On the occasion of the 80th birthday of L.P. Nesenyuk, a talented designer and developer of modern gyroscopic technology

V. G. Peshehonov\textsuperscript{1}, O. A. Stepanov\textsuperscript{2}, O. M. Yashnikova\textsuperscript{3}, and Yu. A. Litvinenko\textsuperscript{4}

\begin{itemize}
\item \textsuperscript{1} Dr. Sci., Academician of the Russian Academy of Sciences, JSC "Elektroprivobor", ITMO University, St.-Petersburg, Russia
\item \textsuperscript{2} Dr. Sci., Corresponding Member of the Russian Academy of Sciences JSC "Elektroprivobor", ITMO University, St.-Petersburg, Russia
\item \textsuperscript{3} JSC "Elektroprivobor", ITMO University, St.-Petersburg, Russia
\item \textsuperscript{4} Cand. Sci., JSC "Elektroprivobor", ITMO University, St.-Petersburg, Russia
\end{itemize}

E-mail: ya_litvinenko@mail.ru

Abstract. The article is in honor of the 80th birthday of Leonid P. Nesenyuk (1940–2009), Doctor of Technical Sciences, Professor, the Winner of the Russian Government Prize, Laureate of the N.N. Ostryakov Prize, the scientist who has made a significant contribution to the development of modern gyroscopy.

1. Biography
Leonid P. Nesenyuk was born in Kiev, Ukraine, on April 25, 1940. His parents were teachers. Both of them graduated from the Physics and Mathematics Faculty of Kiev University. His father, Nesenyuk Petr, was a math teacher, and his mother, Nesenyuk Raisa, a physics teacher. At the age of seven, Lenya went to School No. 92 with Ukrainian as a teaching language. The school was located in Lenin Street (now Bohdan Khmelnytsky Street), 11. The family lived in the school premises since his father was appointed Director after the end of World War II [1].
Lenya was a curious and active boy: in his school years, he went in for sports and was a member of different study groups. His hobby and passion was marine modeling, and many times he was a winner of regional and city mathematics olympiads. His parents tried to cultivate love for art in him and his sister Alice. The family often went to theaters. Nesenyuk retained his interest in art throughout his life.

Nesenyuk received an excellent education at the Instrument Engineering Faculty of N.E. Bauman Moscow Higher Technical College Bauman Moscow State Technical University. In those days, there was a great demand for engineers in gyroscopic devices. That was the reason why in 1959, N.E. Bauman Technical College Bauman Moscow State Technical University announced an additional admission of students from other universities to the 2nd and 3rd-year courses.

The curriculum was so broad that the students had to take additional exams in no less than 10 different subjects before December 1. Apart from courses in mathematics and physics, students attended classes for novices in mechanical engineering workshops, which began at 7 o’clock in the morning. Everybody worked hard, and all of them knew: the students who would fail the exams in additional subjects at the beginning of December would be expelled (in fact, approximately 20% of the students were either expelled or were unable to withstand that race). Even at that rough time, Nesenyuk went to theaters, visited art exhibitions, and had a reputation of a know-all in literature and art among his fellow students. He studied hard and, at the same time, worked part-time as a laboratory assistant.

After the fifth-year, Nesenyuk went to Leningrad for a diploma course. It is in this city that he lived and worked for the rest of his life after he joined the Central Scientific and Research Institute (CSRI) Elektropribor in 1963.

2. Scientific work
The first independent scientific work of engineer Leonid Nesenyuk was a study of the ship motion effect on the vertical gyro performance. The results of observations obtained on a submarine and surface ships provided a large amount of data, which allowed Nesenyuk to assess the statistical characteristics of ship motions and identify the spectra of linear accelerations that affect the accuracy of gyroscopic devices. That was laborious, time-consuming work, which significantly advanced understanding of how ship motions affect marine gyro instruments. Probabilistic models of gyroscopic devices and the impacts to which the latter are subjected are widely used in the works of Leonid Nesenyuk. Both he and his scientific adviser Igor’ Chelpanov, professor and honored worker of science and technology of the Russian Federation followed the frequency approach in their joint and independent research. Though Nesenyuk was proficient in a more complicated Kalman filtering theory and practice, he gave preference to frequency methods and achieved significant results in this area. These methods were generalized in relation to vertical gyros in his Candidate of Sciences dissertation (1969) and in the monograph Calculation of Characteristics of Navigation Gyro Devices written by I.B. Chelpanov, L.P. Nesenyuk, and M.V. Braginskii (in Russian) [2], published in 1978. Later, in his Doctor of Sciences dissertation Analytical Methods for Calculating Optimal-Accuracy Ship
Gyroscopic Systems (1990), Nesenyuk continued developing frequency methods of analysis and synthesis of gyroscopic systems. His doctoral dissertation was read backwards and forwards by his colleagues.

In the 1980s, Leonid Nesenyuk was already one of the leading gyroscopists at Elektropribor. He was appointed Head of the Inertial Systems Department. Nesenyuk was one of the first researchers to realize the potential opened up owing to medium earth orbiting satellite navigation systems (SNS). Whereas the developers of navigation systems traditionally considered them as a means of periodic high-precision correction of data from gyroscopic devices, his ambitions were to develop qualitatively new integrated navigation systems in which data from inertial sensors and SNS could be optimally integrated. He tried out the first development prototype of the integrated system through the streets of St. Petersburg on his well-worn Zhiguli.

Later on, the system was taken for trials on the Gulf of Finland on the border patrol ship Vyborg, research vessels Professor Shtokman and Nikolai Matusevich. After those successful trials, a decision was taken to purchase some fiber optic gyroscopes (FOG), which gave a start to the Mininavigation R&D and later, a prototype with the same name was manufactured [3].

In the same period, the idea of creating a FOG-based gyrocompass emerged. It was at Nesenyuk’s suggestion that a prototype of an attitude and heading reference system (AHRS) Mininavigation K with autocompensating rotation of the FOG-based unit of sensors was developed. Nesenyuk and a group of like-minded colleagues undertook titanic activities, which resulted in the creation of a series of FOG-based inertial measurement units (IMU), which have found wide application both as part of integrated systems and as an autonomous means of navigation and orientation/attitude reference. After the first tests, the idea was implemented in the Zenith-SK course detector for the autonomous deep-submergence vehicle Rus’, in transport heading indicators for ground-based mobile missile systems, and in the Bekar-N small-sized gyroscopic stabilization and heading reference system [4].

Judging by the studies mentioned above, it is obvious that Leonid Nesenyuk was a talented development engineer who generated new challenging engineering approaches and implemented them in an optimal way. In 2002, Nesenyuk was awarded the N.N. Ostryakov prize for the accomplishments in the development of FOG-based gyroscopic systems. The prize was named after the outstanding designer of gyroscopic devices. Since 1996, the prize has been awarded by the Academy of Navigation and Motion Control. Leonid Nesenyuk was one of the active members of Academy.
The development of a strapdown inertial navigation system (SINS) with FOGs required that the FOG accuracy be increased by at least an order of magnitude. Professor Nesenyuk took charge of the group concerned with the development of the new gyroscope with the required accuracy. He initiated collaboration with the Department of Physics and Technology of Optical Systems of St. Petersburg ITMO University headed by Professor I.K. Meshkovsky. A large number of technical problems and organizational matters were resolved in the process of the development; additional contractors were involved to work for this project.

The FOG breadboards were developed within the shortest possible time. Thereafter, in 2007, some FOG prototypes were manufactured. The gyros demonstrated satisfactory characteristics and, thus, paved the way towards the creation of SINS with FOGs of our own production.

Already at the beginning of 2009, the experimental FOG-based SINS underwent the first tests, which confirmed that the FOG accuracy grade and its operational characteristics were sufficient for the development of a FOG-based SINS that could replace shipborne medium-accuracy INS with triaxial stabilizers on floated or dynamically tuned gyroscopes [5].
In 1997, V.G. Peshekhonov, General Director of the CSRI Elektropribor, set the task to study the possibilities of creating domestic micromechanical sensitive elements and find a technological base capable of implementing the required technical characteristics. This pioneering project was again taken over by Professor Nesenyuk. First, he was going to develop only inertial measurement modules using purchased MEMS gyros. But since there were no domestic MEMS gyros, he decided to start with the development of such gyros. The research team led by Nesenyuk successively designed different variants of MEMS gyros, studied their characteristics, identified the factors affecting their accuracy parameters, and achieved remarkable results.

The experience of the CSRI Elektropribor in the development of strapdown IMU and attitude control systems based on fiber-optic gyroscopes made it possible to develop an integrated inertial/satellite attitude and navigation system using domestic MEMS gyros. The software, calibration and test methods, as well as the design solutions created during the development of systems on fiber-optic gyroscopes were largely used in the development of systems on MEMS gyros [6].

Creation of a new scientific school at Elektropribor was one of the results of Nesenyuk’s work in this area. The employees of the CSRI Elektropribor involved in that project successfully defended a Doctor of Sciences dissertation and some Candidate of Sciences dissertations on MEMS gyros.
Another very important line of Nesenyuk’s scientific activities was gravimetry. The CSRI Elektropribor and the Schmidt Institute of Physics of the Earth of the Russian Academy of Sciences had been successfully working together in this field for a long time, but Nesenyuk added a fresh impetus in the research, so that gravimetric projects continued developing more quickly and efficiently. He suggested using GNSS data in the processing of gravimetric data, owing to which the survey accuracy increased considerably. The next significant step was the development of an airborne gravimeter. It took several years to develop the Chekan-AM airborne gravimeter, which is currently successfully used not only by all offshore exploration expeditions in Russia, but also by foreign companies from Norway, Great Britain, the USA, and Germany [7]. Together with his colleagues who were engaged in the development of a mobile gravimeter, Nesenyuk was awarded the Prize of the Government of the Russian Federation in the field of science and technology in 2005.

It is important to mention another essential aspect of Professor Nesenyuk’s activities: promotion of science and research in the CSRI Elektropribor and in the Academy of Navigation and Motion Control and involvement of capable and concerned youth in scientific research. Although he was overloaded with work, he would always find time to support initiatives concerned with youth education, whether it was giving lectures for students of intensive targeted training groups or participating in the conference of young scientists Navigation and Motion Control, wherein Nesenyuk was a permanent head of the section on integrated INS/GNSS systems and delivered many plenary lectures. He never missed the opportunity of going to the Ladoga test base to participate in youth scientific workshops. Since 2011, the attendees of the Conference of Young Scientists compete for prizes named in memory of outstanding researchers who worked for the CSRI Elektropribor and made significant scientific contributions to the development of the Institute. One of the prizes is named to honor Leonid Nesenyuk. [8].
Fig. 6. Participants of the workshop for young scientists at the Ladoga test base of the CSRI Elektropribor. September 2003.

Of course, Leonid Nesenyuk took part not only in scientific events intended for youth, but also in all other conferences held by CSRI Elektropribor. Since he had a good command of English, he was ready to engage in scientific communication at the international level as soon as the opportunity came. Nesenyuk attended all Soviet-Chinese symposia on inertial technology held in 1991–1994. He was a member of the program committee and head of sections of the annual International Conference on Integrated Navigation Systems held at the CSRI Elektropribor since 1994, an organizer of symposia on gravimetry, visited different scientific events abroad: in the USA, Germany, and France.

Leonid Nesenyuk was known as an all-round intellectually developed person. He could play tennis, was a good swimmer, and, in addition, an excellent chess player. He used to say: “All of us play chess the same way! One of us is just more lucky, whereas others may have a bad luck”. These words have become the motto of the famous E2–E4 chess club at Elektropribor, wherein Leonid Nesenyuk became the first champion in 1971. Nesenyuk was very musical. He loved classical music and often visited symphony and chamber music concerts. At the same time, he liked good jazz and gypsy songs. Regardless of the topic of discussion, the interlocutors were always impressed by his broad knowledge, prodigious memory, kindness, diligence and respect to other people. Life was always in full swing around Leonid Nesenyuk. He was surrounded by many young people who strove for interesting work. He generously shared his knowledge and energy with them, gave them moral support and, when the time came, let them sail on their own. Leonid Nesenyuk always sincerely rejoiced at the achievements of his students. Scientific lines laid down by Leonid Nesenyuk are currently being developed by his disciples, among whom are the First Deputy General Director A.V. Sokolov, heads of departments G.A. Adushev, Ya.V. Belyaev, D.V. Volynsky, A.A. Krasnov, and O.M. Yashnikova. The personality of Leonid Nesenyuk, scientist, intellectual, erudite, has had a profound impact on people who worked with him. The scientific legacy of Leonid Nesenyuk will continue to be the basis for scientific research of his colleagues, students, and followers for many years to come.
References

[1]. Pamyati professora Nesenyuka. Ezbrannye trudy i vospominaniya (In Memory of Professor L. P. Nesenyuk. Selected Papers and Memoirs) St. Petersburg, CSRI Elektropribor, 2010.

[2]. Chelpanov, I.B., Nesenyuk, L.P., and Braginskii, M.V., Raschet kharakteristik navigatsionnykh priborov (Calculation of Characteristics of Navigation Gyrodevices), Leningrad, Sudostroenie, 1978.

[3]. Blazhnov, B.A., Nesenyuk, L.P., Peshekhorov V.G., and Starosel’tsev, L.P., Miniature integrated orientation and navigation systems for hydrographic vessels and boats, Giroskopiya i Navigatsiya, 2001, no.1, pp 20-30.

[4]. Nesenyuk, L.P., Starosel’tsev, L.P., Ignat’ev S.V., and Evsteeva, O.M., Autonomous attitude control system for underwater vehicles based on fiber-optic rotation sensors, Sbornik trudov Nauchno-teknicheskoy konferentsii “Tekhnicheskie problemy osvoyeniya Mirovogo okeana”. IPMT DVO RAN, Vladivostok: Dal’nauka, 2007, pp. 16–32.

[5]. Meshkovsky, I.K., Strigalev, V.Ye., Deineka, G.B., Peshekhorov, V.G., and Nesenyuk L.P., A Three-Axis Fiber-Optic Gyroscope for Marine Navigation Systems, Proc.16th Saint Petersburg International Conference on Integrated Navigation Systems, St.Petersburg: CSRI Elektropribor, 2009, pp. 7–11.

[6]. Peshekhorov, V.G., Nesenyuk L.P., Gryazin, D.G., Nekrasov, Ya.A., Evstifeev, M.I., Blazhnov, B.A., and Aksenenko, V.D., Inertial modules based on micromechanical sensors. Development and test results, Giroskopiya i Navigatsiya, 2008, no. 3, pp. 3–12.

[7]. Zheleznyak, L.K., Koneshov, V.N., Nesenyuk, L.P., Peshekhorov, V.G., Elinson, L.S., Il’in, V.N., Chichinadze, M.V., Bronstein, I.G., Knyazev, Yu.A., Parusnikov, N.A., Dual-purpose gravimeters for measurements from sea vessels and aircraft, Izvestiya vuzov. Priborostroenie, 2005, vol. 48, no. 5, pp. 23–28.

[8]. Peshekhorov, V.G., Stepanov, O.A., Litvinenko, Yu.A., Eliseev, D.P., and Yashnikova, O.M. The experience in holding the Conference of Young Scientists “Navigation and Motion Control”. The 16th IAIN World Congress 2018 in Makuhari Messe, Chiba, Japan, November 2018, IET, 2018, pp. B4-2.