modifying the present journal (perhaps also with more frequent publishing) instead of introducing a new publication.

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THE EDITORS COMMENT: The editors of *Reviews of Modern Physics* agree wholeheartedly on the value of shorter reviews designed to keep members of the physics community abreast of new advances in the many subdisciplines of physics. Several considerations, however, cause us to question the advisability of abandoning our present format in favor of very short articles.

First, it is exceedingly difficult to get good people to write very short reviews or articles. The shorter and more superficial the article must be, the less attractive an undertaking it becomes for the serious physicist. One of the main advantages of writing for RMP has always been the freedom to write *long* articles and to cover one's topic in depth.

On the other hand, a physicist in the midst of active research often does not have the time to write a lengthy, comprehensive review. Since 1974, therefore, we have encouraged the submission of shorter and more personal "perspectives" in addition to traditional reviews. We have solicited articles on frontier topics in physics for which we relax our requirements that a review be complete, provided the author is a major contributor to the field and makes an effort to be pedagogical. Our hope has been that in such cases the vitality and excitement of work in a new field will be of interest to our readers, and that the balance sacrificed in a single perspective will be regained over a five-to-ten-year period by articles from other leading workers in the field whose approaches are different.

What we term a "shorter," perspective article is, of course, a good deal longer than the five-page review suggested by Herman. For truly short articles, a second difficulty arises. This is that someone needs to identify which topics are important and why. The traditional approach, employing referees, due process, and so on, would be both cumbersome and inappropriate in the selection of many brief, informal articles, more akin to letters than to reviews. One solution to such a problem would be to employ an editorial staff to write all the articles. But this, of course, would be entirely alien to the concept of the review journal as a place in which physicists can communicate with each other about work in their respective fields.

Finally, granting the usefulness of very short, timely reports, the editors feel that the case for publishing them in RMP is severely weakened by the fact that several journals already exist to fill the need which Herman describes. Among these are *Physical Review's* Comments and Addenda section and particularly the *Comments* journals of Gordon and Breach (*Comments on Nuclear and Particle Physics, Comments on Solid State Physics,* etc.). As long as such sources of timely information exist, it seems to us that RMP can be most valuable to the physics community in its present role, as an archival—though we hope not fusty—journal, in which physicists may speak to each other at some length about their respective fields.

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5/2/78 *Reviews of Modern Physics*

Space colonies

We were glad to see Philip Chapman's review of four books on space colonization (January, pages 59–60). We agree that the movement to colonize space is already underway and that it may grow to "a magnitude comparable to the ecological or anti-war movements of the 1960's." We feel that physicists should join this movement because it is the perfect marriage of idealism and self-interest. Idealistically, space colonization offers a definite, plausible way to overcome the present economic malaise of the United States and to alleviate many of the world's problems. (Supportive reasoning can be found in the four books cited in the review.) Pragmatically, space colonization and/or space industrialization will surely provide new opportunities to utilize labor, resources and research facilities. In particular, such efforts should create many jobs for physicists willing to consider challenging problems in developing and applying new, space-related technology.

What should physicists do to encourage the growth of this technology? First, we should make an effort to become well-informed on the issues involved. (Again, read the books!) Then we should engage in a constructive dialogue that will assist in solidifying the fundamental concepts propelling humanity "up and out" into space. Contributions to this dialogue can take two forms: professional scientific work applicable to the many problems involved, or political action.

Immediate political action is needed in the next few months. Specifically, two resolutions were submitted to the US House of Representatives on 15 December 1977. The first, House Concurrent Resolution 451, sponsored by Olin E. Teague (D-Texas), calls for study of a national

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goal to construct by "the year 2000 the first manned structures in space for the conversion of solar energy and other extraterrestrial resources" for the "use of human beings everywhere." The second resolution, House Concurrent Resolution 447, supports Teague's resolution, and was submitted by Corinne C. (Lindy) Boggs (D-Louisiana), David A. Stockman (R-Michigan) and Barbara A. Mikulski (D-Maryland). Both resolutions are expected to be voted on during the current session of Congress. We urge all our colleagues to write their representatives in support of these resolutions. (House of Representatives, Washington, D.C. 20515.)

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2/2/78

Higher-resolution tomography

The article by William Swindell and Harrison Barrett (December, page 32) on computerized tomography "suggests that future improvements in resolution or signal-to-noise ratio will be achieved only by increasing the patient dose. Because this is normally unacceptable, significant improvements in resolution should not be expected." I beg to differ with this remark, especially since it tends to discourage research on the important problem of dose reduction in computed tomography, an area in which your readers might profitably work.

I have reviewed some of the many possibilities for substantial dose reduction in computed tomography,[1] and the National Cancer Institute of the National Institutes of Health is issuing contracts for "Reconstruction algorithms for dose reduction in x-ray computed tomography."[2] This is an area which has, for the most part, been ignored by the commercial manufacturers of x-ray scanners, primarily because most of them have focused on only a single, computationally rapid algorithm (convolution) and because high dose permits sharp images, which improve sales.

The argument that the resolution limit has been reached is based on at least two assumptions: that the reconstructed image is a linear function of the data and that no *a priori* information is available about the object being reconstructed. Such assumptions lead to a worst-case estimate of the signal-to-noise ratio. Nonlinear algorithms and intelligent use of known information should improve the signal-to-noise ratio considerably, although both are generally lacking from the software of commercial scanners.

But beyond these considerations, it is clear that the time has come for physicists to take a fresh look at the problem of reconstruction from projections. The very formulation of the equations used for reconstruction is subject to doubt. Consider the detector width, which is 3 mm or more in most commercial scanners. It is this width that gives rise to the "line" integrals (really strip integrals) which are the starting point for all common reconstruction algorithms. It is not necessary to collect the data this way. With available technology one could measure many of the dynamic properties of each photon or particle transmitted or scattered through a patient. In particular, spatial resolutions of 0.1 mm or less should be attainable in determining where an x-ray photon strikes a detector. Thus we see that much of the information is thrown away by the very method of data collection. This mode of data collection is dictated by mathematical presumptions rather than the fundamental physics of the problem.

The spatial resolution of x-ray scanners is seven orders of magnitude worse than the Rayleigh limit for x-rays. By careful study of the physics of the interaction of radiation with tissues and with detectors, and by the development of new classes of inverse scattering algorithms for reconstructing images from recoverable data,[3] I expect that it should be possible to get much closer to the latter limit without increasing the dose to the patient.

The rewards for such efforts are great: Higher spatial resolution could catch many tumors during their long, slow growth phase (up to 1–3 mm diameter), a stage during which, moreover, they are not likely to have metastasized (sending cancerous cells throughout the body); screening of asymptomatic people might become acceptable, rather than waiting for the late stages of massive disease. Today there are few circumstances in which we can detect such small tumors. Computed tomography at sufficiently low dose might make it possible to screen each person as part of a regular checkup for cancer and an enormous variety of other pathological conditions.

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1/18/78

THE AUTHORS COMMENT: We share Richard Gordon's conviction that nonlinear algorithms, especially those that incorporate *a priori* information about the object, will prove valuable in computed tomography. Indeed, we are among the bidders for the NIH contracts to which he refers. We also agree with Gordon concerning the need for higher spatial resolution in computed-tomography images. Much of our current research,[1] which uses film as a high-resolution detector, is directed to this end.

We cannot, however, endorse the optimism shown by Gordon in the penultimate paragraph of his letter. For example, his statement that it should be possible to get much closer to the Rayleigh limit without increasing patient dose ignores some rather basic statistical limitations. As we have shown,[2] the required patient dose with any linear algorithm varies inversely as the fourth power of the spatial resolution distance, ϵ (assuming the beam height is maintained at a constant multiple of ϵ). It is difficult to know what Gordon meant by "much closer," but for the sake of illustration let us assume that he meant only one order of magnitude out of the possible seven. Then, even ignoring any detector-size limitations, the fourth-power law says that we must increase the patient dose by four orders of magnitude to maintain the same density discrimination. Unfortunately, a similar analysis has not been carried out for nonlinear algorithms, but it appears to us highly improbable that nonlinear methods could make up for this factor of 10^{-4} in the number of detected quanta. Compared with linear processing algorithms, our estimate is that nonlinear methods might afford an advantage of a factor of two or so in resolution for the same density discrimination and patient dose. For the same spatial resolution, this would correspond to a dose reduction of between eight and sixteen times, depending upon whether the beam height is scaled with the resolution distance. It could be argued that this where the potential benefit of nonlinear methods really lies, that is, in reducing dose rather than in improving the resolution.

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2/10/78

Correction

December 1977, page 70–In the obituary of Manuel Sandoval Vallarta, the 13th and 14th lines of the second paragraph should read: "... the intensity of cosmic rays observed along 'allowed directions' is equal to that at infinity ..." □