Commemorating the 90th anniversary of Joseph Grigorevich Hakobyan. Milestones of creative and design activities

Joseph Grigorevich HAKOBYAN was born on 28 August 1931 in Saratov, the city to which his parents were assigned when after graduating from the Communist Institute of Journalism in 1929. In 1935 the family returned to Moscow, and Joseph went to school No. 59. When the Great Patriotic War broke out, Joseph was in a pioneer camp near Moscow. The camp was closed and he stayed with his mother in Moscow until September 1941. His father, as a Regimental Commissioner, joined the field forces in the evening on 22 June 1941. Joseph could never forget bombardments of Moscow, which started on 27 July, air raid alerts every evening and nights spent in a bomb shelter, blacking-out, antiaircraft balloons, sound detecting units, searchlight units, antiaircraft artillery fire. In September 1941, the mother and son were evacuated to a small remote village in Chkalov Region (currently Orenburg Region), then they moved to Orsk, and in 1944 to Buguruslan where his mother worked as the editor-in-chief in the Buguruslanskaya Pravda newspaper and Joseph studied in Kalinin school which he finished in 1949 with a medal.

Buguruslan is a small country town with population less than 50 k people. But an experienced short-wave radio amateur from Moscow happened to be evacuated there. He was a student of Ernst Krenkel, a radio specialist and Arctic explorer well known in the Soviet Union. This person arranged a radio operator course and short-wave radio club in the town in 1947 (!). Joseph finished the course and perfectly mastered the Morse code, he actively took part in works on creation of a short-wave amateur radio station for two years. As an operator, he held radio communication sessions with radio amateurs from all continents. Meanwhile, he never abandoned his education and participated in Moscow absentia competitions on physics and mathematics.

After school, he decided to study in Moscow State University (MSU). There was no Physical and Technical Institute at that time but a Physical and Technical Faculty existed in Moscow State University. He chose the Physical Faculty because Radar Department was a part of the Radiophysics Division. His admission interview in MSU was successful and his radar amateur experience was highly appreciated.

In 1949 MSU occupied small facilities in downtown Moscow on Mokhovaya Street. Construction of a new building on Lenin Hills was only at the design stage. Students were involved into the beginning of MSU laying out and construction. Their dormitory was on Stromynka Street, about 9 students lived in one room; to attend the classes, they had to cross the whole city. But there was innovative atmosphere, outstanding teachers, and exciting topics. At that time, more

than 20 k students studied in MSU, but it turned out that there was no collective short-wave radio station in the University. Joseph and another short-wave radio amateur (Great Patriotic War veteran Yu. Lobanov) approached I. Petrovsky, Rector of MSU, Member of the Academy of Sciences, asking for a facility and assistance to arrange a radio club. The Rector met the needs of the students and allocated the facility in the dormitory on Stromynka Street, where the collective radio station was launched, managed by the initiators. Further history of the station after the new MSU building construction and new students admission is unknown.

The MSU reserve-officer training department prepared competent radar engineers based on the foreign equipment left following the War. After second and fourth years of education, instead of vacations, the students undertook two-month internship in air defence units (before domestic military radars were invented) which used American and British equipment. This was of great benefit for the Radar Department students. Professor Vladimir Vasilevich Migulin, Head of the Department, multiple Laureate of the Stalin Prize, invited leading specialists of research institutes and design bureaus working on the radar issues to lecture. But even such education approach was not sufficient for the students to become fully competent specialists – work experience in research institutes and design bureaus was required to achieve this goal.

J. G. Hakobyan's diploma paper directly related to the radar issues. The Main Missile and Artillery Directorate of the Ministry of Defence requested to create a highly accurate crystal range-marker oscillator for radars. To do this, collision excitation and quick forced crystal oscillation damping issues had to be solved. In 1953 J. G. Hakobyan was appointed a responsible designer for this device. A crystal resonator is easily excited by an electrical pulse but it is very hard to damp its oscillations, since it has a high Q-factor. The work was successfully completed, several articles on the issue of crystal oscillation damping within 2–3 periods were published in research journals, and the diploma paper was highly appreciated.

Following his graduation, J. G. Hakobyan was assigned to the resident postgraduate training program of the Radar Department. Professor V. V. Migulin was his research advisor. However, the research advisor proposed a thesis paper topic not related to the radars. Statistical radiophysics development was booming at that time. J. G. Hakobyan was offered to work on synchronization of electric oscillators using an external signal under fluctuation jamming. It was required not only to create a theory of synchronization under jamming, but also to check the estimation conclusions by experiments. At that time, prominent physicists and mathematicians were occupied with the theoretical studies of synchronization under jamming. Several works were published by R. V. Khokhlov, future Member of the Academy of Sciences and Rector of MSU, V. I. Tikhonov, Professor of Zhukovsky Air Force Engineering Academy, and, most importantly, Ruslan Leontevich Stratonovich, the author of prominent theoretical works on statistical radiophysics.

J. G. Hakobyan, Member of the Russian Academy of Rocket and Artillery Sciences, remembers that R. L. Stratonovich was the real genius gifted equally even to Lev Davidovich Landau, Member of the Academy of Sciences. R. L. Stratonovich demonstrated his extraordinary abilities in everything. He was able to solve mentally such mathematical tasks that even luminaries in mathematics could not solve. Considering the general situation, it was very hard to write a creative theoretical part, and even harder to set up experiments and confirm the theoretical results even for outstanding theorists. J. G. Hakobyan managed to establish creative cooperation with R. L. Stratonovich, and they published their joint theoretical works. J. G. Hakobyan's thesis for his degree of the Candidate of Sciences (1959) covered the Einstein – Fokker – Planck non-linear differential equation solution, tables and plots of the functions, the experimental part of the thesis confirmed the estimations correctness. Prominent scientists S. M. Rytov and V. I. Tikhonov were his opponents during the thesis presentation. S. M. Rytov offered Joseph a position in Lebedev Physical Institute of the Academy of Sciences of the Soviet Union. It could appear that a young scientist having research skills should make his career in the statistical radiophysics, but he

was assigned to work in newly created Special Design Bureau No. 15 (OsKB-15, currently, JSC V. V. Tikhomirov Scientific Research Institute of Instrument Design) after the resident post-graduate programme. The Bureau was headed by Viktor Vasilevich Tikhomirov, General Design Engineer, Corresponding Member of the Academy of Sciences of the USSR, multiple Laureate of the Stalin Prize.

In 1958 OsKB-15 jointly with Machine Building Design Bureau "Vympel" (Chief Design Engineer and Head I. I. Toropov) was assigned to develop a surface-to-air missile complex with missiles controlled by semi-active radar homing heads (RHH) with Doppler selection ensuring homing on low-flying targets. During his first meeting with newly employed senior engineer J. G. Hakobyan, V. V. Tikhomirov decided to assign him to the laboratory to develop RHH. It was a fully new area, the RHH with Doppler selection had not been previously developed, there was no solid state hardware base, digital equipment was just emerging. It was required to create a mini analogue receiver of continuous radio signal with narrow-band Doppler filtering and a direction finder using mini vacuum tubes with fly leads and only domestic radio hardware.

By August 1958, a team of 7 people headed by J. G. Hakobyan created a non-structural prototype of the receiver and direction finder of the RHH, mock-up lighting radio signal generator; a fighter radar was adjusted to be used for target indication, the RHH mock-up and designator were located in two separate vans on an aerodrome in Zhukovsky; they performed a number of successful test flights. Then V. V. Tikhomirov established a separate laboratory for RHH development that reported to him personally. In 1960 he established Radar Homing Head Department and appointed J. G. Hakobyan, Candidate of Physical and Mathematical Sciences, its Head and Chief Design Engineer. It should be noted that about 1,000 people worked in OsKB-15 at that time, but only one of them was Candidate of Engineering Sciences (!), J. G. Hakobyan became the second person having a scientific degree.

Development of RHH 1SB4 progressed very hard. People worked almost round the clock, spent nights in the office to avoid travel time. Under the applicable standards, equipment vibration resistance was to be within the vibration range up to 2,000 Hz under the sinusoidal input for the entire vibration frequency range, hardware broke down and thin connecting leads broke on resonating frequencies. The RHH designers managed to prove that the tests had to be with noise-type vibrations not causing the hardware resonance. The relevant testing equipment was created; today missile element testing with vibration noise is legalized.

When developing RHH 1SB4 for Kub surface-to-air missile complex 3M9, numerous new research issues had to be solved: scanning noise, antipode impact addressing (target signal re-reflected by earth or water surfaces), impact of distortions due to a radioparent radome on homing accuracy, target interception on a missile flight trajectory, etc. Due to many reasons, the Kub surface-to-air missile complex creation had to be postponed, and in 1962 V. V. Tikhomirov was relieved from his office. Yuriy Nikolayevich Figurovskiy was appointed the Chief Design Engineer of Kub and the Head of the enterprise. Kub factory and joined tests were successfully completed in 1965. A record-breaking low flight altitude of the hit target was just 15 m above ground. More than 100 controlled launches were performed during the tests. In 1972 the Lenin Prize and later the State Prize were awarded for development and mass production of Kub. At that time, several works were printed in publicly available and restricted access scientific publications, Inventor's Certificates were issued. The Kub surface-to-air missile complex was modified thrice, its characteristics were significantly improved, as well as jamming resistance. RHH 1SB4 was in great demand, so three plants were engaged in its mass production in different cities.

Kub's success was appraised by V. P. Efremov and L. V. Lyulyev, creators of the Krug surface-to-air missile complex. They proposed to install RHH 1SB4 in Krug surface-to-air missile complex missile 3M8. In 1967–1968 this work was successfully completed and confirmed by 19 controlled launches with warhead detonation directed towards the target. But the work was stopped by V. P. Efremov and L. V. Lyulyev when discussing further developments of surface-to-air

missile complexes 300P and 300V as it could become a competitor to 300V. However, the joint efforts allowed cooperation when developing the Buk surface-to-air missile complex.

The RHH's ability to intercept a target when it is lost on a flight trajectory allowed opting out of target interception on a launcher used for Kub. The required distance between the launcher and an illumination radar exceeded 100 m due to the influence of the transmitter's direct signal on the RHH via side lobes of the radar and RHH. Thus, illumination and missile radars could be placed on the same vehicle for the Buk surface-to-air missile complex the design of which was requested in 1969. Design Bureau "Novator" was assigned to develop missile 9M38, L. V. Lyulyev being the Chief Design Engineer managing this design bureau. Development of RHH 9E50 for this missile was easier than for 1SB4. It was possible not to use vacuum tubes, and use only transistors and brand-new microcircuits. Analogue computing systems were replaced with hard-wired digital computers. The RHH was equipped to receive radio correction signals which made it possible to adjust a flight mission under extensive target manoeuvring and report on jamming actuation. At the height of the Buk testing on site, the Emba new jamming station for external jamming protection was created; the General Customer requested to ensure protection against such jamming as well, i.e. additionally to the agreed Terms of Reference. The Buk testing was stopped, there was a need to find ways to protect against the new jamming. Proponents of the command control (and there were quite a few of them) predicted the end of radar homing. But J. G. Hakobyan managed to find a technical solution ensuring the RHH protection against such jamming and further Buk testing. There are several works in publicly available and restricted access scientific publications on anti-jamming, Inventor's Certificates were issued, academic degrees were gained. Buk was fielded in 1982 and received the State Prize of the USSR. It was upgraded four times, the Russian Federation Government Prize was awarded for two of them.

At the same time, Scientific Research Institute of Instrument Design started development of intercept aerial launch platform (IALP) MiG-31 with "Vympel" missile K-33. This RHH's peculiarity is intermittent operation; since MiG-31 was to be able to ensure four targets firing simultaneously, target lock-on was possible only on the missile flight trajectory. The RHH was equipped to receive radio correction signals. MiG-31 development and testing in Akhtubinsk were completed only in 1984. Only domestic hardware components were used, including transistors and a hard-wired special digital computer. Inventor's Certificates were issued for the technical solutions adopted for this design, the articles were published. The Lenin Prize and State Prize of the USSR were awarded for achievements related to the IALP development (Chief Design Engineer K. K. Vasilchenko).

Along with the RHH development, J. G. Hakobyan initiated and managed civil and research works. In 1970 receivers for Large Siberian Solar Radio Telescope were developed and awarded the Prize of the Council of Ministers of the USSR. Upon a Central Aerohydrodynamic Institute's request, laser Doppler velocity meters for gas and liquid flows were developed and installed on several wind tunnels of this Institute. In the 1990^{s} creation of hi-tech medical equipment was started. Non-invasive bilirubin meter, uroflow meter for urologic examination and three options of a digital ECG recorder (with desktop computer, with laptop and a small portable one having combined power supply and integrated printer) were developed and certified. Software for cardiac waveforms reading and provisional diagnosis making was installed on all the ECG recorders. The developments were awarded diplomas and medals on international exhibitions in Brussels and Düsseldorf. But their mass production was not launched, since medical officials were not willing to order domestic equipment, giving preference to foreign substitutes (which were more expensive and less efficient). Articles were published and patents were issued following the civil developments.

In the middle of the 1970^{s} there was information on development of the active RHH in the USA which applied the "launch-and-forget" principle. The department of Scientific Research Institute of Instrument Design managed by J. G. Hakobyan and worked on the RHH development started to work in this area.

The Soyuz joint research and test work with Research and Production Corporation "Istok" (Head S. I. Rebrov) on the ARHH for medium-range air-to-air missiles was started in 1979; in 1982 the order for Design Bureau "Vympel" to develop air-to-air missile K-77 with ARHH 9B-1348 was issued. Scientific Research Institute of Instrument Design was appointed the main designer of the ARHH, Research and Production Corporation "Istok" – the co-designer. When Research Institute "Agat" was established in Moscow in 1986, the work proceeded there. A small multiple-beam klystron by "Istok" was used as the output tube of the ARHH's transmitter. Under the cooperation, the ARHH's blocks were partly developed by "Agat" and partly – by "Istok". The work was hard, there were multiple reciprocal claims demonstrating relations of the Ministry of Radio Technology and the Ministry of Electronics Industry. The work was successfully completed in 1994, but the mass production was not launched: Kiev Plant "Kommunist", which produced the ARHH prototypes ended up in another country, and, in general, it was hard time – the "chaotic nineties". Foreign customers were interested in supplies of missile PBB-AE (the missile's export name). Thus, "Istok" and "Agat" autonomously arranged the ARHH mass production, and "Vympel" – the missile mass production. Thanks to this, the companies managed to survive the chaotic nineties. ARHH 9B-1348 was developed using modern hardware components, included a reprogrammable digital computer developed by "Agat" and domestic microcircuits.

Works performed at that time significantly prompted the technology of the ARHH creation, ensured a several-fold decrease of the ARHH's weight and dimensions and the use of modern (including imported) hardware components for further developments made it possible to consider the ARHH for short-range missiles as well. The semiconductor technology progress has allowed to stop using vacuum tubes for the ARHH's transmitters for which high voltage power is required, and to develop the transmitters within the Ku and Ka bands with semiconductor hardware, which minimise the cold start readiness time.

Cutting edge digital and analogue technologies were used in recent developments of JSC Machine-Building Design Bureau "Fakel", JSC Machine Building Design Bureau "Vympel", OJSC Dolgoprudnenskoye Scientific Production Plant and JSC Experimental Design Bureau "Novator". Possibility of half-scale and mathematical simulation ("Agat" has two half-scale simulation benches) ensured significant reduction of the site testing scope. During the entire history of the RHH and ARHH development, no foreign developments were copied, and the domestic developments meet the level of their foreign substitutes. Under the military technical cooperation, several types of the ARHH were developed for foreign customers and highly rated.

After 21 years in the "Agat" CEO and General Design Engineer office, J. G. Hakobyan changed his position and became General Design Engineer – Deputy CEO (CEO Dmitriy Dmitrievich Evseev) in 2007, and Research Advisor – Advisor to CEO of "Agat" (CEO Mikhail Alekseevich Ivanchikhin) in 2016.

Recent works published by J. G. Hakobyan are dedicated to protection of high-security facilities against mass aerial attacks and impact of radar signal reflection from ground surface when tracking the ARHH and by air target radars "bottom-up" over an underlying surface.

J. G. Hakobyan is the Honoured Scientist of the Russia Federation, Member of the Russian Academy of Rocket and Artillery Sciences, Doctor of Engineering Sciences, Professor, Laureate of the Lenin Prize, Laureate of the State Prize of the USSR, two-time Laureate of the Russian Federation Government Prize, Laureate of the A. A. Raspletin Prize and A. A. Raspletin Large Golden Medal of the Academy of Sciences of the USSR, two-time Laureate of the Zolotaya Ideya Prize, Laureate of the Peter the Great National Prize, Laureate of the V. D. Kalmykov Prize, Laureate of the National Academy of Technologies of France. He was awarded 12 orders, including Lenin Order, Order of the October Revolution, Badge of Honour, Order "For Merit to the Fatherland" of the 2nd, 3rd and 4th degrees, Ivan Kalita Order, Public Recognition Silver Star, Friendship Medal (China), Honourable Officer Order (Belgium), 28 medals, has titles of honour: Honourable Radio Operator of the USSR, Merited Mechanical Engineer of the Russian

Federation, Honorary Citizen of Zhukovsky technopolis, he published 270 research works and created 72 inventions. J. G. Hakobyan is also a Member of the International Informatization Academy and a Corresponding Member of the Russian Academy of Electrical Engineering Sciences. Currently, he is a Research Advisor and Advisor to CEO of JSC Moscow Research Institute “Agat”.