

An American Perspective on the Legacy of Anatoly I. Grigoriev in Space Medicine

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INTRODUCTION: Academician Anatoly Ivanovich Grigoriev was a physician, member of the Russian Academy of Sciences Presidium, and a celebrated leader of science in the Soviet Union and Russia—but in the United States, he will be remembered as a friend and mentor. His contributions to space and medicine of extreme environments had a profound impact on human space exploration. He fostered collaboration in many areas of space–human factors, especially in the areas of renal function, endocrinology, and fluids and electrolytes. The joint efforts between NASA and the Soviet/Russian Space Program constitute the foundation for mutual respect and scientific endeavors that continue to transcend the world's political events.

DISCUSSION: This article briefly summarizes Grigoriev's contributions in our long and historical collaboration in human spaceflight. Multiple sources were used, with much drawn from firsthand knowledge through our personal interfaces and working collaboration.

KEYWORDS: spaceflight, history, space medicine, international, legacy.

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Anatoly Ivanovich Grigoriev was born March 23, 1943, in Medelivka, Zhytomyr Oblast, Union of Soviet Socialist Republics (USSR). He was married to Dorokhova Bella Radikovna, a physician biochemist with the Institute of Medical and Biomedical Problems (IBMP), Russian Academy of Sciences (RAS). Together with his spouse, Bella, and their children, he was always a welcoming and exceptional host to his Russian and international colleagues.

In 1966, Grigoriev attended the Pirogov Russian National Research Medical University and became a physician with a keen interest in nephrology. He was a student and research assistant to Professor Anton Yakovlevich Pytal, head of the urological clinic of the 2nd Institute of Medicine. Eventually, he joined the current IBMP and worked with Academicians Vasily Vasilievich Parin and Oleg Georgievich Gazenko.

IBMP, in collaboration with the USSR Air Force Institute of Aerospace Medicine, Academies of Sciences and Medicine, and the Ministry of Health, provided the biomedical training and support of cosmonauts assigned to flight on Salyut stations, the Mir station, the Soyuz, and eventually the U.S. Space Shuttle and the current International Space Station (ISS). Academician Grigoriev, together with Academician Oleg

Gazenko, developed and managed the biological research satellite Bion program, contributing to the international collaboration under the auspices of the USSR Academy of Sciences Interkosmos program.⁷

The Bion satellites were used to conduct research on the adaptation of living systems of different evolutionary levels to the influence of gravity. This included the implementation of unique terrestrial simulation experimentation, which provided a greater understanding of the changes in body systems and their interactions under the influence of extreme spaceflight.⁹

At IBMP, Grigoriev defended his candidate's dissertation ("The effect of long-term experimental hypokinesia and space-flight conditions on the functional state of human kidneys")

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in 1971 and his Ph.D. dissertation (“The regulation of water-electrolyte metabolism and kidney function in humans during space flights”) in 1981. His career with IBMP spanned several decades, and he assumed a variety of increasing roles both in management and with the RAS (see **Table I**).

Academician Grigoriev fostered a close relationship with the cosmonauts in preparation for flight, especially with Valeri Polyakov, M.D., who still holds the longest record of a single stay in low Earth orbit of 437.749 d. He developed and tested new methods for mitigating the physiological effects of the space environment by collaborating with Academician Guy Severin and Professor Arnold Barer.⁸

For many years, Academician Grigoriev actively participated in various international scientific societies, commissions, and working groups (see **Table II**). These activities served the international space medicine community and human spaceflight well. His tireless contributions to space medicine and life sciences research were acknowledged by a variety of national and international prestigious awards, which are highlighted in **Table III**.

International Cooperation

During the height of the Cold War and Space Race, Soviet and NASA physicians and scientists worked closely together on a variety of issues related to human spaceflight and space medicine which were considered humanitarian activities. This included sharing of knowledge, joint research initiatives, and a joint spaceflight. As a senior physician, academician, and leader in Soviet/Russian space medicine, Grigoriev was at the forefront of these international collaborations.

NASA/USSR/Russia joint biomedical working group. In the early 1970s, there was interest in establishing a joint working

group between the United States and the USSR. This group was established as the Joint Working Group (JWG) on Space Biology and Medicine.² In 1994, this group was reconstituted as a U.S./Russia JWG. Academician Grigoriev worked closely with his U.S. counterparts in sponsoring and supporting the Apollo-Soyuz Test Project, Spacebridge (telemedicine) in the aftermath of the 1988 earthquake in Soviet Armenia, and the second publication of *Foundations of Space Biology and Medicine*. Some of the key activities of the JWG were the bed rest studies to standardize crew selection medical protocols.

Apollo-Soyuz test project. The docking of the Apollo capsule and the Soyuz demonstrated in 1975 that two nations with different geopolitical philosophies, technologies, and approaches to medical standards, as well as language and culture, could work closely together.¹¹ This effort set the stage for future collaboration using the Space Shuttle, Mir orbital station, and the ISS.

Spacebridge to Armenia and follow-on Spacebridge projects. In the aftermath of a massive earthquake in Soviet Armenia in 1988, the JWG developed a program using telemedicine to connect patients in Yerevan, Armenia, with physicians in Moscow and the United States. This program was extended to Ufa, Russia, after a train accident.⁶ This initial effort led to two more successful telemedicine programs in which Academician Grigoriev was involved. The following two events demonstrated his continued support of this JWG program: 1) a 1994 live telemedicine demonstration at a hearing at the U.S. Senate led by Senator John D. “Jay” Rockefeller, who was joined by Academician Grigoriev and NASA’s Drs. Harry Holloway and Arnold Nicogossian; and 2) a 1996 live telemedicine demonstration held during the American Medical Association’s 150th

Table I. Academician Grigoriev’s Career Developments.

YEAR	RECOGNITIONS AND HONORS
1970–1973	Researcher
1973–1979	Senior Fellow
1979–1982	Head of Laboratory
1982–1983	Head of Department
1983–1988	Deputy Director
1986	Appointed Professor
1988	Corresponding Member of the USSR Academy of Medical Sciences
1988–2008	Director of the Institute for Medical and Biological Problems*
2008–2023	Senior Science Advisor, Institute for Medical and Biological Problems
1990	Corresponding Member of the Academy of Sciences of the USSR
1993–2005	Chair, Scientific Council for Space Medicine of the Russian Academy of Medical Sciences
1989–2011	Co-Chair U.S./Russia/USSR Joint Working Group on Space Biology and Medicine
1993–2023	Co-Chair of the Ministry of Health and Ministry of Defense Medical Commission for Cosmonaut Flight Certification
1993	Member of the Russian Academy of Medical Sciences
1996–2008	Chief Medical Officer, Russian Space Program
2000–2021	Co-Chair, Multilateral Medical Policy Board
1989–2008	Editor-in-Chief, <i>Aviakosmicheskaya i Ekologicheskaya Meditsina</i>
2009–2022	Editor-in-Chief, <i>Human Physiology</i> , a journal of the RAS
2001–2022	Counselor of the RAS, Chairman of the Scientific Council “Space biology and physiology”
2008–2017	Vice President of the RAS
2013–2022	Board of Trustees of the Russian Science Foundation

*Election as director was due to reorganization and the status of the State Scientific Center of the Russian Federation.

Table II. Commissions and Committees (Start Date Until 2023).

YEAR	COMMISSION/COMMITTEE	ROLE
1983–2008	Medical Support of Space Flight on the Orbital Stations Salyut and Mir	Head
1983–1990	Soviet-French Working Group on Space Biology and Medicine	Co-Chair
1989–1992	Soviet-Russia-U.S. Working Group on Space Biology and Medicine	Co-Chair
1992–1994	Joint Russia-U.S. Working Group on Space Life Science and Life Support Systems	Co-Chair
1994–2017	Joint Russia-U.S. Working Group on Space Biomedicine, Life Support Systems, and Microgravity Science	Co-Chair
1991–2017	Joint Working Group of European Space Agency/IBMP on Life Sciences	Co-Chair
1989–1993	Section of Life Sciences, International Academy of Astronautics	Chair
1992–2007	Commission on Gravitational Physiology, International Union of Physiological Sciences	Member
1991	Space Biology and Physiology of the Space Sciences	Chair
1993	Space Medicine Division of Biomedical Sciences, Medical Sciences	Chair
1993	Scientific Council on Space Medicine of Medical Sciences	Chair
1988–2008	Main Medical Commission, Russia's Space Agency on Medical Certification of Candidates for Cosmonauts, Astronauts, and Cosmonauts' Instructors	Chair
1998	Coordinating Council of the Ministry of Science and Technology of Russia in the Priority Line "Technology of Living Systems"	Member
1999	"Organism and Environment" of the Scientific Council of RAS for Physiological Sciences	Chair
1995	Scientific-Technical Council of Rosaviakosmos and Sciences	Deputy Chairman
1997–2023	RAS	Full member
1993–2023	Russia Academy of Medical Sciences	Full member
1996–2023	Russia Academy of Natural Sciences	Full member
1997–2023	Academy of Astronautics Tsiolkovsky	Full member
1985–2023	International Academy of Astronautics	Full member (Vice President – 1993–2003)
1991	Aerospace Medical Association	Member
1994	New York Academy of Sciences	Member
1995	International Academy of Sciences	Member
2004–2008	International Astronautical Federation	Vice President

anniversary meeting in Philadelphia. This demonstration linked Dr. Michael DeBakey, Dr. Sam Lee Pool, and colleagues in Houston, TX; Dr. Grigoriev, Dr. Oleg Orlov, and colleagues in Moscow, Russia; Drs. Earl Ferguson and Ashot Sargsyan in Krasnoyarsk-26 (a closed former Soviet city now known as Zheleznogorsk), Russia; and Dr. Nicogossian, Dr. Ronald Merrell, and Mr. Charles Doarn via a telemedicine link in Philadelphia, PA. This multi-international link demonstrated the utility of telemedicine on the internet. Telemedicine in Russia grew after these initial programs.¹

Gore-Chernomyrdin – space biomedical center. In the 1990s, under the Vice President Al Gore/Victor Chernomyrdin Commission, Dr. Grigoriev worked with officials at Lomonosov Moscow State University, NASA, and the U.S. Department of State to establish a western-style medical school at Moscow State University, where Grigoriev established and served as the chair of environmental and extreme medicine. This commission also established the Space Biomedical Center for Research and Training at this academic institution, which included a telemedicine curriculum. A key proponent of this medical training was Dr. Michael DeBakey, who lent his expertise in the education of medical students. Academician Grigoriev mentored over 30 candidates for Doctor of Science in space biology and medicine of extreme environments through this effort.

Mir/Shuttle program (ISS-Phase 1). In the early 1990s, Russia became part of the ISS program and, as part of that participation, the Space Shuttle docked with the Mir space station.

This collaboration led to flights of cosmonauts on the shuttle and U.S. astronauts on Mir. Known as Phase 1, this entire program was designed to garner operational experience in preparation for the ISS program. Academician Grigoriev was key in the development of an international space medicine program to sustain the selection, training, and support of the multinational crews operating, working, and living in a space habitat designed and built by five different countries. Under his leadership, he and his colleagues were participatory collaborators on the Multilateral Medical Operations Working Group. This working group, which was based on earlier foundations of the JWG and Apollo-Soyuz Test Project, established the framework that ISS and its panels and boards would use in support of crew selection and certification and all operational aspects of crew health and safety.^{3,5} Academician Grigoriev served as the chief medical officer and cochair of the Multilateral Medical Policy Board from its inception in 1998 until his retirement in 2020.

Joint publications on space biology and medicine. Two key book volumes were another outcome of the JWG. The first, *Foundations of Space Biology and Medicine*, was a deliverable from a NASA and USSR Academy of Sciences agreement between Hugh Dryden (NASA) and Anatoliy Blagonravov (USSR). This volume, edited by Drs. Melvin Galvin (NASA) and Oleg Gazenko (USSR), consisted of four books and was published in 1975. It covered a wide range of known materials based on the experiences of both the United States and USSR in spaceflight up to that point. This book series included a

Table III. Awards and Recognition.

YEAR	AWARD
1976	Badge of Honor Medal of USSR
1982	Red Banner of Labor Medal awarded by the USSR
1984	Sergei Pavlovich Korolev Medal of the USSR Cosmonautics Federation
1985	The Banner of Labor, awarded by the German Democratic Republic
1987	Yuri Gagarin Medal of the USSR Cosmonautics Federation
1988	Hubertus Strughold Award of the Aerospace Medical Association
1988	Jan Evangelista Purkyně Honorary Merit in the Biomedical Sciences awarded by the Czech Academy of Sciences
1989	Honorary Doctor of the University of Lyon (France)
1989	Laureate of the USSR State Prize
1993	Golden Decoration of Honor for Services to the Federal Republic of Austria
1993	NASA Public Service Medal
1995, 1999, 2001	Prize of the International Academy of Astronautics
1996	Title of the Honored Scientist of Russia
1996	Medal for the COSPAR International Cooperation
1996	Allan D. Emil Memorial Award of the International Astronautical Federation
1996	Melbourne W. Boynton Award from the American Astronautical Association
1996	Vasily Vasilievich Parin Award from the Russian Academy of Medical Sciences
1996, 2003	Russian Federation Government Prize
1996	Hermann Julius Oberth Award from <i>Internationaler Förderkreis Für Raumfahrt</i>
1999	François-Xavier Bagnoux Award from the University of Michigan
2001	Louis H. Bauer Award of the Aerospace Medical Association
2001	Order of Dostyk (Friendship of the II Degree) – Kazakhstan
2002, 2013	Russian Federation State Prize in Science and Technology
2002	NASA Silver Snoopy Award
2003	Recipient of the Order "For Merit to the Fatherland," IV class, of the Russian Federation
2003	Vasily Vasilievich Parin Award from the Russian Academy of Medical Sciences
2003	Medal of the Ministry of Health of the Russian Federation for merit to Russian health care
2003	Badge of K.E. Tsiolkovsky of the Russian Space Agency
2003	Star of Icarus Medal of the Russian Space Agency
2003	N.V. Timofeev-Resovsky Medal
2004	Officer of the Legion of Honor Order (France)
2005	Medal of the University of Pierre and Marie Curie (France) for merits in science and medicine
2005	Mereny-Scholz Medal (Hungary) for merits in science
2005	Award of the Hungarian Society of Aerospace Medicine
2006	"Triumph" Award for outstanding achievements in the field of experimental and theoretical research
2007	Gold medal named after Academician V.F. Utkin
2007	Jubilee silver medal named after N.M. Sissakian of the RAS
2008	Recipient of the Order "For Merit to the Fatherland," III class, of the Russian Federation
2008	"A.I. Burnazyán" badge of the Russian Federal Medical-Biological Agency
2008	Demidov Prize for outstanding contribution to fundamental and applied research in space biology and medicine
2008	S.I. Vavilov Medal for great personal contribution to the development of the educational process in Russia
2008	N.I. Pirogov Medal of the Russian Academy of Medical Sciences
2009	A.A. Ukhtomsky Award of the RAS
2009	National Prize "Vocation"
2011	"50 Years of Yu.A. Gagarin" Medal
2011	Medal of the International Association of Space Flight Participants
2013	Recipient of the Order "For Merit to the Fatherland," II class, of the Russian Federation
2013	Leon Abgarovich Orbeli Award from the RAS
2013	Mikhail V. Lomonosov I Degree Medal awarded by Moscow State University
2014	Ivan Mikhaylovich Sechenov Gold Medal awarded by the RAS
2016	Commemorative medal "Academician O.G. Gazenko" of the Russian Federation of Cosmonautics
2018	Badge of the Golden Cross of the Russian Federal Medical-Biological Agency
2019	"Space Without Borders" medal of State Space Corporation "Roscosmos"
2021	Badge of K.E. Tsiolkovskiy of State Space Corporation "Roscosmos"

plethora of contributors from both nations, including Academician Grigoriev.

As the knowledge grew on both sides, a new agreement was established to develop a five-volume set (six books in total); Academician Grigoriev served as a contributor and editor along with others, including Academician Gazenko Grigoriev and Drs. Nicogossian and Stanley Mohler. This compendium

was published by the American Institute of Aeronautics and Astronautics in the mid-1990s.

The knowledge and collaboration over Academician Grigoriev's career have been instrumental in not only understanding life's processes in the extreme environment of space and on Earth, but also protecting the international community of men and women who have flown in space.

Summary

Academician Grigoriev authored or coauthored over 400 scientific publications, including 7 monographs and 16 chapters in various books, and held 22 patents. He served as the editor-in-chief of the Russian journal *Aviakosmicheskaya i Ekologicheskaya Meditsina (Aerospace and Environmental Medicine)*, was a member of the editorial board of the journal *Human Physiology*, was an adviser to the drafting committee of *Space Medicine and Technology* (China), was a coeditor of the joint Russo-American *Labor Fundamentals of Space Biology and Medicine*, and contributed to seminal papers in support of crew health. While a lifetime of scholarly work is too extensive to be listed here, some of Academician Grigoriev's work in physiology and its impact on the safety of the crew is especially worth noting, including research on protein expression endocrinology (Grigoriev et al.⁴) and work on electrolytes with Dr. Carolyn Huntoon.¹⁰

It is with great sadness that we mourn the loss of our friend, colleague, and space medicine pioneer. His contributions to the field of space medicine, space physiology, telemedicine, and international collaboration are immeasurable. Academician Grigoriev leaves the future of Russian space medicine efforts in the able hands of a new generation of leaders. His impact on the international community, especially in the United States, transcends politics and culture. Many of those in the United States can attribute their career paths to Academician Grigoriev because of his guidance, knowledge, and, simply, his friendship. His legacy will endure and influence those who come after him both in Russia and around the world as human spaceflight continues to grow.

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