ФУНДАМЕНТАЛЬНАЯ НАУКА И ИННОВАЦИЯ

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После обретения независимости Арменией возникла парадоксальная ситуация с научными исследованиями. Страны, аналогичные Армении по материальным и людским ресурсам, не в состоянии выделять достаточно средств на фундаментальную науку. Даже небольшие Европейские страны с высоким уровнем жизни практически не предоставляют государственной поддержки фундаментальной науке. Армения, как составная часть СССР, обладала широкой сетью научных учреждений, занимающихся фундаментальными исследованиями. Некоторые из них продолжают работу и в настоящее время, хотя структура их финансирования претерпела радикальные изменения в части государственного финансирования, доля которого значительно уменьшилась.

Государственное финансирование фундаментальной науки в Армении - это очень сложный и противоречивый вопрос. Были попытки упорядочить этот процесс. В 1991-ом году при Министерстве экономики был создан отдел, регулирующий финансирование науки. Работали экспертные комиссии, которые рассматривали темы и определяли объем их финансирования. Было введено тематическое финансирование - напрямую финансировались интересные и конкурентоспособные проекты. Это был шаг вперед. Главным действующим лицом в науке стал руководитель проекта. К сожалению, начатый процесс реорганизации системы финансирования не был завершен. Вместо сокращения числа тем и, соответственно, большего финансирования наиболее успешных из них, произошло их увеличение и распыление и так весьма скудных бюджетных средств. Сохранение научного потенциала - это прежде всего создание рабочих мест, оснащенных всем необходимым для научной работы, а не предоставление ученому минимальных средств для выживания.

В Ереванском Физическом Институте (ЕрФИ) многие поняли, что бессмысленно требовать у государства денег на фундаментальную науку. На выделяемые скудные средства невозможно проводить полноценные исследования. Необходимо было находить нетривиальные решения, использовать международные связи института. Руководитель отделения ускорительной физики Валерий Никогосян пытается получить заказы для изготовления деталей супер-современного ускорителя ТЕСЛА, планируемого к постройке в Германии. Много заказов для промышленности Армении было привлечено из крупнейших физических центров учеными отделения экспериментальной физики. Сотрудники отделения прикладной физики выполняют заказы промышленных предприятий Армении. Ведущие учетные института постоянно подготавливают проекты для представления в международные фонды, специально созданные для поддержания научных исследований в бывших республиках СССР.

За последнее десятилетие сильно сократились сроки внедрения результатов научных работ. Переходный период от фундаментальных исследований до практического применения сократился до 2-3 лет. Фундаментальные исследования часто имеют конкретно направленный инновационный характер, ставя конечной целью создание коммерческого продукта или услуги. Почувствовать и приспособить для своих нужд эту тенденцию развития современной науки особенно важно для стран, подобных Армении, у которых нет средств для поддержания программ многолетних исследований. Проиллюстрировать сказанное можно работами, проводящимися в отделении физики космических лучей ЕрФИ. На первый взгляд, очень сложно найти прикладное применение исследованиям в области космического излучения. Нередко в газетах и по радио сообщают о так называемых магнитных днях, связанных с активностью солнца. В эти дни советуют быть особенно осторожными людям с хроническими заболеваниями. Оказывается, что и электроника, расположенная на спутниках, также весьма чувствительна к потокам проникающей радиации, возникающим на солнце во время вспышек. В настоящее время человечество очень сильно зависит от спутниковых технологий, которые обеспечивают связь, навигацию, предсказывают урожаи, локализуют лесные пожары и многое-многое иное. Массовый выход спутничков из строя может привести к глобальной катастрофе.

Используя экспериментальные установки одной из крупнейших в мире обсерваторий космических лучей на горе Арагац, возможно регистрировать предвестники надвигающихся солнечных бурь за полчаса до прихода основной массы ускоренных частиц. Этого времени достаточно, чтобы дать сигнал спутниковым службам на отключение электроники, что в большинстве случаев позволяет избежать порчи аппаратуры и потери спутников.

В настоящее время с использованием 3 солнечных мониторов, 3-х уровневой локальной компьютерной сети и специализированного математического обеспечения в отделении физики космических лучей ЕрФИ создали пробную службу оповещения, и в поиске заказчиков неоценимую помощь оказывают коллеги из американской диаспоры.

Значительную помощь в оценке инновационного потенциала научных разработок и в обучении ученых новому экономическому мышлению оказывают семинары, организуемые в Армении Международным Научно-Техническим Центром (МНТЦ) под руководством Юрия Гаспаряна. Семинары поморгают ученым Армении овладеть инструментарием для представления своих работ в виде, понятном международному бизнесу, методике ведения переговоров и организации работ, нацеленных на изготовление конечного продукта или услуги. МНТЦ организует также семинары в зарубежных странах, стараясь найти деловых партнеров ученым из бывшего СССР. Участие в апреле этого года в таком семинаре в Бостоне позволило нам найти деловых партнеров и начать работы в такой бурно развивающейся области, как количественный анализ геномов и диагностика генетических заболеваний. Было бы очень полезно, если бы и в республике была создана служба, помогающая ученым в экспертных оценках интеллектуального продукта и организующая маркетинг и поиск деловых партнеров.

В заключение хочется сказать, что поддержка инновационных тенденций в фундаментальной науке Армении позволит не только со временем перейти на полное или частичное самофинансирование, но и создать рабочие места для молодых ученых, способствуя сохранению и развитию научных школ Армении, находящихся сейчас у опасной черты уничтожения. ▼

OPINION INTERVIEW

What's it like to be a top scientist in a country without a science policy? **Ashot Chilingarian** should know. He runs a cosmic ray observatory at the top of Mount Aragats in Armenia, a leftover from the cold war. It is the leading laboratory of its kind in the world, and our best chance of getting reliable early warnings of severe solar radiation storms that can cause billions of dollars' worth of damage to satellites, telecoms and power systems. At this time of year it takes him a 10-hour ride through the snow in an old Soviet bulldozer to get there, and each time he prays the storms haven't blown the roof off. He could work in the West for many times his Armenian salary. **Fred Pearce** asks him why he stays

On a cosmic shoestring

What are the big differences between working under the Soviet system and today?

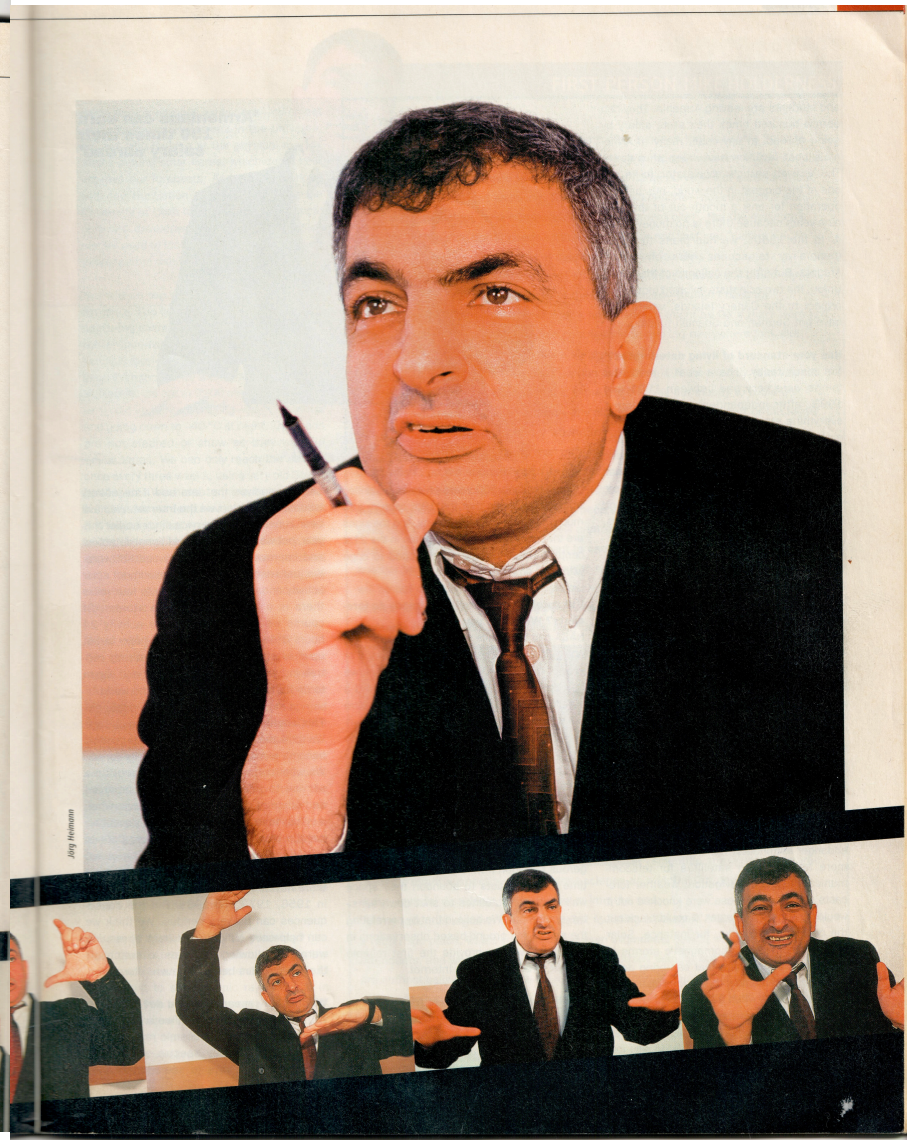
In Soviet times, much of our work was secret. I couldn't send papers to Western journals, or participate in international conferences. International collaboration only occurred under the strict supervision of bureaucrats from Moscow. So we were ignored. But I did have as much money as I wanted to do my work. Our institute's budget was many times what it is today. We did well because we used to be part of a big Soviet ministry where military science was concentrated. Fifty years ago, when the observatory was set up, cosmic ray research was seen as part of the theoretical basis for the Soviet atomic bomb project. Particle physics was then mostly done with cosmic rays. Later, we investigated the hazards from cosmic rays to the electronics on military missiles. Today, Armenia is independent and that is all gone. There is not even a science policy in Armenia. Basically, I have nobody to report to. I can collaborate with whomever I choose, send PhD students to international conferences and start whatever projects I like. I have total freedom—if I can find the money.

How have you kept going? Where does your funding come from?

Our overall budget for this observatory is only $200 000 a year—that's for a total staff of 100, including 40 scientists. In the West it would cost a hundred times more to do what we do, because of higher salaries and so on. About a sixth of our budget is supposed to come from the Armenian government. But for the past two years it has not been meeting its obligations. It doesn't even pay the electricity bill. We scientists haven't been paid a salary by them since last April. So our strategy is to build an international reputation, through collaborations and scientific networks, to attract international funds. Two-thirds of our money now comes from scientific institutions abroad, half of that in grants from the International Science and Technology Centre in Moscow, set up to provide peaceful employment for ex-Soviet weapons and radiation scientists. We got money from NATO to establish Internet links. The rest comes from the Armenian diaspora. We have some good friends among Armenians in the US, who help us.

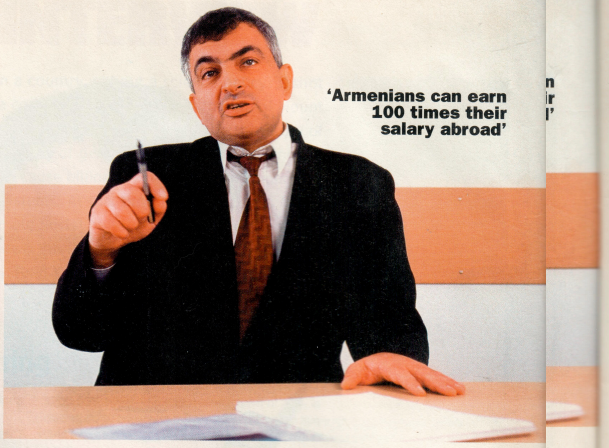
Armenia was seen as the science centre of the Soviet Union, for physics especially. Has that all gone?

Yes, and you can understand why. The average government salary for scientists is only $30 a month, though here we pay an extra $100 a month from our international funds. Because of this many scientists



Jörg Heimann

and students are leaving Armenia. They can earn a hundred times their state salary by going abroad. In any case, many of Armenia's best facilities have been shut down. The Yerevan particle accelerator, in its day one of the biggest in the world, has been in operation for only a month out of the past nine years because there is no money to run it. In the 1980s, we had plans to install gamma-ray telescopes here on Mount Aragats. But after the collapse of the Soviet Union, the two scientists involved moved the project to the Canary Islands, where they have got German and Spanish funding.



'Armenians can earn 100 times their salary abroad'

Has your standard of living deteriorated?
Not much today. I have what I need. But things were very bad between 1991 and 1993, after independence, when almost everything stopped in Armenia. We had no electricity or heating most of the time, and there was no water in my family's apartment on the 15th floor. I had to go and fetch water from the street several times a day. There was no lift and no light in the corridors and it was terribly difficult to climb the icy steps.

Do you come from a scientific family?
My father, Agassi, was director of Armenia's Institute of Zoology. I have worked as a physicist in Armenia for 30 years, with short periods at CERN, and in Moscow, Dublin and Karlsruhe. I became head of the cosmic ray observatory in 1993. My son graduates in mathematics from Moscow State University this summer. He is only interested in computers and helps maintain our server here. I hope I can persuade him to work in Armenia.

Does the observatory have a future?
Yes. One of our main future commercial activities is going to be forecasting solar radiation storms, when unpredictable fluxes of protons and electrons cross the Solar System and reach the Earth. They can cripple satellites and endanger astronauts. The world is depending more and more on satellites for telecommunications, GPS navigation, weather forecasts and so on. If these were knocked out it would be a global disaster. It could black out the cellphone networks, for instance. Solar storms also set off geomagnetic storms in the Earth's atmosphere that can bring down power grids. Remember the famous disaster in Quebec in 1989, when a solar storm knocked out electrical transformers? The province had no electricity for 10 hours in freezing temperatures. We are at a time of historically low activity from this space weather. We know from examining 500 years of ice cores drilled from the Antarctic that the 19th century saw much more intense solar activity. And the signs are that activity is now rising again in the 21st century. Satellites are not equipped to cope with this, so there is real danger.

But surely NASA satellites already do forecasts? What can you offer?
NASA can announce when the storms arrive, but it cannot give accurate early warnings or predict how severe they will be. We think we can do that. NASA uses detectors aboard a satellite in space. They can directly measure the low-energy solar particles that do the damage. But on the ground we can use a much larger array of detectors, covering hundreds of square metres, to measure the much smaller fluxes of high-energy particles that come ahead of them. These high-energy particles reach the Earth from the Sun in as little as 10 minutes. That can provide between 30 and 60 minutes' warning of the most dangerous radiation from solar storms—enough time for astronauts to abandon their space walks and for satellites to shut down sensitive equipment. We believe that by correlating the space and ground-based observations in real time, we can provide the first reliable instant forecasts via the Internet.

What equipment do you use for this?
We use neutron monitors that we have had since Soviet times, plus a muon telescope and a solar scintillation telescope. If we detect abrupt increases, our software will start to analyse the data and if necessary issue a formal alert via the Internet. We have been running a test service since earlier this year, but we are planning additional detectors and improved data handling and software. We just reached a period of maximum solar activity and over the next three to four years there is a high risk of severe storms. Of course we cannot watch solar activity 24 hours a day from here. But we hope to set up an alert system with other cosmic ray centres in Switzerland, Bolivia, Tibet and Japan to do that. It will be the best in the world.

This could be a lucrative business . . .
We think the forecast and alert system could become a major commercial activity for us. We want commercial contracts to provide a service to telecommunications companies and others. I can say that our service, when it is fully functioning, will be the only accurate service that can forecast the hazard of—in particular—very severe radiation storms. Such storms are expected to be very rare—there have been three in the past 50 years, in 1956, 1972 and 1989. But the consequences can be very serious. We think we can help save billions of dollars by issuing warnings, allowing satellites to switch off their electronics before a severe storm.

What other research do you do?
With German collaborators, we are trying to discover the origins of cosmic rays. We are analysing the energy spectra of different nuclei in cosmic rays to see whether they come from supernova explosions—the most powerful known explosions in the Universe. We are also looking at the physical mechanisms behind solar flares, which could help improve our forecasts. And we are working with the Huntsman Cancer Institute at the University of Utah to see whether statistical software developed for cosmic ray physics can be used to isolate how gene clusters are expressed in cancerous tissue.

You are on top of the highest mountain in Armenia. The height must make it good for capturing cosmic rays, but it must make life rather inconvenient . . .
Yes. It is lovely in summer, but the winters are long. Even though we are at the same latitude as Naples, we are at 3200 metres and it gets very cold up here, averaging –15 °C in winter and going down to –40 °C at night. The roads are not cleared of snow as they were in Soviet times. We can only reach the station once every three weeks, using very old Soviet bulldozers. We have tunnels between the buildings so we don't have to go outside. But it is the winds that are most dangerous. I am afraid the roof on our main laboratory may blow off this winter. It has not been repaired for a long time. Over New Year the electricity line blew down and we had no power to operate the equipment.

What will you do if it does blow off?
Oh, that's easy. We'll go and get it back again. We don't have another. The physical structure of our buildings is actually our biggest problem. We get money from abroad for equipment and scientific personnel, but nobody wants to pay for basic infrastructure. The government should do that, but I'm sure we will not get money from them in the future. We are trying to raise money from the Armenian diaspora in the US to repair our buildings. We would like to make money from tourists using rooms here in summer. It is a lovely spot, 3200 metres up on the shore of Lake Kari with the summit of Mount Aragats behind. There is good walking. But first we have to repair the rooms.

It sounds daunting. Why do you stay?
I like the mountains. But also, whatever the problems, I can do my science here. And I don't want to stop cosmic ray research in Armenia. We have done really good work here, and we will do so again.

Fred Pearce travelled to Armenia with LEAD International

FIRST PERSON MIKE HOLDERNESS

A mall too far

THERE was dismay in museumland last month after rumours that London's Science Museum might turn itself into a theme park. Naturally the museum has to pay its bills, but the idea of leasing space to commercial brand-name purveyors of entertainment and refreshment seemed shocking. The reality is less definite—not so much a plan, rather "a methodology for a framework for a development plan". But the museum's spokespeople do say that it needs commercial income and that you "cannot run an organisation like this without decent catering and retail facilities".

Well, maybe they should make a real effort to do without commercial brand-names. It's not that I object to the existence of these companies—though I have my reservations about Starbucks, McDonald's and Disney. It might be OK if there were just one of each. What worries me is their contribution to making everywhere look like everywhere else, and everywhere like a shopping mall.

Not long ago, I took the train from London to Poitiers in France, partly to evade the responsibility for climate change that a plane trip involves but mostly to avoid the aesthetic nightmare that is an airport—any airport, since they're all part of the same distributed mall. Imagine my horror when the Futuroscope science theme park I was visiting was at the end of a strip mall on the city outskirts, with only the smallest clues that I wasn't on the approaches to an airport somewhere in America.

Scientists must, I say, take a stand against any notion of institutions like the Science Museum going that way. So many young people develop an interest in science within its walls that if it is transmuted into merely another flavour of mall, our intellectual life must suffer. Either the young who want to carry science forward will see it as just another branch of commerce, or those who want to do something other with their lives will be put off altogether. Which would serve the suits but not science. After all, good science is about pure curiosity: applications are accidents, which may be accidentally profitable (semiconductors), accidentally destructive and profitable at the same time (plutonium), or deeply unsettling for the commercial order (climate change forecasting).

I know of no research on what impels people into scientific careers, but I suspect it's a certain intellectual dissidence, an unwillingness or inability to accept received wisdom. And there's no dissident temperament so powerful as one armed with scientific argument. Conspiracy theorists might suspect a plot to redraw science as a McDayOut and marginalise those youthful dissidents by driving them into the arts.

If we lose this argument, then I suggest founding a Museum Museum. This would be a rather sad place, where redundant museum attendants play at being museum attendants, and where the mahogany cases of utterly useless but interesting objects are authentically dusty because there is, by definition, no money for cleaning.

If we can't maintain a proper museum, we must at least manage such a meta-museum, a record of how museums were before the mall metastasised. To let the institution pass unrecorded would be an act of cultural vandalism equal to the burning of the Library of Alexandria.

Science Museum/SSPL

strict consent procedures for whole-body specimens, he maintains that "consent is not important for body parts." Others find this view unacceptable. The Nuffield Council on Bioethics has spent years drawing up standards and ethical requirements aimed at plugging such loopholes, explains Thomas, after the revelation that in the 1990s some British hospitals had taken body parts from dead infants without consent (*Science*, 6 December 2002, p. 1867). "Von Hagens's posturing indicates that he takes the view that he is exempt from observing these requirements or standards."

Von Hagens will also have to overcome legal hurdles if he is to exhibit in the United States. The city of Munich asked him to show signed donor contracts for his plastinated cadavers, but he refused on grounds of privacy and the request was eventually dropped. But in the United States, says Wade, the Uniform Anatomical Gift Act can be used to force him to do so. And even if he does show that he has obtained informed consent, states' anatomy boards will have to give him the go-ahead based on their judgement of his intentions, says Lynn Romrell, chair of the anatomy board in Florida that blocked Von Hagens in 1998. "We decided that his intentions were not educational," says Romrell, and it will be up to Von Hagens to convince the anatomy boards in other states.

In spite of these barriers, Von Hagens says that his plans to conquer the United States in 2004 are "definite," although he is keeping his intended dates and venues under wraps. An American tour is bound to be controversial, says Wade, because "this country doesn't believe that anyone's death should be used for someone else's profit." But then again, Von Hagens is no stranger to controversy. He thrives on it. –JOHN BOHANNON

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Solar Physics

A Space Weather Aerie in the Caucasus?

The enterprising director of a cosmic ray observatory in Armenia is hoping to launch a global network of ground stations that would complement space-based forecasting

If you're in Armenia and want to catch some solar rays, try scaling the southern peak of Mount Aragats. There, 3200 meters up, an observatory run by the Cosmic Ray Division (CRD) of the Yerevan Physics Institute casts an unblinking eye on our star. Now the Soviet-era holdover is spearheading a bold new venture: a worldwide alert service that would warn of devastating solar storms approximately half an hour before their radiation blasts strike Earth's atmosphere.

During crests in its 11-year activity cycle, the sun occasionally unleashes a violent flare often accompanied by a billion-ton burst of plasma known as a coronal mass ejection. Such solar storms have knocked out several satellites in the past 2 decades and brought down Quebec's power grid in March 1989, and they could threaten astronauts by disrupting onboard instruments or walloping them with radiation.

To forecast space weather, scientists monitor the stream of ionized particles from the sun using Earth-orbiting satellites and two spacecraft—NASA's Advanced Composition Explorer (ACE) and the Solar and Heliospheric Observatory (SOHO), a joint NASA–European Space Agency mission—that pirouette in a part of our solar system where the gravitational fields of Earth and the sun roughly cancel each other out. ACE and SOHO pick up the deluge of particles that can wreak havoc on satellites and power grids.

But many experts argue that it is risky to rely solely on satellites to flag oncoming solar storms. For one, congressional appropriators are threatening the U.S.'s premier space weather forecasting service—the National Oceanic and Atmospheric Administration's Space Environment Center (SEC), a satellite-based alert and research unit—with a 40% cut to its proposed $8.3 million budget in 2004. And the space-based sensors themselves are not fail-safe, as the recent drama surrounding SOHO demonstrated (*Science*, 4 July, p. 31).

An alert system on terra firma could provide a safety net in case spaceborne sensors were to falter. "That's a valid paradigm," says Joseph Kunches, chief of SEC's space weather operations division. In a proposal to the International Science and Technology Center (ISTC), a Moscow-based outfit that funds nonproliferation activities across the former Soviet Union, CRD director Ashot Chilingarian has outlined a novel ground-based network that would rely on the detection of high-energy particles that pelt Earth roughly 30 minutes before the brunt of a solar storm arrives. "It's a fascinating project that promises to have critical applications," says physicist Alex Chao of the Stanford Linear Accelerator Center in Menlo Park, California.

With a unique combination of detectors and homespun analytical software, Chilingarian's team thinks it can spot the high-energy vanguard of an oncoming solar storm reliably enough to allow operators to take precautions such as flicking electronic switches to safe mode. In its ISTC proposal, now being vetted by the U.S. Department of State, CRD aims to construct a pair of prototypes of detectors that could be deployed at stations around the world. Chilingarian has launched negotiations with space weather centers in Greece, Israel, Russia, the United States, and elsewhere

Solar flair. Ashot Chilingarian hopes to secure his center's future by launching a space weather alert service.

Where the sun doesn't shine. In winter, underground tunnels are often the only way for technician Tigran Yepiscoposian and others to move between buildings.

CREDITS (TOP TO BOTTOM): HRAYR KHACHATRIAN/COURTESY OF THE SUPPORT COMMITTEE FOR ARMENIA'S COSMIC RAY DIVISION (SU)

to form a network for global coverage. "He's young, aggressive, and energetic. I think he can succeed," says Yasushi Muraki of the Solar-Terrestrial Environment Laboratory at Nagoya University in Japan.

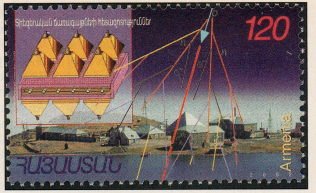
A child of the Soviet atom bomb program, CRD was founded in 1943 by two Armenian brothers, physicists Abraham and Artem Alikhanian. There were higher mountains in the Soviet Union, but Aragats was near a major city, Yerevan, and far from the war's frontlines. Before the advent of massive particle accelerators, cosmic rays were the best source of high-energy particles, and the Alikhanian brothers were "clever enough to see a connection between cosmic ray research and the theoretical research of the atomic bomb project," says Chilingarian. Although data gathered at Aragats don't appear to have helped in the development of the Soviet atom bomb, he says, the nuclear connection allowed Artem to build an impressive cosmic ray observatory. When it came to money, the sky was the limit.

By 1993, when Chilingarian was handed CRD's reins, state funding had all but evaporated. It's hard enough doing science at the summit: In winter, average snow depth tops 1.5 meters, and scientists are forced to scuttle from building to building through tunnels without going outdoors for days on end. Compounding their woes, their instruments were rapidly becoming antiquated. Chilingarian began a campaign to link up with other cosmic ray facilities. Drawing on his talents as a software engineer, he authored a neural network program that several multi-center collaborations use for data analysis.

Chilingarian's latest innovation is a system linking more sensitive solar monitors with fast electronics and Global Positioning System receivers to forecast potential hazards of violent solar storms. The idea for meshing data from ground-based detectors to sound an alarm came in the 1990s from someone Chilingarian calls "a giant in the field": Lev Dorman, head of Israel's Cosmic Ray Center in Tel Aviv and a senior figure at the Institute of Terrestrial Magnetism, Ionosphere, and Radiowave Propagation in Troitsk, Russia.

Chilingarian's epiphany—that Dorman's concept was feasible—came on the heels of a nasty solar storm on 14 July 2000. The Aragats detectors, near the summit and at Nor Amberd station 1200 meters down the mountain, tracked fluxes in all three classes of secondary particles produced when protons and ions from the sun impinge on the atmosphere: charged particles (electrons, protons, pions, and low-energy muons), neutrons, and high-energy muons. After the data suggested that high-energy particles could serve as a harbinger of an ill solar wind, Chilingarian says, "we decided to build our monitoring system." Although "there are several unknowns" in the relation between high- and low-energy particles, notes astronomer Vahe Petrosian of Stanford University, "none appear to be insurmountable." Such an alert service, adds Hartmut Gemmeke, head of electronics and data processing at the Forschungszentrum Karlsruhe in Germany, would "provide a necessary source for reliable and easily accessible data." He predicts that it will take 3 to 5 years to gather enough data to see if the system will pan out.

"If successful," says Chao, "this method could save satellites, power grids, and other items of interest." Charged particles overload electrical systems with extra current, initiating fake commands, altering memory files, and burning silicon chips. Turning off electronics means that the particles "pass through silicon without any consequences," Chilingarian explains. And most important to CRD, success as a space weather sentinel would make its services indispensable. That could prove to be the center's salvation as it struggles, in the economic wilderness of the Caucasus, to keep its finger on the solar pulse. –RICHARD STONE



National pride. Armenia marked CRD's 60th anniversary this year with a postage stamp.

CREDIT: ARMENIAN POSTAL SERVICE

Genomics

Sequencers Examine Priorities

Now that genomes can be decoded quickly, researchers are debating how to choose which organisms to sequence next

The most conspicuous feature of a recent gene-sequencing meeting in Virginia might have been what was absent: There was no verbal venom between once-cutthroat competitors. Instead, the Whitehead Institute's Eric Lander and former Celera president J. Craig Venter, their race to sequence the human genome behind them, calmly chatted away. Walking by the pair, Edward Rubin, director of the Department of Energy's (DOE's) Joint Genome Institute in Walnut Creek, California, did a double take. "Instead of shooting at each other, they're pointing their cannons in the same direction," says Rubin.

The invitation-only, closed-door gathering on 21 and 22 July marked a turning point in the world of gene sequencing. There, officials from the National Human Genome Research Institute (NHGRI) in Bethesda, Maryland, estimated that in the best-case scenario, over the next 4 years U.S. sequencing centers would generate a staggering 460 billion bases, the equivalent of 22 mammalian genomes. But with all the "obvious" organisms—including the human, the mouse, and the rat—now sequenced, or nearly so, the genetics community and NHGRI, its principal funder, are weighing how to proceed. The country's three massive sequencing centers, fearful of becoming mere factories churning out base after base, are lobbying to preserve influence in choosing which organisms to sequence and analyzing the genetic data they produce. Scientists who mobilized around beloved animals, from the honeybee to the chicken, and won them a spot in the sequencing queue are now wondering what they will target next.

The 30 to 40 prominent researchers who attended the meeting, many of whom commented with surprise on its collegiality, agreed that sequencing should now be driven by biological unknowns rather than popularity contests. "We should turn to using sequencing capacity to answer scientific questions that are of seminal importance," wrote Princeton University President Shirley Tilghman in an e-mail message. And if that means sequencing an organism "that by biologists' standard is obscure," she added, "so be it."

Many participants believe that today's system for prioritizing organisms doesn't capture the most pressing scientific questions. They suggested adding a new layer of four committees to the review process to divvy up sequencing proposals according to scientific goals, such as clarifying evolution or helping shed light on the human genome. Each committee, in turn, would make funding recommendations to an existing NHGRI grant review panel.

those who want to work in science, to do so in Armenia," says Tsaganov. He notes that currently, almost all graduate science students leave Yerevan to work outside the country.

"There is no doubt that a modern synchrotron light source in Armenia will do much to curb the brain drain," says Yeremian, who started it all when she heard about a project called SESAME. Hovnanian knows this, and knows that it's going to take much more pushing to find the rest of the $35 million necessary to complete this project.

But, he also knows what he has to do. "Anything you want to make happen, you need politics," he says. As a former head of the National Association of Home Builders, and head of their political action committee, he has more than a few political contacts in his rolodex.

In fact, Hovnanian notes, the US officials who have wanted to help Armenia through the years are happy to have such a useful project to support. And Pallone and McConnell obviously agree.

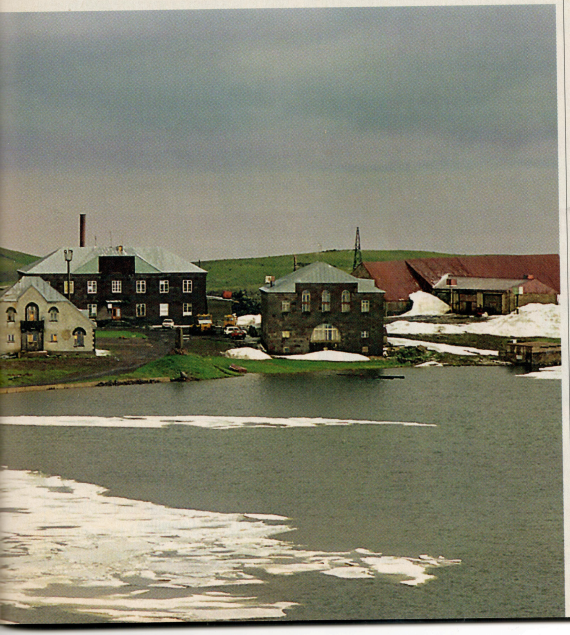
"I am pleased that I have been able to secure much needed assistance for Armenia, and in particular, funding relating to a synchrotron light source facility which is used for basic and applied research in physics, chemistry and biology," McConnell told AIM.

"Within the next few weeks, the Senate will mark-up the Fiscal Year 2002 Foreign Operations Appropriations Bills, and I intend to do all I can to secure adequate levels of funding for Armenia," said the Senator who is a senior member on the Senate Appropriations Committee.

Congressman Pallone, too, addressed similar concerns as he responded to AIM. "The CANDLE project would significantly elevate scientific research in the Caucasus region, and provide another economic spark to the Armenian economy. This project would keep area scientists from having to travel thousands of miles to the nearest comparable facility.

"I have no doubt that CANDLE will be a huge boost to the Armenian economy in a couple of years. Until that time, I will continue to work to see that this important project receives critical financial support from our government through the appropriate process," he adds.

"CANDLE makes me optimistic about our scientific future," says Tsaganov. He's not alone.



The Future is In the Sun

Armenia's Cosmic Ray Division Goes Where No Man Has Gone Before

Currently there are two different approaches to monitoring and forecasting the severity and impact of imminent solar radiation storms. A space-based approach is championed by NASA, and is funded by the US government and US tax dollars. The second is a ground-based system to study the same kinds of particles, such as at the Cosmic Ray Division (CRD) of the Yerevan Physics Institute, in Armenia. The CRD depends on donations channeled through the Fund for Armenian Relief's Armenian National Science and Education Fund (ANSEF).

Even though the support bases are incomparably unmatched, the quality of research that the two produce is not only equal, but also absolutely complementary. First, there are no other ground-based research centers working on this area of cosmic ray research. NASA's system to devise these alert systems using satellites is not as reliable, say some scientists, because their stations can't be as big as ground-based stations – on Armenia's Mt. Aragats, each ground-based station covers a square kilometer area. But more importantly, the satellite itself goes on standby when it senses damaging particles approaching, and so it can't alert other satellites.

Anahid Yeremian of Stanford University, a specialist in accelerator physics (see accompanying article on CANDLE) has been working with CRD to enhance their international contacts, and has helped with proposal writing and submissions. She explains the value of CRD's research.

"CRD's research is of both theoretical and practical interest. The data collected at the two high altitude observatories – one at 2,000 meters (just above the Byurakan Observatory) and a larger one at 3200 meters – is analyzed using sophisticated mathematical methodology and software developed by the CRD's Ashot Chilingarian," she says.

And this data has practical, immediate and commercial implications. Satellites, for example, depend on the flawless functioning of their high-technology systems to be able to gather or distribute data. "Yet, solar radiation storms caused by violent explosions on the sun can unleash intense fluxes of charged particles which often adversely affect the normal functioning of satellites by disrupting space-borne electronics, and endangering space station crews," Yeremian explains. Depending on their energy, these particles can reach the earth within 10 minutes to several hours after explosions on the sun.

View of the CRD station on Aragats. Photo by **Mkhitar Khachatrian.**

CRD director Ashot Chilingarian, with Nerses Gevorkian, and Gagik Gharagyozian in the CRD control room on Aragats. Photo by **Mkhitar Khachatrian.**

Professor Chilingarian, 52, CRD Director, says that with their data and analysis techniques, he can send alerts on the arrival of the harmful particles from the sun about a half hour before damaging fluxes of particles reach the earth. This allows sufficient time to shut down the electronics on satellites, take protective measures on ground-based power grids and warn airlines scheduling flights over the poles. Thus, the data from Mt. Aragats is an important piece of the puzzle cosmic ray physicists all around the world are trying to put together.

The CRD conducts this research in partnership with such international research organizations as NATO and the International Science and Technology Center, with offices in Moscow, and funded by the US, Europe and Japan, to employ scientists who used to work on weapons research in the USSR.

The CRD's sites have been working uninterrupted since 1943, when they were set up by the same Alikhanian Brothers who established the Yerevan Physics Institute. Their collaborators include scientists in Japan, Switzerland and others from around the world. Their web site http://crdlx5.yerphi.am is the first among cosmic ray research stations around the world to broadcast their data online in real time. Chilingarian himself says, "If the CRD didn't exist, and we had to recreate it today, we couldn't."

Yet, this example of success-against-all-odds was having a hard time paying its staff and meeting its overhead. With stations at various elevations around the country, the CRD's 100-person staff includes bulldozer drivers, cooks, guards and other technical support personnel. In addition, transportation and repair bills are high. Electricity bills are higher.

When Yeremian, a Yerevan-born scientist went back to Armenia in 1999, after being away for 30 years, she wanted to find colleagues and see what the state of scientific research was. It didn't take her long to meet the staff of CRD and volunteer to help.

"I had done a lot of proposal writing for Boeing, for Stanford. So I helped them with language, with format," she says. "And they're not afraid to ask for help. They know what they're good at, and what they're not."

But what she mostly helped them with was finding sources of funding. "I approached Tavit Najarian of the Fund for Armenian Relief (FAR) and explained the need, and FAR basically saved them," she explains. "I said to Edgar Housepian, on ANSEF's board, 'You cannot imagine how much you've done.' Essentially, the Diaspora is supporting salaries and operational expenses, so that this world-class center can continue to seek funds for specific research projects that have universal value." A support group was also set up, based in the Boston area, headed up by Joe Dagdigian, 60, a software engineer.

Since then, through ANSEF (and also through the Armenian Engineers and Scientists of America, in Glendale, California) donations are being collected and channeled for the CRD's annual $40,000 in overhead expenses.

"Armenia's economy, intellectual development and security depend on its participation in and contribution to world science," says Dagdigian

Photos: Zach Marshall

Hit it over the Alps

Every summer weekend, several dozen CERN physicists gather to enjoy a beloved American tradition: They play for the Quarks and the Leptons in an international softball league.

The games are hosted by the US Marines at a site just north of Geneva, with a view of the Swiss Alps over the centerfield fence.

Playing the Marines is "like jocks versus nerds, and we tend to give them a run for their money," says Jim Degenhardt, a postdoc from the University of Pennsylvania working on the ATLAS experiment. "Unfortunately, the jocks usually win, but we all have fun."

Americans who grew up playing baseball or softball are in the minority on the two CERN teams. Some of the European players, particularly the English, had never seen a baseball bat before arriving at CERN, but by the end of the summer they can hit a baseball at least as comfortably as they hit a cricket ball. The teams have a strong tradition of coaching anyone with the desire to learn, yet remain avidly competitive.

Their competition includes teams of employees from international companies and organizations like Merrill Lynch, Caterpillar, and the United Nations.

The Quarks and the Leptons are part of the CERN softball club, which fields more women in this co-ed league—and, incidentally, more talented women—than any other club. It was also the first ball club in the world to have a page on the World Wide Web, beating out any team from Major League Baseball. (Of course it had a leg up, since the Web was invented at CERN.)

Vicki Moeller, an ATLAS collaborator from the University of Cambridge, says, "Sipping A&W [root beer] between innings, looking out on Geneva and the lake from our field, and hitting a game-winning two-run double in the bottom of the ninth is a great way to spend a Sunday afternoon."

Zach Marshall

Armenia detects space weather

On Mount Aragats, the highest point in the Armenian landscape, atop a volcano ribboned with glaciers, lava-born fissures, and medieval fortifications, an early 20th century observatory is leading Armenian physics in new, 21st century directions.

After the fall of the Soviet Union, Armenian researchers realized they could not afford to maintain their observatories and develop large detectors for competitive research in high-energy physics.

Taking advantage of the airy altitude of their observatories, they began investigating new avenues of research.

"We found our niche in the relatively new science of space weather," explains Ashot Chilingarian, director

"You don't need a huge detector to make excellent physics. Instead, you need a small detector in the appropriate place."

Research into solar flares and geomagnetic storms is increasingly valuable as the world depends more on satellite technologies. Solar flares, for example, can knock out an entire satellite or power grid.

The ground-based detectors designed and fabricated by Armenian scientists, each no wider than a meter, complement space-based systems that forecast space weather. They record millions of particles produced in cosmic ray showers from the sun.

The success of these detectors has contributed to their dispersal around the globe. Armenia leads the Space Environmental Viewing and Analysis Network, or SEVAN, and has crafted SEVAN detectors for Croatia, Bulgaria, India, and Slovakia. This network can provide reliable 24-hour forecasting and advanced solar storm warnings, crucial to sophisticated technologies that protect astronauts and your next door neighbor's GPS.

Another detector program studies the multiplication and acceleration of electrons in thunder clouds, which can affect air travel. This little-understood phenomenon has been puzzling scientists since the 1990s.

Daisy Yuhas

Photo courtesy of Ashot Chilingarian