usually shows up as a surplus in the receipts column, may indicate that material has been lost or stolen on its way through the plant. On the other hand, it may indicate only that supervisors have failed to keep good discipline over those who measure and account for the goods. The risk in tolerating bad bookkeeping is that, although not harmful in itself, it creates an atmosphere in which theft is easy.

The NRC refers to discrepancies in the fuel shipment records as "inventory differences" or ID's. Normally, one expects a certain amount of sloppiness in keeping accounts. This is especially true of nuclear fuel handling, where the material being counted may be inaccessible and, in some chemical processes, very hard to measure. Nevertheless, the NRC officials decided that they wanted to allow for no more than a small variability in the discrepancies on the fuel account books. They devised a term for this concept, strongly disliked by statisticians who have looked at the problem, called the "limit of error" on inventory differences or LEID. The statisticians say the term has not been defined in a precise or even in a consistent manner. Each processor may come up with his own definition. But in any case, LEID is meant to represent the degree of uncertainty in measurement one may tolerate under normal conditions and still be confident—95 percent of the time—that no theft or loss has occurred.

If statisticians were allowed to define the concept, they would say that the ID is the estimator of losses or discrepancies, and that two times the standard deviation of the ID gives you a figure for uncertainty in measuring the ID—called in this case the LEID. If the ratio of the ID to the LEID is less than 1, one may accept the statistical hypothesis (with a 5 percent level of significance) that there has been no loss or theft. In practice, one may feel confident that no thefts or losses have occurred if, 95 percent of the time, the reported ID is less than the index of LEID.

When the statisticians applied this concept to actual figures sent in by NRC licensees, they got the disquieting results shown in the chart. Between 1974 and 1978, the NRC received 803 inventory reports which included data on ID's and LEID in computing the ID's. Among these, the statisticians found, the ID exceeded the LEID in 375 cases—nearly half the time. Had this happened at a bank, a massive search for the embezzler would have been launched. The statistical alarms were ringing almost continuously.

The NRC staff recently tested these results a second time to find out if there had been a flaw in the calculations. Using more recent and more carefully selected data, the staff managed to lower the statistical alarm rate. In this study, the ID exceeded the LEID only about one-third of the time. But that is far above the business-as-usual rate of 5 percent. Dan Lurie, the statistician who briefed the commission on the problem last March, simply concludes: "Something is wrong."

No one can say for certain just what is wrong, although many possibilities have been discussed. The one judged by the NRC staff to be the least probable is that large quantities of fuel are being lost or diverted. There is a mundane explanation for the discrepancies. Most of the trouble derives from sloppy accounting and measuring at the plants, the NRC staff thinks. The statisticians at the NRC also see flaws in the theoretical structure of the accounting system. As one said, "There is blame for everyone: there have been sloppy measurements, bad calculations, and—what's a nice word for coercion?—management impositions."

The NRC statisticians think several things could be done to reduce the false alarm rate (which is what they judge the problem to be) and thereby make the account books more meaningful. The first step, according to Roger Moore, a Census Bureau official who until recently was in charge of applied statistics at the NRC, is to do away with the NRC's vague and inconsistent regulatory term, "limit of error." He says, "It should have been drowned when it was born." A standard statistical term should be substituted in its place, and he has one in mind: twice the standard deviation of the ID. Then, Moore says, something should be done to repeal a letter of guidance sent out to licensees by the NRC in 1974. The letter "got us into trouble," he thinks, for "that was when things began to come apart, I mean really apart."

The letter, sent out in December 1974 by R. G. Page, put a limit on what the NRC called the limit of error. It seems to have been an attempt to tighten up the original regulation, but it made matters worse. Instead of developing a better statistical basis for reading the books, this action switched the NRC to a purely arbitrary system of investigating discrepancies. Although expressed in more complicated terms, the revised rule of 1974 triggers the alarm when the reported ID is larger than 1 percent of a plant's deliveries or shipments. It is an unso-

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A Cooler Look at Laser Weapons

The Department of Defense, which has spent two decades trying to produce a new tank, has been talking a lot lately about laser beam weapons. Apparently, the generals are going to build some space-based laser stations, castles in the sky that will strike down Russian missiles a few seconds after launch. The Air Force is going to equip its planes with laser-beam antiaircraft and antisatellite guns, the Army will field laser-toting tanks, if it has managed to build any tanks by 1990, and of course the Navy will go to sea with lasers galore.

Supporters of laser weapons say that the Reagan Administration will make still larger the sizable sums already being expended on laser research. For the last several years the Pentagon has been funding these high-vacuum theoretical weapons at an annual budget of around $200 million on the largely implicit premise that, with infusion of sufficient money, Buck Rogers can be made to live. Unfortunately, a number of physical obstacles still stand in the way of this reanimation.

One is the weather. The lasers can mug a MiG in a clear sky, but are very disappointing in fog or drizzle. What if the other side should be so disobliging as to attack on a rainy day? While the generals are working on that problem, the technicians are trying to fix another of nature's quirks, that so far one of the best materials for lasing is deuterium fluoride. New deuterium is a substance expensive even by the Pentagon's standards of gold-plating, and fluorine is too unpleasant a gas to risk having aboard any military vehicle.

There is of course the carbon-dioxide laser. This is the leading candidate for arming the Pentagon's Battlestar Galacticas. The first difficulty with these fancy space stations is that of deciding where to put them. If you place them in low orbit, their field of view is rather small and you need a great many to cover Redland. If, on the other hand, you put them in high, geosynchronous orbit, they are sitting targets. Of course, you can then build a fleet of small space stations to protect the vulnerable big one, following the Navy's principle of constructing aircraft carriers which need a small fleet of other ships to defend them. But the trouble here is that the aircraft carriers provide targets worth a mere billion dollars apiece, whereas the laser space stations would probably cost at least $10 billion each.

That's only where the serious problems begin. The carbon dioxide lasers are real gas guzzlers. One parked in geosynchronous orbit would need about 100,000 tons of consumables shuttled up there to top up its tank. Three such stations would be required to provide global coverage. Conceivably, the Russians might not sit quietly on the sidelines while this cumbersome armada to make America number one again was slowly being assembled in the wild blue yonder.

Even if the Soviet Union took no steps to interfere during the construction process, there would be ample opportunity for attacking the laser stations by the same stratagem which has defeated all other antiballistic missile systems: money. When the means of attack cost less than the necessary countermeasures, the defense is in a no-win game. The laser stations depend on sensors which can be blinded; they can be attacked by lumps of chicken wire—projectiles in a form that would require inordinate amounts of laser energy to be destroyed; and their prime purpose of shooting down Russian missiles during the boost phase can be defeated by arranging for the missiles to enshroud themselves in a curtain of smoke that dissipates the laser pulse.

These and other problems of laser weapons are described in a study published last month by physicists M. Callaham and Kosta Tsipis of the Massachusetts Institute of Technology*. Although written from the perspective of arms control, the study delineates problems that are less often dwelt upon by the proponents of laser weapons. These problems are so severe, in the MIT physicists' opinion, that a space-based antimissile laser system lies probably 20 years or more in the future, and certainly not within the visible technological horizon. As for uses within the atmosphere, what promise there is for viable weapons probably requires the development of a new generation of lasers.

Now that the physics of how laser light interacts with a target are better understood, says the MIT report, "There is little if any doubt that, in principle at least, and in the absence of counter-measures, an appropriately designed and operated laser can inflict lethal damage onto many targets of military significance." The problems come with the operational systems—the tracking, targeting, aiming, defeat of countermeasures, self-protection, and viability under battlefield conditions—into which the laser device must be incorporated. It is at this point that the technological sweetness of a device that reaches its target at lightspeed becomes soured with the realities of battlefield conditions.

The MIT physicists approve the vigorous research programs on carbon dioxide and carbon monoxide lasers, even though they doubt they will make practical airborne weapons. The most useful goal of military laser research, they believe, is to enable the development of defensive countermeasures against any form of laser attack.

*M. Callahan and K. Tsipis, *High Energy Laser Weapons—A Technical Assessment*, Department of Physics, Massachusetts Institute of Technology, Cambridge, 1980.

French Have Rocket Aimed at NASA's Shuttle

The repeated delays suffered by NASA's shuttle program have enabled the Europeans at last to offer credible competition to the United States' virtual monopoly of space launch vehicles. The Europeans' hopes are pinned on Ariane, a predominantly French rocket which, at its first firing in December 1979, enjoyed a perfect flight.

A second firing, in May last year, was less successful; the rocket disintegrated in flight a few minutes after takeoff from the French launch site of Kourou in French Guiana. Nonetheless, Ariane struck a major blow against her rival the shuttle when Intelsat, the international telecommunications satellite organization, placed orders to launch three of its nine Intelsat-5 global communications satellites aboard the French rocket. The satellites had been intended as shuttle cargo, but NASA lost the order because of the continual delays.

Ariane itself has now fallen behind because the cause of the May 1980 failure, now determined as an instability of combustion, is proving particularly troublesome to fix. The French National Center for Space Studies says that the third flight of Ariane will be delayed several months beyond the scheduled March date.

The European contractors for Ariane had been talking boldly of building some 40 rockets over the next decade. In the view of *Le Monde*, the new delay of Ariane is a "setback with heavy consequences for Europe." Foreign customers, attracted to Ariane, may turn again toward America, the French newspaper warns.

That dire possibility is made more likely by the shuttle's recent progress. After months of engine failures and sloughed tiles, things at last seem to be going right for the vexed program. The main engine passed its certification test, the tiles are being glued back on, and on 29 December Columbia, the first manned shuttle vehicle, was rolled out of its plant to the launch pad. What NASA calls the "pencil date" for launch is 14 March 1981, the same period as had been scheduled for the third Ariane flight. Columbia will be the first shuttle to be launched from ground zero; an experimental vehicle, Enterprise, flew from a Boeing mother ship.

Biologists Need Code on Commercial Behavior

The commercialization of biotechnology has produced new stresses and strains in the fabric of academic life, and scientists should develop a new set of principles governing researchers' behavior in the face of these commercial incentives.

So suggests Stanford University President Donald Kennedy in a recent talk given at the University of Pennsylvania. "Scientists who once shared prepublication information freely and exchanged cell lines without hesitation are now much more reluctant to do so," Kennedy observes. Graduate students may find that their access to a large body of significant work in molecular genetics is seriously reduced, and "the fragile network of informal communication that characterizes every especially active field is liable to rupture," Kennedy warned.

Nicholas Wade