Oslo for the award ceremony on 10 December—but it may not permit him to return.

"He won't go if he thinks it will be a one-way trip," says one of his American friends. Sakharov has often said it is his "mission" to remain in the Soviet Union permanently. This choice—made despite many invitations to teach abroad at prominent Western institutions—has led one Harvard professor to describe him as "a Christ-like figure" who goes out into the wilderness while others remain behind.

The aegis of Sakharov's Nobel comes at a time when other forms of protection for Soviet scientists are crumbling. Last week the Soviet Academy of Sciences, whose members have traditionally enjoyed a certain degree of political autonomy, celebrated its 250th birthday. According to news reports, party ideology dominated the proceedings; Mstislav V. Keldysh, who as the academy's president had preserved

Andrei Sakharov

some of its trappings of autonomy, resigned; Mikhail Suslov, a top party ideologue with no scientific credentials, gave the keynote address and announced who the new, "elected" president of the academy would be, astronomer Vladimir Kotelnikov. (However the election of the new president is expected to take place, as always, by a secret ballot among the members.)

To some American scientists, the Nobel will only enhance the glow around a man to whom the word "saint" has been applied for some time. Apparently both his Soviet and his American colleagues use the term, among other things because of Sakharov's habits of self-denial and personal frugality. One American notes his physical bearing; "He has an other-worldly quality. He is the opposite of the prototypal, temperamental Easterner. He is a slight person. He walks slowly. He is balding. . . .

"Considering some of the things he says he's very unexpressive with his voice and gestures. . . . And his general proposals sometimes seem to relate to the world after this."—DEBORAH SHAPLEY

Lie Detectors: PSE Gains Audience Despite Critics' Doubts

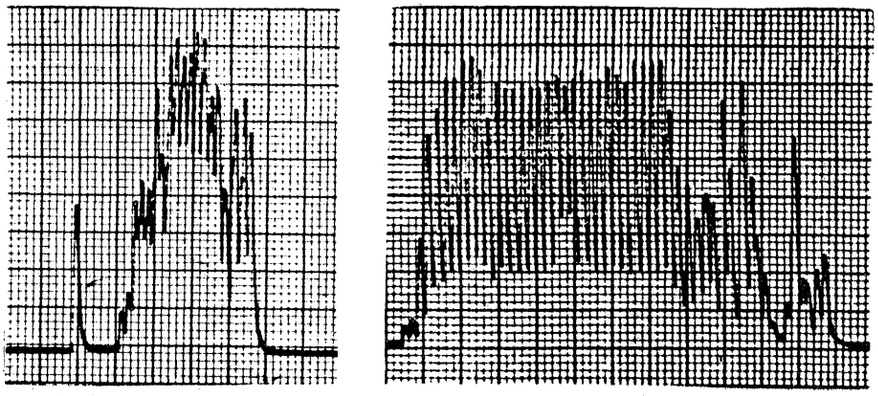
Ultimately, the PSE could affect human communication the way the development of the atomic bomb affected warfare.—International Moneyline, a newsletter.

The above agitated observation reflects the fascination felt in some quarters over a recently developed instrument called the psychological stress evaluator, or PSE. The PSE has become the first competition of the polygraph (or lie detector) since the latter was developed in the 1920's. Whereas a polygraph tests a subject's psychophysiological responses to questioning by measuring his or her respiration, blood pressure, and skin conductivity, the PSE registers stress by measuring certain inaudible modulations in the voice. Because it can be operated simply with the tape recording of a voice, "it is the first lie detector that can be used on a dead man," notes its inventor, Allan D. Bell.

The PSE has been the object of considerable attention and controversy and the subject of articles in *Playboy* and *Penthouse*, as well as publications aimed at law enforcement and security personnel. Its reliability as an aid to lie detection has come under attack—notably in a study commissioned in 1973 by the Army—and its versatility and simplicity have aroused ethical concerns because they give it a real edge over the polygraph when it comes to invading privacy.

The PSE was introduced a few years ago by Dektor Counterintelligence and Security, an adventurous little electronics company run by ex-Army sleuths who believe a man's reach should exceed his grasp. (Dektor was in the news last year, it may be recalled, for coming up with an ingenious counterexplanation for the 18½-minute gap in Rose Mary Woods' tape. See *Science*, 22 February 1974 and 21 June 1974.) The PSE was born in Allan Bell's basement. Bell, a retired Army intelligence officer who quit 5 years ago to form Dektor, says the search for a new way to measure stress was triggered by a market research assignment to come up with a way to measure the emotionality with which people answer questions by pollsters. Bell and the PSE's coinventors, Charles McQuiston and Bill Ford, set out to seek "identifiable emissions from the human body." Odors and voice were the best prospects, but odors are so numerous and easily dispelled or adulterated that they settled on the voice. They discovered that all muscles, including those controlling the vocal cords, vibrate slightly when in use, a phenomenon that is believed to be an involuntary function of the central nervous system. This is called the muscle microtremor and had already been identified, although the inventors didn't know it at the time—"we reinvented the wheel," says Bell. What was not known was that this tremor, which is transmitted to vocal cords, is suppressed by activity of the autonomic nervous system when the speaker is under stress. It is analogous, and may be directly related, to the suppression of the brain's alpha waves (which are associated with a relaxed waking state) when a person is making a conscious effort to think.

The PSE is more versatile than the polygraph because the subject is not required to be hooked up, immobile, to a machine, and, in fact, doesn't even need to be present; the analysis is made from a tape recording, and can be done on a tape made from a telephone conversation or a broadcast. In a lie detection situation the subject is asked the same carefully designed set of questions (innocuous "control" questions interspersed with significant ones) that are asked in a polygraph exam. The tape is then played back through the PSE—a portable affair ensconced in an inconspicuous black suitcase—at a speed four times slower than that at which it was recorded, and a needle on a moving graph chart plots the stress. If the waveform travels up and down erratically, the frequency modulation of the



In an unstressed utterance, at left, the overall configuration resembles a wave, produced by the microtremor that oscillates at 8 to 14 cycles a second. The other chart shows heavy stress as the tremor is obliterated.

microtremor is being registered. This indicates no stress. When the speaker is under stress, however, the tremor is suppressed and tracings become more uniform.

Best known of the early PSE experiments is Dektor's run-through of contestants on the television show "To Tell the Truth." By taping each person when he said "My name is . . . ," they claimed 95 percent accuracy in spotting the real John Does. The PSE made its forensic debut in Howard County, Maryland, where a police lieutenant named Michael Kradz, who subsequently joined Dektor, reported a number of successes using the PSE, most of which contributed to clearing suspects of offenses ranging from shoplifting to murder.

Dektor has sold more than 700 of the instruments (now priced at $4200), mostly to retail and industrial firms who want to catch sticky-fingered employees, to private investigative firms, and to local law enforcement agencies. And sales are going up, says Bell, despite cold water thrown on the PSE by a report produced for the Army in 1973. The Department of Defense bought five of the machines and turned three of them over to the Army whose Land Warfare Laboratory paid Joseph Kubis, a psychologist and polygraph researcher at Fordham University, $27,500 to conduct a comparative study of the worth of the polygraph, the PSE, and another machine similar to the PSE called the voice stress analyzer. Kubis, using laboratory subjects, gave the polygraph a 76 percent accuracy rating and the PSE 33 percent, or about the same as chance (he did a "triad" study, testing people in three roles—perpetrator, lookout, and innocent bystander).

The Kubis report has gotten a good deal of attention, and is cited by all the PSE's critics. Bell, of course, dismisses the study as a slipshod piece of work and says no other research has confirmed the Kubis findings. Kubis counters that at least one other well-controlled experiment agrees with his conclusions, and that research with "live" cases, which Dektor favors, yield very poor results. The Army, while declining to give the Kubis report official endorsement, has nonetheless acted on its findings. It allocated one of the machines for use in research not related to lie detection, and "destroyed" the other two, according to an Army spokesman, who was as emphatic about disassociating the military from the PSE as if he had been asked about plans to deploy a new nerve gas.

The government is clearly in no hurry to attract more attacks on its surveillance habits, and Bell doesn't mind having this market closed to him, as he thinks the government is a nuisance to do business with anyway and not too bright.

Reliability aside, there has been considerable concern over the potential for unethical use of the PSE. The main problem is created by the fact that it can be used without the subject's knowledge. Robert Smith, formerly of the American Civil Liberties Union, points out that job interviews can be taped and run through the instrument without the person's knowledge and he can be denied employment on the basis of stressed-looking squiggles. He also says that the PSE, again unlike the polygraph, can be used in conjunction with wiretapping. And, he says, "people's careers can ride on other people going around analyzing their voice tapes." That comment is in reference to the fact that some PSE operators and journalists have been having fun analyzing the public utterances of various interesting people. Indeed, one free-lance writer, ex-CIA computer specialist George O'Toole, has written a whole book explaining why Lee Harvey Oswald didn't kill anyone—based in large part on a PSE analysis of Oswald's statements after he was captured. ("I didn't shoot anybody, no sir," said Oswald with no stress.) Other colorful PSE uses have been the taping of John Dean (no stress) and John Mitchell (stress) at the Watergate hearings, and of Howard Hughes' telephone press conference where he denied ever having heard of Clifford Irving (Dektor claims to have known before anyone else that Irving was a fraud because their analysis of Hughes' PSE chart showed him to be sincere).

Allan Bell does not suffer moral dilemmas about any of this. First of all, he emphasizes, anyone who buys a PSE must take a 3-day training course in its use, and if the customer flunks there is no sale, or he can pay for more training until he passes. As for surreptitious use, Bell says that in uncontrolled conditions—such as taping a presidential press conference or a phone conversation—there is no way of telling whether a person is lying, only whether he is "stressing." No stress is a reliable indicator that a person thinks he is speaking truth, but stress can arise from a variety of causes that can only be weeded out in a carefully controlled situation. As for broader ethical considerations, Bell answers with a question: "Which is immoral—for a person to lie, or for a lie to be uncovered?" Bell suspects that some businessmen have bought the PSE to determine whether associates are squaring with them in business dealings, but that doesn't bother him—Dektor did the same thing, and canceled a deal because they believed they were being lied to about the promised delivery of some money.

Least enamored of the PSE is the 1200-member American Polygraph Association (APA), which in 1973 passed a resolution saying none of its members would be allowed to operate a PSE unless it were used in conjunction with a polygraph test. Kirk Barefoot of the APA says the PSE quite simply doesn't meet the organization's standards because a lie-detecting machine should be tuned into a minimum of two physiological responses, and the PSE measures only one. The APA also looks askance at PSE training requirements, as polygraph operators must go to school for 6 weeks followed by a 6-month internship.

Dektor counters these objections by attacking the motives of the APA. Bell says the two instruments are about equally reliable when used by skilled examiners with well-constructed tests; as for training, well, it's much easier to use a PSE. Bell says the obvious reason for APA hostility is that the PSE poses a threat to the tight-knit fraternity of polygraph operators. Many companies would naturally turn to the PSE because it's cheaper to have an in-house truth specialist, and it costs a lot to farm out an employee for polygraph training.

Dektor went after the law enforcement and security market because that's where the money and the people willing to spend it adventurously were to be found. Bell be-

turously were to be found. Bell believes, though, that the most interesting applications of the machine will be in psychological research, diagnosis, and testing.

The PSE can do several other things the polygraph can't. It can chart whole sentences in addition to simple yes-no answers to which the polygraph is limited. The PSE picks up stress instantaneously because the microtremor is the result of an electrical signal and does not have to wait for the flow and ebb of body chemicals as does the polygraph, says Bell. It can also register changes of stress levels within a single syllable. It can be used with more people in more situations because the subject is free to roam about, and intoxication with drugs or alcohol does not, it is claimed, distort the microtremor.

The academic community has not displayed much interest in the instrument to date—Bell explains that this community is "conservative almost to the point of being immobile"—but some researchers have been fooling around with it. One has done a study proving that stage fright increases in proportion to the number of people in an audience; another has analyzed stress among dental patients. One researcher, says Bell, has done psychological diagnoses of alcoholics using an "emotion-producing word test." By charting stress reactions to lists of words, the researcher can

Radioactive Waste Site Search Gets Into Deep Water

The search for a permanent disposal site for radioactive wastes that remain toxic for centuries—one of the key unresolved problems of the nuclear era—hit another snag recently.

Sandia Laboratories, of Albuquerque, New Mexico, which is managing the search for an underground repository in the remote areas of southeastern New Mexico, reports that the latest test hole has discovered unexpected geologic conditions that may render the immediate area under investigation unsuitable.

But Wendell Weart, Sandia's project manager, remains optimistic that a textbook-perfect site can be found by shifting the hunt a few miles to the south and southwest of the current study area, which is due east of Carlsbad on the Eddy County–Lee County line.

The proposed storage facility would handle the radioactive wastes generated by the commercial nuclear power industry. Such wastes are in temporary holding facilities now, but their volume is expected to swell as nuclear plants come on line in greater numbers.

The latest snag is the second to disrupt or delay plans to build storage caverns in bedded salt layers deep underground. The search in New Mexico was launched after previous efforts to build the facility in an abandoned salt mine near Lyons, Kansas, were abruptly terminated because of unanticipated problems. Although that site had been under consideration for many years by the old Atomic Energy Commission (since absorbed into the new Energy Research and Development Administration), it was not until 1971 that the commission and its contractors discovered two major problems with it. One was a series of abandoned gas and oil drill holes in the area. Another was an adjacent salt mine's extensive use of water to dissolve out the salt—including a hydraulic fracturing technique which had resulted in the disappearance underground of some 175,000 gallons of water. Both discoveries cast doubt on the long-term safety and integrity of the proposed Lyons site, since it appeared possible that water might penetrate the area and allow radioactive wastes to escape.

Thus the Lyons site, which had become the focus of political controversy, was abandoned, and a search was launched for another suitable site—preferably in bedded salt, which has been deemed the most advantageous geologic formation for long-term disposal by committees of the National Academy of Sciences and is the preferred formation in some foreign countries as well. Salt's many virtues include the fact that it flows plastically, thus healing any fractures; it is a good radiation shield; it dissipates heat well; and it has almost always been geologically stable for millions of years.

A survey for possible sites conducted by the U.S. Geological Survey resulted in attention being focused next on the salt beds of southeastern New Mexico. The area under investigation has not had previous extensive drilling, so there is not apt to be a problem of drill holes penetrating the repository area, according to officials of the energy research agency.

But the immediate area under study, roughly three square miles in size, has developed an unexpected problem. The first two test holes, drilled while Oak Ridge National Laboratory was in charge of the project, encountered no insurmountable difficulties. But the third test hole—drilled after Sandia took over management in April—unexpectedly hit a big pocket of brine, containing toxic gases in solution, some 2710 feet deep, about 200 feet below the level of the proposed waste disposal facility. The brine pocket was found in fractures in a bed of anhydrite rock, an evaporative rock commonly found in layers alternating with salt layers. Dissolved in the brine were such gases as hydrogen sulfide, which is toxic, and methane, which is explosive.

The presence of the brine was disturbing for two reasons. One was that the gases could pose a safety hazard for workers building the facility or operating it. Although a 200-foot buffer between the facility and the brine would ordinarily be considered sufficient, according to Weart, geologic conditions make it difficult to be certain the buffer would always be that thick.

The second disturbing aspect is that the presence of the brine solution may indicate that fluids have been migrating underground, thereby threatening the integrity of the site. Although many experts believe the brine has probably been there since the formation was laid down hundreds of millions of years ago, Weart said, others warn that it might be connected to adjacent aquifers. Age-dating tests will be conducted in an effort to resolve the matter.

The geologic problems were caused by the unexpected presence of a "thumb" sticking out of the buried Capitan Reef, an ancient coral reef which is shaped somewhat like a horseshoe, with the proposed repository area inside its semicircle. Where the bedded salt and anhydrite rock abut the thumb, there are many fractures and the beds incline upward at a 75° angle, far more than the 1° or 2° angle for other beds nearby. The sharp incline in itself would make planning the proposed repository difficult.

William Armstrong, a nuclear waste management engineer with the energy agency's New Mexico office, describes the problems as much less severe than at Lyons. But he said that in these days of doubt over things nuclear, the energy agency is "looking for a super-safe place." He added: "If anything went wrong it would hit the headlines. If we hit a gas brine pocket and killed a few people, hell, it would be spread all over the front pages"—even though it would really be a mining accident, not a nuclear mishap, in his opinion.

The latest problems may delay the repository project for several months (depending on the level of funding allowed for catch-up work) and will unquestionably increase the costs somewhat. Sandia will propose a thorough geophysical survey to find a likely site for further test drilling.—PHILIP M. BOFFEY

determine the shape of the circumstances that have gotten the subject in his present fix. The success of tests such as this leads Bell to boast, "We can do 6 months worth of psychoanalysis in 10 minutes."

The psychological stress evaluator has an interestingly ambivalent status as both a forensic and a clinical instrument. As the Michigan attorney general wrote in response to a request for clarification of the PSE status under Michigan's polygraph examiners law: "... a very narrow line separates the use of mechanical devices for the purpose of measuring stress and the use of such device to determine truthfulness." (He decided that the act did apply to the PSE in the latter case.) Forensically speaking, the PSE is in a kind of limbo. Nineteen states have laws licensing or regulating polygraph use, and presumably in those states where other instruments are not banned, forensic use of the PSE would be decided on a case-by-case basis. One state, North Carolina, licenses PSE operators (80 hours of training is required); elsewhere, a person armed with nothing but a Dektor training certificate can call himself a PSE operator. The other states, including New York and California, have no laws because of strenuous opposition by labor unions to legislation they think will legitimize the use of lie detectors in employment (six states now ban compulsory preemployment polygraph testing).

One individual who is determined that the PSE shall gain full respectability in the eyes of the law is John W. Heisse, a Burlington, Vermont, otolaryngologist. Heisse is the head of the International Society of Stress Analysts (ISSA), a fledgling organization of 200 PSE, polygraph, and voice analyzer users from the fields of law enforcement, industrial security, business, law, and health. Heisse is perhaps the PSE's most fervid partisan. He has rerun the Kubis study, using the contract's "alternate specifications," and claims the PSE came out with 97 percent reliability. He has used the instrument to prove that people with laryngectomies still register muscle microtremor; he has tested the effects of dozens of drugs on PSE subjects. He has a "death test" to see how anxious people are about death, and a suicide test—five questions relating to death that can be asked over the phone. If the subject shows no stress in answering, it means he is definitely preparing to kill himself. Heisse says in seven cases the test unfortunately proved correct. He has also tried the PSE with hypnotized subjects and discovered that they show *no* muscle microtremor—not because of stress but because they are unusually relaxed. He says the same finding applies to persons who have been brainwashed. (Quick to see an application here, Heisse went off to San Francisco to chart Patty Hearst's tapes, but he won't tell what he found.)

In addition to these activities, Heisse says he has been doing all the lie-detecting work for the city of Burlington—that is, until Vermont passed a law saying only polygraphers can do truthfulness verification work. Heisse believes this law was passed just to protect the jobs of Vermont's three polygraphers. He has raised $100,000, gathered 300 pages of evidence, and is suing the state of Vermont. The outcome of this case could set a significant precedent if and when PSE's proliferate enough to attract the attention of other lawmakers.

Meanwhile Allan Bell wants to go back to the drawing board. "The PSE is to stress analysis of the voice what the Model T is to locomotion," he declares. More work needs to be done on waveform analysis, on quantitative measures of mind-body interaction, and on "flesh mechanics." The stress evaluator, he points out, is measuring something no one has been able to define, so it would be nice to really pin it down, perhaps by locating the specific area of the brain where stress originates. One of the possible "end product configurations" envisaged by Bell's agile mind would be a machine that supplied a continuous meter readout of stress levels to a psychiatrist while his patient lay chatting on the couch. Some might find this a distressing symptom of human willingness to defer to machines. But fortunately, unlike the atom bomb, the PSE is only as effective as he who operates it.—CONSTANCE HOLDEN

Alaskan Gas: The Feds Umpire Another Confused Pipeline Debate

When the fabulous 10-billion-barrel Prudhoe Bay oil field was discovered in 1968 on the Alaskan North Slope a lot of natural gas was known to be present along with the oil. Indeed, as further exploratory drilling would show, there was some 26 trillion cubic feet of gas—or more than a tenth of the nation's present natural gas reserves—just at Prudhoe Bay alone, and this field covered only a small part of a vast province in which other oil and gas fields would no doubt eventually be found.

But not until now, 7 years after the discovery of this major new gas reserve, has the issue of how to get the natural gas out of northern Alaska finally been joined. Yet this issue is every bit as consequential as the one that was in hot dispute until the fall of 1973 over the Trans-Alaska (oil) Pipeline System (TAPS). And, as in the case of the TAPS controversy, at the heart of this new one is the question whether the resource should be moved by pipeline from the North Slope down through Canada to U.S. markets or by a combination system consisting of a trans-Alaska pipeline and a fleet of tankers.

As everyone has known for at least 3 years, the nation's need to bring on new supplies of natural gas has assumed emergency proportions. And, besides that, once TAPS is completed in late 1977 or early 1978 and the oil begins to flow, it will be only a few years before removal of the gas at Prudhoe will have to begin if the flow of oil to the wells is not to be inhibited. (For the first 2 years or so, all gas extracted incidental to the recovery of oil can simply be reinjected; in this way, the gas need not be flared and the field can be "stabilized" for optimum oil recovery.)

These circumstances, together with the fact that the closely related TAPS issue became a highly visible item on the public agenda as early as 1969, makes it apparent that the federal officials and congressional leaders seriously involved in questions of energy development have overlooked or chosen to ignore some very plain handwriting on the wall.

Until the controversy over TAPS was finally resolved by Congress 2 years ago in favor of this combined pipeline-tanker system, the environmental groups that were opposing the project tried hard but unsuccessfully to have this issue considered jointly with the question of how to transport the gas. Their argument was that it made no sense to consider these matters separately, for it might be appropriate to build the gas and oil pipelines in a common transportation corridor. Reasonable as this argument may seem, it was given short shrift because both the oil companies that