Russian Planetary Exploration

History, Development, Legacy, Prospects

Brian Harvey

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Contents

Author's preface ix

Acknowledgements xi

List of figures xiii

List of abbreviations and acronyms xix

1 ***Aelita*** 1
The long school summer of 1883 1
Aelita and the role of science fiction in Russia 2
Perelman, Tsander and Shargei 4
After suppression, revival 7
Venus at the time of the space age 8
Mars at the time of the space age 13
Prelude to the interplanetary age 15
References 16

2 **First plans** 17
Soviet rocketry 17
Germany's progress 18
R-7 rocket 19
The idea of an Earth satellite 21
The idea of an interplanetary probe 23
The First Cosmic Ship 26
Planning the first Venus and Mars missions 26
The rocket for the Mars, Venus probes 29
Tracking system 31
The man-to-Mars programme in the 1950s 35

Korabl Mars Venera and the *Tizhuly Mezhplanetny Korabl* (TMK) . . 36
Another way to go: *Kosmoplan* 39
Ready for Mars and Venus 41
References 42

3 The first Mars, Venus probes 43
1M and 1V series, 1960 43
Hiding in plain view: *Tyzhuli sputnik* 49
The first automatic interplanetary station to Venus 51
'Sabotage is not excluded' 54
Re-design 56
The 2MV series in 1962 60
Mars 1 64
3MV series: 1964 Venus missions 68
Improving the launcher: the 8K78M 72
3MV: 1964 Mars missions 73
Zond 2 postscript 76
End of the first series 78
References 79

4 OKB Lavochkin 81
OKB-301 Lavochkin 81
Three-part reorganization: Lavochkin, ministry, institute 84
Lavochkin's redesign 87
New spacecraft: new rocket – the UR-500 (8K82) 89
Russia reaches the evening star 93
First descent 98
Venera 5, 6 102
New tracking systems 106
Under new management 108
References 109

5 First landfall on Venus, Mars 111
First landfall on Venus 111
Baseline Venus: Venera 8 115
Babakin's first design: Mars 69 120
Design challenges of Mars 69 123
Broken windows, broken hopes 127
Mars 71S: an orbiter to fly ahead of the landing fleet 128
How to reach and soft-land? 130
Mini-rovers 134
The loss of Mars 71S and its consequences 138
On the way at last 139
Georgi Babakin, 1914–1971 140
First to reach the surface of Mars 142

Mars 3: first to soft-land 144
The orbital missions 146
The great Mars fleet: the problem of 2T-212 154
On their way 157
Mars 6 reaches *Mare Erythraeum* 158
The short success of Mars 5 161
Mars fleet aftermath 165
References 168

6 The high summer of Soviet planetary exploration, 1975–1986 171
New generation 171
Venera 9 lands on a mountainside 174
Venera 10 176
Venera 11, 12: the first sounds of another world 184
Venera 13, 14: drilling the rocks 191
Venera 13 and 14 outcomes 196
Venera 15 and 16: the plan 199
Venera 15, 16: the mission 202
Venera 15, 16: outcomes 205
Toward VEGA: the balloon project 211
VEGA: the mission 213
VEGA: spacecraft and instruments 215
VEGA at Venus 218
The balloon journeys 223
Breaking the curse of Suslov: VEGA at Comet Halley 227
The interception of Halley: scientific results 229
High summer 232
References 235

7 Phobos, crisis and decline 239
The Martians strike back: Projects 5NM, 5M 239
New chief designer: Vyacheslav Kovtunenko; new spacecraft: UMVL . 243
Phobos: last of the Soviet Mars probes 246
'We can shoot them all later' 251
Precarious arrival at Mars 252
Manoeuvring to the moon 254
'The last message from the dying Phobos 2' 257
Science results from Phobos 261
Putting it back together again 266
The Soviet Union becomes Russia 269
Completed by candlelight 270
After Mars 96? 273
Mars 96: last of the heavyweights 275
Instead of Mars, the Andes: the short, sorry flight of Mars 96. 281
Hard times 284

Planetary spacecraft leave from Baikonour again 286
References 287

8 Returning to the planets? 291
Critical paths to Mars 291
Biosphere 292
Manovtsev, Ulybyshev and Bozhko fly to Mars 293
The Mir experience 296
Critical nuclear, electric paths 298
Aelita – not the film, but the real thing 299
Aelita: the new TMK–MEK 300
Aelita: Chelomei's UR-700M 302
End of *Aelita* 302
Following *Aelita*: Energiya's new designs 303
DZhVS: long-duration Venus lander 308
Final Soviet period plans 310
Vesta mission 310
Putting Mars back together again 314
Return to Phobos? Phobos Grunt 314
Fire and ice 318
Keeping the dream alive 321
References 322

9 The legacy 325
References 331

Appendix A Soviet and Russian planetary missions 333

Appendix B Where are they now? 335

Appendix C Bibliography 339
Books 339
Journal articles, articles, reports, papers, brochures and similar publications 340
Booklets 344
Internet 344
Periodicals and journals consulted 345

Index 347

Author's preface

The many, great and deserved achievements of the United States and Europe in planetary exploration in recent years can obscure the fact that it was the Soviet Union that forged the way to the planets. The idea of flying to Venus and Mars dates to tsarist times and the popular film made in the 1920s about a Mars colony, *Aelita*. Plans for an expedition to Mars were put on the drawing board in Stalin's Soviet Union. It can be forgotten that the Soviet manned moon rocket, the N-1, was originally designed with a view to sending cosmonauts to Mars – until the moon race diverted planners from their original purpose. Calculations for the first unmanned flights to the planets were done within months of the first Sputnik going into orbit.

The Soviet Union achieved many important firsts in its programme of planetary exploration.

- First probes to Venus (1961) and Mars (1962).
- First probe to reach the surface of another world, Venus (1966).
- First soft-landing on Venus (1970).
- First soft-landing on Mars (1971).
- First picture from the surface of Mars (1971).
- First surface analysis of the rocks of another planet, Venus (1972).
- First pictures from the surface of Venus (1975).
- First spacecraft to orbit Venus (1975).
- First on-site laboratory analysis of the rocks and soil of Venus (1982).
- First radar maps of another planet, Venus (1983).
- First balloon to fly in the atmosphere of another planet (1985).
- First close flyby of a comet, Comet Halley (1986).
- First interception of a moon in orbit around another planet, Phobos (1989).

These spaceships were equipped with a sophisticated range of instruments and experiments. The scientific haul from these missions was considerable and transformed our

views of the planets Venus and Mars. Results from these missions were made available to the scientific community. Although the Western image of Soviet Mars probes is that they all failed, in reality they contributed much to our early knowledge of the planet.

To this day, four Russian spacecraft still circle Venus and another four orbit Mars. Ten landers still sit on the surface of Venus while three found their way to the surface of Mars. The Soviet Union/Russia launched 54 interplanetary spacecraft, so they were an important part of its programme of space exploration.

Now, 50 years after the first Sputnik, the Russians are making fresh plans to return to the planets. Due to the extreme financial crisis which beset the Russian Federation in its early days, only one deep space probe was launched in the post-Soviet period (Mars 96). The Russian space programme for 2006–2015 includes the recovery of a soil sample mission from the Martian moon Phobos over 2009–2011. Now is a good time to put the Soviet and Russian deep space programme into its historical perspective. It represents an archive of experience and knowledge useful to those planning new missions to Venus, Mars and farther afield. This book tells the story of the Soviet deep space programme: the space probes and their often inventive designs; the people who built them; the key decisions that were made; the scientific outcomes; the knowledge learned; the heartbreaking failures; and also the joyous successes.

Brian Harvey
Dublin, Ireland, 2007

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Figures

Konstantin Tsiolkovsky 2
Jules Verne – popular in tsarist Russia 3
Yakov Perelman 4
Friedrich Tsander: 'Onward to Mars!' 5
Yuri Kondratyuk 6
Nikolai Rynin's book 8
Crescent Venus through a telescope 9
Gavril Tikhov 10
Gavril Tikhov in Pulkhovo 11
Gavril Tikhov on astrobiology 12
Yuri Surkov 15
GIRD-09 18
Sergei Korolev 20
Mikhail Tikhonravov's satellite team 22
Mikhail Tikhonravov 23
The calculator of trajectories – Mstislav Keldysh 25
The First Cosmic Ship 27
Gleb Yuri Maksimov 28
8K78 30
Mikhail Ryazansky 32
Dish at Simferopol 33
The Pluton system 34
Konstantin Feoktistov 37
Korolev and Feoktistov 38
Vladimir Chelomei 39
Kosmoplan 40
Mstislav Keldysh 44
Petr Bratslavets 45
Shmaia Dolginov 47
Konstantin Gringauz 47

Launcher for the first Mars probes, the 8K78 48
AIS design 50
Boris Raushenbakh 52
The AIS on its way 53
Vsevolod Avduyevsky 57
Yevgeni Boguslavsky 59
Vera Mikhnevich 60
Vladimir Krasnopolsky 61
Alexander Lebedinsky 62
Coolant dome on solar panel (left) 63
Mars 1 66
Tatiana Nazarova 67
Vladimir Kurt 71
Zond 2 tracked from Yevpatoria 74
Zond 3 77
Zond 3 over the moon 78
Semyon Lavochkin 82
Georgi Babakin 83
Oleg Ivanovsky 84
Sergei Korolev and Mstislav Keldysh 85
Sergei Afanasayev 86
Kiril Florensky 88
Viktor Kerzhanovich 89
Vladimir Chelomei at the blackboard 90
The Proton rocket 92
Venera 2 95
Venera 3 96
Venera 4 in assembly 98
Venera 4 cabin 100
Mikhail Marov 102
Venera 5 descent 103
Venera 6 105
Tracking ship *Cosmonaut Yuri Gagarin* 107
Large tracking dish 108
Sergei Korolev died in 1966 109
Venera 7 112
Venera 7 top antenna 114
Oleg Rzhiga 115
Venera 8 116
Venera 8 in preparation 118
Georgi Babakin, chief designer 121
Vasili Moroz 122
Mars 69 – original design 123
Mars 69 – second design 125
Mars 69 completed 126
Mars 71S orbiter 129
Mars 71P lander in cone 131
Yuri Koptev 132
Mars 71P lander 134

Alexander Kemurdzhian 135
Vadim Istomin 136
Mars 71P system of relay 137
Mars 2 140
Mars 3 141
Sergei Kryukov 142
Mars 2, 3 landing sites 143
The edge of Mars from Mars 3 144
Mars 3 surface picture 145
Mars 3 horizon, enhancement 146
Mars crescent from Mars 3 147
Mars 3 picture of a distant Mars 148
Mars crater from Mars 3 149
Mars mountains from Mars 3 150
Mars 3 view of Mars 152
Arnold Selivanov 156
Mars 4 passes Mars 158
Mars 6, 7 landing sites 159
Mars 6 coming in to land 160
Mars 5 162
Craters from Mars 5. 163
View from Mars 5 165
Valentin Gluskho 166
Roald Sagdeev 167
The 4V1 series (Venera 9) 172
The new Venera lander 174
Venera lander in shell 175
Venera 9, first image. 177
Venera 9, first panorama. 177
Venera 9, rocky terrain 178
Venera 10, first panorama 178
Venera 10, first image 179
Venera 10, second image 180
Venera 9, image of clouds of Venus 180
Venera 9 set, Venera 10 set 182
Venera 12 in preparation 184
Venera 12 at Baikonour 185
Venera 12 lander 187
Vladimir Barmin 188
Lev Mukhin. 189
Leonid Ksinformaliti 191
Venera 13 sets 193
Venera 14 sets 194
Venera 13: first image 195
Venera 13: second image 195
Venera 14: first image 196
Venera 14: second image 196
Venera 13, details of rocks 197
Venera 13, ridge on horizon 198

Venera 15, 16 series 200
Alexei Bogomolov 201
Venera 15, 16 radar system Polyus. 202
Venera 15, 16 *tessera* 203
Venera 15, 16 arachnoids 204
Venera 15, 16 coronae features 205
Venera 15, 16 volcanic caldera. 207
Venera 15, 16 *Maxwell Montes* 208
Nitrogen supplies determined the length of the mission 210
VEGA balloon concept. 211
VEGA target Comet Halley 212
VEGA spacecraft 214
VEGA launch 215
Vladimir Perminov 216
Vyacheslav Linkin 217
VEGA assembly conference. 219
VEGA with lander shell 220
VEGA international collaboration 221
VEGA landers 222
VEGA aerostats in flight. 224
Dishes at Yevpatoria 225
VEGA gondola 226
VEGA closes in on Halley 228
VEGA mission control 229
VEGA 1 at Halley 230
The core of comet Halley 231
Astron 236
Project 4NM 240
Alexander Vinogradov 242
Project 5M 243
Vyacheslav Kovtunenko 244
UMVL 245
Phobos hovering 247
CBPS 248
Phobos in assembly 249
Phobos 1 launch. 252
Phobos mission control. 253
Phobos in Mars orbit 254
Moon Phobos in sight 255
Moon Phobos closer view 256
Jupiter seen by Phobos 2 in Mars orbit 257
Moon Phobos close image. 258
Phobos 2 last image of Moon Phobos 259
Moon Phobos over *Tharsis* region of Mars. 260
Mars equator from Phobos 2 262
Phobos 2 image of chaotic Martian terrain. 263
Phobos 2 over *Vallis Marineris* 265
Mars 94. 267
Mars 94 plan 268

Mars 96 in assembly 271
Mars 98 plan 272
Mars 98. 273
Mars 98 Marsokhod 274
Mars sample return 276
Mars 96 penetrator. 278
Mars 96 surface station. 279
Biosphere in Krasnoyarsk 293
The *bochka* 294
Anatoli Grigoriev 296
Cosmonaut Dr Valeri Poliakov 297
Salyut space garden 298
Vladimir Chelomei with Mstislav Keldysh 301
Valentin Glushko – ashes to Venus?. 303
Medical tests on Salyut 305
Mir truss – assembly work for Mars 306
Venus airships 309
French balloons over Mars in early 1990s plan 312
Soviet period sample return mission 315
Old target, new target: Phobos 317
Tsiolkovsky probe. 319

MAPS

Location of Venus probes 337

TABLES

B.1 Landing coordinates of Soviet spacecraft on other worlds. 335
B.2 Interplanetary missions orbiting the Sun 336
B.3 Orbiting Venus 336
B.4 Orbiting Mars. 336
B.5 Crushed in Venusian atmosphere 336

Abbreviations and acronyms

1MV	Number 1 series for Mars and Venus (1M for Mars, 1V for Venus)
AIS	Automatic Interplanetary Station
ANGSTREM	X-ray spectrometer
APS	Autonomous Propulsion System
APX	Alpha particle, proton and X-ray spectrometer
ASPERA	Mass spectrometer and particle imager
AVD	*Avarinoye Vyklyuchennie Dvigatelei* (emergency cut-off of engines)
BOZ	*Blok Obespecheyna Zapushka* (ignition insurance system)
CBPS	Combined Braking and Propulsion System
CNES	Centre National d'Etudes Spatiales
DPI	Accelerometer
DYMIO	Ion spectrometer
DZhVS	Long-duration Venus station
ERTA	*Elektro Raketny Transportniy Apparat*
ESA	European Space Agency
FGB	*Funksionali Gruzovoi Blok* (functional cargo block)
FONEMA	Ion and high-energy spectrometer
GDL	Gas Dynamic Laboratory (in Leningrad)
GDR	German Democratic Republic
GIRD	Group for the Study of Reactive Propulsion/Devices
glasnost	Openness
GLONASS	Navigation systems
GPS	Global Positioning System
GSMZ	*Imeni Semyon Lavochkin* (state union machine building plant dedicated to the memory of Semyon Lavochkin)
HEND	High-Energy Neutron Detector

ICBM	InterContinental Ballistic Missile
IKI	*Institut Kosmicheski Izledovatl* (Institute for Space Research)
IMAP	Magnetometer
IMBP	Institute for Medical and Biological Problems
IRE	Institute of Radiotechnology and Electronics
IZMIRAN	Institute of Terrestrial Magnetism
JIMO	Jupiter Icy Moon Orbiter
KAMERTON	Seismometer
KBKhA	*K.B. Khim Automatiki* (Design Bureau for Chemical Automatics)
KGB	Internal security police
KMV	*Korabl Mars Venera* (spaceship for Mars and Venus)
LAL	Long-term Automated Lander
M	Modified version (e.g., 8K78M)
MAREMF	Electron spectrometer and magnetometer
MARIPROB	Plasma and ion detector
MARSPOST	MARS Piloted Orbital STation
Mavr	Linguistic combination of Mars and Venera
MEK	Mars Expeditionary Complex
METGG	Meteorology instrument system
MPK	Mars Piloted Complex
MV	Mars Venus
N	*Nositel* (carrier)
NASA	National Aeronautics and Space Administration
NEK	Scientific Experimental Complex
NII PDS	Scientific Research Institute of Parachute Landing Facilities
NIPs	Scientific measurement points
NITS	Babakin Scientific Research Centre
NPO AP	Scientific Production Association for Automatics and Instrument Development
NPO	Science and Production Organization
NPO-PM	Scientific Production Association *Pridlanoi Mekhaniki*
NSSDC	National Space Science Data Centre
OIMS	All-Union Society to Study Interplanetary Communications
OKB	*Opytnoye Konstruktorskoyue Buro* (experimental design bureau)
OPTIMISM	Seismometer, magnetometer
OSOVIAKHIM	Society for the Support of Aviation and Chemical Development
P	*Pasadka* (lander)
PEGAS	Gamma-ray spectrometer
perestroika	Transformation, reform
PHOTON	Gamma spectrometer
PrOP-M	*Pribori Otchenki Prokhodimosti-Mars* (instrument for evaluating cross-country movement)

PS	Preliminary Satellite
RKA	Russian Space Agency
RT	*ReTranslyator* (relay station)
SFINCSS	AKA *Sphinx*
SLED	Solar Low-Energy Detector
SPICAM	Optical multichannel spectrometer
SVET	High-resolution mapping spectrophotometer
TERMOSCAN	Scanning infrared radiometer
TERMOZOND	Temperature probe
TMK	*Tizhuly Mezhplanetny Korabl* (Heavy Orbital Station)
TsAGI	*Tsentralni Aero Girodinamichevsky Institut* (Zhukovsky Central Institute of Aerodynamics)
TsBIRP	Central Bureau for the Study of the Problems of Rockets
TsDUC	Centre for Long Range Space Communications
UDMH	Unsymmetrical Dimethyl Methyl Hydrazine
UMV	Universal Mars Venus
UMVL	Universal Mars Venus Luna
UR	*Universalnaya Raketa* (Universal Rocket)
VEGA (VEHA)	VE = Venus and HA = Halley ('g' and 'h' sound similar in Russian)
VPM-73	Visual Polarimeter Mars 1973

1

Aelita

That Mars is inhabited by beings of some sort or other we may consider as certain as it is uncertain what those beings may be.

– Percival Lowell, in *Mars and its canals*, 1906.

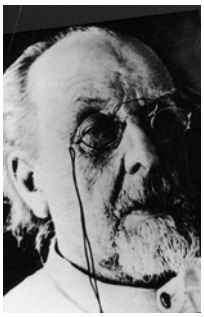
THE LONG SCHOOL SUMMER OF 1883

Russia's exploration of the planets dates to summer of 1883 and the writings of a teacher in the town of Kaluga, Konstantin Tsiolkovsky. He was the first Russian to describe interplanetary journeys.

Born in Izhevskoye in September 1857, Konstantin Tsiolkovsky was the son of a forest ranger, but suffered from scarlet fever when he was ten years old and this left him largely deaf for the rest of his life. His mother nursed him through school and, possibly on account of his deafness, he read books endlessly, by the age of 17 mastering higher mathematics, differential calculus and spherical trigonometry. He managed to obtain a teaching post in the town of Kaluga, where he spent the rest of his life.

During the long school summer of 1883, Tsiolkovsky came across the idea of interplanetary space travel, though we still do not know precisely how or exactly what sparked his interest. This became the guiding interest of his life. It should be noted that Tsiolkovsky was no dreamy theorist. This remarkable self-taught man was also a mathematician, inventor, writer and and practical engineer, for he built hearing aids, wind tunnels and even small centrifuges.

That summer, 1883, Tsiolkovsky wrote his first book, *Free space*, which described how an interplanetary traveller would be weightless. He went on to devise the formula for the thrust of a rocket engine and 'Tsiolkovsky's formula' became the basis of all



Konstantin Tsiolkovsky

subsequent rocket science and is now the first thing taught in rocket school. In *On the moon* (1893) and *Dreams of Earth and heaven* (1895) he outlined flight beyond the Earth – accurately calculating the velocities required – and in *Interplanetary flight* he sketched a space station that could travel deep into space bringing with it its own, closed ecosystem. *Investigating space with reaction devices* (1903) explained how decaying nuclear fuel would be necessary for long space journeys, for they offered superior propulsion to liquid-fuel rockets. He showed how it might be possible to soft-land on other planets. Eventually, he predicted, 'people will ascend into the heavens and found settlements there.'

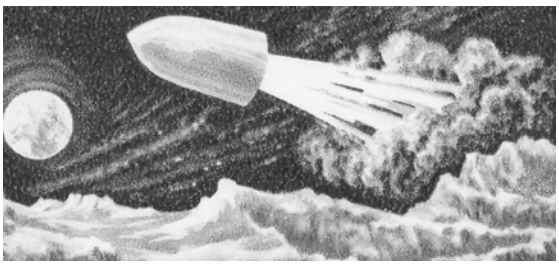
In *Cosmic rocket trains* (1918) Tsiolkovsky turned specifically to the problem of reaching a sufficient velocity to escape Earth's gravity for interplanetary journey. The key was to use rocket stages, with one stage falling away after another, either on top of one another or in parallel, each achieving ever greater height and speed than its predecessor. In a famous letter to B.N. Vorobyov on 12th August 1911, Tsiolkovsky wrote:

Human kind will not remain forever confined to Earth. In pursuit of light and space it will, timidly at first, probe the limits of the atmosphere and later extend its control across the entire solar system.

The Bolshevik government gave him a pension and in the final years before his death in September 1935, his home in Kaluga became a place of pilgrimage for amateur rocket-builders, enthusiasts, journalists and popularizers of science. He published no fewer than 60 works – articles, books, even science fiction – in his last ten years. He lived out his last autumn days on his veranda, surrounded by books, manuscripts and the odd globe. His home is now a shrine, museum and memorial.

AELITA AND THE ROLE OF SCIENCE FICTION IN RUSSIA

Science fiction circulated widely in pre-revolutionary and revolutionary Russia, the writings of Frenchman Jules Verne being much the most popular. One of those



Jules Verne – popular in tsarist Russia

inspired by Jules Verne was a young boy from Odessa on the Black Sea, Valentin Glushko. When aged 13 in the year 1921, he read the 1865 book by Jules Verne *From the Earth to the moon*. In the following year, still only 14, he made his own observations of Venus, Mars and Jupiter in the Odessa Observatory and these were published the following year in *Astronomical Bulletin* and the magazine *Mirovodenie*. The following year, aged 16, he wrote to and received a treasured reply from Konstantin Tsiolkovsky. When Valentin Glushko completed his studies in 1928 he went straight into the Gas Dynamic Laboratory (GDL) in Leningrad to design and build rocket motors, becoming, eventually, the greatest rocket engine designer of all time [1].

Verne's science fiction may have been the first of its kind in Russia and it unleashed a huge upsurge in the genre. Mars was the focus of Russian science fiction. In the same year that H.G. Wells published *War of the worlds*, 1908, the dissident Bolshevik, philosopher and doctor Alexander Boganov (1873–1928) published *Red Star* (*Krasnaya Zvezda*), the tale of benign Martians seeking cooperation from humans. The landmark novel of the period was *Aelita*, written in 1923 by Alexei Tolstoy (1883–1945). It was the story of two cosmonauts who arrived on Mars to find it under the yoke of a cruel empire. To complicate things, one of the two, cosmonaut Los, fell in love with Princess Aelita, Queen of Mars, after whom the novel was named. Meanwhile, fellow cosmonaut Gusev led a plot to overthrow her imperial government and establish a model society. The novel was approved by the authorities and quickly turned into a popular film, in turn prompting interest in the written text. The film, directed by the recently returned from exile Yakov Protazanov, had a cast which included Tuskub, King of Mars and a 'bearded astronomer' and was rated highly for its design and production values. Yuliya Solntseva (1901–89) starred as Queen Aelita, setting her off on a long career in acting and, after the war, as a director, winning international recognition (she was on the jury of the Cannes film festival). *Aelita* had such an appeal that some parents named their daughters Aelita.

The success of *Aelita* later inspired a second film, the silent movie *Space journey* (1935), a flight to the moon which showed cosmonauts weightless and in spacesuits, the first ever film to do so (the ailing Tsiolkovsky was technical advisor). A novel of the time also dealt with a flight to Mars: *Jump into nowhere*, a less political novel describing a scientific mission to Mars on a liquid propellant rocket.

The 1920s were a period of space fever in the new Soviet Union [2]. The new government was quick to enlist technology in support of national industrial, economic

and scientific development. Aeroplane design was used as a cutting edge design field to improve Soviet technology and a vast aeroplane, the *Maxim Gorky*, was constructed as an airborne propaganda unit. Manned balloons flew high into the atmosphere. As early as 1918, Lenin authorized the establishment of the central institute of aerodynamics, TsAGI (*Tsentralni Aero Girodinamichevsky Institut*) by the founder of Russian aviation, Professor Nikolai Zhukovsky. The following year saw the establishment of the Zhukovsky Academy. The year 1924 saw the setting up of the Central Bureau for the Study of the Problems of Rockets (TsBIRP) which saw its brief as 'to disseminate and publish correct information about the position of interplanetary travel' and also the All Union Society to Study Interplanetary Communications (OIMS), whose title was self-explanatory, with 200 members who included Tsiolkovsky and Tsander. Its first meeting was in Pulkhovo Observatory on 20th June 1924. Interplanetary clubs appeared in other cities. A Society for the Support of Aviation and Chemical Development, OSOVIAKHIM, was formed to enlist and develop public support for aviation, including rocketry and it attracted wide public support.

PERELMAN, TSANDER AND SHARGEI

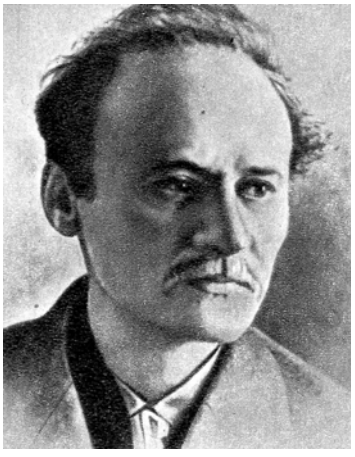
The greatest popularizer of spaceflight in the early years was Yakov Perelman (1882–1942) who published – in 1915 wartime Petrograd – *Interplanetary travel*. This was so popular that it went through ten reprints in the following 20 years. *Interplanetary travel* explored how the idea of reaching distant planets could be made possible through such means as anti-gravity (H.G. Wells), a great gun (Jules Verne), solar propulsion or Tsiolkovsky's rocket, which he favoured. Perelman's *Interplanetary travel* was republished in 1929 in an entirely new edition and at once sold 150,000 copies. Perelman became vice-chairperson of LenGIRD, the Leningrad branch of the

Yakov Perelman

amateur Group for the Study of Reactive Devices (GIRD), whose Moscow branch was to launch the first liquid-fuel rocket. Between 1917 and 1941, no fewer than 535 separate publications addressed issues of spaceflight.

Riga-born Lithuanian Friedrich Tsander (1887–1933), a son of a merchant family on his father's side and musicians on his mother's part, was read Tsiolkovsky's *Exploration of space by reactive devices* by a teacher in the course of school in 1905 and thereafter resolved to devote his life to space travel. His house stood on a hill, and there he made a shed from which he could observe the moon, Saturn and Mars. He made mathematical calculations as to the best paths of interplanetary journeys, landings and return trajectories [3].

Graduating from Riga Polytechnic, Friedrich Tsander went to work in the *Motor* aircraft plant in Moscow in 1919. In his spare time, he gave lectures on space travel in the early Soviet Union and encouraged many people to join the cause. Even when Moscow was freezing and starving, he set up a model hydroponic garden to grow food in an air-tight laboratory, simulating the conditions of interplanetary travel. Indeed, his children were enlisted in the good cause, for he named his daughter Astra and his son Mercury. To Tsander may be attributed the first ideas of a space shuttle, for he saw that winged spaceships were an efficient way to land on other worlds that had an atmosphere and a means of returning to the Earth. He outlined his concept of a space shuttle and the use of aircraft to bring a rocket to altitude in lectures to the Moscow regional conference of inventors in 1921. His main work was *Flights to other planets*, published in the magazine *Technology and life* in 1924. He was no mere theorist, for he joined the GIRD group and spent the last years of his life building small liquid-fuel rockets. In the course of doing so and aged only 46, he contracted typhoid fever. His slogan in GIRD was 'Onward to Mars' because it was the planet with an atmosphere and the place most likely to sustain life. In the view of the GIRD leader, Sergei Korolev, it was Friedrich Tsander more than anyone else in the group who looked furthest ahead to interplanetary flight. Tsander died in Kislodovsk Sanitorium in the



Friedrich Tsander: 'Onward to Mars!'

Yuri Kondratyuk

Caucasus on 28th March 1933. Korolev broke the news to the entire, shocked GIRD group in its basement laboratory. Korolev concluded his speech at the funeral with Tsander's own words, 'Onward to Mars!'

It was Yuri Kondratyuk (1897–1942) who wrote the most about the potential of interplanetary travel during the early days. Yuri Kondratyuk was mentioned fleetingly in the Soviet histories of the 1950s and years later the enigma surrounding this extraordinary man began to unravel. Kondratyuk was not his name at all, for he was really Alexander Shargei. During the civil war, he was conscripted into the White army, the Bolshevik penalty for which was death. To survive, he deliberately took on the identity of a dead man, Yuri Kondratyuk, acquiring his birth certificate.

In 1916, while still under his original name of Shargei, he wrote *Conquest of interplanetary space* in the polytechnic in Petrograd, but circulation was restricted during the wartime conditions and he was soon forced into the tsar's army in any case. This was revised in 1919 as *To those who will read to build*, but its circulation was overtaken by the civil war now raging. *Conquest of interplanetary space* was eventually published in 1929, but as a new, first edition, now under the name of Kondratyuk, in the hope that memory of the now receding 1916 edition would be forgotten. In an additional precaution to avoid the attention of the authorities, he had it published in distant Novosibirsk. *Conquest of interplanetary space* was important, for it outlined how a rocket could leave Earth and fly into space, the use of decaying atomic fuel and solar energy for propulsion and addressed issues of trajectories, guidance and stability. For landing on another planet, he recommended that the bottom stage be left behind and serve as a platform for the return spacecraft, the very technique followed by the American and Russian lunar modules 40 years later. He also suggested that, instead of direct landings, spacecraft be sent down from orbit around the planet, to which they would return for their flight home. For returning to the Earth, he recommended either aerobraking or a high-speed entry into the atmosphere, the very approach followed by Zond and Apollo to return from the moon over 1968–72. Shargei suggested the use of gravity assist to bounce from one planet to another, a technique later used by the Russian VEGA spacecraft.

Kondratyuk was several times invited to join Friedrich Tsander's rocket group, but in letters he kept pushing them away, privately afraid that if he were to be

scrutinized by the police for a new job with them, his secret identity would be exposed. He eventually and probably reluctantly left Moscow to get away from them, become a hydro-electric plant engineer and died fighting the Germans in the snows outside Moscow in February 1942. German troops picked up Yuri Kondratyuk's notebook, full of interplanetary drawings, from his body. But his true identity was not uncovered for more than half a century.

When John F. Kennedy decided the United States should go to the moon in 1961, NASA spent almost 18 months deciding on the best way to get there. Both direct ascent using a huge rocket and Earth orbit rendezvous presented significant problems. The deadlock was only broken where someone remembered the theories of Yuri Kondratyuk for rendezvous in planetary (or lunar) orbit, the technique eventually adopted.

So high was the level of interest in space travel in the 1920s that Professor Nikolai Rynin made a nine-volume compilation of all that was known about the subject at the time. Called *Space travels*, it was in reality an encyclopaedia. Rynin had been organizer of Russia's aerodynamic laboratory in the days of the tsar. Not much aerodynamics was undertaken during the revolution or subsequent civil war, so Nikolai Rynin began his compilation quietly during this difficult time, even though he was cold and hungry. Only one Soviet space encyclopaedia was ever published subsequently, by Valentin Glushko in 1985.

The first exhibition of spacecraft designs was held in Moscow from April to June 1927 under the auspices of the Association of Inventors and it featured the works of Tsiolkosvky and Tsander as well as famous westerners. 12,000 people came to see the models and drawings. Exhibitions were also held in Kiev.

AFTER SUPPRESSION, REVIVAL

The Soviet space boom ended in 1936–7. Stalin decided that the construction of socialism required a strict focus on national industry and military defence, a world in which space travel, collaboration with foreign organizations and amateur societies had no place. The patron of the main rocket research institute, Marshal Tukhachevsky, was shot, as were two leading rocketeers Ivan Kleimenov and Georgi Langemaak. GIRD leader Sergei Korolev was sent to the Gulag and then worked in a confined location (*sharashka*), while the GDL's Valentin Glushko was soon arrested too. The chairman of OSOVIAKHIM, Robert Eideman, was executed.

Rocketry and space development in the USSR temporarily ceased in 1937, although some limited work was undertaken on the development of small solid-fuel rockets to help to get military aircraft airborne quickly from short runways. Both Yakov Perelman and Nikolai Rynin died of starvation during the siege of Leningrad.

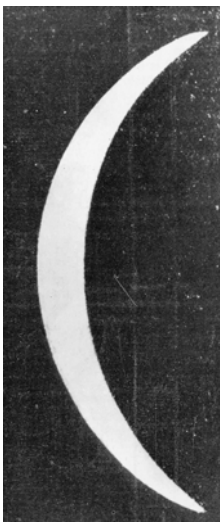
Not until Stalin's death was the discourse evident in the first 15 years of the Soviet Union restored. Fiction and non-fiction writing about space exploration came out into the open once more. A complete collection of Tsiolkovsky's works was published in 1954, as were the works of Tsander and Kondratyuk. Some of this was inspired by the desire, at a time of American military supremacy, to show that Soviet science was

Nikolai Rynin's book

as good as that of the West. Mars fiction reappeared with Georgi Martinov's *220 days in a starship*, in which American astronauts travel first to Mars, but they become stranded and must be rescued by Russian cosmonauts. A conference took place in Leningrad in February 1956 to discuss the Moon, Mars and Venus. The Soviet media of the 1950s were full of discussion of future flights of satellites and, later, journeys to the moon and nearby planets. By 4th October, Soviet citizens were well prepared for the first satellite launching. They were not in the slightest surprised, unlike ordinary American people, though this did not dim their pride in its achievement. Sergei Khrushchev, son of the Soviet leader, pointed out that his generation was reared on the science fiction of Tolstoy and Perelman. The launch of an Earth satellite was not a fantastic idea at all: 'we had been waiting for engineers to turn the dream into reality' for some time [4].

VENUS AT THE TIME OF THE SPACE AGE

And what of the planets that they hoped to visit? Venus was well known to the ancient astronomers. The Italian Galileo Galilei was the first to observe the phases of Venus

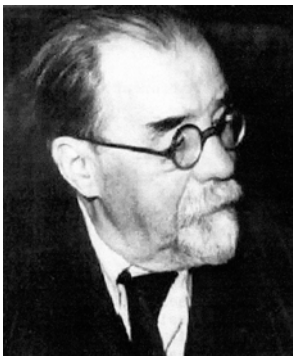


Crescent Venus through a telescope

through his telescope in 1610. It was a Russian, Mikhail Lomonosov (1711–1765), who was the first to determine in 1761 that there was an atmosphere around the planet and estimated that it to be at least equal to and possibly greater than Earth's atmosphere [5].

The early telescope astronomers found Venus a really frustrating object. Most quickly came to the conclusion that the planet was shrouded in thick cloud, though this did not stop some astronomers with gifted eyesight and observational powers from making and publishing maps of the planets showing its landmasses, continents and oceans. Venus was calculated to be a similar size to Earth, which it is, 12,104 km in diameter compared with Earth's 12,756 km. Venus orbits at an average of 108.2m km from the sun, compared with Earth's 149m km. The clouds made the rotational period difficult to calculate and the matter was not settled until the late 20th century (243 days). An important breakthrough came in the 1930s, when observers at the Mount Wilson Observatory in the United States fitted filters to their telescopes in an attempt to characterize the atmosphere of the planet. They found a high level of carbon dioxide, with suggestions of a high surface temperature. Up till this time, the popular image was that – just as Mars was a dry world, with the Martians conserving its remaining water in its canals – whilst in symmetry, Venus was a dripping wet, steaming, swampy, carboniferous planet, like the jungle of the Congo, such a picture being painted in 1918 by Swedish Nobel Chemistry prize winner Svane Arrhenius.

Enter Gavril Adrianovich Tikhov (1875–1960). Although hardly known in the West, he had a profound influence on how Venus (and Mars) were perceived at the time of the space age and, in turn, on the direction of the early exploration programme there. He was born in Smolevichi, Minsk on 1st May 1875, the son of a railway station master. He was a promising child, winning a gold medal when he graduated from Simferopol Gymnasium in 1893, whence he went to Moscow University to study



Gavril Tikhov

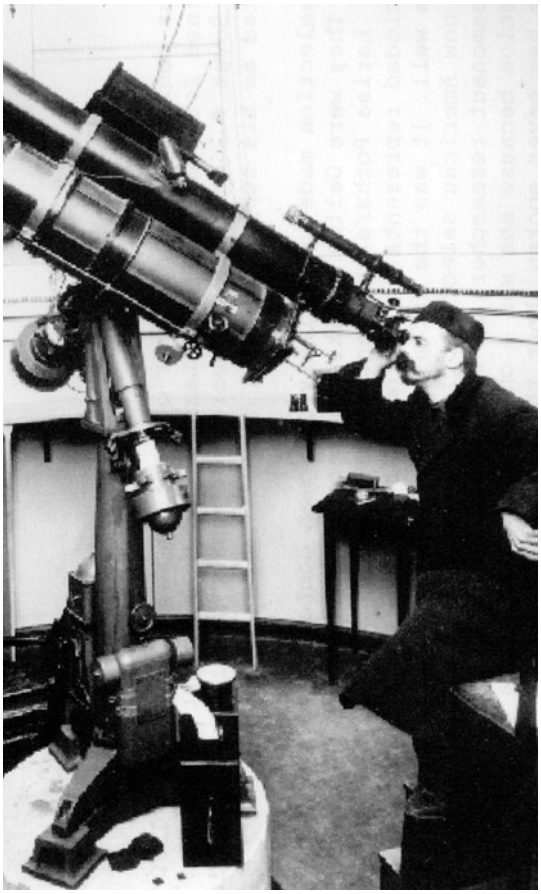
mathematics for the following four years. Graduating from there in 1897, he married Ludmila Popova and then travelled to France – and from 1898 to 1900 enlisted in the Sorbonne. There, astronomy captured his attention and he became assistant to Jules Janssen at Meudon Astrophysics Observatory. It was there that Gavril Tikhov first showed that astronomy was not something to be done only from books and began to show his practical bent. He ascended in a balloon with fellow Russian astronomers A.P. Gansky and French colleagues on 15th November 1899 to observe meteors and later went up Mont Blanc to get a better view of the heavens.

Gavril Tikhov returned to Moscow where he earned an income as a mathematics teacher. Not long after, he was invited to Pulkhovo Observatory in St Petersburg by the astrospectroscopic pioneer A.A. Belopolsky and began to study for an MA there in astronomy and geodesy, which he was awarded in 1913. It was in Pulkhovo that he first began to study the planets in 1909 with a 76.2 cm telescope. Belopolsky pioneered the use of coloured filters to improve our knowledge of stars, but Tikhov applied them to the surface of Mars.

The war put an end to his astronomical studies and in 1914 he joined the Central Aeronautical Navigation Station. There, he applied his observational skills to develop aerial photography to be used for military photoreconnaissance. The systems he developed were well regarded and used by the British and French Air Forces. He wrote the first textbook on aerial reconnaissance, *Improvement of photography and visual air intelligence*, before being conscripted into the army in 1917.

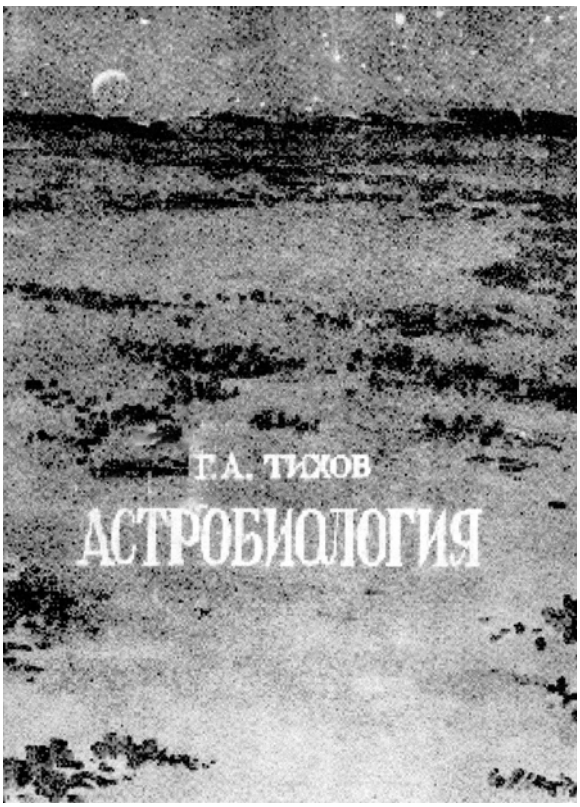
The war over, in 1919 Gavril Tikhov returned to work at Pulkhovo Observatory, work which he combined with a lectureship in the University of St Petersburg, later Leningrad. He was appointed Director of Astrophysics, a post he held till 1941. In the meantime, he was elected to the Academy of Sciences in 1927 and was awarded a PhD in 1935. In 1941, he headed for central Asia to observe the eclipse there and ended up staying in the region. Many leading scientists were evacuated there during the war.

Once the war was over, the government asked him to organize the Kazakh Academy of Sciences. This suited him, for although most of evacuated scientists were happy to return to Moscow and other regions of Russia, some were content to remain. Alma Ata became one of the leading centres of excellence in Soviet astronomy.



Gavril Tikhov in Pulkhovo

There in 1947 he established the world's first department of astrobotany, which he headed (it would now be called exobiology). His observatory was equipped with a 20 cm Maksutov telescope specially adapted for lunar and planetary observations (a 70 cm replacement arrived in 1964). Central to Tikhov's approach was the notion that plants were plentiful on the planets and he believed that he could predict the nature of such plant life through observation. Whilst some of his claims may now be regarded as fanciful, Tikhov was a serious observer and his skills had already been successfully applied to aerial photography. His observatory attracted young graduates from all over the Soviet Union. He often led them on expeditions into the high mountains to study how plants survived in cold, high-altitude, thin-air régimes. In his lectures, Tikhov was a declared enemy of geocentrism (that life in space should be imitative of Earthly life) and argued that it could take many different forms. According to a writer on Tikhov, David Darling, the idea of life on Jupiter's icy moons would not have surprised him [6].



Gavril Tikhov on astrobiology

Tikhov was an acknowledged expert in the colours of stars and variable stars. He was a voluminous writer and popularizer of astronomy, publishing no fewer than 165 books, articles and papers, including an autobiography *Sixty years at the telescope* (1959). His most famous books were *Astrobotany* (1949) and *Astrobiology* (1953). Turning his attention to Venus, Tikhov analyzed, through filters, the light of Venus. Due to the nature of its atmosphere, the plants there, he predicted, would be blue plants rather than Earth's homely green.

As the space age drew near, Tikhov inspired a renewed interest in the planets in the USSR. Telescopic studies of Venus intensified in the 1950s, notably by Russian astronomer N.A. Kozyrev. The views of Venus were still benign. Surface temperatures were estimated in the region of 60°C to 76°C with watery oceans.

Tikhov's conventional wisdom was challenged by V. Beloussov of the Academy of Sciences who predicted in 1961 that Venus would be found to be a hot, primaeval, lifeless planet full of ridges and volcanoes. The then vice-president of the Academy of Sciences Mstislav Keldysh asked the radio astronomers of Pushino Observatory to use their 22 m dish to scan Venus' surface to try determine its temperature. Similar experiments were carried out in the United States and in other parts of the world,