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An Issue Dedicated to Science in the  
Union of Soviet Socialist Republics,  
Hungary, and Czechoslovakia

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<p>The European Science Notes Information Bulletin (<i>ESNIB</i>) 90-08 is a compilation of reports on recent developments in European science of specific interest to the U.S. research and development community, and is issued in support of the mission of the Office of Naval Research European Office (ONREUR). Issue Number 90-08 is dedicated to science in the Union of Soviet Socialist Republics, Hungary, and Czechoslovakia. During the past year, the scientists at ONREUR have received and accepted many invitations to visit institutions throughout Eastern Europe and the U.S.S.R. These visits, mostly made during the past 10 months, have resulted in a fresh look at the state of science in this part of the world. This issue of <i>ESNIB</i> presents a concise assessment from the perspective of this office. For the sake of completeness, we include some articles published in earlier issues of <i>ESNIB</i>. This is not a political assessment, but rather a group of reports on the state of science, with some personal observations on life and travel in these countries. As such, it is a window, albeit small, on the processes affecting the scientific health of greater Europe.</p>						
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<b>The Fifth International Conference on Megagauss Magnetic Field Generation and Related Topics - Megagauss V . . . . .</b>	<b>Marco S. Di Capua</b>	<b>25</b>
This article contains a review of the history of the Megagauss conferences and summaries of keynote papers. Also, Soviet contributions are emphasized.		
<b>The 20th European Conference on Laser Interaction with Matter . . . . .</b>	<b>Marco S. Di Capua</b>	<b>31</b>
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<b>Institutions of Research and Higher Learning in Tomsk, U.S.S.R. . . . .</b>	<b>Marco S. Di Capua</b>	<b>35</b>
This article contains a brief survey of the higher-learning institutions located on Tomsk, Siberia, U.S.S.R.		
<b>I.V. Kurchatov Institute of Atomic Energy, Moscow, U.S.S.R. . . . .</b>	<b>Marco S. Di Capua</b>	<b>37</b>
Dr. Di Capua shares a historical perspective on nuclear science and discusses exciting developments in plasma physics and pulse power technology at the I.V. Kurchatov Institute.		
<b>Institute of High Temperatures of the U.S.S.R. Academy of Sciences . . . . .</b>	<b>Marco S. Di Capua</b>	<b>39</b>
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The author describes the GOL III Experiment and the Ion Beam Diode Research at the institute.		
<b>The International Workshop on Physics and Technique of High-Power Opening Switches . . . . .</b>	<b>Marco S. Di Capua</b>	<b>43</b>
This report summarizes some of the contributions of the Soviet laboratories. The author also provides a brief summary at the end of the report to capture the flavor of the U.S. presentations.		
<b>The 1989 High Energy Rate Fabrication Conference - Some Emphasis on Soviet Contributions . . . . .</b>	<b>Marco S. Di Capua</b>	<b>47</b>
This conference discusses effects and applications of shock waves, and high-strain-rate phenomena on materials. The conference is unique as the majority of the participants are from Eastern Europe. Some themes addressed by the author are: explosive welding, hardening, and clodding of materials, Soviet technology developments applications, and compaction of $T_c$ superconductors.		
<b>Notes About My U.S.S.R. Visit . . . . .</b>	<b>Marco S. Di Capua</b>	<b>50</b>
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Dr Di Capua provides a collection of his general observations on recent developments in Soviet science policy--personnel, funding, structures, cooperatives, and conversion of military industry.		
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The author summarizes activities on the 45th R/V Mendeleev cruise. He also discusses dialogue with Soviet physicists and other scientists.		
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<b>Research Institutes Related to the Engineering and Science in the U.S.S.R. . . .</b>	<b>Michael J. Koczak</b>	<b>80</b>
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<b>A Select Bibliography on Soviet Science Policy . . . . .</b>	<b>Julian Cooper</b>	<b>98</b>
This bibliography provides ESNIB articles that pertain to Soviet science policy.		
<b>The Selling of Soviet Space at Space Commerce '90 . . . . .</b>	<b>Larry Jendro</b>	<b>99</b>
At this conference, the Soviets marketed some of their space capabilities. The author summarizes this marketing endeavor.		

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- An Assessment in Computing, Telecommunications, and Microelectronics . . . . . J.F. Blackburn 102**

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Samples of Research . . . . . J.F. Blackburn 108**

The author presents a brief summary of the papers in some technical reports from members of the Institute.

- Computer and Automation Institute . . . . . Richard Franke 111**

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## Czechoslovakia

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Dr Di Capua discusses strain measurements in micro-objects, photoelastic investigations in optical fibers, continuum mechanics of polycrystalline media, and basalt fiber technology for insulation and composite reinforcements at the C.S.F.R. Academy of Sciences.

- Scanning Electron Microscopy Developments at the Institute of  
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The development of scanning electron microscopy at the Institute of Scientific Instruments of the C.S.F.R. Academy of Sciences and the TESLA company in Brno has an interesting connection with the manufacture of cathode ray tubes.

- X-Ray Diagnostics and Laser Research at the Nuclear Science and  
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This article summarizes research in the Department of Physical Electronics and its groups; e.g., lasers for intercosmos, ion beam, optoelectronics, fiber optics, and x-ray diagnostics.

- The Prague Institute for Advanced Studies . . . . . Marco S. Di Capua 128**

The Prague Institute for Advanced Studies can be an effective channel for resources in specific areas. This article gives some insight into those areas.

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**European Community Initiatives**

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**European Community Science and Technology Cooperation with Central and Eastern Europe . . . . . Anthony Rock 133**

The EC has completed its network of first generation trade and cooperation agreements. These agreements provide for cooperation in numerous areas of mutual interest, including science and technology.

**European Parliament Proposal for European Community Science and Technology Cooperation with Central and Eastern Europe . . . . . Anthony Rock 137**

The European Parliament has adopted a proposal paralleling the European Commission's effort to develop scientific and technological collaboration with Central and Eastern Europe.

# An Issue Dedicated to Science in the Union of Soviet Socialist Republics, Hungary, and Czechoslovakia

by Dr. James E. Andrews, ONREUR Scientific Director

The past year and a half have seen fundamental changes in the political and social structures of the Soviet Union and the countries of Eastern Europe. The rapid adaptation to the new freedoms and opportunities in scientific circles has been far reaching and has perhaps presaged the movement towards individual freedoms and market economies throughout the rest of the body of those societies. Certainly, the scientific and technical community has seized the initiative for cooperation, exchange, and marketing on both an institutional and an individual level. Nowhere is this more apparent than in the Soviet Union. Institutions now have the authority to enter international agreements on their own recognition. In many cases, individual scientists are assuming this prerogative to their own research groups. A new and aggressive approach to marketing their skills and technologies is appearing. Individual institutes are encouraging scientists to gain experience in the West, while setting up conditions that will encourage the return rather than the emigration of the talent. Soviet scientists working at all levels in European laboratories--in one case as the head of one of the Max Planck Institutes--are becoming more common. Usual arrangements may find the Soviet scientist retaining all or a major part of his salary at home, while the Western institution is responsible for hard-currency costs--living expenses, local travel, and the like.

Infrastructure varies widely from country to country and within countries. In general, the scientific communities are not well equipped, and capitalization of science will be one of the major problems for these countries in achieving parity with their Western counterparts. This problem has promoted strengths in theory over experimental capabilities. The social structure of science is also an issue. One example is the case of the Academy of Science of the German Democratic Republic (GDR) which employs some 24,000 scientists and administrators. By contrast, the world-renowned Max Planck Institutes of the Federal Republic of Germany have a total population of 13,000. With the GDR's more applied and less

technologically advanced profile there will certainly be personnel costs in the coming union of these scientific systems with German reunification.

Related to all of these developments is a major push from the East to commercialize their scientific capabilities and in so doing seek Western capitalization for future developments. For instance, the latest Soviet research vessels are available for charter through a Canadian firm; the Soviet remote sensing establishment is putting on glamorous road shows in conjunction with Western conference centers (e.g., Earth Mission 2000) to promote the sale of imagery and other products. We even see proposals arising for joint research in areas such as pulsed power and nonacoustic antisubmarine warfare--virtual scientific no-go areas in the very recent past for both East and West.

The European Community (EC) is following these developments closely. The article in this issue by Mr. Anthony Rock (Science Counsellor to the U.S. Mission to the EC) outlines EC plans to open programs such as those in Human Mobility and training to Eastern European scientists and engineers. This will enhance the supply of scientific talent throughout the community and build strong ties for the future. The European Parliament has also proposed setting aside up to 10 percent of the Framework Program over the next 8 years for scientific programs in Eastern Europe.

These new circumstances have resulted in the rapid opening of new scientific dialogues. There is a significant need to characterize and assess this changing relationship between Western and Eastern European science and technology and its impact. The Office of Naval Research European Office (ONREUR) looks to take advantage of the changed environment we find in Europe to expand communications as much as possible. Communication brings understanding. Understanding fosters cooperation. Cooperation can permanently eliminate barriers. During the past year, the scientists of the ONREUR have received and accepted many invitations to visit institu-

tions throughout Eastern Europe and the U.S.S.R. These visits, mostly made during the past 10 months, have resulted in a fresh look at the state of science in this part of the world. This issue of the European Science Notes Information Bulletin (*ESNIB* 90-08) presents these reports as a unit. The intent is to provide in one volume a concise assessment from the perspective of this office. For the sake of completeness, we include some articles published in earlier issues of *ESNIB*. This is not a political assessment - that set of topics has been extensively

covered in the print and electronic media. This is a group of reports on the state of science, with some personal observations on life and travel in these countries. As such, it is a window, albeit small, on the processes affecting the scientific health of greater Europe.

This issue of *ESNIB* owes much, both in content and substance, to Dr. Marco Di Capua. In focusing his final assessment for ONREUR on the Soviet Union and Central Europe, he has contributed the core articles from which the issue grew.

# Union of Soviet Socialist Republics

## The T-14 Tokomak

by Marco S. Di Capua, formerly the Liaison Scientist for Physics in the Office of Naval Research European Office. Dr. Di Capua is an experimental physicist on leave from the Lawrence Livermore National Laboratory of the University of California.

### Introduction

The T-14 Tokomak (T-14) at the I.V. Kurchatov Institute of Atomic Energy, Troitsk Branch, is witness to the awareness of the leadership of U.S.S.R. science of the potential of inductive systems to store, condition, and deliver large amounts of pulsed electrical energy. In the T-14, these techniques apply to heat and compress Tokomak plasmas to thermonuclear conditions.

The uniqueness of T-14 Tokomak at Kurchatov lies in: imaginative use of inductive energy store that bypasses the need of sub-gigajoule capacitor banks, absence of iron in the ohmic heating transformer, and very large energy densities.

This article emphasizes the unique power conditioning technology developed for the T-14, known as TSP in the U.S.S.R., under the leadership of E. Azizov. S.V. Mirnov leads the plasma physics effort.

### Processing of the T-14 Tokomak Plasma

Processing of the T-14 Tokomak plasma will take place in two heating stages at constant volume and two compression stages. Table 1 outlines the processes.

In Stage 1a, plasma formation and heating takes place through ohmic heating by toroidal currents induced by coils that share the same axis as the major axis of the torus. With a rise of the toroidal current to 300 kA, at the end of Stage 1a, 70 ms into the discharge the major radius is  $\sim 1.1$  m, the minor radius is  $\sim 0.3$  m,  $n_e = 5.0E + 20 \text{ m}^{-3}$ ,  $T_e = T_i = 1$  keV. In Stage 1b, a combination of ohmic currents, neutral beams, and, RF at the ion cyclotron resonance frequency (20 MHz) heat the plasma further, to 2 keV, preparing the plasma torus for the two compression stages.

The adiabatic compression of the plasma to thermonuclear conditions, through reduction of the major and minor torus radii, takes place in Stages 2 and 3. In Stage 2, a rapid excursion of the toroidal field compresses the

plasma reducing the minor radius from 0.32 m to 0.2 m, increasing the plasma current to 480 kA. An excursion of the poloidal field (Stage 3) then compresses the plasma simultaneously in the minor and major radial dimensions: from 0.2 to 0.125 m and from 1.1 to 0.4 m, respectively, raising the toroidal current to 1.2 MA.

**Table 1. Processing and Parameters of the T-14 Tokomak Plasma**

Stage	1(a)	1(b)	2	3
Process	OH	OH+NB +ICH	a compress.	R compress.
Major radius R, (m)	1.06	1.06	1.06	0.4
Minor radius a, (m)	0.32	0.32	0.20	0.125
Toroidal field (T)	2.0	2.0	5.0	12.8
Toroidal field coils current (kA)	< 330	830	830	
Toroidal Plasma Current, (kA)	300	300	480	1200
$n_e$ ( $E + 19 \text{ m}^{-3}$ )	5	5	13	100
$T_e$ (keV)	1	2	3	12
$T_i$ (keV)	1	2.5	4	15

OH - Ohmic heating

NB - Neutral beam heating

ICH - Ion cyclotron radiofrequency heating

### The Toroidal Field Coils

In T-14, thirty-two wedge-shaped,  $\sim 5$ -m diameter single turn, chromium bronze alloy coils spaced about 50 cm apart at the outer perimeter, produce the toroidal confinement field. The alloy is the interior of a high-strength steel annulus that carries the hoop loads. The toroidal field on the plasma surface, 2 T at the end of

Stage 1b, will reach 5 T after Stage 2 and 13.8 T after the Stage 3 compression (22 T at the surface of the coils).

## The Vacuum Chamber

Explosive fabrication at the D.V. Yefremov Institute (see this issue, page 14) produced the complex scalloped shape of the T-14 vacuum chamber. The chamber has one port for every two coils. Carbon-carbon composite material coats the interior except the throat where the covering is boron nitride.

## Power Conditioning for the Toroidal Field

The compression process by the toroidal field is conceptually quite simple: generators energized by a flywheel, drive a current through the primary of an air-core transformer. Interruption of the primary current drives a current through a secondary winding whose electrical load are the toroidal field coils. Current flowing in the toroidal field coils induces the surface current on the plasma that performs the plasma compression.

The technology to carry out this process is remarkable. Four 270-MVA motor-driven generators will store 960 MJ of kinetic energy each in flywheels. These flywheels are the kinetic energy store at the heart of the T-14 system, feeding through generators, that share their same shafts, all ohmic heating, equilibrium, and toroidal field coils. The generators will deliver 1.9 GJ in 5 seconds to the magnetic field loads, including the primary of the T-14 transformer, slowing down from 3000 to 2100 RPM in the process.

Eight coils, configured as a fat torus, with a minor radius of 8 m and a major radius of 5.4 m, will store 900 MJ at a current of 130 kA. This current flows through a connection series of:

- A thyristor to connect the coils to the MG during the energy storage phase
- The coils that store the energy
- One switch that opens to produce the toroidal confinement field for the heating phase (SWH)
- Switches in series with each coil that open for the compression phase (SWC).

In Stage 1, opening of switch SWH inserts parallel resistors in the circuit, producing a small primary current drop that forms the initial current pulse in the toroidal coils (330 kA, 60 ms risetime, 200 ms duration). This current produces the toroidal field that confines the plasma during the ohmic, neutral particle, and RF heating stages.

For the Stage 2 compression, energy transfer from the transformer/inductive store primary to the secondary that

feeds the toroidal field coils takes place through the action of the eight SWC switches. These are sets of two-element opening switches that operate in parallel (one set for each primary coil). One opening switch element of the set is a RU40/150-8 (Larionov, 1987), compressed air-driven, accelerated hammer switch with a 150-kA conductive phase that can last as long as 8 s ( $I^2 \cdot t = 2.0E + 11 \text{ A}^2 \text{ s}$ ). This rating exceeds the 130 kA, 5 s pulse required to collect the magnetic energy in the primary winding coils.

When this switch opens, it transfers the current to the other, a fast, explosively driven switch similar to a RV30/300-4 (see this issue, page 14, The D.V. Yefremov Scientific Research Institute of Electrophysical Apparatus, U.S.S.R.; Volkov, 1989) that opens against 30 kV in 2 ms. As the explosive switch opens, the current through the series connection of the 32 coils (1 to 1/7 transformer ratio) rises to 830 kA in a few ms. This current in the coils induces 30 MA that flows on the surface of the torus-shaped plasma accomplishing the Stage 2 compression.

A 5-kV PIV, 1-MA, solid-state diode, in series with the secondary windings, prevents current flow in the secondary during the accumulation phase in the primary. Coarse schematic diagrams and parameter tables of the T-14 pulse power systems appear in a recent book on the physics and technique of powerful impulsive systems (Velikhov, 1987).

## Present and Future Status of the T-14

The T-14 now operates with a 1-T toroidal field using the diode in the secondary as an opening switch when the voltage reverses. One of the eight opening switch assemblies is on hand with more on the way soon. Two generators are working now. Preliminary measurements of plasma properties are taking place in collaboration with General Atomics from San Diego, who has a physicist, Neil Brooks, assigned to the T-14 facility for a year. The neutral beam injectors (2 MW) may be ready late in 1990.

## Conclusions

The T-14 Tokamak is a remarkable experimental device and a feat of innovative electrical engineering, elegant, conceptually simple, and yet complex. In addition to the imaginative power conditioning systems, the elegant shapes of the toroidal field coils and the vacuum chamber could very well find a home in an industrial art exhibition.

The Kurchatov staff is impatient to put T-14 into operation. However, U.S.S.R. political uncertainty, that filters down to all levels, (see this issue, page 61, Science Funding, Organization, and Personnel in the Soviet Union--An Assessment) delays the commissioning pro-

cess. Reliable operation of the T-14 power conditioning system could be a source of confidence on the applicability of inductive storage techniques to break-even magnetic compression fusion devices.

I asked how difficult it was for the inductive energy side of the house to convince perhaps more traditional plasma physicists about the untested blessings of their developing technology. My host, a plasma physicist, shook his head muttering: "Ah...all the noise from these explosions!"

In a dialogue with E. Azizov, we both agreed that pulsed-power development had reached a plateau and that industrial and commercial applications are critical to fuel the next state of exponential growth. As a first step, E. Azizov is proposing, with E. Velikhov's concurrence, a workshop in summer 1991 that will examine pulse power in industrial and commercial contexts.

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# The Megavolt Pulse Power Accelerator Complex Angara 5-1, I.V. Kurchatov Institute of Atomic Energy, Troitsk Branch

by Marco S. Di Capua

## The Angara 5-1 Accelerator Complex

The Angara 5-1 accelerator complex at the Troitsk branch of the I.V. Kurchatov Institute of Atomic Energy is a research facility to perform research on power compression (in time) and focusing (in space) for inertial confinement fusion (ICF). The Angara 5-1 achieves the final power compression by imploding plasma liners, with Lorentz forces originating with powerful short pulses of electrical current. For the initial power compression DC-charged Marx generators in the periphery of a circle, pulse charge spoke-like, water dielectric pulse-forming lines that inject a short (70 ns), high current (6 MA), high voltage (1.35 MV) pulse into a vacuum transmission line that feeds the imploding plasma liner at the center of the circle. I visited the facility in June 1990 and a brief description of the Angara 5-1 components follows.

**Marx Generators and Water Dielectric Pulse-Forming Lines.** The design of the Angara 5-1 facility at Troitsk called for eight, 2-, 75-kJ, 1.5-TW modules. The 20-m long, 3-m diameter modules, are the spokes in a circle with an overall diameter of 50 m. As designed, 14-stage, 190-kJ Marx generators (@ 75-kV charging voltage) in each module pulse charge a 2.4-m diameter water Blumlein circuit in 1.5  $\mu$ s with 90 percent efficiency. The Marx

generators have three parallel branches with 14 switches per branch. The switches divide in two groups: nine low-pressure switches in the upper stages operating close to breakdown, and the three triggered switches of the lower stages at higher pressure.

Five triggered V/n gas switches form the pulse in the Blumlein and synchronize the modules. The interval between module pulses is acceptable (6 to 12-ns jitter) on 70 percent of the shots. Gas prepulse switches in the modules add another 5 ns of jitter. Each module has two diverter switches that fire with a command trigger 80 ns after the main switches, grounding the intermediate conductor of the Blumlein through 3 resistors. These diverters prevent damage of accelerator components arising from late water breakdowns.

Water breakdown and decreased reliability of the Marx systems (60-kV charge limit) have taken a severe bite from the output power of Angara 5-1 specified in its design. The output power into an inductive load was expected to be 9 TW which is only 75 percent of the sum of the power of the modules. The output power is now 6 TW with 1.35 MV (instead of the 1.8-MV design value) in the 2- $\Omega$  output line (60-kV Marx charge). The facility delivers a 6-MA, 70-ns pulse into a short circuit load with 600 kJ of energy at the time of current peak.

**The Vacuum Region.** Eight (one for each module), 1.2-m mean diameter, 30-nH, 65-kV  $\text{cm}^{-1}$  stacked (multi-ring) insulators, separate the water dielectric of the modules from the common vacuum region. The insulators are at a radius of 1.5 m from the centerline of the accelerator. 30-cm diameter, 1- to 3-cm gap coaxial magnetically insulated vacuum transmission lines (MITLs) join to anode and cathode disk current collectors. Two geometries were tried. In one geometry, the MITL diameter and gap decreases along the direction of pulse propagation and the MITLs join in a collector close to the load. In the other, the 1-m long MITLs transition to the collector, and join it at a 40-cm radius. Apparently, the efficiency of energy transport for either geometry is about 80 percent (Grabovsky, 1988). However, researchers prefer the latter, more inductive system that, while driving less current, causes less damage to experimental hardware that slows down the experimental turnaround. The convolution to the collector plate is open; i.e., the external conductor "peels" away from the center conductor at the edge of the disk leaving the disk (cathode) open at the bottom.

## Diagnostics

**The Data Acquisition System.** Supervised by V.I. Zaitzev (1989), the data acquisition system consists of two 500-m<sup>2</sup> screen rooms. One houses digitizers and computers while the other houses oscilloscopes.

The data recording complement is:

- 24 1-GHz channels (eight 6-LOR-TSCH M oscillographs) (see this issue, page 16, The Institute of High-Current Electronics in Tomsk)
- 48 500-MHz oscilloscope channels (similar to the vacuum tube Tektronix 556 oscillograph)
- 50 100-Mhz digitizers (1 V full screen sensitivity, 256 × 256 digitizing screen, 0.7 ns max between points)
- Several tens of slower channels.

Table 1 summarizes the partition of diagnostic channels.

**Table 1. Summary of Partition of Diagnostic Channels on Angara 5-1**

Diagnostics	Channels
Accelerator performance	100
Power flow	16
Load	20

The screen room can synchronize 48 fast channels. The computer stores one-line timing diagrams that compensate the length of diagnostic cables, patch cables, and

attenuators. A computer system processes the digitizer data with a 10-minute turnaround.

Data from the 1-GHz oscillographs, that have fiber optic links with 15- $\mu\text{m}$  fibers that couple light directly to photographic film. Physicists perform decisions on the course of the experiments using the digitized data. They perform more detailed analyses on the photographic data that returns in one hour.

**Electrical Diagnostics.** A wave approach to power flow calculations exploits signals from capacitive voltage probes and magnetic current probes that measure the parameters of the propagating and reflected waves at two locations in the water dielectric output line. The inductance of the load is the ratio of the time integral of the voltage at the load (as calculated from the wave reflection ratio), divided by the measured current. Rogoski coils measure the current at the load.

**Optical Diagnostics.** The module configuration allows a direct line-of-sight diagnostic through the imploding liner load. A 1-ns ruby laser, coupled to a framing camera allows simultaneous shadowgraphy, shadow interferometry, and Faraday rotation measurements on the imploding plasma load.

**X-Ray Diagnostics.** Grabovsky (1988) and Velikhov (1989) describe the x-ray diagnostics in detail. Zaitzev (1990) describes time-resolved spectral measurements in the 0.1 to 1 keV spectral region with a 10-channel spectrograph with multi-layer mirror dispersive elements and 2-4-ns time resolution pin semiconductor detectors.

**Particle Diagnostics.** 15 and 42-m long tubes are available for fast ion and neutron time-of-flight measurements.

## Operational Notes

With no hardware or diagnostic changes, the facility turnaround time is about 2 hours. Angara 5-1, with liner loads, has fired about 2,000 shots. The downtime to replace spark gaps or capacitors is one day. Occasionally, they use evening shifts to perform maintenance. Evening shifts, however, are an exception.

## Experiments on Angara 5-1

In one series of experiments, Angara 5-1 delivered currents of 3 to 4 MA to imploding Al, Cu, and W multiwire shells (6 to 24 wires) that simulate cylindrical liners with initial radii of 0.4 to 1.5 cm, heights of 1 to 3 cm, and linear mass densities of 1 to 2.0 E-04  $\text{g cm}^{-1}$ . The wire shells, compressing to a 1-mm diameter column, converted 20 to 25 percent of the Angara 5-1 energy into 100 kJ of vacuum ultraviolet and soft x-ray radiation (Bekhtev, 1989) with up to 24 kJ in the Al  $K_{\alpha}$  line and 20

percent of the total yield above 2 keV. Aivasov (1990) describes the most recent results on wire implosions.

N<sub>2</sub> and Xe gas puff implosions (M 6 nozzle, 2.0E-04 g cm<sup>-1</sup>, R<sub>0</sub> = 1 - 1.5 cm, L = 1.0 cm) compressing onto a 2-mm core have been performed. D<sub>2</sub> pinches reveal the scaling laws and the mechanisms of neutron production (1.0E + 12 neutrons with currents of 1.6 - 1.8 MA). Indirect drive target experiments have also been performed, but no details were given except for a mention that the targets would be utilizing the Mokov pressure drive, a term I am not familiar with.

### Plasma Erosion Switches on Angara 5-1

Wire liner experiments use plasma erosion opening switches successfully to improve trapping of the electron flow and to reduce the effects of asynchronism of the modules (Velikhov, 1989). The switch, located at a radius of 50 cm, just at the transition from the coaxial lines to the disk collector, conducts 2 MA before opening, with current rise rates of 1.0E + 14 A s<sup>-1</sup> allowing a current rise of 3.5 MA to the wire load in 30 ns. Twenty-four plasma sources fire 30 cm away from the power feed, 8-10 μs before the power pulse. A 1.5-μF capacitor charged to 25 kV delivers a 30-kA pulse with a 2-μs risetime to each gun.

### Plans for the Facility

An ion beam driver upgrade is planned with 6-MV, 6-TW, 6-Ω output. The design for this oil facility, to fit in the same building and to be called Angara 5-M (M is the initial letter for oil in Russian) is now complete. However, there are no funds allocated at present for the upgrade. A high priority in V. Smirnov's agenda is to build two modules to prove the design.

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# The Terscol Conference on Materials Undergoing Rapid Deformation and the Institute for Strength Physics and Materials in Tomsk

by Marco S. Di Capua and Yasu-Yuki Horie. Dr. Di Capua was the Liaison Scientist for Physics in the Office of Naval Research European Office. Dr. Horie is a professor of Civil Engineering and Materials Science at North Carolina State University, Raleigh.

## Aim of the Conference

Organized by Academician V.E. Panin and his co-worker S.G. Psakhie of the Institute for Strength Physics and Materials (IFPM, Tomsk) of the Siberian Branch of the U.S.S.R. Academy of Sciences (Academy) the International Conference on New Physical and Mechanical Methods of Investigation of Materials Under Loading aimed to discuss:

- Theoretical and experimental studies of condensed matter under shock wave loading
- Computer modeling of materials under high energy loading
- New branches of theoretical and experimental investigations of the stress deformed state of solids
- New methods for the theoretical investigations of electronic, vibrational, and thermodynamic properties of the deformed solids.

Sponsors of the conference included the Kabardino-Balkar State University, the Soviet, and the Party authorities of the Kabardino-Balkar Republic, Tomsk State University, and the Research Institute of Applied Mathematics and Mechanics in Tomsk.

More than 160 scientists from the U.S.S.R., U.S., Federal Republic of Germany (FRG), Japan, Italy, and Academy of Sciences, Prague, Czech and Slovak Federal Republic (C.S.F.R.), were present at the conference. Participants included two full members and one corresponding member of the Academy, and 46 Doctors of Science. There were 54 oral and 75 poster papers.

The meeting took place in the northern slopes of the Caucasus Mountains, in Terscol (2,000 m), at the headwaters of the Baksan River, in the Baksan Gorge at the foot of Mount Cheget (~3,000 m) and one valley away from Mount Elbrus (5,300 m), the highest mountain in Europe.

## Motivation for the Conference

The organizing committee (V.E. Panin, V.E. Egorushkin, Y.A. Khon, P.V. Makarov, S.G. Psakhie, and L.B. Zuev) felt that further research progress on the mechan-

ics of deformed solids and, in the creation of a new generation of materials requires the development of new theoretical and experimental methods that exploit the latest results of physics, mechanics, and information technologies. With this aim, the conference examined three main areas:

- New methods of theoretical and experimental investigations of deformed state of solids under high energy loading
- New branches of theoretical and experimental investigations of the stress-deformed states of solids
- New methods for the theoretical investigation of electronic, vibrational, and thermodynamic properties of the deformed solids.

Academician V.E. Panin, Professors M. Meyers, University of California San Diego, R. Prummer, Ernst Mach Institute (EMI), FRG (Di Capua, 1989), Y. Horie, North Carolina State University, K. Kawata, Japan, C. Patuelli, University of Bologna, Italy, and L. Berka, C.S.F.R., presented review papers.

## Academician Panin's Remarks

Panin discussed some of his ideas on waves of plastic deformation and fracture of solids. Panin began by stressing the inadequacy of our understanding of matter under the effect of high-energy action; i.e., when the stresses are high enough to cause plastic deformation and yet sufficiently low where material strength still determines the behavior of the deformed material (below the hydrodynamic limit; see, for example, [Knauss, 1988]). In his brief review of the field of mechanics, Panin identified the interfaces in crystallites as critical to the behavior of materials deforming at high strain rates caused by the migration of zones of high stress concentration.

Panin suggests that high rate deformations produce highly excited states in crystals. Panin regards a crystal, undergoing plastic deformation, as a nonhomogeneous, highly nonequilibrium system that advances to equilibrium as the stress-gradient field drives structures through the crystal, and the material transits through

successive potential minima as highly excited states in the crystal alter the interatomic potentials.

In particular, Panin suggests that shear deformations in a crystal propagate, across grain boundaries, through oscillatory shear waves, to neighboring crystals. These translational flow vortices propagate the waves of plastic deformation in the solid at a much faster rate than diffusion driven deformations.

The idea of rotation within the lattice was explored in the 1960s in the U.S. (Micropolar theory, Cosserat theory; Mindlin, 1965; Green, 1964). However, lack of experimental evidence hampered further developments in this direction.

### Conclusions of the Organizing Committee

The conclusions of the conference organizing committee were:

- Interfaces play a basic role in the formation of plastic shears
- Plastic deformation of solids may display wave-like properties
- Structural levels play a role in the development of plastic deformation and fracturing of structured solids
- Possibilities exist to create complex integrated models of shock loading and shock compaction
- Shock compression offers methods to enhance properties of high-temperature superconductors
- The application of computer modeling offers new opportunities to understand structured materials.

### Recommendations of the Conference Organizing Committee

The committee recommended to:

- Develop the studies of structured materials by a combined application of the methods of physics, mechanics, and computer modeling of the behavior of structured media
- Develop new methods for experimental studies, including:
  - Automation of experiments and
  - Methods for computer modeling of materials
- Develop, on the basis of the scientific results, engineering methods for technological applications
- Convene the Second International Conference "The New Physical and Mechanical Methods of Investigation of Materials Under Loading" in 1992 in Tomsk.

### Conclusions About the Conference

The conclusions of the organizing committee reflect our mixed feelings about this conference and about

Panin's view of solid deformations. While we find the "new" wave approach Panin proposes exciting (Panin, 1982, 1982a, 1987, 1990), we have difficulty reconciling this approach with more traditional approaches to the description of plastic deformations. A second difficulty we have is that the physical concept of a wave implies conservation concepts, energy, for example, in its kinetic and potential forms. We have not been able to identify what are the conservation principles in his formulation, and, if there is no conservation, what the dissipation terms are and what their role is in propagation of the wave.

We believe Panin's ideas, which have been in print since 1982, and are difficult to understand, deserve a careful and honest consideration. Should they have experimental confirmation, they would alter fundamentally the approach to formulation of constitutive relations, and may lead to development of new materials (Di Capua, 1989a). Perhaps L. Berka's approach (see this issue, page 122, Micromechanics and Scanning Electron Microscopy Research at the C.S.F.R. Academy of Sciences)--real-time SEM during the deformation process--could provide the experimental evidence Panin's theories so sorely require for further development.

### The Debut of Tomsk in the Scientific Community

This conference is another step in the debut of the Tomsk Academy Akademgorodok research institutes into the open scientific community. The debut took place in stages: the visit of one of us (Di Capua) to the Institute of High Current Electronics (ISE) (see this issue, page 16, The Institute of High-Current Electronics in Tomsk), the visit of an American delegation (Kristiansen, 1990) to ISE, the visit of one of us (Horie) to IFPM in February 1990, The International Workshop on Physics and Technique of High-Power Opening Switches (ESNIB 90-01:31-32) (republished in this issue, page 43) and visits connected with the Beams '90 conference in Novosibirsk.

A parallel agenda of this conference was to further Panin's research undertakings and to increase their prestige by hosting an international conference. Moreover, it was clear, from the excitement of the Soviet delegates, that this was the first conference in the Soviet Union to combine materials science and high loading rates.

### The Institute of Strength Physics and Materials

Another article in this issue (page 35, Institutions of Research and Higher Learning in Tomsk) has a brief description of the Academy Institutes at Akademgorodok in Tomsk and their relationship to Tomsk University and the Tomsk Polytechnic. This section describes the research at the IFPM in some more detail.

The task of IFPM is to "develop fundamental research to generate new technical and technological solutions

leading to revolutionary changes in various fields of industrial production..." The 400-staff institute divides in 6 departments and 7 centers, with 3 or 4 laboratories in each department. The centers focus on applied research. The IFPM is adding two new buildings and its staff may increase to 800 in a few years.

The departments, with some of their research topics, are:

- Theory of Solid State Physics and Materials
  - Theory of strongly excited states
  - Theory of structured continuous media
- Composite Materials and Powder Metallurgy
  - Nickel aluminides
- Self-propagating High Temperature Synthesis\* (SHS) through laser ignition
  - SHS by hot isostatic pressing
- Strength Physics and Wear Resistance
  - Plastic wave measurements using speckle laser interferometry
- Ceramic and Polymeric Materials
  - Materials with damping structure (NiTi + TiC and ZrO<sub>2</sub>[Y])
  - Fine powder production through plasma processing
  - Comminution of minerals
- Computer-Aided Design of Materials
  - SHS
  - Automata simulation of SHS and fracture dynamics
  - Element dynamics (mesoscopic simulation of grains)
- Protective and Hardening Coatings
  - Plasma coating of ceramics on metals

\* (See this issue, page 74, MATECH '90--The First European East-West Symposium on Materials and Processes.)

Therefore, by looking at this list, a parallel between the conference and the structure of IFPM is easy to imagine.

The IFPM is unique in the world by the resources it commits to basic and applied research in a field that borders between dynamic loading and materials science. Our surprise is that Knauss's Foreign Applied Science Assessment Center (FASAC) (see this issue, page 97, Foreign Applied Science Assessment Center on Soviet Science and Technology) review (1988) does not discuss Panin's work or even mention IFPM in its discussion. One option is that Panin has published most of his work in *Izvestiya VUZ Fizika*, a journal that perhaps materials researchers would not normally consult. The other is that a research evaluation was not possible as long as Tomsk remained closed to visitors.

## Bright Young People at the Conference

At this conference one of us (Di Capua) interacted with three young, articulate, and, quick-on-their-feet U.S.S.R. scientists who could easily pass for faculty members at a university anywhere in Europe or the U.S.:

- Sergei Alexeev, IFPM, Tomsk. This young collaborator of S. Psakhie contributed to the organization of the conference, taking charge of all arrangements for the foreign delegation.
- Nail Achmadejev, Bakshir Branch, Academy, 450025 Ufa. (see this issue, page 52, *Adventures on the Road to Tomsk*). His research concerns the dynamic (spalling) fracture of solids. He has authored a monograph on the dynamic failure of solids in tension waves (Achmadejev, 1988) with over 600 references! At this meeting, he discussed models of physical and chemical reactions in shock compression as they apply to surface treatment of materials.
- Lev Altshuler, now retired, Rostovskaya Nabereshiad, 3-148, 119121 Moscow, who also discussed chemical reactions and phase transitions in shock waves (in solids). Altshuler is a lovely old timer in the field of rapid deformations and has the mental agility of a person half his age (Lev is 77).
- Leonid Yastrebov, Department of Metals Science, Tsiolkovsky Aviation Technology Institute, Moscow. Yastrebov discussed the electronic structure of disordered solid solutions under all-round tensile deformation. Yastrebov is a coauthor of a text on one electron theory of solids (Yastrebov, 1987).

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# Solid-State and Condensed-Matter Physics Research in the Soviet Union

by Dean L. Mitchell, formerly the Liaison Scientist for Solid-State Physics in Europe and the Middle East for the Office of Naval Research European Office.

## Introduction

The following report is based on visits to Leningrad and Moscow during May 1990. The coverage includes: the International Symposium on Progress in Heterostructure Physics and Applications in Leningrad; the Physics Institute of the Academy of Sciences, (also known as FIAN or the Lebedev Institute) in Moscow; the Institute of Radio Engineering and Electronics (IRE) in Moscow; and the Institute of Solid-State Physics in Chernogolovka, a science center located 70 km from Moscow. The trip was arranged through personal contacts developed during previous research visits to the Soviet Union in 1967-1968, 1979, and 1976.

## Symposium on Progress in Heterostructure Physics and Applications

The 60th birthday of Zhores Alferov, director of the Physical Technical Institute in Leningrad (known locally as Fiztek), was the occasion for the Symposium on Progress in Heterostructure Physics and Applications held in Leningrad on May 16-18, 1990. The event drew eight invited participants from abroad and 150 attendees from the U.S.S.R., including delegates from all the main research institutes of the Academy of Sciences of the U.S.S.R. involved in solid-state and condensed-matter research. The foreign delegates included R. Dupuis, L. Esaki, and M. Panish - U.S.; J. Nishizawa - Japan; K. von Klitzing - Federal Republic of Germany (FRG); K. Thissen - German Democratic Republic; J. Ripper - Brazil; and D. Mitchell - (U.S.) Office of Naval Research European Office, London. Pre-eminent among the Soviet attendees were academicians Yu. Gulgaev, L. Keldysh, and I. Khalatnikov. I. Prokhorov was scheduled to deliver the opening address but, because of illness, was replaced by Keldysh.

The topic of the symposium, heterojunction physics and applications, was selected to celebrate Alferov's contributions to the field, notably the invention or discovery of the double heterojunction laser in 1967-1968. In his opening address, Keldysh noted that he chaired the committee that rejected Alferov's paper on the double heterojunction laser which was submitted to the International Conference on the Physics of Semiconductors held in Moscow in 1968. No matter, he jested, Alferov later was

allowed to fill a last-minute vacant slot and, at least, presented his paper orally.

The papers presented at the symposium generally were reviews of past work, mainly by researchers at Fiztek. The present state of the art for Algas lasers at Fiztek was reported by P. Kopyev. He reviewed recent work on short-period superlattices which, used with quantum well structures, allows lower threshold currents and higher efficiencies than previously attained with quantum wells alone because of combined electron and optical confinement effects. He cited threshold currents of  $53\text{-}175\text{A}/\text{cm}^2$  in type II structures for spacings ranging from 20 to 5.8 nm.

The venue for the symposium was the Hotel Leningrad, except the opening session which was held in the main building of the Leningrad branch of the Academy of Sciences. The Leningrad building was the historical headquarters for the Russian Academy of Sciences founded by Tsarina Elizabeth in the 18th century. The presidium and the headquarters were moved to Moscow on Stalin's orders in the early 1930s.

On Tuesday morning, the foreign delegates were driven to Fiztek for a reception by Alferov in his office. He spoke of the history of the room where we were sitting which previously was part of A.F. Ioffe's apartment. Ioffe lived there until he was summarily dismissed as Fiztek's director in 1951 under direct orders of Beria. The doorway from his apartment to Fiztek was then sealed until he was able to move to other living quarters some months later.

Fiztek has moved to officially re-establish Ioffe's image and reputation; a room is set aside as a memorial. The room is furnished with his desk, personal library, pictures, and memorabilia that were gathered from archives or donated by friends and family.

## Physics Institute of the Academy of Sciences

The visit to the Physics Institute of the Academy of Sciences (FIAN) was confined mainly to A. Shotov's group which is engaged in basic and applied studies of IV-VI semiconductors. Shotov heads a group of about 30 investigators that is engaged in an across-the-board program of research on the lead-salts, including investigations of the growth, characterization, physical properties, and applications of IV-VI semiconductors. The systems

under study include lead-tin-telluride, lead-sulphide-selenide, and variants of these with inclusion of rare-earth and transition-metal elements. The laboratories are well equipped with growth facilities, characterization facilities, and equipment for electrical and optical studies of basic physical properties.

The crystal growth facility mainly uses growth chambers based on the hot-wall technique developed at the Naval Ordnance Laboratory in White Oak, Maryland (renamed the Naval Surface Warfare Center). The original design has been modified to allow sequential depositions by a three-barrel source. This permits fabrication of heterolattice device structures *in situ*. There are six separate operational growth chambers in the crystal growth facility. This large number permits each growth chamber to be dedicated to a particular alloy composition, thus reducing problems of cross-contamination. The group is now preparing new laboratory spaces for installation of a molecular beam deposition system later this year.

The technologies for the growth, characterization, and fabrication of optoelectronic devices using IV-VI semiconductor alloy systems have been developed to an advanced level in several European laboratories. The range of applications includes lasers, detectors, mixers, and displays--mainly for operation in the infrared region of the spectrum. The main centers for these developments are located at the Fraunhofer Institute at Freiburg and Wurzburg University, FRG; the University of Linz, Austria; the Eidgenössische Technische Hochschule (ETH) Zurich, Switzerland; and, FIAN, Moscow. Of these, Shotov's group at FIAN is the largest, and overall has capabilities for fabricating the broadest range of devices.

As with other laboratories that I visited in the Soviet Union, there is strong drive to seek market outlets for research results emanating from the laboratory. Shotov, in fact, has already marketed devices and transferred the electronics materials techniques developed in their laboratory to institutes and firms which, presumably, supply components for the Soviet space and defense programs. They are now exploring the potential for markets abroad for hard currency. They fabricate and test special devices, mainly lasers, inhouse. Overall, Shotov's laboratory has a good balance between basic semiconductor research and applied device development. As a result, this laboratory is in the forefront of IV-VI semiconductor device research.

The work to date has mainly been on layers deposited on BAF or NaCl substrates. There did not appear to be any serious effort to develop the materials growth processes, which would allow hybridization with III-V on silicon hybrid devices as at the ETH. However, the laboratory can grow high-quality heterojunction devices and superlattices. The ability to fabricate even more sophis-

ticated devices will improve when the molecular beam system is installed later this year.

## The Institute of Solid-State Physics

The Institute of Solid-State Physics (Institute) in Chernogolovka is located 70 km northwest of Moscow. Chernogolovka was developed as a "science city" with several basic research institutes placed there to take advantage of the open spaces and improved residential life provided by the rural setting. Several of the institutes located along the route leading to Chernogolovka and in Chernogolovka itself were, and perhaps still are, engaged in classified research. As a result, western scientists were not allowed to visit the Institute until 2 years ago. The previous travel restrictions now have been eased and the Institute has been given autonomy to arrange visits to it by foreigners. This is a tangible result of the introduction of the policies of Perestroika (restructuring) and Glasnost (openness) (P&G) introduced by M. Gorbachev 3 years ago.

The visit to the Institute was abbreviated since we did not arrive from Moscow until nearly noon and departed again at 4 p.m. However, the visit was long enough for me to visit several laboratories that were more modern and better equipped than others that I have visited in the Soviet Union. One reason is the relative youth in terms of the average age of the research staff. Another reason is the relatively young age of the laboratory buildings and research instrumentation.

I was particularly impressed by the research in V. Timofeev's group which is engaged in basic studies of the electronic structure and excitations in semiconductors. During the past year, the laboratory acquired a 16.5-T superconducting magnet and millikelvin facility from Oxford Instruments costing \$0.5-1.0 million in hard currency. The magnet facility is equal to any in the West and is the centerpiece of the research in the group.

Timofeev and his colleagues recently reported observations of features in the luminescence spectra of AlGa heterostructures that correspond to filling factors of  $1/7$ ,  $1/9$ , and  $1/11$  for the fractional quantum Hall effect. The samples were prepared by K. Ploog at the Max Planck Institute (MPI), Stuttgart, and experiments were carried out at the High Magnetic Field Laboratory (Laboratory), Grenoble, France. The samples were delta-doped to provide a separation between excitation and recombination positions so that only luminescence from extended conduction states would be observed. The line-shapes for  $1/7$ ,  $1/9$ , and  $1/11$  were distorted, indicating the possible onset of Wigner crystallization.

These experiments are at the forefront of what can be achieved with advanced semiconductor materials synthesis and photolithographic processing. Indeed, the samples used by Timofeev were prepared at the MPI, Stuttgart. The layers prepared with the molecular beam

deposition system at the Institute were not good enough to resolve the spectral peaks. The concept of the experiment and most measurements, however, were carried out at the Institute although the data for publication were obtained in the higher magnetic fields available at the Laboratory.

## The Institute of Radio Engineering and Electronics

The IRE is located on the old campus of Moscow State University which faces the Kremlin walls in central Moscow. The buildings are old and creaky; the laboratories are cramped. I was impressed, however, to see western-manufactured personal computers (PCs) in each of the laboratories that I visited. I was told that the hard currency for the PCs was obtained in return for special devices and circuitry fabricated at the IRE.

The host for the visit was A. Vystavkin who is IRE's deputy director. He also heads a large group involved with research on Superconducting Quantum Interference Devices (SQUIDS) and millimeter-wave devices using superconducting Josephson junctions.

The research on superconducting devices and device physics at the IRE spans the range from very basic studies of the superconducting and normal-state electronic properties of low-temperature bulk superconductors and thin films. The IRE has a broad range of capabilities, including photolithography and computer-aided design (CAD) facilities that allow in-house fabrication of complex integrated circuits. These include superconducting devices and hybrid semiconductor/superconductor devices and circuitry. The research emphasis is more applied than basic. The basic studies appear motivated by the desire to improve the performance of particular devices. The IRE, in fact, appears to be an actual supplier of superconducting circuitry used in advanced defense and space systems. My impression was that they only supplied custom-designed circuits for special applications.

The superconducting circuit development is based on the use of low-temperature niobium and lead-based alloys. I did not see the work on high-temperature superconductors in progress, although such work was mentioned in passing.

During private discussions, Vystavkin discussed a most interesting new direction of research at the IRE. He mentioned new types of computer architectures and modes for computation that are being explored by

K. Likharev and his students at Moscow State University. Likharev has a joint appointment at the IRE where his ideas have taken hold and now are being developed in both hardware and software programs. More recently, Likharev has made important contributions to the understanding of ultra-small junction devices where Coulomb blockade effects are important; i.e., where the tunneling barrier characteristics of mesoscopic devices change with the transfer of a single electronic charge across the barrier.

Recent experimental work in Sweden, the Netherlands, and the U.S. have confirmed Likharev's theoretical predictions on the feasibility of making devices sensitive to the transfer of a single electronic charge, or less, across a tunnel barrier. Researchers at Delft have fabricated a single-electron turnstile, based on Likharev's ideas, which provides a current that is fixed, to high accuracy, by the magnitude of the drive frequency. This is the current/frequency effect analogous to the voltage/frequency fixed ratio which results from the Josephson effect. Although the microfabrication and materials processing capabilities in the IRE are apparently not sufficient to make such devices at present, it does appear that the IRE has programs to provide the circuit design and computational architectures to use such devices when available.

## Changes I Observed

The time of my visit to the U.S.S.R. was during a period of great uncertainty: Lithuania had seceded from the U.S.S.R. and was under blockade; new food prices had been announced and panic buying had denuded the shelves in the food stores; and, the various Soviets, from the city level to the all-union level were debating the future of the country in ways that seemed to reflect a veritable "Tower of Babel." Considering the general state of the society, it was encouraging to visit laboratories where the primary concern remained the problems of research. This is not "Ivory Towerism" so much as it is an attitude, or belief, that the future of Russia will need to rely on the research and the skills of the institutes to develop new technologies for a market-based economy. The institutes are elitist institutions and the scientists tend to view themselves as essential to the changes, whatever they may be, during the processes of decentralization now underway.

# D.V. Yefremov Scientific Research Institute of Electrophysical Apparatus

by Marco S. Di Capua

I visited the D.V. Yefremov Research Institute of Electrophysical Apparatus (NIEFA), Leningrad, U.S.S.R., as part of the scientific itinerary of 20 U.S. scientists attending the The International Workshop on Physics and Techniques on High-Power Opening Switches (see this issue, page 43) and the Megagauss V meeting. I report on other institutes that were part of the itinerary elsewhere: The Institute of High Temperatures of the U.S.S.R. Academy of Sciences, page 39; the I.V. Kurchatov Institute of Atomic Energy, page 37; The T-14 Tokomak, page 3; The Megavolt Pulse Power Accelerator Complex Angara 5-1, page 5; and the Institute of Nuclear Physics, Siberian Branch of the U.S.S.R. Academy of Sciences, page 42.

The director of the Institute, Academician V.I. Glukhii, was away so Dr. V.A. Burtsev, Technological Laser Department, greeted us. Dr. Burtsev provided a brief history and overview of an institute, established in 1945 to develop mass spectrometers for U isotope separation (known as calutrons in the U.S.) (see this issue, page 37, I.V. Kurchatov Institute of Atomic Energy). This separation method later proved to be uneconomical. The institute then addressed itself to designing and constructing charged particle accelerators for scientific and technical purposes.

The NIEFA employs about 1,200 engineers and scientists and 3,800 technicians. A construction plan next door that employs about 4,000, bringing the total staff up to about 10,000 people. The NIEFA is now restructuring and is trying to branch out from accelerators to a more modern series of electrophysical apparatus. During the introductory remarks, Burtsev emphasized several times NIEFA's capabilities on laser technology, which is not surprising since he leads that group.

NIEFA is organized into several departments:

- Vacuum Technology
- Radiation Resistance of Materials
- Homopolar Generators
- Liquid Metal MHD Pumps
- Tokomak Systems and Supplies including Inductive Storage Systems, Commutators, and Breakers
- Inductive Storage Systems
- Induction Accelerators for Medicine, Industry, Radiation Chemistry, and Cross-Link Polymerization
- CO<sub>2</sub> Lasers for Cutting and Welding

- Plasma Technology
- Cyclic Accelerators for Particle Physics Research
- Ion Implanters for Semiconductor Fabrication

## Pulse Power Research and Development

**Explosive Switches and Inductive Energy Storage.** The NIEFA developed the inductive storage system for the T-14 Tokomak at Kurchatov. The T-14 at Tokomak article (this issue, page 3) describes the pulse power system of the T-14 in some detail. Our hosts emphasized inductors that store 300 kA for 2.5 s and explosively actuated switches that open or close in hundreds of  $\mu$ s against voltages of 30 or 40 kV. The explosively actuated switch that I examined consists of two ogive-contoured copper electrodes, clamped by deformable conical washers, and makes contact at the periphery. A polyethylene washer, whose central hole contains an explosive charge, fills the internal gap between the electrodes. Detonation of the charge extrudes the polyethylene radially at the periphery, forming an insulating gap between the electrodes, opening the switch in 20 to 200  $\mu$ s. In a closing switch configuration, a soft metal replaces the core of the polyethylene as a washer material.

Tables 1 and 2 provide the characteristics of the explosive opening and closing switches that appear in the catalog devoted to apparatus for impulsive storage of energy (nn, 1989); Volkov, 1989a and Volkov, 1989b, respectively.

**Table 1. Opening Switches (Volkov, 1989a)**

	Opening Switch Type*		
	RV1 20/100	RV2 20/100	RV30 30/300-4
Maximum Working Current (kA)	100	100	300
Maximum Working Voltage (kV)	20	2	30
Maximum Jitter ( $\mu$ s)	50	50	50
Time to Establish Electrical Strength After Current Switching ( $\mu$ s)	300	200	2000
Explosive mass (g)	1.2	0.8	2
Mass of Replaceable Washer (kg)	1.7	0.5	5
Operational life (# of shots)	30	30	30
Switch mass (kg)	40	12	76

\*RV - Russian designation for opening explosive switch

Table 2. Closing Switches (Volkov, 1989b)

	Closing Switch Type*	
	ZV1- 20/100	ZV- 30/300
Maximum Working Current (kA)	100	300
Maximum Opening Voltage (kV)	20	30
Maximum Jitter ( $\mu$ s)	10	20
Maximum Continuous Current (kA)	2	10
Explosive mass (g)	0.5	2
Mass of replaceable washer (g)	20	100
Switch mass (kg)	9.8	5

\*ZV - Russian designation for closing explosive switch

The switches are designed to operate as part of a rotating machinery inductive energy storage/power multiplication system, where closing switches (in the storage phase of the cycle) connect the spinning generator to the primary of an air core inductive store (15-100 MJ [Gerasimov, 1989]). In the pulse delivery phase, opening switches cause a magnetic flux collapse in the primary circuit therefore energizing the secondary of the store (similar to an automobile ignition coil).

**Megavolt Switch Technology.** The NIEFA supports the Angara V and Stand 300 facilities at Kurchatov (see this issue, page 5, The Megavolt Pulse Power Accelerator Complex Angara 5-1) and provided the 4-MV, 0.3-MA Blumlein circuit switches that operate with a 10-ns jitter when triggered with a 100-kV pulse, and the diverter switches that protect the output end of the accelerator. We saw a test stand consisting of a 4-MV, oil-insulated Marx and 100-kV, 0.6- $\mu$ F capacitors.

**Electron Beam and Laser Excitation Technology.** NEVA 1, a small coaxial line machine, is the testbed for the Kurchatov support work, as well as for development in laser excitation technology. This coaxial accelerator has an oil-insulated Marx generator, a water coaxial transmission line, a triggered gas switch, and a self-breaking output switch. In NEVA, we saw an arrangement for laser excitation with a brush-like cathode with 5-cm long, very coarse carbon fibers that gave the cathode an appearance of a giant shoe-brush ( $I = 300$  kA,  $V = 400$  kV,  $j = 50-100$  A cm<sup>-2</sup>, 10 cm x 90 cm (?)). A closely spaced wire anode defines the positive boundary in the diode ( $E_{ave} = 250$  kV cm<sup>-1</sup>, anode-cathode gap = 2 cm). A conventional hibachi-like structure supports the 10- $\mu$ thick metal foil diaphragm that separates the lasing gas (2 bar) and diode vacuum (1.0E-05 Tor) region. The C fibers stabilize emission from the cathode providing a uniform current density. A 1-T field, to prevent the beam from pinching, will be provided in the future.

Another laser facility that utilizes a C fiber cathode is LIRA. The LIRA has an air-insulated fast Marx (400-ns pulse) with 0.2  $\mu$ F epoxy potted capacitors designed for 70 kV and operated at 50 kV. The LIRA produces a 200-ns, 80-kA electron pulse with a 240-kV mean energy at 15 A cm<sup>-2</sup> at the center and 2 A cm<sup>-2</sup> at the edge with a repetition rate up to 10 Hz. All the gaps, which appeared to be oversized, seemed to be triggered. The laser chamber dimensions were 200x30x30 cm<sup>3</sup>.

**Plasma Focus Research.** A 1.5-MA, 200/400-ns driving pulse produces neutron yields of 1.0E+10, which is a factor of 10 increase over the yields that result from 5- $\mu$ s pulses.

**Magnetic Insulation Research.** The INUS-4, a 14-stage, 2.5-MV, 200-kJ, air-insulated Marx generator drives magnetic insulation experiments a 2-m long, 30-cm OD, 12-cm ID magnetically insulated vacuum transmission line with pulses of several durations (3, 10, 100  $\mu$ s). They observe plasma motion at 1.0E+06 cm s<sup>-1</sup> that does not expand according to MHD theory. The research addresses the effect of long-duration ( $\mu$ s) pulses on anode and cathode plasmas, electron transport in magnetically insulated feeds, and the physics of electron beam diodes.

## Conclusions

The facilities at NIEFA, Kurchatov, and the Institute of High Temperatures are all of the same vintage and are beginning to show some age. The experimental apparatus appeared quite dated and the equipment in the machine shops appeared to be manually operated (no numerically controlled machine tools). However, the explosively driven switches and inductive storage systems incorporated in T-14 are state of the art and so is the carbon brush cathode laser excitation technique.

The exhibit room displayed models of the lasers, accelerators, and radiographic equipment NIEFA produces for medical and industrial applications. While their external appeared up to date, I do not know how their performance and price compares to equipment available elsewhere.

## References

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# The Institute of High-Current Electronics in Tomsk, U.S.S.R.

by Marco S. Di Capua

## Introduction

Academician G.A. Mesyats established the Institute of High-Current Electronics (ISE) of the Siberian Branch of the U.S.S.R. Academy of Sciences (Academy) in 1977. The ISE evolved from pulse-power research activities dating from the early 1960s at the Institute of Nuclear Physics of the Tomsk Polytechnic University (IAF-TPU) (Di Capua, 1990a) and moved to its present location at Akademgorodok in Tomsk in 1979.

Sergei P. Bugaev, a corresponding member of the Academy, leads the ISE's staff of 400 with 150 scientists which count among them: one more corresponding member of the Academy (B.M. Koval'chuk), 10 Doctors of Science (equivalent to a U.S. Ph.D. with several years experience and some publications) and 40 candidates, with Ph.D.-like training. Yu. D. Korolev is the Deputy Director.

In his welcome remarks, Bugaev described the initial research areas explored by Mesyats from the 1960s through the 1970s:

- Fast, high-power electrical discharges in gases, vacuum, and surfaces
- Nanosecond techniques for pulse formation at high powers.

The move to Akademgorodok in 1979 allowed a broad expansion of research programs for the decade of the 1980s. The following summary provides a bird's-eye view of the activities. In selected areas, this report discusses the facilities and research in more detailed sections below.

**Development of High Voltage, High Power-Pulse Generators.** Research on megavolt (MV) high-current switching, MV fast storage, transformers, and insulators leading to development of:

- A lineage of water dielectric energy storage, pulse-power generator with an intermediate store charged by a Christofilos-type induction linac source. The acronym for this lineage, SNOP, describes its application: High-Current Nanosecond Compression of Conductors. The ISE commissioned the latest generation, SNOP-3, in 1987 (R.B. Baksht and A.V. Luchinskii).
- A lineage of water dielectric energy storage pulsed-power generators with a pulse-forming line charged by Abramyan-type Tesla transformers. These generators, known by the acronym SINUS (High-Current Nanosecond Accelerator), drive

microwave generators in single and repetitive pulse modes. The ISE commissioned SINUS 7, the latest in the series, in 1989 (S.D. Korovin).

- A lineage of inductive energy storage pulse-power generators charged by low-inductance, Marx-bank capacitive stores. The ISE leadership identifies these generators by the GI acronym (Impulse Generator) while the scientists add a T to it (GIT, for Current Impulse Generator, B.M. Koval'chuk). The scientists and the leadership expect to settle on a single acronym by the beginning of the Beams-90 conference. GIT-16, the youngest member of the GI generation will hopefully operate, with one half of the modules in place, in December 1990.

## Research on Generation of Intense Charged Particle Beams.

- Electron and ion emission from steady and pulsed plasmas ( $1.0E+04 - 1.0E+05$  V,  $1.0 - 1.0E+3$  A,  $1.0E-06 - 1.0E-01$  s)
- Generation of large area particle beams ( $1.0E+03 - 1.0E+04$  cm<sup>2</sup>,  $0.1 - 50$  A cm<sup>-2</sup>,  $0.3 - 0.8$  MV,  $1 \mu\text{s} - 1$  ms pulses)
- Generation of hollow electron beams with magnetically insulated coaxial diodes to power microwave generators.

## Research on Generation of Intense Coherent EM Radiation at Microwave Wavelengths.

- Generation of cm microwaves by single and repetitively pulsed Multiwave Cerenkov Oscillators (MWCO). To deliver large RF power, MWCO research specifically addresses multimode operation of oversized devices (S.D. Korovin) in contrast with single mode devices studied at the Institute of Applied Physics (Department of Physics and Astronomy of the Academy) in Gorki. The RADAN sources (see below) power the small generators while the SINUS sources power the larger ones.

## Research on Generation of Intense Coherent Optical Radiation.

- Diffuse discharge laser pumping
- Electron beam laser pumping
- Investigations of new laser media
- Development of CO<sub>2</sub> and XeCl lasers.

## Research on Electrical Discharges.

- Vacuum discharges

- Diffuse high-pressure discharges
- Spark channels
- Exploding wires on SNOP-3
- Imploding liners on SNOP-3.

**Interaction of High-Energy Density Beams with Condensed Matter.** This research applies pulsed-power technology to expose dielectrics to particle beam and x rays. Research projects involve:

- Nonequilibrium phenomena induced in dielectrics through electron and x-ray exposure: short-lived relaxation phenomena ( $1.0E + 10 \text{ W kg}^{-1}$ ) and intraband luminescence
- Induced conductivity of subionic electrons
- Cold brittle fracture of dielectrics and crystals with low failure thresholds ( $10\text{-}100 \text{ W kg}^{-1}$ ; Vaisburd, 1988)
- Effects of high-energy density beams on condensed matter (Pogrebnjak, 1987).

**Technological Systems and Joint Projects Section.** Incorporates the results of research into systems and undertakes joint technology projects with other institutes. The products are:

- Compact particle beam accelerators for research
- X-ray generators for nondestructive testing
- Repetitively pulsed-particle beams for welding, soldering, and tempering
- Metal and gas ion sources for ion implantation.

## ISE Organization and Budgets

The formal ISE organization, as spelled out in the 1988 Akademgorodok directory, comprises six departments that divide into laboratories (leaders in parenthesis):

1. Electron and Ion Beams Department (S.P. Bugaev)
  - Electron beam laboratory (V.I. Koshelev)
  - Ion beam laboratory (G.P. Bashenov)
2. Pulse-Power Techniques Department (B.M. Koval'chuk)
3. Gas Lasers Department (Ju. I. Buichkov)
  - Low-temperature plasmas laboratory (Ju. D. Korolev)
4. High-Energy Densities Department (A.V. Lushinski)
  - High-energy densities laboratory (N.A. Ratahin)
5. Plasma Emission Electronics Department (P.M. Shanin)
  - Laboratory of continuous beams (S.I. Beliuk)
  - Engineering technical center
  - Optical sources group
  - Laboratory of vacuum electronics (D.I. Proskurovskii)
  - Laboratory of solid-state physics
  - Laboratory of physical electronics (S.D. Korovin)

- Theory (V.G. Bagnov)
- Electron source laboratory (V.F. Landl)
- Electron radiation technology laboratory (E.B. Yarklevich)
- Excimer source laboratory (I.N. Kononov)
- Data acquisition laboratory

### 6. Fabrication Department (V.Y. Borisov).

There is a Special Construction Bureau for High-Power Electronics attached to ISE consisting of:

- Laboratory for electron-ion beam technology
- Fabrication department
- Mechanical shops.

Senior scientists collaborate with Bugaev in key areas that reveal little overlap with the formal organization above:

- Fast energy stores (B.M. Koval'chuk)
- Megavolt range high-current switches (Yu. F. Potalitsyn)
- Opening switches and ion diodes (V. Bystritskii)
- GI-4 and GI-16 (B.M. Koval'chuk)
- Transformer systems (S.D. Korovin)
- Rep rate pulsed systems (S.D. Korovin)
- Low-temperature plasmas and beam processing (Y. Korolev).

Like most science budgets in the U.S.S.R., the ISE's annual budget is in a state of flux (see this issue, page 61, Science Funding, Organization, and Personnel in the U.S.S.R.). The ISE quoted a figure of 5 million rubles last year. This year, I heard a 4-million rubles figure. Last year, the Academy provided 1.6 million rubles and contracts with several ministries made up the balance. In dinner conversations, the ISE leaders spoke about a severe budget shortfall (consistent with a drop from 5 to 4 million rubles or even greater) that new contracts must cover. Taking a generous figure of 5,000 rubles for 1 man-year of labor, labor costs would amount to 2 million rubles leaving 2 to 3 million rubles for overhead and outside purchases.

## The GI Pulsed-Power Lineage at ISE

In 1981, B.M. Koval'chuk conceived a lineage of inductive energy storage, pulse-power generators charged by low-inductance, Marx-bank capacitive stores that continues to evolve to this day. The ISE identifies these generators by GI or GIT depending on who you talk to (see above). This report uses the GI identification that appears in ISE overhead transparencies and static exhibits.

The lineage incorporates Marina, Double (Anan'in, 1988), GI-4, and GI-16. Table 1 summarizes some of their characteristics.

Table 1. ISE Low-Inductance Accelerator Series - 72 kV charge

Generator/ Location	Num Marx	Time (ns)	Voltage (MV)	Energy (MJ)	Cap. ( $\mu$ F)	Cap. Unit	Ind. (nH)	Cur (MA)	I.t (Cb)
Marina(at IEP now)	3	1200	1	0.180	0.4	72	1350	.3	0.36
Doubl/TPI	4	1200	1	0.240	0.52	36	900	.43	0.52
GI-4/ISE	36	1200	1	2.17	4.8	1728	100	3.9	4.7
GI-16/ISE	144	1200	1	10.	19.2	6912	19	16	20

The dual role of these sources is to drive imploding plasma loads and to deliver, through auxiliary opening switches, MV, MA electrical pulses to bremsstrahlung diode loads.

### The GI-4 Facility at ISE

The GI-4, also known as GIT-4, operating since 1987, is the fourth generation in the GI generator lineage. GI-4 consists of four identical building blocks.

**The GI-4 Building Block.** This is a compact, low inductance (400- nH), oil-insulated, 500-kJ, Marx generator with an erected voltage of 1 MV. A parallel connection of 9 Marx units make up the building block. Each Marx unit in turn consists of a parallel connection of 4, 12-stage sub-Marxes ( $0.4 \mu\text{F}/12 = 33 \text{ nF}$  erected capacitance per sub-Marx). Nine units times (\*) four sub-Marxes per unit \* 33 nF per sub-Marx yield an erected capacitance of  $1.2 \mu\text{F}$  for the building block. In GI-4, four building blocks connect in parallel to a collector that feeds the inductive store.

**The Marx Unit.** The NK-100-.40,  $0.4\text{-}\mu\text{F}$ , 100-kV Marx capacitors have a polypropylene case. The cover-case seal is caulked. Two stacks of 12 capacitors facing each other, share a spark gap envelope and (+ -) charging resistors, forming half a unit. Ground is at the top and the high-voltage output is at the bottom.

To achieve a compact, low-inductance configuration, the spark gap electrodes distribute at a regular interval along a common, artificial air pressurized (1 to 2 bar), fiberglass-epoxy tube (the envelope) that runs the height of the Marx. For each stage, bolts that penetrate the walls of the envelope connect to spherical electrodes, facing each other across the diameter in the interior of the envelope. The fiberglass-epoxy envelope is the structural element that supports the weight of the capacitors when the Marx lifts out of the oil tank. Operators purge the artificial air after each firing.

Tubular polyethylene envelopes for two water-charging resistors (+ and -) run parallel on opposite sides of the spark gap envelope. Prongs, penetrating through the wall of the resistor envelopes, deliver the charging current to the capacitors. The three envelopes (spark gap envelope and charging resistors) define the symmetry plane of the two capacitor stacks that face each other. The stage-to-stage resistance of the electrolyte is  $1.0\text{E} + 03 \Omega$ .

This Marx design has several advantages:

- Compact, low inductance
- Small number of parts
- UV preillumination of the gaps for low jitter
- Reproducible operation.

The Gamma Marx, built in 1984, was the first version of this design. In a second version (three Marxes for Marina), the gaps had a polyethylene envelope. A third version for Marina incorporated the fiberglass-epoxy envelopes that are now standard. These envelopes, wound on a mandrel, provide dimensional stability to the gaps allowing very reproducible operation of the Marx.

In GI-4, four oil-insulated outputs at the bottom of the Marx feed a plate collector supported by an annular insulator with  $\text{SF}_6$  in the interior. The inductance of the Marx, up to the vacuum insulators is 100 nH (Bugaev, 1988). A 50-cm long stack of beveled insulators and gradient rings of conventional design (bevel facing the positive gradient ring) rated at 6 MV for 50 ns and 1.5 MV for  $1.2 \mu\text{s}$ , stacks on top of the collector plate. Resistors ( $800 \Omega$  each) connect successive gradient rings, dividing the potential across the stack. An interchangeable 44-cm long center conductor carries the current to the load.

Plasma sources for plasma opening switches (POS) lodge in the central region of an optional hollow annular flux excluder that projects in the vacuum, in the gap between the center conductor and the insulator. Bugaev (1988) provides a very brief description of GIT-4 and cross-sectional sketches of the accelerator and plasma guns.

**GI-4 Short Circuit Performance.** Table 2 displays the performance of GI-4 into a short circuit load (nnb, 1990; Bugaev, 1988).

**Table 2 Performance of GI-4 into a Short Circuit Load**

Erected Voltage (MV)	Current (MA)	Current (MA)	Energy (MJ)	Charge (kV)
0.48	2.1	1.7	0.55	40
0.72	3.2	2.6	1.2	60
0.96	4.2	3.5	2.2	80
tau/4 (μs)	1.6	1.9		
L(μH)	0.1	0.2		

**μs POS on GI-4.** The literature documents, to some extent, the unique μs POS efforts at ISE. (Di Capua, 1990b; Bystritskii, 1990?; Ryutov, 1990; nna, 1988). While a detailed discussion of POS is beyond the scope of this review, this section discusses selected applications within the context of research on GI-4.

**GI-4 Short Circuit Performance with POS.** To optimize the opening speed of POS, ISE performed experiments on GI-4 changing the anode-cathode configurations and the number of guns. Table 3 summarizes the results (nnb, 1990). The conclusions of the experiments is that POS open faster at higher current densities. Experiments with highly transparent rod anodes confirm these conclusions.

**Table 3 Plasma Opening Switch Experiments on GI-4**

Cathode Radius (cm)	Gap (cm)	Peak Current (MA)	Load Current (MA)	Risetime Into Load (ns)	Gun number
24	4	2.7	2.4	150	(?)
14	3.5	2.6	2.6	100	64
14	3.5	2.0	2.0	75	32(*)
14	3.5	2.0	2.0	50	32

(\*) Gun at oblique incidence

**GI-4 Liner Experiments.** One task of GI-4 is to drive imploding liners. A display in the laboratory projects gas puff liner currents up to 4 MA, liner velocities of  $5 - 9.0E + 07 \text{ cm s}^{-1}$ ,  $n_i = 3.0E + 20 \text{ cm}^{-3}$ ,  $T_e = 3 \text{ to } 5 \text{ keV}$ , 100 kJ of x rays below 3 keV and 30 kJ of x rays above 3 keV.

Experimental data with a POS in parallel with an imploding liner load shows a rise of the drive current to

2.7 MA in  $1.1 \mu\text{s}$  ( $di/dt = 2.5E + 12 \text{ A s}^{-1}$ ,  $V = 300 \text{ kV}$ ,  $L = 120 \text{ nH}$ ). The POS switch transfers 1.5 MA to the liner in 75 ns. The label of the power waveform I saw (3 TW peak) is inconsistent with the measured voltage at opening ( $V = 750 \text{ kV}$ ). A vacuum photodiode measures a 60-ns full width at half maximum (FWHM) x-ray output below 0.1 keV.

**GI-4 Experiments with Field Emission Diodes.** To deliver MV, MA pulses to field emission diodes, GI-4 also exploits auxiliary plasma opening switches to generate the high-voltage pulse. In this configuration, the GI-4 Marxes feed a 1.2-m long, 100- to 400-nH coaxial inductive energy store with an outer diameter (anode) of 0.21 m, and an interchangeable inner cathode. The interelectrode gaps are from 3 to 7 cm, depending on the cathode diameter. The inductance between the switch and the load ranges between 60 and 150 nH. (Bastrikov, 1989; p. 26) quotes 1.5 MV into a 5-cm gap diode at 600-kV erected voltage.

**GI-4 Experiments with Cascaded POS.** Since POS open more effectively with loads that draw large currents, Koval'chuk discussed schemes (Di Capua, 1990b; Koval'chuk, 1988) to cascade a plasma opening switch and a plasma-filled diode.

In early experiments, using plasma-filled diode loads with conical cathodes and axial plasma injection, a 480-kV Marx voltage delivered 2.1 MA to the switch and a peak current of 1.7 MA at 1.5 MV to the load.

In a more recent experiment, a 3-m long magnetically insulated vacuum transmission line (MITL) with a POS at the input replaced the plasma-filled diode. A short circuit terminates the MITL. In this operating mode, the opening of the first switch transfers a rapidly rising current pulse that opens the second switch in 10-ns time scales. Filtered positive-intrinsic-negative (PIN) diodes reveal bremsstrahlung from electrons with a 4-MV peak energy while measurements of the 10-ns risetime current pulse launched in the MITL suggest a 6-MV propagating pulse assuming the MITL operates at  $I_{\text{min}}$ . These results are very encouraging. However:

- The digitizers that logged the data had a coarse resolution (10 ns).
- The electrical length of the MITL ( $t_{\text{one way}} = 14 \text{ ns}$  at 0.7 c) is marginal to resolve the risetime of the pulse.
- There may be plasma growth on the MITL cathode which, by reducing the impedance, would cause the MITL to draw a larger current for a given voltage.
- I did not examine the data so I cannot judge the validity of the above observations.

**GI-4 POS Plasma Sources.** The GI-4 POS operates with two types of plasma sources: capillary and flash board. I believe that ISE uses capillary sources exclusively now. In

the ISE capillary sources, the inner conductor of RG 213-like, coaxial cable recesses into the polyethylene insulator forming a 1.3-mm diameter, 5-mm deep bore. A 10-kA pulse with a 2- $\mu$ s half-period feeds each of the 32 or 64 sources located externally to the outer electrode. A conference presentation by D. Getman and A. Kim reviews measurements of the plasma properties of these sources (Di Capua, 1990b).

**GI-4 POS General Observations.** Since the POS resistance drops dramatically for delay times longer than 1.5  $\mu$ s, the 1.2- $\mu$ s delay times required to allow the GI-4 Marx generator to attain are marginal to allow the POS to attain a high resistance after opening. In most experiments, the resistance stayed at 1  $\Omega$  or below. The experiments with the MITL load are encouraging. The data will have to undergo much scrutiny to show firmly the durability of the results and the applicability of the POS concept to feed field emission loads with inductive stores.

## The GI-16 Facility

The GI-16 is the newest member of the GI fast-Marx inductive energy store family. This facility, which will drive imploding liners and bremsstrahlung diode loads, expects to make extensive use, for power conditioning, of the POS technology developed on GI-4.

**GI-16 Energy Storage.** The GI-16 will have 16 Marx building blocks, same as the GI-4 blocks, in a 25-m diameter circle (16 x 9 x 4 x 12 = 6,912, NK-100-0.40 [0.4  $\mu$ F, 100 kV] capacitors). These capacitors could store 14 MJ at full voltage. Since the 12-stage Marx design voltage is 1 MV, the facility will store 10 MJ at a capacitor charge of 83 kV. The oil vacuum interface for each Marx building block is a 26-stage (15 mm per insulator) tapered stack of beveled insulators where inter-stage resistors provide the voltage grading. Beyond the interface, 16 horizontal, 4-m long, 22-cm OD, 16-cm ID, coaxial transmission lines (~1 MA each) feed the current to a 1.5-m diameter collector drum.

**Present State of the GI-16 Facility.** Construction progresses inside a building with a concrete roof supported by precast concrete trusses. As usual in such a facility, there is a rectangular diagnostic pit at the center. Construction began in 1987 and may be complete in 1991. The 16 Marx tanks are in place and the central part, including the POS, is in design and manufacture. While one insulator stack is installed, the openings and flanges for the other insulators were still absent when I visited. Capacitor deliveries, at the annual rate of 1,500, pace the progress of the facility. One half of the capacitors are in place so far, and Koval'chuk plans to begin operation with eight modules (one half of the facility) at the end of 1990. Technicians were installing diagnostic cables (RG-213-like) as I visited the facility in June 1990.

**Oil Storage and Handling of GI-16.** Exterior underground tanks store ~120 m<sup>3</sup> of insulating oil. Oil transfer from the Marxes to the storage tank will take place under vacuum; and under dry air pressure, from the storage tank to the Marx tanks. A 20-cm thick blanket of carbon dioxide will cover the free surface of the oil above the Marx generators.

Koval'chuk does not foresee problems with precipitation of moisture from the oil in winter. However, he foresees that enhanced viscosity of the oil at low temperatures will significantly increase the time required for oil transfer from the underground tanks to the Marxes.

**Expected Performance of the GI-16 Facility.** The bottom entry of Table 1 lists the electrical characteristics for the full GI-16. Projected outputs for imploding plasma loads are:  $V = 0.5 - 1.0E + 08$  cm s<sup>-1</sup>,  $n_i = 1.0E + 21$  cm<sup>-3</sup>,  $T_e = 3 - 10$  keV, 1 MJ of x rays below 3 keV and 100 kJ of x rays above 3 keV.

For the MV bremsstrahlung diode driver configuration, ISE expects to operate a POS at the central collector. The design of the switch will depend on the GI-4 scaling experiments.

## SNOP-3--a Water Dielectric Accelerator Charged by an Inductive Multi-Stage Linac Pulse Transformer

Commissioned in 1985, SNOP-3 (Kovsharov, 1987) is a two-stage water dielectric accelerator with a Christofilos-type inductive linac, pulse transformer high-voltage supply. The inductive linac configuration of SNOP-3 is very similar to the one of MODUL, described by El'chanikov (1982) and summarized by the same author (1987).

The primary windings of the inductive linac are 24 glycerine insulated, Permalloy-core cavities fed through coaxial cables by two NK-50-3 (50 kV, 40 nH, 3  $\mu$ F) capacitors switched in series (180 kJ). A glycerine-impregnated polyethylene film wrapping insulates the single turn (rod) secondary. This secondary, charges in 1.2  $\mu$ s, a 1.3- $\Omega$ , 75-ns water dielectric intermediate store to ~1.4 MV. The intermediate store launches, through a self-breaking, single-site switch, a ~1.1-MV pulse into a 0.65- $\Omega$ , 37-ns, pulse-forming line. This line launches a 0.75-MV peak pulse into the 45-ns, 0.65- $\Omega$  output line through self-breaking water switches that penetrate 12 openings in a metal prepulse isolation plate (Fedushak, 1988).

The stacked insulator of SNOP-3 is of conventional design (Ratakhin, 1988). The inductance of the insulator and vacuum feed is 30 nH. The SNOP-3 can deliver 1.4 MV into an open-circuit, 1.2 MA - 90 ns to peak into a short-circuit, ~1 - TW into a matched load. The April 1989 Laguna Beach, California, z-pinch meeting heard R. Baksht describe some of the SNOP-3 results.

It is possible that SNOP-3 was the imaginative technology developed at ISE for the ANGARA-5 module. Instead, the choice was a more conventional Marx generator approach (Di Capua, 1990c).

**Liner Experiments on SNOP-3.** Experiments with gas puffs and multiple wire array liners began in 1985. A vacuum prepulse switch isolates the multiwire arrays while gas puffs exploit the prepulse and flash boards for preionization (Baksh, 1988). A static display in the laboratory quotes gas puff liner currents up to 2 MA, liner velocities of  $4 - 6.0E + 07 \text{ cm s}^{-1}$ ,  $n_i = 1.0E + 20 \text{ cm}^{-3}$ ,  $T_e = 1 \text{ to } 3 \text{ keV}$ , 5 kJ of x rays below 3 keV and 0.5 kJ of x rays above 3 keV and  $16\text{-MW cm}^{-2}$  radiation fluxes at the wall of closed wire enclosures.

Typical liner parameters are  $45\text{-}90 \text{ mg cm}^{-1}$ ,  $r_{\text{initial}} = 5 \text{ mm}$  and  $r_{\text{final}} = 2 \text{ mm}$ , 100-ns run-in times. Current waveforms peak at 1.2 MA producing x-ray outputs of  $100 \text{ J ns}^{-1}$  in the 0.2 - 0.13-keV spectral range and  $40 \text{ J ns}^{-1}$  in the 0.29 - 0.135-keV range (Baksh, 1988).

Flux compression of a 1.5-T seed field with a highly preionized gas puff has yielded 4 MG, estimated through geometric compression (Ratakhin, 1988). Continuum emission overwhelmed the light of Zeeman-split lines intended for magnetic field measurements. The object of the field is to stabilize the z-pinch.

**Diagnostics on SNOP-3.** This includes x-ray and visible spectrum streak and framing cameras. The current sensors near the load display the same behavior as in other laboratories; that is, the signals clamp after peak current. This could be because of flashing of the insulator or a failure of the gap of the diagnostic.

**Bremsstrahlung Diodes on SNOP-3.** With a 1 MV, 0.5 MA diode SNOP-3 supposedly produces 30 kR.

## Repetitive Pulse Power at ISE

The ISE has a very active program on repetitive pulse power based upon oil-dielectric transformer technology.

**The SINUS Series Repetitive Generators.** In this lineage, a tapered Tesla transformer (Abramyan, 1971) charges an oil-dielectric energy-storage, pulse-forming line (PFL). The transformer core and a diaphragm-like insulating envelope of the  $\text{N}_2$  gas switch support the PFL. The accelerator shell and a conical insulator that separates the gas from the vacuum complete the envelope of the switch, supporting the output cathode stalk. El'chaninov (1987) discusses this transformer approach to PFL pulse charging in some detail.

Table 4 (nna, 1990) displays the characteristics of the SINUS generators:

In SINUS 7, commercial capacitors, with cases modified by ISE, discharge through thyristors across the single-turn primary of the transformer, charging the capacitance of the oil-insulated PFL in  $200 \mu\text{s}$ . The capaci-

tors and thyristors (installed on water-cooled heat sinks) distribute along the top of the tank of the accelerator. The primary voltage and current are 500 V and 100 kA, respectively. I do not understand the role of a partial ferromagnetic core described by other ISE visitors. The 1600 x voltage gain for SINUS L agrees with a  $\sim 3000$  x gain (4000 turn-transformer) for SINUS 7.

**Table 4. Characteristics of the SINUS Generators**

	Energy	Current	Rep.	Pulse
RITA 220	220 kV	0.7 kA	10 Hz	3 ns
SINUS M3	220 kV	0.7 kA	1 Hz	3 ns
SINUS 5	600 kV	6 kA	100 Hz	5 ns
SINUS 6L	800 kV	8 kA	1 Hz	25 ns
SINUS K	450 kV	4.5 kA	1000 Hz	25 ns
SINUS 7M	1500 kV	50 kA	Single	50 ns
SINUS 7	1500 kV	50 kA	50 Hz	50 ns
SINUS 8	200 kV	15 kA	400 Hz	20 ns

I understand SINUS 7 has fired about  $1.0E + 06$  pulses at rep rates between 1 and 10 Hz. The 50-Hz operation awaits the arrival of the 100-kW power supply. When I visited the laboratory, the connectors for the thyristor-to-thyristor, water-cooling links were open.

**The RADAN Compact Pulsed-Power Sources.** A spin-off of research and development at ISE (Special Construction Bureau for High-Power Electronics) and the Institute of Electrophysics, Sverdlovsk, (IEF) is the RADAN commercial line of small, repetitive pulse-power generators (Shpak, 1988a; 1988b). These  $\sim 20\text{-}\Omega$  generators reportedly deliver 100 - 300 kV rectangular 2 - 4-ns pulses with  $< 1\text{-ns}$  risetime leading edges at repetition rates up to 25 Hz. While I saw one of these generators at ISE hooked to a microwave generator and photographs for a commercial brochure, I have not seen the output waveforms yet. The Pulse-Power Laboratory of Texas Tech University, Lubbock, has one of this generators which, according to the staff (Kristiansen, 1990), works as advertised.

These generators rely on a pulse transformer in oil that charges a transmission line with  $\text{N}_2$  (40 bar) insulation. Synchronization takes place through laser-induced breakdown of an adjustable gap in the switch. The unit has two nested conical metallized ceramic insulators at the output. One supports the switching electrode while the other supports the cathode stalk.

The ISE expects this product line will be a commercial success--powering lasers; x-ray sources for nondestructive evaluation, sterilization, and polymer cross-linking; compact relativistic microwave generators, etc.

### Single Pulse Microwave Generation at ISE

**Cerenkov Oscillator Experiments on SINUS 6-L.** An annular, ~ 5-cm diameter, 400 to 700 keV, 3 to 8 kA, 25-ns beam has produced 10 - 15-ns, 100-MW pulses of 4-mm radiation with 4 percent efficiency (Korovin, 1988) and 500 MW at 8 mm with efficiencies approaching 20 percent in the Flimatron or traveling wave tube (TWT) configuration (nna, 1990). An Orotron (nna, 1990) configuration produces 120 MW of 8-mm microwaves with 3 percent efficiency. A BWO configuration (nn, 1990) produces 0.5 GW at 3 cm with 35 percent efficiency at 500-kV beam energy. Korovin (1988) describes slits in the central corrugated rod for mode control and conversion of coaxial-to-waveguide modes through a conical transition before the launch of the wave into space.

**Diagnostics on SINUS 6 L.** In this experiment, Ge hot electron semiconductor detectors and calorimeters measure microwave power and energy. Cut-off waveguides measure wavelengths and microwave excited gaseous discharges display the microwave mode patterns (Korovin, 1988; nna, 1990).

**Microwave Generation on GAMMA.** The 0.8-MJ Marx generator in GAMMA drives a diode directly, without pulse-forming elements: 1.4 - 1.6 MV, 3 - 50 kA, 1 - 1.5 μs, 1 MJ in the Marx, 30 - 140 kJ in the beam. An annular cathode produces a hollow electron beam (5- 14-cm diameter) within a magnetic field (1.4 - 3.2 T) that transports the beam through the 1.5-m long slow wave structure. This structure, which has no center conductor (unlike the SINUS 6 L configuration), consists of two periodic sections joined by a drift tube (nnc, 1990). Asymmetric magnet coils dump the electron beam upstream from a 1-m diameter dielectric lens that directs the microwaves into the atmosphere. The multiwave generator has operated in the multiwave Cerenkov generator mode (MWCG) and the multiwave diffraction generator mode (MWDG).

As Koshelev explained it, in a MWCG, the upstream and downstream sections of the slow wave structure are identical. The upstream section modulates the beam (backward mode) and the downstream section extract RF power from the beam in the "Pi" mode.

In a MWDG, the two slow wave structures supposedly are different and the second structure acts as a diffraction grating for higher orders.

Tables 5 and 6 (nnc, 1990) display the most important parameters of the MWCG and MWDG experiments. The data in the column (\*\*) may have appeared in a paper by Bugaev (1987).

Intriguing questions remain:

- Why is the microwave pulse so much shorter than the electrical driving pulse? One option is that the interaction may grow until the beam breaks up and is

lost to the wall. Another option is that microwaves penetrate into the diode region and disrupt the beam.

- What distinguishes the MWCG and MWDG generators of the table if the upstream and downstream structures have the same pitch?

Bugaev (1988a, 1988b, 1988c, and 1988d) discusses the Gamma experiments in some more detail.

**Table 5. MWCG Beam Interaction With the "Pi" Mode of Oscillation**

Period, 1st sec, (mm)	15	15	4	15
Period, 2nd sec, (mm)	15	15	4	4
Diameter slow. wv. str., (mm)	84	140	118	118
Radiation λ, (mm)	32	32	8.6-9.7	8.9-9.4
Diameter/λ	3	5	13	13
uw power (at generator), GW	0.2-5	5-15	1.5-3	0.6-1.3
uw power (atmosphere), GW	0.1-2.5	2.5-7.5	.75-1.5	0.3-0.6
P <sub>uw</sub> / P <sub>beam</sub> (%)	3-10	20-50	15-20	10-15
Pulse duration (ns)	60-600	50-100	70	20-60
		(**)		

**Table 6. MWDG Operating in the "2 Pi", "3 Pi", E01-E0m Mode**

Period, 1st sec, (mm)	4	7	15
Period, 2nd sec, (mm)	4	7	32
Diameter slow. wv. str., (mm)	118	118	84
Radiation λ, (mm)	5	6.5-11.3	2.3(?)
Diameter/λ	24	10-18	4
μw power (at generator), GW	-	2-9	-
μw power (atmosphere), GW	0.4-1.0	1.0-4.5	0.5-1.0
P <sub>μw</sub> / P <sub>beam</sub> (%)	5-10	8-33	10
Pulse duration (μs)	0.7-1.8	0.1-0.7	0.1-0.25

### Data Acquisition and Reduction at ISE

Computerized data acquisition and reduction (DA&R), while still rudimentary, are a top priority of the ISE leadership. Therefore, DA&R is undergoing very rapid development in anticipation of GI 16 operation. The ISE DA&R approaches couple well to data recorders available locally.

One diagnostic mainstay at ISE, as well as at other pulse-power laboratories, is the 6-LOR - TSCH M "1-GHz" oscilloscope. This oscilloscope incorporates three, 24-kV, cathode ray tubes (CRT) (2 beams each, 63 V per mm). Each CRT couples to one sweep generator (fast: 30-ns, 10-cm sweep; slow: 500-ns, 10-cm sweep) that can synchronize and time with the other two.

While a lens relays the image to 35-mm film, ISE has applied a digitizing camera (see below) to the 6-LOR. The 6-LOR oscilloscope appears to be standard issue at

the U.S.S.R. pulse-power laboratories I visited (Kurchatov-T. Jitsk Branch, ISE, and TPU).

Another recording device is the KOI-1, "7-GHz" oscilloscope which has a rugged appearance. Despite the -7 kV cathode voltage and the +25 kV anode voltage of the 1TVU-7 tube, this scope carries no ionizing radiation hazard warnings. The unit I saw had a 5- to 100-ns full-sweep (35 mm) plug-in. My ISE colleagues looked for the fast 0.5 - 2.5-ns full sweep plug-in (without success) to settle a debate whether the slowest sweep for the fast plug-in was 2.5 or 10 ns. The sensitivity is 0.6 V per mm. The connectors on the scope are equivalent to the "N" type series.

In one recording mode, the film makes direct contact with the oscilloscope face. In the computer data acquisition mode, a KTP-73 television camera with a high sensitivity LI-702 256 x 2048 charged, coupled device array acquires the trace (Yanchuk, 1988). This reference shows well-resolved oscillograms of a 10-GHz signal and a 0.5-ns risetime pulse.

Throughout ISE, the cables are RG-213 quality so the data reduction process for fast data must incorporate an algorithm to compensate attenuation at high frequencies. Time was brief so I could not discuss the compensation scheme in detail.

Diagnostic cables at ISE run in conduits that end with bulkheads. All cables are single shield RG-213 type. In some instances, I saw a flexible shield (Heliac outer-shield appearance) covering selected cables in experimental bays. Soviet colleagues said that this shield is a new product and Heliac-like cable is not available at present. I saw some N-type microwave attenuators. I did not see attenuators specific to pulse-power applications (Di Capua, 1986).

## Conclusions

The laboratories, buildings, and facilities of ISE are quite similar in size, layout, and equipment to facilities that perform similar research in U.S. or European laboratories.

I found, from a Darwinian evolutionary viewpoint, the ISE pulse-power approach fascinating. I suppose that the isolated maturation of ISE pulse-power activities (Tomsk was closed until 1989; Di Capua, 1990a) bred a very specialized diversity in the ISE approach to the solution of technical problems in energy storage, power conditioning, and particle-beam generation. Isolation from the more traditional Yefremov (Di Capua, 1990d) pulse-power concepts is also evident from the ISE approach to the design of the Angara module. Hence, the ISE pulse-power generator concepts are unique, not only in the international community but in the U.S.S.R. as well.

To complement their unique pulse-power approach (inductive stores fed by low-inductance, high-voltage Marxes), ISE has chosen to excel in understanding and developing plasma opening switches that operate in the microsecond domain (nna, 1988; Ryutov, 1990; Bystritskii, 1990?; Di Capua, 1990b). These developments in plasma opening switches capitalize on a traditional strength of ISE: the interaction of beams and plasmas.

There is a lively understanding of the interaction of high-power electron beams and electromagnetic fields at ISE. This understanding has stimulated the development of unique high-power microwave devices. Notwithstanding that microwave power measurements, and hence the efficiencies, could be off by factors of 2 or 3 (not unusual, even when very sophisticated diagnostics are available) the breadth, scope, and strength of ISE's program is unique. However, the short duration of the high-power microwave pulses may very well bear witness to the vigor of the electron-field interaction.

In informal discussions, my Soviet colleagues expressed curiosity about the proposal-writing process, funding mechanisms for science, and the uncertainties associated with U.S. research funding (Di Capua, 1990e). I was asked by several whether contracting agencies issuing experimental science grants required the delivery of a piece of apparatus. Scientists were somewhat puzzled to hear that the fondest dream of a contract officer may be a Nobel prize-winning discovery by his grantee. In its absence, a blazing trail of *Physics Letters* articles would have to do.

Prompted by my query on whether the GI-4 Marx concept had been patented or not, lively questions arose about the legal framework of intellectual property and patent rights in the U.S. and Europe. The scientists wanted to know who assigns the price to a patent. I believe I succeeded in explaining to them that the market does, through an informal bidding system when industry wishes to commercialize a patented concept or idea.

A recurring theme of our conversations was a common viewpoint that pulse-power development has now reached a plateau and that renewed growth must rely upon industrial applications (Yatsui, 1988). The interest of ISE in these applications is evident from 26 papers presented at a recent symposium (Fedushak, 1988).

However, there are still difficulties in finding an application niche for pulse power. I believe they agreed with the argument that commercial success of pulse power requires applications in:

- Processing of very high value-added products
- Unique processes that cannot be carried out any other way
- Processing of low value items with very large throughputs. Magnetic forming is one example.

Except for magnetic forming, commercial applications have been elusive. The ISE's approach to repetitive pulse-power systems poises them for a quick start at the gate should applications materialize.

There is quite a degree of uncertainty for funding of basic and applied science in the U.S.S.R. (Di Capua, 1990c). Besides cuts in spending for research with military applications, it is likely that science funding will shift from institutes to projects. Under these new circumstances, unique long-term approaches, such as those developed at ISE, may feel pressure to conform to short-term fashion. Consequently, the unique niche of pulse-power science and technology at ISE I have just described, could be at risk of disappearing before it bears fruit.

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# The Fifth International Conference on Megagauss Magnetic Field Generation and Related Topics - Megagauss V

by Marco S. Di Capua

## Introduction

Imagine a thermodynamic engine with magnetic flux as the working fluid held in a vessel that is a current loop. Consider the possibility of performing mechanical work on the magnetic flux by shrinking the loop with a high explosive. Such a process, through the law of conservation of magnetic flux, transforms mechanical energy released from the detonation of an explosive into energy of the compressed magnetic field that the loop can release as electrical energy into a load by interrupting the current; i.e., a normally closed electrical opening switch in parallel with the load. The loop or circuit, called a magnetocumulative generator (MCG), thus delivers submicrosecond electrical power pulses into a load at multi-TW power levels. Alternatively, these power levels are only attainable through very elaborate pulse power accelerators with dielectric energy storage.

The pulse generation process, also called magnetic flux compression, was the main topic of the Megagauss V Conference that took place in Novosibirsk, U.S.S.R., July 3-7, 1989. Opening switch work was discussed as well. A companion workshop dealt with plasma opening switches in great detail (see this issue, page 43, the International Workshop on Physics and Technique of High-Power Opening Switches). Other topics covered at this meeting were production of high magnetic fields, applications of high fields, codes, and modeling including conductivity at high temperatures and high-magnetic fields, experimental facilities, power conditioning, liner implosions, and electromagnetic launchers. I was disappointed that A. Pavlovskii, Kurchatov Institute, Moscow, and F. Herlach, Catholic University of Louvain, Belgium, were not present.

In this summary, I review the history of the Megagauss conferences and summarize the keynote papers. In like manner, I review some new developments on opening switches for MCG applications, staging of generators, disk generators, electron accelerators, betatron accelerators, table-top-sized MCG generators, and convolutes for current concentration. I discuss only a small cross section of presentations from a 5-day meeting. At the same time, I emphasize Soviet contributions.

The conference coordinated with visits to the I.V. Kurchatov Institute of Atomic Energy, Moscow, page 37; T-14 Tokamak, page 3; the Megavolt Pulse Power Accelerator Complex Angara 5-1, page 5; The Institute of

High Temperatures, page 39; and The Institute for Nuclear Physics, Novosibirsk, page 42. In this issue, I also discuss life in the U.S.S.R. (Notes About My U.S.S.R. Visit, page 50); provide useful suggestions for scientific travelers (page 52) and review Science Funding, Organization, and Personnel in the Soviet Union (page 61).

## Megagauss History

The Megagauss Conference series has a colorful history (Knoepfel, 1987) connected with the desire to prompt, within a plasma, in the laboratory, a pulsed thermonuclear reaction. Two better-known approaches involve lasers and particle beams. The third approach, the undercurrent of this meeting, is a combination of high explosives and electrical circuits that produce large currents (MA) for plasma heating and high magnetic fields (MG) for plasma confinement. While it became clear from the very beginning of flux compression research that this goal could hardly be reached in the laboratory, it was believed that its pursuit would motivate research in a new area: the physics of high-energy density.

This lofty thermonuclear fusion goal has since been scaled down as beam techniques (laser and particle) have taken the limelight as well as the lion's share of the research funding for laboratory scale pulsed fusion.

The first results were discussed in a meeting at Frascati (Rome, Italy) in 1965 (Knoepfel, 1966). The Enrico Fermi School on the physics of high-energy density at Varenna (Caldirola, 1969) followed the Frascati meeting and developed some of the topics more extensively. A 10-year hiatus intervened before Megagauss II in Washington (1979). Megagauss III took place in Novosibirsk in 1983, followed by IV in Santa Fe, New Mexico, in 1986, and the present 1989 Megagauss V in Novosibirsk.

## Keynote Papers

V. Titov, Lavrentyev Institute of Hydrodynamics, Novosibirsk, U.S.S.R., reminisced in the opening remarks of the conference about the early days of flux compression. He told us how fortunate we were to have among us Max Fowler, Los Alamos National Laboratory (LANL), Los Alamos, New Mexico, a pioneer in the field who has witnessed all Megagauss conferences.

Titov reviewed the challenges that flux compression still faces: more stable implosions and production of magnetic fields above 10 MG. Titov then took a look at what the future may have in store: currents of 100s of MA, field energies between 10 and 100 MJ, and delivery of  $10.0E+13$  W pulses to electrical loads using opening switches. Other challenges faced by the field, according to Titov, are: forming young scientists in an area that is absent from university curricula; complicated, dangerous, and costly experiments; and difficulties interfacing explosive methods to produce high-energy densities and sensitive atomic physics measurements in a high magnetic field environment. The rewards are producing sub-microsecond MV, MA pulses (using labor intensive, less capital intensive facilities), and producing super high magnetic fields in useable volumes that open new vistas in the physics of high-energy densities, and possibly studying materials at extreme conditions.

M. Dolotienko read A. Pavlovskii's keynote paper that began with a brief review of A. Sakharov's contributions to the field--his suggestion in 1951 to transform chemical energy into electromagnetic energy through high explosives leading to the production of megagauss fields. An often quoted, but unsubstantiated, field value of 25 MG came up in Pavlovskii's presentation. Dolotienko implied that this number was most likely below 5 MG, a "limit that is impossible to explain in usual terms." Dolotienko then emphasized the limitations on magnetic flux compression resulting from the mixing of conductor and magnetic field induced by the Rayleigh-Taylor instability.

Next, Dolotienko described a new twist in methods to stabilize a cylindrical MCG. In previously described work (Herlach, 1987) Pavlovskii suggested stabilizing the outer conductor (armature) by composing it of thin wires, in an axial direction, embedded in an epoxy matrix. The wires then fuse as the liner implodes. A variant is to have several layers of wires to add cool copper mass progressively as the liner implodes.

In another design, wires with a helicoidal pitch, form the inner conductor (stator). This rifling pitch (azimuthal current) produces an axial component of the magnetic field, in addition to the azimuthal component, that stabilizes the field-conductor interface.

Pavlovskii's presentation emphasized a useful design rule: instabilities set in and magnetic field energy cumulation stops when the energy density in the conductor and the fields become equivalent. To overcome this limitation, according to Pavlovskii, staging of generators results in a gain in efficiency. Staging cumulates energy slowly so higher energy density stages operate over progressively shorter intervals. Throughout his presentation, a magnetic field intensity that kept surfacing as a "durable" result was 6 MG at armature velocities of  $4 \text{ km s}^{-1}$ . Questions arose whether stable field conductor geometries could operate at the 10-MG level with gas dynamic cumu-

lation systems that could propel armatures at velocities of  $7 \text{ km s}^{-1}$  with initial fields of the order of 30 kG.

With a view towards the future, Pavlovskii described experimental areas where new results may arise: optical diagnostics, further developments of energetic explosives, use of gas guns or electromagnetic launchers to accelerate multiple projectiles that can form a ring, and compress the magnetic field pre-formed by a superconducting coil (Herlach, 1987), and work on low and super-low temperatures in high field regions. From Pavlovskii's viewpoint, the issue of stability of the field - conductor interface still looms quite large as it did almost 25 years ago (Knoepfel, 1966).

G. Shvetsov, Lavrentiev Institute of Hydrodynamics, Novosibirsk, delivered F. Herlach's review paper. This review paper emphasized facilities for DC or quasi DC high field research at the Oxford, Grenoble, Amsterdam, Toulouse, Louvain, and Tokyo research centers. D. Mitchell describes some of the European high magnetic field research facilities in recent articles (see ESNIB 89-08:42-43, 44-45; 89-09:38-40). Some of these facilities can attain 4 MG in useable bores.

### Opening Switches for MCG Applications

The Soviet literature has discussed opening switches that rely upon the compression of a plasma channel by a high explosive for at least a decade (Pavlovskii, 1977). At the last Megagauss meeting, P. Zubkov, Lavrentyev Institute of Hydrodynamics, also hinted at the same fact. N.V. Popkov discussed an explosively driven opening switch, ideally suited for experiments with annular energy stores. This switch opens by radial inward compression of the plasma against a higher density core by a cylindrical shock wave that raises the plasma resistance.

According to Popkov, the switch opens as the detonation products shock the plasma channel and the interface of the detonation products and plasma channel becomes unstable. Initiation of the detonation and diffusion of the detonation products into the plasma play an important role operating the switch.

In the conduction phase, the  $0.32\text{-}\Omega$ , 1.5-eV plasma annulus carries 15 MA currents at  $100 \text{ kA cm}^{-2}$  current densities,  $400 \text{ kA cm}^{-1}$  linear current densities with 20- to 200- $\mu\text{s}$  rise times. The switch opens to  $0.6 \text{ }\Omega$  in  $0.5 \text{ }\mu\text{s}$  (1 MV !) transferring the current with rise times of  $1.0E+13 \text{ A s}^{-1}$  to a  $0.16\text{-}\Omega$  load located at the centerline (see Figure 1). The geometry ensures that the final inductance is larger than the initial inductance.

In a following presentation, Popkov discussed the application of an MCG generator as a source for a short, high-voltage pulse to drive high-power vacuum diode loads. In this scheme, an MCG generator drives the primary of a pulse transformer. A coaxial, explosively actuated switch in the secondary opens to  $0.7 \text{ }\Omega$  in about  $0.5 \text{ }\mu\text{s}$ . (Note: The notation used by Popkov in his talk

could be confusing since  $7/10 \Omega$ , which could be interpreted as 7 to  $10 \Omega$ , was sprinkled throughout his visual presentation.) I interpreted this notation to be  $0.7 \Omega$  which is a higher impedance than the  $0.3 \Omega$  considered for the electron beam loads. The design goal is to deliver a 1.2-MV, 500-ns, 1-MA pulse into a matched load. The experimental results quoted in the abstract (100-kJ pulse of electrons at 35 GW) appear to be low in comparison with the design goals.

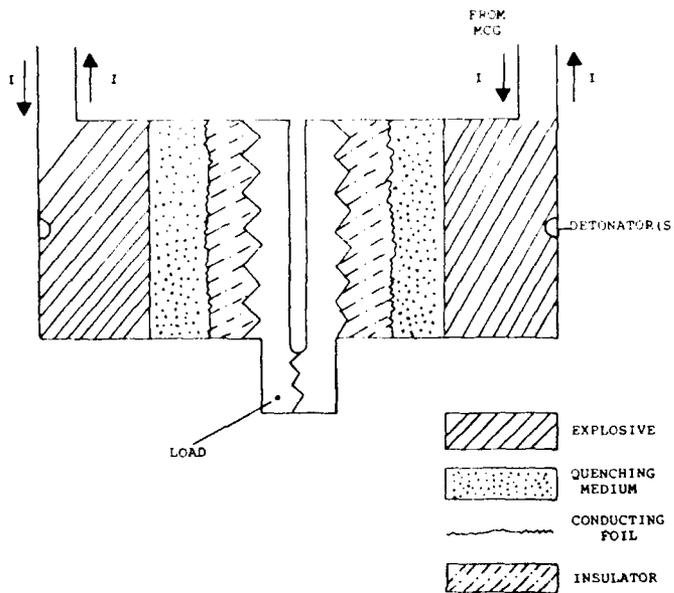


Figure 1. Explosively Driven Opening Switch

As in any scheme driven by an MCG generator, the biggest challenge is to match the generator and load impedances. Popkov hinted there were considerable difficulties in executing the experiment and suggested that a plasma-filled diode that draws a large current during the conduction phase of the switch may improve the efficiency of the system. Shorter pulses will require cascading of other switches like plasma opening switches (see this issue, page 43, The International Workshop on Physics and Technique of High-Power Opening Switches).

Answering a question of how often such experiments are fired, Popkov reiterated that flux compression experiments are very large, costly, and time consuming. Therefore, MCG research work must be considered within the context of other pulse power research.

V.K. Chernyshev's group at Kurchatov, has obtained good experimental measurements on current interruption in explosively formed fuses. V. Ivanov discussed switching by foils pushed by explosives against ridged dielectrics that transferred 3 MA into a 50-nH load within  $2 \mu\text{s}$  at a current density of  $0.2 \text{ MA cm}^{-1}$ . According to one participant, Ivanov's described designs and techniques originally developed by J. Goforth, LANL. In

other experiments, the group tested a switch with radial current flow where self-regulation improves the azimuthal uniformity of current density.

### Staging of Generators

The goal of generator staging through transformer coupling is to deliver TW electrical pulses to useful electrical loads ( $\sim 500 \text{ kV}$  and above). Staging of generators through transformer coupling was suggested for the first time in the literature in 1969 (Cummings, 1969). At this conference, Popkov discussed a two stage switched explosive generator. In a first stage, a 7-MA, 20-kV generator with a  $7\text{-}\mu\text{s}$  run time powers a second stage with a 4-MA output current, a 300-kV voltage and a  $1\text{-}\mu\text{s}$  run time. The load for this generator is a plasma-shortened vacuum inductor. The shorting plasma in this inductor opens in 20-40 ns providing a 2-MA, 100-ns, 600-kV pulse in a 30-nH load.

Another staging scheme discussed in some detail consists of four generators loaded in parallel and discharged in series. The series connection loads four more generators in parallel which then discharge in series. To obtain larger power multiplications, Pavlovskii suggested the application of plasma flow switches that would open under the pressure of the magnetic field in the energy store.

E. Zharinov discussed in some detail the differences in efficiency between coupling of cascaded systems with flux transformers and flux traps. Zharinov concludes that cascaded systems that rely on flux traps for coupling are more efficient than transformer coupled systems. Pavlovskii and Chernyshev feel that the flux traps, which are very dear at Kurchatov, have had little acceptance in laboratories in the West.

The future, according to V.K. Chernyshev, lies with staged connections of generators that drive switches that open in ns timescales producing very large electric fields that could launch powerful electromagnetic waves.

### Disk Explosive Magnetic Generators (DEMG)

In a session of the conference devoted to DEMGs, Chernyshev discussed basic scaling relationships for helical generators that limit their performance to currents of a few MA, cumulation times of a few tens of  $\mu\text{s}$ , and current rise times of  $1.0\text{E} + 12 \text{ A s}^{-1}$ . An examination of the scaling relationships suggested that disk generators may produce current pulses of 100s of MA with current rise times in the  $1.0\text{E} + 12 - 1.0\text{E} + 14 \text{ A s}^{-1}$ . Two Russian papers at Megagauss III that described DEMGs went unnoticed by the U.S. technical community.

These advantages are possible by a clever exploitation of: the  $r^{-1}$  dependence of the magnetic field; an extra degree of freedom afforded by a radial distribution of explosive (axial thickness as a function of radius); tailor-

ing of the magnetic flux area elements as a function of radius; and the potential ability to cascade an arbitrary number of stages on a common axis.

The main drawbacks of the DEMG configuration are: the tight machining tolerances of thin shells of complex shapes (to accommodate the radial distribution of magnetic flux); precision surface finishes to prevent jetting; precision casting of explosives with complex shapes to minimize flux losses; and voidless castings to circumvent the danger of explosive detonation through the impulsive current loading of downstream stages.

A 3-module, 1-m diameter disk amplifier (V.A. Shevtsov, Kurchatov) loaded with 50 kg of Composition B explosive per disk, takes a  $3.0E+11 \text{ A s}^{-1}$ , 12-MA, 40- $\mu\text{s}$  seed current pulse from a helical generator into a 110-nH initial inductance and delivers 256 MA at  $2.0E+13 \text{ A s}^{-1}$ , in a  $1.0E+13$ -W pulse into a 3-nH load with a current amplification of 20 and a power amplification of about 30. Another design by A.S. Kravchenko delivered 100 MJ, 10 TW, and 80 MA into a 15-nH load.

The DEMG designs, however, must be viewed with some skepticism. To attain the low final inductance, the DEMGs inductive loads are at large radii. Consequently, DEMGs require power conditioning through a combination of transformers, opening switches, and convolutes to deliver useable electrical energy into a load. R. Reinovsky, LANL, has examined the Soviet DEMG designs presented at Megagauss V and discusses results of hydrodynamic modeling coupled to Los Alamos first principles fuse models (Reinovsky, 1990).

### Megagauss Fields and Electron Accelerators

Ideas to exploit MCGs for particle acceleration are almost as old as the MCG field itself. According to Popkov, A. Sakharov had proposed to apply an MCG to create an ironless pulsed betatron, and the production of MV, MA electron beams has been an important goal of the effort at LANL. However, practitioners of the field acknowledge that the stumbling block in this application is to match the sub-m $\Omega$  impedance of the MCG with the  $1\Omega$  or so impedance of the accelerator.

V. Panasyuk, All-Union Research Institute of Optical and Physical Measurements, Moscow, discussed the applicability of MCG generators as power sources to perform experiments on the interaction of synchrotron radiation with matter in very high magnetic fields. The question raised by Panasyuk is whether it is possible to use the same MCG source to power the betatron accelerator/synchrotron radiator and the field coil.

Panasyuk discussed a synchrotron light source (see ESNIB 90-01:36-39 for a superconducting racetrack magnet, RF-drive design) where a rising betatron magnetic field accelerates electrons that orbit stably within a single turn coil with spherical inner walls. A gap in the coil allows synchrotron light, emitted in the tangential direc-

tion, to escape. This configuration (first proposed by Hill in 1944 and discussed in Panasyuk, 1972; Pavlovskii, 1976) forms a trap in the central region. A capacitor-driven coil source ( $36 - 3\text{-}\mu\text{f}$ , 50-kV capacitors) accelerates  $1.0E+10 - 1.0E+11$  electrons in  $3\mu\text{s}$  to 120 MeV producing x rays in the 30-250-nm wavelength range. The source could produce a few hundred watts of UV or dozens of kilowatts of x rays. I believe the MCG driven device has not been implemented yet and I could not judge the extent of implementation of the capacitor-driven concept.

### Tabletop MCG Generators

Popkov described an interesting single turn generator to power z-pinch and theta pinch experiments. The generator appears in Figure 2. The HE charge is off-center and the coil, as shown in the figure, is asymmetric. This configuration allows the armature to short out the seed current source (through the pins at the left) and provides a rapidly rising current at the end of the cumulation process (wider conductor at the right). An optional explosive coaxial switch shunts the current to the plasma load. The design permits a parallel connection of two or four units.

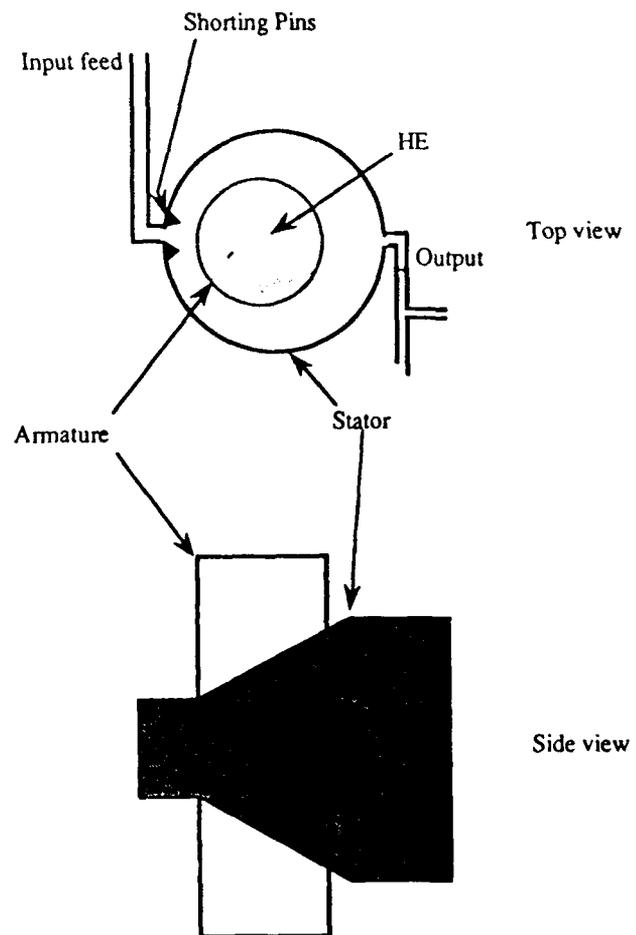


Figure 2. The M-10MJ, 10-MA Pavlovski Generator Described by Popkov

Popkov briefly mentioned:

- Compression of a thin, 50-mm long, 25-mm diameter metal liner in 10  $\mu$ s with a 10-MA pulse where he measured the voltage across the liner and the current and voltage derivatives.
- Parallel connection of several MCG through cables to an explosive switch cascaded with a plasma switch to drive a 10-mm long, 1-mm diameter capillary z-pinch. Popkov quoted a peak current of 6 to 7 MA and a 500-ns, full-width half-maximum 1-MV spike at a 4 - 5 MA current level implying power levels of 5 TW.
- A theta pinch configuration driven where the liner is a thin metal deposit on the wall of a quartz chamber. This liner can compress the embedded field that leaks into the center early in the pulse. These experiments were also performed at the MA,  $\mu$ s level.

### Convolute Theory

Convolute is a term adopted by I. Smith and P. Spence (formerly Physics International), Pulse Sciences Incorporated, San Leandro, California, in the mid 1970s to describe conductor configurations that allow the geometrical convergence of electrical power pulses with a minimum inductance penalty in the final stage of pulsed power accelerators. G. Schneyerson, M.I. Kalinin Leningrad Polytechnic Institute (LPI), Leningrad, discussed results of a systematic study of convolutes with the goal of determining the current density distribution of pulsed currents in complicated conductor geometries. The current distribution establishes the magnetic field configuration and hence the inductance of the conductor configuration. Schneyerson calculates the inductance of many practical configurations for pulsed power design such as scalloped conductors, inductance contributions of slots, field configurations of slots, holes. These results are even more important in current feeds operating at electric fields above 250 kV cm<sup>-1</sup> where field emission becomes possible and where the magnetic field, through magnetic insulation, is expected to prevent electrons from crossing the gap between the conductors.

Schneyerson at LPI, he has published papers on high current, low inductance, current feeds and has written a book on this subject: *Fields and Transient Processes in Equipment of Ultrapowerful Current*. Schneyerson appears to have a powerful visualization ability for the three-dimensional current distributions in complicated geometries and knows how to formulate analytical estimates for the inductances arising from the current distributions. This ability probably results from his interest in generating pulsed magnetic fields (to 400 T) using small coils (a few mm) and MA,  $\mu$ s currents.

A chapter in a recent book (Kushinskii, 1987) captures the flavor of Schneyerson's group work on capacitors, cables, spark gaps, cable conductors, and inductance calculations for impulsive current generators.

### Loads for MCG Generators

The meeting was exceedingly disappointing in this area. Abstracts and authors mentioned loads only in passing and there was no indication of success or failure in driving them.

### Other Contributions

- Production of MG fields by adiabatic compression of tori launched by coaxial rail gun accelerators at the Air Force Weapons Laboratory in Albuquerque, New Mexico, and at Lawrence Livermore National Laboratory (LLNL) (Hartmann, 1989).
- Pulse power from helical generators to drive plasma foci (Bocur Novak University of Bucharest, Romania).
- An intriguing question on the dependence of the resistance of a metal on the history of loading (S. Sashkina, Efremov).
- Production of MG fields in 30- $\mu$ m thick frozen D<sub>2</sub> or DT fibers carrying 250-kA currents in 125- $\mu$ m radius channels. New experiments at 1.2 MA in a 5-cm long fiber driven with 200 kJ could produce a 10-keV plasma at 6.0E + 28 m<sup>-3</sup> (D. Scudder, LANL).
- Plasma flow switch calculations (R. Bowers, LANL).
- Design, precision fabrication methods, and testing of helical flux compressors (P. Pincosi, LLNL).
- Optimization of helical generators (A. Pavlovskii, Kurchatov).
- Modeling of exploding metallic fuses for current interruption (I. Lindemuth and R. Reinovsky, LANL).
- Two-dimensional behavior of megagauss-field-confined solid fiber z-pinches (I. Lindemuth, LANL).
- Disk generator developments (C. Fowler, LANL).
- Flyer plate experiments (J. Osher, LLNL).
- EM gun experiments (R. Hawke, LLNL).
- Megagauss fields in the Saturn accelerator (R. Spielman, SNLA).
- Opening fuses for flux compression generators (I. Lindemuth and R. Reinovsky, LANL).

## Conclusions, Recommendations, and Unanswered Questions

As a Russian speaker, I found the monotonous, barely inflected Russian of many the presentations inappropriate for an audience that had traveled to the center of Siberia from afar to attend this meeting. Many Russian speakers showed little regard for the superhuman efforts of the interpreters who attempted to render complicated technical presentations from Russian into English. The survey talks were particularly poor in this respect. Ineffective session chairmen, prodded by some participants, attempted to rein in the speakers, improving matters for only a few seconds at a time. A large fraction of sparse visuals with cyrillic captions wisped ephemerally on the screen. Short and barren abstracts exacerbated comprehension problems. Moreover, according to participants who had attended previous Megagauss meetings, many Soviet talks described work that had been previously reported on (see references to previous work in this report).

I strongly urge that for future gatherings, all participants take the time to produce short presentations and clear transparencies where the research motivation, methods, and new results are clearly stated. This approach will give the interpreters a chance to convey the substance of the research, and newcomers in the audience a chance to distinguish the new from the old.

The leadership of A. Pavlovskii and V.K. Chernyshev strongly flavors the research at the I.V. Kurchatov Institute of Atomic Energy (see this issue, page 37, I.V. Kurchatov Institute of Atomic Energy, Moscow, U.S.S.R.), which performs a significant fraction of the Soviet research on MCG generators. A full third of the presentations at MG 5 were from Kurchatov.

I have enormous difficulty assessing the Kurchatov results not having examined the Kurchatov facilities in detail. As a practicing physicist, I am curious about:

- Diagnostic techniques that produce almost textbook wave forms (steady baselines, unclamped current wave forms, clean voltage wave forms)
- Opening switches that appear to defy our humble understanding of basic plasma processes
- Complicated layers of multiple conductors that are immune to the jetting that is observed in the shock compression processes of smooth shells
- The size of their effort and the turnaround time of their experiments
- Their success in coupling such energy rich systems to ICF targets.

Maybe, as glasnost ripples through science, we will be afforded a better understanding of their almost magical experimental powers through a visit to experimental facilities and direct, face to face, on-site discussions with our Soviet scientific counterparts.

At this moment, large-scale applications of flux compression await development of pulse transformers and opening switches that can match sub-m  $\Omega$  impedance sources to more  $\Omega$ -like loads.

## Acknowledgements

I single out Max Fowler, Irv Lindemuth, R. Spielman, and T. Goforth for cordial technical discussions as I wrote this report. Notwithstanding these discussions, I assume full responsibility for the article's contents.

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# The 20th European Conference on Laser Interaction with Matter

by Marco S. Di Capua

## Introduction

The 20th European Conference on Laser Interaction with Matter (ECLIM) took place in the village of Schliersee, southern Bavaria, Federal Republic of Germany (FRG). Exceptionally, this year's meeting coordinated with two other meetings: The 5th International Workshop on Atomic Physics for Heavy Ion Fusion and Hirschegg 1989 (ESNIB 89-08:54-70) of the European Heavy Ion Fusion research groups.

Unlike the 19th ECLIM Madrid meeting (October 3-7, 1988), that took place in the political wake of the 8th Session of the International Seminar on Nuclear War (Erice, Italy, 22-26 August 1988), the atmosphere at this ECLIM was unusually subdued. Conjectures about the U.S. Department of Energy (DOE) Nevada Test Site underground test aspects of the Halite-Centurion inertial confinement fusion (ICF) program in Erice produced cries for international cooperation in ICF. The cooperation issue reawakened 6 weeks later at the 19th ECLIM culminating with the formulation of the "Madrid Manifesto," sponsored by G. Velarde, Nuclear Fusion Institute, Madrid Polytechnic University, that formally called for a personal commitment from ICF scientists to international cooperation in the ICF field.

The maturation of the laser-matter interaction field in Europe continues to be evident at this ECLIM and the flavor of the meeting was deservedly European, with noticeable Soviet and Central European participation, and a strong emphasis in areas of laser-matter interaction other than ICF. Participation from DOE National Laboratories was limited to overview talks. The few participants from DOE-sponsored laboratories shied away from detailed questioning or detailed technical discussions throughout the oral and poster sessions. Significant exceptions were the Naval Research Laboratory (NRL) contribution (R. Lehberg) on optical beam smoothing techniques for direct drive ICF; a discussion on Raman back scattering, R.P. Drake, University of California, Davis; laser-matter interaction experiments at  $1.0E + 17 - 1.0E + 19 \text{ W cm}^{-2}$  irradiance, G. Schappert, Los Alamos National Laboratory; and a presentation on KrF lasers, S. Coggshall, Los Alamos National Laboratory.

## U.S.S.R. Contributions

U.S.S.R. Laser Facilities for Laser-Matter Interaction Research. N. Kovalsky's, I.V. Kurchatov Institute of Atomic Energy, Moscow, overview of the status and perspective of laser research in the U.S.S.R. began with a description of the lasers that are available for laser-matter interaction experiments. These are:

- DELFIN - Lebedev,  $1.06 \mu\text{m}$  Nd-glass, 2 kJ/2 ns, 2 TW, 1 beam
- MISHEN - Kurchatov,  $1.06/0.53 \mu\text{m}$  Nd-glass,  $30 \text{ J}/0.3 \text{ ns}$  (diagnostic),  $300 \text{ J}/3 \text{ ns}$  (main), 0.1 TW, 2 beams
- TIR - Kurchatov,  $9.4/10.6 \mu\text{m}$  CO<sub>2</sub>, 0.5 kJ, 1 beam
- TIR X - Kurchatov,  $0.308 \mu\text{m}$  XeCl, 100 J, 30/3 ns, 0.25 TW XeCl, e-beam pumped system
- KAMMERTON - Institute of General Physics (IGP),  $1.06/0.53 \mu\text{m}$ , 0.1 kJ, 1 beam (Bulatov, 1979)
- UMI 35 - IGP,  $1.06 \mu\text{m}$  Nd-glass slabs
- PROGRESS - S.I. Vavilov Institute of Optics, Leningrad,  $1.06 \mu\text{m}$ , 1 kJ, 3 TW, 6 beams
- ISKRA 5 - All-Union Research Institute of Experimental Physics (AURIEP),  $1.3 \mu\text{m}$  Iodine, 30-kJ, 0.25-ns, 120-TW,  $60 \mu\text{rad}$  divergence,  $1.0E + 6$  energy contrast, 12 beams
- SOKOL -  $1.06 \mu\text{m}$  Nd-glass, 0.3 kJ, 0.3 TW, 24 beams.

Research activities on these facilities are:

- DELFIN - Spherical ICF target implosions: diagnostics development
- TIR - Laser-plasma interactions: hot electrons, stimulated Brillouin scattering (SBS), stimulated Raman scattering (SRS), self-focusing
- TIR X - Excimer laser technology development
- KAMMERTON - Laser-plasma interaction, equations of state (Ageev, 1988), spontaneous magnetic field generation, SBS, and SRS processes
- UMI-35 - A Nd-glass test bed for the 200 kJ laser system designs

- PROGRESS - Uniformity of target illumination; test bed for oscillator and pulse shaping systems for the 200-kJ laser system design
- SOKOL - Automatic alignment system, study of engineering issues associated with the 200-kJ, 24-beam laser system design
- MISHEN - Plane foil target acceleration, Rayleigh-Taylor instability, hydrodynamic efficiency, and equation of state (EOS) studies. According to Kovalsky, experience in the last 10 years with the Mishen and UMI-35 facilities has led to the conclusion that flat elements (discs) perform better than slabs (at the Brewster angle) in large aperture amplifiers. Therefore, they have ground the edges of the Mishen slabs, reconfiguring them as 75- and 100-mm disks. In a sequence of two slides, we first saw the Mishen original slabs previously used on Mishen, followed by a slide of the new disk amplifiers
- ISKRA 5 - Neutron source in reverse "corona" configuration, VUV and x-ray lasing stability, and efficiency of spherical implosions. This 12-channel facility, which has been under construction 7 years, has just delivered its first 120-TW, high-power pulse (December 1989). The layout of the system is very conventional: the pulse from the oscillator, after division into 12 equal parts, feeds 12 five-stage identical amplifiers (therefore ISKRA 5). 1- $\mu$  flash lamps pump the first stage, an open discharge pumps the last two with a total capacitive energy storage of 60 MJ at 50 kV. The atmospheric pressure fill is C<sub>3</sub>F<sub>7</sub>I, Xe, and CO<sub>2</sub>. The diameter of each stage increases by a factor of two with a signal input close to saturation level. Spatial filters and bleachable dye filters couple successive stages. The third amplifier has a beam aperture of 0.19 m and the output amplifier has a 0.7-m aperture and 8 m of active medium. ISKRA 5 delivered a 100-TW pulse "to the wall" in December 1989 with 60 percent efficient conversion into the second and third harmonics through KDP crystals. Kovalsky expects the first target experiments in November-December 1990.

**The 200-kJ Laser System.** Kovalsky then discussed two schemes for the module of the 200-kJ amplifier. One scheme is a glass 20 channel classical master oscillator power amplifier (MOPA) scheme. The Mishen or Progress configurations, designated as "320" with 45- or 100-mm rods would be adequate as preamplifiers. Two configurations of disk amplifiers are under consideration for this scheme: one is composed of a stack of four, two-segment active elements with a cross-sectional dimension of 50 x 50 cm<sup>2</sup> operating at a energy density of

6 J cm<sup>-2</sup> (1-ns pulse) at the output for a total of 10 kJ feeding a KDP frequency doubler at an energy density of 4 J cm<sup>-2</sup>. The other is a stack of four, four-segment elements (32cm x 32cm) giving a total area of 4E + 03 cm<sup>2</sup>.

**Phase Conjugation and the 200-kJ System.** A second scheme championed by the State Institute of Optics and the Kurchatov Institute incorporates wave front reversal (WFR) cells also known as phase conjugate mirrors and output pulse compressors. Seminal ideas on wave front reversal arose in the U.S.S.R. (Zeldovich, 1972) and Wang proposed their application to laser fusion a couple of years later (Wang, 1978). Readable overviews of phase conjugation have appeared periodically in the literature (Giuliano, 1981; Feinberg, 1988).

Kovalsky described a laser scheme that has undergone experimental tests at the State Institute of Atomic Energy. A TEM<sub>00</sub> oscillator (30ns FWHM) feeds an amplifier whose output focuses (50cm focal length) onto a 15-bar, SF<sub>6</sub> gas cell (80 percent reflectivity). The beam, returning from the WFR is reamplified, undergoes spatial filtering, and splits into 9 beams that are individually amplified and focused (260 cm focal length) onto nine-300, cm-long SBS WFR pulse compressors. The splitter, now acting as an adder, collects the beams into a 4-J diffraction limited output beam with a FWHM of 2 ns. Experimentally, a balance of input energy in different beams and a choice of the appropriate compression regime provide a jitter of the beams that is less than the rise time of the 9 individual pulses.

A natural extension of this approach, to boost the output to a 10-kJ, 3-ns pulse, is presently under study. In this approach, the reconstituted beams from the stage described above, in a second stage, would undergo: an 81-fold split, individual amplification, WFR, reamplification, and reconstitution. A third stage would split the output of the second stage 729-fold, amplify the beams, feed them through Fresnel prisms into WFR SBS compression cells, reamplify them, and recombine them into an output beam. Judging simply from the number of components, this appears an awesome task for 10 kJ of output energy.

Notwithstanding the number of beams and components, Kovalsky believes that this approach has some advantages:

- Long-pulse, low power density operation up to the compression cell
- Efficient operation because of long-pulse, double-pass amplification
- Pulse shape control through introduction of variable delays
- Uniform illumination of the target because of spatial incoherence of the individual beams.

**Overall Strategy of the U.S.S.R. Laser Program.** From an overall strategy viewpoint, Kovalsky considers that excimer lasers are the only gas laser that can be considered now as a driver of future ICF reactors. However, excimer laser technology at present is not sufficiently developed to compete with Nd-glass lasers. Consequently, there are no doubts in his mind that Nd-glass lasers are presently (and will be in near future) favored to carry out experimental investigations of the laser-matter interactions up to 100- to 200-kJ energy levels. However, it is also clear that such large scale facilities are ill-suited for detailed investigations of physical processes (there is insufficient flexibility to change experimental and to develop new diagnostics, and the shot rate is too low).

Therefore, since facilities with energies in the 1- to 10-kJ range are the best to perform physics modeling experiments, the direction of U.S.S.R. laser technology development is to build several glass and/or excimer laser facilities in the 10-kJ class, minimizing risks through a sequence of small technological steps with the expectation that such facilities will be built regardless whether the 200-kJ system gets the go-ahead. Moreover, several glass facilities would be sufficiently agile, in comparison to a larger one, to foster progress in the physics front.

Kovalsky believes that the decision of the Kurchatov, Lebedev, IGP, AURIEP, Vavilov, and Yefremov (NII-EFA) Institutes to join forces and start the 200-kJ glass laser project facility, with NII-EFA (see this issue, page 14, D.V. Yefremov Scientific Research Institute of Electrophysical Apparatus, U.S.S.R.) as a system integrator, is a major achievement of the last 2 years since these institutes had to vault strong disagreements.

In summary:

- The U.S.S.R. has begun the design of a 200-kJ glass laser system with NII-EFA as a system integrator
- At present, research is proceeding at:
  1. I.V. Kurchatov Institute of Atomic Energy - large amplifiers
  2. P.N. Lebedev Institute of Physics - Prism type large scale active mirrors and intensive studies of powerful ps pulse solid-state laser system
  3. State Institute of Atomic Energy - Alternative schemes with composite active elements incorporating WFR cells and output pulse compressors
  4. All-Union Research Institute of Experimental Physics - Adjustment operations were conducted in March 1990, and 100-TW laser pulse were obtained on the ISKRA 5 12-beam photo-dissociative iodine laser

- Cooperation of European countries in development of large-scale lasers can considerably accelerate the progress in Laser Fusion.

**Nonlinear Optics For High-Power Lasers.** G. Pasmanik, Institute of Applied Optics, Gor'kiy, discussed research on phase-locking of multiple channel amplifiers through nonlinear optics. The concept appears schematically in Figure 5 of Giuliano's article (Giuliano, 1981). In Pasmanik's scheme, the output of an optical fiber illuminates the wall of the cavity containing the pellet. Reflected light from the wall exits through a small aperture in the wall of the cavity (an aperture that will become the entrance pupil for the returning high-power beam), and enters the high-power amplifier chain after collection through the final focusing lens. Phase conjugation takes place after amplification ensuring autofocusing of the amplified laser beam through the small aperture in the cavity wall after the return pass through the amplifier chain.

The success of this scheme depends on phase conjugation of signals with a large gain. The SBS is the choice method for phase conjugation which also allows time compression of light pulses, thus circumventing the transverse instability of light beams that arises by self focusing. Moreover, SBS's threshold nature prevents self excitation of the amplifier chain. In his presentation, Pasmanik discussed phase conjugation of the output radiation from multichannel systems built from low-grade optical elements, and pulse compression that yields the maximum energy extraction efficiency from the amplifying medium. Pasmanik's didactic presentation considered a projected system only and the data in his paper is the projected cost (U.S. \$0.5 million) for a 10-kJ system. (No ruble to dollar conversion rate given!). Pasmanik's references describe experimental testing of a two-beam, phase-locking arrangement for single (Pasmanik, 1989), and repetitive pulses (Andreev, 1990?). V. Sidorin, GPI, also reported on SBS pulse compression in solid-state lasers at 19 ECLIM (Paper P 2-6). Pasmanik is organizing a nonlinear optics school in Prague in collaboration with L. Pina (see this issue, page 126, X-Ray Diagnostics and Laser Research at the Nuclear Science and Engineering Physics Faculty, Czech Technical University in Prague).

**Applications of Lasers to the Study of Thermodynamic Properties of Matter.** S.I. Anisimov, Landau Institute, Moscow, brought up the question of validity of the Thomas-Fermi model and the shell effects that cause oscillations in the Hugoniot (pressure as a function of density) at Gbar pressures arising in underground nuclear explosions. Anisimov suggested pressure cumulation in systems driven by x rays to reach these pressures in the laboratory.

## Contributions from Central Europe

**Radiation from the Interaction Region of Counterstreaming Plasmas.** P. Glas, Central Institute of Optics and Spectroscopy, Academy of Sciences of the German Democratic Republic (GDR), Berlin, discussed experimental results from the irradiation of two metal foils Al-Al or Cu-Al separated by 0.3 to 0.5 mm by a 30-J, 1.06- $\mu\text{m}$ , 6-ns laser pulse with peak intensities up to  $1.0\text{E} + 14 \text{ W cm}^{-2}$ . The experimental data for Al-Al foils shows that, contrary to expectations based upon hydrodynamic calculations, that the plasmas interpenetrate freely, with no increase of ion temperature. A cooler plasma resulting from the ablation of an Au spacer placed between the foils could cool the Al plasma leading to a population inversion in the interaction region. Glas has also performed preliminary experiments on radiation cooling of the Al plasma by replacing one of the opposing Al foils by a Cu foil. Glas's spectral measurements show a population inversion in the plasma. However, the plasma length is insufficient to obtain a large gain coefficient.

**Imaging of Laser-Produced Plasmas with Bent Crystals.** E. Forster, Friedrich Schiller University, Jena, and P. Glas, Berlin, discussed x-ray images of plasmas at 0.4 nm with  $1.0\text{E}-02 - 1.0\text{E}-04$  spectral resolution through Bragg reflection in toroidally and spherically shaped quartz, silicon, KAP, and KDD crystals. Forster believes his fabrication method yields consistent high-quality imaging devices that allow absolute determination of wavelengths without using reference lines. Forster would like to commercialize these crystals abroad.

M. Szustakowski reviewed progress at the Institute of Plasma Physics and Laser Microfusion, Warsaw, Poland. The program occupies a niche in development of diagnostics for laser-produced, often in collaboration with other institutes:

- A 1000 line mm<sup>-1</sup> transmission grating spectrometer (H. Fiedorovicz) with moderate ( $\delta\lambda = 0.6 \text{ nm}$ ) over the 0.3 - 2 keV spectral range coupled to an electronically digitized, charge-coupled device (CCD) array. The detector is a Czech and Slovak Federal Republic (C.S.F.R.) similar to a Type 123 Fairchild array (in collaboration with Max Planck Institute for Quantum Optics, Garching, FRG; the Institute of Physics, C.S.F.R. Academy of Sciences (B. Rus); and the Department of Physical Electronics, Faculty of Nuclear Science and Physical Engineering (L. Pina), Czech Technical University, Prague, C.S.F.R. (see this issue, page 126, X-Ray Diagnostics and Laser Research at the Nuclear Science and Engineering Physics Faculty, Czech Technical University, Prague); and the P.N. Lebedev Physical Institute (M. Koshevoi), Moscow, U.S.S.R. R. Arendzikowski has coupled the detector to a flat

ADP crystal spectrometer that operates in the 5- to 8- $\text{\AA}$  spectral range.

- Measurement of velocity distributions of ions from a laser heated (1.06  $\mu\text{m}$ , 1.5 ns,  $1.0\text{E} + 14 - 1.0\text{E} + 15 \text{ W cm}^{-2}$ ) 40- $\mu\text{m}$  thick Au foil. The collector of the Thomson parabola ion spectrometer feeds directly the deflection plates of an "old technology" 1-GHz bandwidth Tektronix oscilloscope. C and H contaminants arrive first to arrive with a  $4.0\text{E} + 07 \text{ cm s}^{-1}$  velocity, followed by  $\text{Au}^+$  at  $1.6\text{E} + 07 \text{ cm s}^{-1}$  from the hot plasma and  $\text{Au}^+$  at  $0.4\text{E} + 07 \text{ cm s}^{-1}$  from the colder plasma region.
- Heating of matter by x rays in cavities. In this experiment just begun, a laser pulse strikes the wall of a cavity formed by two parallel plates that are oblique to the propagating pulse. X rays resulting from the plasma on one plate (the wall of the cavity) heat the opposite plate.
- The Perun 100 GW pulsed iodine photodissociation laser system, K. Rohlema (Rohlema, 1988), Institute of Physics, C.S.F.R. Academy of Sciences, Prague. This 10 cm-beam diameter laser generates and amplifies 80 J, 1.31  $\mu\text{m}$ , subnanosecond pulses. A frequency doubling crystal is on order from the U.S.S.R. The basis of the design is a system built originally at the Lebedev Physical Institute in Moscow, U.S.S.R. I visited this modern facility in a trip to Prague, C.S.F.R..

## Conclusions

A significant number of scientists from the U.S.S.R., Poland, Czechoslovakia, and the GDR interacted with the other European participants as if the "Cold War" and the "division" of Europe had perhaps taken place a couple of centuries ago. Most visible U.S.S.R. scientists were Academician N.G. Basov and V.B. Rozanov (who appears to know, on a first name basis, many U.S. researchers in the laser and particle beam ICF field), P.N. Lebedev Physical Institute, Moscow; N. Kovalsky, I.V. Kurchatov Institute of Atomic Energy (ESNIB 89-10:28-32), Moscow; and G.A. Pasmanik, Institute of Applied Physics, Gor'iky.

Some U.S.S.R. scientists expressed considerable skepticism about feasibility of the 200-kJ system because of realistic doubts about the capabilities of the high technology infrastructure of the U.S.S.R. nonmilitary industrial sector to embark on a project of such magnitude (see this issue, page 61, Science Funding, Organization, and Personnel in the U.S.S.R.). Moreover, Kovalsky hinted that the future of the 200-kJ system depended greatly on the value and sign of the derivative of Perestroika.

The emphasis on the high risk, high-payoff, SBS phase conjugation and pulse compression approach of the U.S.S.R. effort on high-power lasers was very evident at this meeting. Clearly, their present effort is severely limited by deficiencies in the industrial infrastructure and by shortages of foreign exchange to buy equipment from the West (see this issue, page 61, Science Funding, Organization, and Personnel in the U.S.S.R.). Finally, it was evident that scientists from Czechoslovakia, Poland, and the GDR are looking West to integrate their programs with European efforts (see this issue, page 118, C.S.F.R. Science in the 1990s).

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# Institutions of Research and Higher Learning in Tomsk, U.S.S.R.

by Marco S. Di Capua

## Introduction

During a Liaison Visit in June 1990, I became acquainted with the Universities and U.S.S.R. Academy of Sciences (Academy) Research Institutes in Tomsk. The universal pride of my hosts on the academic accomplishments of Tomsk encouraged me to write this brief survey.

Founded in 1664, Tomsk was a usual Siberian frontier town populated by merchants, manufacturers, and traders connected with the fish, lumber, and gold economy. Since the middle of the last century, however, Tomsk, also called the Athens of Siberia, acquired the reputation as an academic city. Rich merchants brought libraries with them, which formed the core of the university library collection. The University of Tomsk (University), established in 1884, was the first in the 7,000-km territory spanning from the Urals to Siberia. The university gave life to other faculties such as the Polytechnic (1900), the Faculty of Medicine, and the Pedagogical Institute. The importance of Tomsk's academic institutions grew as industry moved East during World War II.

At present, Tomsk has six institutions of higher learning:

- Tomsk V.V. Kyubishev State University
- Tomsk S.M. Kirov Polytechnic University
- Tomsk Institute of Automatic Controls Systems and Radioelectronics
- Tomsk State Medical Institute
- The Pedagogical Institute
- Tomsk Civil Engineering Institute.

The University has 700 faculty members, 8,000 students, and a 3.3-million volume library. The Polytechnic has 1,200 faculty, 17,000 students, and a 2.5-million volume library. The Medical, Civil Engineering, and Automatic Control Institutes have extensive libraries (350,000, 400,000, and 330,000 volumes, respectively). University students (about 30,000) comprise about 6 percent of the total population (approximately 500,000) of Tomsk. More details about these institutions appear in (nn, 1989).

## The Akademgorodok Research Institutes

This deep educational base incubated, within the University and Polytechnic departments, the research

institutes of the Siberian Division of the U.S.S.R. Academy of Sciences at Akademgorodok.

Akademgorodok, established in 1969, assembles in a campus, four institutes of the Siberian Division of the U.S.S.R. Academy of Sciences. The institutes and foundation dates are:

- The Institute for Atmospheric Optics (IAO) (1969) with the Optika Scientific Instrument Design Office (1972) and the Scientific Technical Complex (NTK)
- The Institute of High Current Electronics (ISE) (1979) with the Special Construction Bureau for High Power Electronics
- The Institute of Strength Physics and Materials (IFPM) (1984)
- The Institute of Oil Chemistry (IChN) (1970).

The total staff of the institutes is about 2,000--with 1,000 at IAO, 400 at ISE, 400 at IChN, and 350 at IFPM. About one-third of the staff are scientists.

### Research Areas at Akademgorodok

Research at IAO studies laser propagation in earth and planetary atmospheres, laser and acoustic atmosphere probing, development of metal vapor lasers, and automation of research in the field of atmospheric optics. One of the strengths of the institute is propagation of waves in absorbing, scattering, and arbitrarily inhomogeneous media. Optika and the Design Bureau produce prototypes of atmospheric sensing apparatus for meteorology, to detect pollutants, development of laser navigation systems for air and water craft, and development of metal vapor lasers.

Research at ISE (see this issue, page 16, The Institute of High-Current Electronics in Tomsk, U.S.S.R.) studies generation of high-voltage, high current pulses, production of intense beams of electrons and ions, relativistic microwave electronics, and compression of plasma liners. The Construction Bureau has produced, through 1987, more than 150 devices such as high-power gas lasers, pulse generators, ns accelerators, electron guns with plasma cathodes, and portable x-ray sources for other U.S.S.R. institutes.

Research at IFPM (see this issue, page 8, The Terscol Conference on Materials Undergoing Rapid Deformation and the Institute for Strength Physics and Materials in Tomsk) studies the electron theory of solids, plastic deformation and failure of crystals, and new physical principles to create high-strength, durable, and corrosion-resistant materials.

The IChN studies the composition and properties of oil and its components, the physical chemistry of oil systems, surface phenomena, and the chemistry of additives for hydrocarbons. Also, IChN develops new methods to

fraction and to remove the heteroatomic and high molecular weight organometallic components of oil.

G. Mesyats' Leadership and the Three-Way Collaboration Between IAF-TPU, ISE, and IEP

The ISE was established by Academician G. A. Mesyats in 1977. Consequently, it evolved from pulse-power research activities dating from the early 1960s at the Institute of Nuclear Physics of the Tomsk Polytechnic University (IAF-TPU) as an example of the continuing symbiosis between Academy institutes and Universities. B. Koval'chuk, V. Bystritskii, and Y. F. Potalitsyn, scientists at ISE, have adjunct teaching positions at IAF-TPU. In addition, as part of the research program, IAF-TPU investigates small-scale, pulse-power concepts in advance of larger scale development at ISE.

G. Mesyats' strong ties to Tomsk (he graduated from IAF-TPU in 1966), his position as Chair of the Presidium of the Urals Department of the Academy (nn, 1989a) (since 1987), and his directorship of the Institute of Electrophysics (IEP) in Sverdlovsk encourages a close relationship between IEP and ISE. Collaboration among the institutes is clear from 11 joint presentations of IEP and ISE at the International Workshop on the Physics and Technique of High-Power Opening Switches (see this issue, page 43) and residence of IEP physicists at IAF-TPU and ISE.

### Conclusions

The size of the Tomsk academic institutions surprised me. I visited the University library which appeared similar to a library at a medium-size U.S. university. I was disappointed, however, that time ran short and I was unable to judge the quality of the collections by looking at the card catalogue.

The Polytechnic facilities have aged gracefully. The 90-year-old buildings are in good condition and the interiors and laboratories appear serviceable.

The layout and appearance of the campus of Akademgorodok struck me by its resemblance to research campuses I visited in France and Germany. Perhaps because of larger maintenance budgets or better workmanship, the condition of the buildings and laboratories is as good as I have seen in European countries.

The collaboration between Academy institutes and the University appears very fruitful. The collaboration provides motivation and job opportunities for students, renews university research activities, and provides an outlet for teaching by institute researchers.

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# I.V. Kurchatov Institute of Atomic Energy, Moscow, U.S.S.R.

by Marco S. Di Capua

## Introduction

The I.V. Kurchatov Institute of Atomic Energy (Institute), the most important center of the Soviet Union in nuclear science and technology, performs research in applied as well as fundamental science. A descriptive leaflet (in Russian, no date) emphasizes the Institute's activities in nuclear energetics, nuclear power generation and cogeneration, shipboard nuclear propulsion for transport and icebreaking, research reactors, controlled thermonuclear fusion, inertially confined fusion, nuclear physics, nuclear chemistry, and isotope research.

According to the leaflet, Igor Vasilievich Kurchatov established the Institute in March 1943 to restart nuclear research in the U.S.S.R. In 1944,  $3.3E + 12$  atoms of Pu became available; in 1946, the first reactor achieved criticality; in 1947, significant quantities of Pu were available; in August 1949, the U.S.S.R. tested its first fission device (Pu), in 1953, the first boosted device, and in 1955, the first multistage thermonuclear device (nn, 1989).

Reviewing a recent anthology of memoirs about Kurchatov (Aleksandrov, 1988), who died of cancer in 1960 at age 57 and is buried in the Kremlin wall, Kuchment (1989) says: "Kurchatov ... was a first rate physicist who combined qualities of J. Robert Oppenheimer and Edward Teller. This blend allowed him to find the right language for dealing with such disparate personalities as his Soviet colleagues, captive German nuclear physicists, marshals of the Soviet Army and such *tough cookies* as Stalin and his *henchman* Lavrenti Beria, overlord of the Soviet Atomic project (italicized words are author's)."

According to a recent report in the New York Times (Keller, 1989), Kurchatov also established the Pu production facilities in the Kyshtim Industrial Complex, east of the Ural Mountains, on the shore of Lake Irtyash. He is honored as a national hero by a two-story stone likeness in the center of town. V. Chertkov, the first Soviet journalist to visit the complex in March 1989, has been quoted in the Washington Post (Smith, 1989) saying: "Beria was the Satan who ruled things here. It was he, namely, who was responsible for building the facility at the cost of many lives."

I include these notes because even up to a few months ago, this effort in the U.S.S.R. was shrouded in mystery. As the references show, many veils are being lifted and now we can begin to understand these institutions within their historical context.

## The Kurchatov Institute

This article describes my visit to the Kurchatov Institute headquarters in June 1990. Our hosts, researchers very much like us, were interested in a genuine exchange of technical information as well as in our personal points of view on research programs. The Angara 5-1 module (AN 5-1) was well prepared for our visit. The hardware was open for viewing, allowing plenty of time to discuss experimental results and planned experiments. This issue, in addition, carries two articles at the Troitsk branch of the Kurchatov Institute. One describes the T-14 Tokamak effort (page 3). The other discusses the megavolt pulse-power accelerator Angara 5-1 (page 5).

## Pulse Power Current Transformers

The most interesting piece of hardware on display was a transmission line transformer that converts the  $2\text{-}\Omega$  output impedance of the generator into  $0.04\ \Omega$ . The transformer consists of 48  $2\text{-}\Omega$  water-dielectric coaxial transmission lines, distributed in 6 concentric circles of 8 lines each, connected in series at the input and in parallel at the output. Each  $2\text{-}\Omega$  transmission line has its own acrylic water vacuum interface that will operate at 300 kV. Sixteen magnetically insulated parallel plate collectors lead the current into the central liner load. In a recent publication, Bulan describes a half-scale version of the transformer that has been tested on AN 5-1 (Bulan, 1988). The larger version is already installed on AN 5-1 and is ready for testing. It is expected that the full scale transformer will deliver about 3 MA at voltages of about 120 kV.

This appears to be a convenient arrangement to convert older coaxial water-dielectric  $2\text{-}\Omega$ -like relativistic electron beam accelerators into low-impedance liner drivers. As a nice feature, this transformer allows an easy parallel connection of the coaxial outputs into collector plates to feed liner loads. The geometry lends itself to implementation of erosion switches as well. A drawback of the transformer is the amount of energy stored in the stray capacitance between the outer conductors of the transmission lines.

A magnetically insulated vacuum transformer that was seen for the first time during a Megagauss 3 institute visit 6 years ago (Demeter, 1983), has finally appeared in the Soviet literature (Bulan, 1988a). The primary of the transformer forms a loop that connects the center con-

ductor and the outer conductor of MITL. Multiple secondaries fill the center of the loop and connect in parallel to an inductive load. N. Yugami (Yugami, 1988) reported results with a transformer of a similar geometry at Beams '88.

Bulan tested a half-scale model of a transformer intended for AN 5-1 on a 400-kV, 2.3- $\Omega$  generator and measured the input and output currents as well as current losses as a function of spacing between the primary and secondary windings, suggesting that there is a minimum spacing (about 6 mm) in their experiment beyond which the electron losses become unacceptable. It is not clear whether these losses are associated with the onset of field emission or with a loss of magnetic insulation. It would seem that, given the complicated field geometry, and experiences at other laboratories with electron losses at impedance discontinuities, that magnetic insulation in the transformer geometry would be difficult to maintain.

### Implosion of Z-pinchs with Embedded Fields

Results from an experiment on the stabilization implosion of plasma liners with embedded magnetic fields stimulated very lively discussions. This experiment, performed on AN 5-1 by E. Gordeev using the transmission line transformer ( $U = 150$  kV,  $Z_{\text{source}} = 0.04$   $\Omega$ ,  $I_{\text{max}} = 2.5$  MA) described in the previous section, had an unusual gas puff liner geometry (length = 1 cm, diameter = 3.5 cm) (Gordeev, 1989). The maximum axial field, applied with external coils was 1 T. Without an axial field, x-ray framing images reveal an  $m = 0$  instability. With an axial field, the striations in the emission appear inclined to the axis suggesting that the conduction electrons are frozen in the magnetic field. An experimental result that corroborates this interpretation is that the inclination of the striae changes by 90 degrees when the applied field reverses. Axial fields above 0.5 T prevent collapse of the shell and the x-ray emission intensity associated with the minimum radius of the shell decreases substantially. Of great interest, of course, are experiments that will be performed with the full-scale transformer at a current of 3 MA.

### Dense Pinches Resulting from Explosion of Thin Wires

S. Bogoliubsky has utilized the current transformer to drive a thin wire in an attempt to obtain radiation collapse (Robson, 1989) along the whole length of the wire. The experiments involved traditional x-ray diagnostics and electrical measurements. Tungsten  $L_{\alpha}$  radiation and Copper  $K_{\alpha}$  radiation reveal a nonradiating core that

could be either an unexploded part of the wire or a cool, dense, weakly ionized plasma at the axis of the plasma channel. This heterogeneous distribution precludes observation of the radiative collapse.

Bogoliubsky has also observed "hot points" that evolve from ring-like structures that form along the discharge channel. These structures collapse into small, very hot sources of x-ray emission. At the moment, it is difficult to say whether the hot points are a nuisance or whether they can be effectively exploited in inertially confined fusion arrangements. A simple guess is probably the former.

### Stand 300

The last installation we visited was Stand 300, a 10-TW, 3.2-MV facility under construction, intended as a nuclear weapons effect simulator, an implosion driver, and possibly as a driver for ion diodes. This facility has eight 300-kJ, 1.2- $\Omega$  vertical modules that incorporate 3.5-MV oil insulated Marx generators and water dielectric transmission lines. All interfaces (oil/water and water/vacuum) lie in the horizontal plane. Convolution of the outputs will take place in vacuum with a projected inductance of 8 nH. The structural components of the Marx generators (Fiberglass-Epoxy) displayed an extraordinary feat of large-scale machining. I did not see any of the water line components or the vacuum interfaces. A. Chernienko, the designer of the water/vacuum interfaces, is not worried about gas bubbles collecting on interface surfaces or water/oil mixtures resulting from diaphragm failures.

### Conclusion

In a very relaxed atmosphere, our Soviet colleagues discussed their successes as well as their disappointments. They shared with us some of their preoccupation with new funding directives that require justification of projects on a yearly basis, and shrinking defense appropriations that result in budget cuts for pulse power installations (see this issue, page 61, Science Funding, Organization, and Personnel in the U.S.S.R.).

The transmission line transformer on AN 5-1, provides Kurchatov with a power source of extraordinary low impedance. This source may open new frontiers on the physics of imploding liners and may provide new insights on the physics of ultra-low impedance, short pulse, pulse power systems.

The most recent report of the research of the Kurchatov group will appear in Ryutov (1990).

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# Institute for High Temperatures of the U.S.S.R. Academy of Sciences

by Marco S. Di Capua

## Introduction

I visited the Institute for High Temperatures (IVTAN) of the U.S.S.R. Academy of Sciences (Academy) as part of the scientific itinerary of a group of 20 U.S. scientists attending the Novosibirsk Opening Switch and Mega-gauss V meetings in early July 1989.

In his welcome greeting, the Director, M. Brialovich, told our group that IVTAN is one of the Soviet Union's leading establishments in the field of thermal physics and new power generating processes. Located in a Moscow suburb, IVTAN has a total staff of 3,500, of which 1,200 are academicians, corresponding members of the Academy, professors, engineers, and technicians. The IVTAN is quite unique since its research proceeds to development of large scale prototypes that IVTAN "incubates" before transferring them to industry. In particular, IVTAN has an experimental test complex that determines that prototypes to be transferred to industry are ready for production.

Brialovich highlighted several research activities that we would not visit because of a lack of time. Among them:

**Physical Properties of Substances at High Temperatures.** A large challenge of this traditional area encompasses methods and techniques to accurately and reliably

measure the properties of matter at extreme conditions. The IVTAN routinely studies thermophysical and electrophysical materials properties such as heats and temperatures of fusion up to 6000°K, heat conductivities up to 2800°K, thermal expansion and electrical resistivity up to 3600°K and combined heat capacities and heat conductivities from 700 to 1700°K. A highlight is the measurement of the C triple point. In the near future, IVTAN plans to commercialize, in diskette form, thermophysical data that exists currently on a computerized data base.

**Heat and Mass Transfer/Physical Gas Dynamics.** This section investigates the combined effects of gas dynamic flows and high energy fluxes as well as the production of shock waves at very high velocities. Two examples of these activities are thermal protection of re-entry objects that are subject to very large thermal stresses and hardening of material surfaces with laser radiation. An example Brialovich gave is laser hardening of a 1.5-m-diameter, 20-ton cylinder for a rolling mill.

**Magnetohydrodynamic (MHD) Generators/Energy Conversion Technology.** The IVTAN developed MHD generators with pulse durations in the 1-10- $\mu$ s range and powers of 20-50 MW to power electromagnets that generate magnetic dipole fields at the ground surface. Meas-

urements of the dipole electric field that accompanies the magnetic field that penetrates the earth's crust reveal the conductivity of geological structures as deep as 20 km. Some of this work was pioneered at the I.V. Kurchatov Institute of Atomic Energy (see preceding article). While geophysicists may be familiar with this probing technique, I have not seen a reference to this technique in the literature. This technique is under test at research facilities in Central Asia, in the Kola Peninsula, and around Lake Baikal. This activity is highlighted in the bilingual IVTAN brochure.

**Applied Aspects of Superconductivity.** Research involves magnet development for superconducting inductive energy storage units (SPIN) to damp oscillations in large electrical power grids, and to deliver energy to power grids in short time-scales compared to the speed up of rotating generators (Pfortenhauer, 1988). The IVTAN has placed substantial emphasis on creating superconducting inductors with conductor configurations that suppress stray fields outside the inductor. Ten- to 100-MJ units are available at present and  $1.0E + 12$  -  $1.0E + 13$  J units are being considered for early next century.

The IVTAN has also developed superconducting magnets for MHD generators. A small explosively driven superconducting system developed 10 MW for 100  $\mu$ s. A superconducting magnet, that the U.S. gave to IVTAN through a cooperative program in MHD power generation that ran until the late 1970s, provided the fields for a 1.65-MW MHD generator.

**Development of a National Energy Plan.** The IVTAN is working on the application of solar energy to space heating and heat pumping, investigating technologies that may become economical in the future. At present, the IVTAN's programs emphasize environmental impact of energy generation and the staff formulates environmental programs for the power generation industry. One of the interests of IVTAN is the clean up of  $SO_x$  and  $NO_x$  from powerplant flue gases through plasma chemistry (electron beams or dilute plasma discharges). According to Brialovich, this approach has a "bright future", circumventing the use of Pt group catalysts. I. Gallimberti, University of Padua, Italy, is developing a similar approach. Plasma chemistry was the subject of a recent symposium organized by M. Capitelli, University of Bari, Italy.

**Gas Discharges and Low Temperature Plasmas.** This area involves nonequilibrium processes in low temperature and nonideal plasmas, such as the working fluid of MHD generators and gas discharge laser systems.

## A Visit to Selected Laboratory Facilities

Dr. Vladimir Fortov, the director of the Center for Thermophysics of Impulsive Loads, guided our group through several facilities, complementing Brialovich's presentation. Fortov, is well known for his work on equations of state (EOS) and on the physics of nonideal plasmas.

**Electron Beam Facility.** Investigations in this facility study the generation, transport and energy recuperation of an electron beam. The idea is to transport energy across large distances with relativistic electron beams (REB) and at the same time to develop beam technology for material treatment purposes. A 1-Mev, 10-kA, 10-100  $\mu$ s Marx generator, in a 2.4-m diameter, 8-m long tank energizes the transport section in a floor below. The high-voltage end of the Marx generator had what appeared to be high-voltage isolation filament transformers for the thermionic cathode. I could not identify the configuration of the high-voltage cathode feed.

The 15-m long beam transport section occupied a heavily shielded 15- or 20-m long vault. Weak magnetic fields stabilize beam transport. Details on transport efficiency, beam stability, or the scheme and the efficiency of beam energy recuperation were not given. Another system (300 kV, 10-20 A, 10  $\mu$ s) transported a 10-A beam in a magnetically guided  $SF_6$  transport system with only 10 mA losses in 30 m.

**Thermophysics of Intense Loading.** One-stage powder guns accelerate projectiles to study the physics of planar impact on targets. A single-stage powder gun provides velocities up to  $1.8 \text{ km s}^{-1}$ . Manganin gauges measure the pressure in the sample, interferometry with an Ar ion laser measures the motion of the free surface, and a pulsed x-ray diffraction system measures lattice properties with 10-ns resolution. The work area appears to be similar to Z. Rosenberg's at Rafael Armament Center in Haifa, Israel (Rosenberg, 1988).

**The Computer Center.** The Computer Center has a 4-MB, 15-Mflop computer that runs hydrocode calculations. The two-dimensional hydrocode has a semi-empirical equation of state that can account for electron as well as radiative transport. We saw results of simulations of

- Compression of  $D_2$  in a conical void resulting from the impact of a 100-ps ion beam on a sector of a spherical metal shell covering the void, reported in 1984
- Oblique impact of an Al plate on a Pb target at  $10 \text{ km s}^{-1}$ .

In such a short visit, it was impossible to judge the speed or the quality of the physics in the simulations. Benchmark problems would be required to assess the

code capabilities against national laboratory codes or commercially available software (ESNIB 89-07:38).

**Blast Simulator Chamber.** The IVTAN has a 6-m diameter, 150-Ton blast chamber, that operates at the 10-kg level, designed to contain the blast of 50 kg of high explosive (HE). Experiments performed in this chamber include generation of pressures up to 2 Mb with flyer plates and determination of EOS for Cu up to 20 Mb with a velocity multiplying scheme that relies upon progressive impact of successively lighter plates. Three-stage multiplier systems provide velocities of  $20 \text{ km s}^{-1}$  that deliver usable pulse lengths of  $100 \mu\text{s}$ . The chamber has also been used to test small magnetocumulative (MCG) generators. Diagnostics in the facility include:

- Shorting pins
- Laser interferometers
- Fast spectrometers with 10-ns resolution
- Diagnostics for plasmas with electron densities as high as  $1.0\text{E} + 19 \text{ cm}^{-3}$ .

A. Deribas, the head of the Special Design Office of High Rate Hydrodynamics of the Siberian Branch of the Academy, is presently designing, for IVTAN, penetrations for one out of four existing 16-m diameter chambers with 30-cm thick steel walls. The design of this chamber facility, rated for 0.5 - 1 Ton (1000 kg) of HE is complete. Since the chamber will operate within the elastic limits, no water containment around the chamber will be necessary. The expected cost of the facility is 6 million Rubles.

**Rail Gun Facility.** We saw a rail gun, similar to devices available in the U.S. and Europe. The gun has a 10-MJ energy store (6-12 kV) that drives a plasma armature with 5 MA at the 5-MJ level. The 1-m long barrel will accelerate 10-g projectiles to 4 to  $5 \text{ km s}^{-1}$  or 2 g up to  $6 \text{ km s}^{-1}$  starting with a projectile initially at rest. The gun has copper/nichrome alloy rails and fiberglass/epoxy/poly-carbonate insulators. The electrodes are good for only one firing. The biggest experimental difficulties are stability of the plasma armature and restrike at the breech. Experimental studies in the gun facility include shock processes, impact processes, EOS at high-energy densities, and related topics. The setup appeared to be nonfunctional since the energy storage bank was missing several switches.

**Exploding Foil Driver.** A 1-MJ capacitor bank drives exploding foils to  $8 \text{ km s}^{-1}$  for EOS work. They hope to reach  $20 \text{ km s}^{-1}$  to obtain data in the 20- to 30-Mb range.

**A Toroidal Autotransformer.** The last piece of apparatus we saw was a toroidal autotransformer equipped with explosive opening switches. Eight switches, developed at the Yefremov Institute in Leningrad, interrupt in parallel 100 kA against 30 kV in about  $10 \mu\text{s}$ . The switches reach an impedance of  $0.5 \Omega$  into an open circuit load.

## Conclusions

The overall impression is one of well-worn facilities. The language barrier and a lack of visual aids, in addition to the inevitably poor acoustics and cramped spaces, handicapped our visit. Since the diagnostic equipment was "thin," I had difficulty assessing the level of research activity in the facilities we visited. Some possibilities that come to mind to explain the lack of equipment are

- In preparation for our visit, the clutter was removed that normally accompanies experiments under execution
- Shortage of diagnostic equipment requires apparatus to be moved from experiment to experiment.

The IVTAN, like the other Soviet institutions, is in the midst of change and has developed a large interest outside its boundaries. As an example, Fortov gave me a short monograph on the application of high current charged particle beams to the generation of high dynamic pressures (Akerman, 1989). This collaboration, between Fortov; M. Basko (ESNIB 89-08:57), Institute of General Physics; G. Mesyats, Sverdlovsk branch of the Academy; and L. Rudakov, I.V. Kurchatov Institute (see preceding article) suggests that the work on the physics of high-energy densities cuts across disciplines and institute boundaries.

Judging from the references, the manuscript was probably submitted in early 1987 and underwent a 2-year production cycle, rather typical for preprints in the Soviet Union. Probably because of the rarity of copying machines, preprints in the Soviet Union are the only vehicle that allows a reasonably rapid dissemination of information in rapidly changing fields.

As another example of these new interests, IVTAN is examining joint ventures with foreign companies; four countries were mentioned specifically--Hungary, U.S., Finland, and the Peoples Republic of China.

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# The Institute of Nuclear Physics, Siberian Branch of the U.S.S.R. Academy of Sciences, Novosibirsk

by Marco S. Di Capua

## Introduction

During a recent visit, the director of the Institute of Nuclear Physics (Institute), Siberian Branch, U.S.S.R. Academy of Sciences, E. Kruglyakov, reviewed the three main directions of the Institute's work on electron beam and accelerator related topics:

1. Research with colliding beams in the 100- to 1-TeV energy range comprise about one-half of the effort
2. Controlled thermonuclear fusion (CTR) including plasma formation, heating, and confinement in open (mirror) magnetic systems (about one quarter of the effort)
3. Industrial applications (about one quarter of the effort) of electron accelerators that include
  - Synchrotron radiation sources for microelectronics
  - Electron sources for materials polymerization
  - Bremsstrahlung radiation sources for food irradiation, sewage disinfection (1 MeV, 100 kW continuous)
  - Electron beam sources for cutting and welding of materials.

At the end of the presentation, D. Ryutov led a tour of the laboratory.

## The GOL III Experiment

Since the early 1970s, Ryutov has been active in heating of open (mirror) plasma confinement systems heated by MeV, multi-kA,  $\mu$ s, electron beams delivered by pulse power sources. According to Ryutov, the goal is to enter a new regime of plasma conditions ( $1.0E + 16 - 1.0E + 17 \text{ cm}^{-3}$ , 1 keV) in a 6-8-cm diameter, 22.5-meter-long plasma column. The plasma is radially wall-confined (a 6 to 7 T field prevents radial energy transport) and multiple mirror axially confined (12-T mirror fields). The energy source for plasma heating is a 1-MeV, 50- to 100-kA beam with a duration of 5- to 7- $\mu$ s and an energy of 100- to 150-kJ (Ryutov, 1988). Turbulent heating (2 stream instability driven) takes place through collective interactions between the completely current neutralized beam and the background plasma.

The GOL III experiment, which was planned 10 years ago to test the concept, is close to operation in a new building. A thyristor switched, 10-MJ store of 6-kV capacitors charged at 4.8 kV feeds single turn Beryllium

copper coils to produce the fields. A series connection of four 2.5-kV thyristors switch one hundred 150- $\mu$ F capacitors that deliver a current of 8 kA from each 250-kJ section.

A field emission diode coupled to the "U 2," SF<sub>6</sub> insulated, LC generator electron source (Arzhannikov, 1989) (80-kA peak, 1 MeV, 100 kJ, 5 $\mu$ s) is presently under test. This large area, ( $\sim 1000$ s of  $\text{cm}^2$ ), large gap (5-10 cm) slit-shaped foil-less diode produces a ribbon beam with small angular spreads. The large dimensions of the foil-less diode reduce the difficulties that arise because of gap closure and the ribbon beam geometry circumvents problems associated with self-pinching of the beam at the diode. Another advantage of the ribbon beam is that multiple diodes could produce staggered beam pulses that can be switched into the plasma using techniques used in conventional particle accelerators.

After current neutralization, a transformation of magnetic flux tubes (through a Ying-Yang coil), which is not installed yet, will provide a 20-fold compression of beam area into a circle with 1-5  $\text{kA cm}^{-2}$ .

At present, a 20-kA peak, 50- $\mu$ s ring down discharge with a 15- $\mu$ s period produces a  $1.0E + 15 \text{ cm}^{-3}$  H plasma in  $1.0E-02$  Torr prefill of H<sub>2</sub> in preparation for injection experiments. The foil-less configuration will require gas injection through a puff-gas valve.

## Ion Beam Diode Research

V.M. Fedorov uses the last water dielectric pulsed-power accelerator in Novosibirsk (VODA 1-10, 1 MV, 150 kA, 10 kJ, 60 ns) in a small ion beam research program. The diode configuration is a 15-kG applied B field ion extraction diode with a 9-cm inner radius and an emission area of 100  $\text{cm}^2$ . The anode is a 20-turn spiral of interleaved 0.3-mm Al and 0.75-mm Mylar. Fedorov operates the diode at a peak voltage of 0.7 MV producing equal amounts of electron and ion currents with a total current of 100 kA with a mean energy of 0.5 MeV. A recent reference describes his latest results (Deichuli, 1988). The generator achieves grading of the stack through a "flux sucking" configuration. The flux sucker, unlike designs attempted in the U.S. that utilized cast epoxy dielectrics (Chen, 1979) that failed by puncture, is a cylinder consisting of a wound, water-impregnated mylar spiral. Fedorov has successfully operated the cylinder with fields of 700  $\text{kV cm}^{-1}$ .

## Conclusions

The GOL III experiment is unique since it is one of the last mirror configurations left in the world and the only mirror configuration heated by a relativistic electron beam. The experimental apparatus and the building constitute a very large investment by Soviet or Western standards and E. Velikhov's interest in the experiment had a large bearing on its funding. The results, which will be reported in the 8th International Conference on High-Power Particle Beams in July 2-9, 1990 in Novosibirsk, should be interesting indeed.

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# The International Workshop on Physics and Technique of High-Power Opening Switches

by Marco S. Di Capua

## Introduction

On July 1 and 2, 1989, the International Workshop on Physics and Technique of High-Power Opening Switches took place at Akademgorodok in Novosibirsk, U.S.S.R. The origins of the workshop go back to the 1984 East Berlin Conference on Electrical Insulation and Discharges in Vacuum. During informal get-togethers, Soviet physicists in the pulse power field expressed great interest in plasma opening switches (POS), a field that was undergoing very rapid development in the U.S. On a quid pro quo exchange of pulse power information about Angara 5, their U.S. colleagues discussed some of the underlying physics of POS. This marked the beginning of Soviet activities in this area.

The scientific secretary, V. Bystritskii, performed an outstanding job in organizing the workshop and the connected scientific tours (*ESNIB* 89-10:39-41). Participants were from the U.S.S.R. (75), the U.S. (22), and Rumania (2), and the workshop languages were English and Russian, with simultaneous translation.

The workshop goal was to review the last 2 or 3 years' progress in theoretical and experimental investigations of high power POS over a wide range of time scales; to review their application to generation of x rays, charged particles and neutrons; and to provide a forum where common problems with this technology could be discussed.

This report summarizes some of the contributions of the Soviet laboratories. There were excellent presenta-

tions from U.S. pulse power centers: Naval Research Laboratory (NRL), Washington, D.C.; Los Alamos National Laboratory (LANL), Los Alamos, New Mexico; Sandia National Laboratories (SNLA), Albuquerque, New Mexico; Lawrence Livermore National Laboratory (LLNL), Cornell University, Texas Tech University, Lubbock, Texas, and Pulse Sciences Incorporated, San Leandro, California. A brief summary at the end of this report will attempt to capture the flavor of the U.S. presentations.

## Contributions from The Institute of High Current Electronics in Tomsk (IHCE) and Tomsk Polytechnic Institute (TP)

B.M. Koval'chuk, a corresponding member of the U.S.S.R. Academy of Sciences, and the head of the Pulsed Engineering Department at IHCE discussed experimental results obtained in GI-4, an experimental installation devoted to investigation of POS with microsecond conduction times.

The basic GI-4 pulse power driving module is an oil-insulated, 500-kJ Marx generator with an erected voltage of 1 MV, an inductance of 400 nH, and an erected capacitance of 1.1  $\mu$ F. Four modules connect in parallel to a 1.2-m-long, 100- to 400-nH coaxial inductive energy store with an outer diameter (anode) of 0.21 m, an inner (cathode) diameter that can be changed from experiment to experiment. Depending on the cathode used, the interelectrode gaps are from 3 to 7 cm. The inductance be-

tween the switch and the load is 60 to 150 nH. The peak short circuit current for this generator is 2.8 MA at 700 kV with a current rise-time of 1.5 to 2  $\mu$ s.

D. Getman and A. Kim described the 32 plasma sources on GI-4. They appear to be conventional polyethylene ablation plasma sources driven by a 10-kA pulse with a 2- $\mu$ s half-period. The guns are located at the outer electrode. Getman and Kim measured the properties of the gun plasma with Langmuir probes. The gun ejects the plasma in two bursts, a fast one with a velocity of  $1.0E+07$  cm s<sup>-1</sup> and a slower one with one third the velocity. They measured a current of 25 A cm<sup>-2</sup>, 9 cm away from the gun in the first burst. The electron temperature in this burst was 7 eV.

A. Bastrikov, IHCE, carefully measured the electron flow to the anode and the ion flow to the cathode of the POS to establish the energy balance in the conduction and opening phases. As determined by calorimetry, the energy dissipated in the switch is consistent with energy calculated by integrating the product of switch current and voltage. More detailed measurements with Faraday cups appear to indicate that the energy deposited at the anode (about 30 to 40 percent of the total) is not connected with the electron flow. Filtered Faraday cup and activation measurements at the cathode (inner electrode) reveal that a flux of protons with energies comparable to the voltage drop across the switch account for the energy flux to the cathode. In early experiments, using plasma field diode loads with conical cathodes and axial plasma injection, a 480-kV Marx voltage delivered 2.1 MA to the switch and a peak current of 1.7 MA at 1.5 MV to the load. Koval'chuk described an attempt to increase the voltage in the switch through a systematic sweep of Marx voltages, plasma gun delay times, and diode geometries.

Since POS open more effectively with loads that draw large currents, Koval'chuk discussed a scheme to cascade a plasma opening switch and a plasma-filled diode. The description of the experiments emphasized the details of such a large number of diode geometries that I could not capture how effective this cascaded technique was in raising the load voltage.

The main conclusion of the GI-4 experiments is that the POS resistance drops dramatically for delay times longer than 1.5  $\mu$ s. However, long delay times are necessary to allow the generator to attain peak current. Koval'chuk apparently operated GI-4 in a "no-win" parameter space where he was unable to raise the "open" impedance of the switch above 1  $\Omega$ . A consensus developed at the workshop that POS on GI-4 could not achieve higher impedances because an increasing number of neutrals in the gap accompany the longer delay times. I could feel that the GI 4 experiments were a disappointment so far. The measured 1.5 to 2x voltage gain is below the 5x voltage gain that was expected in the design of the experiment.

Ya. Krasic described the beam research facilities under his direction at the Institute for Nuclear Physics, Tomsk Polytechnic University (INP TP). These are Vera, a 600-KV, 8- $\Omega$ , 80-ns generator; Tonus (1.2 MV, 50 kA, 50 ns, 0.03 Hz) and Double. Double, built by Koval'chuk at IHCE, is a 3- $\mu$ s, 600-900-kV, 8- $\Omega$ , 250-kJ accelerator that delivers pulses of either polarity. With POS, Double delivers an 80-ns pulse to drive particle beam diodes.

In the Double experiments, Krasic found, as Koval'chuk did, a low opening voltage for long switch conduction times and improved performance of the switch for large plasma velocities and shorter delay times. A switch cathode configuration with spiral conductors that provide an additional axial magnetic field component increases the impedance of the switch by 1.5 x. This magnetic field component also appears to inhibit plasma motion towards the load. Krasic also drives an applied B-field diode with the short pulse from Double. He found that the diode magnetic field degrades the performance of the switch. The magnitude of the currents and voltages in the switch and the load are not available at this time. Nor am I able to confirm, from other sources, an 8- $\Omega$  impedance for the switch.

Krasic also discussed an intriguing technique to drive ion diodes with two short sequential pulses of opposite polarity from the nanosecond accelerator tonus. The first pulse creates a plasma on the cathode electrode. The reverse polarity pulse that follows extracts ions from the plasma preformed by the first pulse on the electrode that was the cathode, and that becomes the anode with the reverse polarity pulse.

V. Bystritskii, IHCE, is developing ion diodes in the Parus accelerator to produce high-intensity ion beams that V. Fortov will use as energy sources at the Institute for High Temperatures (IVTAN) in Moscow (ESNIB 89-10:33-35) to produce Mbar pressures in matter through ablation of target materials. Parus is a 800-kV, 2.8- $\Omega$ , 0.3-TW, 80-ns generator with a large (200-keV) prepulse. A spherical, applied B-field, magnetically insulated ion diode, where electron impact to the anode dominates anode plasma formation, produces about 100 A cm<sup>-2</sup> of ions that deliver about 600 J at  $1.0E+04$  A cm<sup>-2</sup> in a 2-cm diameter focal spot. Diode efficiency at 700 kV was about 20 percent. A spring pendulum and an acoustic probe determined the momentum coupled to the target through ablation of the target material. By coupling the 5.5- $\Omega$  ion diode with a shunt POS that conducts 300 kA and opens to 25  $\Omega$  in 10 ns, Bystritskii shortened the diode pulse to 40 ns producing a 1.5 x voltage gain in the diode.

In a poster, Bystritskii presented an idea for a Z-pinch experiment that has a remarkably different twist. In his concept, developed in collaboration with G. Mesyats' group at the Institute of Electrophysics in Sverdlovsk,

Bystritskii proposes to focus the energetic ions that the POS produces as it opens onto an imploding deuterium liner. This liner is the electrical load that carries the generator current once the switch opens. With this approach, Bystritskii believes he can overcome the ion range limitation in the plasma caused by decreasing electron ion collision cross sections. This bootstrapping approach, which could produce up to  $1.0E + 13$  neutrons with a 100-kJ generator, is perhaps the most original concept I saw at this conference.

### Contributions from the Kurchatov Institute of Atomic Energy, Moscow

V. Smirnov, Troitsk Branch, I.V. Kurchatov Institute of Nuclear Energy, discussed the application of POS on Angara 5-1 (ESNIB 89-10:28-31) to reduce the effect of the jitter between the 8 modules and to improve trapping of the electron flow in the coaxial to disk current collector transitions.

The disk collector that connects the convoluted outputs of the 8 modules is very convenient for installation of the POS. The 24 plasma sources 30 cm away from the power feed, fire from a master trigger 8 to 10  $\mu$ s before the power pulse. A 1.5- $\mu$ f capacitor charged to 25 kV delivers a 30-kA pulse with a 2- $\mu$ s risetime to each gun. The plasma, produced in a carbon-coated polyethylene disk, reaches the switching region through rods in the anode. A spiral electrode collimates the plasma flow from the guns. A plasma burst of  $1.0E + 13$  cm<sup>-3</sup> with a velocity of  $1.0E + 07$  cm s<sup>-1</sup> is optimum for current commutation.

The POS, at a radius of 50 cm, carries 2 MA during the conduction phase of the switch. When the switch opens, current rise rates of  $1.0E + 14$  A s<sup>-1</sup>, allow a current rise of 3.5 MA in 30 ns into an imploding liner load composed of thin wires. Smirnov estimated a 2.5 to 3 power amplification in this experiment that shortens, from 70 to 30 ns, the current rise time to the load. Smirnov concluded that he needs more detailed information to assess the effect of shorter current rise times on liner stability and liner radiation output.

L. Zakatov described G. Dolgachev's opening switch experiments on the Taina facility at the Kurchatov Institute in Moscow. In Taina, two coaxial energy stores meet at a common plane, which is the location of the POS. The 500-kV Marx generators deliver 100 kA to each of the 1.5-m-long, 30-cm OD, negative inner conductor coaxial stores. The clever idea behind locating the switch at the symmetry plane of a double-sided feed, is to eliminate axial acceleration forces and to produce exclusively radial ion acceleration, thereby causing switch operation exclusively in the erosion mode. This eliminates the opening physics associated with axial ion acceleration.

Zakatov injected a  $1.0E + 13$  -  $1.0E + 14$  cm<sup>-3</sup> (5- to 10-mC) plasma into the gap from 72 guns along a 10-cm distance and along a 50-cm distance. The translator missed the difference in the details of the physics for these two configurations. The peak current in the switch was 200 kA with 1.2- $\mu$ s conduction time, and the peak opening voltage was 1.5 MV with a 150-ns pulse width with a 150 kA into the load. The ion current density was 500 A cm<sup>-2</sup>. Zakatov measured electron density in the plasma through Stark broadening of the H alpha line and obtained the distribution of radial ion energies with Thompson parabolas. In another experiment, Zakatov cascaded two POS and established that the switch opens caused by the erosion of a critical amount of charge rather than at a threshold current. This observation suggests that the experiment operated in the desired radial ion current mode.

To settle the issue of current versus charge control of POS opening, L. Zakatov suggested feeding the switch with a current wave form with a spike. A variable timing and magnitude for the spike would produce current pulses with the same charge and variable peak current.

### Contributions from the D.V. Yefremov Scientific Institute of Electrophysical Apparatus

V.I. Engelko described work on a magnetically insulated vacuum transmission line (MITL) with 3- $\mu$ s pulses. This is a long pulse compared to the 50-ns or so pulses that are normally associated with MITL operation. The 2-m-long coax has an inner radius of 6.25 cm and an outer radius of 15 cm. The pulse power source is a 1-MV Marx generator with a 120-nF capacity. Several diode configurations (planar, spherical, and blade) terminated the transmission line. Engelko mapped the electron flow in the gap by inserting charge collectors and determined that the current density peaks at radius where Creedon's parapotential flow theory predicts the edge of the sheath should be. However, unlike predicted by theory, the electron flow extends as far as the anode. These data settles a long-standing question on how far across the gap the current sheath extends in a MITL and profiles of current density could be used to validate the results from numerical simulations.

### The U.S. Presentations

The general caliber of the U.S. presentations was excellent. The speakers had taken the time to prepare their work and spoke clearly, slowly, and distinctly so that translators, as well as English-speaking U.S.S.R. scientists in the audience, could follow. Presenters, affiliation, and topics follow.

- C. Mendel (SNLA) - electron flow launched during the POS opening process
- P. Ottinger (NRL) - theoretical POS work at NRL
- R. Commiso (NRL) - short and long conduction experimental results
- N. Roderick (University of New Mexico) - two-dimensional single fluid MHD simulations of POS
- R. Mason (LANL) - the ANTHEM and ISIS simulations that use an implicit moment method to circumvent time step and cell size limitations normally encountered in plasma calculations
- D. Hinshelwood (NRL) - experimental work on microsecond conduction switches
- D. Mc Daniel (SNLA) - POS experiments on PBFA II
- R. Stinnett (SNLA) - ion diode experiments on PBFA II
- R. Reinovsky (LANL) - exploding foil switches
- A. Guenther (LANL) - laser activated switches
- P. VanDevender (SNLA) - pulse power switching for ICF
- I. Vitkovitsky, (RDA, Alexandria, Virginia) - high voltage characteristics of metal vapors
- R. Bartsch (LANL) - plasma flow switches
- H. Kirbie (LLNL) - magnetic switching techniques
- J. Osher (LLNL) - exploding foils as opening switches
- P. Turchi (RDA) - plasmadynamic processes in opening switches

## Conclusions

Roundtable discussions at the end of the sessions underscored a substantial progress in the understanding of POS for short pulse operation (50-100 ns). Recent progress in numerical simulations of short conduction times POS (Mason, 1988, 1989) suggests that the POS opening process is more complex than a simple combination of ion erosion and magnetic insulation. The present understanding of physical processes in the POS suggests that opening takes place through three mechanisms:

1. A magnetic piston opens a gap in the plasma at the cathode. Some ions propelled into the cathode account for the "erosion" feature of the opening suggested in previous theories.
2. Magnetic insulation at the anode as  $v \times B$  forces push the conduction electrons towards the load.
3. Advection as magnetic fields get carried downstream with emission electrons.

On the basis of these mechanisms, an "opening current", or "charge transfer" may be overly simplistic parameters to characterize the opening of the switch.

There still remain many open questions about the underlying physics of the switch for long conduction times (300 ns or more). There are phenomena that may be important and are not included in simulation models. For example:

- Do plasmas formed at the electrodes affect the physics of the switch?
- Can neutrals become a source of charged particles in the switch?

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# The 1989 High Energy Rate Fabrication Conference - Some Emphasis on Soviet Contributions

by Marco S. Di Capua

High Energy Rate Fabrication (HERF) '89, held at Ljubljana, the capital of the Republic of Slovenia (Yugoslavia) September 18-22, 1989, takes place in a 3-year cycle (San Antonio, 1983; Novosibirsk, 1986). The HERF conference discusses effects and applications of shock waves, and high-strain-rate phenomena on materials. These topics are similar to those covered in 5-year cycles by the EXPLOMET (Meyers, 1989) conference series. The HERF conference draws most of participants from Eastern Europe, including the Soviet Union, while EXPLOMET draws researchers from Europe and the U.S.

The HERF conference gathered 60 participants from the host country Yugoslavia, 45 from the U.S.S.R., 8 from the U.S., 7 from Poland, Hungary, and Czechoslovakia, and 10 from European Community countries at the Ljubljana convention center. The interpreters translated the Soviet papers into fluent English with ease. Registration, payments, room reservations, and list of participants were highly automated, confirming my observation of widespread application of informatics in Slovenia. In effect, electronic terminals are common in airports, hotels, banks, and stores. Business supply outlets as well, display a large choice of personal computers, accessories, software, and manuals.

The themes of the conference I found interesting were:

- Compacting of high  $T_c$  superconductors
- Explosive welding, hardening, and cladding of materials
- Some unusual views on mathematical modeling
- Soviet technology developments and applications.

S. Petrovic, the conference chair, distributed the proceedings on the first day of the conference (nna, 1989).

## Compaction of High $T_c$ Superconductors

The meeting devoted significant attention explosive shock compaction of high  $T_c$  superconductors. This technique offers some advantages in preparing monoliths to near final form, starting with rigid ceramic powders. The goal is enhancing connectivity of the superconducting particles by increasing the density of the compacted material. This enhanced connectivity may hold a key in the quest to raise the current conducting capacity of high  $T_c$  superconductors. So far, the shock treatment appears to lower the critical current. However, partial recovery is

possible by annealing the material after compression. The August 1989 Topical Meeting on Shock Compression of Condensed Matter in Albuquerque, New Mexico, (nmb, 1989) also covered this topic in some detail.

K. Staudhammer's research, Los Alamos National Laboratory, New Mexico, and Fraunhofer Institute for Applied Materials Research, Bremen, Federal Republic of Germany (FRG), tried to determine whether the low-critical currents measured in shock compacted materials arise from the explosive compaction process or with the raw powder itself. Staudhammer found shock parameters that yield crack- and melt-free  $YBa_2Cu_3O_{7-x}$  parts with densities greater than 94 percent of the theoretical density. This suggests that the low critical current may be a property of the raw powder.

A paper of L. Murr, now at the University of Texas at El Paso, discussed the optimization of the encapsulation and consolidation of superconducting powders into monoliths with an explosively welded copper matrix. Murr emphasized the difficulty in identifying the explosive forming process trajectory that increases the compaction of the powder, optimizes the welding of the matrix, and maintains (and, perhaps enhances) the properties of the superconducting material itself. Introducing defects that pin magnetic flux vortices increases the critical current thereby enhancing the superconducting properties. Murr and Alan Hare, Northwest Technical Industries (NTI), Sequim, Washington, performed pioneering work on explosive compaction of high temperature superconductors and hold a patent on the process.

A. Szalay, Research Institute of the Electrical Industry, Budapest, Hungary, talked about high- $T_c$  superconducting rings to measure magnetic fields below  $10\mu T$  with SQUID devices for medical diagnostics.

After the session, A. Deribas and V. Nesterenko, Special Design Office of High Rate Hydrodynamics, U.S.S.R. Academy of Sciences, Novosibirsk, who also delivered papers at the Albuquerque meeting, emphasized that investigations of shock processing of high  $T_c$  superconductors ought to continue. They feel that progress in other facets of high  $T_c$  research may suggest an optimal trajectory for shock processing in pressure, density, and time. Finding this optimal trajectory is a laborious process requiring large investments. However, a large possible payoff may justify the investment.

Superconductor compaction through the impact of a projectile launched with a light gas gun (see *ESNIB* 89-04:31-35), by guaranteeing tightly controlled and reproducible conditions, may be the avenue that leads to an optimal compaction path. In particular, C. L. Seaman (Seaman, 1989), University of California, San Diego, in collaboration with W. Nellis group from Lawrence Livermore National Laboratory (LLNL) (Weir, 1989), compacted a few tenths of a gram of high  $T_c$  powder at peak pressures in the 30-200-kbar range in  $\mu$ s time scales with a projectile launched from the LLNL two-stage light gas gun. Seaman produced an orderly configuration of crystallites with smooth intercrystalline boundaries. Seaman created, at 167 kbar, the flux-pinning sites that raise the critical current density in the material to  $320 \text{ A cm}^{-2}$ . The flux-pinning sites remain after annealing the material above  $900^\circ\text{C}$ . According to Nellis, explosive compaction of larger samples could reproduce the pressure-volume-time trajectory the gas gun delivers.

## Explosive Welding and Processing of Materials

**A View of Soviet Efforts.** The Soviet speakers and their organizations that stood out in these areas at the meeting were:

A. Deribas, Special Design Office of High Rate Hydrodynamics, showed a variety of chamber designs for explosion containment. Deribas has now completed the design of the penetrations for an existing 16-m diameter chamber with 30-cm thick walls, for V. Fortov, Institute for High Temperatures (see *ESNIB* 89-10:33-35), to contain explosions in the 500 to 1000-kg range.

Deribas' presentation emphasized mass production of parts, such as hardening of the blades (frogs) of railway track switches, through explosive processing in chambers. Deribas can supply, for hard currency, the chambers built by his institute.

V. Nesterenko, Special Design Office, described processing of amorphous magnetically soft foils into parts for electronic applications. Nesterenko also showed that explosive compaction could form motor armatures with magnetically hard Mg-Al-C alloys. Annealing of the compacted part recovers some of the residual induction lost during the compaction process.

I. Maticin, Lavrentiev Institute of Hydrodynamics, described compaction of ceramic insulators that incorporate concentric metal-ceramic-metal seals for high power lasers. Calculations with the HEMP finite difference code, performed by M. Wilkins, LLNL, determined the configuration of the explosive, ceramic, and metal for compaction.

L. Pervukhin, ANITIM NPO State Corporation, Barnaul, 300 km SE from Novosibirsk, described clad products such as stainless steel-on-steel, aluminum on

steel, titanium on steel, bronze on steel (bearing applications), and tool steel-on-steel. ANITIM's products aim at the chemical process and agricultural industry emphasizing frugal use of the valuable material. ANITIM, who also designs and constructs explosive containment vessels, also wishes to market its products in the West.

A. Derzhavets, All-Union Research and Designer's Institute on Explosive Methods of Geophysical Exploration, Ramenskoye (Moscow), talked about arrays of oil well casing perforating charges, explosively driven diverters for down-hole oil recovery, and explosive and detonator compositions that operate reliably at  $250^\circ\text{C}$  temperatures and pressures of 750 MPa. A very recent, lavishly illustrated 94-page catalog describes their products in detail (nnc, 1989) underlining a strong desire to open a market for its products.

V. Petushkov, E.O. Paton Welding Electric Welding Institute, Kiev, performs microstructural analysis of explosive welds. This work appears out-of-date.

I.V. Yakovlev, Lavrentiev Institute of Hydrodynamics, Novosibirsk, U.S.S.R. presented very clean, time-resolved measurements of temperature and pressure excursions of shock compressed Ti powders reinforced with Mo fibers. The aim of his research is to understand how the Ti matrix "wets" the Mo, providing a reliable fiber matrix bond.

Academician V.Y. Panin, Institute for Physics of Hardness and Materials, Tomsk, discussed some revolutionary ideas (Panin, 1987) on production of highly excited states in crystals by very high-rate deformations. Panin, regards a crystal-undergoing-plastic deformation as a nonhomogeneous, highly nonequilibrium system that advances to equilibrium as the stress-gradient field drives structures through the crystal. In particular, Panin suggests that shear deformations in a crystal propagate, across grain boundaries, through oscillatory shear waves, to neighboring crystals. Translational flow vortices support waves of plastic deformation in the solid. These propagate at a much faster rate than diffusion-driven deformations. Panin suggests that the dynamic deformation process produces highly excited states in the crystal that alters the interatomic potentials. Panin hopes to discuss some of these models at workshop in Terscol (Caucasus, U.S.S.R.) (Psakhie, 1989) on "New Physical Methods of Investigations of Materials Under Loading."

G.V. Sakovich, Lavrentiev Institute of Hydrodynamics, described the synthesis of diamond clusters through a process where pressure rises to 20-40 Gpa in  $1 \mu$ s and temperatures attain  $3500\text{-}4000^\circ\text{K}$  in explosives bearing organic compounds, such as benzene and acetone. Sakovich's claims achieve an almost complete conversion of free C into the diamond phase. V. Titov's laboratory in Novosibirsk is designing a pilot plant to produce diamond dust in industrial quantities for wear-resistant coatings on

machine parts, as well as for grinding and cutting compounds.

A. Antipenko, Institute of Chemical Physics, Chernogolobka (Moscow), performed detailed measurements of the detonation speed in RDX and TNT as a function of density. He associates a plateau that appears in the curve as the density increases, with the change of free C into diamond. V. Drobishev produced a higher yield of diamonds in soot-loaded explosives (amorphous C) than in graphite-loaded explosives (crystalline phase C). These results suggest that the rearrangement into diamond of the crystalline structure of graphite is energetically unfavorable. The optimal C fraction in the production process is a trade secret of the Moscow and Novosibirsk groups.

### Some Western Efforts

Explosive cladding of materials appears to enjoy a renaissance, filling requirements of the aerospace industry to bond unique material combinations such as Ti-Al or unusual geometries. In particular, R. Hardwick, ICI Explosives, Stevenston, U.K., discussed a simple method to produce multilaminar composites. In this method, a sheet of explosive drives a massive plate that collides with the laminae, maintaining the steepness of the collision angle between the plates. Hardwick also suggested an *interesting technique to roll the resulting clad billet*. When the yield strength of the two layers of material is different the rolling process curls the sheet. Rolling two sheets face-to-face simultaneously, cancels the curling forces, allowing the plates to exit the rollers free of distortion. This approach successfully produced, for the chemical industry, large plates of Hastelloy clad steel.

With another technique, ICI assembles steel joints on Al pipes in a production environment with explosive swaging. Al pipes are lighter and support larger deflections than steel pipes allowing greater freedom in directional drilling of oil wells. For durability, however, these pipes require steel joints.

### Summary and Conclusions

Discussions with U.S. and U.K. colleagues at the meeting centered upon assessing the Soviet presentations. A consensus developed that in many instances, Soviet researchers devote large resources to repeat published Western research. So some of the papers submitted to this HERF symposium have lost historical perspective.

Many Soviet papers on explosive welding and processing of materials, such as hardening, suggest that application of these techniques may be wider in the U.S.S.R. than elsewhere. In Western economies, explosives' use falls under very tight, and therefore expensive, safety and environmental restrictions. In the Soviet economy, there

are no resource distributing market processes to force a selection of efficient fabrication methods. Moreover, environmental and safety regulations are weaker than in the West. Therefore, easily accountable material costs have a larger impact in the choice of industrial processes.

In contrast, commercial success of explosive processing in Western economies, depends on:

- Cheap raw materials
- Valuable final product
- No alternative fabrication methods
- A large market for the final product that affords economies of scale.

These considerations restrict explosive fabrication to unique assemblies such as Ti to Al composites, or to recondition parts that already incorporate a very large processed value. One example is remanufacture of built-in bearing races in helicopter rotor shafts.

In the U.S there are three companies active in explosive processing: Explosive Fabricators, Louisville, Colorado; NTI, Sequim, Washington; and the specialty explosives division of E. I. DuPont. DuPont has been producing polycrystalline diamond powder by explosive synthesis (Beard, 1988) for more than 15 years in an underground limestone mine in Pennsylvania. Development also takes place at national laboratories (Livermore, Los Alamos, Army Aberdeen Ballistic Research Laboratory.) The Center for Explosives Technology Research (CETR) in Socorro, New Mexico, associated with the New Mexico Institute of Mining and Technology, Socorro, also performs explosive processing research.

In the FRG, Sur Met, Aachen, performs high HERF processes in closed chambers. Sur Met was absent at this conference and the capabilities of its facilities are unknown. In Japan, Akira Sawaoka of the Tokyo Institute of Technology, Yokohama, is also active in this field.

Future developments in material compaction will probably emphasize planar geometries that avoid the radial dependence of processing path in cylindrical geometries. Compaction may involve cold isostatic pressing followed by final compaction by a shock wave (Beard, 1988). Explosive processing may also be useful in compaction of polycrystalline materials, such as artificial diamonds, where large temperature excursions alter the structure.

Researchers may be able to determine using gas guns, for example, optimal trajectories in pressure-volume-time space that allow appropriate relaxation processes to develop during compaction. These optimal trajectories afford some control over the compaction process. Molecular dynamics calculations of excited states in crystals may shed some light on what the optimal trajectories may be. A knowledge of the optimal trajectory will allow tailoring of the explosive compaction process.

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## Notes About My U.S.S.R. Visit

by Marco S. Di Capua

### Introduction

A visit to the Soviet Union is a rather unusual event for an ONREUR liaison scientist. However, these are unusual times in the Soviet Union, so I spent 2 weeks as a paying guest of the U.S.S.R. Academy of Sciences (Academy). The occasion for the visit was to normalize relations in the pulse power field. Relations were informally suspended when Andrei Sakharov was exiled to Gor'iky and the Soviet Union intervened in Afghanistan. Now Sakharov is back in Moscow, Soviet troops are no longer in Afghanistan, and the Soviet leadership is blowing refreshing winds from Moscow.

### Background

A concrete result of these changes was the visit of a Soviet delegation to pulse power laboratories in the U.S. in May 1989. The visit coincided with Soviet participation at the Laguna Beach Z-pinch and at the Buffalo Institute of Electrical and Electronics Engineers Plasma Science meetings. The visit was also an occasion to encourage U.S. participation at two back-to-back meetings--an International Workshop on the Physics and Technique of High Power Opening Switches (Novosibirsk, July 1-2, 1989), and the 5th International Conference on Mega-gauss Magnetic Field Generation and Related Topics (Novosibirsk, July 3-7, 1989). These two areas are a subset of physics of high energy density research where

sporadic individual contacts have been maintained throughout the years, notwithstanding the possible application of these topics in areas of national security.

### Our Hosts

Our host, Vitaly Bystritskii, Institute of High Current Electronics, Siberian Branch of the Academy at Tomsk, organized the visit with wholehearted support from Genady Mesyats, a vice president of the Academy who now directs a new institute of the Academy's Ural branch. Some of Mesyats' U.S. colleagues maintained contact with him during the freeze so this invitation was a gesture to thank his U.S. counterparts and perhaps to show the Academy leadership that relations in this field were returning to normal.

Bystritskii's goals were to reciprocate after his U.S. visit and to provide the warmest possible atmosphere to optimize the productivity of scientific exchanges in the opening switch area. To achieve these goals, Bystritskii organized the visit outside the usual Intourist channels, a most difficult and trying enterprise at which he succeeded admirably. Among the difficulties, trials, and successes:

- Marginal, awkward, unreliable, slow, and expensive communication links: intracity, intercity, inter-region, and international.
- Hotels and airlines keep reservations and passenger lists on notebooks or loose sheets of paper (hard copy memory systems), so minor changes or

additions become a nightmare and the specter of lost lists always looms.

- Frustrating demands for cooperation from a system where a concept of reward for the common man is extinct.
- Soviet visas withheld until the last minute (this appears to be a reciprocal U.S.-Soviet problem).
- The Intourist bypass involved requisition of hotel rooms by the Academy; this bypass demanded all the "blat" (influence) the Academy could muster.
- Assignment of Academy personnel to drive, guide, and lead us through a tight schedule of Institute work visits from early morning till late afternoon followed by tours to local sights. These tours lasted well into the long evening daylight hours (the sun set in Moscow and Novosibirsk at 2330, and in Leningrad it took a brief dip into the horizon [330° azimuth at 2345] reappearing in the very early morning with a weak northeasterly bearing). Darkness never interrupted the long dusk that blended into dawn and children were still playing outdoors at 0100).

Our hosts met the challenges with admirable aplomb and it was evident from the minute we landed that we were their honored guests. They were genuinely happy to have us there and did their utmost, up to the limits of their physical endurance, for us.

### Observations About Everyday Life

The attention devoted by the media to recent events in the Soviet Union may have dulled Western feelings for the changes that may be taking place under the new leadership. As a liaison scientist, I feel compelled to record a few remarks that resulted from my personal observations or candid conversations with hosts, guides, and Soviet colleagues:

- The infrastructure, with the exception of the Moscow Underground, is severely decapitalized. Deferred maintenance is evident everywhere.
- The food distribution system seems to be out of touch with a country that spans ten time zones. Refrigeration is scarce (never saw a refrigerated truck or refrigerated rail car) and food conservation means (packaging, antioxidants, sequestering agents), judging from the state of goods on market shelves, appears to be primitive or nonexistent.
- A fair fraction of the population seems to spend long unproductive hours in interminable queues waiting for items that may become unavailable. The psychological, social, and economic impact of these queues must be beyond measure.

- Food shortages appear to be common, and hoarding affords some protection by offering bartering possibilities. It is also a source of instabilities that exacerbate shortages.
- Perestroika is freeing some economic structures without improving the productivity of the foundations. In some distribution systems, goods appear to enter and leave through the rear door. The prices of diverted goods are beyond the reach of the average wage earner, fueling severe inflation.
- The service sector of the economy does not function. As an example, a private vehicle damaged by an accident is a total loss unless the owner has access to foreign currency, housing priority lists, automobile priority lists, or stores that distribute Western goods. Even with such access, competent mechanics are hard to find. Humor on this sector abounds.
- Inconvertibility of the Soviet Ruble into hard currency is a source of large distortions in the economy. The disparity between the free (and illegal) market (about 8 R to \$1) and the official market (0.6 R to \$1) is another dormant inflation fuze that is beginning to stir.

### Some Other Observations

Apparently, Chairman Gorbachov's policies have made some impact on alcohol consumption. At one time public drunkenness may have been a significant problem. Admitting that I viewed a minuscule cross section of life, both during our tours and in the excursions I took on my own, I did not witness a single case. Similarly, compared to tales I have heard from participants at previous meetings, drinking at the social functions could even be described as shy of moderate with no pressure from our hosts to engage in endless toasts.

Another interesting contrast is the absence of homeless people that are so evident in large American and European cities. I may speculate that housing, even though marginal, is available to everybody. Homelessness may be illegal or safety nets exist to prevent it.

Wherever I went, I was struck by the beauty, happiness, and healthy appearance of children. Perhaps because their freshness contrasts with what is otherwise a somewhat drab environment. I was also struck by the summer traveling crowds at train stations and airports. At 0300, a stroll across the waiting room of the Novosibirsk train station searching for a restaurant revealed an orderly crowd of perhaps a couple of thousand people waiting for connections. And, yes, a dimly lit restaurant in the basement rewarded me, for 25 kopecks, with the tastiest cabbage and sour cream soup I have ever had.

# Adventures on the Road to Tomsk - Visas, Air Travel, Creature Comforts, Telephones, and Parvenus in the U.S.S.R.

by Marco S. Di Capua

## A Visa Odyssey

Tomsk (62N, 85W), a city in mid Siberia, opened to foreigners in 1989. The U.S.S.R. Consulate (Consulate) in London declined to grant me a visa to visit Tomsk on two occasions; in 1989 as a member of a U.S. delegation participating at the International Workshop on Physics and Technique of High-Power Opening Switches (this issue, page 43) and the Fifth International Conference on Megagauss Magnetic Field Generation and Related Topics (this issue, page 25), and, again in June 1990 for an individual visit. In 1989, my host made fruitless efforts to get the visa after my arrival in the U.S.S.R. In 1990, our joint efforts in Moscow were successful. I chronicle my efforts with the hope that travelers who read this article will benefit from the lessons I learned from interacting with the U.S.S.R. visa bureaucracy.

After the unsuccessful visa effort of 1989, the Institute of High Current Electronics (ISE) of the U.S.S.R. Academy of Sciences (Academy) in Tomsk invited me to visit in February 1990. I had to decline this invitation. Instead, I proposed a visit for June 1990 since I would be traveling to the U.S.S.R. to attend the International Conference on New Physical and Mechanical Methods to Investigate Materials Under Loading in Terscol (this issue, page 8, The Terscol Conference on Materials Undergoing Rapid Deformation and the Institute for Strength Physics and Materials in Tomsk) at the foot of Mount Elbrus, in the Kabardin-Balkar Autonomous Soviet Socialist Republic.

The ISE agreed with this proposal and sent me a telegram which I received through the British Postal System. The I.V. Kurchatov Institute in Troitsk, near Moscow, also agreed with a proposed visit during the same trip, inviting me by a FAX sent to the Office of Naval Research European Office.

I submitted the visa application to the Soviet Consulate in London enclosing the invitation to the conference, the telegram from Tomsk, and the FAX from Troitsk, as supporting documents. One day before my departure, the Consulate released the visa issued 7 days earlier, for the route specified in the conference invitation, excluding Tomsk and restricting the permanence in Moscow, therefore excluding the option to visit Troitsk on the agreed date. Apparently the paperwork for the Tomsk and Moscow visits never percolated through the Foreign Ministry bureaucracy to the Consulate. So, without internal evidence, the Consulate (perhaps doubting the telegram and

the FAX were genuine) declined the visa for Tomsk and restricted the stay in Moscow.

Having learned a lesson from the visa denial of 1989, I had, in the meantime, armed myself with an extensive list of phone numbers and Telex addresses in the U.S.S.R. This latest visa denial unleashed an unprecedented barrage of international telephone calls, telexes, and FAX messages from London, spanning three continents and 15 time zones. Fortunately, I had also allowed a free day upon my arrival in Moscow to adjust to the time difference and to contact Soviet colleagues. This free day in Moscow proved to be critical. On this free day, my efforts spawned a last-minute, high-level intercession by the U.S.S.R. Academy of Sciences (Academy), on my behalf, in Moscow, at Department of Visas and Permissions (UVIR) of the City Department of Home Affairs (GUV) of the Mosgorispolkoma (Moscow City Council Committee). Within 16 hours of my arrival, UVIR in Moscow issued the visa for Tomsk and the necessary time extension.

Under different circumstances, a visit to the Moscow UVIR (Kolpachny Pereulok 10, Phone 924-9349) could ruin someone's whole day....or perhaps even 2! In one instance I am aware of, it took UVIR 2 days to issue a visa extension to allow the departure of a U.S. interpreter who missed his out-bound flight caused by a 1-day delay of his flight out of Siberia. I believe pressure exerted from a high level accounted for the rapid visa changes I got at the Moscow UVIR.

## Visa Conclusions

- Fill the visa application with care, submitting all the supporting documents. From my experience, FAXes and telegrams carry little weight with U.S.S.R. Consulates.
- For unusual visit locations, insist that the host route the invitation through the Foreign Ministry and send you papers carrying an official-looking stamp or seal (see this issue, page 57, The Soviet Research Establishment under Perestroika and Glasnost).
- Examine the visa (issued as a form that attaches to the passport) with care ensuring that it includes the cities you intend to visit in the route. The routing appears in the middle of the visa form.

- Check that the visa dates cover the period of the intended visit. The dates of the interval of validity appear below the prescribed route.
- Tell the host immediately (by telex, FAX, or telephone) about any discrepancies in the visa. A timely notification may allow the host some leadtime to prepare the paperwork to rectify the situation with UVIR upon your arrival in the U.S.S.R. In my trip in 1989, these efforts failed in Novosibirsk.
- If possible, allow a free day in Moscow upon arrival to sort out travel complications. This free day could also come handy to retrieve misrouted baggage.
- The passport office in the hotels retains the passport and visa for a day, to stamp in the visa the duration of your stay. The office organizes passports by country. Pick up the passport and visa promptly because the passport office (which operates independently of the check-in desk) may be closed just when you need your passport to exchange currency or for departure. Hosts are normally in charge of this procedure but they are human and sometimes they forget.

### **Airline Ticketing, Bald Tires, and Wrapped Luggage for Air Travel Within the U.S.S.R.**

I believe a few remarks about my experiences with Aeroflot travel within the U.S.S.R. may benefit future travelers.

- Air travel tickets, when they can be bought with Rubles, are quite cheap even by U.S.S.R. salary standards. (The airfare between Moscow and Tomsk, a 4-hour, 1,000-km flight is 60 Rubles, which represents one-third of the monthly wage of a trainman in the Moscow underground and one-fifth of the monthly wage of a scientific researcher). At the tourist exchange rate of 6 Rubles to the dollar, the price bears no connection with reality, the costs of fuel, or equipment replacement costs.
- Aeroflot, the U.S.S.R. internal air carrier system, saturates in the spring and summer travel periods. Hence, airplanes are full and airport crowds await the release of empty seats; i.e., thousands of people flying on standby.
- Hard copy is the rudimentary basis of the reservations system, that is: passenger lists at the airports. As a corollary of the above, there are painfully long and slow queues everywhere--at ticket outlets, airport counters, and cashiers.
- Aeroflot functions on Moscow time. The departure times that appear on the ticket are written accordingly. The most important time is the beginning of registration (1 1/2 to 2 hours before departure!) Registration closes about 45 minutes before departure and once registration is over, Aeroflot distributes the remaining unused seats to the waiting throngs.
- U.S.S.R. hosts are keenly aware of the crowds and the registration procedure. Therefore, their insistence on timely arrival at the airports is understandable.
- Commercial aircraft are equivalent to U.S. equipment of 20 years ago. The weakness of composite material technology was clear in the wide-body, four-engine, Il-86 aircraft I took from Moscow to Mineralny Vody in the Caucasus. The aircraft, which came into service in 1980, has low bypass ratio engines (small diameter fans) and floor panels, ostensibly manufactured with honeycomb composites (Taylor, 1988), buckled in the interior.
- Conscious of the endemic deferred maintenance throughout the U.S.S.R., I spotted exposed tire fabric in the nose wheel of the Boeing 727-like, Tu-154 M aircraft for the flight from Moscow to Tomsk. I rationalized boarding the airplane on the basis of the waiting throngs. Had I refused, 50 people would have been happy to take my place and then ...I would have had to wait 2 weeks for a seat to open again. I also looked at the better condition of the rubber of the landing gear that supports the heavy wing and propulsion section of the aircraft (Taylor, 1988a), rationalizing perhaps that the weight of the aircraft would balance on the main landing gear if the nosewheel gave up what remained of its ghost. (I was not aware, however, of the role of the nosewheel to control the airplane in case of engine loss on lift-off.) Well, ignorance in some cases is bliss!
- I witnessed a serious security lapse at Moscow's Domodedovo Airport where the only route to the Intourist lounge is a 150-m long walk on the tarmac with no security check at the door. I spent 30 minutes walking among unsecured parked aircraft looking for this lounge upon arrival from Tomsk without ever being questioned. A recent epidemic of hijackings (June-July 1990; Karacs, 1990) is a witness to lax security. Gun-carrying aircraft crews, and ill-disguised plainclothes, gun-carrying air marshals on aircraft, however, provide some degree of comfort.
- For a fee, attendants at many Soviet airports will wrap travelers' suitcases with kraft paper and tie them with heavy string before checkin. According to my hosts, wrapping prevents damage to luggage that is difficult to replace, discourages robbers, and will keep the contents together in case rough handling or a rough landing open the suitcase. A double

wrapping job on my new wheeled suitcase at the Tomsk Airport allowed me to board the aircraft to Moscow with confidence that the suitcase would remain intact in case a blown front wheel would disperse the contents of the aircraft on the runway. The attendant did a very professional job, cutting wheel slots in the bottom with great skill so the suitcase could roll unimpeded!

- If taxis or Academy cars are not available, you can still reach the Moscow airports via public transportation. Soviet scientists told me this was difficult or impossible. However, when my host became ill, I took the direct bus from the Air Station on Leningradskii Prospekt (300 m north of Dinamo Metro station) to Sheremetyevo 2. I saw buses at this station with Sheremetyevo 1, Domodedovo, and Vnukovo Airports destinations as well. Alternatively, the 551 city bus route connects Sheremetyevo with the Rechnaya Vokzal Metro station and the 517 bus connects Sheremetyevo with the Planernaya station.

### Air Travel Conclusions

Allow plenty of time for connections and registration at airports. A missed flight will lead to severe delays for you and headaches for your hosts. Do not examine aircraft. What you see may give you the jitters. Get your luggage wrapped; it will save wear and give you peace of mind. And, there is a public transportation alternative to the taxi, Academy, and Intourist transportation services. Finally do not attempt to check-through luggage to other destinations in the Soviet Union because Moscow's 4 airports (Sheremetyevo 1, Sheremetyevo 2, Domodedovo, Vnukhovo) are as distant from each other as airports in London, Paris, New York, or Washington, D.C.

### Hot Water, Propki, Food and Kipitil'nicki

Hot water availability during summer travel in the U.S.S.R. is chancy at best. Central heating plants are a feature of Soviet cities, and hot water systems can be down for weeks at a time during the summer maintenance season. Another summer consequence of the system is that heat losses overwhelm the insufficient summer hot water throughput. Therefore, hot water when available in summer, is lukewarm at most. In the guest house at Tomsk, I conscientiously shut off a hot water faucet that was running 'round the clock in the ground-floor bathroom. I did not know that it would take another 24 hours before a continuous water flow would restore warmth to the pipes!

Propki (pl. of propka, the common sink or bathtub plug), have been absent in all hotel rooms that I have occupied in a total of 4-weeks travel in the U.S.S.R.

Sometimes the dejurnaya (floor manager of the hotel) possesses a precious rubber one, with a diameter compatible with the sink or tub outlet. Why are propki unavailable? Several explanations come to mind. One is that propki, as everything else in the U.S.S.R., are scarce so guests take them home when they find them. This explanation is somewhat credible since the floor manager, in one or two occasions, asked me to return the propka personally! A second explanation is that since (when available!) the infinite supply of hot water is free, propki are not really necessary. Nail Achmadejev, a physicist from the Academy of Sciences in Ufa, in the Bashkir Autonomous Soviet Socialist Republic, offered a third explanation--the most plausible of all. Nail claims that propki are absent because U.S.S.R. sinks have no cast-in overflows. Consequently presence of a propka represents a risk of a flood. After his remark I did check the sinks and indeed, overflows were absent!

Eating in the Soviet Union is a challenging task that offers rewards to the resourceful and adventurous. State and hotel restaurants require reservations even when they are half-empty or half-full, for that matter. Cooperative and joint-venture restaurants, many of which require hard currency, are expensive and generally booked. So, if you enjoy eating out, collect phone numbers and addresses from friends, colleagues and guidebooks, or make reservations as you walk past a restaurant that appeals to you.

It was rewarding to eat at the cafe's and restaurants where ordinary Soviets eat (Walker, 1989; see: Visitor Notes on the Soviet Union, page 50, this issue). While hygienic conditions sometimes may resemble those encountered in eating establishments of lesser developed countries, I found the food tasty and nourishing. For grazers, snack bars (called buffets, located at hallway ends of selected floors in hotels) are a convenient alternative. These buffets serve mostly cold food. I greatly enjoyed the dairy products, Kfir, Smetana and Twork, in combination with occasional salads and steamed buck-wheat.

Fluid intake can be a problem if you do not drink tea and the buffet or restaurant has run out of Pepsi Cola (availability is spotty, but widespread). Instant coffee may be found occasionally but do not count on it. Fruit juices and carbonated fruit water can be pleasant. I found the ubiquitous (even on Aeroflot flights) mineral water, which the Soviets enjoy, undrinkable because of its high bicarbonate content.

Other travelers disagree with my opinion on local food. For example, Karacs (1990a) exaggerates when he says "The meat pies and hot dogs sold on the streets are heavily laced with salmonella and the few cafes in town sell no coffee, no edible food and the stench and filth can deter even the hungriest customer."

A few days in Moscow can put Western junk food in perspective, and McDonald's in Gorky Street (the street

has since been renamed with a prerevolutionary name), the largest in the world is thriving. But queuing time on a good day is 2 hours. Needless to say, even after 2 weeks, I felt no urge to eat at McDonald's.

Kipitil'nicki (pl. of kipitil'nick) are an essential part of the travel kits of local Soviet travelers. These devices are immersion heaters that travelers use to boil water for tea and coffee at odd hours when hotel buffets close. (Buffets open late in the morning and close early at night!)

### Creature Comfort Conclusions

If there is hot water--take a shower! Weeks may pass before you can take one again. Carry a universal Rubbermaid® diaphragm plug if you intend to wash clothes during your stay or if you wish to luxuriate in a tub (when hot water is available!). And, if you require coffee at odd hours, bring an immersion heater and some instant coffee with you! Finally, make timely reservations and, when food is available at the buffet, buy it. Should you be hungry again, the buffet could be closed, the lines could be interminable, or the item that caught your fancy could be sold out. I still dream about the golden rolls I did not buy at the 5th floor buffet of the Academy of Sciences Hotel in Moscow.

### Telephones, FAXes, and Telexes

My experiences with the telephones in the U.S.S.R. suggest that a working knowledge of the language and dogged perseverance allow one to exploit the system successfully. International calls to the U.S.S.R. are possible. The stumbling blocks are saturated circuits, indifferent Soviet operators, Western operators' ignorance of the intricacies of the U.S.S.R. telephone system and the lack of a telephone-answering infrastructure in U.S.S.R. scientific institutes. Hence, it is common to wait 2 or 3 hours for a line to clear only to find out that the call routing is incorrect or there is no answer at the other end. Knowing in advance the routing of the call is helpful. Telephone companies secretly guard this routing in most instances. For calls to Tomsk, for example, it is very effective to route calls through the Novosibirsk operator. I also avoided frustration by calling colleagues at home in the evening.

Long-distance direct dial calls within the U.S.S.R. from unrestricted phones such as those found in Academy hotel rooms are easy and cheap... once you know the system. As any other, the Soviet phone system has its idiosyncrasies. In the U.S.S.R., absence of instructions such as those found in the front pages of phone books elsewhere (I have never seen a phone book in the U.S.S.R.!) is a hurdle. A Soviet colleague taught me the dialing sequence that works from the Academy hotels in

Moscow: (8) + (Area Code) + (7-Digit Number) or (8) + (Area Code) + (2) + (6-Digit Number).

Once these details are known, calls are fast and effective... except when nobody answers the phone on the other side. Answering phones, except for those of institute directors, is a low priority in the Soviet Union. Therefore, phone numbers of institute directors are useful since normally somebody answers them. On several occasions, I could reach my party by leaving a message through this route.

I failed placing international calls from the Academy of Sciences hotel. I contacted the international operators that serve Moscow domestic and business numbers (8 + 196). However, these operators could not place any calls from the hotel. Collect calls from the U.S.S.R. may be impossible. Numbers (3334101 or 3377001) for the international operators assigned to the hotel were busy 'round-the-clock for the 3 days I tried to communicate a change of plans to my office and family in London. Curiously, I had much better luck calling the U.K. from Novosibirsk last year, where I got a line in a matter of minutes.

The good news is there are debit card phones in some hotel lobbies. The bad news is that these are outrageously expensive (\$34 for a 2-minute call to the U.K.) or... cards are not available at times.

FAXes now exist at several institutes and scientists use them for internal as well as international transmission. FAXes work 24 hours a day. However, these machines are still hostage to saturated incoming and outgoing circuits and the vagaries of operator connections. Telexes are perhaps the most reliable system of communication. Unfortunately, in the U.S. Telex connections have fallen victims of the quickly spreading FAX popularity.

### Communications Conclusions

Yes, one can call, FAX or Telex the U.S.S.R. However, it takes patience, persistence, a rudimentary knowledge of the language, and perhaps a bit of luck to get through. To call from Moscow to the West, however, on the basis of my experience and experience of scientists and businessmen that I have talked to (and...newspaper reports (Hitchens, 1990))... you might as well attempt a call to Mars!

### A Brief Note about Academy Hotels

I stayed at two Academy hotels. One, the Akademicheskii Hotel, is older but very central, within sight of the Oktiabriaskaya Metro station. This hotel has two 14-story buildings, with buffets on the 5th and 11th floors of Building 2. Rooms, though spartan, are comfortable and the telephones dial directly into the U.S.S.R. phone system.

The second, Uzkoe, palatial but isolated, opened 6 months ago, on the grounds of the nursing home of the Academy, within sight of the Moscow Outer Ring Road. On Academician Bargi Road, the Uzkoe is a 15-minute ride away (165 or 805 bus line) from the Tiopli Stan Metro station. Academy cars and drivers are scarce at the Uzkoe. Since there is no shuttle service to the center of Moscow yet, the luxury of Uzkoe hardly balances its very inconvenient location--75 minutes to get into town!.

### Maps and Guidebooks

I can recommend one comprehensive guidebook to the U.S.S.R. (Walker, 1989). This guide has a detailed section on U.S.S.R. history and covers many regions of the U.S.S.R. For Moscow, (Baedeker, 1987) is useful. Distortions are common in city U.S.S.R. issue maps (mapping does not preserve angles or distance scales) and maps are incomplete, therefore misleading. I found the Falk plan of Moscow, that accompanies the Baedeker guide, a useful approximation. The National Geographic maps (Chamberlin, 1967 and Peele, 1976) were invaluable travel, orientation, and conversation companions with U.S. and U.S.S.R. scientists. Curiously, I also met a German scientist who was traveling with these same maps.

### Spotting the Parvenus in Moscow

I found traveling in the U.S.S.R. a *hurry-up and wait* experience. Therefore, a diversion such as spotting parvenus, can pleasantly while away time in the wait phase of travel.

Two scientists from Lebedev, taught me, at a traffic light, a simple technique to spot the parvenus bred by the rapid (?) changes that are taking place in U.S.S.R. society.

This technique relies upon the observation that upstarts often drive German-made luxury cars that would raise eyebrows even in western countries. However, some Soviet leaders, and, foreign diplomats and businessmen drive such cars as well. How to spot the "successful" private citizens?

You can distinguish the parvenus by the license plate sequence that identifies private motor vehicles: a white field with a small cyrillic letter followed by 4 numbers and 2 or 3 cyrillic capital letters. So...happy spotting as you wait for late colleagues, your Academy car, bus, or the traffic light to change!

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# The Soviet Research Establishment Under Perestroika and Glasnost -- A Personal View

by Dean L. Mitchell

The following perspectives on current research life in the Union Soviet Socialist Republics (U.S.S.R.) were gleaned during a 2-week scientific liaison visit to Leningrad and Moscow in May 1990.

There have been remarkable changes in Soviet life, including how the research establishment operates, since the introduction of the policies Perestroika or restructuring, and Glasnost or openness (P&G), by Mikhail Gorbachev 3 years ago. However, many aspects of Soviet research life remain the same under P&G as 23 years ago when I spent 10 months at the Physical-Technical Institute in Leningrad as a visiting scientist under the exchange agreement between the National Academy of Sciences of the U.S. and the Academy of Sciences of the U.S.S.R. The vignettes that follow present a personal view on what has changed - and what has remained the same.

## How to Get In, How to Get Out

In spite of all the changes brought about by P&G, travel by western scientists in the Soviet Union is still severely restricted. The application for a visa requires documentation of an invitation by an organization or individual together with written assurances that accommodations and internal travel for the visitor will be covered while in the Soviet Union. The invitation can be from the Academy of Sciences, from an institute, or from a private individual with bona fide reasons for inviting the visitor from abroad. The main changes in procedures from before P&G are that personal invitations are now granted more frequently than in the past, and that the funding and the responsibility for visits by foreign scientists has been delegated to the research institutes by the Academy of Sciences rather than being centralized in the Presidium of the Academy, as before. The conditions of travel, however, continue to be very restricted both physically, because of the shortage of western-style accommodations, and bureaucratically, since access to the institutes still requires several layers of bureaucratic approval. I did not notice any real simplification in arranging this trip to the Soviet Union compared with what I had encountered on previous trips in 1969 and 1976. However, once inside the Soviet Union, I did sense an atmosphere of openness that was not present on earlier trips. Scientists now are much more open and are willing to

discuss a wider range of topics in one-on-one conversations than before.

Scientific travel in the other direction, i.e., from the Soviet Union to the West, however, has increased from a trickle to a flood under P&G. The only requirement now placed on scientists traveling abroad, apart from security restrictions, is the assurance that hard-currency expenses will be covered as documented in a letter of invitation. One scientist explained to me that both the trickle and the flood have their origins in the same bureaucratic timidity. Previously, if something went wrong, the bureaucrat had to answer "why" he issued a visa. Now, the bureaucrat must be ready to answer "why not," if challenged. This is called "The Law of Minimal Responsibility;" it appears to have universal origins in bureaucratic organizations.

Freedom to travel abroad now appears to be fairly common, at least in the research institutes of the Soviet Academy of Sciences. Z. Alferov, Director of the Physical-Technical Institute (also called FizTek or the Ioffe Institute) in Leningrad, said that the policy of the Ioffe Institute, in the absence of any national policy, was to freely grant permission for scientists to travel abroad. This same freedom applies to employment in foreign laboratories for periods of a year or two. In such cases, he said, the Ioffe Institute would continue to pay two-thirds of the ruble salary and hold the position open. This is the same policy as would apply for a person on sabbatical. While it is possible to extend 1-year leaves, Alferov said that he did expect scientists abroad to resign, so if they did not intend to return, their position could be refilled.

The directors of two other institutes said that essentially the same policies were in effect in their institutes. The present attitude of management in the basic research institutes is to allow scientists freedom to leave and to return. At present, at least, the strategy is to make it attractive for scientists to return rather than to penalize those that leave. The number of Soviet scientists now working abroad is already a significant drain on research talent of the top laboratories. The loss of top-level theorists is particularly noticeable. There was a general feeling that the present situation is not stable so that many scientists are rushing to leave now in expectation that the "open borders" will not last.

While I was in Leningrad, discussions were underway in the Supreme Soviet on legislation to codify national policy regarding the policies and conditions for travel

abroad. Y. Gulyaev, a member of a science and technology subcommission to the Supreme Soviet, who was at the same symposium said that the advice of the subcommission was to allow open two-way travel for Soviet scientists and also, to allow more open access to the Soviet Union by western scientists. Even if the legislation is passed, however, it will be some time before the reduction of bureaucratic barriers and improvement in travel accommodations will allow any significant increase in foreign access. Support for the policy of open travel by Soviet scientists is widespread in the scientific community. I did not sense, however, a similar strong support for increasing the number of foreign scientists visiting Soviet laboratories.

### How It Is Run

The basic research enterprise in the Soviet Union, for the most part, is synonymous with the Academy of Sciences whose institutes dominate Soviet research. The policies of P&G have introduced some cracks in the monolithic structure of the Academy but, by-and-large, the Soviet research establishment remains the most bureaucratic and most hierarchical research establishment of any scientifically advanced country. At the same time, some changes have been made:

- The Russian Physical Society has been allowed to re-establish itself after being suppressed by Stalin
- Local branches of the Academy and the research institutes have been granted increased autonomy in their operations as in foreign travel, for example
- The directors of Institutes and the leadership of the Academy must stand for election on a scheduled basis, typically every 5 years.

The introduction of open elections is the change, so far, which is likely to have the largest impact on research policies in the institutes which, in the past, tended towards extreme conservatism.

Previously, laboratory directors tended to serve for life. V. Tuchkevich, previous director of the Ioffe Institute, served until he was well into his eighties. The importance to an institute of a strong and long-serving director can be inferred from a list of Tuchkevich's many positions including: (1) head of a semiconductor research group in the Physical Technical Institute; (2) director of the institute; (3) president of the Leningrad branch of the Academy of Sciences; (4) full academician in the Academy; and, (5) vice president and member of the Presidium of the Academy. In short, Tuchkevich participated directly in the decision making process, which defines research directions and allocates research funds, at every level from the laboratory bench to ministerial level policy boards.

Z. Alferov, his successor, was elected to the position 3 years ago when Tuchkevich retired. Since then, he has successfully acquired most of the positions held by Tuchkevich. However, he will be required to stand for election to the directorship of the Institute in 2 years and each 5 years thereafter, if he wins.

Re-election is no longer a certainty as shown by the election 2 years ago of L. Keldysh who displaced N. Basov as Director of the Physics Institute of the Academy of Sciences (also called FIAN or the Lebedev Institute). Basov rose to a strong position in the academy through his leadership of the Russian high-power laser program. Recently, however, there was a desire for a new style of leadership among researchers at the Lebedev Institute. As a result, Keldysh was urged to stand for the office by his colleagues. Although a reluctant candidate, he ran and won.

Some elections do follow the formulas of the past. The position of president of the Academy was up for election a few months ago. Several academicians and vice-presidents were nominated to stand for election along with the incumbent. Before the first ballot, however, all other candidates withdrew allowing G. Marchuk, the current incumbent, to be elected unanimously.

### How Is It Funded

A position in a leading research institute previously was a guarantee for a lifetime in research free of concerns about funding or controls over research directions, at least for publishing scientists. This has changed. Western-style "carrot-and-stick" research management is much in evidence although many entrenched mid-level workers are resisting strongly in attempts to stop or slow the processes of change. New management and allocation strategies have been announced which are aimed at making the research enterprise more responsive. The key themes are to promote "New Research Directions," particularly those expected to have impact on marketable technologies. Institutes continue to receive one-third to one-half of their funding from the Academy in a block-funding mode, as before. The rest of the funding, however, is competitive and requires submission of research proposals which describe the research directions to be pursued. These typically focus on some aspect of research or technology with "deliverables" either stated or implied.

The proposed research may be very basic--or may be quite applied. The more technologically oriented research, however, is expected to receive funding from ministries or firms rather than the Academy. For example, the Institute for Solid State Physics at Chernogolovka has developed very advanced low-temperature cryogenic equipment and instrumentation on a par with that obtainable abroad. The Soviet space program is

willing to buy their equipment--and pay hard currency--to have a reliable supply with technical backup inside the Soviet Union. Some laboratories have profited by this more competitive approach to research funding and project management; others have lost ground. Funding at the Ioffe Institute has almost doubled in the 3 years since Alferov became director and reorganized it into four semiautonomous laboratory departments.

Other institutes have not fared as well and, understandably, many scientists are unhappy with the new management and allocation strategies. Some feel that basic research, particularly theory, may suffer in this drive to make research more marketable; others are disturbed that their personal lines of research are no longer fashionable.

One example of these changes in research emphasis and directions is given by the reorganization of the theory group at the Ioffe Institute and the dispersal of its members among the four new research departments. The theory group attained international stature under the leadership of Lev Gurevich and was widely recognized as a center for fundamental theory in solid-state and condensed matter physics. The stature declined somewhat under the leadership of Oleg Constantinov, as some senior theorists moved elsewhere, however, it continued as a major center for solid-state theory and for the training of young theorists. The group was essentially autonomous under the previous funding policy and management style of the Academy. Today, the theorists work in smaller groups within the four research departments and no longer are autonomous. There is considerable pressure to interact more directly with experimentalists in the laboratories where they are located. Some theorists see the changes as a liberation from the "cloister" atmosphere of previous times when theorists tended to talk only to other theorists. Others are less sanguine. The longer-term benefits and liabilities of the changes in research climate remain to be determined.

## Market Issues

All of the laboratory directors with whom I spoke were conscious of the needs to develop marketable technologies in the Soviet Union in order to stabilize the economy. There was, however, a "Tower of Babel" of suggestions on how this might be achieved. I spoke with one Soviet scientist, now abroad, who is involved in a new organization called Society Science. According to him, the U.S.S.R. Society Science (the Society) was initiated 2 years ago on the suggestion of M. Gorbachev as a public corporation with a rather loose charter to commercialize products and services developed from research originating in the laboratories of the Soviet Academy of Sciences. The Society, headed by E. Velikov, a vice president of the Academy of Sciences, is intended to shortcut the bureau-

cracy of the academy in order to attract able researchers to its applied research and development projects. The Society can offer them supplementary funding for this purpose and can offer them a share in the profits. The officers of the Society are empowered, or shortly will be, to enter into profit-making joint ventures with western companies. Development of research instrumentation for sale in western countries is viewed as a potential source of hard currency and as a way to utilize the skilled workers and precision equipment previously used in the arms industry.

As reported to me, the Society is in a policy struggle with other elements of the leadership on how best to make use of the high-technology production capabilities made redundant by the arms standdown. According to the scientist with whom I spoke, E. Velikov is arguing for maintaining the high-technology capabilities of the armament industries by turning out advanced scientific and technical equipment for western markets. The conservative leader, N. Ligachev, is reported to be arguing for the conversion of the factories and institutes to production of consumer goods. Gorbachev presumably backs Velikov.

I asked several laboratory directors about this organization when I arrived. They gave me blank stares. I discovered later that the blank stares did not mean that such an organization did not exist but rather, that there are so many such organizations that no one can keep track. Alferov, in fact, confessed that under the present system, researchers in the Ioffe Institute may establish cooperatives and market technology from the institute through joint ventures with firms abroad without his knowledge or consent. Indeed, the Ioffe Institute itself has taken steps to market technologies developed at the institute in return for hard currency from abroad.

Eficap, a venture capital electronics firm, has been established in Finland to use technology developed in the Ioffe Institute to manufacture and sell electro-optic components including lasers, detectors, mixers, etc. This cooperative venture is at a formative stage with Eficap actively seeking links to major electronics firms and/or distributors in the west to help develop and market the products.

I encountered several examples of such arrangements being established by the institutes or by private individuals with access to the research products of the institutes. An extreme example of the pressure to market was cited by a Soviet colleague who said that there was a defense laboratory in the South with expertise in the advanced technologies connected with laser- and wire-guided armaments. When their defense contracts were canceled, they attempted to market their technology abroad--without the knowledge or consent of officials in Moscow. True or not, such stories are credible during the present chaotic stage of decentralization.

## Role of the Communist Party

Perhaps the most startling change in Soviet life that I noticed during this visit was the open criticism and even vilification of the Communist Party. This is more evident in urban rather than rural areas and also more evident among the intelligentsia rather than among the working class. In Leningrad, the city government no longer has any significant Communist participation. Furthermore, there is serious talk of forming a free-enterprise zone in the Leningrad region with more-or-less open economic borders with the west. There also is the question of what to do with the Communist Party Headquarters in Central Leningrad now that Communists no longer have a direct role in city government.

Alferov spoke openly about historical wrongs perpetuated by the communist leaders. Sitting in his office at the Ioffe Institute, Alferov told us that A.F. Ioffe, after whom it is named, formerly had his apartment in the same wing of the institute as where we were sitting. Ioffe was deposed as director in 1951 on direct orders of Beria who is quoted, "I don't want any German trained scientists involved in the nuclear program." The door to the room where we sat was sealed and was essentially "fenced."

In a move to rectify these historical wrongs, the institute has dedicated a memorial study room to Ioffe's memory where his books, photos, and memorabilia are collected and on display. I had heard earlier that Ioffe was evicted at the time of the Jewish doctors crisis but was still considered important enough to be given his own institute in the former French Embassy located on the banks of the Neva in Central Leningrad. I visited the institute, called the Semiconductor Institute in 1967 while at FizTek. In the early seventies, a scientist from the institute was involved in the attempt to hijack a plane from Leningrad to Finland. Some midlevel scientists saw this as an opportunity to increase their influence and so stirred moves to have the Semiconductor Institute dissolved and its parts rejoined with Fiztek. The moves was successful and the former Semiconductor Institute now forms what is essentially one of its four departments.

None of the laboratory directors with whom I spoke continues to take an active role in the Communist Party leadership or activities in their institutes. At some institutes, the party has been evicted from the offices they formerly occupied. In others, they are being asked to pay rent or to move out. At the laboratory level, the party has entirely lost any real influence it ever had in the internal affairs of the institutes.

The scientists whom I spoke with, who were still party members, also were careful to point out that they no longer took part in party activities. Several commented that they were only remaining in the party until the next general meeting when, it is expected, the party will fragment and they will be able to help split the spoils. A "dowry," so to speak.

## Where Will It Lead

The removal of the structures of central control of the research enterprise in The Soviet Union has given rise to what appears a formless and leaderless anarchy. This is more apparent than real. Russian research and, indeed, the Russian Intelligentsia have a very strong tradition of providing the leadership and the points-of-view that identify Russian life and the directions that it takes during times of anarchy and disorder. This sense-of-the-past/sense-of-the-future is very much a part of the scientific heritage of Russia, a heritage that extends from the times of Euler to today.

The present multiplicity of views on how to organize, how to fund, and how to direct research is not unexpected in a country where previously any divergent views expressed in public could lead to the end of a career. These are heady times and the newly won freedom of expression has given rise to more babble than good sense - at this time. However, from this babble, a sense of political give-and-take appears to be emerging, perhaps more in the scientific arena than in the wider political scene. If economic and political conditions can be stabilized during the next years, then the Soviet, or perhaps, the Russian research establishment is one of the main resources available to lead Russia into the 21st century.

# Science Funding, Organization, and Personnel in the Soviet Union - An Assessment

by Marco S. Di Capua

## Introduction

I developed my impressions about science in the U.S.S.R. during my 2-year assignment as a Liaison Scientist with the Office of Naval Research European Office in London, U.K., through: two visits (2 weeks each in the U.S.S.R., in June of 1989 and June of 1990), discussions with Soviet and U.S. scientists at several conferences in Europe and Asia, conversations with scientists from the newly emerging democracies of Central Europe, and newly published information.

This article collects my general observations on recent developments in Soviet science policy: personnel, funding, structures, cooperatives, and conversion of military industry. I have prepared other articles for this special issue of *European Science News and Information Bulletin* (ESNIB 90-08) devoted to the Soviet Union and, the newly emerging democracies of Central Europe, that review in detail scientific conferences and discuss laboratory visits in two areas of applied science: physics of high-energy density and pulse electromagnetics.

This special issue of *ESNIB* carries other articles of a general nature. One, by my colleague D. Mitchell, reviews the Soviet Research Establishment under Perestroika and Glasnost - a Personal View (see this issue, page 57). Another projects my impressions about the U.S.S.R. day-to-day economy (see this issue, page 50, Notes on My U.S.S.R. Visit), and a third (see this issue, page 52, Adventures on the Road to Tomsk) provides useful travel information for scientists. J. Cooper, Birmingham University, U.K., contributed a Select Bibliography on Soviet Science Policy (page 98) for this issue.

Within the last two years or so, the magazines *Physics Today* and *Science* (see references) have been devoting increasing attention to science in the Soviet Union. Here, I discuss some of their observations on the basis of my recent experience.

## A Caveat

Generalizations about science funding, organization, and personnel in a country as large and as complex as the Soviet Union, run the risk of being misleading and partly inaccurate. However, a combination of published reports on changes taking place in Soviet science funding and organization, conversations I have had with scientists familiar with the funding process, and pronouncements

made by Soviet leaders, all show a state of rapid change at best, and crisis at worst.

In 1986, the Scientific Affairs Division of the North Atlantic Treaty Organization (NATO), reviewed the status of Soviet science in the civilian sector in a workshop that assembled Sovietologists and non-Soviet science administrators and scientists familiar with Soviet scientific exchange programs. The workshop produced a survey of referenced factual and anecdotal information (Sinclair, 1987) that I complement with new information arising from the pace of changes since 1986.

## The Soviet Scientific Establishment

A recent report from National Technical Information Service (NTIS) (nn, 1990) provides some figures on Science and Technology (S&T) resources available in the Soviet Union. Complementary details about science funding appear in Fortescue's (1990) book on *Science Policy in the Soviet Union*. NTIS reports that:

- The 1990 Soviet research and development (R&D) 1990 budget is  $4.0E + 10$  Rubles. The 1991 budget will be  $4.4E + 10$  Rubles
- The total expenditure of the Soviet State Committee on Science and Technology (GKNT) on the 15 paid Scientific and Technical programs it controlled was  $4.3E + 08$  Rubles in 1989 and will increase to  $7.7E + 08$  Rubles in 1990 (Berry 1990)
- Fixed R&D capital amounts to  $4.6$  to  $5.0E + 10$  Rubles, located in various institutes, design construction bureaus, and laboratories
- The Soviet Union counts about 14 million scientists, technicians, "rationalizers" and designers. This last figure for scientific workers arose from the membership of various all-union scientific societies. Of these, there are about 1.5 million researchers and teachers, 50,000 Doctors of Science (Ph.D. + experience + publications) and 500,000 Candidates of Science (Ph.D.)
- The Soviet Union has about 5,100 research establishments including 2,700 research institutes. According to Berry (1990), there are 23 interbranch scientific and technical complexes, only a fraction of which are linked to the Academy of Sciences. More details can be found in Berry (1988).

As a calibration, the average monthly salary in the Soviet Union is about 250 Rubles (Womack, 1990), and, scientists with degrees earn 300 Rubles. Hence, taking 250 Rubles as an average, (scientists with degrees are a small fraction of the total), one would estimate that salaries for scientists, technicians, designers, and "rationalizers" ( $13.5 \text{ million} * 12 * 250 = 4.05 \text{E} + 10 \text{ Rubles}$ ) are close to the total R&D budget. Teachers that do not participate in R&D, or pro-forma memberships in professional societies may inflate the 13.5 million figure.

### An All-Soviet Conference on Soviet Science and Technology Policy

According to recent reports, 1,000 leading Soviet scientists, science managers, and planners held an extraordinary meeting in Moscow on February 19 and 20, 1990, to discuss strategies to accelerate the development of science and technology (S&T) in the Soviet Union.

According to (nn, 1990), representatives of all structures of the S&T complex participated in round-table discussions on various (not strictly S&T-related themes), including:

- Economic reform problems
- Leasing relationships
- Methods to stimulate machine construction
- Defense facilities conversion
- Computer science stimulation
- Education problems.

The conference discussed plans to rescue S&T from its present state of stagnation. At this meeting, Politburo member N.N. Slyunkov candidly admitted that attempts under Perestroika (See: *The New Objectives of Soviet Science in: [Matcheret, 1987]*) to find an effective mechanism for managing S&T progress so far have failed. Following this admission, conference participants went on to discuss planned changes in science policy that could combine state sponsorship and market methods.

The plans reflect a concern growing within the science community (including representatives of the Communist party, official state organs, and independent scientific organizations) that development of Soviet S&T requires introduction of a system of economic incentives, including tax benefits, preferential credits, differentiated prices, wage incentives, and competitive investment.

The meeting heard State Committee for Science and Technology (GKNT) proposals to change centrally planned administrative control of science to state support for S&T programs. State support for programs would replace priorities of ministries that bicker over their narrow interests and arbitrary bureaucratic directives issued without the benefit of consultation. Central planning

would only retain a small number of "large-scale, intersectorial programs of national significance."

In the proposed changes,

- Independent bodies of experts representing a variety of socioeconomic and scientific interests would provide objective, long-range forecasts stating the priority directions.
- New laws concerning intellectual property, scientific research organizations, and the status of scientific personnel would promote S&T innovation.
- The government would create a Council of S&T under the direction of the President of the Soviet Union, M. Gorbachev. The council would include representatives of GOSPLAN, the State Committee for Planning, GKNT, the State Committee for Education, the President of the Soviet Academy of Sciences, the Minister of Finance, major scientists, designers, and public figures.

Besides the state support of S&T, which would be 10 percent of the total, funds from individual enterprises, local and Republic governments, bond issues, a network of banks for commercial innovation and various special "antimonopoly" and "innovation" funds would support high-risk projects. Support would take place on a competitive basis with a larger fraction of the money going to projects rather than to institutes.

The conference also endorsed small flexible enterprises such as S&T cooperatives and engineering centers as vehicles for S&T innovation, both in research and in production of items with a high-technology content. I discuss these cooperatives in more detail below.

### The Present Situation

Some changes in funding methods, funding levels, and science management are in place already. According to one report (Goodwin, 1990):

- The Soviet Academy of Sciences (Academy) had an increase of funding in 1989 (from  $1.2\text{E} + 09$  rubles to  $1.7\text{E} + 09$  rubles) notwithstanding a directive by the Supreme Soviet to reduce the budget deficit (see below). The increase was earmarked for technological innovations.
- Academies of the Constitutional Republics also receive resources to promote interesting new technologies in industry.

Other reports, echoed by Soviet colleagues I spoke with, discuss other developments in the science management, resource, and personnel areas.

In the science management area:

- The structural changes in the Academy brought about by Perestroika (including mandatory retirement and limits on the terms of institute

directors) have yet to alter the status quo. Older Academicians, remaining as advisers, still retain effective control (Palca, 1990).

- High-level experts that can offer impartial advice are hard to find. The few that give impartial advice have difficulty being heard. Therefore, politics and personal interests distort scientific priorities.

From the resource viewpoint:

- The U.S.S.R. has a growing budget deficit problem. According to R. McKinnon, Stanford University, as quoted in Wallich (1990), this deficit "is a natural result of liberalization [without taxation]: the 'profits' of previously state controlled enterprises no longer flow to Moscow." Other economists, however, have different views on the sources of the deficit (Cooper, 1990).
- Consequently, scientists report funding shortages that hamper research progress.
- Dislocations in the Soviet economy delay deliveries of equipment. Shortages of laboratory supplies are now acute (Palca, 1990.)
- Some laboratories now sell under-utilized apparatus to meet current operating expenses
- According to Academician G.A. Mesyats<sup>1</sup>, (Rogers, 1990) paring of the Soviet military budget caused a shortage of funds at the Academy because, in many areas, the Academy relied upon military funding.
- Some important institutes may run out of money to pay salaries before the end of 1990 and some scientists are already taking vacation or leave without pay (anon, 1990).
- Applied science institute directors now realize that they have to make up a sizeable fraction of their budgets by selling research and equipment to industry or other institutes. Many scientists have difficulty with the role of science promoters.
- Hard currency (HC) accounts are now part of the link between Soviet and foreign science. I explore this in more detail below.
- Access of Soviet scientists to foreign literature ranges between the cumbersome and the impossible due to a lack of inter-library loan infrastructure and HC for journal subscriptions (Parrott, 1987).
- Lack of HC for page charges has insulated Soviet science from the world science peer review process

<sup>1</sup>Mesyats is the Chairman of the Ural Division of the Academy, Director of the Academy Institute of Electrophysics in Sverdlovsk (Urals) and founder of the Institute of High Current Electronics (ISE) in Tomsk (see this issue, page 35, Institutions of Research and Higher Learning in Tomsk, U.S.S.R.; page 16, The Institute of High-Current Electronics in Tomsk; also [Kristiansen, 1990])

by discouraging publication of their work in European, American, or Asian (EAA) journals

From the science personnel viewpoint:

- To relieve budget pressures, institute directors encourage researchers to take temporary positions abroad (Bremner, 1990).
- Some well-known scientists echo the anti-Semitic and nationalist views of political organizations such as Pamyat, blaming the present condition of the Soviet Union on Jews (Patuelli, 1990) and non-Russians. Soviet political commentators see this trend as a threat to reforms under way (Rogov, 1990).
- Consequently, Jewish and Armenian scientists especially, are emigrating to the U.S. and Israel in increasing numbers (Palca 1990; Holden, 1990; Bremner, 1990). The Soviet Union can ill afford this loss of qualified personnel.
- Cooperatives aggravate existing morale problems (see a more detailed discussion on cooperatives below).

### The Role of Hard Currency Accounts

As of August 1990, Soviet citizens can legally own and spend HC (Womack, 1990). Also, regulations already in place, allow authorized enterprises (Bootle, 1990; Huhs, 1990), such as economic development and artistic performing companies (Kisselgoff, 1990), to spend a part of the HC they earn.

The implications of these new directives are extraordinary. The unconvertible Ruble has been a wall that has insulated the Soviet economy from other world economies and Soviet people from the rest of the world. Now there is a breach on this wall as well! I examine what these new directives mean, in more detail, below.

Institutions, for example, may now use HC to:

- Purchase, maintain, and update experimental and computer equipment from abroad.
- Purchase information hardware and software such as: copiers, FAXes, technical books, conference proceedings and scientific journals (see Parrott [1987] for an appraisal of past Soviet performance in the science information area).
- Remove from arbitrary Moscow control--the "we have no HC" obstacle to travel--(see Rabkin [1987] for an interesting, though dated, view of exchanges).
- Initiate collaborative research links with scientific laboratories elsewhere in the world.
- Make "at risk" and marketing HC investments abroad for joint EAA ventures. This ability to invest HC is a fundamental change from the "you provide

HC abroad, we provide the Ruble effort locally, you take all the risk, we have no HC" attitude of the past.

For individuals,

- Possession of HC and an ability to spend it (now legal in the Soviet Union), will add inducement for scientists to earn HC abroad through temporary positions and consulting arrangements while on leave from Soviet institutes and Universities.

To gather the HC seed that would make HC generation self-sustaining, some institutes have discovered the tourism side of scientific conferences, exploiting HC conference fees and HC contributions from accompanying persons. The attempts of scientific institutes to offer good value for money, in my experience, are more successful than Intourist's, the Soviet tourism organization (Di Capua, 1990; Kristiansen, 1990; also see this issue, page 52, *Adventures on the Road to Tomsk*). Another example of scientific tourism is a recent offering of Arctic ice-breaker tours.

The joint U.S.S.R.-British Juno project is perhaps the apex of scientific tourism. In Juno, the Soviet Union agreed, for UKL 15 million, to train and send a British astronaut to the Soviet space station Mir for 8 days. When private financial backing for Juno collapsed in England, the Soviets agreed to reduce the price to UKL 2.5 million. This reduction is in exchange for Soviet participation in the experiments of the British astronauts and, Juno's help to the Soviets in industrial processes and creating export opportunities (Fagan, 1990).

Scientists view research funding from abroad as another possible route to earn HC. Scientists from at least three institutes asked me how to channel research proposals, for HC, to U.S. organizations. Similarly, intense efforts to market technology developments and equipment, for HC, are under way. Even scientific-technical cooperatives are getting into this area (see below). However, Soviet scientists' understanding of world market requirements for results, quality, and reliability of equipment appears limited.

There is a desire in the Soviet Union to expand scientific cooperation and exchanges with scientific institutions elsewhere, even in sensitive areas; for example, pulse power (Miller, 1990), nonlinear optics (see this issue, page 126, *X-Ray Diagnostics and Laser Research at the Nuclear Science and Engineering Physics Faculty, Czech Technical University, Prague*), or underwater acoustics (Feit, 1990).

### The Emergence of Scientific-Technical Cooperatives

Scientific-technical cooperatives in the Soviet Union attract young, energetic, and enterprising scientists. According to a recent article, these cooperatives have pro-

duced 7 million rubles worth of industrial products in "the last six months" (sic) (nn, 1990). Several young scientists I met who participate in cooperatives, asked me for advice on marketing products such as software, and epitaxial growth high  $T_c$  superconductors.

With the present state of affairs, cooperatives will have a mixed impact. By sparking enterprise, they boost the morale of young scientists that participate in them by providing them an opportunity to control their future. However, they will have a very negative impact on the institutes to which they attach. The negative impact arises from unresolved conflicts of interest as the scientists' loyalties divide between the institutes where they belong and nominally after-hours cooperative ventures.

Even though views of what a conflicts-of-interest are, may differ in the U.S. and the U.S.S.R. societies, private activities of scientists, overlapping into the working environment, will aggravate the morale and discipline problems that already are endemic in the Soviet work place (Fortescue, 1987; this issue, page 57, *The Soviet Research Establishment under Perestroika and Glasnost - a Personal View*).

Other economic activities involve small enterprises that fall within schemes for transition to a market economy. One I became familiar with, in Sverdlovsk, that is probably an offshoot of military industry conversion (see below), assembles personal computers (PC) from imported parts and sells the PCs for HC to other enterprises that have earned HC themselves.

### Science and Technology in Industry

A Soviet scientist shared his views on the difficulties S&T faces in industry. His views coincide in part with those of Fortescue (1987). The first difficulty is that in a planned economy, civilian industries have little incentive to produce items where a new or higher technological content adds value. The disincentive arises because:

- Production of such items takes more resources, increasing the cost of the final product.
- Central planners do not recognize, with higher payments to the producer, the value new technology adds to products.
- It is easier for industry to meet production quotas with low technology products.
- Without competition, items sell independently of technology content (there is nothing better to buy)
- The need for full employment discourages the introduction of technology that increases the efficiency of manufacturing
- Control of industry by separate ministries (each branch of industry is controlled by one ministry) hampers the cross flow of ideas. Concepts only

reach the prototype stage, and good ideas are aborted because they do not fit with production plans (G. Mesyats in: Miller, 1990).

A second difficulty with industry, according to the same Soviet colleague, is that its leaders expect solutions to today's production problems (filling the quotas) and are unwilling to pay for R&D that will yield long-term benefits.

A third difficulty in industry is that the democratization process, under Perestroika, established workers councils that participate in the decisions of resource allocation; that is, micro management by the masses. These councils assign resources where results are most visible and short-term benefits larger. Hence, R&D suffers.

Parallel democratization developments in Italian state enterprises brought economic growth in Italy to a halt in the mid seventies. Privatization of those that were still profitable, closure of others, and export-driven economic growth solved this problem. The same solutions may work for the Soviet Union.

M. Gorbachev has recognized these difficulties in a recent speech (Karaes, 1990) stating: "We can no longer tolerate the managerial system which rejects scientific and technical progress...and generates squandering and waste."

### Technology Transfer in the Academy

There are structural problems with the Academy as well, since Academy laboratories have a difficulty communicating with universities, ideas in universities are difficult to put into production and, while university laboratories can make prototypes, universities have no funds or facilities for production. According to Mesyats (Rogers, 1990) "the Soviet government is attempting to smooth out the technology transfer process by [introducing] Special Design Offices and other types of administrative layering." This restructuring has been underway since 1985 (Macheret, 1987).

Attempts to facilitate technology transfer from Academy laboratories have produced a chaotic situation where entrepreneurial scientists may establish cooperatives to market technologies without the knowledge or consent of institute directors (see this issue, page 57, The Soviet Research Establishment under Perestroika and Glasnost - a Personal View). Ineffectual laws on intellectual property fuel this Wild West atmosphere.

### Conversion of Military R&D

Some of the scientists I spoke to believe that redirection of resources from the military to sectors of the economy other than R&D and S&T is another root of funding

difficulties. There is still some debate on how large the shortfall caused by this redirection is. One view on this shortfall is that the funding increase for the Academy intends to compensate the military research budget reductions (Cooper, 1990).

Two Academicians I know of, and perhaps others, are very active in conversion activities. One is E. Velikhov, who in the past has proposed restraint in nuclear arms (Velikhov, 1989) and on SDI activities (Velikhov, 1986). Velikhov believes that military industries could be the base for new enterprises to produce goods with a high-technology content (see this issue, page 57, The Soviet Research Establishment under Perestroika and Glasnost - a Personal View). McRae (1990) claims the U.S.S.R. has 120 military manufacturing plants that are the cutting edge of electronic, electrical and mechanical engineering technology. These factories may be the hope to construct the new manufacturing base Velikhov is striving for.

Mesyats, who participates in the conversion of military state-owned factories to private concerns in the Urals, spoke about the conversion of military state-owned factories to private industrial concerns at the Lawrence Livermore National Laboratory, California, in February 1990 (nna, 1990). According to Mesyats, (Miller, 1990), "...this conversion has left many technical specialists out in the cold [with unemployment rates approaching 30 percent (Rogers, 1990)]. High level specialists who were profiting from the military are upset because the switch [to civilian production] has touched their style of life."

A positive facet, however, according to Mesyats, is that these dramatic changes have produced a "sale on ideas...There is [now] a big push to implement new ideas in [the newly privatized formerly military industries] private industry. The cut in state funding is breaking down the barriers between science's conception and industry implementation" (Miller, 1990).

Since there are no existing commercial manufacturers that could shelter the newly privatized military organizations in the Soviet Union, a converse arrangement may arise where military factories shelter organizations that satisfy civilian needs. An advantage of this approach, favored by Velikhov, is that it would maintain the technology capabilities of military industries (see this issue, page 57, The Soviet Research Establishment under Perestroika and Glasnost - a Personal View).

However, some questions arise. Can the prices of the civilian goods these organizations produce reflect the production inputs (equipment, labor, raw materials)? Are the military willing to relinquish enough production so converted industries could have an impact on the civilian economy? Would injection of European, Ameri-

can, and Asian (EAA) technology into these enterprises increase Soviet military capability? Perhaps studies by the International Monetary Fund and the World Bank, proposed at the July 1990 Houston summit, will answer some of these concerns.

## Do We Dare to Tell What May Happen Next?

The state of science in the Soviet Union reflects the state of society and the economy, and uncertainties in Soviet science parallel those in the society. As in society, there is resistance to adopt new structures that endow science with the flexibility it requires to adapt to change. The established order (Goodwin, 1990) wants to retain power and privilege.

Capital shortages in experimental science parallel capital shortages in the economy. Laboratory facilities missed the microprocessor revolution and laboratories are now beginning to implement data acquisition and process control computers that became standard in America and Europe 15 years ago.

Unavailability of off-the-shelf components also causes experimentalists great trouble. With vertical integration, suppliers at the component level do not exist and industry has no interest in diverting to other users, components it requires in the assembly process. Consequently, unavailability of off-the-shelf components for experimental equipment has caused inefficiency in experimental work.

There is some change in this front, however. I am aware of a trade show, held with a Soviet conference on pulse power, that displayed off-the-shelf components (often produced on demand). I presume that the same shows may take place in other fields. I am also aware, from a colleague that visited ISE (see this issue, page 16, The Institute of High-Current Electronics in Tomsk) twice, in 1989 and 1990, that the number of personal computers at ISE has grown substantially (Hinshelwood, 1990). Consequently, if developments in the pulse power field are the norm, extrapolations suggest that the Soviet experimental establishment has a faint hope of making up lost time as the microprocessor and high-technology revolution bypassed the Soviet Union.

I cannot judge the state of Soviet theoretical science. In the past, theory has been one of the strengths of Soviet science. However, even theoretical research now requires computational resources. Recognizing this problem, The World Laboratory is attempting to help, providing computer time at the Ettore Majorana Center of Scientific Culture in Erice, Italy.

The unique pattern of support for basic science in the Soviet Union for the last few decades is perhaps its biggest weakness. In the past, leading research institutes guaranteed scientific workers positions in basic research, free

from concerns about funding, research directions, relevance or productivity. In the view of one Soviet scientist (R. Sagdeev as quoted in [Irwin, 1990]), "we have for years been castigating ourselves for our failure to apply fundamental research findings to improve productivity;...but...we have not faced up to the real problem: Soviet fundamental science is too weak to contribute much to practical applications." Therefore Soviet basic science faces the challenge to impose a measure of quality control on the face of budget cuts and in competition with a new emphasis on applied science.

From a North American and European standpoint, we may see increasing number of Soviet emigres, with an S&T background, looking for work in North America (Palca 1990; Holden, 1990; Bremner, 1990). One scientist I spoke to, however, feels that the best scientist are idealists and would want to remain to improve the lot of the Soviet people. So in his view, the emigres are likely to be, not only second-rate people, but the product of a system that leans to overspecialization and where quality is short.

With the easing of restrictions imposed by the Soviet government, North America and Europe may see Soviet and Central European graduate students replacing students from Asia (Hong Kong, Taiwan, Peoples Republic of China and Korea; Holden, 1990a). Upon their return to the Soviet Union, these American- and European-trained scientists could become an effective force for change in the science as well as politics. However, Soviet students will face tough competition from Czech, Polish, Hungarian, and Yugoslavian students who may have an easier time adapting to universities in Europe and North America.

As permission to travel becomes decentralized, (see this issue, page 57, The Soviet Research Establishment under Perestroika and Glasnost - a Personal View) there will be more support requests from Soviet scientists to attend conferences in Europe, America, and Asia (EAA). Invitations to EAA scientists to attend HC fee-paid conferences in the Soviet Union and to visit previously closed Soviet laboratories will become more frequent (see articles on visits to Tomsk, this issue).

In addition to a genuine desire for information exchange, Soviet laboratory directors often offer travel support for EAA scientists within the Soviet Union with hopes to exchange, in a *quid-pro-quo* basis, travel support in EAA. As a second agenda, Soviet hosts are delighted to make, for HC, travel arrangements in the Soviet Union for those who must pay fees. A third hidden agenda is a wish that U.S. Departments of Defense and Energy may reciprocate the hospitality and authorize visits to their laboratories in the U.S.

We will see increasing marketing overtures in EAA for basic research, unique apparatus, and joint research ventures (Kristiansen, 1990). These overtures may be espe-

cially vigorous from institutes and research-industrial co-operatives that have HC accounts.

In the long term, the global economy would benefit from exploiting some complementarily (Huhs, 1990) between the Soviet and the advanced EAA economies. This complementarily arises from shortage of capital in the Soviet Union, shortage of resources in EAA, an extensive basic science establishment with high potential in the U.S.S.R., and, strong applied science elsewhere.

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# Report on Participation in the 45th Mediterranean Cruise of the Soviet R/V D. Mendeleev

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## Introduction

During October 9-18, 1989, in waters near Greece, I participated in the 45th R/V Mendeleev cruise; and on November 1-2 in the port of Civitavecchia, Italy, I attended a meeting on future neutrino detectors. During the cruise, tests were carried out using photomultipliers that are planned for employment in a large underwater neutrino detector, as well as ordinary oceanographic and geophysical measurements. Many discussions took place both with physicists and other scientists, the environment encouraging a health cross disciplinary dialogue. Below are comments on:

- General operations of the cruise and Soviet Deep Underwater Muon and Neutrino Detection (DUMAND), team activities
- Organization for new neutrino astronomy efforts in the U.S.S.R., where at least three large-scale efforts are in progress
- Workshop held aboard the Mendeleev in Civitavecchia, with short discussions of neutrino astronomy efforts in Italy and discussions of possible future fourth generation (1 km<sup>2</sup> scale) instruments.

## General Operations of the Cruise and Soviet DUMAND Team Activities

In October 1989, I spent a little more than a week aboard the R/V D. Mendeleev in waters off Greece. S.O. Flyckt of the Philips Corporation/Eindhoven, Gary Bernhardt of Benthos, North Falmouth, Massachusetts, and I boarded the vessel in Salonica, Greece on October 9. Nine days later, Flyckt and I left in Pireus, Greece, but Gary stayed on board until the ship arrived in Civitavecchia on October 31. The invitation to participate came from Igor Zheleznykh and his superior, Academician M.A. Markov, of the Institute of Nuclear Research (INR), Moscow, and was cosponsored by Alexander Eremeev and Director, V.S. Yastrebov, of the Institute of Oceanology (IO) of the U.S.S.R. Academy of Sciences. The IO has a cooperative agreement with the INR group on Soviet DUMAND in the ocean.

The purpose of the trip was to test jointly some photomultipliers intended for use in DUMAND-type of neutrino detectors (deep water, detecting muon-produced Cherenkov radiation with photomultipliers), such as both

we and the Soviets are pursuing. The venture included two optical modules from Kiel (containing Philips Photo Multipliers [PMT]), brought on board by Michael Preischl and Boris Hoffarth under the auspices of Peter Koske of Kiel and Flyckt. Preischl and Hoffarth came aboard at the time that Flyckt and I disembarked at Pireus. While not much was accomplished on DUMAND detectors experimentally during the early part of the cruise, we all learned a lot about each other's activities. However, the Soviet team persisted, making steady progress on each attempt (every week or so) and claim to have succeeded in counting muons during the Atlantic portion of their cruise (which ended in Kaliningrad on December 21).

The Soviet DUMAND team consisted of Igor Zheleznykh (Deputy Department Chief), Nikolay Surin (working physicist in charge), Vladimir Zhukov (physicist), Lev Zhukov (multitalented mechanic), Andrei Deyneko (physicist), Alexander Permyakov (physicist/electronics engineer), and Nikolay Sheremet (geophysicist). Sheremet is from the IO and the rest are from INR.

The Soviet DUMAND instrument consisted of 8 Hamamatsu photomultipliers (15 inch PMTs, in Benthos 16-in glass instrument housings) designed to be deployed in a cube 8 m on a side, erected from an inverted umbrella arrangement. The ship's crane did not have adequate deck clearance to get the full structure overboard, so the DUMAND team shortened the configuration, first using 4 PMTs (increasing to 6 PMTs later, I understand) during the Atlantic activities after we left.

A technical innovation is the insertion of an equatorial bearing ring of Titanium in the Benthos housings, a sort of Titanium gasket. The gasket has a U channel cross section, protecting the glass mating surfaces, ground flat (#12 finish) on the mating surface, and seems to be only several mm thick. The gasket is bonded to the glass with what was said to be a ceramic-containing epoxy that matches the mechanical coefficients. Supposedly, the Materials Research Institute in Kiev developed it for the DUMAND group. They were secretive about the exact details and compositions, saying that they were trying for an international patent. Gary was naturally quite interested in this innovation since it is a long-standing myth in the community that one cannot put any material at all (not even grease) on the glass mating surfaces or they will spallate under pressure. The Russians claim thorough

testing in tanks and to 5-km depth, but do not have long-term exposure testing yet. They were quite interested in commercial possibilities, including license to Benthos.

The team worked very hard and seem talented and enthusiastic. They were, however, extremely innocent about work in the capricious ocean. Having had 8 years of experience going to sea with tests for DUMAND Hawaii, it was not hard to see at least a dozen problems with their design. I tried to communicate some of these concerns in a tactful way, but the young physicists were not enthusiastic about advice, so I let it drop. Later they did in fact bend the instrument arms as predicted. Fortunately, having taken one suggestion about protecting the spheres from colliding during the severe motions at the air-sea interface, they did not break the housings. I concluded that the Soviet DUMAND team has a few years of catching up to do. They do learn fast though, and these long cruises (3 months!) offer a lot of time to learn, repair, and try again.

The biggest problem our Soviet colleagues seem to face experimentally is the terrible lack of equipment. I was shocked at both the lack of tools (no socket wrenches, for example) and lack of expendables; e.g., no electrical tape supply. Their laboratory was very poorly equipped. A few hundred dollars spent at Sears would have made their lives a lot easier. On the other hand, they are expert improvisers, reminding me much of the way we used to do things when doing cosmic ray work in the mountains (though we were never as ill equipped as they). Their electronics capabilities were quite primitive, the circuits being handmade from discrete components mostly. In fact, the circuitry was being assembled (soldered together) for the first time while we were aboard. I would say their electronics were a decade behind ours in general.

The lack of tools and expendables seemed to be universal among the groups aboard (about 150 scientists in about 15 teams). There were, however, a half dozen or so personal computers (PC), mostly IBM clones (eastern and western). There was a great lack of paper or ribbon for the printers (no lasers). The machines seemed to be mostly used for playing computer games, which were immensely popular. The DUMAND group was running a Fortran Monte Carlo simulation on their Turbo PC. The ship's computers were the butt of everyone's jokes, being machines apparently installed when the ship was built (they looked like the earliest PDP machines, with huge tape drives), yet they were being used to process some of the ship's ongoing data. Apparently, they have not discovered that PCs can be used for word processing.

The ship's equipment was sadly out of date. When we first went aboard, the Captain and Chief Scientist invited us to have the free run of the ship, and they were quite explicit about having nothing to hide. We poked around

many places at all times of the day and found nothing suspicious. The ship was carrying out the usual measurements in transit (bathymetry, gravity, magnetics), but all the instruments seemed to be quite ancient (at least to my inexpert eyes). The onboard communications were also out of date, and the main communications with Moscow seemed to be via Morse Code! They had no functional satellite communications, except a Japanese-made Satellite Navigation System unit (no Global Positioning System U.S.). They had a standard VHF transceiver, which I used in a futile attempt to make phone patch to Athens via the Radio Hellas marine operator.

On the other side of the balance sheet, I have nothing but praise for the Captain and crew. They were friendly, professional, calm (working overboard in a major storm), and efficient. We saw about 20 deployments and recoveries of instrument packages, and as far as I know all were successfully brought back on board. I would be happy to go to sea with them.

### Neutrino Astronomy in the U.S.S.R.

The organization for neutrino astronomy in the U.S.S.R. is fairly complex, and on a much greater scale than in the U.S. I have heard several times now from Soviet colleagues that a document was signed at Gorbachev's level, which sets out the priorities in High-Energy Physics (HEP) in the U.S.S.R. According to these discussions, there are three equal major initiatives: in accelerators (UNK, etc.), Extensive Air Shower (principally the newly planned 1000-km<sup>2</sup> array of Kristiansen from Moscow University), and neutrino astronomy. A.A. Logunov, V.P. Academy, Chairman State Committee of Science and Technology, heads all three.

Academicians G.T. Zatsepin and A. Chudakov have, in overlapping ways, the multiple programs at the Baksan Neutrino Observatory, and several collaborations with Italians in Mount Blanc and Grand Sasso. M.A. Markov is retired secretary of the Academy but still exceedingly influential as Department Chief of Neutrino Telescopes in the Ocean and Antarctica, Institute for Nuclear Research. While V.A. Matveev is the Director of INR (Rubakov Deputy) (both young theoreticians), Zheleznykh and Markov have assembled an impressive collaboration working on:

- Optical techniques in the ocean (Surin + 6 people)
- Acoustic methods (Karayevsky + 3)
- Radio methods in the antarctic (Provorov and Gogyin + 5)
- Photodevices (Sadegov + 4)
- New scintillation techniques (Manufactured at Grosny) (Beresnev + 6)

- Institute of Energetics, Moscow and Institute of Antarctic and Arctic (5)
- Institute of Oceanology (Eremeev + 5)
- U. Rostov on the Don (5)
- Kiev Institute of Materials (few)
- Kharkov (scintillator)
- Physical Institute of Academy of Sciences (few)
- Lebedev (Fedorov + 4)
- Institute for Physical and Technical Measurements (equivalent of National Institute of Standards and Technology).

I am not sure how many of these people really are fulltime on neutrino projects. However, the list impressively long--all concerned with neutrino astronomy in the ocean and ice, and I know of concrete activity on most items listed.

There are, for example, ongoing activities for several seasons now at the Vostok station in Antarctica in an attempt to test the feasibility of radio detection of neutrino-induced cascades in ice. Igor also described a plan for acoustical tests in the Atlantic next year, directed by Karayesky at INR and the Institute for Physical and Technical Measurements. The instrument string is said to be for deep ocean deployment, pop up 50-m tall with a self-recording package at the top. The bandwidth is 1-30 Khz, sampling. The top hydrophone is an HF isotope, then an 8-element linear unequally spaced array, then 4 more horizontally directed hydrophones spaced 10 m apart. The goal is to measure the HF background in the ocean and set limits on the ultra high energy regime,  $\sim 10^{15}$  eV (eV = Electron Volts) neutrino flux. They are soliciting collaborators on this project too.

The goal of the optical ocean operations is to build some sort of detector equivalent to the 20,000 m<sup>2</sup> DUMAND II, but located near Europe. I would like to see this go ahead scientifically, because it would complement our field of view from the Pacific, the two detectors thus covering the entire sky all the time. The Soviets have not settled upon a site, but have considered the Black Sea (off Gelendjikh), the Mediterranean, and the Atlantic. The Black Sea is attractive because of lack of bioluminescence below about 200 m where it is anaerobic. They are focusing on a location near Italy right now for the practical reason that the Italians seem to be able to obtain large amounts of money for such endeavors these days; e.g., Gran Sasso. Moreover, the Soviets have a long tradition of collaborating with some Italian groups, and have good working relations with them (including at the new Gran Sasso Laboratory) on the huge large volume, LVD (a thousand ton liquid scintillator-based neutrino detector being built in Gran Sasso) experiment. On the Mendeleev cruise, the team explored a deep site off southwestern Greece (21 33' E, 36 42' N, about 4-km deep [location

pointed out by Leonidas Resvanis of U. Athens]), which is apparently quite attractive oceanographically.

The Lake Baykal group has become quite independent, though reporting in some way to Markov but apparently not Zheleznykh. Domogatsky and Bezrukov head up that operation, involving some 50 people. Another operation is headed by A. Petrukhin of the Moscow Institute of Physics and Engineering (about 15 people) in collaboration with Illichov (5 people) of the Far East Institute of Oceanology in Vladivostok. Both operations aim at substantial DUMAND type of neutrino detectors.

Petrukhin's group has been doing detailed bioluminescence studies in the Pacific and Indian Oceans. Another INR department, run by Shtranykh (electronics laboratory), has been carrying out the other reported bioluminescence studies in the Atlantic. Both are reported as studies for DUMAND, and have been useful to us in understanding the almost universal nature of this deep ocean, motion-stimulable optical phenomena.

Apparently, there is little communication between the groups; in fact, in several instances we knew more about what other Soviet groups were doing than did Igor and his group! In fact, poor communications among scientists is certainly one of the most backwards aspects of scientific life in Russia. *Glasnost* or not, they remain heavily isolated in their own small groups. A few Xerox and FAX machines would be a great help. Aboard the ship, they copy things by hand or typewriter.

In summary, third generation neutrino telescopes, as well as exploratory technology for speculative techniques, are being pushed by at least three major groups in the Soviet Union. They are hurting for modern technology, but have a lot of enthusiasm, and many people. I cannot estimate what the total equivalent budget would be in the U.S. Perhaps the U.S.S.R. spends an equivalent of \$10 million/year on neutrino astronomy.

### Civitavecchia Workshop on Future Neutrino Telescopes

On November 1, 1989, at the small workshop held aboard the R/V Mendeleev in Civitavecchia, Italy, we reviewed present generation neutrino detector plans and discussed how to plan for a world neutrino detector in the 1km<sup>2</sup> class, to be built around the turn of the century.

Professor Mille Baldo-Ceolin of Padova described a detector under consideration for emplacement near Gran Sasso, one that is similar to the U.S. GRANDE proposal (proposed pond-type of water cherenkov detector). The rough dimensions are 100,000 m<sup>2</sup> by 40-m deep, with two or three layers (the modified GRANDE proposal for Arkansas is about 30,000 m<sup>2</sup>). The detector would be located at an altitude of about 1000 m in a pit requiring substantial civil engineering, for which a study has been carried out. Apparently, there are already col-

laborators from Italy, France, and Switzerland. They are carrying out Monte Carlo studies with the aim of preparing a proposal soon. The most optimistic time would be about 1 year for approval, plus 3 to 4 years for construction, thus possibly operational in 1995.

Professor Michelangelo Ambrosio of Naples described the Southern Italian Neutrino and Gamma Ray Astrophysical Observatory (SINGAO) project, a collaboration of Universities of Bari, Cosenza, Lecce, Palermo, Roma, the Frascati National Laboratory, and Leeds University, England. The site is about 1000-m altitude inland of Naples at Toppo di Castelgrande. The detector is to be made with 15,000m<sup>2</sup> of Resistive Plate Chambers (cost 10<sup>5</sup> lira/m<sup>2</sup>) for muon counters. These would be 8-10 planes, with 5 m of concrete. This would comprise a muon array for Extensive Air Shower (EAS) studies going downwards, and a neutrino detector for upcoming muons. The timing requirements for this latter capability are daunting (require an up-to-down ratio of better than 10<sup>-11</sup>). For the EAS capability, there would also be 3,000 each of two m<sup>2</sup> shower counters spread about to give an EAS array area of 9 km<sup>2</sup>. A 144-m<sup>2</sup> test module is now under construction. Several years of development are needed, so the big array could not be ready before 1996 (funding is not assured).

I summarized the DUMAND II plans, S. O. Flyckt and G. Bernhardt presented technical discussions of PMTs and housings, and the oceanographers gave a briefing about their multidisciplinary studies of seismically triggered benthic flows. They showed us just-acquired data, confirming the correlation of small earthquakes and benthic flows observed near Crete.

Finally, I led a discussion of the possibilities for fourth generation instruments beyond these detectors discussed above. Everyone realizes that such a project will be a massive undertaking, and will only go forward if we have good results from DUMAND II and other initiatives though the mid-1990s. To set the scale (for example, using a DUMAND style of technology), a straight forward extrapolation of scale would imply that we would need 10,000 optical modules. At a cost of \$10,000/module (averaging over everything else) this implies a total project cost of approximately \$100 million. This number is not outrageous by present accelerator detector standards, but is much larger than any nonaccelerator project (though the unapproved Super-Kamiokande in Japan is about \$50 million, and the recently approved SNO project in Canada is around \$70 million). A substantial international collaboration will be needed to bring such an instrument into being.

## U.S.S.R. Biotechnology: Looking for Extramural Associations

*by Dr. Keith E. Cooksey, the Liaison Scientist for Biochemistry, Microbiology and Marine Biotechnology in Europe and the Middle East for the Office of Naval Research European Office. Dr. Cooksey is on leave of absence from Montana State University, Bozeman, Montana Department of Microbiology where he is Professor of Microbiology.*

### Introduction

The Russian word *Perestroika* is found throughout this issue and is commonly seen in the print and electronic media. The word is used to describe the restructuring of Soviet society. Although not always appreciated outside the Soviet Union, restructuring also applies to science, as well as society in general. This means that the old paternalistic and stable means of funding science are to be replaced by procedures rather more like those in the West. Whether this is a major reason for the current interest of the Soviet scientific establishment in entrepreneurial ventures, the fact remains that the scientific system is likely to be shorter of money than before. Since the Soviet Union is not yet a market economy, entrepreneurial activity must, to a large extent, involve associations with societies outside their own country.

The biotechnological fraternity in the U.S.S.R. has not lagged in this regard; in particular, they have sought to build scientific bridges at the practical level. From all accounts, the level of biotechnological expertise available there is very high, but the science itself is often (but not always) less sophisticated than that in Europe, Japan, and the U.S. This is partially because of the lack of modern biological instrumentation and research foci have come previously from the very upper levels of administration. From what I have read, the Soviets recognize that rather large advances in biotechnology can be made quickly with an injection of the type of sophisticated instrumentation available outside the U.S.S.R. Access to this equipment requires hard currency and this also may fuel their desire for outside interactions. In fact, it is not until quite recently that Soviet scientists were able to travel freely outside the Eastern Bloc countries. Thus, their only fruit-

ful contact with fast-moving fields (and biotechnology is surely one of the fastest), was by meeting scientists who had travelled to their country.

### The U.K. Liaison Visit to the U.S.S.R.

The fact that the Soviets want to build associations quickly and not wait for the usual bureaucratic channels to operate is exemplified by the approach made last year to a small U.K. company, GB Biotechnology. The contact was made by the Director General of the Shemyakin Institute of Bio-organic Chemistry, Professor Vadim T. Ivanov. Ivanov proposed that GB Biotechnology should help in fostering a relationship between the U.S.S.R. and the U.K. The Shemyakin Institute is the foremost biotechnological center in the Soviet Union with a staff of about 2,000 people; GB Biotechnology is a tiny company with a staff of less than 10. Why such a giant should come to such a small company is not entirely certain. However, it is well known that large organizations like governments are slow to move, and in this case, time seemed to be of the essence. The choice of a small company therefore made sense, especially one already known for its connections throughout the U.K. biotechnological scene through its magazine *The Genetic Engineer and Biotechnologist* (1). Therefore, GB Biotechnology could arrange a visit to the U.S.S.R. of senior representatives of the British biotechnological industry and the lead government agency, the Department of Trade and Industry. This in turn was followed by a trip to the U.K. by the Soviets. The information gathered was later presented at a 1-day workshop for British industry. The workshop was sponsored by the Center for Russian and East European Studies of the University of Birmingham and organized by GB Biotechnology. My article owes much to the Report of the U.K. Department of Trade and Industry, "Overseas Science and Technology Expert Mission on Biotechnology to the U.S.S.R." (2), and an interview with Dr. R.N. Greenshields, Managing Director of GB Biotechnology Ltd. The U.K. Overseas Science and Technology Expert Missions (OSTEMS) have a rationale similar to that defining the roles of the Office of Naval Research European Office and the Office of Naval Research Asia.

Led by Greenshields, the British mission consisted of Dr. Brian Richards, British Biotechnology Ltd., Oxford; Dr. Gwyn Humphreys, Cell Tech Ltd., Slough; representing industry, Dr. Harry Rothman, Bristol University; Dr. Shirley Lanning, The U.K. Biotechnology Trade Association, with Dr. Anthony Rimmington from the University of Birmingham's Center for Russian and East European Studies as recorder; i.e., a party biased to industrial interests and one well-versed in exploiting basic research. Although the group visited only the Shemyakin Institute and the Institute of Molecular Genetics in Moscow; the Bio-Center at Pouschino; and the Institute of

Bio-organic Chemistry, Oil Chemistry, and Biological Science in Kiev, they believe that they gained a balanced picture of biotechnology in the U.S.S.R. They made the point that they could have made more extensive trips and only lack of time prevented them. The Soviets allowed them to go anywhere they wished and were quite open during information exchange sessions.

### Status of Biotechnology in the U.S.S.R.

The U.S.S.R. was a pioneer in what could be termed *modern nonrecombinant* biotechnology. By this, I mean the exploitation of fermentations other than alcoholic. Probably because of the relative lack of government environmental controls, large tracts of Siberian forests were sprayed with *Bacillus thuringiensis* products to control tent moths. Later, and until very recently, single cell protein (SCP) from hydrocarbon feedstock was a major industry. Although this technology was researched beyond the pilot plant stage outside the U.S.S.R., it was never brought to commercial fruition. Ideas for further development in the West were laid to rest by the 1973 oil crisis. The scientific press in the U.K. has thought it noteworthy to comment that the lack of environmental controls in the U.S.S.R. may make it an ideal area for testing and release of genetically engineered microorganisms (3). The point was made that Soviet biotechnology has little public confidence because of pollution problems arising from several SCP plants, but no such misgivings exist concerning Western companies. Western observers were told that it is now very difficult to get permission to build a biotechnological plant in the U.S.S.R.--so low is the industry's public esteem. I suggest that if Western organizations regard the U.S.S.R. as an inexpensive testing ground, confidence in them will also erode rapidly. Both of the industries mentioned so far; i.e., SCP and microbial insecticides, are relatively unsophisticated, scale-up rather easily, and have little need for downstream-processing other than a continuous centrifuge. In contrast, new biotechnology outside the U.S.S.R. requires as much expertise in the product's recovery as in its initial biosynthesis. This is because the materials desired are considerably more closely defined in their ultimate function. Prime Minister Ryzhkov appears to have diverted emphasis from low-cost bulk products to high-value materials with pharmaceutical-like action. Here the Western experience can help the Soviet Union. This is not to say that no new products of this type are made in the U.S.S.R. Interferon is prepared at Vil'nyus in Lithuania and there are plans to produce other interferons, human growth hormone, and pro-insulin elsewhere.

This brings up a further point. Up to now I have referred to the Soviet Union or the U.S.S.R. Anyone reading the daily papers realizes that these geopolitical

entities are not the same as in former times. What does this mean for biotechnology? Anthony Rimmington, writing in the *Genetic Engineer and Biotechnologist* (1), notes that plants that represent the cutting edge of Soviet biotechnology have been built in the Baltic Republics. Apart from the interferon plant in Vil'nyus, there is also a new interleukin-2 plant in Riga in Latvia which also hopes to capitalize on cell-free protein synthesis research by Academician Aleksandr Spirin. It would be used to produce biologically-active peptides. The loss of these installations as well as the expertise needed to run them will result in a considerable setback for the Soviets.

### The Desire for Interactions Outside the U.S.S.R.

One of the reasons that Soviet research institutes may be very interested in extramural commercial ventures for the scaleup of their biotechnology expertise and products is that they can now keep hard currency in their institutes for use as development funds or to buy Western equipment and products. The British mission to the U.S.S.R. had the impression that some naiveté existed concerning the sale or licensing of innovative products, especially outside the country. It is hard enough for a Western scientific entrepreneur brought up in a market economy to sell ideas. How much harder will it be for someone without this experience? Some of the complaints heard by the British group will be familiar to U.S. scientists in universities and industry. Evidently, Soviet industry is slow to appreciate the advances in research too. Few outside Japan, it seems, see universities and research institutes as mines of information that can be turned into a profit. Thus the Soviet government, like the U.S. and U.K., is encouraging the development of research consortia between universities and the applied research institutes. Bear in mind that it is the institutes that are the centers of research in the U.S.S.R., not normally the universities. This has led to a shortage of biotechnologically trained graduates. However, the Shemyakin Institute has tried to ameliorate this problem by inhouse training for up to 100 university students per year. All through the Department of Trade and Industry report there are statements praising this institute. For instance, it appears notable in that it has probably the only state-of-the-art pilot plant in the country, a containment facility (unknown P-level, but probably P3 or P4), and 25 percent of its budget in hard currency. This is reflected in the amount of Western equipment in its laboratories. It is reported that the Shemyakin has received \$1 million from Monsanto for molecular biology and that they have also a joint venture with Amersham International, U.K., for

diagnostics development. Obviously, not all Soviet biotechnology needs help in cooperative ventures.

### How to Build Biotechnological Bridges

The question now arises how best to establish communication pathways with those who desire them. From their actions, it is obvious that the Soviets are too impatient to wait for purely diplomatic overtures to filter down to the level of the individual scientist. Besides the mission mentioned here, at least two other groups have made contact through workshops. Thus in fall 1989, the U.S.S.R. Academy of Sciences (Academy) and the Center for Non-linear Studies of the University of Leeds, U.K., organized a workshop on Neurocomputers and Attention in Moscow (4). Further, the Academy and The Johns Hopkins University brought to the U.S.S.R. some cell biologists to talk about the cytoskeleton and cell division (5). The joint workshop therefore, with the appropriate participants, is a reasonable format for the establishing collaborations, as well as assessing the commercial relevance of the ideas of our Soviet colleagues.

### Conclusions

My research has led me to believe that the biotechnological gap between East and West is not so much the quality of the basic science, but of its application to technological problems. *Perestroika* is happening at all levels of organization and management in the U.S.S.R. This, in turn, should lead to a restructuring of the transfer of knowledge from the basic science to technology. Once that is underway, Soviet biotechnology will become as sophisticated as that beyond its borders. In the meantime, there are opportunities for further collaboration. They can be promoted by face-to-face meetings with academia and industry from both sides.

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# MATECH '90 - The First European East-West Symposium on Materials and Processes

*by Michael J. Koczak, the Liaison Scientist for Materials for the Office of Naval Research European Office. Dr. Koczak is on sabbatical leave from Drexel University, Philadelphia, Pennsylvania, where he is a Professor of Materials Engineering.*

## Introduction

The First European East-West Symposium on Materials and Processes--MATECH '90--June 10-18, 1990, in Helsinki was a unique opportunity for a window on Soviet materials and processing technology. Professor Kaj Liljus, Director of the Institute of Materials Science and Technology, Helsinki University, planned and hosted the well-organized conference. The unique and seminal conference provided an opportunity for 200 Soviet academicians, scholars, and university professors to meet their international colleagues. The conference goals were to highlight recent developments in materials and processes. In addition, the format was a neutral venue for technological/marketing exchange. More important from a social sense, the technical program and venue provided a first and valuable opportunity for informal meetings between Eastern and Western scientists. Also, it established contacts between Soviet and Western academic and industrial laboratories. Invitations were openly extended to Western scientists for visits, scientific exchanges, and collaborative efforts. In terms of business/marketing perspective for materials technology it provided an opportunity for the Soviet scientists to promote and market their materials and processes in search of an export market and hard currency for their research establishments. Nearly all the laboratories and institutes are actively engaged in expanding their scientific and important business contacts in the West. The internal Soviet orchestration of these efforts has not completely crystallized and many groups are acting independently. This can be regarded as an effort to gain valuable western currency for the very survival of their institutes. In nearly every presentation, the Eastern scientists, to varying degrees, expressed their wish for expanded international interaction coupled with a desire for exchange visits, licensing, marketing joint programs, sale of raw materials, and semifinished and finished products.

As a result of the need for international exchange, the Eastern speakers were provided with conference support for registration and living expenses. Apparently, the logistics and support mechanism, arranged by the University of Helsinki, provided an appropriate means for exchange. Despite the occasional difficulties in simultaneous translation, limited-extended abstracts, and the language barrier in direct person-to-person communica-

tions, a proactive position of fellowship to somewhat cautious interest was extended by the Soviet delegation. The 5-day conference provided an ample opportunity for exchange and discussion. Although the language barrier existed and translation was provided, difficulties were experienced in the communication process, particularly by the older academicians. In general, the younger scientists expressed the greatest interest, and many had facility with the English language. These future academicians are foreseen as a new wave of young and talented Soviet researchers who will be seeking graduate, postdoctoral, and visiting scientist status in the Western countries and possibly displacing the demographics of current foreign research profiles in developed countries. In addition to the personal contacts, a door has been opened to discover the talented scientists, research centers, and associated technologies; i.e., materials and processes that have developed over the last 50 years in a sheltered or restricted environment.

Finland is promoting its location as the ideal site for East-West exchange. The venue in Helsinki was particularly useful for the U.S.S.R. because of the ease of travel and proximity to Leningrad. Several speakers were invited and received complimentary registrations. In contrast, the Western attendees had a significant registration fee without the benefit of a conference proceeding and with very limited abstracts. As a result, the audience had to rely on limited translation and their ability to quickly assimilate the data presented. For hard information, the need for extended abstracts and/or proceedings was clearly felt. This difficulty was accentuated with the difficulty of simultaneous translation. Despite these organization and presentation hurdles, the conference provided a unique opportunity for the meeting of Eastern and Western scientists in the materials community. Over the last 50 years, it was undoubtedly the largest congregation of Soviet materials experts outside of the U.S.S.R.

## MATECH '90 Conference

With the rise of entrepreneurial activities in the U.S.S.R., several research initiatives and unique laboratories have been established. In a country of dynamic changes, the entire science structural system and mechanism is being altered. With the eventual change in the currency and political systems, a newly independent con-

federation of laboratories is seeking valued contacts, exchanges of information, and research support. This is seen as a means of establishing a stronger, independent, financial position. In many cases, the laboratories and research efforts under previous control were isolated and research was being narrowly defined with little interaction even within the U.S.S.R. With the new openness and independence of the various republics, the individual institutes and scientists are not only seeking their foreign counterparts, but are actively seeking networked research and product support for their expertise, processes, and finished materials.

Nearly every Soviet speaker indicated willingness to make contacts, extend invitations for visits, seek joint partners, and welcome investments in their technology. Although the scientists were not experienced in marketing and investment, they nevertheless appeared sincere in their motivation. The institutes and groups within institutes are acting independently from their central government. Consequently, the rules for these exchanges are particularly flexible and the outcome variable. Nevertheless, there is a long history of Soviet talent in the materials area and it should be explored. The difficulty is the wide spectrum of institutes in various republics that are virtually unknown to Western scientists. Since the linkages of changing and weakening authority from the central Soviet umbrella organizations is apparent, the financial vulnerability of these institutes and the scholars may be linked to the institute's marketing abilities. The need of hard currency for Soviet technology has become a strong driving force for the maintenance, development, and future of Soviet and the republics' science base.

With the revived freedoms in several republics, the academics and researchers have a mixed blessing. They have a new freedom in the ability to change directions of their research groups to assist the development of their republics. However, the previous rigid structure did not provide for an effective intramural/intermural communications network among academicians, industry, and government laboratories. The infrastructure for the external and internal technology transfer may not effectively exist and must be quickly developed. In addition, the concept of technology transfer and marketing to the technical community is not a trait that is quickly acquired by individuals who have lived in a rigid self-supporting system. Consequently, there will be an initial learning curve for the dissemination of technology to the Western countries. To aid this process, several marketing companies have blossomed to market the technology of the Eastern materials communities. Technoinvest represents several Soviet institutes as a marketing service/agent. Technoinvest is based in Berlin and is apparently state affiliated. In addition, independent agents exist in a Washington-based marketing firm. Kiser Associates has represented

NMTK in Chernoklova near Moscow and is promoting the high-temperature synthesis (SHS) technology.

## Plenary Session

The plenary session involved a series of lectures from the European Community (EC) and the U.S.S.R. The theme included the era of the 80s was noted as "Eurosclerosis," while the 90s can be typified as "Euroeuphoria" with an era of bridge building to combine the knowledge, skills, and technology for cooperative mutually-beneficial research, development, and production activities. The emphasis is seen in commercial rather than defense areas. Under several joint European programs, the EC is seeking to join the best laboratories and universities in Europe to promote research and education. With the diminishing defense emphasis in materials for the European programs, materials programs are centered in the long-lived recyclable materials, improved corrosion resistance, and functional materials.

O.M. Nefedov, the Soviet Academy of Science, highlighted that cooperation was sought in several areas: (1) materials for nuclear fusion, (2) composites, and (3) ceramics. The specialty interests included high-strength and amorphous alloys, intermetallics, aluminum-lithium alloys, Group IV carbides, diamond and diamond-like coating, polymer membranes, polymer additions, catalysis, waste-free materials, and SHS reactions. The mode of interaction was bilateral via currency-free, cooperative networks. The importance of human contacts was emphasized for the exchange of information and technologies.

## Conference Technical Sessions

The conference was divided into ten sessions and four workshops. Generally, the topics were practical in their outlook with only one session on mathematical modeling.

The sessions included:

- Recent achievements in research and development at high temperatures
- Surface engineering
- Powder metallurgy and ceramics
- Magnetic, optical, and electronic materials
- Polymeric materials
- Joining and bonding
- Mathematical modeling of materials and processes
- Developments in surface analytical techniques
- Special topics
- New building materials.

The workshops included:

- Materials processing in thermal plasmas
- Self propagating high-temperature synthesis (SHS)
- Mathematical modeling of casting, forming, and thermal processes
- Data applications of thermodynamics.

## Technical Program

The novel aspects of the conference emphasized the areas of diamond-film technology, SHS reactions, iron-nitrogen steels, aluminum-lithium alloys, high-pressure consolidation, plasma, and laser-surface modification, microwave sintering of materials, and a single-crystal direct casting. Technology of these areas developed over several years, and the markets and the Soviet systems are enjoying more freedom and exchange.

From my viewpoint, the following major areas reflected a combination of strength in research of the U.S.S.R. with interest in the West:

- Self-propagating synthesis
- Diamond coatings
- Nitrogen-containing steels
- Aluminum-lithium alloys.

In addition, a few selected papers are highlighted for their special interest:

- Tunable lasers
- Carbon/carbon composites
- Ohno casting process.

## Self-Propagating Synthesis

Soviet scientists and Kiser Research Inc., Washington, D.C., represented SHS materials. The areas of study or "product lines," have been divided into six areas: (1) powders, (2) sintered products, (3) densified parts, (4) metallurgical products, (5) joining, and (6) coatings. These areas can be considered in the initial research stages, prototype, or industrial production. The production of powders and sintered components is considered as the most advanced level of SHS technology, while the joining and coating areas are in the prototype and development stages. The MNTK Institute in Chernoglovka, founded in 1987, has 2,000 people involved in their research initiative, and has the capability of powder production, tasked research projects, and/or product startup demonstration projects. The combustion-synthesis reactions is perhaps one of the prime examples of the materials marketing and technology transfer available. The materials available from the SHS reactions include molybdenum disilicide, yttrium barium copper oxide super-

conducting powder, boron nitride, and a variety of metal-matrix composites.

The SHS particulate-metal matrix composites are termed "STIM" alloys and produced via a powder metallurgical process presumably utilizing elemental powders. Consolidation occurs within a 2-5 minute SHS ignition and densification stage. The STIM 1B/3 is composed of reinforced titanium diboride/titanium carbide reinforcement in a titanium carbide/titanium diboride solid solution. A titanium-titanium boride composite, STIM-4 is formulated for metal-fabrication blocks, drawing dies, and rolls. The alloy has a boride size of 1-2 $\mu$ . STIM-3B/3 is a composite of titanium and chromium carbides in a nickel-alloy matrix, while STIM 5 is composed of titanium and molybdenum nitrides and carbides in a nickel-solid solution for cutting-tool utilization. Besides sintered articles, there are SHS coatings which have been utilized based upon Cr-Fe-B-Al SHS reactions on ferrous substrates. The coating thickness is 40-120 $\mu$  with an internal layer of Fe<sub>2</sub>B and an external coating of (FeCr)-B-Al.

Interesting SHS papers concerned combustion synthesis of Ti-B-Al, and a centrifugal ceramic thermal process which were discussed by Professor Odawara, Tokyo Institute of Technology. Aluminum and ferrous oxide powders are combined in a tubular form. The interior surface of the tube is ignited and the effects of the centrifugal forces enhance densification and help provide for greater uniformity. Typically, the reaction proceeds along the interior surface first and then radially outward creating a spinel structure. Tubes 3-m long, have been successfully fabricated.

The SHS technology is certainly a cost-effective procedure for the fabrication of oxides, intermetallics, and composite structures. The technology can be effectively combined with hot-consolidation procedures to produce materials near full density. The questions of material homogeneity and reaction efficiency, and the ability to scale the process for larger complex shape are key questions. The conundrum is whether the technology can progress to high-performance/mass-production structural applications.

The First International Symposium on Self Propagating High-Temperature Synthesis will be held in Alma Alta, U.S.S.R., in September 1991. For conference details contact:

Dr. P.V. Zhirkov  
Institute Of Structural Macrokinetics  
U.S.S.R. Academy of Sciences  
142432, Chernogolovka, Moscow U.S.S.R.

For commercial interest in SHS technology contact:

Kiser Research, Inc.  
1233 20 Street NW, Suite 505  
Washington, D.C. 20036  
Tel: 202-223-5806

## Carbon - Carbon Materials

Dr. V.I. Kostikov, State Research Institute of Graphite, Moscow, discussed the developments in carbon-carbon composites. Manufacturing techniques involving two-dimensional (2-D) and three-dimensional (3-D) weaving approaches have been considered with the utilization of phenylformaldehyde resin with conversion density ranges were from 1.4 - 1.9 g/cm<sup>3</sup>. In addition, chemical vapor deposition (CVD) reactions were considered in the temperature ranges from 850-1050°C as well as hydrogenation reactions. The processing approaches considered isothermal reactions, as well as carbonization under temperature, and pressure gradients for thick wall sections. The mechanical properties were 300 MPa for a balanced 2-D weave, 250 MPa for a XYZ weave (i.e., 2-2-3), and up to 750 MPa for a primarily unidirectional or longitudinal XYZ weave. The compressive strength was significantly lower; e.g., 100-200 MPa.

## Ohno Solidification Process

The needs of the electronic industries require the production of high-purity materials. These highly demanding alloys require low inclusion levels, no contamination from mold walls, and minimization of the associated transverse solidification grain structures. The Ohno Continuous Casting (OCC) process allows for the solidification of a metal stream, outside of a mold wall. The high-purity metals allow heat to be efficiently transferred longitudinally thereby allowing for rapid cooling with directional single-crystal growth. The unique OCC process has been applied to horizontal, vertical, and rotor production of high-purity materials.

## Nitrogen-Containing Steels

During World War II, there was a shortage of vital alloying elements for the ferrous industry, high-nitrogen-containing steels were investigated and developed. From a physical metallurgy viewpoint, there are strong similarities between the Fe-C and the Fe-N phase diagrams. The ability of nitrogen to form very fine and stable nitrides and carbonitrides, promote this continued interest in Fe-N steels. The U.S.S.R. and the Federal Republic of Germany (FRG) presented papers on the new, or lost generation of nitrogen-containing austenitic and ferritic steels. The ferritic steels discussed by G. Stein and J. Menzel, Vereinigte Schmiedewerke, Essen, FRG, emphasized the development of nitride precipitates which are more stable than carbides and higher creep rupture strength at temperatures in excess of 600°C. The scale of production of the nitrogen steels was not disclosed as well as the issues of high-temperature stability and welding/joining considerations. The strengthening effects of

nitrogen-containing ferrous and titanium alloys is not questioned. However, the role of the interstitial nitrogen on secondary-forming, joining, and thermal treatments leaves an open question concerning the effective applicability of these nitrogen containing alloys.

## Aluminum-Lithium Alloys

The U.S.S.R. has an established position in the development of aluminum-lithium alloys with the development of the 1420 Al-Li-Mg systems in 1960. The U.S.S.R. application of 1420 was utilized in aircraft structure in vertical takeoff aircraft in 1970 and new generations are currently being considered; e.g., 1421, 1423, and 1429. Utilization of Al-Li-welded structures on supersonic aircraft can enhance performance by weight reductions inherent in the low-density Al-Li alloys coupled with the removal of fasteners. The weld integrity and nondestructive evaluation inspectability is as an obvious key issue in this regard. A weldable, aluminum-lithium alloy, 1423, limits the levels of hydrogen, sodium, iron, and silicon, and couples the grain refinement effects of scandium. The mechanical properties of the U.S.S.R. aluminum-lithium alloys are detailed in Table 1. In addition, developments in Al-Cu-Li-Mg alloys have been reported as well as the laminated composite structures termed ALOR which are similar to ARALL<sup>®</sup> or the GLARE laminated, aluminum-resin composite systems. The long history of Al-Li developments is a highlight of the U.S.S.R.'s materials developments which was presented by Academician Fridlyander, who has a distinguished record in aluminum alloy developments.

## Spray Deposition

Processing improvements via the Osprey approach has also improved the performance of aluminum-lithium alloys. The Osprey process developed by Professor A. Singer, formerly of the University of Swansea, U.K., has found that Al-Li alloys particularly lend themselves to the spray deposition process. The conventional solidification approaches are not sufficient to refine the Al-Li structure. Also, the powder Rapid Solidification Technology (RST) approaches may not be appropriate. These pyrophoric Al-Li systems have a low-vapor pressure of lithium, and interstitial-oxygen and -hydrogen levels may be difficult to control. ALCAN, Banbury, U.K., has produced spray deposited aluminum-lithium alloys in billet form with exceptionally good transverse properties and ductilities. An interesting development would be the combination of the newer Soviet aluminum-lithium alloys combined with the spray deposition process. In this manner, the benefits of both alloy design and improved materials processing can be combined for an improved aluminum-lithium alloy.

**Table 1. Aluminum Lithium Alloy Properties**

Alloy	Orientation	UTS(MPa)	YS(MPa)	%E	KIC MPa $\sqrt{m}$
1420	L	412	255	2	25
	T	392	250	7	
	ST	310	240	3	
1421		490	440	N/A	
1429 (P/M)	L	472-492	334-336	9-12	
1440	L	480	460	5	
	T	470	390	4	
1450		540	451	6	
ALOR*		720	550		
1423	<b>Temperature</b>	<b>UTS(MPa)</b>	<b>UTST(MPa)</b>	<b>YS(MPa)</b>	
	298°K	520	520	461	
	78°K	637	617	539	
	4°K	804	754	687	

\*Epoxy composite aluminum laminate similar to ARALL®

L = Longitudinal, T = Transverse, ST = Short Transverse, P/M = Powder Metallurgy, N/A = Not Available

## Diamond and Diamond-Like Carbon Coatings

The area of diamond coatings and diamond-like films is an attractive research area with applications in areas that require high hardness, wear resistance, low friction high thermal and chemical stability. In addition, the optical, electrical, and thermal properties can be tailored depending upon the degree of carbon conversion. The Institute for Problems in Materials Science has joined with the Poltava plant for the production of synthetic-diamond powders and diamond instruments. They produce diamond powders in the forms of coarse and fine grades. For details contact:

Institute for Problems of Materials Science  
The Academy of Science of the Ukraine  
Krgiganovskogo Str 3  
252180, Kiev - 180 Ukraine  
Telephone: 444-22-71  
Telex: 131257 STAN  
FAX: 044-444 04 92

The institutes in the U.S.S.R. also involved in diamond research include:

- The Institute of Metal Physics - Kiev (B.V. Deryagin)
- Institute for Physical Chemistry - Moscow (B.V. Spitysn, D.F Fedoseev)
- The Institute of Electronics - Minsk (E.J. Tochitsky)
- Frantsevich Institute for Problems of Materials (IPMS) - Kiev - (Y.W. Naidich, L.A. Lavrinenko)
- Institute for Superhard Materials - Ukraine Academy of Sciences - Kiev (A.E. Shilo, E.K. Bondarev, A.S. Smolyar).

The production of diamond and diamond-like films can be separated based upon the kinetics of the deposi-

tion process. At lower temperatures, crystallization was reported for metastable crystals at room temperature and atmospheric pressure for diamond whiskers at a growth rate of 1/2 mm/hr with lengths up to 2 mm. Diamond-like films were reported to have grown at rates of 100 A/hr on metal and glass substrates via pulsed high-temperature nucleation techniques. In addition, other techniques were mentioned that include high-pressure diamond growth from carbon iron-solid solutions, homogeneous condensation of diamond powders, and low-temperature growth at 200°C on polymer and metal substrates. The Institute for Physical Chemistry, Moscow, is examining the chemical vapor deposition of diamond films; i.e., B.V. Spitysn and D.F Fedoseev, via methane-decomposition reactions and can produce films 4-mm square and 2- $\mu$  thick at optimum growth rates of 10  $\mu$ /hr at 1000°C. In addition, brief mention was made of the following topics:

- Polycrystal-diamond films with B doping which are electrically active with concentrations  $3 \times 10^{14}/\text{cm}^3$  and P doping which inhibits electrical activity
- Growth of diamond films on Cu and SiC at elevated temperatures (e.g., 875 - 1175°C) with thicknesses of 10  $\mu$  and up to 8-mm wide
- Heat conductivity of 1200 - 1800 W/m/K which were achieved in high-purity diamond crystals.

The difficulty in evaluating this area of materials study is the variety of phases that can be produced from amorphous carbon, diamond-like to crystalline diamond. In many cases, the required Raman spectroscopy for the films was not provided to clarify the levels of carbon, diamond, hydrogen, and methane species within the films. Nevertheless, there are clear efforts in the U.S.S.R. in diamond research and an in-depth evaluation of their capability and materials would be appropriate.

## Metal Forming and Superplasticity

The Institute of Metals Superplasticity Problems, Ufa, which is related to the U.S.S.R. Academy of Sciences, has been studying superplasticity in several nonferrous systems; e.g., Ti, Al, Mg, intermetallics, and ceramics. Their aim is to obtain a submicron grain structure; e.g., 0.1 - 0.5  $\mu$ , for superplastic deformation which can be induced at 0.4 to 0.5 of the homologous melting temperature ( $T/T_m$ ). Billets up to 500 mm in diameter have been produced and subjected to superplastic deformations. In addition, titanium turbine discs were superplastically formed via a disc-rolling operation. The forging of metal-matrix composite blades; e.g., Al-B, Mg-B, is also being studied at the institute for aircraft, ship, and power systems applications.

The utilization of explosive/impulse loading is actively studied at the Byelorussian Powder Metallurgy Association, Minsk, under the leadership of O.V. Roman. The facility can perform hydrodynamic compaction up to pressures of 20 kbar with typical pressures of 6 kbar at a rate of 10 cycles per hour. Explosive compaction can consolidate powders, ceramics, and laminated composite structures. Also, it is utilized to weld dissimilar materials and produce machine tool dies. Dr. Roman is an enthusiastic advocate of powder fabrication and effectively promotes the technology. Consolidated materials include Al, BN, silicon nitride, Cu/Ti laminates, MnAlC powders, and intermetallics. The process may be limited to small articles and questions of trapped and absorbed gases may limit elevated-temperature applications.

## Crystals for Tunable Lasers

T.T. Basiev, General Physics Institute, U.S.S.R. Academy of Sciences, Moscow, discussed the utilization of crystals for tunable lasers. The laser crystals have a continuable tunable range of 0.42 to 1.6  $\mu$  which incorporates the blue-green spectrum. The system is based on LiF( $F^{+2}$ ), LiF ( $F^{-2}$ ), NaF (c.c.) laser crystals, Ba(NO<sub>3</sub>)<sub>2</sub> solid-state raman shifters, and LiNbO<sub>3</sub>, LiIO<sub>3</sub> crystal frequency doublers which provide the system the range of frequencies. The institute has provided two versions of commercial tunable color centers (i.e., MASLAN - 201

and MASLAN - 203) which they claim have no counterparts in the world. The power levels of these lasers were not provided; nevertheless, they can serve as sources for further optical signal amplification. The physical characteristics of the halide crystals was discussed as passive Q-switchers, saturable absorbers, and spatial-temporal correctors for Nd lasers.

## Summary

The MATECH '90 conference was an effective catalyzing agent to develop relations between East and West in bringing 200 Soviet specialists from 70 research centers, universities, space, and military establishments. A subsequent conference, MATECH '91, has been organized to be held in Helsinki from May 26-31, 1991, and MATECH '92 has been arranged for June 15-19, 1992. Clearly, Finland is establishing its position as an intermediary between East-West technology transfer with a combined conference, technical exhibit, workshop, and a suitable neutral venue for exchange and cooperation. The attendance from other countries was primarily West German, Scandinavian, and Japanese with very limited representation from the U.S. and U.K. The presentations were rather uneven with some real peaks of technological excellence. The real difficulty is to assess the capability and quality of the research efforts based on the difficulties in communication with the limited conference abstracts and processing, physical, and mechanical property data. The abstracts and attendance lists are available from:

INTAG Publishing, Ltd. Oy  
PL 121, SF 02101  
Espoo, Finland  
FAX: 358-0-455 2250

Details concerning the next MATECH conferences can be obtained from:

MATECH '91 Office  
Attn: Pentti Attila  
PL 121, SF 02101  
Espoo, Finland  
Telephone: 358-0-451 2768  
FAX: 358-0-451 2799

# Research Institutes Related to the Engineering and Science in the U.S.S.R.

by Michael J. Korzak

## Introduction

One of the difficulties of assessing the quality and development of U.S.S.R. science and technology is related to lack of complete information concerning the institutes and academies in Russia and the 14 republics. There are limited sources of information that address Soviet science and technology public policy (1-10) as well as the science programs. In addition, the level of East-West contact over the last 50 years has been highly filtered and the true essence of the research activities has not been actively disseminated. Consequently, the levels of research activity and the communication of these science programs has been severely restricted. A related difficulty is the limited number of visits by western scientists to Soviet laboratories; therefore, a judgement regarding the quality of the staffing, physical facilities, and research quality is very limited. In an effort to document U.S.S.R. laboratories in the engineering sciences, the following article can serve as a starting point, and although somewhat incomplete, it will reflect a summary of the U.S.S.R. institutes in Russia and the related republics associated with the Academies of Science. The U.S.S.R. review provides initially a listing of the major and largest Academy of Sciences in Moscow, Russia followed by the 14 republics' science and engineering capabilities.

## Background

With the gradual independence of the republics, the affiliation and the relative linkages between the various academies of science will become more autonomous and the degree of cooperation possibly reduced. As a result, the following list seeks to provide a summary of the variety of institutes related to the various academies in the Soviet republics. The list has excluded details concerning the departments in social and language sciences. In addition, industrial, defense, and government research laboratories have not been included. Further information can be gleaned from several sources (1-10) which expand and supplement this base of information. One of the most comprehensive lists of universities and research institutes is *The World Of Learning* (1). In addition, *The Status of Soviet Civil Science* (2) details the education system; scientific organizations; information networks; selected candid case studies in cosmic physics, chemistry, and materials; and a summary of Soviet exchanges. *The Guide*

*to World Science* (3) provides a summary of demographic and political background, and details the science activities in selected areas; e.g., natural sciences, industrial science, and technology as well as providing an index of establishments. *The International Research Centers Directory* provides a useful world guide to university, institute, and government research centers (4). A more selective list is the *Science and Technology in the U.S.S.R.* which provides selective reading to several regions. Specifically, the *Science and Technology in the U.S.S.R.* edited by M.J. Berry of the University of Birmingham (5), and *Science and Technology in Eastern Europe* edited by Gyorgy Darvas (6). In comparing the lists of these various sources, they range from a simple compilation of research centers (1,4) to rather in-depth expositions of the politics and quality of Soviet research (2). Under the Gorbachev administration, the question of the scientist role and science policy in general has been addressed recently by several authors (7-10).

## Organizational Structure of U.S.S.R. Research Activity

An organizational structure of Soviet science can be seen from the charts depicted in Figures 1 and 2 which shows the important position of the Soviet Academy of Science. The Soviet Academy of Science serves as a rather autonomous group, outside of party control and plans approximately 80-85 percent of Soviet research (2). The Ministry of Higher Education conducts a smaller portion of research and is primarily responsible for educational matters. Beneath the Academies General Assembly are five sections; e.g., earth sciences, social sciences, etc.(see Figure 2). These sections subdivide into departments and further into institutes within these departments. As a result, the research institutes are controlled by apparently two organizations--the Soviet Academy of Science and the Council Of Ministers of the Republics. The topics and control of the research activity are depicted in Figure 3 with inputs from several organizations to include the Academy of Science (2). An important question is the maintenance of this organizational infrastructure and financial support in light of the independence of the various republics. Figures 1-3 reprinted by permission of Kluwer Academic Publishers.

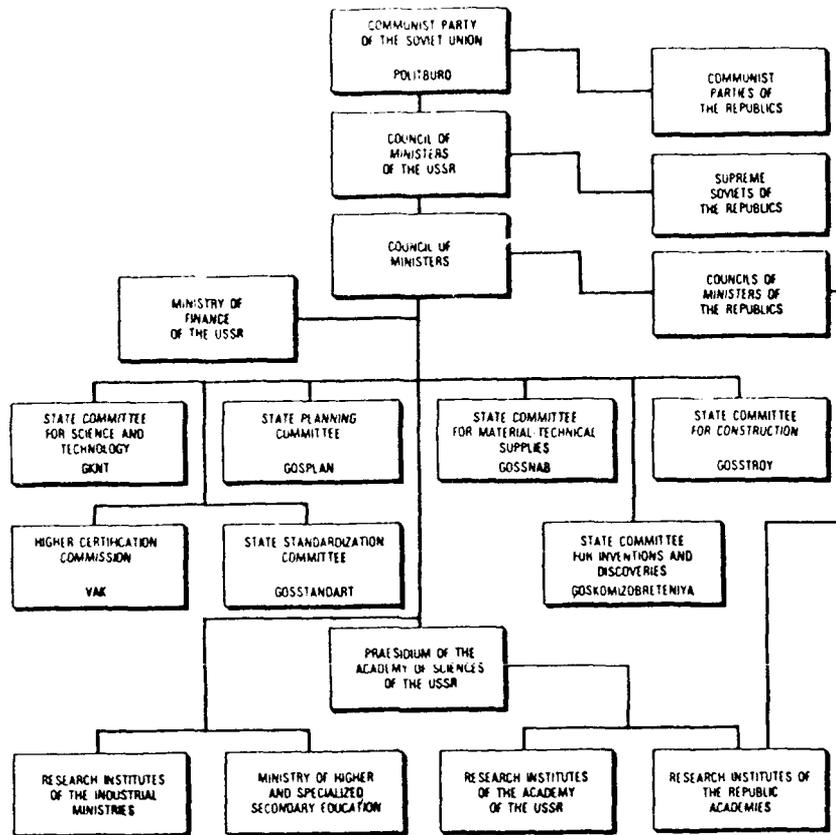


Figure 1. Scientific and Technological Development in the Soviet Union: Management Structure and Organization

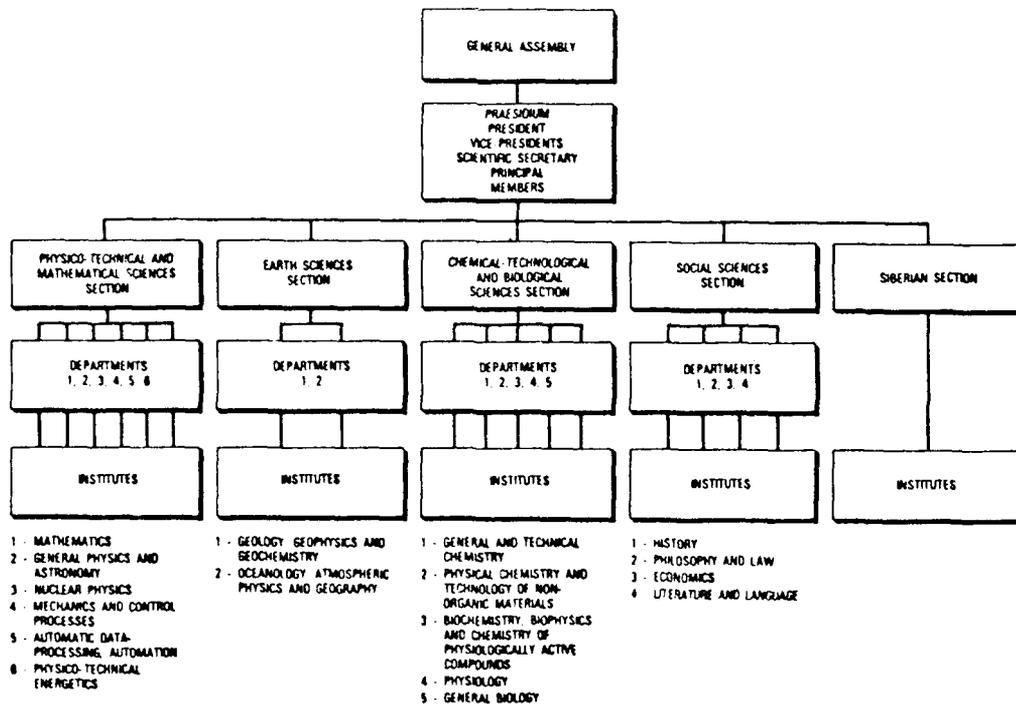


Figure 2. Organization of the Academy of Sciences of the U.S.S.R.

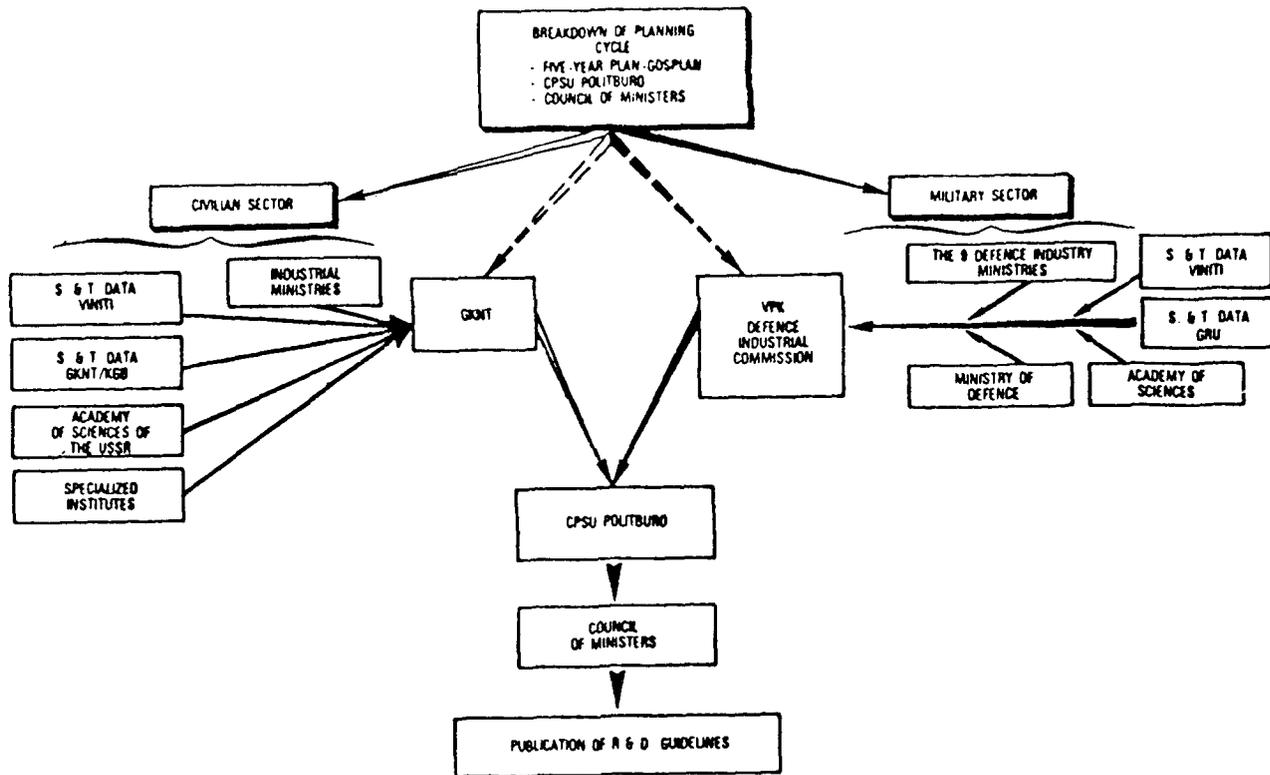


Figure 3. Formulation of Guidelines for Scientific and Technical R&D in the U.S.S.R.

### The Structure of the Soviet Academy of Science

The Soviet Academy of Science is the largest and centered in Moscow. A compilation is provided in three parts detailing in the first part the 15 Academies of Science (see Table 1); i.e., the Soviet and the 14 republics. The sections of the academies, and their departments as a general survey are presented in Appendices A and B. Specifically, Appendix B shows the selected institutes of the 15 academies in engineering and sciences in order to indicate the scope of efforts in these departments. Appendix C provides an alphabetical list of selected research institutes in the physical sciences and engineering.

Appendix B provides information on the selected institutes in the U.S.S.R. Academy of Sciences and the Academies of the 14 republics. The list was selectively chosen to reflect the activities in engineering and the physical sciences and excludes arts, social sciences, and languages.

### References

- (1) *The World of Learning*, Europa Publications, 40th Edition, (1990).
- (2) *The Status of Soviet Civil Science*, C. Sinclair, ed., Martinus Nijhoff Publishers, (1987).
- (3) *The Guide to World Science*, Volume 11, U.S.S.R., A. Pernet, ed., Francis Hodgson Publishers, (1976).
- (4) *The International Research Centers Directory (1988-1989)*, D. Smith, ed., Gale Research Company, (1988).

Table 1. The 15 Academies of Science Academy of Sciences of the U.S.S.R. - Moscow

#### Academies of Sciences of the 14 Republics of the U.S.S.R.

##### Academy of Sciences

- Armenia
- Azerbaidzan
- Byelorussian
- Estonia
- Georgia
- Kazakh
- Kirgiz
- Latvia
- Lithuania
- Moldavia
- Tadjhik
- Turkumen
- Ukrania
- Uzbek

- (5) *Science and Technology in the U.S.S.R.*, M.J. Berry, ed., Longman Publication, (1988).
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- (7) Balzer, H.D., *Soviet Science Policy on the Edge of Reform*, Westview Press, (1989).
- (8) Fortescue, S., *Soviet Science Policy*, Routledge, (1990).
- (9) Josephson, P., *Scientists, The Public and Party Under Gorbachev*, The Harriman Institute Forum, (May 1990).
- (10) Kneen, P., *Soviet Science Policy Under Gorbachev*, Soviet Studies, Vol. XLI, 1, 67, (1989).

## Appendix A

### Union of Soviet Socialist Republics Academy and Research Institutes

#### Academy of Sciences of the U.S.S.R.

117901 Moscow

Leninskii Pr. 14

Telephone: 234-21-53

Telex: 411964

#### Sections of the Academy and Their Departments

- I. Section of Physical-Technical and Mathematical Sciences
  1. Department of Mathematics
  2. Department of General Physics and Astronomy
  3. Department of Nuclear Physics
  4. Department of Physical Technical Problems of Power Engineering
  5. Department of Problems of Engineering, Mechanics, and Control Processes
  6. Department of Information Science, Computer Technology, and Automation
- II. Section of Chemical, Technological, and Biological Sciences
  1. Department of General and Technical Chemistry
  2. Department of Physical Chemistry and Technology of Inorganic Materials
  3. Department of Biochemistry, Biophysics, and Physiological Chemistry
  4. Department of Physiology
  5. Department of General Biology
- III. Section of Earth Sciences
  1. Department of Geology, Geophysics, Geochemistry, and Mining Science
  2. Department of Oceanology, Atmospheric Physics, and Geography
- IV. Section of Social Sciences
  1. Department of History
  2. Department of Philosophy and Law
- V. Siberian Department
- VI. Far Eastern Department
- VII. Urals Department

#### Organizational Structure of the Academies of Sciences of the Soviet Republics Academies of the Union Republics

- I. Armenian S.S.R. Academy of Sciences, 375019 Yerevan, Pr Marshalla Bagramyana 24
  1. Department of Physical and Mathematical Sciences
  2. Department of Physico-Technical Sciences and Mechanics
  3. Department of Chemical Sciences
  4. Department of Earth Sciences
  5. Department of Biological Sciences
  6. Department of History and Economics
  7. Department of Philosophy and Philology
- II. Azerbaidzhan S.S.R. Academy of Sciences, Baku, Ul. Kommunisticheskaya 10
  1. Department of Physical-Engineering and Mathematical Sciences
  2. Department of Chemical Sciences
  3. Department of Earth Sciences
  4. Department of Biological Sciences
  5. Department of Social Sciences

- III. Byelorussian S.S.R. Academy of Sciences, 220072 Minsk, Leninskii pr. 66, Telephone: 39-58-36
  1. Department of Physical and Mathematical Sciences and Computer Science
  2. Department of Physical and Engineering Sciences of Machine Building and Energetics
  3. Department of Chemical and Geological Sciences
  3. Department of Biological Sciences
  4. Department of Social Sciences
- IV. Estonian S.S.R. Academy of Sciences, 200103 Tallinn, Kohtu 6
  1. Department of Physics and Astronomy
  2. Department of Computer Science and Applied Physics
  3. Department of Chemical, Geological, and Biological Sciences
  4. Department of Social Science
- V. Georgian S.S.R. Academy of Sciences, 380024 Tbilisi, Ul. Dzerzhinskogo 8
  1. Department of Mathematics and Physics
  2. Department of Earth Science
  3. Department of Applied Mechanics and Control Processes
  4. Department of Chemistry and Chemical Technology
  5. Department of Biology
  6. Department of Social Sciences
  7. Department of Linguistics and Literature
- VI. Kazakh S.S.R. Academy of Sciences, 480021 Alam-Ata, Ul. Schevchenko 28
  1. Department of Physical-Mathematical Sciences
  2. Department of Earth Sciences
  3. Department of Chemical-Technological Sciences
  4. Department of Biological Sciences
  5. Department of Social Sciences
- VII. Kirgiz S.S.R. Academy of Sciences, 720071 Frunze, Leninskii Pr. 265-a
  1. Department of Physical-Engineering and Mathematical Sciences
  2. Department of Chemical-Technological and Biological Sciences
  3. Department of Social Sciences
- VIII. Latvian S.S.R. Academy of Sciences, Riga, Ul. Turgeneva 19
  1. Department of Physical and Engineering Sciences
  2. Department of Chemical and Biological Sciences
  3. Department of Social Sciences
- IX. Lithuanian S.S.R. Academy of Sciences, 232600 Vilnius, Lenino pr. 3
  1. Department of Physical, Technical, and Mathematical Sciences
  2. Department of Chemical and Biological Sciences
  3. Department of Social Sciences
- X. Moldavian S.S.R. Academy of Sciences, Kishinev, Pr. Lenina 1
  1. Department of Physical-Engineering and Mathematical Sciences
  2. Department of Biological and Chemical Sciences
  3. Department of Social Sciences
- XI. Tadzhik S.S.R. Academy of Sciences, Dushanbe
  1. Department of Physical-Engineering and Chemical Sciences
  2. Department of Biological Sciences
  3. Department of Social Sciences
- XII. Turkmen S.S.R. Academy of Sciences, 744000 Ashkhabad, Ul. Gogolya 15
  1. Department of Physical-Engineering and Chemical Sciences
  2. Department of Biological Sciences
  3. Department of Social Sciences

- XIII. Ukrainian S.S.R. Academy of Sciences, 252601 Kiev, Ul. Vladimirskaya 54, Telephone: 225-22-39
1. Department of Mathematics, Mechanics, and Cybernetics
  2. Department of Informatics, Computers, and Automation
  3. Department of Mechanics
  4. Department of Physics and Astronomy
  5. Department of Physical-Engineering Problems of Materials
  6. Department of Physical-Engineering Problems of Energy
  7. Department of Earth Problems
  8. Section of Chemical-Engineering and Biological Sciences
  9. Department of General Biology
  10. Department of Biochemistry, Physiology, and Theoretical Medicine
  11. Department of Economics
  12. Department of History, Philosophy, and Law
  13. Department of Language, Literature, and Art
- XIV. Uzbek S.S.R. Academy of Sciences, Tashkent, Ul. Kuibysheva 15
1. Department of Physical-Mathematical Sciences
  2. Department of Mechanics and Control Processes
  3. Department of Earth Sciences
  4. Department of Chemical-Technological Sciences
  5. Department of Biological Sciences
  6. Department of Philosophy, Economics, and Law
  7. Department of History, Linguistics, and Literature

**Appendix B****Union of Soviet Socialist Republics Academy and Research Institutes****Academy of Sciences of the U.S.S.R.**

- I. Section of Physical-Technical and Mathematical Sciences
  1. Department of Mathematics
  2. Department of General Physics and Astronomy
    - a. Institute of Space Research
    - b. Institute of Crystallography
    - c. Institute of High Pressure Physics
    - d. Institute of Solid State Physics
    - e. Institute of Physical Problems
    - f. Institute of Theoretical Physics
    - g. Physical-Technical Institute
    - h. Physics Institute
    - i. Institute of Spectroscopy
    - j. Acoustics Institute
    - k. Institute of Precision Mechanics and Computing Technology
    - l. Institute of General Physics
    - m. Institute of Applied Physics
  3. Department of Nuclear Physics
    - a. Institute of Nuclear Research
    - b. Leningrad Institute of Nuclear Physics
  4. Department of Physical Technical Problems of Power Engineering
    - a. Institute of High Temperatures
    - b. National Committee on Thermal and Mass Exchange
    - c. Institute of Energy Problems of Chemical Physics
    - d. Institute of Geothermal Problems
  5. Department of Problems of Engineering, Mechanics, and Control Processes
    - a. Institute of Control Problems (Automation and Telemechanics)
    - b. Institute of Problems of Mechanics
    - c. Institute of Machine Science
    - d. Institute of Superplasticity of Metals
    - e. U.S.S.R. National Committee on Theoretical and Applied Mechanics
  6. Department of Information Science, Computer Technology, and Automation
- II. Section of Chemical, Technological, and Biological Sciences
  1. Department of General and Technical Chemistry
    - a. Institute of Macro-Molecular Compounds
    - b. Institute of Preto-Chemical Synthesis
    - c. Institute of Organic Chemistry
    - d. Institute of Physical Chemistry
    - e. Institute of Metallo-organic Chemistry
    - f. Institute of Chemical Physics
    - g. Institute of Electro-Chemistry
    - h. Institute of Elementary Organic Compounds
    - i. Institute of Structural Macrokintics
    - j. Institute of Synthetic Polymer Materials
  2. Department of Physical Chemistry and Technology of Inorganic Materials
    - a. Institute of Metallurgy
    - b. Institute of General and Inorganic Chemistry
    - c. Institute of Silicates Chemistry

- d. Institute of New Chemical Problems
- e. Institute of Chemistry of Highly Pure Substances
- f. Interbranch Research Centre of Technical Ceramics
- g. U.S.S.R. National Committee on Welding
- 3. Department of Biochemistry, Biophysics, and Physiological Chemistry
- 4. Department of Physiology
- 5. Department of General Biology
- III. Section of Earth Sciences
  - 1. Attached to the Section
    - a. All-Union Mineralogical Society
  - 2. Department of Geology, Geophysics, Geochemistry, and Mining Science
    - a. Institute of Geology
    - b. Institute of Geochemistry and Analytical Chemistry
    - c. All-Union Scientific Research Institute of Economics of Mineralogical Raw Materials and Prospecting
    - d. Institute of Mining
    - e. Institute of Mineralogy, Geochemistry, and Crystallochemistry of Rare Elements
  - 3. Department of Oceanology, Atmospheric Physics, and Geography
- IV. Section of Social Sciences
  - 1. Department of History
  - 2. Department of Philosophy and Law
- V. Siberian Department
- VI. Far Eastern Department
- VII. Urals Department

The academies of the 14 republics are provided below with a similar tabulation of their institutes in engineering and physical sciences.

### Academies of the Union Republics

- I. Armenian S.S.R. Academy of Sciences, 375019 Yerevan, Pr Marshala Bagramyana 24
  - 1. Attached to the Presidium
    - a. Council on Problems of Machine-Building
    - b. Council on Semiconductors
  - 2. Department of Physical and Mathematical Sciences
    - a. Institute of the Applied Problems of Physics
  - 3. Department of Physico-Technical Sciences and Mechanics
    - a. Institute of Mechanics
    - b. Institute of Radiophysics and Electronics
    - c. Institute of Physical Investigation
    - d. Special Experimental Construction Technological Institute
  - 4. Department of Chemical Sciences
    - a. Institute of Fine Organic Chemistry
    - b. Institute of Organic Chemistry
    - c. Institute of Chemical Physics
    - d. Institute of General and Inorganic Chemistry
  - 5. Department of Earth Sciences
    - a. Institute of Geology
    - b. Institute of Geophysics and Engineering Seismology
  - 6. Department of Biological Sciences
  - 7. Department of History and Economics
  - 8. Department of Philosophy and Philology

- 
- II. Azerbaidzhan S.S.R. Academy of Sciences, Baku, Ul. Kommunisticheskaya 10
1. Attached to the Presidium
    - a. Scientific Council on Complex Problems (Cybernetics)
    - b. Council on Exploitation of Scientific Equipment
  2. Department of Physical-Engineering and Mathematical Sciences
    - a. Institute of Physics
    - b. Institute of Mathematics and Mechanics
    - c. Azerbaidzhan Physical Society
  3. Department of Chemical Sciences
    - a. Institute of Chloro-organic Synthesis
    - b. Institute of Inorganic and Physical Chemistry
    - c. Institute of Chemical Additives
    - d. Institute of Theoretical Problems of Chemical Technology
    - e. Azerbaidzhan Section of All-Union Chemical Society
  4. Department of Earth Sciences
    - a. Institute of Geology
    - b. Institute for the Study of Natural Resources from Space
    - c. Commission on Mining
    - d. Mineralogical Society
  5. Department of Biological Sciences
  6. Department of Social Sciences
- III. Byelorussian S.S.R. Academy of Sciences, 220072 Minsk, Leninskii pr. 66, Telephone: 39-58-36
1. Department of Physical and Mathematical Sciences and Computer Science
    - a. Institute of Physics
    - b. Institute of Solid State and Semiconductor Physics
    - c. Branch of Institute of Physics
    - d. Branch of Institute of Solid State and Semiconductor Physics
    - e. Institute of Electronics
  2. Department of Physical and Engineering Sciences of Machine Building and Energetics
    - a. Institute of Heat and Mass Transfer
    - b. Physical-Engineering Institute
    - c. Branch of Physical-Engineering Institute
    - d. Institute of Nuclear Energy
    - e. Institute of Engineering Cybernetics
    - f. Institute of Mechanics of Metallopolymer Systems
    - g. Institute of Reliability of Machines
    - h. Institute of Applied Physics
  3. Department of Chemical and Geological Sciences
    - a. Institute of Physical-Organic Chemistry
    - b. Institute of General and Inorganic Chemistry
    - c. Institute of Geochemistry and Geophysics
  4. Department of Biological Sciences
  5. Department of Social Sciences
- IV. Estonian S.S.R. Academy of Sciences, 200103 Tallinn, Kohtu 6
1. Department of Physics and Astronomy
    - a. Institute of Physics
    - b. Institute of Chemical and Biological Physics
  2. Department of Computer Science and Applied Physics
    - a. Institute of Cybernetics
    - b. Institute of Thermal and Electrical Physics
  3. Department of Chemical, Geological, and Biological Sciences
    - a. Institute of Chemistry
    - b. Institute of Geology
  4. Department of Social Science
-

- V. Georgian S.S.R. Academy of Sciences, 380024 Tbilisi, Ul. Dzerzhinskogo 8
1. Department of Mathematics and Physics
    - a. Institute of Physics
    - b. Abastumani Astrophysical Observatory
    - c. Physical Technical Institute
  2. Department of Earth Science
    - a. Geological Institute
    - b. Institute of Geophysics
    - c. Georgian Commission on Clay Studies
  3. Department of Applied Mechanics and Control Processes
    - a. Institute of Cybernetics
    - b. Institute of Control systems
    - c. Institute of Constructional Mechanics and Seismic Resistance
    - d. Institute of Mining Mechanics
    - e. Institute of Mechanics of Machines
  4. Department of Chemistry and Chemical Technology
    - a. Institute of Physical and Organic Chemistry
    - b. Institute of Inorganic Chemistry and Electrical Chemistry
    - c. Institute of Pharmaceutical Chemistry
    - d. Institute of Metallurgy
  5. Department of Biology
  6. Department of Social Sciences
  7. Department of Linguistics and Literature
- VI. Kazakh S.S.R. Academy of Sciences, 480021 Alam-Ata, Ul. Schevchenko 28
1. Department of Physical-Mathematical Sciences
    - a. Institute of Nuclear Physics
    - b. Institute of High Energy Physics
    - c. Institute of Mathematics and Mechanics
  2. Department of Earth Sciences
    - a. Institute of Geological Sciences
    - b. Institute of Mining
    - c. Institute of Hydrogeology and Hydrophysics
  3. Department of Chemical-Technological Sciences
    - a. Institute of Metallurgy and Ore Enrichment
    - b. Institute of Chemical Sciences
    - c. Institute of Organic Catalysis and Electro-chemistry
    - d. Institute of Petroleum Chemistry
  4. Department of Biological Sciences
    - a. Institute of Soil Science
  5. Department of Social Sciences
- VII. Kirgiz S.S.R. Academy of Sciences, 720071 Frunze, Leninskii Pr. 265-a
1. Department of Physical-Engineering and Mathematical Sciences
    - a. Institute of Physics and Mathematics
    - b. Institute of Physics and Mechanics of Rocks
    - c. Institute of Automation
    - d. Institute of Geology
  2. Department of Chemical-Technological and Biological Sciences
    - a. Institute of Inorganic and Physical Chemistry
    - b. Institute of Organic Chemistry
    - c. Institute of Biochemistry and Physiology
  3. Department of Social Sciences
- VIII. Latvian S.S.R. Academy of Sciences, Riga, Ul. Turgeneva 19
1. Department of Physical and Engineering Sciences
    - a. Institute of Physics

- b. Institute of Electronics and Computing Technology
  - c. Institute of Energy
  - d. Institute of Mechanics of Polymer Compounds
  - 2. Department of Chemical and Biological Sciences
    - a. Institute of Inorganic Chemistry
    - b. Institute of Organic Synthesis
    - c. Institute of Wood
  - 3. Department of Social Sciences
- IX. Lithuanian S.S.R. Academy of Sciences, 232600 Vilnius, Lenino pr. 3
- 1. Department of Physical Technical and Mathematical Sciences
    - a. Institute of Physics
    - b. Institute of Mathematics and Cybernetics
    - c. Institute of Physical and Technical Problems of Power Engineering
    - d. Institute of Semiconductor Physics
  - 2. Department of Chemical and Biological Sciences
    - a. Institute of Chemistry and Chemical Technology
    - b. Institute of Biochemistry
- X. Moldavian S.S.R. Academy of Sciences, Kishinev, Pr. Lenina 1
- 1. Department of Physical-Engineering and Mathematical Sciences
    - a. Institute of Mathematics and Computing Centre
    - b. Institute of Applied Physics
    - c. Institute of Geophysics and geology
    - d. Section of Energy Cybernetics
  - 2. Department of Biological and Chemical Sciences
    - a. Institute of Chemistry
  - 3. Department of Social Sciences
- XI. Tadzhik S.S.R. Academy of Sciences, Dushanbe
- 1. Department of Physical-Engineering and Chemical Sciences
    - a. Physical-Engineering Institute
    - b. Institute of Astrophysics
    - c. Institute of Seismic Resistant Construction and Seismology
    - d. Institute of Chemistry
    - e. Tadzhik Branch of the All-Union Mineralogical Society
    - f. Institute of Mathematics
  - 2. Department of Biological Sciences
  - 3. Department of Social Sciences
- XII. Turkmen S.S.R. Academy of Sciences, 744000 Ashkhabad, Ul. Gogolya 15
- 1. Attached to the Presidium
    - a. Council on Coordination of Science Investigations
  - 2. Department of Physical-Engineering and Chemical Sciences
    - a. Physical-Engineering Institute
    - b. Institute of Chemistry
    - c. Institute of Earth and Atmospheric Physics
    - d. Institute of Geology
  - 3. Department of Biological Sciences
  - 4. Department of Social Sciences
- XIII. Ukrainian S.S.R. Academy of Sciences, 252601 Kiev, Ul. Vladimirskaya 54, Telephone: 225-22-39
- 1. Department of Mathematics, Mechanics, and Cybernetics
    - a. Institute of Cybernetics
    - b. Institute of Applied Mechanics and Mathematics
    - c. Institute of Applied Mathematics and Mechanics
  - 2. Department of Informatics, Computers, and Automation

3. Department of Mechanics
  - a. Institute of Mechanics
  - b. Institute of Hydromechanics
  - c. Institute of Strength Problems
  - d. Institute of Mechanics of Geological Engineering
  - e. Institute of Engineering Mechanics
4. Department of Physics and Astronomy
  - a. Institute of Physics
  - b. Institute of Physics of Metals
  - c. Institute of Semiconductor Physics
  - d. Physical-Engineering Institute
  - e. Physical-Engineering Institute of Low Temperatures
  - f. Institute of Radio Physics and Electronics
  - g. Donetsk Physical Engineering Institute
  - h. Institute of Theoretical Physics
  - i. Institute of Nuclear Research
5. Department of Physical-Engineering Problems of Materials
  - a. Institute of Electrical Welding
  - b. Institute of Problems of Materials
  - c. Institute of Foundry Problems
  - d. Physical-Mechanical Institute
  - e. Institute of Supraresistant Materials
  - f. Electro-hydraulics Design Bureau
6. Department of Physical-Engineering Problems of Energy
  - a. Institute of Electrical Dynamics
  - b. Institute of Engineering Thermal Physics
  - c. Institute of Problems of Engineering
  - d. Institute of Energy Simulation Problems
  - e. Institute of Energy Saving Problems
7. Department of Earth Problems
  - a. Institute of Geology
  - b. Institute of Geophysics
  - c. Poltava Gravimetric Observatory
  - d. Institute of Geology and Geochemistry of Mineral Fuels
  - e. Institute of Geochemistry and Physics of Minerals
  - f. Marine Hydrophysical Institute
8. Section of Chemical-Engineering and Biological Sciences
  - a. Institute of Physics and Chemistry
  - b. Institute of Colloidal Chemistry and Chemistry of Water
  - c. Institute of General and Inorganic Chemistry
  - d. Institute of Organic Chemistry
  - e. Institute of Chemistry of High Molecular Compounds
  - f. Institute of Bioorganic Chemistry
  - g. Institute of Surface Chemistry
  - h. Institute of Physical Chemistry
  - i. Institute of Gas
  - j. Institute of Physical-Organic Chemistry and Coal Chemistry
9. Department of General Biology
10. Department of Biochemistry, Physiology, and Theoretical Medicine
11. Department of Economics
12. Department of History, Philosophy, and Law
13. Department of Language, Literature, and Art

**XIV. Uzbek S.S.R. Academy of Sciences, Tashkent, Ul. Kuibysheva 15**

1. Department of Physical-Mathematical Sciences
  - a. Physical-Engineering Institute
  - b. Institute of Nuclear Physics
  - c. Institute of Mathematics
  - d. Institute of Electronics
  - e. Institute of Cybernetics and Computing Centre
2. Department of Mechanics and Control Processes
  - a. Institute of Mechanics and Seismic Resistance of Constructions
  - b. Uzbek Institute of Energy and Automation
3. Department of Earth Sciences
  - a. Institute of Geology and Geophysics
  - b. Institute of Seismology
  - c. Hydro-Geological Society "Tukan"
4. Department of Chemical-Technological Sciences
  - a. Institute of Chemistry
  - b. Institute of Bioorganic Chemistry
  - c. Institute of Chemistry and Physics of Polymers
5. Department of Biological Sciences
6. Department of Philosophy, Economics, and Law
7. Department of History, Linguistics, and Literature

**Appendix C****Selected Research Institutes in the Physical Sciences and Engineering****A**

Acoustics Institute, Moscow U.S.S.R.  
All-Union Institute for Systems Research, Moscow, U.S.S.R.  
All-Union Research Institute of Cybernetics, Moscow, U.S.S.R.  
All-Union Research Institute of Marine Fisheries and Oceanography (VNIRO), Moscow, U.S.S.R.  
All-Union Research Institute of Metrology, Leningrad, U.S.S.R.  
All-Union Research Institute of Optical Physical Measurements, Moscow, U.S.S.R.  
Applied Mathematics Institute, Moscow, U.S.S.R.  
Applied Physics Institute, Gorkiy, U.S.S.R.  
Armenian S.S.R. Academy of Sciences, Yerevan, U.S.S.R.  
Astrophysical Institute, Alma Ata 68, U.S.S.R.  
Astrophysical Observatory-Abastumani, Abastumani, U.S.S.R.  
Atmospheric Optics Institute, Tomsk, U.S.S.R.  
Atmospheric Physics Institute, Moscow, U.S.S.R.  
Automation Institute, Frunze, U.S.S.R.  
Azerbaijani S.S.R. Academy of Sciences, Baku, U.S.S.R.

**B**

Biochemistry Institute, Moscow, U.S.S.R.  
Biochemistry Institute, Yerevan, U.S.S.R.  
Biochemistry and Physiology Institute, Frunze, U.S.S.R.  
Biological and Medical Chemistry Institute, Moscow, U.S.S.R.  
Bioorganic Chemistry Institute-Moscow, Moscow, U.S.S.R.  
Bioorganic Chemistry Institute-Vladivostok, Vladivostok, U.S.S.R.  
Byelorussian S.S.R. Academy of Sciences, Minsk, U.S.S.R.

**C**

Catalysis Institute, Novosibirsk, U.S.S.R.  
Chemical Kinetics and Combustion Institute, Novosibirsk, U.S.S.R.  
Chemical Physics Institute, Moscow, U.S.S.R.  
Chemical Sciences Institute, Alma Ata, U.S.S.R.  
Chemistry Institute-Gorkiy, Gorkiy, U.S.S.R.  
Chemistry Institute-Sverdlovsk, Sverdlovsk, U.S.S.R.  
Chemistry Institute-Ufa, Ufa, U.S.S.R.  
Chemistry Institute-Vladivostok, Vladivostok, U.S.S.R.  
Chemistry and Metallurgy Institute, Karaganda, U.S.S.R.  
Complex Scientific Research Institute-Khabarovsk, Khabarovsk, U.S.S.R.  
Complex Scientific Research Institute-Magadan, Magadan, U.S.S.R.  
Computational Mathematics Department, Moscow, U.S.S.R.  
Computer Center-Krasnoyarsk, Krasnoyarsk, U.S.S.R.  
Computer Center-Leningrad, Leningrad, U.S.S.R.  
Computer Center-Moscow, Moscow, U.S.S.R.  
Computer Center-Novosibirsk, Novosibirsk, U.S.S.R.  
Computer Center-Yerevan, Yerevan, U.S.S.R.  
Control Systems Institute, Tbilisi, U.S.S.R.  
Crimean Astrophysical Observatory, Nauchnyy, U.S.S.R.  
Crystallography Institute, Moscow, U.S.S.R.  
Cybernetics Institute-Baku, Baku, U.S.S.R.  
Cybernetics Institute-Tbilisi, Tbilisi, U.S.S.R.

**E**

Earth Physics Institute, Moscow, U.S.S.R.  
Earth's Crust Institute, Irkutsk, U.S.S.R.  
Electrochemistry Institute-Moscow, Moscow, U.S.S.R.  
Electrochemistry Institute-Sverdlovsk, Sverdlovsk, U.S.S.R.  
Estonian S.S.R. Academy of Sciences, Kohtu, U.S.S.R.

**G**

General and Inorganic Chemistry Institute-Moscow, Moscow, U.S.S.R.  
General and Inorganic Chemistry Institute-Yerevan, Yerevan, U.S.S.R.  
General Physics Institute, Moscow, U.S.S.R.  
Geochemistry and Analytical Chemistry Institute, Moscow, U.S.S.R.  
Geochemistry Institute, Irkutsk, U.S.S.R.  
Geology and Geophysics Institute-Krasnoyarsk, Krasnoyarsk, U.S.S.R.  
Geology and Geophysics Institute-Novosibirsk, Novosibirsk, U.S.S.R.  
Geophysics Institute, Sverdlovsk-Sverdlovsk, U.S.S.R.  
Geophysics Institute-Tbilisi, Tbilisi, U.S.S.R.  
Georgian S.S.R. Academy of Sciences, Tbilisi, U.S.S.R.

**H**

Heat and Mass Transfer Institute, Minsk, U.S.S.R.  
High Current Electronics Institute, Tomsk, U.S.S.R.  
Hydrodynamics Institute, Novosibirsk, U.S.S.R.

**I**

Informatics Problems Institute, Moscow, U.S.S.R.  
Inorganic Chemistry Institute, Novosibirsk, U.S.S.R.  
Institute of Astrophysics and Atmospheric Physics, Tartu-Toravere, U.S.S.R.  
Institute of Automation and Control Processes, Vladivostok, U.S.S.R.  
Institute of Automation and Electrometry, Novosibirsk, U.S.S.R.  
Institute of Biochemistry and Physiology of Microorganisms, Pushchino, U.S.S.R.  
Institute of Biochemistry and Physiology of Plant Growth and Microorganisms, Saratov, U.S.S.R.  
Institute of Biological Physics, Pushchino, U.S.S.R.  
Institute of Chemical Additives, Baku, U.S.S.R.  
Institute of Chemical Physics, Yerevan, U.S.S.R.  
Institute of Chemical Physics and Biophysics, Tallinn, U.S.S.R.  
Institute of Construction Mechanics and Seismic Stability, Tbilisi, U.S.S.R.  
Institute of Continuum Mechanics, Perm, U.S.S.R.  
Institute of Control Problems, Moscow, U.S.S.R.  
Institute of Cybernetics Problems, Moscow, U.S.S.R.  
Institute of Elementoorganic Compounds, Moscow, U.S.S.R.  
Institute of Fine Organic Chemistry, Yerevan, U.S.S.R.  
Institute of General and Inorganic Chemistry-Minsk, Minsk, U.S.S.R.  
Institute of Geology-Tallinn, Tallinn, U.S.S.R.  
Institute of Geology-Tbilisi, Tbilisi, U.S.S.R.  
Institute of Geology-Vladivostok, Vladivostok, U.S.S.R.  
Institute of Geology-Yakutsk, Yakutsk, U.S.S.R.  
Institute of Geophysics and Seismology Engineering, Leninakan, U.S.S.R.  
Institute of Geothermal Problems, Makhachkaia, U.S.S.R.  
Institute of High-Energy Physics, Alma Ata, U.S.S.R.  
Institute of High Molecular Compounds, Leningrad, U.S.S.R.  
Institute of High Pressure Physics, Troitsk, U.S.S.R.  
Institute of High Temperatures, Moscow, U.S.S.R.  
Institute of Information Transmission Problems, Moscow, U.S.S.R.  
Institute of Inorganic Chemistry and Electrochemistry, Tbilisi, U.S.S.R.

Institute of Inorganic and Physical Chemistry, Frunze, U.S.S.R.  
Institute of Machine Mechanics, Tbilisi, U.S.S.R.  
Institute of Mathematics and Mechanics-Baku, Baku, U.S.S.R.  
Institute of Mechanics, Yerevan, U.S.S.R.  
Institute of Metallurgy and Ore Dressing, Alma Ata, U.S.S.R.  
Institute of Microelectronics and Ultrafine Materials Technology Problems, Chernogolovka, U.S.S.R.  
Institute of Mineralogy, Geochemistry, and Crystal Chemistry of Rare Elements, Moscow, U.S.S.R.  
Institute of New Chemical Problems, Chernogolovka, U.S.S.R.  
Institute of Organic Catalysis and Electrochemistry, Alma Ata, U.S.S.R.  
Institute of Physical Chemistry, Moscow, U.S.S.R.  
Institute of Physical Organic Chemistry-Minsk, Minsk, U.S.S.R.  
Institute of Physical Organic Chemistry-Tbilisi, Tbilisi, U.S.S.R.  
Institute of Physical Problems, Moscow, U.S.S.R.  
Institute of Precision Mechanics and Computation Techniques, Moscow, U.S.S.R.  
Institute of Rock Physics and Mechanics, Frunze, U.S.S.R.  
Institute of Semiconductor Physics, Novosibirsk, U.S.S.R.  
Institute of Solid State and Semiconductor Physics, Minsk, U.S.S.R.  
Institute for the Study of Mechanical Problems, Moscow, U.S.S.R.  
Institute of Theoretical and Applied Mechanics, Novosibirsk, U.S.S.R.  
Institute of Theoretical Problems of Chemical Technology, Baku, U.S.S.R.  
Institute of Thermal Physics and Electrophysics, Tallinn, U.S.S.R.

**K**

Kazakh S.S.R. Academy of Sciences, Alam-Ata, U.S.S.R.  
Kirgiz S.S.R. Academy of Sciences, Frunze, U.S.S.R.

**L**

Latvian S.S.R. Academy of Sciences, Riga, U.S.S.R.  
Lithuanian S.S.R. Academy of Sciences, Vilnius, U.S.S.R.

**M**

Marine Biology Institute, Murmansk, Dalniye Zelentsy, U.S.S.R.  
Marine Biology Institute-Petropavlovsk-Kamchatskiy, Petropavlovsk-Kamchatskiy, U.S.S.R.  
Marine Biology Institute-Vladivostok, Vladivostok, U.S.S.R.  
Marine Geology and Geophysics Institute, Novo Aleksandrovsk, U.S.S.R.  
Mathematics Institute-Leningrad, Leningrad, U.S.S.R.  
Mathematics Institute-Moscow, Moscow, U.S.S.R.  
Mathematics Institute-Novosibirsk, Novosibirsk, U.S.S.R.  
Mathematics Institute-Tbilisi, Tbilisi, U.S.S.R.  
Mathematics Institute-Yerevan, Yerevan, U.S.S.R.  
Mathematics and Mechanics Institute-Alma Ata, Alma Ata, U.S.S.R.  
Mathematics and Mechanics Institute-Sverdlovsk, Sverdlovsk, U.S.S.R.  
Metal Physics Institute, Sverdlovsk, U.S.S.R.  
Metallurgy Institute-Moscow, Moscow, U.S.S.R.  
Metallurgy Institute-Sverdlovsk, Sverdlovsk, U.S.S.R.  
Metallurgy Institute-Tbilisi, Tbilisi, U.S.S.R.  
Microbiology Institute, Moscow, U.S.S.R.  
Microelectronics Institute, Yaroslavl, U.S.S.R.  
Mining Institute-Alma Ata, Alma Ata, U.S.S.R.  
Mining Institute-Apatity, Apatity, U.S.S.R.  
Mining Institute-Lyubertsy, Lyubertsy, U.S.S.R.  
Mining Institute-Novosibirsk, Novosibirsk, U.S.S.R.  
Mining Institute-Tbilisi, Tbilisi, U.S.S.R.  
Moldavian S.S.R. Academy of Sciences, Kishinev, U.S.S.R.  
Molecular Biology Institute, Moscow, U.S.S.R.

**N**

Nuclear Physics Institute-Alma Ata, Alma Ata, U.S.S.R.  
Nuclear Physics Institute, Leningrad, Gatchina, U.S.S.R.  
Nuclear Physics Institute-Novosibirsk, Novosibirsk, U.S.S.R.  
Nuclear Power Engineering Institute, Minsk, U.S.S.R.  
Nuclear Research Institute, Moscow, U.S.S.R.  
Nuclear Structure and Charged Particle Reaction Data Center, Moscow, U.S.S.R.

**O**

Organic Chemistry Institute-Frunze, Frunze, U.S.S.R.  
Organic Chemistry Institute-Irkutsk, Irkutsk, U.S.S.R.  
Organic Chemistry Institute-Moscow, Moscow, U.S.S.R.  
Organic Chemistry Institute-Novosibirsk, Novosibirsk, U.S.S.R.  
Organic Chemistry Institute-Yerevan, Yerevan, U.S.S.R.  
Organic and Physical Chemistry Institute, Kazan, U.S.S.R.

**P**

Physical Technical Institute-Kazan, Kazan, U.S.S.R.  
Physical Technical Institute-Leningrad, Leningrad, U.S.S.R.  
Physical Technical Institute-Minsk, Minsk, U.S.S.R.  
Physical Technical Institute-Sukhumi, Sukhumi, U.S.S.R.  
Physics Institute-Baku, Baku, U.S.S.R.  
Physics Institute-Krasnoyarsk, Krasnoyarsk, U.S.S.R.  
Physics Institute-Makhachkala, Makhachkala, U.S.S.R.  
Physics Institute-Minsk, Minsk, U.S.S.R.  
Physics Institute-Moscow, Moscow, U.S.S.R.  
Physics Institute-Tartu, Tartu, U.S.S.R.  
Physics Institute-Tbilisi, Tbilisi, U.S.S.R.  
Physics and Mathematics Institute, Frunze, U.S.S.R.  
Physics Research Institute, Yerevan, U.S.S.R.

**R**

Radio Engineering and Electronics Institute, Moscow, U.S.S.R.  
Radio Engineering and Electronics Institute, Saratov Branch, Saratov, U.S.S.R.  
Radio Engineering Institute, Moscow, U.S.S.R.  
Radio Physics and Electronics Institute, Yerevan, U.S.S.R.  
Research Institute of Carcinogenesis, Moscow, U.S.S.R.  
Research Institute of Inorganic and Physical Chemistry, Baku, U.S.S.R.  
Research Institute of Machine Science, Moscow, U.S.S.R.  
Research Institute of Radio Physics, Gorkiy, U.S.S.R.

**S**

Shemakha Astrophysical Observatory, Shemakha, U.S.S.R.  
Silicate Chemistry Institute, Leningrad, U.S.S.R.  
Solid State Chemistry Institute, Novosibirsk, U.S.S.R.  
Solid State Physics Institute-Chernogolovka, Chernogolovka, U.S.S.R.  
Solid State Physics Institute-Yerevan, Yerevan, U.S.S.R.  
Space Physics Research and Aeronomy Institute, Yakutsk, U.S.S.R.  
Space Research Institute, Moscow, U.S.S.R.  
Special Astrophysical Observatory, Nizhniy Arkyz, U.S.S.R.  
Spectroscopy Institute, Troitsk, U.S.S.R.

**T**

Tadzhik S.S.R. Academy of Sciences, Dushanbe, U.S.S.R.  
Thermal Physics Institute, Novosibirsk, U.S.S.R.  
Turkmen S.S.R. Academy of Sciences, Ashkhabad, U.S.S.R.

**U**

Ukrainian S.S.R. Academy of Sciences, Kiev, U.S.S.R.  
Uzbek S.S.R. Academy of Sciences, Tashkent, U.S.S.R.

# Foreign Applied Science Assessment Center on Soviet Science and Technology

by Marco S. Di Capua

The Foreign Applied Sciences Assessment Center (FASAC) is operated for the Federal Government by Science Applications International Corporation (SAIC) to improve U.S. knowledge of foreign applied science and to increase awareness of new foreign technologies with military, economic or political importance. Such knowledge can reduce technological surprise, support estimates of the consequences of technology transfer, and provide a background for U.S. research and development decisions.

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Soviet Applied Discrete Mathematics Research  
Soviet Fast-Reaction Chemistry Research\*
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Soviet Computer Science Research  
Soviet Applied Mathematics Research:  
Mathematical Theory of Systems, Control,  
and Statistical Signal Processing  
Selected Soviet Microelectronics Research Topics  
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- FY-85 FASAC Integration Report: Selected Aspects of Soviet Applied Science  
Soviet Research on Robotics and Related Research on Artificial Intelligence  
Soviet Applied Mathematics Research:  
Electromagnetic Scattering  
Soviet Low-Energy (Tunable) Lasers Research\*  
Soviet Heterogeneous Catalysis Research  
Soviet Science and Technology Education  
Soviet Space Science Research  
FASAC Special Report: Effects of Soviet Education Reform on the Military  
Soviet Tribology Research  
Soviet Spacecraft Engineering Research

- Soviet Exoatmospheric Neutral Particle Beam Research  
Soviet Combustion Research  
Soviet Remote Sensing Research and Technology  
Soviet Dynamic Fracture Mechanics Research  
FY-86/89 Soviet Magnetic Confinement Fusion Research  
Recent Soviet Microelectronics Research on III-V Compound Semiconductors  
Soviet Ionospheric Modification Research  
Soviet High-Power Radio Frequency Research  
Free-World Microelectronic Manufacturing Equipment  
FASAC Integration Report II: Soviet Science as viewed by Western Scientists  
Soviet Software for Soviet Computers  
West European Magnetic Confinement Fusion Research  
FY-86/89 Soviet Oceanographic Synthetic Aperture Radar Research (SAR)  
Soviet Research in Low-Observable Materials\*  
Soviet and East European Research Related to Molecular Electronics  
Soviet Phase-Conjugation Research  
Soviet Atmospheric Acoustics Research  
Precision Timekeeping Research in the Soviet Union  
Soviet Optical Processing Research  
Soviet Satellite Communications Science and Technology  
FASAC Integration Report III: Soviet Information Sciences  
Soviet Radiation Cone Research\*
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# The Selling of Soviet Space at Space Commerce '90

by LCDR Larry Jendro USN, the Liaison Officer for Oceanography and Environmental Systems at the Office of Naval Research European Office. LCDR Jendro is an active duty naval officer from the U.S. Navy's oceanography community.

## Introduction

Soviet space capabilities were advertised via a variety of media at Space Commerce '90, an international conference on the commercial and industrial use of space, held in Montreux Switzerland in March 1990. The Soviets presented aspects of their space program now open for commercialization in four separate conference presentations. Non-Soviet organizations also promoted the sales of Soviet space capabilities. A Finnish organization, EKE Group, erected an elaborate display in the exhibition area. At the same time, the trade magazine, *interavia SPACE markets*, featured four articles describing Soviet space capabilities.

## Soviet Presentations

During the conference, four presentations were given by Soviets describing commercial opportunities in the Soviet space program.

**Soviet Space-Processing Programme and Prospects for the Utilization of Soviet Know-How by Foreign Companies**, I. Barmin, Director of the Research Centre Splav, Glavkosmos, U.S.S.R. Barmin described three phases of the Soviet materials space processing program which is to be put on a commercial basis by the end of the 1990s. First, an experimental phase will sort out the materials and technologies that will be used in space processing. This phase will end in the early 1990s. Pilot and full-scale production of materials will be done in the second stage. The initial objective of this stage will be to perfect the principal methods of obtaining the specific materials required for the production of materials in space. The focus will then shift to bringing the design characteristics of space processing equipment to an optimum level. The third stage, to start in the late 1990s, will be the commercial production of materials. Photographs or drawings functional descriptions and technical data of various available, and planned processing units: SPLAV-02, ZONA-02, ZONA-03, ZONA-04, KASHTAN, KONSTANTA-02, and FAZA were presented.

**The Utilization of Made-in-Space Images for the Nature and Environmental Survey**, Mr. Selivanov, Vice Director, Institute of Space Devices Moscow, U.S.S.R. Selivanov described three optical and side-looking radar remote sensing systems--Resours-O, Resours-F, and Ocean-O. He concluded by stating that the Soviet Union

was "ready to continue cooperation in any of the named systems."

**Soviet System of Launch Vehicles and its Commercial Capacities**, Georg Fomin, Vice Director, Foton Design Bureau, Kubishev, U.S.S.R. Fomin presented several Soviet launch vehicles capable of launching spacecraft from between 1 and 20 tons to a variety of earth orbits, and described the system of carrier rockets now in use in the U.S.S.R. Performance and service characteristics of Soviet and "foreign" carrier rockets were compared.

**MIR Orbital Station, its Tasks and Capabilities**, Leonid Gorshkov, Vice-Director, NPO Energia, Moscow, U.S.S.R. Gorshkov described the special place manned missions of spacecraft and orbital space stations have in the Soviet space program. He emphasized the length of time MIR has been in orbit, and also pointed out the unique research opportunities provided by manned space vehicles that remain in space for extended periods.

Although some of these presentations seemed to be limited to descriptions of what the Soviets were doing, constant references to desired "cooperation" made it obvious that the Soviets are interested in doing business. Unfortunately, only the first of these articles, "The Soviet Program for Material Processing in Micro-gravity," was subsequently published in the proceedings of the conference--Space Commerce, Proceedings of the Third International Conference on the Commercial and Industrial Uses of Outer Space, Montreux, Switzerland, March 26-29, 1990, John J Egan, Editor.

## Soviet Exhibit

Various aspects of the Soviet space program were also being marketed with a very glossy exhibit in the conference exhibition hall. The exhibit was one of the largest and most impressive on display, with very nice, shiny, fibre-glass models, expertly lighted and arranged. Featured were satellite launch facilities, space on Soviet satellites, platforms for manufacturing in micro-gravity, and the manufacture of space technology and special metal products. Interestingly, the exhibit was not manned by Russians but by a Finn from the EKE Group and a Briton representing Commercial Space Technologies (CST) Ltd. According to the CST representative, the exhibit was the work of the EKE Group.

The exhibit advertised services available from Glavkosmos, U.S.S.R. These included space and services on

the manned space orbital complex made up of MIR, SOYUZ-TM, PROGRESS, and KVANT.

MIR is the permanently operated manned space station that provides for the docking of up to 5 operational modules, and one cargo and one transport spacecraft.

SOYUZ-TM is the manned transport spacecraft designed to deliver a team of up to three cosmonauts to the MIR space station.

PROGRESS is the unmanned cargo spacecraft designed to:

- Deliver different payloads (fuel, food, materials processing facilities) of up to two tons to the MIR station
- Resupply MIR's propulsion system and on-board support systems with fuel and air
- Correct the trajectory of the orbital complex with its own propulsion unit
- Remove waste material from the MIR station.

KAVANT is an operational module supporting scientific experiments containing the following technical equipment:

- Telescope with aperture mask
- Scintillation gas spectrometer
- High-energy spectrometer
- X-ray spectrometer
- Ultraviolet spectrometer.

The Splav-2 processing facility was also advertised in the display. The Splav-2 facility is intended for the on-board manufacture of materials by homogeneous and directional crystallization techniques via gaseous phase epitaxial growth. The facility is composed of both sample processing chambers and control units. During the pre-launch ground preparation, the materials are placed into quartz ampules that are fitted into 12 metallic capsules in the processing unit. Each capsule is processed separately under a unique processing schedule, controlled with high precision by the automatic control system. This schedule allows selection of heating rate, maximum temperature, melting duration, and cooling rates (two different cooling rates are available and the temperature at which the cooling rates are shifted can be selected). Process parameters can be transmitted to earth during the processing, as can a record of micro forces acting on the sample (see Table 1).

Another display in the exhibit promoted the Proton Launch vehicle. The exhibit provided a record of the Proton Launch Vehicle successes: Salyut, and MIR orbiting space stations; probes to the Moon, Venus, Mars, and Halley's Comet; Raduga, Ekran, and Gorizont communications satellites. The exhibit also announced Proton's capabilities to lift satellites of 20 tons to low earth orbit or of two tons to geosynchronous orbit.

**Table 1. Splav-2 Technical Specifications**

Heater temperature, C	500-1050
Cooling-down rates, C/hr	2.8,5.6,11.3,22
Temperature maintenance error, C	±3
Maximum temperature gradient, C/sm	140
Capsule's exterior diameter, mm	20
Thermal zone length, mm	150

Satellite remote-sensing data and images were not advertised in the displays but CST's representative said they are available.

The Soviets themselves were also marketing the services mentioned above via advertising handouts through the organizations:

GLAVCOSMOS U.S.S.R.  
9, Krasnoproletarskaya ul.  
193030, Moscow, U.S.S.R.

V/O LICENINTORG  
11, Minskaya ul.  
121108, Moscow, U.S.S.R.

The EKE Group said they could offer "better and more competitive terms" because they were marketing the Soviet services in connection with a barter construction project under work.

### Soviet Marketing Via a Periodical

The Soviet space sales pitch was also delivered in a trade magazine freely distributed during the conference. The necessity of the Soviets entering the commercial space market was the subject of the cover story on this very glossy space industry periodical *interavia SPACE markets*. The Jan/Feb 1990 edition was headlined "U.S.S.R. Facing New Realities." This story was told in four articles on the Soviet space effort: "Soviet Space at the Crossroads", "Moscow's Proton Factory", "Soviet Earth Observation Gets Less Remote," and "Energia's Next Stage."

Although these articles covered a wide range of activities associated with the Soviet space program, two consistent messages were clear. First, there is an amazing new openness unveiling the once secret Soviet space program. Second, the Soviets have a strong desire to market space services. All of the articles are very well supported by many photographs, diagrams, and specifications. "Moscow's Proton Factory" describes the A.M. Khrunnitshev factory, a previously well-hidden plant where components of the Proton launch vehicle and space station modules undergo final integration and testing. According to the general designer of NPO Mashinostroeniye, Dr. Herbert A. Yefremov, "We used to be just

a mailbox number." Today, the products of the factory are displayed in color photos in *interavia SPACE markets*. The photos show various perspectives of all three stages of the Proton launch vehicles in the assembly hall. Also revealed are MIR modules including a pressurized habitable module, materials processing modules, and a remote-sensing payload. The text describes the facility and the work in process in detail. Photos of a space platform to be used for near-term remote-sensing missions, including the second Almaz SAR mission and the KVANT 4 remote-sensing module taken in the same plant, appear in the article, "Soviet Earth Observation gets Less Remote."

The strong desire of the Soviets to market space services is analyzed by the writers for *interavia SPACE markets*. In the opening paragraph of "Soviet Earth Observation Gets Less Remote," Stéphane Chenard writes "In general, Soviet Managers appear almost desperate to secure foreign support for their programs. Everything is seemingly open to cooperation from production of ground terminals to entire new satellites." The motivation for this intensity in foreign marketing effort is discussed in "Soviet Space at the Crossroads," edited by Chris Bulloch. Two reasons are given for the Soviet space programs current predicament: (1) failure to promote the utility of space activities to either the general populace or their newly elected deputies; (2) lack of a coherent strategy of a space program driven in the past to extol the achievements of Soviet technology. Together these factors are said to have put the space program in danger in

this time of serious reassessment of Soviet budgetary priorities.

### Comments

An inference that could be drawn from this multimedia sales effort might be that the Soviet government developed and conducted a coordinated campaign to market its space capabilities. This did not seem to be true. The Soviet presentations at the conference constantly mentioned "cooperation" and gave the impression that almost all aspects of the Soviet space program were open for negotiation, but they fell far short of asking us to buy. A coordinated marketing approach probably would have developed a clearer sales message. The elaborate display in the exhibition hall was the result of the Finnish group acting independently of, and perhaps even in competition with, the Soviet government. *interavia SPACE markets* is a publication of the Jane's Information Group an organization well-known for its independence. What may have looked like a coordinated campaign of advertising by the Soviets was really the expression of several individual interests. That this variety of interests, all advertising of the Soviet space program, coincided at Montreux is a tribute to Space Commerce '90, which acted as a focal point for this amazing development in international business.

# Hungary

## An Assessment in Computing, Telecommunications, and Microelectronics

by J.F. Blackburn. Dr. Blackburn was the London representative of the Commerce Department for Industrial Assessment in Computer Science and Telecommunications.

### Introduction

This assessment of Hungary's technology and market potential in computing, telecommunications, and microelectronics is based on a visit to Budapest, May 2-4, 1990. Three important new laws were passed in Hungary in 1988 and 1989 designed to encourage investment from abroad. Later in this report I will discuss this in some detail in the section on discussions with individuals.

Hungary is a nation of 10.7 million inhabitants. There are also some 5 million Hungarians living abroad--Transylvania, Czechoslovakia, Yugoslavia, the U.S.S.R., the U.S., and Canada. Minorities within Hungary include less than 5 percent of the population.

The Hungarians began changes in their economic system before Czechoslovakia began taking its recent steps. As far back as the 1960s, Janos Kadar proposed a *New Economic Mechanism*, which combined central government planning with a market economy. Most plants and companies are state owned, but management is allowed wide discretionary powers. The government requires the decentralized enterprises to compete and make a profit. Businesses that consistently lose money must declare bankruptcy. Supply and demand, rather than state edicts, determine prices. The government now intends to have 50-60 percent of enterprises privatized over the next 5 years.

Exports provide nearly half of Hungary's national income. For example, Hungary produces 10 percent of the world's exports of buses. Other export products include porcelain, clothing, locks, nuclear instruments, current meters, cranes, motor-trains, tractor-trailers, refrigerators, wine, foodstuffs, shoes, rubber products, lamps, medical instruments, and electronic devices.

### Telecommunications

The Hungarian government has begun a badly needed 10-year development plan for the telecommunications

industry. The public network is analogue and, as in Czechoslovakia, the waiting period for a private telephone is up to 10 years. The waiting list for telephones stands at 498,000. At the same time, Hungary exports a lot of telephone equipment to the U.S.S.R. and Czechoslovakia. Hungary exports telephones, crossbar switches, cable systems, and microwave systems. As of 1988, Hungary had an installed base of 1,048,924 main telephone lines. The telex network had 12,614 subscribers.

The 10-year development program for the public switching network is expected to cost about 400 billion Forint (\$6.3 billion). The upgrade will include:

- Three million additional phone lines
- Data transmission capability
- Waiting time for a telephone to 1 year
- Digital transmission and switching
- Optical fiber transmission
- Integrated Services Digital Network (ISDN).

The Hungarian government is sponsoring a project called the Information Infrastructure Development Program (abbreviated IIF in Hungarian). The Computer and Automation Institute of the Hungarian Academy of Sciences is managing the project. The project is to create an information infrastructure to support research and technical development activity in Hungary.

The IIF includes:

- Access to databases provided by Hungarian companies and foreign companies
- Management information services for the R&D community
- Office automation services, including E-mail, bulletin board, text processing, desktop publishing, and teleconferencing.
- File access and management
- Computing services.

The architecture of the IIF system enables companies, institutions, and government authorities to establish and integrate their own local networks, thus increasing the number of users. The network subsystem of IIF allows computers to be connected to the packet-switched data network, which may include mainframe computer, mini-computers, and personal computers (PCs). I will provide more details later in a summary of discussions with individuals.

More than 16 companies in Hungary are concerned with telecommunications products, as manufacturers, or exporting/importing. I will provide a list of prominent companies in a summary of discussions with individuals.

Hungary needs foreign capital and foreign licenses to upgrade the public network to be completed by 2000. Tenders are now being given to potential equipment suppliers through Electroimpex, the export/import company. Among the companies that have thus far responded to these tenders are: Siemens, Northern Telecom, Samsung of Korea, and the Canadian/Austrian combine, Kras Kap (see page 107).

Hungarian manufactured products satisfy less than 50 percent of the domestic market for computers. Three of the principal manufacturers of computers in Hungary are Videoton, Controll, and Muszertechnika (see separate discussion beginning on page 105). Later, I will discuss this subject more fully. The dollar value of the installed base is about \$1 billion.

Software production is an important industry in Hungary. There are about 40,000 people working in the software industry in Hungary. Most of the work is custom software.

Most of the computers made in Hungary are fabricated from components obtained principally from the Far Eastern suppliers, either directly or through an Eastern European supplier. As in Czechoslovakia, the PCs are mainly compatible with the International Business Machines (IBM) PC/AT and PC/XT. Most of the minicomputers and mainframes are compatible with Digital Equipment Corporation (DEC) PDPs and Virtual Address Exchanges (VAX). The Hungarian manufacturers are able to get components incorporating Intel 80286, 80386, and 80486 microprocessors.

The best estimate I could get of the installed base of computers came from Mr. Elek Straub, IBM, and from the John Von Neumann, Society for Computing Sciences. There are probably 250,000 professional PCs, 97 percent of which are compatible with IBM products. Most of them are either imported from Far Eastern suppliers or made with components from the Far East.

There are about 300 mainframe computers in Hungary coming from Western suppliers:

- IBM - about 100
- Siemens - about 50

- Group including Honeywell, International Computers Limited (ICL), Control Data Corporation (CDC), Bull, and perhaps others - about 150
- Eastern Europe (German Democratic Republic, Bulgaria, Poland) or Hungary - about 300.
- In Hungary, there are perhaps 500 minicomputers, similar to the DEC PDPs, manufactured in Hungary, most coming from the Physical Research Institute for Physics (KFKI). A working arrangement exists between DEC and KFKI.

The main obstacles to sales in Hungary by Western suppliers have been Hungarian government favoring Eastern suppliers, Coordinating Committee for Multilateral Export Control (COCOM) regulations against such sales, and lack of western currency in Hungary. For example, COCOM regulations prevent IBM from selling large computer systems, its SNA communications system, or any communications boxes based on the X.25 protocol.

## Summaries of Discussions with Individuals

I spoke to several individuals and here I summarize pertinent information from those discussions.

**Mr. Peter Ikladi, Director, Department of Electronics Industry, Ministry of Industry.** Mr. Ikladi spoke of several new laws in Hungary designed to encourage investment from abroad. Tables 1, 2, and 3 present facts about Acts VI, XXIV, and XIII.

**Table 1. Economic Associations - Act VI - 1988**

**Act VI will**

- Renew the Hungarian economy by enabling an easy, unhindered flow and reallocation of capital in the economy to match investment requirements judged as most useful
- Make possible the necessary, and most appropriate, concentration of capital and use other means tailored to all economic tasks
- Recognize company forms: unlimited partnership, deposit or limited partnership, union, joint enterprises, limited liability company, company limited by shares.

**Table 2. Foreign Investment - Act XXIV - 1989**

**Act XXIV will**

- Provide the basis, along with Act VI, for Hungarian citizens and corporate entities to establish various types of companies in some of which foreign parties can participate
- Reconfirm several existing state guarantees at a higher legal level; provides new guarantees and more favorable tax allowances
- Further a market-economy in Hungary in which private initiative plays an important role
- Create greater opportunities for competitive forces in fields such as manufacturing, trade, and services

**Table 3. Transformation of Business - Organizations and Companies Act XIII - 1989**

**Act XIII will**

- Close the first stage of the new economic legislation
- Regulate company forms
- Provide basic guarantees for both private and foreign investors
- Assist in the transformation of the different company forms
- Transform state-owned companies and cooperatives
- Transform business organizations falling under the Act VI, including partnerships, public companies limited by shares, and limited liability companies.

Foreign participation in Hungarian economic associations can be by establishing Hungarian companies with foreign participation, creating fully foreign-owned firms, participating in existing Hungarian companies.

The central aim of the transformation for a state-owned company or cooperative is to enable it to enter into business relationships more easily. Such relationships could take the form of the establishment of joint ventures with transformed companies or the actual investment in transformed companies by foreign investors.

According to Mr. Ikladi, the government believes that 50-60 percent of all companies should be privatized over the next 5 years. Some political parties want even faster change, for example the Free Democratic Party. To date, foreign capital brought into Hungary has been for services. Hungary has less foreign capital than Greece or Portugal. The country needs and wants more industrial capital. The new laws briefly described above protect the capital by law, make tax-free joint ventures for 5 years, and allow 100 percent foreign ownership. Until recently, the maximum foreign ownership in an enterprise was 51 percent.

Ikladi believes that the most useful form of foreign capital is in the form of a joint venture. He said that 60-70 percent of machinery produced in Hungary is exported. Hungarian commerce, he said, must be reoriented because (1) it was formerly Eastern oriented and is now becoming Western oriented, and (2) the country has a lot of borrowed foreign currency (about \$20 billion) and the policy needs to be an independent one.

In the future, it is expected that Hungarian commerce will be in dollars, even with Eastern countries. Hungary is eager to meet the expectations of the demand; i.e., telephones. World bank experts were recently in Hungary to discuss finances.

The Hungarian machinery industry needs a wider market. Among other things, the new laws make it possible

to change state capital into shares, which will facilitate marketing government ownership.

One barrier that still remains for bringing in products from the West is a 5-10 percent customs tax. The plan is to liberalize the market even further.

## The Computer Market

Computer production in Hungary started 5-6 years ago and the domestic market is met by less than 50 percent Hungarian products.

Videoton makes IBM-compatible PCs and minicomputers. Muszertechnika makes PCs only. There is a well-developed software market and many Hungarian companies are in this market. Also, there are Hungarian experts in software working in France, the Federal Republic of Germany (FRG) and Sweden. There are 30-50,000 people working in the software production and marketing (mostly custom) in Hungary. Most computers are bought privately.

## Telecommunications

The government has begun a 10-year development for the telecommunications industry. The public network is analogue, small towns in Hungary have only operators, and even in Budapest the waiting period for a telephone is up to 10 years. (One person I met, Professor Ivan Futo, lives about 10 miles from Budapest and works in Budapest, but has no phone at home.) Nonetheless, according to Mr. Ikladi, the public telephone system in Hungary is the best in the East. Hungary exports telephones and crossbar switches to the U.S.S.R. and to Czechoslovakia.

Hungary also exports cable systems and microwave systems. Hungary has a special cable development program based on several joint ventures:

- Joint venture with Northern Telephone of Canada to develop digital switches with data storage
- Joint venture with Siemens and Standard Elektrik Lorans of FRG for digital and microwave systems
- Joint venture with Alcatel of France on a 64-K bit microwave system and on cellular radio
- Joint venture with Bond Company of Australia for cellular radio development
- Joint venture with Ericsson of Sweden on cellular radio.

The cost of the 10-year development for the public switching network will be about 400 billion Forint (\$6.3 billion). The upgrade will include:

- Three million additional phone lines
- Data transmission capability
- Reduction in the delay in getting a phone to 1 year

- Digital transmission and switching
- Optical fiber transmission
- Integrated Services Digital Network (ISDN).

**Mr. Andras Kolesar, Sales Director, Controll Cooperative for Electronics and Computer Technics, Budapest.** Controll is a private company with seven owners. According to Mr. Kolesar, the main obstacles to importing computer and communications products is the COCOM regulations. The computers sold by Controll are mainly IBM- and DEC-compatible. The Far Eastern countries are the principal component suppliers. There was an attempt to make minicomputers and mainframes IBM 360-compatible, but this was unsuccessful. With the beginning of some liberalization at the beginning of the 1980s, small companies like Controll could enter the business. Controll has sold many thousands of PCs (perhaps 60,000), a little under 300 minicomputers, and about 50 mainframe systems.

Controll is now in second or third place as a supplier of computers in Hungary. Controll's business is mainly hardware systems and service, like installation of local area networks (LANs). Of 140 employees, about 30 people are doing special software. Turnover of the company is about 1 billion Forint/year (\$15.9 million). Customers include the election board, banks, the electricity board, and the machine tool industry. Important considerations for the industry in the future are joint ventures and education.

In telecommunications, Controll installs its own LANs with transmission speed of 2.5 Mb/sec. The largest installed has 10 file servers, using Intel 386s and 140 workstations using Intel 286s. Because it is difficult to buy directly from Intel, Controll buys mother boards, rather than chips, from the Far Eastern suppliers and assembles the computers in Hungary. The company must have sales of about 100,000 computers/year to justify starting with chips. Transmission on the public network is possible using modems at a speed of 1000-2400 baud, but the network is noisy.

**Mr. Elek Straub, Managing Director, IBM, Hungary.** The estimated installed base of computers in Hungary is about \$1 billion. Sources are Eastern Europe - 40 percent, Western Europe - 40 percent, and locally produced - 20 percent. Of the Western Europe portion, IBM is responsible for about 30-40 percent; e.g, 12-16 percent of the total installed base. Small machines comprise only about 5 percent of IBM sales. Most of the value of sales has come from mid-range computers like the AS400, the 370-compatibles--4361, 4381, and 9700.

Imports from the Eastern Bloc countries has slackened considerably since autumn 1989. There is now movement toward liberalization on the part of the Hungarian government toward purchases from the West and on the part of COCOM toward selling to the East. Future

buys of about 30-40 percent will probably go to IBM. A company called Szamalk, a systems house, and the KFKI are working with DEC. Siemens, ICL, and Bull seem to be underselling the prices charged in the West. COCOM regulations forbid IBM's selling of its communications system SNA or any boxes based on the X.25 protocol. In the future, they hope to sell IBM 3090 systems for hotels and the financial services and transportation industries.

**Mrs. Josef Toth, President, John Von Neumann Society for Computing Sciences; Mr. Jozsef Uszta, Head of Section, Central Statistical Office; Mr. Csaba Gergely, Vice President, John Von Neumann Society for Computing Sciences; Dr. Peter Hanak, Vice President, John Von Neumann Society for Computing Sciences; and Mrs. Olga Szilvassy, Head of Section, Department of International Relations, Ministry of Industry.** In Hungary, there are 200 corporate members in the International Federation of Information Processing (IFIP). Members of IFIP are large users of computers and are companies representative of the computer industry.

Videoton has been number one among the local marketers of computers. Other important companies include: Muszertechnika, Orion, Microsystems, Controll, Szamalk (joint effort with DEC and KFKI), SZUV (working with UNISYS), and TERTA (Telefongyer).

The Central Statistical Office uses an IBM 370/158 and there are six mainframe computers at the Financial Data Center. There are perhaps 500 minicomputers, similar to the DEC PDPs, coming from KFKI. Table 4 presents Hungary's computer industry suppliers and their respective percentages.

**Table 4. Hungary's Computer Suppliers**

IBM compatible PCs - 97 percent

Mainframes (German Democratic Republic and U.S.S.R.) - 50 percent

Mainframes from the West (IBM, Siemens, Honeywell, ICL, CDC, Bull, and others; few Japanese computers in Hungary) - 50 percent

**Dr. Peter Bakonyi, Deputy Director, Computer and Automation Institute, Hungarian Academy of Sciences, Budapest.** The Hungarian Academy of Sciences has seven divisions. The computer center of the Academy of Sciences has an IBM 370, 3031, and 4381. The Computer and Automation Institute (Institute) has about 500 employees (about 300 are professionals). The Institute has developed products and equipment in telecommunications. The main computer network services are: line mode terminal access, full screen terminal access, E-mail, file access and management, and directory.

The IIF system's architecture enables companies, institutions, and government authorities to create and integrate their own local networks, thus increasing the

number of users. The IIF's network subsystem allows computers to be connected to the packet-switched data network, which may include mainframes, megaminicomputers, and PCs.

As of 1986, Hungary had a circuit-switched data network imported from Japan with speeds of 2400, 4800, and 9600 baud. Since a packet-switched network could not be imported because of COCOM rules, they implemented one locally. Research began in 1975, and by 1986 they were achieving good results which are now being implemented. The range of products partially in production include a postal, telephone, and telegraph-(PTT) operated and managed data network, some privately managed data networks, miniswitches, and terminal concentrators. The system has been based on the packet assembly/disassembly (PAD) recommendations X.3, X.28, X.29, and X.25 of the International Consultive Committee for Telegraph and Telephone (CCITT). The public-switched data network and the telephone network provide for terminal access to the PAD of the packet subnetwork.

At present, the PTT-operated main switch has 70 X.25/X.75 interfaces, and 16 PAD ports. The throughput of the switch is 200 packets/sec and the speed of the international and national interface is 9.6 kbit/sec. The 64 kbit/sec is under development.

The network can be connected to EUNET, USNET, and BITNET.

**Mr. Ivan Nemeskeri, President, Society for Telecommunications, Budapest.** There is a strong development program underway in Hungary, the main purpose of which is to reach the Western European level of service. The network will be a part of the Hungarian PTT with Hungarian companies providing much of the equipment. Some specific objectives are to:

- Reach 3 million phone lines by 2000 (2.5 million new and 0.5 million renew)
- Reduce the waiting time for a phone to not more than 1 year.

Today, foreign capital and foreign licenses are needed. The telephone switches now made by Hungarian companies are analogue, but in the future they will be digital. Hungarian companies make the data transmission systems, cables, and telephone sets. Also, Hungarian companies make all necessary equipment for analogue systems, but not for digital systems.

Hungary is divided into 100 trunkline regions. The country is requesting proposals for products needed for the new system from both foreign and domestic manufacturers. They will issue tenders over the next 2 years; the work is to be completed by 2000. Table 5 lists Hungarian companies that are concerned with telecommunications products.

**Table 5. Hungarian Telecommunications Companies**

Telefongyer
Merestechniki Fejlesztó Vallalat (MIKI)
Elektronika
Technika
Pont
Gyártja Mechanikai Laboratorium
Elektroimpex
Research Institute for Telecommunications
Association of the Hungarian Telecommunications Industries Microelectronics Company
Mechanikai Muvek
Kontakta
Videoton
Muszertechniki Szövetkezet Jászberény (MICoOP)
Elektronikus Műrökeszulekek Gyara
Fenomechanikai Vallalat
Budapesti Radiotechnische Fabrik

**Mr. Tanko Zoltan, Vice President, Muszertechnika, Budapest.** The main activities of Muszertechnika are assembly, sales and service of PCs, and educational activities. The company started in a garage in 1981, is a private share holding company, and the largest such company in Hungary. The turnover of the company reached \$60 million in 1989; assets are about \$20 million. There are 400 employees, 150 of whom are engineers. Besides the manufacture, sale, and service of PCs, the company also manufactures and sells color scoreboards and AC motor drives.

Muszertechnika has four companies outside of Hungary in Switzerland; Cleveland, Ohio; Taiwan; and Munich, FRG. The U.S.-based company sells computer products in the U.S.; it sold about \$800K the first year and broke even. The Taiwan company purchases products such as mother boards with Intel chips for use in Hungary and other Eastern European countries. Most parts used by Muszertechnika come from Taiwan. However, Winchester diskdrives come from the U.S., and floppy diskdrives come from Japan. The company has an original equipment manufacturer (OEM) contract with Seagate for Winchester disks.

The subsidiary in the FRG is a software company. Among its customers are Siemens and the Dresden Bank. The Swiss company handles financial matters for its parent company. The breakdown of the company's business is: hardware - 70 percent, software - 10 percent, and service and training - 20 percent.

The company has other OEM contracts with the American software companies--3 COM and Microsoft. An important product in U.S. sales is the Disk Coprocessor Board (DCB), which was developed by Muszertech-

nika. This board is a card with an Intel 80188 processor and a small computer system interface output. The DCB handles Winchester disks with up to 2.2 Gbytes under Novell Inc.'s Advanced Network Operating System V2.X or IBM's PC DOS or Microsoft's DOS. Mr. Zoltan mentioned that Sony has developed a laser-scanning read/write 300 Mbyte disk drive. The DCB will work with this drive and Muszertechnika has an OEM contract with Sony for this.

**Professor Karoly Geher, Technical University of Budapest.** The Technical University of Budapest has seven faculties (or schools). Professor Geher is chair of the Institute of Communication Electronics, Faculty of Electrical Engineering. This is the only faculty in the university to give graduate degrees. This faculty was established in 1949 and contains 12 departments (institutes). The Institute of Communication Electronics has a teaching staff of 60 that covers seven specialties. Professor Geher's own interest is in computer-aided design (CAD).

Annual meetings are held between the Technical Universities of Budapest, Prague, and Warsaw to conduct workshops on electrical circuit theory. These are usually attended by 25-30 people and the location rotates. I visited four of the specialized groups:

- Television - observed a device for putting special characters in various languages in text presented on television. For example, the Hungarian language has 19 special characters. The Philips company will include this device in its sets
- CAD - observed a demonstration of a LAN used in design of circuits

- LAN - for intercompany communication
- Speech synthesis and recognition.

**Mr. Peter Hosszu and Mrs. Bea Bartos, Electroimpex.** Electroimpex is a trading house for importing and exporting many kinds of high-technology equipment. The company also handles tenders for the Hungarian government in acquiring equipment and preparing telecommunications tenders. A tender will be issued for card-operated pay phones. Tenders have thus far been issued for:

- Analogue and digital transmission equipment
- Optical transmission equipment
- Telex exchanges
- Telex and data equipment
- Telex terminals
- FAX terminals
- Lead batteries
- Coaxial telephone cable
- Generators
- Measuring instruments
- Integrated rural microwave equipment
- Cabling machinery.

Companies that have responded thus far include: Caterpillar (generators), Siemens, Alcatel, Sagem, and a Japanese company.

# The Institute of Communication Electronics, Technical University of Budapest, Samples of Research

by J.F. Blackburn

## Introduction

Following a visit to the Institute of Communication Electronics (Institute), Technical University of Budapest, on May 4, 1990, Professor Karoly Geher, Director, sent copies of some technical reports from members of the Institute. To convey some idea of the research taking place there, I am giving a brief summary of the papers in this report. I am also including references to enable interested persons to obtain more information.

**A Function Capability Model of Modular Systems, Laszlo T. Koczy, Technical University of Budapest.** This paper deals with certain aspects of forming convenient structures of multiprocessor real-time control systems. The work is restricted to a problem that differs considerably from the problems connected with the usual concepts of reliability. The formulation of reliability is determined by the special requirements for the stored program control of large switching exchanges with which the author is dealing. The public service nature of telecommunication service requires that international recommendations and standards, with strict specifications for all parameters important from the user's viewpoint, be fulfilled with a certain high probability, but less than one. System organizing and traffic dimensioning always provide functions operating according to these criteria, but security is never much higher for economic reasons. As switching exchanges perform their services at numerous distributed locations (subscribers, trunks), the probability of their functioning is understood in the sense that a certain minimal percentage must be operating; e.g., 95 percent of all circuits.

Contrary to the relatively moderate requirements concerning the minimal operating percentage at a given time, the allowed maximal time for catastrophic malfunction is very low. For example, it may be 1 hour within 20 years of continuous operation. In a data processing system, a small failure can bring about catastrophic consequences, while a total malfunction is an inconvenience, only causing some delay. For a switching exchange, a small failure is an inconvenience for the few subscribers involved, while a total malfunction leads to catastrophic consequences, even to a general panic.

The structure of a switching system, consisting of given components, should ensure the lowest possible probability of a total malfunction. It is assumed that the reliability of the components themselves is never perfect.

The paper describes a method for forming an optimal structure, if some reasonable constraints are accepted. Two examples were used to show how these systems can be covered by a directed tree graph corresponding to a hierarchical structure. Some results were shown concerning the optimal formation of these trees, from the point of view of maximum reliability (Koczy, 1987).

**Integrated Systems Digital Network (ISDN)-like Islands for the Hungarian Communications Network, Gabor Nemeth, Technical University of Budapest.** In Hungary, there is no digital telephone network. Therefore, the move toward ISDN requires a special strategy. The author takes the conceptual view of the end user in which access to a series of otherwise independent networks on a call-by-call basis is an effective first step. In certain areas, ISDN-like islands can be created.

The ISDN architecture defines interfaces, which permit the realization of distributed processing, in a way covered by recognized international standards. The ISDN has two basic roles:

- Provide a digital connection to make sophisticated voice and data services possible
- Provide the framework for distributed processing by out-of-band signaling.

Although Hungary has no digital voice network, they have a digital telex/data network, digital Private Base Exchanges (PBX), and exchanges for the lowest network layer, several Local Area Networks (LAN), and computer networks. Thus, a strategy consisting of two routes leading toward a future ISDN seems advisable. (1) Realize an Integrated Data Network based on the present digital telex/data network, providing only various data services. (2) Form ISDN-like islands on the lowest network layer providing voice services through connection to the public phone network, and data services through connection to the telex/data network in case of a connection outside of the island. For subscribers within the island, both basic voice and data services would be provided by the island itself.

If a standardized integrated access were provided for the subscriber, then the network itself might be realized by various subnetworks transparent to the subscriber. Thus, an ISDN island connects several independent networks on a common interface point. This concept makes possible the enhancement of the various networks and the

possible subnetworks of the subscribers independently, but maintains their compatibility.

The ISDN access is a digital interface divided into two types: (1) B channels carrying subscriber information, and (2) D channels carrying signal and control information. The signaling D channel controls the information-carrying channels providing advanced distributed processing through the interface point. The D channel also can carry packet data.

The key requirements to achieve ISDN compatibility from subscriber to subscriber are transparent 64 Kb/s transmission, integration of voice and data, and common channel signaling. With the given communications network in Hungary, the first and third requirements cannot be fulfilled at present outside the proposed ISDN islands. Thus, to achieve connection among these ISDN islands, they must cooperate through conventional in-band signaling, limited in speed and function. This paper provides, in some technical detail, a method for achieving these ISDN-like islands and the suggested interaction with existing services (Nemeth).

**Design and Implementation of a 2400-Baud, Half Duplex DQPSK Modem Using TMS 32010 Processor, S. Gajdos, T. Fulop, and E. Simonyi, Technical University of Budapest.** This paper describes how direct signal synthesis and improved synchronization capability are used to build a simple modem transmitter. In the receiver software timing, coherent demodulation and reduced computational complexity are introduced. An experimental data link is examined to prove the usefulness of the approach.

The computational capability of digital signal processing makes possible the application of procedures and algorithms that were not realizable in practice using other approaches. Under the recommendation of the International Consultative Committee for Telegraph and Telephone V26 bis, the 2400-bit/sec, half duplex synchronous modem uses a carrier frequency of 1800 Hz and DQPSK modulation technique. The aim of the work was to minimize the number of the external hardware components by effectively using the digital signal processing software capability and the self-timing programming technique (Gajdos, 1987).

**New Multiple Access Algorithms for Integrating Voice and Data on Local Area Networks, V. Garai, Cs. Szabo, and T. Szep, Technical University of Budapest.** This paper deals with voice and data integration on a standard carrier sense multiple access with collision detection bus on the ethernet system. Two classes of protocols: (1) based on transmitting voice packets in strings, and (2) based on transmitting voice packets in individual time slots (but with central timing and control) are considered

(the first one in a more detailed fashion). Two new protocol versions are proposed. Voice throughput calculations and the impact of silence detection on voice throughput are given, considering finite and different propagation delays. Simulation results were presented to explore the data throughput-delay performance of these protocols (Garai, 1988).

**Generation of Test Signals for the D2-Multiple Analog Component (MAC)/Packet Direct Broadcast Satellite Coding System, P. Ferenczy and I. Kovacs, Technical University of Budapest.** The D2-MAC/packet is the new coding system for the direct broadcasting satellites (DBS) in Europe. One question is that of new, efficient, and powerful test signals to be created to test the new equipment based on this new coding system. A whole series of well-established measuring and test signals are readily applicable for the D2-MAC/packet system. However, because of the essential time division approach of the system, certain equipment parameters must have the evaluation of dedicated test signals and measuring methods that can match the demand placed on hitherto irrelevant or nonexistent parameters. Research has been done at Technical University of Budapest on both theoretical and practical aspects of these problems; an overview is presented in this paper.

They designed relatively simple test signals to test the D2-MAC/packet decoders to be used for DBS reception in Europe. As a result, vital technical characteristics can be checked. They outlined the construction of a simple and a more advanced static signal generator design that can serve future manufacturers of MAC receivers and the service industry, as well (Ferenczy, Kovacs, 1988).

**Design of Medium Speed, Pulse Code, Modulation Receiver Circuits, M. Nemes et al., Technical University of Budapest.** Optical fibers at low and medium speeds show practically no dispersion. The receiver amplifier produces whole linear distortion. The receiver should be sensitive, simple, and easily reproducible. Its pole zero pattern and bandwidth can be optimized to yield maximum sensitivity. This paper dealt with the optimal choice of bandwidth, problems of choosing proper transistors for the high-gain bandwidth product amplifiers, and design of large bandwidth voltage amplifier stages.

Researchers built a receiver for 2 and 8 Mb/s, using a transimpedance amplifier with a feedback resistor of 30 K  $\Omega$ . The transimpedance amplifier consists of an input/output emitter follower and a cascade stage. Second stage amplification and limitation is done by a differential amplifier. Sensitivity of the circuit is better than -50 dBm. They built the whole circuit in a discrete form using BFY90 transistors (Nemes et al.).

**Timer and Flow Control with a Joint Model for Open System Interconnection (OSI) Protocols**, K. Abdulmagied et al., Technical University of Budapest. This paper presents a general timer model, which can be used for any OSI protocols. The paper concentrates on the aspects of the timer and dataflow control. The corresponding models of the timer facilities and their compact relation with the dataflow control were developed. The operation was described for a basic mode (modulo 8 mode). All data inside the window mechanism cannot be transmitted successfully if the timer indicates the time over message with maximum number of attempts for retransmission process.

The timer was described based on the definition of a general finite state machine  $T = \langle S, X, Y, d, r \rangle$  where:

- S is the set of internal states
- X is the input alphabet
- Y is the output alphabet
- d is the state transition function

$$d: S \times X \rightarrow S$$

- r the output function.

$$r: S \times X \rightarrow Y$$

In the case of n timers running in parallel, T is decomposable into the direct product of n elementary finite automata  $T_i \langle i=1 \dots n \rangle$ , so that each  $T_i$  can perform autonomously one timing process, where,  $T = \langle S_i, X_i, Y_i, d_i, r_i \rangle$  (Abdulmagied et al.).

**Line Equalizer for Digital Communication**, E. Halasz et al., Technical University of Budapest. This paper described the design concept for equalizer circuits used in low-speed digital transmission. The coefficients of the transfer function or the parameters of circuit elements are optimized in the frequency domain. In the regenerative repeaters of PCM systems (with 10, 30, and 120 channels), the equalizers are built with active or passive linear circuits containing L, C, R elements. Briefly de-

scribed are the mathematical model of a computer-aided iterative design of equalizers, an illustration of the equalizer circuits, and the features of certain computer programs developed for the design of  $\sqrt{f}$  line equalizers. Examples were given of all of the above.

The method applies to certain types of the line equalizer: (1) line equalizers given by voltage transfer function, or (2) active or passive linear circuits with R, L, C elements. Detailed examples showed the efficiency of the computer programs. About 200 real and testcase problems have been solved and successfully checked by time domain analysis and/or measure of eye diagram (Halasz et al., 1988).

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# Computer and Automation Institute

by Richard Franke, formerly the Liaison Scientist for Mathematics and Scientific Computing in Europe and the Middle East for the Office of Naval Research European Office. In September 1989, Dr. Franke returned to the Naval Postgraduate School, Monterey, California, where he is a Professor of Mathematics.

## Introduction

My visit to the Magyar Tudományos Akadémia (MTA) Számítástechnikai és Automatizálási Kutató Intézet (SZTAKI) in Budapest was organized by Dr. Tamás Várady, head of the Department of CAD/CAM in Mechanical Engineering. The SZTAKI consists of several scientific divisions and departments, including Applied Mathematics, Electronic, Process Control, Mechanical Engineering Automation, Computer Networks, and Computer Sciences Divisions, and some other smaller groups. About 500 people are employed at SZTAKI, two-thirds of whom work in scientific and technical areas. In addition to the research activities, MTA also grants advanced degrees. The SZTAKI receives about 85 percent of its financial support from contracts with industry and others, with MTA furnishing the remainder. Thus, the organization depends to a great extent on delivering marketable basic and applied research. Some contracts have been negotiated in the West and these bring in desired hard currency. A continuing problem for SZTAKI employees occurs because currency restrictions make travel to Western countries difficult. Purchases of Western books and equipment are also difficult, independent of the amount being spent; hopefully, liberalization will help to overcome this problem.

The SZTAKI is located on the Buda side of the not-too-blue Danube River, within a kilometer or two of the downtown area. While office space is not overly generous; it is perhaps no worse than that at many universities or other research facilities in the West. There appears to be a reasonable number of microcomputers (mostly AT-type machines) available for both the scientific and secretarial staff, although not every office I saw was equipped with one. The Computer Division (which I did not visit) supplies central computer services using IBM 3031 and 370/148 computers as well as mini- and microcomputers.

I was very impressed by the openness of the facility itself (for example, the door was open to the street, with no guard nor name badges evident). Happily, this open atmosphere carried over to the scientists I talked to. Almost everyone I met at SZTAKI spoke excellent English; many had visited or worked for extended periods in Western Europe or the U.S. Because my visit was during the summer, I was not able to meet as many people as would have been possible during a period when vacations are not so popular.

## Principal SZTAKI Activities

One of the principal activities of SZTAKI is in geometric modeling. This emphasis was initiated by Dr. Joe Hatvany, and was given an impetus because early visitors to SZTAKI included Steven A. Coons, from the U.S. (deceased; originator of a transfinite blending interpolant now known as a Coons patch), and Malcolm Sabin from the U.K. (well-known contemporary in computer-aided geometric design [CAGD] and related areas). More recently, close contacts have been established with Cambridge University and the Cranfield Institute (both in the U.K.) through Graham Jared and Mike Pratt. There have been a series of Anglo-Hungarian seminars on CAGD in 1982, 1983, and 1985 (see references for the Proceedings), with the next one planned for 1990.

Early work was to automate two-dimensional (2-D) engineering drawings in a program called GRECO. This work then evolved into design and representation of free-form shapes (the FFS system) used to design and manufacture free-form parts. This system was originally implemented on a PDP 11/40. Another system has been developed especially for shoe design and last manufacturing, carried out in cooperation with VICAM-ATOM in Vienna. The work on FFS has evolved in two further ways. First, to a solid modeler based on the BUILD modeler at Cranfield, called FFSOLID. Second, a new modeler for free-form surfaces with a general underlying patch topology. This system is called FFS-GT.

The FFSOLID system creates a fully evaluated boundary model of objects that can be bounded by planar, quadric, or free-form surfaces. The free-form surfaces are parametric double-quadratics (dq-s), defined and investigated by Várady in his dissertation (Várady, 1985). Simply, curves that are dq-s are two quadratics defined on left and right halves of an interval and joined with tangent continuity. The curve has the same number of free parameters as a cubic, with the curve more closely approximating the Bezier polygon than do cubic curves. The rectangular patch is the straightforward generalization of the curve. The system was discussed at a recent conference (see ESNIB 89-04:24) and the paper will appear in the Proceedings (see Várady, 1989).

The FFS-GT system is based on a general patch topology, resulting in different patch boundaries than are usually allowed. While four-sided patches are convenient, three- and five-sided patches often occur naturally at

places such as corners and aircraft wing-body joins, respectively. Since these kinds of patches are necessary, there seems to be little additional complexity in allowing an arbitrary topology, with  $n$ -sided patches, and T-nodes where one side of a patch joins two others, having a node along the interior of the boundary. Given a general parametric patch topology, a network of curves over the patch boundaries is defined using parametric cubic curves, with the surface then being completed using a  $C^1$  blending scheme. Smooth blending schemes for  $n$ -sided patches are nontrivial and have received much attention in the CAGD literature recently; the method used in FFS-GT will be discussed later. One option available for monitoring the quality of the curve network is an interrogation of curvatures resulting in a display of line segments directed toward the center of curvature having magnitude proportional to curvature. Similarly, one may display tangent vectors, torsion vectors, and the Bezier polygon. Naturally, as the system deals with space curves, it may be necessary to change the viewpoint to obtain an accurate assessment of the geometric behavior of a given curve.

The surface may be defined by the designer, or data may be input from an existing surface. In the former case, the system is still in a primitive developmental state. In the latter case, the results of measurements taken from a front fender of a Polski Fiat (a Fiat 650 made under license in Poland) was demonstrated to me. The network of curves was drawn on the actual fender by someone familiar with design, in a way that was felt to capture the important aspects of the surface, but without regard to the connection topology of the patches. As a result, there were the usual four-sided patches as well as three- and five-sided patches, but including one nine-sided patch (this patch may have been treated as a patch with fewer sides, but with T-nodes, although there seems to be little advantage in doing that). Of course, the network also included a number of T-nodes. The digitized data for the patch boundary curves are fit using least square methods. Incompatibilities between tangent vectors at a vertex are resolved by fitting the best tangential plane at the vertex and then projecting tangent vectors into it; the system gives the user a warning message.

The surface is completed using the Gregory (1974) patch. The subdivision of nonfour-sided patches into four-sided patches is described in Hermann and Renner. The boundaries of the subdivision are parametric cubic curves, and the choice of curves has a significant influence on the surface, so appropriate choices are important. Special considerations are necessary in order to assure  $G^1$  continuity. Additional complications occur in the case of T-nodes on the boundary. The T-nodes are handled by subdividing the adjacent area into two four-sided patches, using an extension of the T-node curve to ensure satisfaction of compatibility conditions. The process involves some parameters, and choices for these are

described in the referenced paper. The surface for the Polski Fiat fender was demonstrated as a ray-traced image, which appeared to be quite satisfactory.

Several additional papers related to the CAGD effort at SZTAKI are included in the references. I also saw a demonstration of NC milling software used by Hungarian industry such as the IKARUS Coach Factory, and the results of a previous effort on design and numerically controlled grinding of cut glass (for the VEB Numerik Factory in the FRG).

I spoke with Dr. Dmitry Chetverikov, the head of a research group in image analysis. The group was formed about 1974 and now includes about 4 or 5 persons. Some of their work has been in the development of 2-D recognition schemes using techniques based on the extraction of contours and geometric invariants such as area, perimeter, and moments. The objects were then classified by matching with a catalog of possible objects. Recent work by Chetverikov has been in textures, including texture regularity, imperfections, and rotation-invariant features. Some references are given below.

Present work involves tracking and recording the movement of small, somewhat cylindrical objects from a series of pictures. The problem is complicated by several features, including that there may be many objects, their speeds and directions can vary greatly, and they may "pop" into or out of the next picture in the series. The approach used is to pair the objects (insofar as possible) in successive pictures by using the series of pictures to estimate the speed and direction of the objects in a given picture and comparing this prediction with the next picture. While the problem has several applications, this investigation is the result of a project investigating a means of monitoring (and hence determining the quality of) the sperm population of bull semen used for artificial insemination.

## Final Comments

The work I discussed with personnel at SZTAKI is interesting and seems to be of good quality. The working atmosphere seems pleasant and is definitely in the spirit of open scientific investigation. The geometric modeling work is handicapped by the lack of state-of-the-art hardware and adequate financial support to allow programming of the necessary handles to be used in interactive design work. The SZTAKI is attempting to interest Western companies in FFS-GT (and in helping to fund completing it). While some earlier programs were not very portable, FFS-GT is written in C and runs on a MicroVax computer. The system has some useful features not available on any other system that I know about (there are many I am not familiar with, however), and appears to have some potentially interesting capabilities. Funding from Western companies would be useful be-

yond just allowing completion of the project, since it would be in the form of needed hard currency as well.

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# Czechoslovakia

## An Assessment in Computing, Telecommunications, and Microelectronics

by J.F. Blackburn

### Introduction

This assessment of the Czechoslovakia technology and market potential in computing, telecommunications, and microelectronics is based on my visit to Prague and Bratislava, April 23-28, 1990, and literature made available to me.

Czechoslovakia has had a centrally planned economy since World War II, with industry producing about 70 percent of the national income. Engineering is the most important industry; this includes electrical engineering, metallurgy, chemicals, and rubber. Consumer goods production includes textiles, leather, glass, porcelain, and ceramics. Czechoslovakia's economy and society is in a state of change because of the *velvet revolution* in late 1989. New laws affecting commerce, company structures, joint ventures, and company ownership have been and are being put into effect. I will discuss this further in a later section of this report.

Czechoslovakia has 15.5 million inhabitants of whom about 64 percent are Czechs, 30 percent are Slovaks, 4 percent are Hungarians, 0.7 percent are Poles and Ukrainians. Also, some 60,000 Germans remained in Czechoslovakia after World War II. The two largest cities are Prague with 1.2 million inhabitants and Bratislava with 380,000.

### The Telecommunications Industry

The telecommunications infrastructure in Czechoslovakia is largely analogue and is inadequate. There are at least 30,000 people on a 10-year waiting list for phones. The Ministry of Communications (Ministry) projects that residential, public, and mobile telephone density will increase rapidly in the next 5 years.

At present, there are about 22,000 people employed in the telecommunications industry and fewer people in the mobile phone industry. The production capacity of the plants in Czechoslovakia is for 450,000 lines per year; half is exported to the Soviet Union. The main telecommuni-

cations manufacturer, Tesla, makes analogue exchanges and other equipment; one digital exchange is installed as an experiment. About 4.5 billion Czech Koruna (\$160 million) worth of telecommunications products per year is produced in Czechoslovakia. Production of satellite dishes is starting by several small firms.

A January 1990 report by the Telecommunications Research Centre (TRC), Barnham, West Sussex, U.K., estimates that the value of the telecommunications market in Czechoslovakia would reach \$370 million by 1990, \$790 million by 2000, and \$930 million 2005.

By the end of 1990, more than 200 nodal telephone areas are expected to be automated, giving 85 percent automatic coverage.

New laws to facilitate joint ventures and foreign borrowing will help Czechoslovakia to attain the objectives suggested in the TRC report. At the same time, the Coordinating Committee for Multilateral Export Control (COCOM) restraints are being relaxed about the sale of modern telecommunications equipment to Czechoslovakia.

### Computers

In my discussions with government, university, and industry people, estimates varied about the number of computers installed in Czechoslovakia. No one seems to know exactly how many of any particular category are installed, particularly personal computers (PC). Probably the best estimate was from the group including Messrs. Simko, Hybs, and Mikulas, from several government ministries (see Table 1).

Apparently, about 10 Czech computer companies supply an estimated 80 percent of the PCs sold in Czechoslovakia. Some of these companies buy PCs made in other Eastern Bloc countries; e.g., Poland, the German Democratic Republic, and Bulgaria. Other companies buy motherboards with Intel chips from Far Eastern suppliers in Taiwan, Singapore, and Korea either directly or through trading companies from other Eastern Bloc

countries (for example, the Taiwan subsidiary of Hungary's Muszertechnika) and assemble the PCs in Czechoslovakia. Of course, some PCs were sold in Czechoslovakia by western suppliers. For example, Mr. Zaruba, Olivetti, says that Olivetti sold about 1,000 PCs. Other western suppliers selling small numbers of PCs include International Computers Limited (ICL) and IBM. Commodore has sold many home-use PCs (perhaps tens of thousands).

**Table 1. Computers in Czechoslovakia**

- About 1,000 mainframe computers installed
- About 400,000 PCs, including small home computers (based on other conversations, I believe there are no more than 250,000 professional PCs)
- About 80,000 PCs were imported privately in 1989
- About 100,000 PCs (estimated annual demand)
- About 2-300,000 demand within 5 years.

Practically all of the professional PCs are International Business Machines (IBM)-compatible; e.g., compatible with the IBM PC/XT or PC/AT. Although a government group told me that most of the PCs made in Czechoslovakia use older Intel chips like the 8088 and 8086, manufacturers say that most of them are getting the later versions--80286, 80386, and 80486. Most of the Czechoslovakia-made minicomputers are compatible with Digital Equipment Corporation (DEC) machines; e.g., DEC PDPs or Virtual Address Exchanges (VAX).

I spoke to Mr. Ivan Bures, Director of Marketing, Kancelarke Stroje, Prague, a company with a turnover of \$178 million. This company's maintenance and service business accounts for well over half the turnover because Kancelarke Stroje maintains not only its own installed base, but also that of several other manufacturers. The company has about 2,000 installed systems.

I also spoke to Mr. Jan Borsuk, Technical Director, Software Division, JZD AK Slusovice, Slusovice, a company that is highly diversified, but mainly in agricultural products. This company has 12 divisions; the largest deals in computers and software. The company employs 5,500 people (called members), owns 5,500 hectares of land, and has an annual turnover of 5.5 billion Koruna (\$196 million). The company makes PCs from components imported from the Far East and has access to Intel 80286, 80386, and 80486 chips.

In addition, I spoke to Messrs. Josef Hlobil and Jaroslav Stros, Kovo Foreign Trade Corporation. This company has a turnover of \$600 million; it sells 80 percent to Eastern Europe, mainly the Soviet Union. The company trades in telecommunications equipment, computers, software, and photographic equipment.

Western suppliers are also selling mainframe and minicomputers. Of the estimated 1,000 such computers installed, about one-third have likely come from Siemens, ICL, Hewlett-Packard, DEC, and IBM. Mr. Kust, Hewlett-Packard, said most of the Hewlett-Packard computer sales were for libraries, hospitals, and factories for maintenance. His company had a turnover of \$12 million in 1989; however, a large share of this was for measuring equipment. About one-third of IBM's sales in value have been PCs and two-thirds have been mainframes and minicomputers.

### Brief Summary of Individual Discussions

I will include here a brief summary of my conversations with the various people with whom I dealt in Prague and Bratislava. You may note occasional inconsistencies between reports of various conversations, but they mainly agree. Almost without exception, the concern with business was with, in the recent past, Czech government restraints on buying from the West, COCOM restraints on selling to the East, and the difficulties in getting *hard* currency.

**Professor Milan Kubat, Czechoslovak Technical University, Prague.** Professor Kubat discussed equipment and technologies in the microelectronics department and in the electrical engineering faculty of the Prague Technical University. They work with two ion implantation systems from Balzers. In 1989, they implanted more than 40,000 wafers for industry and research, using silicon and gallium arsenide wafers. They used other materials, including metals and biomaterials, and implanted about 27 kinds of elements (ions). The university cooperates with the Uppsala University, Sweden; Surrey University, U.K.; and the University of Lisbon, Portugal.

The department has several up-to-date pieces of equipment for semiconductor diagnostics, especially specific resistance and lifetime measurement: deep-level transient spectroscopy, doping concentration measurements, scanning microscopy with Scanning Electron Microbe, SiO measurements, optical diagnostics of semiconductor structures, and others. Simulation and modeling of microelectronic structures and technologies is also available. About 200 PCs (PC-XT and AT) are operating.

In addition to his university work, Professor Kubat works with Tesla and Czech Kolben Danek, which manufactures power components, such as thyristors, diodes, and insulated gate bipolar transistors. Tesla has about 20 factories and manufactures computers, telecommunications products, and microelectronics products. Tesla-Bratislava recently formed a joint venture with Philips Netherlands, to produce Video Cassette Recorders in Bratislava and Venice. This venture employs about 500 people. Furthermore, Tesla employs about 95,000

people; about 24,000 of them work in telecommunications, computers, measuring equipment, and components.

**Ing. Ladislav Kubicek, Director, Foreign Relations Department, Ministry of Industry.** On April 19, several new laws were passed about trade and investment (see Table 2). Kubicek will send English language versions of these as soon as they become available.

**Table 2. New Czechoslovakian Trade and Investment Laws**

- Law 1 - Encourages joint ventures, defines and states the rights of a state enterprise, and provides a law on foreign trade.
- Law 2 - Defines the process of proceeding from central planning to a private enterprise economy.
- Law 3 - Gives the definition and functions of a limited company; the kinds of companies are:
  - (1) Private - wholly, privately owned
  - (2) Limited - more than 50 percent privately owned, but with some government ownership
  - (3) State - government owned.

Mr. Kubicek said there are two divergent views in the government on economics. The Finance Minister, Mr. Vaclav Klaus, believes in keeping the debt down and lowering development investment. Others favor a more aggressive approach--borrowing to finance investment in developing and manufacturing. Mr. Kubicek estimated the turnover of Tesla at about 40 billion Czech Koruna (about \$1.4 billion).

A recent agreement was negotiated with Pittsburgh University to establish a management school in Czechoslovakia, to begin January 1991. Students would spend a year in the management school in Czechoslovakia, followed by several months in Pittsburgh, and then receive an MBA. In preparation, a special English language training program will begin in autumn 1990.

In the Eastern Bloc there is an agreed-upon standard for PCs and mainframes to insure compatibility. The PCs are mainly IBM-compatible and mainframes are mainly DEC- and IBM-compatible. There are some ICL and Siemens mainframe computers installed, mainly older models. Winchester disks will soon be manufactured in Czechoslovakia.

In a meeting with: Dipl. Ing. Timotej Simko, Director, Department Federal Ministry of Metallurgy, Engineering, and Electrotechnical Industry; Ing. Josef Hybs, Director, Department Computers and Control; and Ing. Jan Mikulas, Federal Ministry of Metallurgy, Engineering, and Electrotechnical Industry, they provided me with the computer company names and their equipment (see Table 3).

**Table 3. Czechoslovakian Computer Companies**

Name	Equipment
ZPA Cakovice	Mainframes
Arima Prague	Peripheral equipment
ZPA Jinonice	Peripheral equipment
ZPA Novy Bor	PCs and peripheral equipment
Zbrojavka Brnv	PCs and peripheral equipment
ZVT Banska Bysbrica	PCs and DEC VAX-compatible computers
ZVT Nameskovo	DEC-compatible computers
Tesla Bratislava	PCs
Kancelarske Stroje Prague	Software and trading
Datasystem Bratislave	Software

**Dr. Ludomir Kovacic, M. Chem., M. Eng., Ph.D., Deputy Director, Division of International Relations, and Ing. Stanislav Smetana, State Commission for Science, Technology and Investments.** Dr. Kovacic said that Czechoslovakia's top priority is to build an information system infrastructure as a foundation for a modern industrial economy which will be supported by a modern telecommunications system. Czechoslovakia is now in discussion with Siemens, Bell Atlantic, and others, and they seek proposals from American firms. Other high priorities are a Central Bank for Development in Prague; the conversion of the military establishment; the conversion of the power stations that are now more than 50 percent coal burning, along with hydropower from the Danube River. Also, nuclear power is a future goal.

**Ing. Bohumil Zaruba and Ing. Lenka Cerna, Olivetti, Prague.** Olivetti has sold about 1,000 PCs in Czechoslovakia. The main competition is from Far Eastern suppliers in Taiwan and Korea in the form of completed PCs or components for assembly in Czechoslovakia. Olivetti has tried to sell facsimile (FAX) machines without success; most FAX machines used in Czechoslovakia are Canon and Minolta.

Olivetti's teleprinter, TE 550E, is selling moderately well, and Olivetti's typewriter sales have been fair. Zaruba thinks ICL is doing quite well with minicomputers and PCs. Olivetti's poor showing in the market is because of the red tape in getting import/export approval. More than 6 months is required to pass through the Czech government rules, Italy's rules, and COCOM's rules. He says that DEC quit trying in Czechoslovakia because of these complications.

**Zdenek Roubicek, Siemens, Prague.** Some of Siemens most successful products have been numerical control systems, medical systems, process automation, and production control. The major marketing obstacles in Czechoslovakia are Czech law, secretiveness, and COCOM. The law is now loosening. But there is still a

lack of information because of equipment shortage and qualified personnel. One of the greatest needs in Czechoslovakia is a modern telecommunications network to replace the present analogue system. Some private companies are beginning to get digital private networks with components from Western countries. A public digital network is now being discussed. According to Roubicek, the bidders include (he thinks the Moran Group has the best chance):

- Moran Group (operator) including Siemens and Bell Atlantic
- Siemens (independently)
- British Telecom, U.K.
- Ericsson, Sweden
- Alcatel, France
- Nokia, Finland.

**Mr. Vaclav Kust, Hewlett-Packard, Prague.** Originally, the company's business in Prague was mainly computers. The market was good in 1980-1982, but dropped in 1983-1984 because of COCOM restrictions. Turnover in 1984-1985 was \$2 million and rose to \$12 million in 1989. As recently as 1988, there were restrictions from the Czechoslovakia government that gave precedence to products made in Czechoslovakia; e.g., the copy of DEC machines. By 1989, \$2-300,000 machines began to sell well for Hewlett-Packard for libraries, hospitals, and factory maintenance.

Hewlett-Packard has two separate lines of equipment in Czechoslovakia--computers and measurement equipment. The company also sells electronic instruments for environment and produce checking. Under present COCOM regulations, approval can be obtained for only one set of test and measurement equipment; COCOM will approve only computers that are now considered obsolete in the West.

Hewlett-Packard will probably provide the measurement and maintenance system for new telecommunications network to be implemented over the next decade. Siemens, Ericsson, and Alcatel partially supply the present analogue network. The present COCOM regulations allow measurement equipment for line speeds of 1GHz or 1.8GHz.

**Professor Ramon Blasko, Institute of Technical Cybernetics, Slovak Academy of Sciences, Bratislava.** Professor Blasko and his colleagues are using a four-processor Inmos T800 transputer system in their work on a highly parallel computation model for logic programming. They consider the logic programming language Prolog a very promising base for developing the kernel language for new generation computer systems devoted to knowledge processing and for applications of artificial intelligence. Parallel processing is the inevitable way of achieving the required high performance.

Blasko's group has developed a computational model based on the data flow principles for Parallel Prolog, exploiting all sources of parallelism in logic programs. The computation process is decomposed into several operators representing independent processes to be processed in parallel and asynchronously. They have designed a parallel inference machine specialized for the logic programming language Parallel Prolog. They used a data flow computation model for computer organization. The scalable architecture is modular and can be adapted to required performance. A microprocessor transputer is used as the basic building element of the system.

**Professor Ivan Kocsis, Deputy Director, Institute of Cybernetics, Bratislava.** Professor Kocsis mentioned work on robots for seam tracking, and parts selection and assembly using visual and tactile sensing. Work is also underway on adapting the transputer to include changes in on-chip logic and connectors to speed up its operation. A variety of chips have been designed here and produced at the Tesla foundry in Bratislava. Professor Kocsis is interested in contacting various organizations in Western Europe and the U.S.

**Ing. Jan Borsuk, Technical Director, Software Division, JZD AK Slusovice, Slusovice.** The company entered the computer business because it needed computers and it was difficult to get timely delivery. As a result, the software division makes PCs out of imported Intel 286, 386, and 486 components that are IBM PC/AT- and XT-compatible. The division also develops applications software. Both their PCs and software are used in the company and sold in Czechoslovakia.

**Dipl.-Ing. Jan Vesely, Marketing Support Manager, IBM, Prague.** The IBM's percentage of the market in Czechoslovakia is considerably less than in western European countries because of COCOM rules and the Czechoslovakia government's policy. Another factor is unavailability of *hard* currency in Czechoslovakia.

The main competition includes locally assembled computers and peripheral equipment by ZPA and the Bulgarian company ZAVT (translates Enterprise Automation Data Processing). The differences in these computers and western-manufactured computers is in reliability, maintenance, and support. The IBM equipment is maintained on contract by the foreign trade corporation Kovo. In the past, an equipment purchase from any western company had to be justified to the State Commission for Industry, Development, and Trade.

The IBM-supplied market, within COCOM rules, includes about two-thirds of the mid-range computers--System 36 and AS400-one-third, System 4300-one-third, and PCs-one-third. Under revised COCOM rules and new Czechoslovakia government laws, IBM anticipates a 30-percent annual growth in Czechoslovakia.

**Mr. Ivan Bures, Director of Marketing, Kancelarake Stroje, Prague.** Kancelarake Stroje is the largest hardware and software company in Czechoslovakia with an annual turnover of 5 billion Koruna (\$178 million). The company has 5,500 employees in three operating divisions with 75 percent business in Czechoslovakia and 25 percent in Bohemia and Slovakia. One division deals in the sale and maintenance of office equipment, copiers, and IBM-compatible PCs. The second division deals with minicomputers and mainframes, with about 2,000 installed systems. The third division (about 400 professional programmers) deals with software development and maintenance. In addition to maintaining the equipment that they sell, Kancelarake Stroje maintains equipment sold by Eastern and Western companies. In fact, its maintenance and service business is larger than its sales business. One of the biggest problems in selling in Czechoslovakia is lack of foreign funds. Mr. Bures suggested

that a seminar for Western investors would be useful and he would be glad to participate in such a seminar.

**Mr. Josef Hlobil and Mr. Jaroslav Stros, Kovo Foreign Trade Corporation.** Kovo's main products are TV transmitters, radio transmitters, telephones, telephone exchanges, minicomputers (DEC-VAX-compatible), PCs (IBM-compatible), software and photographic equipment. Kovo also maintains equipment sold by other companies. Kovo supplies 15 TV studios per year. Mr. Hlobil said that the main need for now is capital from Europe, U.S., and Canada.

An important problem to be worked out is the convertibility of the Koruna and a build-up of the electronics industry, including the upgrade of the telecommunications system. Also, the country needs better information on American technology and products. Mr. Hlobil suggested a seminar on this subject in the U.S. or in Czechoslovakia.

## C.S.F.R. Science in the 1990s

by Marco S. Di Capua

### Introduction

In late June 1990, I visited the headquarters of the State Commission for Science Technology and Investments (SK VTRI) of the Czech and Slovak Federal Republic (C.S.F.R.) in Prague. This organization, which holds supraministerial rank, funds all scientific research within the C.S.F.R. Academician Armin Delong, the new chairman, with rank of deputy prime minister, appointed since the election of Vaclav Havel to the presidency of the C.S.F.R., and Dr. Scarlett Vasilukova-Reslova, the deputy chair, discussed with me their hopes for the future of C.S.F.R. science and technology.

Academician Delong is a low-current electron beam physicist and electron microscopist who is reluctantly on leave as Director of the Institute of Scientific Instruments of the C.S.F.R. Academy of Sciences (Academy) in Brno (see this issue, page 124, Scanning Electron Microscopy Developments at the Institute of Scientific Instruments and TESLA in Brno).

Dr. Vasilukova-Reslova is a molecular biologist who has worked on oncology, immunology, and aging at the Institute of Cancer Research. She was a visiting professor at Michigan State University, East Lansing, until her return to Prague in March 1990.

Our conversation in Academician Delong's office began with a dialogue on proposal review and funding methods at Office of Naval Research (ONR). We also discussed ONR's methods used to choose new research initiatives and to support medium-term scientific research. The basis for their interest in ONR's approach to research funding is that the SK VTRI leadership is now restructuring the funding system for C.S.F.R. science (M.J., 1990b). Their idea is to develop a grant-based system with a similar structure to those that operate in the U.S. and Europe. Dr. Vasilukova-Reslova has posed similar questions to National Science Foundation (NSF) officials. She visited them in Washington, D.C., and has received a NSF delegation in Prague as well.

### Restructuring of Science Funding in the C.S.F.R.

The previous government funded university research in blocks, making small distinctions on who received the money. Since faculty promotions under the old regime rewarded, in many instances, political leanings rather than academic abilities (see this issue, page 129, Renewal of Czech and Slovak Universities), some of the research funds reached mediocre people. Moreover, with faculty

members choosing their own research, the means to concentrate resources at universities in areas of excellence were quite limited. Besides, entire areas of science could be eliminated if the political attitudes of the scientists were at odds with the leadership (Whitehead, 1990).

This system had some advantages, however. Stable funding maintained some areas of excellence, providing a nominal support of scientific activity. Besides, the administration of the system did not require a large bureaucracy.

In the C.S.F.R., the challenges in research funding for the future are to:

- Find the funds to support research
- Establish optimal methods (blocks or grants), priorities, and structures for administration
- Provide resources to modernize laboratory equipment and update libraries
- Provide funds for travel and international cooperation.

To fight inflation, the Finance Minister, Vaclav Klaus, pushed a tight budget through, limiting the funds to support research. There are also uncertainties about the economic contraction that may accompany the transition to a market economy.

The SK VTRI is formulating its budgets and policies now. The budgets for 1991 will probably be ready by September 1990. In the long term, Dr. Reslova expects that successive approximations should lead, within 3 to 5 years, to scientific research funding corresponding to 3 percent of the gross national product (GNP). This fraction, while smaller than Japan, is comparable to that of other developed economies.

From a policy standpoint, SK VTRI hopes to create a science funding system that provides an optimal blend of block funding and grants. To avoid major shocks to a functioning, yet fragile system, block funding will probably continue for some time. As procedures for grant funding are phased in, block funding will be probably partially phased out. Dr. Reslova expects the transition to take 2 or 3 years.

Dr. Reslova told me that a big challenge facing the SK VTRI leadership is to engage a cadre of qualified and impartial scientific officers to contribute to the formulation of public policy on science and technology and to choose proposals for funding within the framework of this policy. At the same time, the SK VTRI leadership would like to bypass the formation of a new bureaucracy that could be a burden for the future.

The choice of new areas of research will be difficult with limited resources. Likely, the C.S.F.R. will concentrate support in areas where nuclei of excellence already exist and carefully branch out in new areas as results and applications warrant it. It was refreshing to hear there is

much thought and discussion of basic science at the service of humanity, a thread that ran through most of the discussions I had with my scientific colleagues.

Another important challenge is to adapt the evolution of the funding system to faculty realignments in academic institutions. Promotions of able faculty members and demotions of less able political appointees is certain to occur as faculties realign on the basis of academic ability.

However, as President Havel has pointed out in a speech delivered in a visit to Salzburg, Austria, the C.S.F.R. wants to maintain the human dimensions of the velvet revolution and forgive those who made mistakes in the past, including the embattled K. Waldheim, President of Austria (nn, 1990a). Moreover, scientists as well as science managers realize that major upheavals could be hazardous to the fragile economic and political recovery processes. Therefore, widespread purges are unlikely and faculty realignments in the sciences will hopefully be gradual.

Dr. Reslova foresees the requirement to maintain and replace some of the laboratory equipment that C.S.F.R. scientists will need to perform research at levels comparable to those of Western Europe. My limited observations indicate that while the quantity and quality of equipment may be less than what is available at a Max Planck Institute in the Federal Republic of Germany (FRG) or at a mainline CNR Italian laboratory, equipment and physical plant compare well to that which is available at universities in Europe. The short-term challenge is to budget maintenance resources so expensive European, American, and Japanese (EAJ) equipment will not deteriorate. In the long term, obsolescent Soviet equipment must be replaced.

A bigger challenge is perhaps to update university libraries (nn, 1990; M.J., 1990a; see this issue, page 129, *Renewal of Czech and Slovak Universities*) that suffer the similar problems as libraries elsewhere--astronomical cost of subscription costs to scientific journals and high costs of specialized technical books. Scarcity of hard currency exacerbates this problem. One immediate necessity is to restart subscriptions to EAJ journals and complete gaps in library collections. Another is to replenish the shelves with modern technical books from EAJ publishers. This will be an expensive transition because Soviet books by Soviet authors and Soviet translations of EAJ books are inexpensive and the C.S.F.R. paid for them in soft currency. Therefore, purchases of publications from EAJ will absorb scarce hard-currency resources.

To gather some perspective on the difficult choices ahead, the present monthly salary of an associate professor is 4,000 Koruna. At the official rate of exchange (25 Koruna = 1 \$ U.S.), a monthly salary is comparable to the price of 3 or 4 specialized textbooks. Spare parts for

a modern infrared spectrophotometer could easily mount up to 4 months' salary.

## The Academy

The Academy employs about 15,000 people and there is uncertainty about what shape the Academy will take. One proposal, discussed by Whitehead (1990), is to replace it with a new institution similar to the U.S. National Academy of Sciences. To achieve this, institutes would be split off and attached to university departments. The Academy would then be a shell providing grants for research.

There is some understandable disagreement with this approach since if institutes had to be self supporting, the quality of basic science could suffer. Otto Wichtere, the head of the Institute of Macromolecular Chemistry and Physics until the Soviet invasion, was quoted by Whitehead (1990), saying that: "...the Academy institutes perform interdisciplinary research that would be difficult to organize in university departments that divide along discipline lines and teaching responsibilities."

My impression, from the two Academy institutes I visited, is that Academy research institutes fulfill the same functions as the Max Planck Laboratories in the FRG or the CNR laboratories in Italy. So it is likely that institutes that perform valuable research will remain intact. Through some necessary pruning, weaker institutes will either be disbanded or absorbed into stronger units within the Academy or the university system. This pruning will strengthen centers of excellence in the process.

The Academicians I spoke to cited widespread agreement that the Academy elections must be depoliticized. Academy workers would like to see a democratic rapport between the president of the Academy and its members. M.J. (1990c) chronicles the evolution of democratic processes in some detail.

## Some Observations on the C.S.F.R. Economy

As hinted above, there is some speculation on how large the GNP is likely to be in the next 3 to 5 years. Scientists I spoke to expect the GNP to drop. One reason is that inefficient enterprises may not survive privatization, with unemployment as a result. There are other reasons, independent of privatization, connected with armaments production, steel production, and energy consumption and production.

**Armaments.** In the past, armaments accounted for a non-negligible fraction of the C.S.F.R. industrial output. Under the Havel presidency, arms production will probably diminish as the C.S.F.R. attempts to implement the human side of its revolution, converting military industry to civilian production.

**Steel Production and Coal Consumption.** According to scientists I spoke to, previous governments placed enormous emphasis on steel production (16 million tons per year) for export and as a raw material in the production of heavy machinery. This production wastes fuel in a truly grand scale (Barber, 1990). Therefore, the northern part of the C.S.F.R. bore the brunt of the deferred, but very real, environmental costs of steel making. (According to one scientist, the C.S.F.R. burns  $1.0E + 8$  tons of 2 percent sulfur coal per year, delivering  $5.0E + 6$  tons of sulfuric acid to the atmosphere in the process.) The C.S.F.R. will probably have difficulty marshaling the resources to clean up the production processes and concurrently restore the environment. The alternative will be to reduce steel output which may imply unacceptable costs in terms of economic contraction and lost exports.

**Natural Gas and Liquid Fuels.** When I visited the C.S.F.R. in late June 1990, scientists were quite worried about energy supplies since the C.S.F.R. depends solely on the Soviet Union for supplies of natural gas, and liquid fuels for transportation (97 per cent). A big unknown at the time was what prices the U.S.S.R. would negotiate for these fuels, how reliable the supply would continue to be, and whether payments would be required in Krona or hard currency. Scientists felt that an equilibration of energy costs with those in world markets, and the balancing of environmental costs would have a large impact in the economic recovery process.

The suspense ended a month later. The U.S.S.R. has cut deliveries of liquid fuels by a third (Hockaday, 1990) arguing that lower output from the Siberian oil fields, arising from decreasing reserves (Barber, 1990), labor unrest, and outdated equipment (Torday, 1990) was threatening the Soviet 1990 bumper harvest. These cuts forced the C.S.F.R. to raise fuel prices by 50 percent (Hockaday, 1990).

**The Infrastructure.** While I am not an economist, I could observe that the infrastructure of housing, roads, railroads, educational buildings, and government buildings appears to be in reasonable shape. The crops in the countryside have a similar appearance to that of the FRG and perhaps even France. Consequently, since the ability of a country to feed and clothe itself is a fundamental ingredient of development, it is likely that the transition to a market economy may not be as difficult (the soft landing approach) as people may fear.

**Trade and Exports.** Historically, the C.S.F.R. has had a strong industry geared to export markets. Consequently, it is very likely that it will follow in the footsteps of the Italian model, expanding their exports of "standard products" such as compact vehicles (Thomson, 1990), machine tools, and heavy machinery. They may then branch out into appliance production and perhaps exports of fresh and processed food as well.

In the short term, the C.S.F.R. realizes that it needs to participate in larger (non-U.S.S.R.) markets at first to sustain growth. The C.S.F.R. has taken a step in this direction already. One is to join the Alps-Adriatic five (C.S.F.R., Hungary, Austria, Italy, and mainly northern Yugoslavia). This "Pentagonale" initiative, the brainchild of Italian Foreign Minister Gianni di Michelis, aims to counterbalance the political and economic power of the FRG (Richards, 1990; Hilton, 1990). This initiative has the Austro-Hungarian empire, to which portions of the five countries belonged to, as a historical precedent. As a curious twist of history, the regional center of power shifted south from Vienna to Venice, which hosted the first "Pentagonale" summit on August 1 and 2 1990.

In the long term, however, the C.S.F.R. future will probably also lie *within the EC, in close partnership with the new FRG* (Greenhouse, 1990) with which it shares a troubled history and an extensive border. There has been a strong German tradition within the C.S.F.R. and German as a spoken second language is quite common. The relationship with the FRG, however, will take some time to develop since the FRG will be preoccupied for some time with the economic consequences of unification.

The economic relationship between the C.S.F.R. and the U.S.S.R. was uncertain when I visited in June. In the past, a large fraction of its industrial production has been absorbed by the U.S.S.R. A frightening clarification arose from a decree, issued in Moscow on 24 July 1990 (Womack, 1990). This decree requires hard currency in economic transactions between the U.S.S.R. and Central Europe (COMECON countries). Consequently, these fragile economies will have to become competitive with Asian economies which can also supply, for HC, the products the U.S.S.R. wants. This development, in addition to payment for energy supplies in hard currency, may accelerate the switch of this fledgling democracies to a market economy.

In addition, the C.S.F.R. political system is still in transition (there are three governments with overlapping authority: the federal, the Czech [led by the Civil Forum movement] and the Slovakian government led by Public Against Violence). On the U.S.S.R. side, the leadership has, at present, more urgent priorities than to shape relationships with the C.S.F.R.

### **The U.S. Role in the Evolution of C.S.F.R. Science**

The scientists and science administrators in the C.S.F.R. I spoke to are very realistic about the limitations of what the U.S. can do for C.S.F.R. science during this transitional period. They are aware of the Support for Eastern European Democracies (SEED) Act budgetary constraints (Palca, 1990) and addition of the C.S.F.R. to

SEED in the super-SEED act that the U.S. Congress will probably pass in 1990.

Therefore, with a mixture of realism and pride, C.S.F.R. science researchers and administrators are aware that recovery will depend in great measure upon their own efforts. However, they also point out that C.S.F.R. science is now fragile and it will need some care and attention to thrive again. The care and attention they would appreciate the most is:

- Contacts with EAJ scientists
- Placing graduate students and post-doctoral students abroad (M.J., 1990b)
- Attracting researchers to hold workshops to update C.S.F.R. researchers
- Contributing to joint research projects where C.S.F.R. scientists can provide well-identified research packages
- Participating in design of experiments where scientists will also reduce and interpret experimental results

A source of strength that the C.S.F.R. hopes to tap is emigre scholars who may aid C.S.F.R. science by returning permanently or on sabbatical leaves. A great advantage of this resource is that they speak the language and have a common culture.

In parallel, according to Prof. Jahn John, the vice-president of the Czech Technical University, C.S.F.R. universities are eager to attract faculty members on sabbatical leave from EAJ. John cited the case of a U.S. faculty member on sabbatical who taught an electronics course in English that attracted a surprisingly large enrollment.

Finally, C.S.F.R. academics have established a private foundation in the C.S.F.R.--the Czechoslovak Fund for Higher Education to aid C.S.F.R. universities (see this issue, page 129, *Renewal of Czech and Slovak Universities*). This organization expects to have affiliates in the U.S., Canada, and Switzerland to establish a fund to aid Czech education.

### **Conclusions**

I was reassured to see that the infrastructure of science in the C.S.F.R. appears to be in reasonable shape. The scientists I spoke to genuinely desire to march into the future without regrets or looking back. The recent sudden decompression may give rise to pressures for participatory decisions that could lead to a paralysis (Ash, 1990) that C.S.F.R. science could very ill afford. The future of C.S.F.R. science will therefore depend on democratic politics tempered by strong leadership. Gauging from the scientists and academics I spoke to, the leadership is present and ready for the challenge.

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# Micromechanics and Scanning Electron Microscopy Research at the C.S.F.R. Academy of Sciences

by Marco S. Di Capua

## Introduction

In a recent visit to the Czech and Slovak Federal Republic (C.S.F.R.) Academy of Sciences (Academy) Department of Theoretical and Applied Mechanics, Prague and Institute of Scientific Instruments, Brno, I discussed:

- Strain measurements in micro-objects
- Photoelastic investigations in optical fibers
- Continuum mechanics of polycrystalline media
- Basalt fiber technology for insulation and composite reinforcements.

## Strain and Stress Measurements in Micro-Objects

Dr. Berka and his collaborators at the Surveying Department, Faculty of Civil Engineering, Czech Technical University, Prague (CTU), (this issue, see page 129, Renewal of Czech and Slovak Universities), and at the Academy's Institute of Scientific Instruments, Brno (see this issue, page 124, Scanning Electron Microscopy Developments at the Institute of Scientific Instruments and TESLA in Brno) have perfected techniques (Berka,

1990) to measure microstrains in materials through a combination of:

- Vacuum-compatible, computer-controlled, hydraulically operated tensile tester (TT) cells that load the specimens
- Desk-top size, scanning electron microscopes (SEMs) that deliver real-time images of the loaded specimen
- Time-base microphotogrammetry (TBMP) to measure, by comparison of SEM images at successive loading stages, the micro-strains in the specimen.

**The TT Cell.** The palm-sized (165 x 110 x 38 mm<sup>3</sup>), vacuum compatible, stainless steel TT (Schenk, 1990) can load a 100-mm long specimen up to 10,000 N for microscopic investigations. A Z-80 microprocessor gathers signals from semiconductor strain gauges in the TT that measure the macroscopic force on, and elongation of, the sample. This microprocessor also controls the pump that delivers a smooth flow of ethyl alcohol under pressure (400 bar) to the hydraulic rams of the TT. The Z-80 controls the scanning coils of the SEM as well, so the electron beam can also expose fiducial marks on the sample under test. Perhaps the most interesting aspects of the cell are:

- Precision mechanics in its construction
- Compatibility with a 1.0E-03-Pa vacuum system
- Microprocessor control to couple the cell to a TESLA BS 343 Mini SEM (see this issue, page 124, Scanning Electron Microscopy Developments at the Institute of Scientific Instruments and TESLA in Brno).

In Berka's experiments, the loading cell mounts in a 230-mm diameter, 75-mm deep vacuum chamber that attaches to the BS 343 SEM. The chamber has simple feedthroughs for the hydraulic capillary and the outputs of the semiconductor gauges.

### Evaluation of Microscopic Photographs in TBMP

To reduce the data, Berka and his collaborators use a stereocomparator with an internal accuracy of  $2\ \mu\text{m}$ . To position the photographs and to correct the distortions in the images, they use fiducial marks or grids engraved on the sample by the same electron beam that performs the scanning. The stereocomparator analyzes two photographs at successive stages of the deformation process. The analysis provides the input data for a computer program that calculates the affine transformation leading from the initial state to the final state on the sample. This affine transformation then provides the strain and rotation fields on the sample.

### Photoelastic Analysis of Stresses in Polarization Maintaining Optical Fibers

Another interesting research project is the photoelastic analysis of stresses in macroscopic models of optical fibers and in optical fibers themselves. The models guide the analysis of the patterns, observed in the fibers, through a polarization microscope (Berka, 1989a, 1989b).

### Basalt Fiber Technology and Production

Berka collaborates with the Institute of Problems of Materials in Kiev, U.S.S.R., and the Research Institute for Glass Technology, Hradec Kralove, C.S.F.R., on technology developments to pull fibers from basalt with diameters ranging from 0.5 to  $10\ \mu\text{m}$  and from 150 to

$350\ \mu\text{m}$ . According to Berka, these fibers can withstand higher temperatures ( $800^\circ\text{C}$ ) and can sustain higher dynamic loadings than glass fibers. Basalt fibers can act as insulation, filter media, and composite reinforcers, resulting in materials with a 30 percent greater strength modulus (than with glass fibers, for example). Thick basalt fibers can act as reinforcements in cement matrix composites.

A Czech firm, Teplotechna, is preparing to develop basalt fiber technology with U.S.S.R. support. Now, Teplotechna is looking for a partner for this technology that uses a plentiful, naturally occurring raw material with excellent properties.

### Conclusions

The advantages of SEM for microstrain measurements are that SEM images provide a better contrast for stereocomparison analysis than optical images. Moreover, by penetrating the sample, the electron beam can reveal features in the interior of the material that are inaccessible through optical imaging.

Micromasurements of strains in materials allow a deeper understanding of the behavior of matter under stress because they describe strain inhomogeneities that develop at the edges and interfaces of polycrystalline as well as heterogeneous grains.

The micromasurement of stresses, however, remains a problem. So far, there is no reliable method to measure stresses in the microscale. However, microfabricated stress gauges could come to the rescue. A combination of microstress measurements and the microstrain measurements described in this report could provide insight on the microstructural foundations of behavior of materials.

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# Scanning Electron Microscopy Developments at the Institute of Scientific Instruments and TESLA in Brno

by Marco S. Di Capua

## Introduction

The development of scanning electron microscopy (SEM) at the Institute of Scientific Instruments of the Czech and Slovak Federal Republic (C.S.F.R.) Academy of Sciences (ISI), and the TESLA company in Brno has an interesting connection with the manufacture, as part of the German World War II effort, of cathode ray tubes (CRT) at TESLA. Incidentally, Tesla is the Czech abbreviation of: low current technology, and, the connection with the name of the inventor Nikolai Tesla is purely coincidental!

In 1949, Academician Armin Delong, now Chair of the State Commission for Science, Technology and Investments (this issue, see page 118, C.S.F.R. Science in the 1990s) spent time in Berlin with Ernst Ruska, the inventor of the transmission electron microscope (TEM), and upon returning to Brno, he began research on electron microscopy, as an offshoot of the CRT research and manufacturing effort. Since then, TESLA and ISI have developed an internationally recognized capability in the SEM field.

ISI's strengths are in:

- Electron emission and electron guns, including field emission and thermal field emission guns
- Magnetic and electrostatic electron optics
- Electron energy analyzers
- Numerical methods for electron optics design
- Ultra high vacuum (UHV) construction techniques
- Development of instrumentation that relies on scanning electronics such as:
  - SEM and TEM
  - Auger spectrometers/microscopes
  - Energy dispersive x-ray (EDX) analysis for small scanning microscopes
  - Electron beam lithography
  - Vector scan shaped beams.

This article discusses:

- A portable, computer-controlled SEM
- New developments in electron lithography
- An electron beam tester with field emission gun.

## The TESLA BS 343 Mini SEM

This is an exciting instrumentation development of TESLA, in collaboration with ISI. In this SEM concept, a "head" incorporates three "columns:"

- An electron beam source and sweeping magnet column
- Detector column with several detector options
  - Secondary electrons
  - Back-scattered electrons
  - X-ray detector with energy analysis
- Turbomolecular pump column (backed by a separate rotating vacuum pump).

The three columns converge on a vacuum chamber with the shape of an oversize rubber plunger (as those commonly used to remove obstructions from stopped sinks). This chamber design concept attaches the microscope head, by suction, to objects or chambers of arbitrary shape. A combination of easily machined adapters and vacuum sealing putty; e.g., Ductseal, achieves the vacuum seal. Vacuum will support the weight of the head.

The maximum resolution of this 15-kV SEM is about 40 nm and the magnification range is 10 to 50,000. A good feature of the instrument is that the scan is synchronous with standard television formats (National Television System Committee [NTSC] or Phase Alternating Line [PAL]) allowing direct recording of the image on entertainment-type video recorders.

## An Electron Beam Tester for VLSI

Another interesting development at ISI is an electron beam tester for nondestructive diagnostic of integrated circuits (IC) under actual operation. In this SEM, the electron source is a W-single-crystal that delivers the 10-nA, 0.2- $\mu$ m diameter, 70-eV probe beam. The microscope has elaborate electron optics to carry the secondary electrons away from the focal spot to the 30- $\mu$ m thick, YAG:Ce<sup>3+</sup> detector crystal. A 15-nm thick Al-layer, biased to 10 kV coats the detector, which can resolve 50-mV energies. In the voltage contrast mode, strobing the electron detector at a slightly different clock rate as the clock rate of the IC, reveals the signals as they travel through the junctions of the IC (Fiser, 1989).

## Projection e-Beam Lithography

Delong cannot wait to return to ISI from his assignment with SK VTRI (see this issue, page 118, C.S.F.R. Science in the 1990s) to continue development of a projection lithography system for 1-to-1 mask reproduction that could reproduce 0.2- $\mu$  features. In this system, exposed sections of the mask, configured as a metal-insulator-metal (MIM) sandwich, emit electrons as a planar cathode, where areas covered by resist do not emit. Because of the tunnel effect, the contrast ratio, between emitting and nonemitting areas, can be 30 orders of magnitude.

The electrons make one spiral trajectory in crossed E and B fields before arriving to the target. The collimated electrons have some angular distribution because of the two-dimensional nature of the electric field at the edges of the metallic emitter. The ISI delivered a preliminary report on this system at the 12th International Conference on Electron Microscopy, Seattle, Washington, August 12-18, 1990.

This system is at a very advanced stage of development and ISI has offered it to TESLA. However, TESLA has declined because of the short-term uncertainties facing science and technology in the C.S.F.R. (see this issue, page 118, C.S.F.R. Science in the 1990s).

## Delong Instruments

With the present changes in the C.S.F.R., a group of scientists at ISI established a company to market subcomponents for SEMs and UHVs. Their rationale for establishing the company is quite similar to the rationale to establish small high-technology companies elsewhere; i.e., TESLA has no interest in marketing subcomponents. However, a small outfit, e.g., Delong Instruments, can do it very effectively. Their first product lines will be:

- UHV pipes, valves, and flanges
- Low-consumption (1 liter per week) LN<sub>2</sub> cryostats
- Modular components for SEMs
  - Energy analyzers
  - Lenses
  - Electron guns.

- Table for 8" mask production for e-beam lithography
  - Laser interferometer positioning within  $\lambda/32$  (20 nm)
  - Storage of mask features in a personal computer.

## TESLA's Competitors

TESLA has technical competitors in the SEM field, namely JEOL in Japan and Philips in the Netherlands, Cambridge Instruments in the U.K., Opton (a division of Zeiss) in the Federal Republic of Germany and Perkin Elmer in the U.S. Now, TESLA offers competitive technology for lower prices because of low labor costs.

## Conclusions

I felt at home during my visit to ISI. Their laboratories were busy, equipment was humming, and we even had the leaks and glitches that usually accompany equipment demonstrations to scientific colleagues. The technology I saw appeared up to date, and ISI scientists told me that their research and TESLA SEM products, which combine the best the C.S.F.R. can offer in mechanical and electrical (electronic) design, have always been well received in international conferences and markets.

I became curious about such an unusual center of excellence within an economic system that rejects high technology (see this issue, page 61, Science Funding, Organizations, and Personnel in the U.S.S.R.). The scientists I spoke to told me that the catalyzer is Academician Delong. Delong has been, since the mid-1960s, supervising the masters and doctoral work of promising students at the Technical University in Brno. Therefore Delong made few mistakes in personnel because he could select the best for ISI and TESLA by judging the quality of their student work. Another selection tool was low pay; those who had no interest in science moved on to better-paying jobs!

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# X-Ray Diagnostics and Laser Research at the Nuclear Science and Engineering Physics Faculty, Czech Technical University, Prague

by Marco S. Di Capua

## Introduction

An article by J. Kohn (this issue, page 129) briefly outlined the history of higher education in the Czech and Slovak Federal Republic (C.S.F.R.) and the origins of the Czech Technical University (CTU) in Prague. The CTU has the faculties outlined in Table 1.

Table 1. Faculties and Staff at CTU

Faculty	Students	Faculty and Staff
Civil Engineering	4,500	780
Mechanical Engineering	4,200	990
Electrical Engineering	4,000	880
Nuclear Science and Engineering Physics	400	245
Architecture	400	117

The Rector of the CTU is Dr. Stanislav Hanzl and the Vice-Rector for Research, Development, and Foreign Relations is Dr. Jan John. The article on C.S.F.R. Science in the 1990s (this issue, page 118) reflects some of John's views on the future of Universities in the C.S.F.R..

## The Faculty of Nuclear Science and Engineering Physics

Table 1 shows that the faculty of Nuclear Science and Engineering Physics at the CTU has a student to faculty and staff ratio below two to one, which affords a very personalized instruction. Through an individual education, resulting from this small ratio, a very demanding course of studies and, selective admissions, many alumni have reached positions of responsibility in C.S.F.R. Science and Technology.

The faculty has departments of:

- Solid State Engineering
- Nuclear Chemistry
- Physics
- Mathematics
- Languages
- Materials Science

- Physical Electronics
- Dosimetry and Applications of Radiation.

The faculty will operate a 100 W continuous duty, 1-kW pulsed, water pool nuclear reactor for teaching and demonstration. The reactor will be fueled early next year. The buildings of the faculty (ca. 1975) are in Prague (Troja). The Faculty of Mathematics and Physics of Charles University shares some facilities with CTU.

## The Department of Physical Electronics

The Department of Physical Electronics (Professor G. Loncar, head), divides into the following groups and activities:

- Lasers for Interkosmos Group

Precision geodesy applied to crustal dynamics (single-shot distance measurements with  $4.E-09$  accuracy over 8000 km)

- ps techniques for ranging
- Si avalanche, single photon ( $@ 0.5 \mu\text{m}$ ) detectors (in collaboration with Department of Solid State Physics)
- Multiple wavelength ranging
- Modular streak cameras
- ps resolution interval meter
- Multiple wavelength picosecond time vernier
- 10 - 40 GHz transistor and strip line circuits.

- Ion Beam Group

Modification and analysis materials with ion beams

- 140-kV, 50- $\mu\text{A}$  ion implanter (clean facility)
- 2.5-MeV van der Graaf generator for particle-induced x-ray emission, Rutherford back scattering, and nuclear reaction analysis.

- Optoelectronics and Fiber Optics Group

Theoretical and experimental research on optical guided waves

- Propagation modes
- Nonlinear phenomena
  - Stimulated Raman Scattering
  - Stimulated Brillouin Scattering
  - Four-photon mixing
  - Self-modulation
- Fiber optics applications.

- Diffraction Optics and Holography Group
- Imaging by diffraction elements
- Recording media for holography
- Holographic optical element design
- Nonlinear optics
  - Two and four wave mixing in BGO, BSO, BTO, BaTiO<sub>3</sub>
  - Self-pumped phase conjugation in BaTiO<sub>3</sub>
  - Brillouin amplifiers, Raman cells
- Pulsed Gas Lasers and Applications Group
- TEA CO<sub>2</sub> lasers
- UV preionizer XeCl laser
- Industrial laser markers
- Laser ablation for dermatology, ophthalmology, and surgery (*continuous wave, 100 W with fiber output*)<sup>1</sup>
- Two-wavelength surgical lasers (through simple change of one optical element)
- Pulse power for lasers<sup>1</sup>
- Computational Physics Group
- Computational physics packages
- Computer algebra for plasma physics calculations
- Computational plasma physics at high-energy densities
  - Medusa code (Di Capua, 1989)
  - Hydrodynamics
    - Radiation transport
 (collaboration with K. Niu, Tokyo Institute of Technology)
- Computer-aided instruction
- Computer-aided design.

### The Laser Matter Interaction Group

I visited the Laser Matter Interaction Group in the Department of Physical Electronics where my host was Dr. Ladislav Pina. The research of this group involves:

- Nd-glass laser (10-20 GW, 1-20 ns, 1.0E + 14 W cm<sup>-2</sup>, 80- $\mu$  focal spot)
- Temporal, spectral, and time-resolved diagnostics
- VUV and x-ray lasers
- X-ray optics and instrumentation
- X-ray cameras
- X-ray spectrometers
- X-ray detectors.

The interest on x-ray instrumentation at CTU stems from an assignment of Professor L. Pina, Central Laser

Facility - Rutherford Appleton Laboratory (CLF-RAL), Oxfordshire, U.K., about 12 years ago (ESNIB 88-09:21-22 and EOARD-LR-88-21). Since then, Pina assembled a laser-matter interaction experimental research group. The modern facilities of this group have up-to-date personal computers (PCs), oscilloscopes, and streak cameras.

In collaboration with the Institute of Plasma Physics and Laser Microfusion in Warsaw, the P.N. Lebedev Institute in Moscow and the Institute of Physics of the Czechoslovak Academy of Sciences, Pina's group has developed a x-ray transmission grating spectrometer with a charge-coupled device (CCD) detector to measure integrated pulsed x-ray spectra. The spectrometer has moderate spectral resolution ( $\delta\lambda < 0.6$  nm) over a broad spectral range (0.3 - 2 keV), and high sensitivity, linearity, and large dynamic range.

Pina's group tested the performance of the spectrometer using a laser created plasma as a x-ray source. The experiments involved calibration of the x-ray spectrograph aiming to develop absolutely calibrated CCD detectors for x-ray diagnostics. Pina's work, presented at the 20th European Conference on Laser Interactions with Matter (see this issue, page 31; Pina, 1990) will appear in a special issue of *Lasers and Particle Beams*.

Pina hopes to work with CLF-RAL to develop and calibrate CCD imaging systems for x-ray lasers, though, he concedes that hard currency for travel is very tight at this moment.

As a curious diagnostics aside, I examined a streak camera with the image tube developed by Shelev, Institute for General Physics (IGP), Moscow, U.S.S.R., and electronics built at the CTU. I also saw a British-made Hadland streak where IGP, as an original equipment manufacturer, supplied the image tube. Therefore the cryptic remark about "time resolved x-ray streak cameras (equipped with Soviet image tubes and British electronics)" seen at the Institute of High-Current Electronics in Tomsk, (see this issue, page 16; Kristiansen, 1990) makes sense since the U.S.S.R. probably barter image tubes for complete Hadland cameras, leading to the question of how many tubes is a camera worth?

### The Future

The equipment I saw in the CTU laboratories is modern with a density of PCs per square meter of office and laboratory space equivalent to what I saw in university laboratories in the Federal Republic of Germany. Some equipment; e.g., the lasers, have perhaps even a more professional appearance than lasers I have seen elsewhere in Europe. The appearance may be because of a long mechanical and electrical engineering tradition in the C.S.F.R. that prizes workmanship.

<sup>1</sup>Designed by Lasers for Intercosmos

Since the equipment is reasonably modern, a primary issue in the change to a market economy is to secure enough funds to maintain expensive capital equipment up-to-date and in good working order. In Pina's research area, capitalization may be a secondary issue at this moment.

Pina foresees big uncertainties in research funding. His concern is that a combination of shortage of funds, economic stagnation, and relaxed emigration policies may encourage scientists to leave, and, cause deterioration and obsolescence of equipment (see this issue, page 118, C.S.F.R. Science in the 1990s).

If the best people leave, and equipment is not tended for, once the C.S.F.R. economy gets back on its feet, perhaps in 3 to 5 years, entire research groups and laboratories may need rebuilding from the ground up, which could take perhaps 10 years. Therefore, Pina identifies, as top priority, to get a resource lifeline that will allow the research establishment to ford this local minimum without drowning.

A second issue Pina sees is a requirement to create positions for physicists within industry. According to Pina, industrial employment of physicists is more prevalent in the Netherlands or in Germany than it is in the C.S.F.R.. The industrial role of physicists could increase, as newly privatized industries carry out the innovation programs that will allow them to survive.

## The International School for Nonlinear and Coherent Optics

Pina and G. Loncar, head of the Department of Physical Electronics, CTU, view Prague as a center where East meets West. As a test of this vision, they are organizing an International School of Laser and Coherent Optics that will harbor periodic workshops on related subjects.

Pina and Loncar plan the first school, on phase conjugation and its application to optical systems, for August of 1991, in collaboration with G. Pasmanik, Institute of Applied Physics, Gorki, U.S.S.R. (see this issue, page 31, 20th European Conference on Laser Interaction with Matter).

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## The Prague Institute For Advanced Studies

by Marco S. Di Capua

On a liaison visit to Czech and Slovak Federal Republic (C.S.F.R.), I learned about the Prague Institute for Advanced Studies (Institute), a new university-level organization, whose aim is to provide:

- Quick and flexible specializations in response to demands of society, particularly in interdisciplinary fields
- An education to exceptionally gifted students in unique fields
- A deep education in specific areas, leading to a Ph.D.-like degree, to graduates of universities
- A system to update the know-how of experts through courses and seminars that lie outside the scope of university studies
- A venue for contacts with foreign scientists and students who have an expertise in specific fields
- A system for a two-way information exchange with other institutions in the C.S.F.R. and abroad.

In the first phase, the organizers expect to focus on:

- Computer Science
- Management
- Applied Social Sciences
- Ecological Technologies
- Advanced Manufacturing Processes
- Materials Engineering.

Computer Science and Management activities will begin in autumn 1990 and will absorb about two-thirds of the effort. Applied Social Sciences and Ecological Tech-

nologies will probably begin in early 1991 absorbing one-sixth of the effort; Advanced Manufacturing Processes will also absorb one-sixth of the effort and will begin in autumn 1991.

The Institute will be initially established within the framework of the Czech Technical University in Prague and initial funding will be in C.S.F.R. Koruna. The Senate of the Institute will select the specializations within the Departments; the Department Chairs will choose the experts who will hold the seminars and will tutor the students. At this moment, there is no funding for the specialists who will be invited to lecture within the framework of their other university duties.

The Institute appears as an interesting response to the sudden decompression of academic institutions since the change of government in Czechoslovakia. The initial

activities appear to be in key disciplines that the C.S.F.R. will require for economic growth. There are questions, however, about how the Institute will complement existing programs at the C.S.F.R. Academy of Sciences, and at academic departments of the Czech Technical University, and the Charles University in Prague, and other C.S.F.R. universities (see this issue, page 129, Renewal of Czech and Slovak Universities; and page 118, C.S.F.R. Science in the 1990s). When adequately funded and organized, it could be an effective channel for resources in specific academic areas.

## References

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# Renewal of Czech and Slovak Universities

*by J.J. Kohn, Professor of Mathematics at Princeton University, Princeton, New Jersey. Professor Kohn was born in Czechoslovakia, emigrated to Ecuador in 1939, and re-emigrated to the U.S. in 1945. Professor Kohn was in Prague in June 1990.*

## Background

For centuries the Czech and Slovak Federal Republic (C.S.F.R.) has been in the geographical, intellectual, and cultural center of Europe. The fact that Prague is west of Vienna appears strange to us, at first, because during the last 40 years the C.S.F.R. was behind the Iron Curtain and we have become accustomed of thinking about the C.S.F.R. as an appendage to the U.S.S.R.

The *velvet revolution*, which has restored democracy to the C.S.F.R., aspires to regain for the country its former central and important role in European economic, cultural, and scientific life. An important part of this is the renewal of the Czech and Slovak universities which I discuss below.

The university tradition in the C.S.F.R. is very strong. The tradition is exemplified by T.G. Masaryk (1886-1948), the country's founder, a well-known philosopher and political writer. Masaryk was a Professor of Philosophy in Vienna and Prague before becoming the first president of the country in 1918 at age 68.

To give an idea of the C.S.F.R.'s leading role in our intellectual heritage of Czech and Slovak Universities, I will briefly discuss some of the leading physicists who worked in Prague and their work (Janta, nd). The history

of the other sciences, music, drama, literature, theology, and linguistics, is as impressive as the sciences.

Until the beginning of this century, most of these activities took place in Prague. Since then, Bratislava, Brno, and Olomouc have developed important universities. At present, there are 21 universities in Bohemia, 8 in Moravia, and 15 in Slovakia totalling 110,000 students--0.6 percent of the population.

## Charles University in Prague

Prague has one of the oldest universities in Europe. Charles University (Karlova Univerzita) was founded in 1348 by the Czech King Charles IV who modeled it on the universities in Paris and Bologna. From the beginning, it emphasized science. One of the first astronomers of the university to gain prominence at the beginning of the 15th century was Jan Ondrejov, called Sindel (? 1375 to 1456), whose research concerned planetary motions. His astronomical tables were essential to the work of Tycho Brahe at the end of the 16th century. (Sindel was also one of the designers of Prague's well-known astronomical clock located in the Old Town Square.) Another famous physician and astronomer, Tadeas Hayek (1525-1600), made a detailed study of the supernova in the constella-

tion of Cassiopeia and observed the great comet in 1577. Using these observations, Tycho Brahe provided powerful arguments against the prevailing Aristotelian view of the universe. Háyek was instrumental in convincing the Court of Rudolph II to invite Tycho Brahe to establish a center for astronomical studies in Prague. In 1600, Johannes Kepler joined this center. In 1605 in Prague, Kepler formulated the first two of his laws on planetary motions based on Brahe's observations.

Scientific research at the highest level continued in Prague until the present. A few prominent scientists who did significant work in Prague before the 20th century:

- A. Strnad (1747-1799) - Started the oldest continuous series of meteorological observations in the world
- Jan Tesánek (1728-1788) - Published the Prague edition of Newton's Principia with his own commentaries which anticipated some of the work of Lagrange
- Frantisek Josef Gerstner (1756-1832) - Pioneered in hydrodynamics and established the forerunner of the Czech Technical University
- Benard Bolzano (1781-1848) - A founder of modern mathematical analysis, did important work in mechanics and in the philosophy of science
- Christian Doppler (1803-1854) - Spent 10 years teaching and doing research in Prague and discovered and investigated during this time his best-known contribution the Doppler effect
- Ernst Mach (1838-1916) - Spent almost 30 years in Prague as Professor of experimental physics devoting himself mostly to studying optics and acoustics
- Jan Purkyne (1787-1869) - Physiologist who first studied shifts in sensitivity to color depending on brightness
- Cenek Strouhal (1850-1922) - Student of Mach who made important contributions to acoustics
- Gregor Mendel (1822-1884) - One of the founders of modern genetics.

In the 20th century, until World War II, Prague was a major scientific center. Perhaps the most prominent figures were the Nobel laureate in chemistry Jaroslav Heyrovsky (1890-1967), the physicists Frantisek Závíska (1897-1945) and Phillipp Frank (1884-1966), the mathematician Eduard Cech, and the statistician Emil Schonbaum. Albert Einstein (1879-1955) spent 16 months (1911-1912) in Prague, and published 11 papers. Einstein stated in print that the scientific atmosphere in Prague greatly stimulated him.

## The Czech Technical University

In the early 1700s, Kristian Josef Willenberg of Lehnice in Silesia petitioned the Emperor Joseph I to establish a school of engineering in Prague. The emperor granted the petition ordering the founding of "the Czech Estates of Engineering," tasked with educating engineers, principally in the arts, and the art and science of fortification construction.

In 1803, Frantisek Josef Gerstner (see above) recommended reorganization of the Prague school, following the model of the *École Polytechnique*, established in Paris in 1794 (Di Capua, 1989). Under Gerstner's leadership, competitive appointments assured the quality of teachers and students. The Prague Polytechnic, together with *École Polytechnique* in Paris, became the most important engineering schools of that period.

Reforms in 1863 implemented equal rights for the Czech and German languages, enabling young Czech scholars to become professors. The situation was unstable. As a result, the Germans, calling for justice, divided the school into Czech and German sections in 1870.

The Czech Technical "High School" then evolved with the introduction of rigid examinations, and the ability to grant doctorates removed the last remaining discrepancy between a technical education and a traditional university. Teaching evolved with changing times and, in the 1920s the present Czech Technical University amalgamated seven relatively independent "High Schools" with several thousand students.

## The Czech and Slovak Universities - 1939 and Beyond

On November 17, 1939, the occupying Germans closed the Czech and Moravian universities. Many of the leading professors fled the country, and many others were killed. The universities reopened again in 1945, but the times were turbulent, and before substantial recovery took place, the Communists came to power in 1948.

Under the Communist regime, the universities endured repeated purges, censorship, isolation, and political interference in all their activities. Despite all these calamities, there remained many outstanding faculty members and, surprisingly, the students acquired immunity to the heavy-handed Marxist indoctrination receiving excellent preparation in the nonpolitical subjects. The graduate and postgraduate levels, however, felt the biggest problems.

## Renewal of Czech and Slovak Universities - The Czechoslovak Universities Development Fund

On March 14, 1990, President Václav Havel received a memorandum suggesting that the C.S.F.R. Universities Development Fund (CUDF) be established in the C.S.F.R., with affiliations in America and in Western Europe, to raise money for the renewal of Czech and Slovak universities. The rectors of the major universities and the leaders of the students signed this memorandum. President Havel wasted no time. On March 16, he established the CUDF and appointing a committee to steer it: Jiri Adámek, Jaroslav Drobnik, Dana Dunajová, Petr Kotáb, Jan Koucky, Antonin Rosicky, Petr Susanka, and Helena Stepánová.

The CUDF incorporated in Prague on March 28, 1990, as a federal independent nonprofit education association. The steering committee was entrusted to assemble an eight-member executive Board of Directors by the end of August. Honorary members of the Board of Directors now include:

- Karl von Schwarzenberg - Chairman of President Havel's foreign consultants
- Václav Klaus - Federal Minister of Finance
- Alexander Dubcek - Chairman of the Federal Parliament
- Jaroslav Korán - Mayor of Prague
- Roman Hofbauer - Mayor of Bratislava
- Radim Paulous - President of Charles University
- Miroslav Kusy - President of Comenius University in Bratislava
- Josef Hromadka - Chairman of the Ecumenical Council of Churches
- Frantisek Cardinal Tomasek - Roman Catholic Prelate
- Petr Dvorsky - Opera singer.

The CUDF already has had some success in raising money in the C.S.F.R. The strife fund of the Czech and Moravian Student Parliament provided 2 million Krona and may provide another 10 million Krona as well as 50,000 Swiss Francs. Pavel Stastny, the graphic artist who designed the Civic Forum logo, will donate all his profits from the commercial use of this symbol. Singer Michal Kocab will donate the proceeds from a rock concert, which will take place in the fall.

## American, Czech, and Slovak Education Fund

In April, Prague attorney Dr. Vladimir Koucky traveled the U.S. to establish the affiliated fund--the

American, Czech, and Slovak Education Fund (ACSEF). After a series of meetings and discussions with people from the academic and business communities, the U.S. foundation began to take shape.

The Wall Street law firm of Herzfeld & Rubin has filed for incorporation of ACSEF as a nonprofit organization with a tax-exempt status with the following Incorporating Directors:

- Joseph J. Kohn - Professor of Mathematics, Princeton University
- Michael Kraus - Professor of Politics, Middlebury College
- Pablo Pick - President of American Petrochemical Corporation
- Jan Svejnar - Professor of Economics, University of Pittsburgh.

Honorary Directors are:

- Thomas Cech - Nobel Prize Winner in biochemistry
- Milos Forman - Cinema Director and Producer
- Henry Kissinger - former U.S. Secretary of State
- Martina Navratilova - Tennis player and 1990 Wimbledon champion
- Jirka Rysavy - President of Corporate Express.

Vladimir Koucky, will be the liaison with the CUDF and with the foundations of other countries, and Irina Rybacek, freelance editor and writer, is the Acting Executive Director.

The ACSEF will work on obtaining support for various projects. Some of the projects have already begun:

- Center for Economic Research and Graduate Education (CERGE). A detailed proposal for CERGE has been prepared by Professors Jan Svejnar (Pittsburgh) and Jozef Zieleniec (Prague). The proposal is backed by the rector of Charles University, high levels of the Czechoslovak government and the President of the University of Pittsburgh. The center expects to have 25 faculty members half of whom will be from outside of the C.S.F.R.; it will strive to attract visiting research professors and will employ about 12 staff members (secretaries, librarians, computer specialists). The CERGE will begin operations in spring 1991 and will start operating on a full scale in the academic year 1991-1992. The proposal requires substantial financing from sources outside of the C.S.F.R. for the first 7 years. Probably part of this project will be supported by the Mellon Foundation. Likewise, computer facilities will be provided by the Digital Equipment, Inc.
- Business School. Will be established in Prague, in collaboration between the University of Pittsburgh and the Czech Ministry of Industry. The University

of Pittsburgh has established a similar school in Budapest in early 1989.

- Middlebury Consortium. Exchange of students.
- Prague Institute for Advanced Study. Will be a counterpart to the Princeton IAS with emphasis on applied science and technology. This institute has already scheduled a series of short visits by distinguished visitors. They are actively cooperating with the Stichting Centrum and the University of Amsterdam. This institute is propelled with great skill and energy by J. Adamek (see this issue, page 128, The Prague Institute for Advanced Studies.)
- Preservation of the Charles University Library. A project initiated in the C.S.F.R. by Dr. Drobnik. This project involves both preservation of old manuscripts and acquisitions of books and journals (see this issue, page 118, C.S.F.R. Science in the 1990s.
- The Central European University (CUE). This project is heavily supported by the Soros Foundation. The CUE will have branches in Prague, Bratislava, and Budapest. Jiri Adamek is organizing the Prague branch; it will be called the Institute for Graduate Studies. The Bratislava Branch, organized by Ivo Novak, will be called the Istropolitana. The Soros Foundation will probably contribute \$25,000,000 over a 5-year period to these two branches.

The ACSEF expects to support these and other projects from the following sources:

- Individuals - Mainly Americans of Czech or Slovak background

- American Czech and Slovak organizations - The Czechoslovak Society for Arts and Sciences, The Masaryk Club of Boston, and others
- Corporations - Mostly from those that plan to do business in the C.S.F.R.
- Foundations
- U.S. Government - Through Congress, National Science Foundation, Department of Defense, and Department of Energy funding agencies.
- Academic exchange programs - Such as those organized by the NAS, IREX, and individual universities.

The Board of ACSEF is working with great enthusiasm, planning to enlarge this group and to establish an active Advisory Council. The goal of ACSEF is to help renew Czech and Slovak higher education so it can resume its traditional world-class status. I believe that this goal can be achieved by the beginning of the next century.

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# European Community Initiatives

## Science and Technology Cooperation with Central and Eastern Europe

*by Patricia Haigh, U.S. Mission to the European Committee (USEC), Brussels*

The European Council of Research Ministers (Council), reviewed favorably a proposal from the European Commission (Commission) for increased scientific and technological (S&T) cooperation with Central and Eastern Europe.

Commission-proposed S&T cooperation with Eastern Europe falls into three categories: (1) regular scientific cooperation, (2) scientific research and development (R&D) activities to encourage the transfer of technology, and (3) cooperation in the field of human resources. The Commission has examined particular S&T strengths in Eastern Europe and cooperative S&T agreements are being explored. The Commission has defined a range of priority sectors for technology transfer. Of particular

importance are those technologies related to energy savings, materials efficiency, nuclear safety, and satisfaction of consumer demand in key areas such as electronics and telecommunications. Cooperative efforts will require some restructuring of EC R&D program objectives to focus on technologies relevant to the needs of Eastern Europe. Every effort will be made to incorporate training into the cooperative efforts.

The Council will continue its review of Commission proposals for S&T cooperation with Central and Eastern Europe in the hope of initiating concrete action by its next meeting in the fall. At the same time, the European Parliament has conducted its own study of S&T cooperation with Eastern Europe.

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## European Community Science and Technology Cooperation with Central and Eastern Europe

*by Anthony Rock, U.S. Mission to the European Communities (USEC)*

### Introduction

Until 1988, absence of relations prohibited European Community (EC) research cooperation with Central and Eastern European countries. However, the EC has completed its network of first generation trade and cooperation agreements. These agreements provide for cooperation in numerous areas of mutual interest, including science and technology (S&T). The European Commission (Commission) has also assumed responsibility for

coordinating Western assistance to these countries in the framework of the Group of 24 (G-24). The first major instrument put in place to assist countries of the region is the Poland and Hungary: Assistance for Economic Restructuring (PHARE) Program, with a 1990 budget of 300 million European Currency Units (ECU).

Agreement was made that action within the framework of G-24 should be extended to the German Democratic Republic (GDR), Czechoslovakia, Yugoslavia, and Bulgaria. The G-24 framework will implement the program

of assistance to Central and Eastern European countries and extend PHARE to the other countries. Provisionally, the EC 1990 budget is 500 million ECUs, 838 million ECUs for 1991, and 970 million ECUs for 1992.

Other important steps taken include the constitution of the European Bank for Reconstruction and Development (EBRD) with a particular role for EC member states and institutions. Loans of up to 1,200 million ECUs are available from the European Investment Bank and the European Coal and Steel Company (ECSC).

### Science and Technology Cooperation

The EC proposed S&T cooperation with Eastern Europe falls into three categories: (1) regular scientific cooperation, (2) particular research and development (R&D) activities to encourage technology transfer, and (3) cooperation in human resources.

The Commission's description of the general situation in Central and Eastern Europe is--sound scientific talent that has been undervalued and underused both for training the workforce and for supplying industry's technological needs. The EC hopes to gain access to a fresh pool of scientific thought, particularly in fundamental research in classical areas. In return, Eastern and Central European countries will gain knowledge in research applications for improving economic growth. Eastern Europe has particular strengths in mathematics, theoretical physics, materials research, life science, fine chemistry, and mechanisms.

Hungary is strong in applied mathematics, operations research and management science, and statistics, and probability.

In the physical sciences, Poland has particular knowledge in acoustics; applied physics; atomic, molecular, mathematical, nuclear and chemical physics; optics; spectroscopy; and the physics of particles and fields.

Czechoslovakia is also notable in astronomy and astrophysics, crystallography, geosciences, and the physics of condensed matter.

In Central and Eastern Europe, Hungary is second only to Poland in instruments and instrumentation. In engineering sciences, Poland is also strong in chemical engineering, metallurgy and mining, materials science, and electrical and electronic engineering. Czechoslovakia specializes in ceramic materials research and in applied computing and cybernetics. Yugoslavia has strengths in electrical and electronic engineering.

In chemistry, Poland and Czechoslovakia are the stronger performers, particularly in analytical chemistry, electro-chemistry, organic chemistry, and polymer science. Hungary, Bulgaria, and Yugoslavia are strong in inorganic and nuclear chemistry.

In the life sciences, Czechoslovakia, Poland, and Hungary are again the strongest performers, excluding the GDR. Particular strengths lie in veterinary medicine, food science and technology, and zoology. The preceding are traditional skills and disciplines are that being lost in the West because of attractions of newer disciplines such as biotechnology.

### Research and Development Activities to Encourage Technology Transfer

There is a large technological gap between the industrialized West and Central and Eastern Europe. The EC studies conclude that this gap is largely the result of deficiencies in former economic and political systems. In these European countries, R&D has been academically oriented and detached from the industry's needs. Innovation is a function of administrative decisions. Long investment gestation has resulted in protracted delays in the introduction of new techniques. Thus, there has been relatively disappointing R&D productivity outside sectors such as space and military industries. Administrative management of technological development was accompanied by privileged access to resources and an alternative system of incentives.

Central and Eastern European countries are characterized by wasteful energy and material intensity. Poland is one of the largest consumers of energy per unit of output. Investment in energy- and material-saving techniques can be an effective form of technology transfer. Energy savings are also bound to have an important benefit for pollution reduction, especially in coal.

Environmental neglect has led to widespread pollution. All the countries in the area are affected by industrial emissions into air and waterways. Since neighboring countries have also been affected, there is a strong element of self interest in any Western assistance in this area.

Nuclear safety is particularly important. On the other hand, the slowdown (including cancellations in Poland) of the nuclear energy program is opening the possibility of exports of conventional power-generating equipment.

Central and Eastern European countries have been unable to satisfy demand for consumer goods. The satisfaction of consumer needs is necessary to ensure the social consensus required for the acceptance of the market economy and the initial sacrifices imposed by its implementation. Hence, there is an urgent need to fill the gap between consumer needs and industrial capacity. In general, investment has often been concentrated on capital goods for an inefficient heavy industry, to the detriment of consumer goods and food production.

The most promising areas for the encouragement of technology transfer are consumer durables (especially electronics), telecommunications, energy and material

savings investments, environmental protection and reclamation, and computers and informatics. Other promising areas are enterprise management and public administration modernization, food processing, chemicals (especially plastics), pharmaceuticals, and biotechnology.

Consumer need is perhaps greatest in consumer electronics. The Commission proposes that an area of particular interest may be converting the military complex in these countries towards the production of consumer durables, beginning with electronics.

There is a particular requirement for developing telecommunications. According to the Commission, the standards and rate of diffusion of telecommunications (both voice and nonvoice) in Eastern Europe has been much lower than countries at a similar development level because of restrictive political systems. Dramatic improvements in this area are a precondition of intensified relations between enterprises to accompany the process of change to market economies.

Current plans for reorganizing the post office in Hungary and Poland open a new opportunity for direct involvement by the West. The transfer might extend from switching equipment to mobile communications, where Central and Eastern European countries might actually benefit from being late starters. At present, EC R&D programs are aimed at technological progress and not directly at preparing and encouraging technology transfer. The EC must encourage introducing and adapting appropriate technologies into the economic systems of Central and Eastern European countries rather than developing new technologies.

The Commission hopes that publicly funded research will be carried out with a view, for example, to future joint ventures, including appropriate support services. The EC officials seem unconcerned that Western industry might lose competitiveness as a result of Central and Eastern European growth capacity and upgrading.

Certain member states that have a similar technological level to Central and Eastern European countries have expressed concern about the effect of possible diversion of trade and R&D effort. The EC officials report that the general stimulus to trade and economic activity created by the internal market completion should, however, offset any such effect. Also, they believe that the Coordinating Committee for Multilateral Expert Control (COCOM) controls may still be an obstacle to technology transfer.

The Commission is wrestling with the question of whether they should focus assistance on rehabilitating existing technological capacity, which might soon be superseded by new, more advanced techniques. They must also decide whether they should scrap inappropriate technology and concentrate on building entirely new structures.

The Commission stresses that cheaper labor might affect the pattern of specialization but not necessarily the choice of technologies. Yet, businessmen must assess the actual opportunities rather than as the object of deliberate policy.

## Cooperation in Human Resources

According to the Commission, they will extend the human capital and mobility program proposed under the EC Third R&D Framework Program to Eastern and Central European countries. At the same time, they will extend its scope to training in R&D management. This program aims to create a pool of highly skilled young researchers at postdoctoral level through stimulating movements and exchanges between European centers of excellence.

The Commission proposes that an additional possibility for meeting skills requirements for industrial development might be an extension of the plan to assist Central and Eastern European countries in higher education to include mobility of pure researchers.

Manager training, particularly for industrial application of new technologies, forms an integral part of the work of the newly created European training foundation. The EC will coordinate activities closely with these efforts.

## Cooperative Implementation Plans

The EC may cooperate with Central and Eastern European countries through coordinated assistance from G-24, assistance through the EBRD, cost, existing community programs, or other S&T cooperative activities. The G-24 Program is the most direct form of assistance. The EC's contribution to assistance for economic restructuring in Poland and Hungary within the framework of G-24 includes training, investment promotion, and environment. Discussions with Poland and Hungary in the course of the PHARE operation have identified a need for assistance with industrial and trade reform with a strong aspect of technical cooperation. The Commission will consider ways and means by which expanded S&T cooperation can be incorporated into actions undertaken within the G-24 framework.

## General Financial Assistance

The European Investment Bank (EIB) provides general financial assistance. International organizations such as the International Bank for Reconstruction and Development (IBRD) also provide financial assistance. The EBRD, a specific instrument, has been newly created and will perform a similar function vis-a-vis Central and Eastern Europe. Access to and use of contemporary

technology would, in many cases, be a critical consideration. While it does not directly finance research, the EBRD could provide finance for this activity as part of a larger investment.

### **Cost Activities**

The Community participates in the cooperation in S&T (cost) framework program along with the European Free Trade Association (EFTA) countries and Yugoslavia. The Commission expects to include Eastern countries in some or all of these efforts.

### **Participation in European Community Programs**

The draft of Council of Research Ministers (Council) decisions on the specific programs within the third Framework Program provides possibilities for developing countries to participate in community R&D programs. Such participation would follow the models already in use by EFTA countries.

(1) Participation on a project-by-project basis within specific programs with the partners in Eastern and Central Europe contributing to general administrative and project costs

(2) **Agreements with Central and Eastern European countries** allowing full participation of organizations based in these countries in a complete program on the same basis as community-based organizations.

To facilitate participation of Central and Eastern European countries in EC programs, some financial assistance may be available to help pay their part of the program costs.

### **European Community and Soviet Cooperation**

Cooperation between the EC and the Soviet Union is based on the trade and cooperation agreement dated April 1, 1990. The agreement provides for collaboration in S&T, including nuclear research. On May 10, 1990, the first meeting took place of the joint committee established by this agreement in Moscow on May 10, 1990.

The Council will continue its review of Commission S&T proposals of cooperation with Central and Eastern European countries in the hope of beginning concrete action by its next meeting in fall 1990. At the same time, the European Parliament completed a study of S&T cooperation with Eastern Europe (see following article).

# European Parliament Proposal for European Community Science and Technology Cooperation with Central and Eastern Europe

by Anthony Rock

## Proposals

The European Parliament (EP) has adopted a proposal paralleling the European Commission's (Commission) effort to develop scientific and technological collaboration with Central and Eastern Europe.

The EP proposes establishing two medium-term aid programs for the countries of Central and Eastern Europe:

- European Assistance for Science and Technology (EAST) - to assist development of research structures and to consolidate scientific and technical potential
- General Research in Environment for Eastern Nations (GREEN) - aimed at acquiring knowledge and scientific and technical resources to combat the problems of the environment (particularly about the effects of energy production from lignite, concerns about nuclear power stations of the Chernobyl-type, and the effects of industrial production processes).

## The EAST Program

According to the EP proposal, the EAST Program should include:

- Training and mobility of research workers to overcoming the consequences of long-term isolation; creating networks between universities, laboratories, and European Community (EC) research centers (including the Joint Research Center) and the countries of Central and Eastern Europe; improving the status of researchers to keep brain-drain to a minimum; and increasing the number of women active in scientific and technological cooperation
- Financing for the contribution made by university and industrial researchers to projects in these areas already being accomplished in community universities and private and public research laboratories
- Identifying and implementing strategic research projects
- Approving common industrial standards

- Fostering cooperation between businesses in East and West; e.g., by organizing seminars, work visits and traineeships, management training, and establishing databases.

## The GREEN Program

The EP proposes that the GREEN Program

- Develop environmental technology for cleaner production processes, and create a common set of rules for environmental impact assessment
- Develop and introduce consistent and generally applicable environmental standards
- Develop facilities to supervise and manage air, soil, and water quality; e.g., satellite monitoring or other air pollution detectors
- Devise instruments for environmental management by businesses and governments specially for the Eastern European situation
- Establish a joint program on energy yield in industrial production cycles and in agriculture.

The EP believes that the EAST and GREEN Programs should associate directly with the EC's Framework Program for research and technological development. Also, they should be integrated in the Fourth Framework Program with a further adequate budgetary appropriation being allocated.

The EP proposes that the framework of the EAST and GREEN Programs should have a maximum life of 8 years. According to the proposal, the EC should make available for the first 4 years a supplemental financial contribution equivalent to 10 percent of appropriations of the Framework Program. A proviso should be included that this percentage is gradually diminished in the following years.

In adopting this proposal, the EP invites the Commission to submit to the that body before the end of 1990 specific proposals that "can be rapidly implemented on the basis of a thorough survey and analysis of the problems and requirements, drawn up in cooperation with the responsible authorities and scientists in each country in question." In fact, EC officials have made several trips to Eastern Europe for reviews of opportunities for science and technology (S&T) cooperation.

## Short-Term Cooperation--Let's Go East

Finally, the EP proposes emergency aid of limited duration to bridge the period until implementation of the EAST and GREEN Programs. The EP proposes that this emergency aid be granted under the title *Let's Go East* (let European technicians and scientists go East) and should include the following actions:

- Send teams of scientists and experts from the EC to the countries in question for 3 to 6 months to:
  1. Assist local research teams
  2. Establish networks of research workers and academics from Eastern and Western Europe, in particular through university-industry joint research projects and scientists-exchange programs
  3. Assist in securing the most accurate and specific assessment possible of the capacities of these countries and their S&T needs
  4. Help identify as rapidly as possible their sectoral policy priorities, in particular in telecommunications and technologies for improving energy productivity
- Assist scientists (financially) from Central and Eastern Europe so they can participate in EC-organized colloquia, congresses, and seminars
- Provide new and used scientific and technical equipment to meet the most urgent requirements.

The EP calls on the Commission to finance this emergency aid program in particular with the Poland and Hungary: Assistance for Economic Restructuring (PHARE) Program.

## European Parliament General Comments

The EP believes that the EC S&T programs on human resources and scientist mobility in the Framework Program should be opened to Central and Eastern European countries.

The EP expressed satisfaction with the narrowing of categories of advanced technology products subjected to Coordinating Committee for Multilateral Export Control (COCOM) rules, and hopes that this trend will continue, in particular, in relation to computers and telecommunications. Facilitating technology transfer will enable Eastern European countries to modernize more rapidly.

Examining the means and rate at which scientific and technological capacity linked to military production activities can be converted or geared to civil purposes. In short, the EP believes that mechanisms should be pursued to convert military industries to civil purposes.

The EP calls on the Interministerial European Research Coordinating Agency (EUREKA) Conference to establish terms from admitting the countries of Central and Eastern Europe.

Finally, the EP calls on the Council of Research Ministers to take steps in the framework of the ministerial meetings between the EC and the European Free Trade Association (EFTA) countries. This would ensure that all partners are involved in the efforts for scientific and technical aid to Central and Eastern Europe.

On July 10, 1990, the EP adopted this proposal for S&T cooperation with Eastern Europe. The EC will now consider it.