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PHYSICS & SOCIETY

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From the Editor

The COVID-19 emergency continues and I am worried about what it will do to the next generation of physicists. At the graduate level, many international students have been unable to join or rejoin their institutions because they cannot travel or get visas. Research labs were closed for months and even now access is restricted. This will delay research. At the undergraduate level, many Universities teach only online and many (including my own institution) claim to use a "hybrid" model which in fact consists of teaching practically everything online, including, believe or not, most labs.

Here in the US, and Minnesota is no exception, panic of the most irrational variety has forced many elementary and secondary schools to go to an online (or fake "hybrid") model, despite clear scientific evidence and experience from other countries that small children are safe attending school. There is a disturbingly strong correlation between the probability that a school district will be online only and the poverty level at that district, where internet access is worst. The pipeline of young people, particularly poorer people, with reasonable education that would allow them to attend college with STEM majors is being stopped. All the talk about inclusivity? Hot air and hypocrisy. Schools close but bars are open! School Board members and University officials are often, indeed usually, untrained in science and are scared about making any courageous decision. They are timid, cowardly, and afraid to get sued.

Oriol T. Valls, the current P&S newsletter editor, is a Condensed Matter theorist.

Conferences are all online. This can work for the formal talks but so what? Take the APS March meeting: a person attending talks all day would be missing 98% of them anyway. Most of the interaction is informal, over coffee or beer, and this is not happening.

Enough for the rant. Recent issues of the newsletter have been light on the "news" part, and I intend to correct this, starting with this issue, where we have several news items, including extensive information on the next Forum election.

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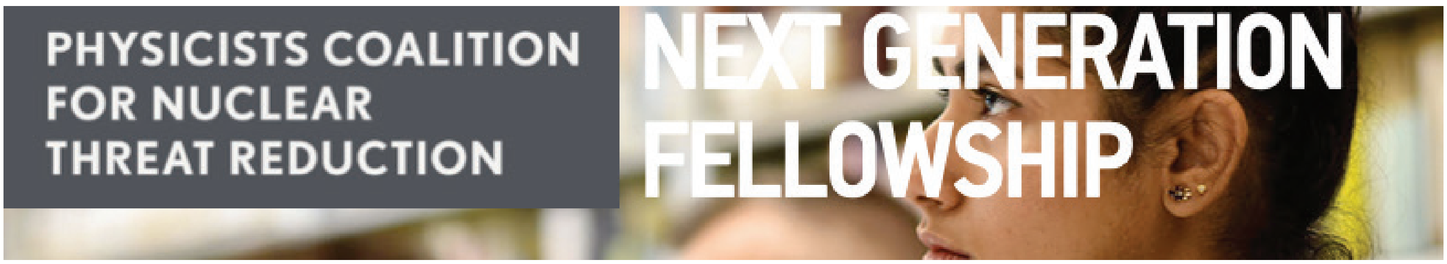
The Physicists Coalition for Nuclear Threat Reduction

The current world arsenal of nuclear weapons consists of more than 9,000 warheads distributed among nine nations, with the majority held by Russia and the US. With the reduction in arms control treaties and new technological development, a new nuclear arms race is emerging. To help counter this increasing danger, the APS, through its Innovation Fund, has established the Physicists Coalition for Nuclear Threat Reduction. The aim of the Coalition is to build a national network of physicists who, as citizen-scientists, would be interested in advocating for feasible steps to reduce the nuclear danger. Advocacy is coordinated by the APS Office of Government Affairs. To engage and update physicists on the nuclear weapons danger, a team of experts in nuclear arms is presenting colloquia at physics departments in universities and other institutions to provide an overview of the issue and discuss the Coalition. To obtain information on or join the Coalition, visit the website physicistscoalition.org.

They invite applications for their Fellowship program:



The **Physicists Coalition for Nuclear Threat Reduction,** an initiative based at Princeton University's Program on Science and Global Security and supported by the American Physical Society (APS), seeks to mobilize a national network of physicists interested in being informed advocates to policymakers and to the public on the nuclear weapon threat and opportunities for its reduction.

To support this effort, the Coalition **invites applications for its Next-Generation Fellowship**, which aims to make more diverse and strengthen participation of graduate students, postdocs and early-career physicists and engineers in advancing nuclear weapons threat reduction.

To strengthen diversity and the inclusion of many viewpoints in the nuclear weapons policy field, the Coalition encourages applicants of every gender, race, ethnicity, religion, sexual orientation and socioeconomic background. There will be up to four Fellows for 2020-2021.

The one-year Coalition Fellowship offers Fellows opportunities including:

1. Partnering with a senior expert to give two talks on nuclear threat reduction at university physics departments, professional meetings, or a national laboratory
2. Partnering with a senior expert on research and writing of a policy memo on a current nuclear weapons policy issue, which could be the basis for an article in the *Bulletin of Atomic Scientists* or similar publication
3. Training [1-2 days] in Washington DC or online in policy communication, advocacy, and scientist-community partnership building with APS and other non-governmental groups
4. Two trips [1-2 days each] to Washington DC for advocacy and outreach to Congress
5. Networking opportunities with key nuclear arms control policy and science advocacy groups
6. Participation in a 4-day Princeton Summer School on Science and Global Security

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(From the Editor continued from page 1)

Please vote. We have also a couple of articles and two book reviews.

But, I believe in great part because of the pandemic, we have been rather short of article contributions recently. Please consider writing yourself. Articles on any "physics and society" related topics, rather broadly understood, are welcome and I have no restriction on points of view. Articles and suggestions for articles should be sent to me, and also letters to the editor. Book reviews should go to the reviews editor directly (ahobson@uark.edu). Content is **not peer reviewed and opinions given are the author's only, not necessarily mine, nor the Forum's or, a fortiori, not the APS's either**.

Oriol

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New Forum-Proposed APS Fellows

Shelly M. Lesher
University of Wisconsin - La Crosse

For advocating on behalf of the essential role of physics in society, and for demonstrating the importance of physics education for all students.

Alexander Glaser
Princeton University

For major contributions to advancing the scientific and technical basis for nuclear arms control, nonproliferation, and disarmament verification.

Andrea Favalli
Los Alamos National Laboratory

For outstanding application of the methods and underlying science of nuclear physics to the crucial issues of nuclear safeguards and security.

Andrea Palounek
Los Alamos National Laboratory

For extensive work on the application of physics to national security in space, advocating on behalf of women and minority students in physics, and for unflagging efforts in launching the Four Corners Section of the American Physical Society.

Michael H. Moloney
American Institute for Physics

For exceptional contributions to physics research enterprise and science policy as overseer of studies conducted by the National Academies of Science boards on Space, and Physics and Astronomy, and by the National Materials Advisory Board; and for visionary leadership as CEO of the American Institute of Physics.

Richard Wiener Research
Corporation for Science Advancement

For leadership on creating Scialog, a unique and highly effective platform for networking early-career scientists and seeding high risk interdisciplinary research to make advances in fundamental science with the long-term goal of solving important global challenges.

Candidates for the Forum Upcoming Election

JENNIFER DAILEY
CANDIDATE FOR "MEMBER AT LARGE"

Biography: Dr. Jen Dailey is an early-career interdisciplinary scientist currently working as a national security analyst at the Johns Hopkins University Applied Physics Laboratory. She marks the APS 2011 March Meeting as the beginning of her career in physics, where she presented her undergraduate research on carbon nanotube-based biosensors. Nearly a decade later, her career has spanned physics, biomedical, and chemical laboratories, elementary school and university science classrooms, and the Senate Congressional buildings in our nation's capital. Her early work in medical diagnostics foreshadowed a commitment to bring together diverse stakeholders to tackle real-world problems. After receiving her B.A. in physics from the University of Pennsylvania in 2012, she completed a Post-Baccalaureate Intramural Research Traineeship in immunology at the National Eye Institute at the National Institutes of Health. She received a National Science Foundation Graduate Research Fellowship to complete her Ph.D. in materials science at Johns Hopkins University, working across the campus to bring engineering solutions to public health problems. While a graduate student, she was involved in mentoring elementary and high school students, and she developed an evidence-based curriculum for non-science major undergraduate students to learn materials science through interactive lessons in "the Science of Chocolate". After receiving her Ph.D., she served as the 2018 APS Congressional Science Policy Fellow, where she worked on health and science policy issues for Senator Ben Cardin. This experience demonstrated the enormous importance of having scientists involved throughout the policy process, even on issues not directly tied to traditional physics problems.

Since completing her Congressional Fellowship, she has served on the APS Physics Policy Committee and the selection committee for future APS Congressional Fellows. She has authored or co-authored 15 publications, receiving over 450 citations to date.

Statement: As a 2018 APS Congressional Science Policy Fellow, I saw firsthand the importance of integrating strong scientific voices into governmental policy and action. Thanks to this experience, I have an even firmer belief that the Forum on Physics and Society (FPS) has an important position in contributing to continuing policy discussions on issues like nuclear weapons and climate change. In the wake of COVID-19, the FPS has the potential to help fill a gap by interfacing more broadly with the public, and especially with students who are seeking learning communities to help grow as scientists. As a Member-at-Large, I would focus on bringing opportunities for community building to those undergraduate and graduate students who are facing difficulties in learning, researching, and networking due to COVID-19. In a year full of policy upheaval, it is more important than ever to embrace opportunities that allow for a broader array of diverse voices from different backgrounds and careers levels to contribute to our ongoing discussions. I would also be interested in what kinds of public outreach we could help facilitate, for example by offering our expertise in development of curricula to augment virtual learning for middle and high school science classrooms in order to introduce important concepts like climate change. Thank you for considering me for the Member-at-Large position.

TARA DRODZENKO
CANDIDATE FOR MEMBER AT LARGE

Biography: Tara is Acting Executive Director at the Outrider Foundation where she focuses on public education and advocacy on nuclear weapons. Tara has 15 years of experience in the National Security field. Before joining Outrider she worked at the U.S. Treasury Department and oversaw more than 20 of the U.S. government's economic sanctions programs, including portions of the Iran and North Korea sanctions. Prior to working at the Treasury Department, she oversaw counterterrorism sanctions at the U.S. State Department. Also while at the State Department, Tara spent several years working on Missile Defense and Arms Control issues, including representing the U.S. at the Senior Group on Proliferation at the North Atlantic Treaty Organization.

Tara earned a Ph.D. in physics from the University of California at Los Angeles. An accomplished speaker and writer, Tara serves as a guest lecturer in university classrooms and as a guest on podcasts and radio. She's has been quoted in the *Seattle Times*, the *Houston Chronicle*, the *Verge*, *Gizmodo*, and *Mashable*. Her op-eds have appeared in *Inkstick Media*, the *Baltimore Sun*, and the *Milwaukee Journal Sentinel*.

Statement of Interest: As a physicist who has spent her entire career at the intersection of science and policy, I am thoroughly convinced of the need for physicists to engage on a broad range of societal issues. In my view, the engagement is necessary not just because physicists may have some sway or add an important voice to a societal debate, but it is just as important that the physics community also be impacted as a result of the interaction. One important example of society impacting APS is the Black Lives Matter Movement and the calls in recent years to dismantle structural and institutional racism. In direct response to this societal movement, APS has launched a new forum on diversity and inclusion. As a Member-at-Large of the Forum on Physics and Society, I would encourage APS to continue to find areas of mutual impact at the interface of society and physics.

In terms of specific topics where I could bring some level of expertise to the Forum, I have spent much of my career working on national security issues. I am committed to education, advocacy, and finding solutions for the twin existential challenges of both nuclear war and climate change. Along the same vein, I believe that APS could continue to have an impact on the issue of military spending. At this crucial moment in time, faced with a global pandemic, racial injustice at home, and the potential for catastrophic climate change, the U.S. military budget is not just ill-advised, it is immoral. As Dr. Martin Luther King Jr. said, "Budgets are moral documents." We make our priorities clear by what we spend our money on. And, the U.S. spends smore on its military than the next eight countries combined—four of whom are our Allies. Given the breadth of challenges humanity faces, it would be prudent to reallocate some U.S. defense spending and to expand the concept of security beyond mere military might. As a Member-at-Large, I would encourage the Forum to examine how nuclear weapons, climate change, and military spending intersect with our notions of security. I would also want to help the Forum examine how it might effect change as well as be changed at the intersection of physics and society.

ROBERT SEMPER
CANDIDATE FOR MEMBER AT LARGE

Biography: Rob Semper joined the Exploratorium in 1977. Over the years he has had a career developing exhibits and exhibitions onsite and worldwide, creating teacher education programs, producing publications, films, online media and communication programs, expanding the informal science education field and leading major initiatives including the recent relocation of the institution to Pier 15/17. Currently as Chief Science Officer, Rob provides strategy and oversight to the science and science education work of the Exploratorium and represents the Exploratorium to the broader world of science, science centers, and STEM education. As Senior Director of Educator Engagement, Rob is also responsible for developing and leading the institutional strategy for educator learning programs. Rob is the author of many journal articles and invited papers and conference talks, and he has been Principal Investigator on over 50 federally and privately funded projects that include developing new online and media resources, experiments using technology to enhance the museum visitor experience, and programs for teachers and museum educators. In 2018, Rob was selected as a member of the Federal STEM Education Advisory Panel, which meets twice a year to evaluate and offer guidance on the federal government's strategic plan for STEM education. Awards include APS Fellow 2019; AAAS Fellow, 2006; and the NSTA 2006 Faraday Science Communicator Award. Before joining the Exploratorium, Rob taught physics and conducted solid state, elementary particle and nuclear physics research. He received his PhD in solid-state physics from the Johns Hopkins University in 1973.

Statement: Since it was founded in 1972, the Forum on Physics and Society has addressed many issues where physics and society intersect such as climate change, energy development, and nuclear arms. These discussions and debates have provided the opportunity for APS members to increase their own understanding of the state of affairs for these particular domains. Today we are faced with a situation where the role of science and even the very value of scientific thinking itself is called into question by members of our society. It is a good time for the physics community to examine the physics society interface more broadly and to discuss its position within the human enterprise as a whole. What is the role of physicists in their community and with the broad issues our society now faces? How can the value of evidence-based thinking connect with a public which seems also enamored with conspiracy theories and apparently anti science views? How does the practice of physics connect with other human experiences such as the practice of artists and humanists. These questions focus on addressing the very core of what it means to be a thinking physicist in society that may seem to be becoming more unscientific all the time.

I have spent over 40 years at the Exploratorium, an institution founded by a physicist, Frank Oppenheimer, who deeply believed in physics as a supremely humanistic endeavor. I have followed with great interest the development of FPS and its role in supporting physicists as they work beyond their academic field, something I have always found inspiring. Over this time my journey as a physicist has gone from working on public understanding of science to appreciating the two-way element of public communication about science to now trying to understand how to deal with the public's apparent lack of appreciation of science in today's culture. Based on this experience, I would suggest that there are a least three quite different topics (among many others I can imagine) that I think FPS might find worth exploring at the physics/society interface in the current critical context. First what is the relationship between the practice of scientists and artists, both creative professional explorers yet thought of so differently in our human society. Second, what do we know about the science of science communications and the features of the audience it tries to serve. Third, what can the role of physicists be in fostering transdisciplinary convergence research designed to meet societal needs. Each of these themes has been the focus of recent National Academy symposia and reports. But I am not sure that thinking about them has penetrated deeply into our community. A discussion in each of these areas with participation by experts inside as well as outside our field could serve to illuminate our connection with the broader community and help us understand what it means to be a physicist in our civil society today. I would like to become a Member-at-Large of the Forum of Physics and Society to foster these discussions.

Physics and Society is the non-peer-reviewed quarterly newsletter of the Forum on Physics and Society, a division of the American Physical Society. It presents letters, commentary, book reviews and articles on the relations of physics and the physics community to government and society. It also carries news of the Forum and provides a medium for Forum members to exchange ideas. ***Opinions expressed are those of the authors alone and do not necessarily reflect the views of the APS or of the Forum. Articles are not peer reviewed.*** Contributed articles (up to 2500 words), letters (500 words), commentary (1000 words), reviews (1000 words) and brief news articles are welcome. Send them to the relevant editor by e-mail (preferred) or regular mail.

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***Physics and Society* can be found on the web at** www.aps.org/units/fps**.**

WARREN W. BUCK
CANDIDATE FOR MEMBER AT LARGE

Biography:

- BS in Math, Morgan State University
- MS in Experimental Plasma Physics, College of William & Mary
- PhD in theoretical High Energy Nuclear Physics, College of William & Mary
- Postdoc, Stony Brook
- Research Scientist, Orsay
- Professor of Physics Emeritus and Founding Chancellor Emeritus, University of Washington Bothell (UWB)
- Adjunct Professor of Physics, University of Washington Seattle
- Adjunct Professor of Physics, College of William & Mary
- Special Advisor (to the President) for Equity in the 21st Century at William & Mary
- Major catalyst in the creation and development of the PhD in Physics degree program at Hampton University
- Major partner in the building of the Jefferson Lab
- First recipient of the CEBAF User of the Year award
- Founding Director of HUGS at CEBAF (Jlab)
- Former Chair of the APS Committee on Education
- Widely published and spoken with many visiting professorships and other honors
- APS Fellow and Life Member
- Principal creator of a new physics BS degree program at UWB. In four years it grew from 4 graduates (in 2017) to 20 With 55 majors (jr and sr) this spring (2020). UWB chosen number 1 in this year's CNBC category of best public university in the nation for its value.

Statement: Physicists have been and are doing a great job of producing good results in fundamental areas of physics that lead to discovery that add to our knowledge. My career has followed that traditional physics path; and I have also pursued university administration to better the options for students in all fields of study; particularly in STEM. While an administrator, it became critical that I speak and converse with the general public; be they elected officials, business executives, children, parents, or citizens of every kind. A necessary ingredient in selling the importance of building the organizations and certainly, a new campus for the University of Washington and learning how universities and businesses really work. One can imagine some of the challenges along the way that had to be negotiated; and there were challenges not foreseen that also had to be negotiated. Skills that are not taught in graduate school nor at the postdoc level. Even full professors do not have such skills. I was fortunate to learn many skills from great individuals who advised me. Today, it is a great opportunity to help advise and guide physicists in additional skills that can aid in a better understanding of just how things work. It is also an opportunity to connect the larger world community to the importance and benefits of sound scientific research and teaching; opening physicists to a broader audience that can sustain the discipline deeper and resiliently. Becoming comfortable with learning for life, not only physics, but also about how to speak and interact with all kinds of folks in all sorts of environments can be a valuable accept.

FREDERICK LAMB
CANDIDATE FOR VICE CHAIR

Biography: Fred Lamb is Research Professor of Physics, Brand and Monica Fortner Endowed Chair of Theoretical Astrophysics Emeritus, and core faculty member in the Program on Arms Control and Domestic & International Security (ACDIS) at the University of Illinois.

He has served on numerous National Academy and NASA astronomy and astrophysics committees, and played a leading role in the conception, design, development, and operation of NASA's highly successful Rossi X-ray Timing Explorer mission. He has been a leader in the High Energy Astrophysics Division of the American Astronomical Society and served as its chair in 1988–1989. He is currently a key member of NASA's Neutron Star Interior Composition Explorer (NICER) science team, which has made the first precise, simultaneous measurements of the mass and radius of a neutron star, and is expected to measure the masses and radii of several more.

He has also, for more than forty years, been involved in efforts to advance national and international security, carrying out research and informing students, the public, and decision makers about nuclear weapons, missile defenses, and national security issues, advocating for better programs and policies. In 1981 he initiated and co-developed an undergraduate course at Illinois titled "Nuclear Weapons, Nuclear War, and Arms Control", which has been taught every year since and has now been taken by more than 3,000 students. During the 1980s he helped found, and later led, the Illinois Alliance to Prevent Nuclear War, which advocated measures to reduce the nuclear threat. He has been a leader in the University's arms control program since 1982. He is a founding member of the recently formed APS-sponsored Physicists Coalition for Reducing the Nuclear Threat.

He served on the American Physical Society's Panel on Public Affairs (POPA) in 2000-2002, and co-chaired the 2003 APS study of boost-phase missile defense. He is currently leading a new study of U.S. missile defense and national security sponsored by POPA. He has served as an expert consultant to a variety of Congressional committees and Executive Branch agencies, and has given nearly 100 lectures on nuclear weapons, missile defense, space policy, and the North Korean and Iranian nuclear and missile programs at national and international symposia, universities, and institutes.

He was elected to membership in the American Academy of Arts and Sciences in 2005 and shared the 2005 Leo Szilard Award of the American Physical Society.

Fred received his bachelor's degree in physics from the California Institute of Technology in 1967 and his D.Phil. in theoretical physics from Oxford University in 1970. He joined the University of Illinois in 1972, becoming professor of physics in 1978 and also professor of astronomy in 1980.

Statement: The physics community, and the membership of the APS Forum on Physics and Society, face major challenges at the present moment. These include the response of the United States to the COVID-19 pandemic, the growing climate emergency, the increasing likelihood of a dangerous new spiral of the nuclear arms race, the need for renewable energy sources, the vital importance of increasing diversity, equity, and inclusion in science and our society generally, and a growing disregard of facts and the understanding provided by science. By virtue of their interests and focus, the Forum and its members are in a special position to play major, constructive roles in helping our nation meet these challenges. As a leader of the Forum, I will seek to increase understanding of these issues by members of the APS and the society at large, and to address these challenges through the activities and actions of the Forum, including the Forum-sponsored talks at APS meetings, articles in the Forum's journal, and by working hard to include more young physicists, women, and other often under-represented physicists, both in the Forum sessions at APS meetings and in the other activities of the Forum. We live in an exciting time, a time when the Forum and its membership can have a crucial positive impact. I look forward to helping make this happen.

JAMES DICKERSON
CANDIDATE FOR VICE CHAIR

Chief Scientists at Consumer Reports

Bio and Statement not available at this time

ARTICLES

Didactic Redesign of Models in Epidemiology, with a Caveat on Probability and Latent Variables *Thomas Colignatus, Samuel van Houten Genootschap, The Netherlands*

1. Introduction

The pandemic of SARS-CoV-2 (virus) and Covid-19 (disease) did not come about because of lack of knowledge in epidemiology but because of inadequate management of Public Health. Epidemiology exists for some 150 years, and what was once known by governments at the level of villages and nations now is rediscovered at the world level. Infectious diseases have always been a good motive for the rich to also protect the poor from becoming infectious. A world with increasing international contacts for persons and goods requires a fitting public health management system or we get the current chaos or worse.

The world is slowly adapting to the permanence of pandemics, not only for the current virus but also for the risk of new ones which the epidemiologists have been warning about for decades. Climate change and the growth of the world population – see Colignatus (2019) – increase the number of "hot spots" where such pathogens can adapt to the human host. Each new pathogen comes with the stages that we have seen for SARS-CoV-1&2, namely a period before it is discovered and its bio-medical properties analysed and a period during which it must be contained before a vaccine is developed. For SARS-CoV-2 the effort at a vaccine looks promising but the virus belongs to the common cold family for which immunity tends not to be retained, and perhaps the first vaccines will not do better. Evolutionary pressure will tend to make the virus less deadly but this would imply many victims before the deadly strains are culled.

The July issue of the *Physics and Society Newsletter* provides an excellent synopsis, and advised reading, of basic epidemiological modeling by Wiener (2020), while Goodman (2020) comments on physics and society. The APS (2020) has made a growing collection of articles available in the *Physical Review* journals. Mathematical biologist Cog (2020) reviews how physicists who want to look into epidemiology might help, and her warning is not to re-invent the wheel. I agree with her, except on didactics, that Heesterbeek et al. (2015) in *Science* of AAAS is advised reading. On the other hand, Richard Gill, the Leiden mathematical statistician with much experience in both the life sciences and physics, thinks that the traditional epidemiological modeling tradition is becoming too inflexible and that approaches as used in physics have more prospects, see his webpage Gill (2020).The appendix to this present article contains a caveat for physicists.

The *purpose of this article* is to review some aspects of the pandemic and focus on a redesign of the didactics of basic epidemiological modeling. Better didactics would help more people to understand these models. Understanding these models helps to see that the present problems of society and the pandemic do not reside in epidemiological modeling but rather in the governance of Public Health. My reference is to the situation in Holland and not the USA. The present article is a summary of Colignatus (2020c).

2. Choice of symbols and model format

As said, Wiener (2020) in the July edition of *Physics and Society* succinctly restates the S(E)IR(D) family of models, using the traditional symbols and equations as used in the epidemiological literature. Dynamic variables are the susceptibles S, infected or infectious I, exposed but not infectious E, recovered or removed R, and deceased D. Wiener (2020:3) also identifies a didactic problem: *By perhaps unfortunate convention R(t) is used to represent the dynamic variable for the removed fraction, and to represent a parameter*. Weisstein (2020a) at *Mathworld* states: *Note that the choice of the notation R_0 is a bit unfortunate, since it has nothing to do with R*. A teacher would not want to accept this. The teaching material better be didactically sound. An argument might be that the models are going to be taught on a wider scale now, no longer within the small community of epidemiology where students can be trained to handle the illogic. Another problem is that R is "removed" in SIR but "recovered" in SIRD, since also D belongs to the "removed" in original SIR. In SIR I includes *all infected and/or infectious* units, but in SEIR it includes only part of the infected, because there are also the exposed E who are infected but not infectious. The tradition in epidemiology opts for using the same labels for new meanings. Instead, for didactics, when the model SIR is extended to SIRD or SEIR(D) then it is better to retain the meaning of what one has learnt for the original variables (including the dynamic properties), and introduce new variables for what is new.

Thus we better relabel the variables to SI(EY)A(CD). A search for possible names gave *Acquitted* as the best choice. The acquitted $A = C + D$ are the cleared or deceased. This avoids the triple use of R for removed, recovered, and reproductive factor. The infected $I = E + Y$ are the exposed and infectious. In SIA $E = 0$ so that $I = Y$.

In SIA(CD) we have $A' = \gamma I$, with γ the acquittal rate from infectiousness, with I' incidence, I prevalence and A cumulated prevalence. The format of ordinary differential equations (ODE) should not distract. The basic structure is given by the Euler-Lotka renewal equation. The deceased are a fraction of the acquitted, $D = \varphi A$, with φ the infection fatality factor (IFF). The latter is often called a "rate" but it is a factor. R_0 is conventionally called the "basic reproduction number" but it is a factor too, since it is defined in relation to the number of the first infected units. The ODE format $D' = \mu I$ or $D' = \mu Y$ can be rejected since it turns the model into a course in differential equations, with the need to prove $D = \varphi A$ which can already be stated from the start. The ODE format also causes distracting questions what μ might be and whether there is a difference between a *lethal acquittal period* and a clearing acquittal period, and how parameters values must be adapted when the acquittal rate γ changes.

We adopt the more common parameters β and γ with $R_0 = \beta \gamma^H$ (rather than α and β by Wiener (2020), and with mathematical constant $H = -1$), and also simplify the equations so that the flow between the compartments is clearer from the start. Analysis will require substitutions but such can be done better when students grasp what is being substituted. The comparison in Table 1 considers SIA(CD) and not SEYA(CD).

Standard SIR(D)	*Didactic redesign into SIA(CD)*	*Nr.*
$S' = -\beta S I$	$S' = -\beta S I$	*(1)*
$I' = \beta S I - \gamma I$	$I' = -S' - A'$ $(N[0] = S + I + A)$	*(2)*
$R' = \gamma I$	$A' = \gamma I$	*(3)*
($D' = \mu I$ and adapt (2))	$(D = \varphi A,\ C = A - D)$	*(4)*

Table 1. Tradition versus didactic redesign

The didactic redesign changes nothing on content. The redesign makes the model more accessible to a wider group of students and researchers from fields new to epidemiology. The redesign is not very relevant for students who can solve the ODE and handle the phase diagram as Wiener (2020) discusses, but education is not only for who need little of it. When experienced researchers from other fields embark upon epidemiology let me invite them to also express concern about the dark elements in the traditional S(E)IR(D) setup, and to encourage epidemiologists to consider the didactic redesign.

Colignatus (2020c) checks, perhaps over-thoroughly, that the SI(EY)A(CD) family of models indeed fits such unity in presentation, within a consistent programming environment and uniform presentation also for scenarios. For variable X we have Xq in numbers and Xp in proportion of the population at the start, $N[0]$, a constant, as distinct from current population $N = N[0] - D$. Checks on examples from the literature show that results are reproduced so that nothing is changed on content indeed, and the examples highlight the use of the models.

3. Clarifying herd resistance

Another element for redesign of didactics concerns the notion of *herd resistance*. This can be explained best by reference to vaccination. The first infectious unit has an offspring of 1 * R_0 units, via direct infection of its contacts. When those contacts have been vaccinated with degree v in the range [0, 1], then this means that $v R_0$ would not be infected and $(1 - v) R_0$ would still be infected. The infection size will remain constant when $(1 - v) R_0 = 1$; it will grow then $(1 - v) R_0 > 1$; and it will reduce when $(1 - v) R_0 < 1$. Rewriting the latter gives a condition for the degree of vaccination to warrant that the infection will be reduced: $v > 1 - 1 / R_0$. Vaccinated units can be allocated to the compartment of the Acquitted too. The general condition $Ap > 1 - 1 / R_0$ can be called *herd resistance*.

The notion means that the herd survives and doesn't become extinct when that particular level is reached, even when there is no vaccination and when the infection is lethal for perhaps most units. The term "herd resistance" is accurate and much preferred above the inadequate term "herd immunity" that is common in the epidemiological literature. Experts know what they mean by the latter term, i.e. that only the herd survives, but policy makers and the general public associate "herd immunity" with protection for all units, which however is not what the notion means. Protection of *all* units can be a special outcome when vaccination is done in a well-mixed population before the onset of infection. But when vaccination is done during a raging epidemic then the compartment of the infectious I can already be large, with still many infectious units causing new infections, called "overshoot", with the subsequent death toll. This source of confusion between experts and non-experts can be prevented by the use of the term "herd resistance".

In March 2020, RIVM (the Dutch CDC) mentioned R_0 = 2.5 and a "herd immunity" (i.e. herd resistance) of 60% as an aim for SARS-CoV-2. In SI(EY)A(CD) for a Dutch population of 17.4 million, a raging epidemic with $R_0 = 2.5$ with IFF = 1.5% can reach 60% with 156.000 deaths, and proceeds after 60% till the limit value of 89.3%, which would mean another 78,000 deceased, compared to 9,000 at the end of May. In Figure 1, taking $R_0 = 2.5$ on the horizontal axis, we can see the vertical value of 60% of so-called "herd immunity" and the limit value A[∞] ≈ 90% of a continuing epidemic. Thus RIVM applied a condition for a *vaccination before onset* to a situation with a *raging epidemic*. This was a serious breakdown of communication between professional advisors and policy makers (and the general public). This is no small matter because RIVM got Dutch prime minister Mark Rutte (2020) to state the target in his address to the nation. Criticism soon caused a political redress from "aim" to "by-product" of national policy, apparently miraculously achieved without such death toll since the stated policy aim was to protect the public from the death by infection. The factual implication however is that Dutch academic epidemiology belongs to the top of the world but in this pandemic the official RIVM leadership

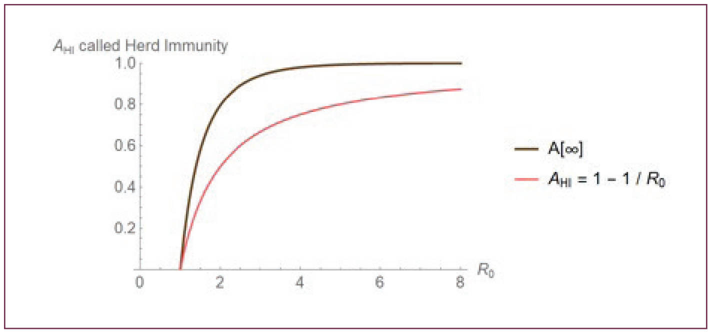

Figure 1. Limit outcome, herd resistance and so-called herd immunity

on infectious diseases, in particular Jaap van Dissel and Aura Timen, has shown to be incompetent. This official leadership failed on more crucial aspects, starting with the slow response in January-March compared with the fast reaction in Japan, Germany and Greece. The RIVM leadership was not replaced and Holland also lost the Spring and Summer of 2020 for sound preparation for the Fall and coming Winter.

The issue can also be explained as follows. As said, Cog (2020) recommends Heesterbeek et al. (2015) in *Science* of AAAS, and I agree, except for the didactics. The latter authors use the *effective* reproduction factor $Re = R_0 Sp$, and then define: *herd immunity: state of the population where the fraction protected is just sufficient to prevent outbreaks* ($Re < 1$). This is a technical definition and authors are free to give such definitions. It may well happen that a domain of excellent research has some terminology that is less perfect but that insiders are familiar with. However, said definition cannot convince in logic and practice. The condition "prevent outbreaks" is not the same as $Re < 1$. The latter $Re < 1$ may occur also during an outbreak, namely when it starts waning. The condition "prevent outbreaks" doesn't fit with an ongoing outbreak. The SARS-CoV-2 episode shows that epidemiologists have been using the condition $Re < 1$ during the outbreak, which is fine to indicate the waning of the epidemic, but they have also been using the term "herd immunity", which is not fine since it suggests protection, which however only applies to the herd (that doesn't become extinct), and which does not apply to a large number of units that will die from the infection during the "overshoot".

The clear didactic solution is not to use the term "herd immunity" but use the term "waning epidemic" for $Re < 1$ and "herd resistance" for $Ap > 1 - 1 / R_0$. The extensive Colignatus (2020c) checks the various definitions in the epidemiological literature about "herd immunity" and conditions like an (asymptotic) steady state. Just stated clarity might seem remarkably simple compared to a huge epidemiological literature but the extensive consideration rejects this literature, as wanting in accuracy for communication with the non-initiated.

But even when a domain of research contains terminology that can be confusing for communication between official experts and policy makers, a Public Health condition remains that official experts should not be locked into their own terminology and try to teach the world to their own illogic, but they would need to remain open to the possible causes for misunderstanding and policy error, and be aware of the possibility of another 78,000 deaths and be clear about this instead of hide it.

4. Public health, life gain measures and loss of immunity

The objective of Public Health is to balance medical and economic issues, i.e. lives and livelihoods, see e.g. Acemoglu et al. (2020). Key criteria are the (quality adjusted) *life-years gained* (QALY gained) and the *Incremental Cost-Effectiveness Ratio* (ICER), defined as a gain divided by the cost for getting this gain. That the SI(EY)A(CD) family of models uses the *death count* and criterion of *lives saved* (lives extended) can be understood from their genesis in 1927, but modern Public Health requires developed life gain measures. In 2018 the (European) ECDC indeed calculated disability adjusted life-years (DALY) for infectious diseases, which can be seen as a useful first step. Teaching SI(EY)A(CD) models as *they are* indoctrinates (epidemiology) students into thinking in a mantra of lives saved only, which conflicts with Public Health application. It is better to extend these basic models with more life gain measures. At the minimum, given the aggregate $D = \varphi$ A from the model and the assumption of homogeneity, we can use the average life expectancy (ALE ψ) at death, and find the total loss of life-years as ψD, which then can be used for scenarios and the ICER. Mathematically it is only a minor additional parameter but it is somewhat remarkable that it isn't much used in epidemiology.

The relevance is shown in the SARS-CoV-2 pandemic for which the infection fatality factor (IFF) differs so much per age group, with thus a different weighted average, especially when we include the lower life expectancy because of comorbidity. The Dutch RIVM model actually has different age groups and a matrix of their contacts, and they should be able to calculate life-years lost, but they don't present these. The official argument (i.e. a comment by Van Dissel) is that lives saved and even more life-years saved are speculative, since it is not warranted how the epidemic would evolve without the interventions. But if the model records a death and the age (group) of death then age-specific life expectancy can be used, and the total loss would be crucial information for Public Health and its economics.

Rather than developing SI(EY)A(CD) models with age groups, Colignatus (2020c) opts for the use of both the population table and the life table. Any course in epidemiology or medical statistics has the life table as its core, with the notion of competing risks of death. Students using SI(EY)A(CD) models must be familiar with the life table too. Given the aggregate $D = \varphi A$ from the model and the assumption of homogeneity, the fatalities can be allocated in proportion to the age groups using their specific factors, using population weights or life table weights. With these tables available within the modeling environment it becomes easier to run scenarios with assumptions on the age-specific IFFs too (rather than take ALE as a single fixed number for all scenarios or neglect it for that reason). Colignatus (2020c) has the IFF = 1.5% with infection prevalence in March 2020 as weights, with a higher prevalence in elderly home care. With population weights with uniform infection, the IFF drops to 1.1%.

An infection with the virus might not result in permanent immunity. It is a corona virus and such viruses are known for the common cold that has no immunity. Annual loss of immunity requires a life table re-computation of life expectancy with repeated application of the age group specific IFF. The 2018 all-cause death now becomes the 2020 other-cause death. The higher annual death toll is an acceleration of the mortality by comorbidity. It is statistically attributed to the virus rather than to comorbidity. This exercise shows that a 10% rise in annual cumulated prevalence (A) implies about a 0.5 year drop in life expectancy. The effect is relatively small since the fatalities are mostly in the higher age groups. If cumulated prevalence would rise to 60% as RIVM suggested, then Dutch life expectancy would reduce with 3 years, but the (by RIVM neglected) overshoot to 90% would reduce life expectancy by some 4.5 years in total. It seems a good suggestion to eradicate the virus.

Other life gain measures are fair innings, proportional shortfall and UnitSqrt. Colignatus (2003, 2020) is a discussion of life gain measures, with the suggestion that the UnitSqrt would be a compromise that likely many people would find interesting.

5. Wider context for democracy

We want to save lives and livelihoods but let us not forget fundamental insights about democracy and science & learning, see Colignatus (2020b). There is something fundamentally wrong in the relation between society in general and science & learning. For the democratic setup of each nation it is advisable to have both an *Economic Supreme Court* for the management of the state in particular and a *National Assembly of Science and Learning* for the flow of information also in this management. For the US electoral system there is the observation that a third of US voters have taxation without representation, see Colignatus (2020a) in the January edition of *Physics and Society*.

Apart from this general diagnosis, the SARS-CoV-2 pandemic comes with its own pecularities. We have seen national emergencies in which epidemiology with the SI(EY)A(CD) criterion of *lives saved* became dominant, including the objective to flatten the curve, prevent the break-down of the health care system, and remain within the capacity of Intensive Care Unit (ICU) beds: but all with neglect of life-years gained and the ICER. The economic cost has been huge while the *life-years gained* are relatively low, and we still don't have proper statistics about the falling away of usual care that was postponed or rescinded because of priority for the *lives saved* related to the virus.

A rather reasonable point of view from epidemiology is that the lock-down prevented an explosive outbreak, and that the prevented death toll is huge, and by implication also the life-years saved. The ICER of the lock-down thus would compare favourably with conventional Public Health outcomes, see e.g. epidemiologists Bonten & Rosendaal (2020) (Dutch). The point however is that the lock-down in many countries was an *emergency break*, and its use was required because of the slow and inadequate response before. It is not quite an argument that a system works since the emergency break had to be applied. Germany, Greece and Japan had a decent system of early warning and source and contact tracing (SCT), see e.g. department director Saito (2020). Holland had years of budget cuts on SCT, with insufficient protests by the RIVM leadership, and when SCT was called upon in 2020 its managers stopped doing it when capacity was reached, in contradiction to their job description to do SCT; and only the dissenting provinces in the North decided to continue and if needed increase capacity and they indeed effected containment in their region.

The paper by epidemiologists Petersen et al. (2020) in *The Lancet* is highly problematic. For decades, these experts have been warning for a pandemic, they must have noticed that national warning and SCT systems were not in shape, but when SARS-CoV-2 arrived in November 2019 to January 2020 they were late on the uptake themselves, so that eventually the emergency brake had to be used in virtually all countries in the world. However, their article does not discuss that they themselves were late on the uptake, and that their scientific leadership on pandemics thus collapsed into the current chaos of this pandemic, with its death and economic misery. The authors are evasive about key criticism: (a) The authors recognise that SARS-CoV-2 of 2020 is "genetically closely related" to SARS-CoV of 2003. The naming is no coincidence. Also in characteristics we see the same virus. Yet the authors subsequently call it "new", which switches to the language of *identity*, while the article concerns empirics and the closeness of charactistics. They suggest that SARS-CoV was eradicated in 2003 and "eliminated from the host [sic] reservoir", while it clearly was not eradicated since it resurfaced in 2019-2020. The authors close their eyes for the return of the virus and they apparently have a vested interest in window-dressing their failure of not recognising it. The true story is that official epidemiology tended to neglect the virus after 2003. Perhaps the reason for this was that it did not reach the West in 2003. Remarkably, in November 2019, precisely when the virus returned to the attention of the world, Smith (2019) posed the very question whether it had been eradicated, and he comes out on the side that epidemiologists should stake out the claim that they had done so. Smith (2019) allows for caution: "The WHO's consensus document on the epidemiology of SARS, published during the pandemic in 2003, stated "The eradication of SARS-CoV is unlikely if infection is zoonotic" (…), which was later found to be the case. Evolution has had time to generate variants in SARS CoV's wildlife hosts [sic] during the past 13 years, so we may see a related virus emerge in the next decade or century. If we declare eradication, we run the risk of SARS someday re-emerging under similar conditions that gave rise to it originally, which has the potential to psychologically undercut any claim of eradication." Now in 2020, the genome and bio-medical and epi characteristics show that the virus hasn't been eradicated. (b) Petersen et al. (2020:table1) mention various characteristics but leave out the important ones of asymptomatic and/or aerosol transmission that cause a pattern of superspreading and clustering, which characteristics confirm that it is the same virus. Of these authors, it has been Koopmans who in Holland has been hindering advance during the Spring and Summer on reconstructing ventilation in schools, elderly care homes, trains and buses for the Fall and Winter. The argument by her team at Erasmus MC has been that aspects had not been proven empirically – concretely by the infection of a lab animal at least 1.5 meters at a distance, which experiment apparently wasn't set up spontaneously – but Richard et al. (including Koopmans) (2020) misrepresent (which *Nature's* peer review apparently allowed) the finding by Van Doremalen et al. (2020) who used a Goldberg drum and who conclude: "Our results indicate that aerosol and fomite transmission of SARS-CoV-2 is plausible, since the virus can remain viable and infectious in aerosols for hours and on surfaces up to days (depending on the inoculum shed)." See Colignatus (2020c) for references.

When the world of epidemiology is closely connected to a bureaucracy that will admit to no failure, then perhaps outside scientists might have the independence that is needed for criticism: but most would lack the competence in epidemiology. The ancient question remains: *Quis custodiet ipsos custodes?* The likely best answer by various philosophers of science has been: *let democracy enable the forum of science & learning to perform*, see Colignatus (2020b).

6. Conclusion

The SARS-CoV-2 pandemic highlights the need for good communication. We should avoid the re-invention of the wheel on epidemiology but we apparently can contribute to the redesign of the didactics of some basic epidemiological models. With sound command of modeling and empirical developments we can diagnose that the cause for the pandemic lies in governance. This puts the relation between democracy and science & learning into focus. The pandemic is only one of more issues that have caused the discussion in Colignatus (2020b) that advises the creation of a national assembly of science and learning.

7. Caveat

A caveat is:

(1) Professor of mathematical statistics Richard Gill has oft quoted Patrick Suppes (1963:334-335): "For those familiar with the applications of probability and mathematical statistics in mathematical psychology or mathematical economics, it is surprising indeed to read the treatement of probability even in the most respected texts of quantum mechanics. (...) What is surprising is that the level of treatment in both terms of mathematical clarity and mathematical depth is surprisingly low. Probability concepts have a strange and awkward appearance in quantum mechanics, as if they had been brought within the framework of the theory only as an afterthought and with apology for their inclusion."

Physicists who look into epidemiological models with their underlying probability theory are advised to check modern probability theory too and check what Gill wrote on the issue.

PM. Gill argues that quantum events provide the empirical evidence that reality is probabilistic, while Colignatus (1981, 2007, 2011) argues that there are the three independent competing views of determinism, volition and randomness, and that there is no discerning experiment to decide what would be reality, since anything that happens can be described in any view.

(2) My own comment is that I am uncomfortable with the lack of logic in the texts intended for a general readership, like me, about Einstein's relativity, see Colignatus (2005). There might be a historical explanation. In the 1800s, physics was much engaged with the notion of an aether, and researchers lost much time on this, till they decided that they would only work with observed variables for which measurement was defined. Apparently this katharsis came with a lot of emotions and a sense of loss, and the use of observed and measured variables has become a deeply engrained dogma in physics. If I understand it well, Einstein thus defined time as measured by clocks, and when those clocks moved at the speed of light then measurement became crooked, and Einstein solved this by suggesting that space itself curved. This uses the same word "space" for something new, which apparently is defined by the measurement outcomes. I have a hard time understanding what this means, for, when space is defined in Euclidean terms, then you cannot change that definition, and if you use another definition of space then I do not understand why you use the same word en what you are speaking about because my understanding of what space is has been given by Euclid. Drawings of masses that depress and make a curved plane are still pictures that use Euclidean space. It is not clear to me why you would use the same word for something else (though I have no problem with "n-dimensional Euclidean space" or that you might choose the surface of the Earth for your system of co-ordinates). For me, it makes more sense to hold that there can be measurement errors when the instrument of measurement has a Lorentz contraction. This suggests that stories for the general public might be written so that there still is Euclidean space but with measurement errors. I would like to read such a story that still fits Einstein's formula's and measurements. In economics and psychology it is common to have hidden or latent variables, i.e. variables that are not observed directly but that have relevance for a theoretical understanding. Also epidemiology has such variables. Thus, physicists looking into epidemiology preferably learn to deal with latent variables rather than start imposing the dogma of observed and measured variables and create new problems in communication.

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Thomas Colignatus is the scientific name of Thomas Cool (cool at dataweb.nl), econometrician (Groningen 1982) and teacher of mathematics (Leiden 2008), Scheveningen, Holland, thomascool.eu. He worked at Erasmus Medical Center (Rotterdam 2002-2004) on (Markov) modeling for screening on the Human Papilloma Virus (HPV) concerning cervical cancer. He is secretary of the Samuel van Houten Genootschap, scientific bureau of the Social Liberal Forum, an initiative for a political party in Holland.

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Tapping More of the Sun's Energy to Deflect Asteroids

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INTRODUCTION

Solar energy, after many years in the shadow of fossil fuels and nuclear fission, is capturing increasing public attention. The world has awakened to the dangers of global warming and climate change, the societal difficulties associated with widespread use of nuclear energy, and the growing promise of solar and other renewable energy resources[1]. This article discusses some of the numbers behind solar energy's increasing popularity and speculates about how we might derive even more energy from our mid-sized star in the event of a potentially fatal global threat from an incoming astero (see Fjgure 1).

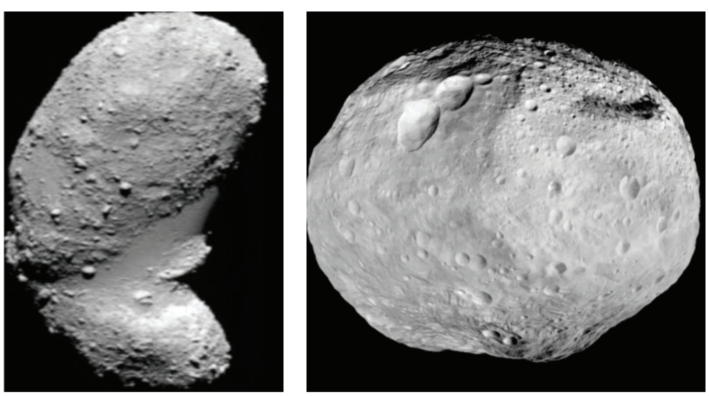

Figure 1: asteroid shapes

Asteroid strikes on Earth and what can be done to prevent them is a topic of increasing concern and study. We now have the means to detect asteroids that are far away and calculate their orbits. The NASA-supported Sentry project[2] at the Jet Propulsion Laboratory/CalTech "…is is a highly automated collision monitoring system that continually scans the most current asteroid catalog for possibilities of future impact with Earth over the next 100 years." Wikipedia defines asteroids as "..minor planets, especially of the inner Solar System… Millions of asteroids exist, many the shattered remnants of planetesimals, bodies within the young Sun's solar nebula that never grew large enough to become planets."[3]

BASICS

The basic physics is straightforward: the Sun is a nuclear fusion machine that fuses massive amounts of hydrogen into helium in a fusion process that releases massive amounts of energy. For his contributions in explaining energy and element production in stars, such as the Sun, Hans Bethe was awarded the Nobel Prize in physics in 1967.[4] for his contributions in explaining energy and element production in stars.

The sun radiates its energy uniformly in all directions, effectively as a 5500 degree Centigrade blackbody (perfect emitter). At this rate, the Sun's hydrogen supply (estimated to be 2 trillion trillion million kilograms) will be exhausted in about five billion years. The Earth, at an average distance from the Sun of 93 million miles, intercepts only 4 parts in 10 billion of the energy radiated.[5] This exceedingly small fraction still provides 6 million quads of energy to the Earth's disc annually, about 10,000 times more than our current annual global energy consumption (600 quads).

The problem with solar energy's use on Earth is not its magnitude but its energy density. It is not a concentrated energy source as are fossil fuels and nuclear power, and gathering it to use it effectively can be expensive. However, great progress is being made in reducing the cost of solar energy, and today it is the fastest growing energy source on the planet.[6]

THE ASTEROID PROBLEM

So why am I concerned about deriving more energy from the Sun? My answer is that we will need that extra energy to protect the Earth from damaging, and even existential, asteroid collisions.

The solar system contains many non-planetary chunks of matter, both large and small (asteroids, meteors, comets), that can do serious damage if they collide with the Earth. For example, it is widely believed that a large asteroid crashed into the Earth 66 million years ago and led to the extinction of the dinosaurs and many other species. These chunks of matter are in orbits around the Sun, and, over time, the orbits of some of these chunks may bring them into collision with the Earth. In fact, the Earth is constantly bombarded by chunks of space matter, most of which burn up in the atmosphere. Given cosmic time scales, a damaging collision of the Earth with a large asteroid is inevitable.The issue then becomes: How do we change its orbit to miss the Earth? This takes lots of energy (how much is discussed below), and the only source of 'lots of energy' that we have is the Sun.

HOW MUCH ENERGY?

My initial 'back-of-the-envelope' approach to this problem, to get a feel for the numbers, is to assume a spherical asteroid with a diameter D of 120 meters (about the size of a baseball field) moving in its orbit at a speed v of 20,000 miles per hour (18,940 meters per second). I further assume that I need to change the asteroid's orbital kinetic energy (KE $= 1/2\ mv^2$) by 10% to divert it from its collision course with the Earth. (Note: 10% is likely a conservative assumption)

To calculate this kinetic energy I assume an asteroid density of 3 grams per cubic centimeter (3,000 kg per cubic meter).[7] At D = 120 m, the asteroid's volume V ($0.5324\ D^3$) is 905,000 m^3. This gives the asteroid a mass of $2.7x10^9$ kg and a kinetic energy of $4.9x10^{17}$ joules (0.46 quads; 1 quad = $1.055x10^{18}$ joules). 10% of this is 0.05 quads. If the asteroid's diameter doubles (to the equivalent of an 80 story building),[8] this number increases to 0.4 quads. If the asteroid's speed also doubles to 40,000 mph, this number goes to 1.6 quads.

Obviously, readers can plug in any numbers they want. NASA Science's 'Solar System Exploration' website[9] says the following about asteroid size: "Asteroids range in size from Vesta—the largest at about 329 miles (530 km) in diameter - to bodies that are less than 33 feet (10 m) across." With respect to asteroid orbital speeds, the Lunar and Planetary Institute website[10] states that: "Asteroids, the most common type of impactor, slam into the Earth at an average velocity of 18 km/s." (40,300 mph).

Plugging in 50 km for D and using the above average impact velocity for v, 10% of the asteroid's KE is 15 million quads, well beyond anything based on Earth-bound systems. Are such numbers possible by tapping into more of the Sun's radiated energy?

THE DYSON APPROACH

Using numbers provided earlier, we can calculate that the Sun's total radiative output is $1.5x10^{16}$ quads, considerably greater than the 15 million quad number above. So the question becomes: How can we capture more of the Sun's energy in case we need it to avoid a catastrophic asteroid collision? Freeman Dyson had one answer when he proposed, in 1960, "..a hypothetical megastructure that completely encompasses a star and captures a large percentage of its power output… The concept is a thought experiment that attempts to explain how a spacefaring civilization would meet its energy requirements once those requirements exceed what can be generated from the home planet's resources alone."[11]

This megastructure is now known as a Dyson Sphere and is the subject of numerous science fiction stories, and engineering and design studies (see Figure 2).

It should be noted that Dyson considered a solid spherical shell of matter surrounding a star to be "..the least plausible variant of the idea." In response to letters commenting on his concept, Dyson replied that "A solid shell or ring surrounding a star is mechanically impossible. The form of 'biosphere' which I envisage consists of a loose collection or swarm of objects traveling on independent orbits around the star."[13]

THE PV APPROACH

So what would a plausible swarm look like? The literature describes several possibilities, most of them swarms of photovoltaic (PV) cells that convert sunlight directly into electricity. Thus, how much electrical energy can be generated by placing arrays of solar cells in orbits around the Sun that are closer to the Sun than 93 million miles? This is of interest because the intensity of solar radiation increases inversely to the square of the distance to the Sun. The goal would be to get as close to the Sun as practical to increase the energy capture and resultant electrical generation. This requires PV devices

Figure 2: sci-fi sketch of what a Dyson Sphere could be[12]

that do not overheat when in such close proximity to the Sun, and one or more means of transmitting/storing the electrical energy generated for later use in deflecting the asteroid - all interesting engineering problems.

The Solar Constant, the energy received by the Earth from the Sun, averaged over its elliptical orbit around the Sun, is 1,360 watts per square meter (w/m^2).[14] This 'Constant' becomes 5,440w/m^2 at half the distance to the Sun and 21,800 w/m^2 at one quarter of the distance to the Sun.

Can a PV array positioned closer to the sun be cooled enough to not burn up and kept at a reasonable operating temperature? This latter issue is also a problem for Earth-based PV systems, as semiconductor devices deteriorate in solar-to-electricity conversion efficiency as they heat up. While recognizing that this can be a difficult problem to solve, I would note that NASA's Parker Solar Probe, currently in an elliptical orbit around the Sun, will be within 4 million miles of the Sun's surface at its point of closest approach while gathering data continuously.

The heat shield that protects the Parker spacecraft "..is made of two panels of superheated carbon-carbon composite sandwiching a lightweight 4.5 inch thick carbon foam core." It weighs only 160 pounds, and at the probe's closest approach to the Sun "..temperatures on the heat shield will reach nearly 2,500 degrees Fahrenheit, but the spacecraft and its instruments will be kept at a relatively comfortable temperature of about 85 degrees Fahrenheit."[15] Excess heat is discarded via a heat sink to space where temperatures are just above absolute zero.

POSSIBLE ORBITS

While there are many possible orbits for satellites around the Sun, I choose only one for purposes of calculation - an object orbiting the Sun at a distance of 30 million miles. The equations of orbital mechanics [16] dictate that this satellite will be moving at 52.6 km/s (117,666 mph). The time to complete one orbit will be 5.77 million seconds (2.2 months), and the orbit's length will be 304 billion meters (189 million miles).

If we assume an orbital spacing between PV arrays of 500 (1000) miles we could place 377,000 (188,500) shielded PV arrays along this orbit. Assuming, conservatively, that each array is capable of generating 80 watts per square foot, based on today's high concentration solar cells (861 watts per square meter), and that each solar array is 100 square meters in area, in principle we could collect 754,000 kWh (2.57x10^{-6} quads) per year per array. The energy harvest of the total swarm of arrays would then be 284 (142) billion kWh, or 0.969 (0.485) quads. If the array areas are increased to 1,000 square meters and the conversion efficiency is increased to 100 watts per square foot, the yearly collected electrical energy totals rise to 12.1 (6.05) quads.

CONCLUSIONS

These numbers give one a feel, energy-wise, for what is possible, with flexibility to change lots of parameters: orbital distance from the Sun, size and efficiency of the PV arrays, number of arrays in one orbit, and even the number of orbits used. The clear conclusion is that, in principle, quads of energy can be harvested by solar arrays in orbits around the Sun if the many associated engineering problems can be addressed. From a pure physics/orbital mechanics perspective, such orbital systems are feasible. An obvious concern is what kind of solar collector can survive such an orbital environment, not only thermally but also in terms of exposure to high-energy radiation from the Sun. I leave it to others to comment on this problem, but with one thought: diamond is a high temperature, high thermal conductivity material that can be doped to act like a semiconductor and serve as a solar cell. Perhaps that is one avenue to pursue.

Other issues are getting the generated electricity from the orbital arrays to the moon or some other intermediate storage location, and then transmitting large quantities of energy to the asteroid to slowly but steadily change its orbital kinetic energy and therefore its orbit. The obvious first guess is the use of directed lasers powered by the generated/stored electricity. I leave it to others more qualified in laser and energy storage technology to discuss this further.

Two final thoughts: the energy levels involved in a collision with a large asteroid may be beyond anything that we can address[16]. Also, analysis of these issues would make an interesting set of PhD problems.

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REVIEWS

Power to the People: How Open Technological Innovation is Arming Tomorrow's Terrorists

Audrey Kurth Cronin, Oxford University Press, New York, NY, 440 pp., 2019, $30.

Power to the People focuses on the way in which terrorism arises when people disgruntled with those in power are able to purchase cheap new technical inventions and think of novel ways to use them in lethal attacks. Since we are living through an era of rapid inventions linked to developments in condensed matter physics, Cronin's worries are very relevant to us as physicists interested in public policy. Last night, the news announced that the Center for Disease Control was sending a representative to California to meet with industrial leaders to persuade them to be careful in vetting news of the spread of the new coronavirus. We are all aware of the dangers of interference in our elections by various nation states. The author asks how long it will be before these techniques are applied by ideological factions rather than nations.

The author divides her work into three major sections. The first section, "Theory," focuses on the difference between the formidably expensive technologies developed by nation-supported militaries and relatively cheap civilian technologies not developed as weapons but enabling private citizens who are driven by ideology to develop strategies to use them as weapons. Here, she presents her initial arguments for our clear and present danger.

The second section, "History," focuses on the historical data that give rise to the theories presented in the first section. Fortunately for your reviewer, the author begins her expression of concern with two cases where terrorist groups in the past have conducted attacks on authority with cheap technologies developed for peaceful purposes: dynamite and the Kalishnikov rifle in all its permutations including the AK-47. Both dynamite and the Kalishnikov were developed for other uses having little to do with the attacks devised by the terrorist organizations: dynamite for use in mining and construction, particularly railroad construction by Alfred Nobel who did not foresee its lethal use by non-governmental forces and the ways in which it would give power to Anarchists although he made a fortune from its global dissemination.

Similarly, Mikhail Timofeyevich Kalashnikov, who was at the time a tank driver in the Soviet Army, designed a rifle to solve the problems of World War I Soviet soldiers who were weighed down by the heavy ammunition and machine guns needed to reliably kill enemy soldiers, as well as the by extensive training they needed to use them accurately. The rifle was designed to be light-weight and very durable as well as to use smaller, lighter cartridges. It could also be used accurately by relatively untrained troops, so it was adopted and modified by any number of global militaries. It and its various modifications were also inexpensive and widely used by terrorists who had little time and money for training or to produce new weapons.

The third section, "Convergence: Widespread Lethal Empowerment," focuses on the international digital revolution through which we are currently living. Certainly the World Wide Web was not developed as a recruiting tool for ISIS although it has been used most effectively in this manner by them. Most of us are familiar with the dangers of guns made with 3-D printers and dangers posed by intelligent drones, but I had not considered the perils presented by artificial intelligence as the technology for devices such as self-driving cars matures. The author emphasizes that terrorists motivated by ideology typically innovate by developing new strategies for using existing civilian technologies rather than developing new technologies equipped for their specific targets.

The book's conclusion, "Strategy for Democracies in an Age of Lethal Empowerment," is unfortunately its weakest part. Although Cronin presents several strategies by which citizens in open societies can defend themselves against terrorist attacks that use new technologies, she does not make a strong case that terrorists can actually launch such attacks. The most valuable part of this conclusion is a list, which I quote here, of the qualities that an innovative technology must have if it is to be used by terrorists to attack their enemies lethally.

The new technology must be: "accessible; simple to use; transportable; concealable; effective; multiuse." Such a technology is almost by definition "not cutting edge; bought off the shelf; part of a cluster of emerging technologies which are combined to magnify overall effects; symbolically resonant which makes them more potent than just their tactical effectiveness; and given to unexpected uses." Of course, this list applies very well to late developments in digital technology.

I'd like to dismiss this volume as just another alarmist tirade against technology but it is hard to dismiss voluminous data documented by experts and presented in this volume's extensive notes and appendices. Audrey Kurth Cronin is the founding director of The Center for Security, Innovation, and New Technology at American University. In the aftermath of 9/11/2001, she worked as a terrorism specialist for The Congressional Research Service and has held various positions in the executive branch including working in the Office of the Secretary of Defense for Policy and the Secretary of the Navy. She has found time to write a number of books about military technology. She is very well qualified to write a book on terrorism and has done thorough research on this topic. Her book is well worth our consideration.

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The Uninhabitable Earth: Life After Warming

David Wallace-Wells (Tim Duggan, New York, 2019). 310 pp. $27.00. ISBN 978-0-525-57670-9.

In 2010 environmentalist Bill McKibben published *Eaarth: Making a Life on a Tough New Planet*, in which he writes, "global warming is . . . *no longer a threat at all*. It's our reality. We've changed the planet." The rest of McKibben's book is a narrative prescribing how we can live on this new planet he calls Eaarth.

Struck by the dire words in Wallace-Wells's title, I expected to find in his book a follow-up to what McKibben had described almost a decade earlier. I did, but I felt that it was written in a nonlinear style that was difficult to follow. After completing the first section of 36 pages which Wallace-Wells calls "Cascades," I gathered that it amounted to the following points:

1. The conditions allowing humans to evolve have changed: "We have . . . exited the state of environmental conditions that allowed the human animal to evolve in the first place, in an unsure and unplanned bet on just what that animal can endure. The climate system that raised us, and raised everything we now know as human culture and civilization is now, like a parent, dead."
2. An enumeration of what Wallace-Wells calls delusions about global warming: It's an Arctic saga that is unfolding remotely; it's strictly a matter of sea level and coastlines; it's a crisis of the natural world rather than the human world; wealth can be a shield against its ravages; fossil fuel burning is the price of continued economic growth; and technology will allow us to engineer our way out of environmental disaster.
3. It is expected that continued fossil fuel combustion would lead to an increased global temperature between 4^{o} and 4.5^{o}C by 2100.
4. We can assign responsibility for reversing the trend: Earth has been brought to the brink of climate catastrophe by the generation of our parents. The generation with the responsibility to avoid it . . . is ours. "We found a way to engineer devastation, and we can engineer our way out of it."
5. The purpose of the book: "This is not a book about the science of warming; it is about what warming means to the way we live on this planet. ...What will it mean to live outside . . . [the] narrow window of environmental conditions that allowed the human animal to evolve . . . probably quite far outside it. That reckoning is the subject of this book."

The second section, “Elements of Chaos,” comprises twelve chapters based on “interviews with dozens of experts, and . . . hundreds of papers published in the best academic journals over the previous decade or so . . an honest and fair portrait of the state of our collective understanding of the many multiplying threats that a warming planet poses to all of us. . . .” These chapters cover the following topics associated with global warming, again, not always in a linear way: temperature increase, hunger, sea level rise, wildfires, unnatural disasters, freshwater drain, marine environment, air pollution, insect spread, economic consequences, military conflict, and impacts on physical and mental well-being.

The third section, “The Climate Kaleidoscope,” expresses Wallace-Wells’s concerns about six aspects of the human future related to global warming, including the following:

1. Storytelling: Wallace-Wells writes that we have engineered Earth so that “ninety-six percent of the world’s animals, by weight, are now humans and their livestock; just four percent are wild.” But this was done at the expense of global warming, which, allowed to continue unabated, “will come to shape everything we do on the planet . . . .” Climate scientists like James Hansen, who first testified to Congress about it in 1988, were guided by what Hansen called “scientific reticence” lest they be perceived as advocates rather than scientists and their advocacy spawn depression leading to inaction. Scientific reticence was based on the expectation that hope can be more motivating than fear--but after the alarming 2018 IPCC report, “scientific reticence” gave way to “tell it like it is.”
2. The Church of Technology: Wallace-Wells regards the technological advance offered by Silicon Valley, which is focused on artificial intelligence, as a diversion from the reality that calls for mitigation against climate change in the form of a complete revamping of energy infrastructure. He also sees building an artificial ecosystem on Earth as more feasible than building one on Mars.
3. Ethics at the End of the World: Wallace-Wells presents five types of responses to the present prospect of future climate change: withdrawal (in order to work things out for yourself), massive activist mobilization, climate fatalism (“an overabundance of humans but a dearth of humanity,” species loneliness (an anthropocentric view that values only human gratification), and climate apathy (continually acclimatizing ourselves to new norms).

The last section, ‘The Anthropic Principle,” revisits many of the author’s preceding ideas and the challenges raised for humans in charting their future. “The question of how bad things will get is not actually a test of science; it is a bet on human activity. ...How much will we do to stall disaster, and how quickly? ...[The] instability [of the climate system] is also a measure of the human power that engineered it ...and which must now stop the damage. ...If humans are responsible for the problem they must be capable of undoing it.”

In spite of the dire consequences he has written about the consequences of climate change, Wallace-Wales says he is optimistic that we will overcome them–with his confidence even taking the form of fathering a child in the course of writing this book. To do this, he points out “that we have all the tools we need, today, to stop it all: a carbon tax and the political apparatus to aggressively phase out dirty energy; a new approach to agricultural practices and a shift away from beef and dairy in the global diet; and the public investment in green energy and carbon capture.” But he doesn’t leave us a blueprint for using them.

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