less than one percent of the plutonium was scraped up; 99 percent remains in the lagoon, which had no remediation though it is a center of traditional economic activity. The lagoon contains almost 30 kilograms of residual plutonium compared to a “few hundred grams” contained in the soil and debris put in the Runit dome.25,26 The Department of Energy has stated that the dome is “an effective and erosion resistant seal for the encapsulated radioactive material within the containment structure”27 even though the concrete has cracked and the dome is leaking. It was unlined when built; its rise and fall with the tides shows that it is in communication with the ocean and lagoon. The Eniwetak cleanup compares very unfavorably with that done after nuclear weapon accidents in Spain and Greenland, where much of the radioactive waste was repatriated to the United States.28

6. Conclusions

U.S. trusteeship of the Marshall Islands, granted by the United Nations after World War II, ended in 1986 when the country became independent. A 20-year “Compact of Free Association” was created, with funds for compensation that have proved sorely inadequate. The compact was renewed; that renewal is ending. A new 20-year agreement with $2.3 billion in total funds has been negotiated. While substantial, this is likely to fall short, given the magnitude of the need and over $2 billion in outstanding claims awarded by the Nuclear Claims Tribunal that have not yet been paid.29

As a tragic coda, climate change is rapidly impacting the country, even as the legacy of U.S. nuclear testing persists. The Marshall Islands for the “High Ambition Coalition” was central to the aspirational goal of limiting global temperature rise to 1.5°C at the 2015 the Conference of Parties in Paris (the so-called COP15).30 The world should be thankful because achieving that target is now seen as essential to minimizing catastrophic damage from climate change. Large emitting countries should express their gratitude by meeting the corresponding deep mitigation of emissions that are required. As for the United States, its enduring debt to the Marshallese people due to testing is compounded by the fact that it is also the world’s leading cumulative emitter of carbon dioxide, the principal greenhouse gas.
Endnotes

1 This article is based on a previous paper by the author: Legacy of U.S. Nuclear Weapons Testing in the Marshall Islands, prepared as comment for the Office of the United Nations High Commissioner for Human Rights, January 2024 See January 2024 at subm-addressing-challenges-barriers-cso-institut-ieer-ieee-ieee-input-1.pdf (chiehr.org) Test yields are from United States Nuclear Test Data, DOE/NV-209-REV 15, December 2000, unless otherwise stated.


6 The dose limits are in an EPA regulation, which can be found at 40 CFR 190.10(a). U.S. regulations and many studies and reports use rad, millirad, rem, and millirem instead of international system of units (SI system) of gray, milligray, siert, and millisierit. The values in those reports and regulations have been converted to international units in this article: 1 rad = 0.01 gray; 1 rem = 0.01 sierit. U.S. reports also use curies for quantities of radioactivity; those values have been converted to the SI system: 1 curie = 37 gigabecquerels.

7 Dates are at the location of the test site.

8 Alfred J. Breslin and Melvin E. Cassidy, Radiological Debris from Operation Castle: Islands of the Mid-Pacific, Health and Safety Laboratory, 18 January 1955 at https://www.osst.gov/servlets/purl/4274357, Table 1 (pdf p. 44) and Figure 27 (pdf p. 48).

9 Alfred J. Breslin and Melvin E. Cassidy, op. cit. 1955, Table I (pdf page 44) and Figure 27 (pdf p. 48).

10 Disclosure: I was an Associate (a consultant designation) of Sanford Cohen & Associates (SC&A) from 2004 to 2018 as part of a team that provided scientific and technical support to the presidency-appointed Advisory Board on Radiation and Worker Health. The Board oversees the U.S. government’s compensation program for workers who contracted cancer resulting from their radiation exposure resulting from work related to nuclear weapons production and testing. (Department of Defense personnel are separately compensated under RECA.) I had no role in any of the studies referenced the testimony or in the testimony itself.


13 Derived from Table 1 (pdf page 44) in Breslin and Cassidy 1955, op. cit.


16 Read off from Figure ES.1 on page ES.3 in NCI 1997.

17 NCI 2004 page 10 (pdf page 11). Underlining in the original.


19 NCI 2004, Table 3. Percentages calculated from the numerical estimates in this table. The estimate in the table is 532 cancers but about 500 in the text.

20 Mayo Clinic, "Hypothyroidism (underactive thyroid)", at https://www.mayoclinic.org/diseases-conditions/hypothyroidism/symptoms-causes/symptoms-causes/syc-2035284


22 I discussed these issues in more detail in a memorandum to a National Academies committee in 2022. Arjun Makhijani, "Memorandum to the National Academies committee on the current status and development of a long-term strategy for low-dose radiation research in the United States", Institute for Energy and Environmental Research, January 2022 at https://ieer.org/wp/wp-content/uploads/2022/01/Arjun-Makhijani-memorandum-to-National-Academies-committee-on-low-level-radiation-2022-01-10.pdf; hereafter Makhijani 2022a. It should be noted that very short-term exposures during the bombings of Hiroshima and Nagasaki have been central to estimation of the cancer risk of radiation – including the conclusion of no-threshold for the risk. But a downward adjustment of the numerical value is generally made in official risk estimates when the same total dose is experienced at low dose rates over long periods. Most of the dose experienced by the most highly exposed Marshallese was in a short period – though longer than the very short principal exposure period during the bombings of Hiroshima and Nagasaki. Hence the qualification "roughly" has been added to provide context for the Marshallese exposures.

23 Calculated from data in Chapters 2 and 3 of IPPNW and IEER 1991, op. cit.

24 As a rule of thumb, it is reasonable to assume that quantities of radioactivity have decayed to very low levels after five to ten half-lives.


27 DOE 2020, op. cit., p. iii.

28 See Makhijani 2024, op cit.

29 Rhea Moss-Christian (Chairperson of the National Nuclear Commission of the Marshall Islands), Testimony before the House Committee on Natural Resources Subcommittee on Oversight & Investigations, October 21, 2021.

30 High Ambition Coalition website at https://www.highambitioncoalition.org/work
Growing up in England in the mid-1970s, cross-country races involved epic battles against wild and icy Arctic winds, wading through deep and icy rivers and clambering up impossibly steep and icy mudbanks. Pretty much everything was icy during those dark midwinter challenges.

Sunshine arrived in the form of my running coach, Wilf Richards. Bearing a striking resemblance to the coach in the film *Chariots of Fire*, my teammates joked he looked old enough to have joined his doppelganger in the 1924 Olympic Games. I sometimes reminisce about him clutching his clunky stopwatch, shouting out lap times as I passed by in the icy rain. I can't help thinking that if by magic his voice came through my earphones during a run and shouted out his old battle cry – “Einstein was wrong!” – my body could perhaps accelerate beyond the speed of light.

Wilf didn't have much in the way of equipment to measure our progress. His stopwatch would jam half the time and he'd calculate the distances of our runs using a strange implement donated by our geography teacher. A little wheel at one end was run along the surface of a map while a dial at the other end showed the distance. The method was so precarious that a bad crease could easily add 500m. Despite the challenges, he'd pour over the data scribbled down in his long tables. Looking up at us with a frown, he'd issue profound declarations such as “if you want to run fast ... you're going to have to run fast.”

Wilf's only piece of reliable equipment was his eye. Even though running is the simplest of sports – you just put one foot in front of the other and off you go - he knew when this fundamental action was performed with beauty. Yet, just like many great art scholars, he struggled to quantify a beautiful style using words and numbers. Some of this struggle comes from the strange things that can emerge from this beauty.

As an example from the mid-1970s, Bill Rodgers won the Boston and New York Marathons four times each. Those eight marathons added up to about 450,000 strides for Bill, all performed beautifully despite one leg being shorter than the other! From more modern times, consider Femke Bol. Speeding down the final stretch with her beautifully fluid style, she was just a few meters away from winning Gold at the recent World Championships. As the holder of the 400m indoors world record, she'd practiced putting one foot in front of the other millions of times previously. And yet, with the world watching, she lost balance and fell over. She couldn't explain why.

Along with all other physics professors, I don't like these running puzzles. I like to cram my General Physics classes with well-explained sports demonstrations. If you want your golf ball to fly far, try launching it at forty-five degrees. And don't forget to tuck your arms close to your body if you want to spin around fast. Skeptics walk away convinced that the power of physics can defeat any sports puzzle. What, then, can physics tell runners? About ten years ago, this question went beyond academic interest when I found out an interesting statistic the hard way – at any one time, one third of all runners are injured. I should have listened to Wilf's prediction: “Your achilles heel will be your achilles heel”.

As is typical of people who spend a lot of time running, I also spend a lot of time with my physiotherapist. In fact, I've spent so much time with Sean Roach that he has become my close friend. We talk a lot about the beauty of running during my sessions. Recently, we've recruited two of my previous physics students – Cooper Boydston and Conor Rowland – to help turn this talk into action by utilizing the latest running technology [1].

These days when I set out for a run, satellites follow my progress with precision and beam down messages to let the ‘watch’ on my wrist know how I'm doing. Perhaps sadly, virtual training partners have now replaced my team-mates; although hopefully my old friends' runs are being tracked by those same satellites. No doubt, Wilf would have embraced all of these advances – as long as they helped in his search for beautiful forms of running. Thinking back to his tables of scribbled numbers, I suspect he would have worried that the sheer amount of data could overwhelm any hope of making sense of it all. Of course, this dilemma goes well beyond running. It lies at the heart of all of today's “big data” projects.

My approach to handling complex running data came from another search for beauty. Around the time that I was running in circles around Wilf, I found an old art book at a yard sale that featured the abstract paintings of Jackson Pollock. I've been mesmerized by his painted patterns ever since (for my latest publication on Pollock see [2]). During the 1950s, Pollock rolled out huge canvases across the floor of his barn and poured paint from a can. A remarkable demonstration of Action Art, his motions through the air were captured by the paint trajectories on the canvas.

During my physiotherapy visits with Sean, I reminisced about using computers to analyze Pollock's paint trajectories in the hope of understanding the beauty of his art. Once we started to brainstorm, it was a short journey to the idea of using computers to assess the beauty of running. Pollock's work contained fractal patterns [3], originating from the multi-scaled swaying motion used by the body when maintaining balance. Given running is often described as a ‘controlled fall,’ would fractal balance turn out to play a key role in running too?

Wilf once declared “all runners think they can win the race, but only one knows they can win.” As my running mates...
pondered the difference between thinking and knowing. Wilf quickly moved on to speculate that this knowledge came from the runner’s ability to feel a good running form. If we interpret this statement scientifically, it emphasizes the role of the body’s forces in propelling the body forward. Exploring an analogy from car mechanics, there’s only so much you can learn from watching the wheels spin. At some point you’ll have to look under the hood at the engine. This interest in visualizing the forces as well as the motion lies at the heart of all physics lessons on mechanics. To look under the hood, Sean and I asked our physics team to develop an accelerometer-based sensor with the aim of combining physics with physiotherapy.

The above illustration shows example results when our sensor is placed on the body’s engine – the sacrum. We refer to them as ‘portraits’ because their tell-tale features vary significantly between runners. How, though, does beauty reveal itself in one portrait more than another? Some running activities demand the body to be highly efficient while others require sheer power. If both qualities can be captured simultaneously in a sustainable, injury-free fashion then that basic running task – of putting one foot in front of the other - has been mastered. This is reflected in the size and shape (including symmetry) of the portrait. The fractal texture generated by the subtle balance variations between the different gait cycles is also expected to play a vital role. In Figure One, all of these features vary as the runner becomes fatigued and so prone to injury. The runner has lost their beauty.

Ultimately, machine learning will categorize and determine the significance of changes in the portraits. This capacity will then be used to provide real-time feedback to the runner. In addition to learning about the body, the sensor will also be able to investigate the role of the only piece of equipment essential to running – the shoe. Should you run barefoot, as previous fads proposed? What about the latest shoes with carbon-fiber plates? What about those with two plates? Allowing people to run healthier and for longer, you can see why we call our sensor the “guardian of the run.”

1. https://projectdasein.com/about/
Not Just for the Boys: Why We Need More Women In Science


This book by Dr. Athene Donald is written based on her own experiences in academia starting with her postdoctoral appointment in experimental physics at Cornell University. Dr. Donald lays out issues in her own academic trajectory and asks- "How much of this was a result of being a woman in STEM?" Through the lens of her own and other women's experiences, Dr. Donald discusses how there is a general lack of support to build or celebrate success of women in academic settings largely governed by men.

Dr. Donald's aim in this book is to bring in the sciences, neuroscience and social sciences to explain her own and other women's experiences in STEM fields. Throughout the book, Dr. Donald brings in research findings interspersed with anecdotes to make the case for the need of more women in the STEM pipeline starting in early grades.

In the chapter "Can You Think of a Female Scientist", Dr. Donald speaks to the history of women in science, starting with documentation of women doing science in the 1700s, and yet few of these women achieved success or recognition in their work. The book notes multiple factors which influence the success of women, including schooling, family and societal connections, and positioning relative to powerful men in academia or work. She introduces the "Matilda Effect" to explain why women are not given due credit throughout history for their work. The Matilda effect was first described by Matilda Joslyn Gage in 1870 in an essay on "Woman as Inventor", and was given this term in 1993 by scientific historian Margaret Rossiter, who found many instances of scientific contributions by women labeled or attributed to male colleagues.

Dr. Donald goes on in later chapters to discuss the ways in which women work in science and how this intersects with recent concepts like team science and synergistic science. In Chapter 4, there is a good discussion of why the early years of a female student matter in order to combat stereotypes and lack of role models and mentors. This leads to a discussion in the next chapter about the importance of creativity in the sciences and developing this in young students. Dr. Donald then showcases the leaky pipeline of women scientists worldwide and discusses possible factors for these leaks including imposter syndrome and lack of supporting infrastructure.

Finally, Dr. Donald brings it all together by speaking about where STEM fields could improve practices to support more women in the field including aspects as broad as the makeup a hiring committee to granular as the wording of a hiring advertisement.

This book is a informational read for anyone who is a teacher or instructor at any level, and for anyone who wants to be a better supporter and advocate for women in STEM. Through the lens of her own career, the author walks us through many of the barriers for women in STEM, and gives advice and proposes solutions to some of the most entrenched roadblocks for women.

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As AI becomes more mainstream, the message of Foolproof is more relevant than ever. Van der Linden relates stories from history and gives accounts of detailed research into the human brain’s workings in three parts: “Viruses of the Mind”, “Infodemic: How the Misinformation Virus Spreads”, and “A Psychological Vaccine Against Misinformation”. Using the field of biology as an analog his book’s goal is to help us “fight back” against misinformation virus by developing a vaccine. Like viruses, misinformation spreads from person to person. With the proper “vaccine,” however, we can identify misinformation and keep it from spreading. Throughout the book he returns to and uses as examples three big recent issues: global warming, COVID-19 vaccines, and elections.

The first part, “Viruses of the Mind”, covers in four chapters all the ways the mind can be duped, which turns out to be an extensive list. For example, the phenomenon in which a statement sounds more true the more often one hears it is known as the “illusory truth effect.” The most interesting part to me as a physicist was about the difficulty of changing one’s pre-existing views of the world. In physics we use experimental evidence to adjust or change our view of the physical world. However, I have seen students refute the evidence and stick with their prior assumptions no matter how much evidence is presented. The reason for this is actually built into the functioning of the brain. As van der Linden explains it “the motivated brain selectively and often consciously seeks out or rejects evidence in a way that supports what you already believe.”

The second part, “Infodemic: How the Misinformation Virus Spreads”, focuses on social media and how we can be led down certain paths, such as filter bubbles and echo chambers. This section starts in ancient Rome with the propaganda wars between Caesar and Antony, showing that this stuff has been around for a long time. But there are fundamental differences in our present time, such as with “speed, reach, and the medium itself.” Turns out research shows that falsehoods move faster on social media than the truth. As van der Linden states, “falsehoods are 70% more likely to be retweeted than true claims.” The nature of the falsehood usually inspires negative emotions (usually fear). Our brains have a larger response to negative emotions than positive ones, and we want to tell others more about the negative. This was a tough group of chapters to read because it showed how easily we are manipulated. My initial reaction was gratitude that I don’t use social media (no twitter or Facebook or smartphone), but I then realized I do use Google and YouTube. In both cases, algorithmic suggestions direct your focus away from your initial search and towards other subjects tailored to hold your attention, in a process known as microtargeting. Microtargeting individuals on social media is a main topic for the three chapters in this section. The amount of information researchers and manipulators can tell from just a person’s likes on Facebook was scary. From someone’s likes they can construct a personality description which then allows them to microtarget information to the individual.

Part three of the book, “A Psychological Vaccine Against Misinformation”, gives us the solution to the viruses of our mind. He continues to use the biology analogy to talk about herd immunity and how to inoculate your friends and family. The first chapter in this section starts with the Korean War and brainwashing. One way to avoid being brainwashed is to pre-expose people to the actual propaganda in a “weakened form”, hence the vaccine analogy. This section contains many examples of how to change people’s minds. Van der Linden breaks down the six ways we are manipulated, DEPICT (Discrediting, Emotion, Polarization, Impersonation, Conspiracy and Trolling). Once the manipulation techniques used to produce misinformation were identified van der Linden and his colleagues were able to develop a vaccine. Their solution was to develop a series of games to play on social media to inoculate people against misinformation. In historical order they are www.getbadnews.com, www.goviralgame.com, and www.harmonysquare.game.

For a book based on a lot of psychological research (with details) it turned out to be an easy and enjoyable read. The research is held together by stories from history, present and past. Each chapter has a summary at the end – like a textbook. Social media is a constant presence for so many of us. More and more I find when I talk with students about getting their schoolwork done it is social media that is causing them difficulties (time spent), it used to be video games. Van der Linden’s solution is education through video games on social media.

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