# Khaim Borisovich Kordonsky. Educator and Researcher (1917-1999)

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**Abstract**

*The article is about Khaim Borisovich Kordonsky (Tula, Russia, 1919 - Boston, USA, 1999) - Soviet mathematician, Doctor of Technical Sciences, Professor at the Riga Red Banner Institute of Civil Aviation Engineers; specialist in the field of probability and reliability theory, leader of the development of the first computer system for making aircraft schedules, Honoured Scientist of the Latvian SSR, Laureate of the State Prize of the Latvian SSR. Kordonsky's entire scientific and teaching career is connected with RCIIGA. He is one of the founders of reliability theory and the author of the first monograph on the application of probability theory to solving real-world problems. The book "Applications of Probability Theory in Engineering" was published in 1963 and was reviewed by Academician Yuri Vladimirovich Linnik, the greatest expert in probability theory and mathematical statistics in the USSR. Khaim Borisovich also worked on scientific problems in statistics, medicine and technical diagnostics. He conducted joint research with the Department of Mathematical Statistics of the Faculty of Informatics and Cybernetics of Moscow State University, headed by Academician Yuri Vasilievich Prokhorov, and collaborated with Academician A. N. Kolmogorov.*

**Keywords:** memories, probability theory, reliability theory, mathematics.

## 1. Life's journey

Khaim Borisovich Kordonsky was born on March 28, 1919, in the city of Tula (USSR). In 1941, he graduated from the Faculty of Mathematics and Mechanics of Leningrad State University as a mechanic. On June 25 the same year he joined the militia. After completing accelerated courses at the Leningrad Air Force Academy named after Zhukovsky, he went to fight in the ranks of the Air Force. He went the way from a militia soldier to lieutenant colonel. He was Deputy Chief Engineer of the largest 218th Aircraft Repair Plant. He received the following awards: "For Defense of Soviet Polar Region", "For the victory over Germany in the Great Patriotic War of 1941-1945", "For services in war" and "Order of the Red Star".

From 1947 to 1950, he studied at the Leningrad Air Force Academy in the Mathematics Department under academician Yury Linnik, one of the world leading experts in mathematical statistics. Friendship bound Yuri Vladimirovich and Khaim Borisovich all their lives. Employees of the academician told me. "Usually serious and concentrated, Yuri Vladimirovich blossomed when he was expecting Khaim Borisovich's arrival from Riga."

After finishing his postgraduate studies and defending his doctoral thesis in 1950 he was sent to Riga, to Riga Higher Military Aviation School. Here Kordonskiy spent all his working life, changing only the name of the university, where for more than 30 years he was the head of the department "Aircraft repair and production technologies". The university was transformed several times and in 1992 it became Aviation University of Riga.

The Kordonsky Scientific School of talented and active young people was established in the department. His students are now working in various countries - from Canada to Australia, most of them in Latvia. They are the corresponding members of the Latvian Academy of Sciences N. Salinieks and J. Rudzitis, RTU professors Yu. Paramonov, A. Andronov, Yu. Martynov, etc. The total number of doctors and candidates of science trained under Kordonsky's supervision exceeded 50.

Khaim Borisovich treated his students like a father. The following comes to mind. In the sixties the buildings of the institute were situated on both sides of a beautiful park. Khaim Borisovich's apartment was in the same street, hundreds of metres from the institute. When he left the department in the evening, he liked to walk around the green square. He was not alone: one of his students was waiting for him, and they walked and talked about their dissertations. Often, hiding behind trees, another student would be waiting for his turn.

In the last years of his stay in Latvia, K. Kordonsky, together with Latvian doctors, led by academician J. Anshelevich, was engaged in research on the application of probabilistic-statistical methods in medicine, especially in cardiac diagnostics.

The merits of H.B. Kordonsky were highly appreciated: he has the title of Honoured Scientist and Technician of the Latvian SSR (1969) and is a laureate of the State Prize of the Latvian SSR (1985).

In 1993, H.B. Kordonsky emigrated to the United States. This was a difficult decision for him, and the desire to be reunited with his daughters and grandchildren who already lived there permanently prevailed. During his time in the United States, he was twice invited to be a visiting professor at Ber-Shev University, where he worked with his beloved student, Ilya Boruchovich Herzbach. Chaim Borisovich died in Boston in 1999.

We are going to talk about two areas of Khaim Borisovich Kordonsky's scientific activity. The first is his contribution to the development and implementation of probabilistic-statistical methods. The second is his contribution to the application of computer technology in civil aviation.

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## 2. Probabilistic-Statistical Legacy

The first studies were devoted to the problems of statistical (sampling) control of product quality. At that time it was the main direction of application of mathematical statistics, and the leading place belonged to Leningrad mathematicians, because the fundamental article by A.N. Kolmogorov "Statistical acceptance control" with admissible number of defective products equal to zero (1951) was published in Leningrad, in the collection of the Leningrad House of Scientific and Technical Propaganda.

Related works:

1953 Kordonsky H.B. Statistical acceptance control on flow and conveyor lines. Vestnik Mashinostroenia, 7.
1955 Kordonsky H.B. Application of Markov chain theory to batch control. Vestnik of Leningrad University, 11.
1956 Kordonsky H.B. The simplest form of product control. Standardization, 5.
1958 Kutai A.K. and Kordonsky H.B. Analysis of accuracy and quality control in mechanical engineering, chapters 3, 4. Mashgiz, M-L.
1959 Kordonsky H.B. Probable product quality. Standardization, 10.
1961 Kordonsky H.B. The distribution of the number of defective units in lots of products. Probability theory and its applications, 3.

And today, references to these first works by Khaim Borisovich Kordonsky are frequent. Thus, in the proceedings of "The International Symposium on Stochastic Models in Reliability, Safety and Logistics", held from 15 to 17 February this year in Israel, in the article Sh. Formanov and T.A. Formanova "Optimal plans of statistical acceptance control taking into account Sheppard corrections" we read: "We consider the problem of optimal plans of statistical acceptance control (SAC) studied by Kh. Kordonsky, S.Kh. Sirajdinov, Van der Varden, K. Stang".

In 1950-1955, under the leadership of Khaim Borisovich Kordonsky, the introduction of statistical methods of quality control was carried out at the VEF Plant, he provided scientific advice to the reliability services of the Avtoelektropribor Plant, the Wagon Plant and the Diesel Plant.

In 1963 a book by Khaim Borisovich Kordonsky Applications of Probability Theory in Engineering was published by the Publishing House of Physical and Mathematical Literature (Moscow, Leningrad). It was the first book in Russian on probability theory and mathematical statistics aimed at engineers, enabling them to master probability and statistical methods and apply them to their work.

A characteristic of Khaim Borisovich Kordonsky was a rare combination of knowledge of the mechanism of the physical processes under consideration and mathematics capable of describing them adequately. As a result, his books and articles (as well as his lectures) were

characterised by a striking simplicity and lucidity in the presentation of material that was quite complicated in content. For example, in his later book Models of Failure, he writes

The log-normal distribution describes the life behaviour of objects that have the property of "hardening" over time. "Hardening is manifested by a gradual decrease in the rate of wear. Therefore, before using the log-normal distribution to describe experimental data, it is necessary to determine, on the basis of the physical nature of the wear process and, if possible, by analysing the behaviour of wear realisations, whether the objects studied have the property of "hardening".

The Riga Aviation Institute, where Khaim Borisovich Kordonsky worked, trained engineers in aircraft operation, not aircraft manufacture. Heim Borisovich Kordonsky immediately saw a huge field for the application of probabilistic-statistical methods in conditions of the highest requirements for the reliability of aviation technology and flight safety. These requirements were ensured by a system of measures such as the use of lead aircraft (which had more flight hours than the entire fleet), inspections (to check the technical condition of the aircraft's power elements), maintenance and repair of aircraft. Many scientific problems arise: how many lead planes are needed and what should be the lead time (so that it is possible, with a certain degree of confidence, to assess the entire fleet in the conditions of its further operation), when to carry out inspections and how to predict the rate of development of the cracks detected, what are the terms and volumes of maintenance and repair work, etc.?

Khaim Borisovich Kordonsky soon became the undisputed authority in civil aviation on these issues. He carried out important research and made recommendations at the request of the Ministry of Civil Aviation, GosNII GA, operating and repair companies. At the same time, a large scientific team of talented and active young people was created in the department. His favourite student Ilya Gertsbach deserves special mention. In 1964 he brilliantly defended his doctoral thesis. His scientific supervisor was Khaim Borisovich, and his official opponent was Academician Boris Vladimirovich Gnedenko. The defence took place in the auditorium of the Academy of Sciences of the Latvian SSR and was a remarkable event in the scientific life of the Latvian capital.

Heim Borisovich Kordonski solved practical problems on a strictly mathematical level. As a result, the models, methods and algorithms he developed were universal and practically applicable to many technical systems (not only aviation and transport).

This fact is reflected in subsequent high-level scientific publications:

1964 Kordonsky H.B. Calculations and tests of fatigue durability. Proceedings of the 4th All-Union Mathematical Congress, Nauka, Moscow.
1966 Gertsbakh I.B., Kordonsky H.B. Failure Models. Soviet Radio, Moscow.
1969 Gertsbakh I. and Kordonsky Kh. Models of Failures. Springer, Berlin - Heidelberg - New York}
1967 Kordonsky Kh.B. Probabilistic analysis of stitching processes. Nauka, Moscow.
1969 Gertsbakh I.B. Models of Prevention. Soviet Radio, Moscow.
2000 Gertsbakh I.B. Reliability Theory with Applications to Preventive Maintenance, Springer, Berlin - Heidelberg - New York.

Let us dwell on two statistical problems posed by the needs of practice.

The first concerned methods of statistical processing of data on aircraft failures. In the literature on mathematical statistics and in data processing manuals, we have always considered the so-called case of complete sampling, where the estimation of the distribution of a random variable and its parameters is carried out on the basis of the exact values of the random variable recorded. In practice, this would mean that each product or performance element of a design would be operated to failure. In reality (to ensure reliability and safety), the operating time is limited by specified resources, premature shutdown (even of serviceable objects), etc. Khaim Borisovich Kordonsky introduced this class of problems into mathematical statistics and proposed the method of partitioning partitions for their solution, using the method of maximum likelihood.

Related publications:

1966 Gertsbakh I.B., Kordonsky H.B. Failure Models. Soviet Radio, Moscow.
1970 Artamanovsky A.V., Kordonsky H.B. Maximum likelihood estimation in simple data grouping. Probability Theory and its Applications, 1.
1985 Kordonski H.B., Rastrigin V.L. Random censoring on trajectories in phase space. Izv. of the Academy of Sciences of the USSR, Technical Cybernetics, 6.
1986 Kordonski Kh.B., Rastrigin V.L., Shulkin Z.A. Estimation of reliability indices under the action of several causes. Izv. of the Academy of Sciences of the USSR, Technical Cybernetics, 6.

Later, this problem developed into a whole branch of mathematical statistics called censored sampling. It is now one of the most important applied branches of mathematical statistics, with hundreds of famous mathematicians working on it, and there is a great deal of monograph and journal literature.

The second problem was the theory of unbiased estimation. At that time, when probability methods were just beginning to be widely used in practice, the models used were very simple. They usually involved one or more uniformly distributed random variables.

Therefore, the main effort of mathematicians was to develop methods to obtain the best estimates of the parameters of the main distributions of the random variables. The best estimates were understood as unbiased estimates with minimum variance. Much progress has been made and such estimates (when they exist) have been found (also for the cases of censored samples).

As experience grew, more complex situations were considered, where the subject of statistical analysis was large systems whose models included many random variables. The task was to estimate the performance of the system as a whole on the basis of statistical data relating to individual elements. This was done "the old-fashioned way": for each random variable (system element) we found the best estimate and substituted it for the corresponding unknown parameter of the probability model of the system. (In modern literature, this method is called the plug-in method).

This ignores the fact that (in the case of small samples) good properties of individual estimates are lost. This is natural, because in selecting these estimates we were not trying to optimise the system as a whole, but its individual elements. In order to get the best estimates for the system as a whole, it is necessary to keep it in mind at once, and not to consider separate problems of estimating individual parameters in isolation.

In mathematical statistics, fundamental results had already been obtained by S.R. Rao, A.N. Kolmogorov and D. Blackwell, but their practical use for the above purpose was out of the question. Under the leadership of Khaim Borisovich Kordonsky, the theory of unbiased estimation was applied for the first time in our country (and perhaps in the world) to the estimation of the performance of complex systems.

I remember a conversation we had after Khaim Borisovich Kordonsky returned from Moscow, a little excited after a business trip and full of energy: Sasha, how are you going to estimate, for example, the average waiting time in a unilinear mass service system with Poisson input flow and exponential service time?

Here are the most important publications on unbiased estimation:

1972 Andronov A.M., Kordonsky H.B., Rosenblit P.Y. Application of unbiased estimation theory to mass service problems. Izv. AS USSR Technical Cybernetics.
1976 Kordonsky H.B., Rosenblit P.Y. On unbiased estimation of polynomials from moments. Probability theory and its applications, 1.
1979 Rosenblit P.J. Statistical estimation of reliability and efficiency characteristics of complex systems. Zinatne, Riga.
1982 Larin M.M. Unbiased estimates of variance and some other characteristics of the inverse normal distribution. Izv. AS USSR, Technical Cybernetics.
1989 Voinov V.G., Nikulin M.S. Unbiased estimates and their applications. Nauka, Moscow.

In downloading the history of Khaim Borisovich Kordonsky as a scientist and educator in probability theory and especially in mathematical statistics, here is a quotation from S. Radhakrishn Rao from the preface to his book Linear statistical methods and their applications, Nauka, Moscow, 1968 (Linear statistical inference and its applications, John Wiley & Sons, New York, 1966): I wish to express my gratitude to Ronald A. Fisher and Professor Mahalanobis, under whose influence I have come to appreciate mathematical statistics as the new method of our century.

In the same words, we express our gratitude to Khaim Borisovich Kordonsky.

## 3. Computer scheduling of civil aviation aircraft

In 1963, the GA Scientific and Computer Centre was established on the basis of the Riga Flight Automation Laboratory, which was part of the RCII GA. After two years of confusion, Associate Professor Lev Fedorovich Krasnikov was appointed its director in 1965. He invited Khaim Borisovich Kordonsky to form the main scientific directions of the NVC. In 1971, the SAA NVC was transformed into the Central Research Institute of Automated Control Systems, headed by Gennady Tikhonovich Kalchenko.

For almost 35 years, Professor K.B. Kordonsky was the scientific director of the work of NVTS GA and the Central Research Institute of ACS GA on computer planning of civil aviation aircraft - the largest airline in the world at that time.

Some of the works of this period of great importance:

1969 Kordonsky H.B., Gerzbach I.B., V. Venyavtsev, Maxim M., Linis V. A heuristic method for aircraft scheduling. In Collection of Automation in Mechanical Engineering, USSR Academy of Sciences, Moscow.

1969 Kordonsky H.B., Linis V. et al. Algorithms for scheduling passenger airplanes. In Proceedings of the 4th Congress on Automatic Control, Warsaw.

1970 Kordonski H.B., Venyavtsev V., et al. Central aircraft scheduling as part of air traffic control. In Proceedings of the 1st International Symposium on Traffic Control, Versailles.

1999 Kordonsky Kh.B., Gertsbakh I.B.. Using Entropy Criterion for Job-Shop Scheduling Algorithm.

Of course, the main result was not the publications, but the central flight plan that civil aviation flew. It was the world's first computerised timetable. Given the state of computer technology at the time, one wonders how this was possible: bicast computers that ran continuously for more than 24 hours to compile a piece of the timetable; punched tapes with the compiled timetable; linotype machines that printed a hard copy of the timetable. It was

made possible by the talents of Khaim Borisovich Kordonsky and the dedication of the young team who believed in him: Valery Venyavtsev, Ilya Gertsbakh, Misha Maxim, Yuri Paramonov and many others.

Ilya Gertsbakh wrote in the introductory article of the Proceedings of the 1999 Aviation Reliability-99 conference dedicated to the 80th birthday of Khaim Kordonsky:

Together with Yu. Paramonov, V. Venyavcev, M. Maksim and V. Linis, I worked on this project for seven years, which were probably the most productive and interesting years of my life. Now I realise that we were all extremely lucky to work under the leadership of such a brilliant scientist and outstanding personality as Khaim Borisovich.

The planning project was a very difficult and complex task. Nobody in the Ministry's top management had the slightest idea of how to approach it or what was meant by the term "computerised scheduling". In addition, the computers at that time were extremely primitive. The "Ural-4", which took up an entire floor of an old church, had less power than a modern pocket calculator. Even with modern computer power, it takes a man of exceptional intellectual courage to take on the challenge of leading such a project.

From Prof. Kordonsky we learnt important things for our whole life. The first lesson was: before you start doing the computerised schedule, you should be able to do it manually. This was wise advice, because it was only after a year of intensive contact with practitioners that we began to understand what scheduling was about, what was essential and what was secondary.

Prof Kordonsky was never a "boss" who gave orders and instructions. He created a stimulating atmosphere of intense exchange and discussion, sometimes heated, but always efficient. He was open to every suggestion and critical comment. Despite this enormous scientific authority, no one was afraid to ask questions or to insist on their opinion. I am convinced that the truly democratic nature of our group was a key factor in the success of the project.

## 4. American Period

The most recent works of Chaim Borisovich Kordonsky are devoted to the theory of calculating the time of degradation of systems whose operating time is measured in different scales (calendar time, number of cycles, hours of operation in different modes, etc.).

Most of these works have been published in leading foreign scientific journals:

1993 Kh.Kordonsky and I.Gertsbakh. Choice of the Best Time Scale for Reliability Analysis. Europ. J.Operat. Res., 65.
1994 Kh.Kordonsky and I.Gertsbakh. Best Time Scale for Age Replacement. Inter. J. of Reliab., Quality and Safety Engineering, 1.
1995 Kh.Kordonsky and I.Gertsbakh. System State Monitoring and Lifetime Scales. I, II. Reliab. Engineering and System Safety, 47, 49.
1997 Kh.Kordonsky and I.Gertsbakh. Multiple Time Scales and the Lifetime Coefficient of Variation: Engineering Applications. Lifetime Data Analysis, 3.
1997 Kh.Kordonsky and I.Gertsbakh. Fatigue Crack Monitoring on Parallel Time Scales. Proceedings of ESREL 97, Lisbon, June 17-20, 1997, 2.
1997 Kh.Kordonsky and I.Gertsbakh. Optimal Preventive Maintenance in Heterogeneous Environments. Europ. J.Operat. Res., 98.
1998 Kh.Kordonsky and I.Gertsbakh. Parallel Time Scales and Two-Dimensional Manufacturer and Individual Customer Warranties. IIE Transactions, 30.

The bright image of Chaim Borisovich Kordonsky will always remain in the memory of his grateful students and followers.

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