different subject. Specifically, in his preface Bowler states "I have restricted myself to those aspects of the subjects which I regard as established and likely to stand, regardless of developments in the future." Accordingly, the approach is phenomenological with a strong emphasis on the properties of the fundamental quarks and leptons and their interactions.

Although it is the most recent of the three, Bowler's book really occupies a place between two other books that also grew out of courses in particle physics. The first is *Introduction to High Energy Physics* by Donald H. Perkins, which uses a traditional or historical approach. This book starts with accelerators and detectors and then proceeds through invariance principles and conservation laws to hadronic interactions, the static quark model, electromagnetic and weak interactions, the quark–parton model, QCD and finally unification. The second is *Modern Elementary Particle Physics* by Gordon Kane, which presents the standard model of electroweak interactions plus QCD. It begins with three generations of fundamental quarks and leptons and the Lagrangian describing their interactions; explores the phenomenology of the gauge bosons (W and Z); and proceeds to QCD, accelerators and detectors, mesons, baryons, deep inelastic lepton–hadron scattering and recent developments, such as speculation beyond the standard model.

I suspect that theorists generally will prefer Kane's approach as it is logically more coherent, and it emphasizes the intellectual as opposed to historical development of the subject. A drawback to this approach is that it presents the standard model as having appeared, fully grown and fully armed, out of the brow of Zeus. It fails to give a true picture of how progress is actually achieved in high energy physics, and it creates the impression that there are no false starts, no blind alleys and no incorrect results. The uninitiated thus hears nothing about the split A_2, the high-y anomaly, monojets, Regge poles, R parity and so on. Unfortunately, in a short course (and in a correspondingly brief book), time and space do not permit exploration of the once popular but now generally discarded or disregarded ideas.

Bowler has rather cleverly avoided this problem by gearing his material toward the past development of our current understanding of the standard model, but he does not present this development as canonical. The crucial role played by experiment at every stage in the process is always before the reader. Moreover, some of Bowler's explanations are real gems of clarity and precision. I especially enjoyed the development of SU(2) and isospin in Chapter 11.

If I have any criticism of this book, it is the order of presentation. It might make more sense to precede the discussion of the development of the quark model with an explanation of charge independence and SU(2), to proceed via the introduction of strangeness to SU(3) and then to SU(3)-color. All this should be done before introducing quarks, color forces and so on.

In general this is a good book, suitable for a short course in high-energy physics, with the emphasis on short. The amount of material presented is significantly less than that presented in Perkins's and Kane's books, either of which would be more appropriate for a one-semester course for first-year graduate students. Nevertheless, there is a real niche for Bowler's book at the advanced undergraduate level, and I recommend it.

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Verification and Compliance: A Problem Solving Approach

Edited by Michael Krepon and Mary Umberger
Ballinger, Cambridge, Mass., 1988. 325 pp. $26.95 hc
ISBN 0-88730-326-9

Toward A Comprehensive Test Ban

Steve Fetter
Ballinger, Cambridge, Mass., 1988. 308 pp. $29.95 hc
ISBN 0-88730-281-5

Making Space Defense Work: Must the Superpowers Cooperate?

A. Fenner Milton, M. Scott Davis and John Parmentola
Pergamon-Brassey's, Washington, D. C., 1989. 220 pp. $23.00 hc
ISBN 0-08-035980

Never before in the history of superpower relations has there been more optimism about negotiating stable nuclear arms control treaties. In the past, the Soviet Union would not accept intrusive verification measures, but under Mikhail Gorbachev, it has turned the verification issue on its head. The Soviets are now willing

to accept enhanced and equal provisions for the monitoring of reduced levels of nuclear arms. There are hopes that as many as four treaties will come before the US Senate in the next couple of years: the Strategic Arms Reduction Treaty, the Threshold Test Ban Treaty, the Chemical Weapons Convention and the Conventional Forces in Europe Treaty. The trio of books reviewed here supplies excellent reference material for those who wish to learn more about the details of nuclear treaties.

Verification and Compliance is a collection of 14 essays by experts on treaty verification. In one essay we learn that the US has not always followed the motto "Trust, but verify." In fact the Naval Treaty of 1922 had no provisions at all for verification or inspection. Secretary of State Frank Kellogg remarked in 1926 that the US would rely upon "international good faith and respect for treaties" rather than tolerate the supervision of any outside body.

By contrast, the much more stringent verification provisions of the Intermediate Nuclear Force Treaty have set the pattern for future arms control treaties. As nuclear weapons systems have gotten smaller and more mobile, the national technical means of verification have been supplemented by extensive cooperative measures and by on-site inspections. Sidney Graybeal and Michael Krepon point out in their chapter that on-site inspections can't prevent all forms of cheating, but they do make cheating much more difficult and risky.

Because mobile missiles and cruise missiles will be hard to monitor, START allows for continuous monitoring of production facilities and designated deployment areas with systematic, challenge and destruction inspections. It provides for data exchanges and tagging. In today's political climate one may expect citizens on both sides to keep their governments honest, but the treaty should be robust enough to be effective without their help.

Like the Constitution, a treaty cannot predict all situations that will arise in the future. The Standing Consultative Commission is the forum in Geneva where the US and Soviet Union work with the "living text" of a treaty. The SCC hears the first questions and complaints regarding the provisions of the treaty. The chapters by Gloria Duffy and Ralph Earle examine the contested compliance issues, such as the Krasnoyarsk, Gomel and Fylingdales radars, the encryption of telemetry from missile tests, and the so-called "narrow" and "broad" interpretations of the Anti-Ballistic Missile Treaty.

Neither side has been perfect. Presidential annual reports to Congress describe some of the charges against both sides, but most members of Congress know which charges to take seriously, and which to ignore. Now that the environment at the SCC has greatly improved, it seems time to consider ways to improve the commission's process. In the concluding chapter, Krepon recommends, among other things, that the intelligence community (rather than the Arms control and Disarmament Agency) once again be responsible for analysis of treaty compliance, in order to depolarize the process.

Toward a Comprehensive Test Ban examines the complicated technical and political issues surrounding nuclear test ban treaties. This book covers past history, modernization, verification, stockpile reliability and confidence, safety and security, nuclear strategy, the development of third-generation nuclear weapons, nuclear proliferation and policy decisions on nuclear testing. Steve Fetter discusses these issues with depth and clarity, making them accessible to busy policymakers. As an example I will discuss Fetter's handling of stockpile reliability and the associated policy decisions.

Stockpile reliability and verification are the main sticking points for a future Comprehensive Test Ban Treaty. Fetter points out the difference between reliability and confidence: Reliability measurements come from nuclear testing, while confidence is the political judgment that one assigns to the results of nuclear testing and other, nonexplosive tests.

Very high levels of reliability can only be proven by many, many tests. Missile reliability is generally assumed to be about 75–90%, and proving that warheads are much more reliable than this range of values would take a tremendous amount of testing. Fetter states that "in recent years only 8% of all tests were done for stockpile purposes, and a few of these were of old weapons. Even if two old warheads were tested each year, this would allow only one stockpile confidence test every 15 years for each weapon type. The normal stockpile surveillance program, which consists of the careful disassembly, inspection and testing of components from many weapons, is far more effective than nuclear testing for detecting deterioration." As it turns out, only 8 out of the 300 nuclear tests conducted by the US have been used

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GLENN T. SEABORG, Introductory Remarks

THE DISCOVERY OF NEPTUNIUM
PHILIP H. ABELSON

THE DISCOVERY OF PLUTONIUM
ARTHUR C. WAHL

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TOWARDS SUPERHEAVY NUCLEI: THE DISCOVERY OF ELEMENTS 107 TO 109
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Y.T. OGANESSIAN

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to evaluate defects in stockpiled weapons.

Past examples of unreliability have been used to show the need for testing. Fetter asserts that "these reliability problems resulted either from design errors that were not revealed by the normal testing program during the development phase of a weapon, or from the unexpected aging and deterioration of weapon components after deployment." These kinds of errors are usually found early in the deployment of a system. "By relying only on warheads that have been tested, produced and deployed for a few years," Fetter writes, "it appears that problems due to design errors can be substantially avoided." Fortunately the military characteristics of warheads have been expanded since 1982 to include "maximizing warhead lifetime, the ability to replicate the warhead at a future date and the ability to incorporate the warhead into other delivery systems."

The reliability issue has been unnecessarily exacerbated in the past because the US has required new warhead designs for each new system rather than designing some of the new missile systems around existing warhead designs. Now that the US arsenal appears to be essentially modernized with the air- and sea-lauched cruise missiles, Trident II, MX missile and Midgetman warheads, and START promises to cap further deployment, there is less incentive to develop many new types of warheads. If one chooses not to develop third-generation nuclear weapons, then a more complete ban will mainly affect the issues of reliability and additional modernization beyond the MX and Trident II.

The Threshold Test Ban Treaty will probably be ratified within a year. Then policymakers will focus on the choice of a complete as opposed to a lowered-yield threshold test ban treaty (about 10 kilotons). The Comprehensive Test Ban Treaty is favored by some because it really would stop development of new weapons at its source, because it would strengthen the Nuclear Nonproliferation Treaty and because it would enhance détente. On the other hand, a lowered-yield treaty would be easier to verify and would maintain confidence in the boosted primaries of the weapons. However, some people say the Comprehensive Test Ban Treaty would be easier to verify because *any* tests, no matter what size, violate the treaty.

The sales for the third book, *Making Space Defense Work* will be diminished because of the sinking relevance of the Strategic Defense Initiative.

This book complements the American Physical Society's report on directed-energy weapons systems (see PHYSICS TODAY, May 1987, page S1) by discussing some of the policy problems for SDI architectures. In spite of the recent shift in the SDI program from exotic beam weapons and space-based kinetic kill vehicles toward the smaller "brilliant pebbles," the book is still relevant. The authors have prepared informative tables describing the advantages and disadvantages of each of the phases (boost, midcourse and terminal) and of the various SDI technologies.

SDI was originally intended to defend the US population by covering the entire country. However, because cruise missiles and depressed-trajectory submarine-launched missiles can fly under a defensive shield, defense of the continental US is clearly very difficult. Thus the goal of SDI was soon compromised to cover only the defense of hardened targets, such as missile silos, in order to complicate a Soviet first strike.

Furthermore, much of the SDI technology seems to have been designed against the present threat from Soviet SS-18 missiles and not against any future threat. Should we invest 50 or 150 or possibly as much as 750 billion dollars when the other side can undercut our defense with the stealth cruise missile? The amazing thing is that SDI got as far as it did in the political process.

The authors discuss these problems eloquently and in some detail but then seem to conclude that some parts of SDI just might be worth deploying. For example, they appear to see some merit in a low-altitude defense system to protect missile fields from re-entry phase, or in a modest area defense of the population. These are surprising conclusions for a book that points out all the problems of SDI. The title of the book, *Making Space Defense Work*, is curious because it implies that SDI can be made to work. The book is certainly worth buying for its well-organized, good scholarship, but it seems that the policy authors didn't listen to the technical authors. The policy-oriented authors seem to have forgotten about the unreliability of complex technologies. Perhaps they were trying very hard to appear open minded and so hesitated to conclude that SDI is, at best, money wasted. One gets the feeling that the SDI issue is similar to Gresham's law of economics: "Bad money forces good money out of circulation." The endless analysis of SDI has occupied the valuable time of many of America's best scholars on strategic studies and

arms control, keeping them from working on the more important issues of START.

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