НАЦІОНАЛЬНЕ КОСМІЧНЕ АГЕНТСТВО УКРАЇНИ

НАЦІОНАЛЬНА АКАДЕМІЯ НАУК УКРАЇНИ

КОСМІЧНА НАУКА І ТЕХНОЛОГІЯ

НАУКОВО-ПРАКТИЧНИЙ ЖУРНАЛ

Журнал засновано в лютому 1995 р. ✦ Виходить 6 разів за рік

КИЇВ **Том 6, № 4, 2000** **KYIV**

Від авторського колективу

Цей спеціальний випуск журналу присвячено науковим дослідженням та технологічним експериментам, які запропоновані українськими вченими та інженерами для реалізації в рамках проекту «Міжнародна Космічна Станція». Навіть такий великий авторський колектив, 210 осіб, не охоплює всіх тих, хто брав участь у виконанні цієї роботи в 1998—2000 рр. Ми висловлюємо щиру подяку всім тим, хто співпрацював з нами на цьому етапі та допоміг у підготовці цього випуску.

Authors' remarks

This special issue of the journal is dedicated to the scientific research and technological experiments, which are proposed by Ukrainian scientists and engineers for the International Space Station program. Even such a large author's team, the 210 persons, does not include all those who have participated in this work during 1998—2000. The authors are grateful to those persons who have collaborated with us at this stage and have helped in preparing this issue.

UKRAINIAN
SCIENTIFIC RESEARCH AND TECHNOLOGICAL EXPERIMENTS
PROPOSED FOR THE INTERNATIONAL SPACE STATION

B. E. Paton, A. A. Negoda, Ya. S. Yatskiv, S. N. Konyukhov

E. L. Kordyum, V. M. Kuntsevich, L. N. Litvinenko, V. V. Nemoshkalenko, V. F. Prisnyakov, V. I. Trefilov

V. P. Bass, S. I. Bondarenko, V. V. Frolkis, V. A. Kordyum, O. V. Korkushko, L. M. Lobanov, V. I. Lyalko, O. V. Morozhenko, V. V. Pilipenko, Yu. A. Pokhyl, Yu. M. Yampolski

O. K. Cheremnykh, V. J. Dranovsky, O. P. Fedorov, S. N. Sedykh, I. B. Vavilova

E. N. Aleksenko, A. P. Alpatov, Yu. V. Aristov, Yu. A. Asnis, V. M. Babich, O. N. Bakalinskaya, G. M. Bakan, O. M. Barabash, V. A. Baraboj, V. V. Baranenko, P. I. Baranskii, P. P. Belonozhko, D. G. Belov, N. A. Belyavskaya, V. A. Berezovsky, E. I. Bersudsky, N. I. Bogatina, T. A. Borisova, Yu. V. Bovt, A. L. Boyko, A. B. Brik, A. V. Bruns, O. V. Budanov, V. A. Buts, A. K. Cheban, G. P. Chemerinsky, V. T. Cherepin, T. M. Cherevchenko, A. A. Chumak, V. P. Churilov, V. P. Delyamoure, O. T. Demkiv, P. A. Dem'yanenko, L. V. Didkovskij, S. A. Dovgij, V. I. Dubodelov, N. S. Dyachenko, A. M. Egorov, V. R. Estrela-Liopis, N. A. Eremenko, V. V. Eremenko, I. I. Eru, N. Yu. Evtushenko, Ya. B. Fainberg, A. D. Fedorovsky, V. B. Fillipov, S. A. Firstov, O. A. Fokov, G. A. Frolov, I. I. Gab, G. D. Gamulya, R. V. Gavrylov, S. I. Gopasyuk, Yu. M. Goryachev, D. M. Grodzinsky, R. I. Gvozdyak, N. H. Himmelreich, A. I. Itsenko, R. K. Ivaschenko, A. B. Kamelin, V. G. Karas', I. F. Kharchenko, A. I. Khizhnyak, V. S. Khoroshilov, D. A. Khramov, O. A. Khymenko, S. I. Klimov, D. A. Klymchuk, S. V. Komissarenko, A. V. Kondrachuk, S. Ya. Kondratyuk, V. E. Korepanov, G. K. Korotaev, A. N. Korsunov, A. G. Kostornov, P. G. Kostyuk, A. V. Kozlov, N. A. Kozyrovska, V. S. Kravets, V. S. Kresanov, V. I. Kugel, Yu. I. Kundiev, E. A. Kuprianova, B. A. Kurchii, B. A. Kyryyevskyy, V. P. Kuz'kov, B. V. Lazebny, V. A. Lototskaya, M. M. Lychak, V. P. Majboroda, I. N. Maksimchuk, S. V. Medvednikov, Yu. A. Melenevsky, M. I. Mendzhul, L. T. Mischenko, Yu. V. Milman, K. Ya. Moiseenko, G. M. Molchanovskaya, I. A. Morozov, R. A. Morozova, Kh. K. Muradjan, V. V. Myshenko, Yu. V. Najdich, O. K. Nazarenko, O. M. Nedukha, V. E. Oliker, O. L. Ostrovska, L. M. Ovsiannikova, Yu. B. Paderno, V. M. Panashenko, V. V. Pasichny, E. S. Paslavsky, V. E. Paznukhov, V. P. Pegueta, I. I. Perekopskiy, I. S. Pilishenko, A. V. Pirozhenko, V. A. Pivtorak, V. A. Pokrovsky, Yu. A. Polulyakh, A. F. Popova, V. I. Prima, M. I. Prokof'ev, O. V. Przhonska, I. M. Rarenko, B. M. Rassamakin, N. V. Rodionova, A. G. Rokhman, K. V. Rusanov, N. V. Ruzhentsev, V. M. Samilov, V. V. Sarnatzkaya, N. S. Scherbakova, D. V. Schur, I. A. Serbinenko, V. A. Seredenko, V. N. Shapar, A. A. Shapoval, A. A. Shcherba, A. H. Shmireva, E. I. Shnyukova, V. M. Shulga, L. M. Shulman, V. O. Shuvalov, V. G. Sinitsin, V. G. Sitalo, M. V. Skok, Yu. D. Skrypnyk, E. I. Slunko, L. L. Solodovnik, B. V. Sorochinsky, I. M. Statsenko, K. N. Stepanov, V. O. Stryzhalo, V. I. Sukhorukov, S. V. Svechnikov, M. N. Surdu, G. I. Tarasov, P. M. Tsarenko, V. N. Tcymbal, V. G. Tkachenko, V. A. Troitskii, A. A. Tsutsaeva, A. M. Tsymbal, O. F. Tyrnov, A. D. Vasil'ev, E. T. Verhovtseva, I. D. Vojtovich, O. L. Voloshenjuk, O. I. Volovik, A. F. Vozianov, L. F. Yakovenko, V. I. Yaremenko, V. A. Yatsenko, V. K. Yavorska, T. P. Yukhno, S. P. Zabolotin, L. P. Zabrodina, V. I. Zagrebelny, E. I. Zhivolub, V. S. Zhuravlev, V. A. Zinchenko, Yu. F. Zinkovskiy, H. K. Zolotareva

Підп. до друку 03.08.00. Формат 84×108/16. Папір офс. № 1. Друк офсетний. Ум. друк. арк. 10.92. Обл.-вид. арк. 10.2. Тираж 200 екз.

CONTENTS

I. BRIEF OVERWIEW OF THE ISS PROJECT: INTERNATIONAL AND UKRAINIAN PARTICIPATION

II. UKRAINIAN SCIENTIFIC RESEARCH AND TECHNOLOGICAL EXPERIMENTS PROPOSED FOR THE ISS

II.1. SPACE TECHNOLOGY AND MATERIALS SCIENCE

UKRAINIAN
SCIENTIFIC RESEARCH AND TECHNOLOGICAL EXPERIMENTS PROPOSED FOR THE INTERNATIONAL SPACE STATION

B. E. Paton, A. A. Negoda, Ya. S. Yatskiv, S. N. Konyukhov

E. L. Kordyum, V. M. Kuntsevich, L. N. Litvinenko, V. V. Nemoshkalenko, V. F. Prisnyakov, V. I. Trefilov

V. P. Bass, S. I. Bondarenko, V. V. Frolkis , V. A. Kordyum, O. V. Korkushko, L. M. Lobanov,
V. I. Lyalko, O. V. Morozhenko, V. V. Pilipenko, Yu. A. Pokhyl, Yu. M. Yampolski

O. K. Cheremnykh, V. J. Dranovsky, O. P. Fedorov, S. N. Sedykh, I. B. Vavilova

E. N. Aleksenko, A. P. Alpatov, Yu. V. Aristov, Yu. A. Asnis, V. M. Babich, O. N. Bakalinskaya,
G. M. Bakan, O. M. Barabash, V. A. Baraboj, V. V. Baranenko, P. I. Baranskii, P. P. Belonozhko, D. G. Belov,
N. A. Belyavskaya, V. A. Berezovsky, E. I. Bersudsky, N. I. Bogatina, T. A. Borisova, Yu. V. Bovt, A. L. Boyko,
A. B. Brik, A. V. Bruns, O. V. Budanov, V. A. Buts, A. K. Cheban, G. P. Chemerinsky, V. T. Cherepin,
T. M. Cherevchenko, A. A. Chumak, V. P. Churilov, V. P. Delyamoure, O. T. Demkiv, P. A. Dem'yanenko,
L. V. Didkovskij, S. A. Dovgij, V. I. Dubodelov, N. S. Dyachenko, A. M. Egorov, V. R. Estrela-Liopis,
N. A. Eremenko, V. V. Eremenko, I. I. Eru, N. Yu. Evtushenko, Ya. B. Fainberg, A. D. Fedorovsky,
V. B. Fillipov, S. A. Firstov, O. A. Fokov, G. A. Frolov, I. I. Gab, G. D. Gamulya, R. V. Gavrylov, S. I. Gopasyuk,
Yu. M. Goryachev, D. M. Grodzinsky, R. I. Gvozdyak, N. H. Himmelreich, A. I. Itsenko, R. K. Ivaschenko,
A. B. Kamelin, V. G. Karas', I. F. Kharchenko, A. I. Khizhnyak, V. S. Khoroshilov, D. A. Khramov,
O. A. Khymenko, S. I. Klimov, D. A. Klymchuk, S. V. Komissarenko, A. V. Kondrachuk, S. Ya. Kondratyuk,
V. E. Korepanov, G. K. Korotaev, A. N. Korsunov, A. G. Kostornov, P. G. Kostyuk, A. V. Kozlov,
N. A. Kozyrovska, V. S. Kravets, V. S. Kresanov, V. I. Kugel, Yu. I. Kundiev, E. A. Kuprianova, B. A. Kurchii,
B. A. Kyryyevskyy, V. P. Kuz'kov, B. V. Lazebny, V. A. Lototskaya, M. M. Lychak, V. P. Majboroda,
I. N. Maksimchuk, S. V. Medvednikov, Yu. A. Melenevsky, M. I. Mendzhul, L. T. Mischenko, Yu. V. Milman,
K. Ya. Moiseenko, G. M. Molchanovskaya, I. A. Morozov, R. A. Morozova, Kh. K. Muradjan, V. V. Myshenko,
Yu. V. Najdich, O. K. Nazarenko, O. M. Nedukha, V. E. Oliker, O. L. Ostrovska, L. M. Ovsiannikova,
Yu. B. Paderno, V. M. Panashenko, V. V. Pasichny, E. S. Paslavsky, V. E. Paznukhov, V. P. Pegueta,
I. I. Perekopskiy, I. S. Pilishenko, A. V. Pirozhenko, V. A. Pivtorak, V. A. Pokrovsky, Yu. A. Polulyakh,
A. F. Popova, V. I. Prima, M. I. Prokof'ev, O. V. Przhonska, I. M. Rarenko, B. M. Rassamakin, N. V. Rodionova,
A. G. Rokhman, K. V. Rusanov, N. V. Ruzhentsev, V. M. Samilov, V. V. Sarnatzkaya, N. S. Scherbakova,
D. V. Schur, I. A. Serbinenko, V. A. Seredenko, V. N. Shapar, A. A. Shapoval, A. A. Shcherba, A. H. Shmireva,
E. I. Shnyukova, V. M. Shulga, L. M. Shulman, V. O. Shuvalov, V. G. Sinitsin, V. G. Sitalo, M. V. Skok,
Yu. D. Skrypnyk, E. I. Slunko, L. L. Solodovnik, B. V. Sorochinsky, I. M. Statsenko, K. N. Stepanov,
V. O. Stryzhalo, V. I. Sukhorukov, S. V. Svechnikov, M. N. Surdu, G. I. Tarasov, P. M. Tsarenko, V. N. Tcymbal,
V. G. Tkachenko, V. A. Troitskii, A. A. Tsutsaeva, A. M. Tsymbal, O. F. Tyrnov, A. D. Vasil'ev,
E. T. Verhovtseva, I. D. Vojtovich, O. L. Voloshenjuk, O. I. Volovik, A. F. Vozianov, L. F. Yakovenko,
V. I. Yaremenko, V. A. Yatsenko, V. K. Yavorska, T. P. Yukhno, S. P. Zabolotin, L. P. Zabrodina,
V. I. Zagrebelny, E. I. Zhivolub, V. S. Zhuravlev, V. A. Zinchenko, Yu. F. Zinkovskiy, H. K. Zolotareva

I. BRIEF OVERWIEW OF THE ISS PROJECT: INTERNATIONAL AND UKRAINIAN PARTICIPATION

Space exploration for various purposes ranging from purely commercial systems of telecommunication and television up to research platforms in the orbits of Earth and other planets of the Solar System is a powerful stimulus for a faster advance of science and technology in the XXI century.

The most ambitious scientific and technological project bursting into a new era of space exploration is the International Space Station (ISS). The ISS will be a multidisciplinary and multinational world-class laboratory for advanced technologies and pioneering research and will create new venues allowing scientists to gain more profound knowledge for the benefit of humanity.

I.1. BRIEF OVERVIEW OF THE ISS PROJECT

Being the initiative of the United States in 1980s, the construction of the ISS became the international project due to Canada, the European states (the ESA members — Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom), Japan, Russia, and Brazil joining the project.

The first agreements were signed between NASA and Canadian Space Agency, and ESA in 1988 and between NASA and NASDA (Japan) in 1989. Under these agreements, the «Columbus», one of the main station modules-laboratories forming the ISS heart as well as separate «free fliers» is the ESA's contribution. Japan produces a sophisticated module. Canada develops a mobile service «hand-manipulator». Using special modules, Italy will deliver experimental equipment, materials, and provision supply to the ISS.

Since 1988 the ISS project was more than once revised and suspended, mainly because of its expences. In 1995, when the President of the USA, W. Clinton assured NASA that the US would provide the required annual funding, the ISS project started becoming a reality. The prospect of the successful ISS assembly and further maintenance was essentially improved, when Russia joined the ISS community. The partnership with Russia envisaged utilization of the main orbital station components, which had been earlier planned for the OSS «Mir-2», as well as of its own research station segment. In January 1998, a mutual agreement between all the space partners was signed and the ISS design and Assembly Sequence was approved.

According to this sequence, the assembly of the main ISS components (Russian service module, the first of the American power modules, multi-purpose logistics module), as well as the delivery of two components of the Mobile Servicing System (MSS, Canadian «hand-manipulator») and of various segments of the truss structure has been planned to be completed by the end of 2001. The MSS having a 110-ton payload capability, is a key component of the ISS, which will service the construction elements attached to the station, releasing and capturing satellites, supporting astronauts during EVA sessions. The Assembly Sequence envisages further attachment of other American power modules, Japanese experimental module and three Russian research modules. The «Columbus» ESA laboratory and American habitation module were planned to be attached in 2004, at which point, a full crew of astronauts up to seven persons could work at the ISS between three and six months.

The ISS Assembly is presented on the fourth page of cover of this issue. The principal features of the ISS Assembly, which were planned in 1998, were as follows (http://spaceflight.nasa.gov/station):

Date	Flight	Launch Vehicle	Element(s)
Nov 20, 1998	1A/R	Russian Proton	Zarya Control Module (Functional Cargo Block — FCB)
Dec 4, 1998	2A	US Orbiter	STS-88 Unity Node (1 Stowage Rack); Pressurized Mating Adapters attached to Unity
May 27, 1999	2A.1	US Orbiter	STS-96 Spacehab — Logistics Flight
Nov 1999	1R	Russian Proton	Zvezda Service Module
Jan 22, 2000	2A.2	US Orbiter	STS-101 Spacehab — Logistics Flight
Feb 2000	3A	US Orbiter	STS-92 Integrated Truss Structure (ITS) Z1; Pressurized Mating Adapter — 3; Ku-band Communications System; Control Moment Gyros (CMGs)
Mar 2000	2R	Russian Soyuz	Expedition 1 Crew
Mar 2000	4A	US Orbiter	STS-97 Integrated Truss Structure P6; Photovoltaic Module; Radiators
Apr 2000	5A	US Orbiter	STS-98 Destiny Laboratory Module
Jun 2000	5A.1	US Orbiter	STS-102 Logistics and Resupply; Lab Outfitting Leonardo Multi-Purpose Logistics Module (MPLM) carries equipment racks
July 2000	6A	US Orbiter	STS-100 Rafaello Multi-Purpose Logistics Module (MPLM) (Lab outfitting); Ultra High Frequency (UHF) antenna; Space Station Remote Manipulating System (SSRMS)
Aug 2000	7A	US Orbiter	STS-104 Joint Airlock; High Pressure Gas Assembly
Sep 2000	4R	Russian Soyuz	Docking Compartment 1 (DC-1); Strela Boom
Nov 2000	7A.1	US Orbiter	STS-105 Donatello Multi-Purpose Logistics Module (MPLM)
Jan 2001	UF-1	US Orbiter	STS-106 Multi-Purpose Logistics Module (MPLM); Photovoltaic Module batteries; Spares Pallet (spares warehouse)
Mar 2001	8A	US Orbiter	STS-108 Central Truss Segment (ITS S0); Mobile Transporter (MT)
May 2001	UF-2	US Orbiter	STS-109 Multi-Purpose Logistics Module (MPLM) with payload racks; Mobile Base System (MBS)
July 2001	9A	US Orbiter	STS-111 First right-side truss segment (ITS S1) with radiators; Crew & Equipment Translation Aid (CETA) Cart A
Aug 2001	11A	US Orbiter	STS-112 First left-side truss segment (ITS P1); Crew & Equipment Translation Aid (CETA) Cart B
Nov 2001	9A.1	US Orbiter	STS-114 Russian provided Science Power Platform (SPP) with four solar arrays
Jan 2002	12A	US Orbiter	STS-115 Second left-side truss segment (ITS P3/P4); Solar array and batteries
Mar 2002	12A.1	US Orbiter	STS-117 Third left-side truss segment (ITS P5); Multi-Purpose Logistics Module (MPLM)
May 2002	13A	US Orbiter	STS-118 Second right-side truss segment (ITS S3/S4); Solar array set and batteries (Photovoltaic Module)
June 2002	3R	Russian Proton	Universal Docking Module (UDM)
July 2002	5R	Russian Soyuz	Docking Compartment 2 (DC2)
July 2002	10A	US Orbiter	STS-120 US Node 2
Aug 2002	10A.1	US Orbiter	STS-121 Propulsion Module
Oct 2002	1J/A	US Orbiter	STS-123 Japanese Experiment Module Experiment Logistics Module (JEM ELM PS) Science Power Platform (SSP) solar arrays with truss
Jan 2003	1J	US Orbiter	STS-124 Kibo Japanese Experiment Module (JEM) Japanese Remote Manipulator System (JEM RMS)
Feb 2003	UF-3	US Orbiter	STS-125 Multi-Purpose Logistics Module (MPLM) Express Pallet
May 2003	UF-4	US Orbiter	STS-127 Express Pallet Spacelab Pallet carrying «Canada Hand» (Special Purpose Dexterous Manipulator)
June 2003	2J/A	US Orbiter	STS-128 Japanese Experiment Module Exposed Facility (JEM EF) Solar Array Batteries
July 2003	9R	Russian Proton	Docking and Stowage Module (DSM)
Aug 2003	14A	US Orbiter	STS-130 Cupola; Science Power Platform (SPP) Solar Arrays Zvezda Micrometeroid and Orbital Debris (MMOD) Shields
Sep 2003	UF-5	US Orbiter	STS-131 Multi-Purpose Logistics Module (MPLM); Express Pallet
Jan 2004	20A	US Orbiter	STS-133 US Node 3
Feb 2004	1E	US Orbiter	STS-134 European Laboratory — Columbus Attached Pressurized Module (APM)
Mar 2004	8R	Russian Soyuz	Research Module 1
Mar 2004	17A	US Orbiter	STS-135 Multi-Purpose Logistics Module (MPLM); Destiny racks
May 2004	18A	US Orbiter	STS-136 Crew Return Vehicle (CRV)
June 2004	19A	US Orbiter	STS-137 Multi-Purpose Logistics Module (MPLM)
July 2004	15A	US Orbiter	STS-138 Solar Arrays and Batteries (Photovoltaic Module S6)
Aug 2004	10R	Russian Soyuz	Research Module 2
Aug 2004	UF-7	US Orbiter	STS-139 Centrifuge Accommodation Module (CAM)
Sep 2004	UF-6	US Orbiter	STS-140 Multi-Purpose Logistics Module (MPLM); Batteries
Nov 2004	16A	US Orbiter	STS-141 Habitation Module

Notes: Additional Progress, Soyuz, H-II Transfer Vehicle and Automated Transfer Vehicle flights for crew transport, logistics and resupply are not listed.

During 1998 — 2004, 45 missions of the US Shuttle and Russian Soyuz and Progress vehicles are scheduled to assemble more than 100 elements of the ISS construction. The ISS assembly will require about 1700 hours of «space roads» that is many more, than has been flown during the whole time of manned space exploration. The plan is to complete the primary ISS assembly in the orbit of 350 km and after that to move the station up into the working orbits of 410—450 km. This phase will mean that the 15-years period of active lifetime of the ISS can be started. The ISS will have the length of 79.9 m and width of 108.6 m, the total mass of about 460 tons and internal volume of 1217 m^3. The station will make one revolution around the Earth with the velocity of 28 000 km per year, and its flight trajectory will enable 85 % of the Earth's surface to be observed. The total cost of the ISS project is about $95.6 billion.

In 1998-2000, six flights have already occurred to assemble the ISS in orbit.

The first station component, the Zarya control module, was launched by a Russian Proton rocket in November 20, 1998. The Russian Zarya (Functional Cargo Block) built by Khrunichev SRPSC under a subcontract to the Boeing Co. for NASA is the US-owned component of the station. This module is designed to provide propulsion, control system, orientation and electrical power for the ISS's first months in orbit. Its docking ports allow attachment of Soyuz manned spacecraft and unmanned Progress spacecraft. The Zarya module has an operational lifetime of at least 15 years, and later, as envisaged by the station's sequence, it will be used as the ISS passageway, docking port and external fuel tank. Two weeks after Zarya rendezvous, in December 4, the first US pressurised module Unity-1 was to be launched and attached to the Zarya module (STS-88 mission). The Unity-1 connecting module is providing six attachment ports to join all the future US modules. In June, 1999 the third ISS mission, the Space Shuttle Discovery rendezvous (STS-96), was completed to perform the necessary testing of equipment and to connect power and data transmission cables to the Zarya — Unity-1 system, as well as to inhabit the ISS.

Afterwards several changes in the Assembly Sequence mentioned above have happened, because of the nine-months delay of the launch of the Russian Zvezda component.

In May 19, 2000, the STS-101 was launched with the seven-member crew. It was a re-scheduled Space Shuttle flight for correction of orbital changes of the ISS, which occurred because of Zvezda delay, and for performance of maintenance tasks. The third major station component, the Russian Zvezda, was docked with the ISS in July 26, 2000 (the fifth flight). This component is the Service Module, the crew's living quarters. It is the first fully Russian station contribution and the core of the Russian station segment. The Service Module enhances and replaces many functions of the Zarya block. It provides functioning of a life support system, navigation, communication and propulsion, as well as of other facilities for the early stage of the ISS. In Sept 8, 2000, the international crew visited the ISS to deliver supplies and outfit the Service Module as well as to complete engineering operations, which are necessary for preparing the station for long-duration habitation. In Oct 11, 2000, STS-92 delivered Integrated Truss Structure, Pressurrized Mating Adapters-3, Communication System and four Control Moment Gyros.

In October 31, 2000 the first long-term Expedition was launched from the Baikonur Cosmodrome to the ISS on Soyuz space vehicle. The crew consists of W. Shepard (USA), Yu. Gidzenko, S. Krikalev (Russia). The astronauts, who are to spend about four months in space, will have to make the station habitable. After installation of all equipment associated with the Electron Oxygen Generation System and testing on-board computers and communication facilities, the crew will start doing the numerous scientific experiments. For the first month and a half the cosmonauts' activity will be monitored by the Russian Flight Control Center and then the NASA Houston Center will control it.

The ISS Assembly Sequence at the current date (on Nov 7, 2000) is the following (for information updated see http://hq.nasa.gov/office and http://spaceflight.nasa.gov/station):

Date	Flight	Launch Vehicle	Element(s)
Nov 20, 1998	1A/R	Russian Proton	Zarya Control Module (Functional Cargo Block — FCB)
Dec 4, 1998	2A	US Orbiter	STS-88 Unity Node (1 Stowage Rack); 2 Pressurized Mating Adapters attached to Unity
May 27, 1999	2A.1	US Orbiter	STS-96 Spacehab — Logistics Flight
May 19, 2000	2A.2a	US Orbiter	STS-101 Spacehab — Maintenance Flight
Jul 12, 2000	1R	Russian Proton	Zvezda Service Module
Sept 8, 2000	2A.2a	US Orbiter	STS-106 Spacehab — Logistics Flight

Date	Flight	Launch Vehicle	Element(s)
Oct 11, 2000	3A	US Orbiter	STS-92 Integrated Truss Structure (ITS) Z1; Pressurized Mating Adapter — 3; Ku-band Communications System; 4 Control Moment Gyros (CMGs)
Oct 31, 2000	2R	Russian Soyuz	Expedition 1 Crew
Nov 30, 2000	4A	US Orbiter	STS-97 Integrated Truss Structure P6; Photovoltaic Module; Radiators
Jan 18, 2001	5A	US Orbiter	STS-98 Destiny Laboratory Module
Feb 15, 2001	5A.1	US Orbiter	STS-102 Logistics and Resupply; Lab Outfitting Leonardo Multi-Purpose Logistics Module (MPLM) carries equipment racks
March 2001	4R	Russian Soyuz	Docking Compartment 1 (DC-1); Strela Boom
April 19, 2001	6A	US Orbiter	STS-100 Rafaello Multi-Purpose Logistics Module (MPLM) (Lab outfitting); Ultra High Frequency (UHF) antenna; Space Station Remote Manipulating System (SSRMS)
May 17, 2001	7A	US Orbiter	STS-104 Joint Airlock; High Pressure Gas Assembly
June 21, 2001	7A.1	US Orbiter	STS-105 Donatello Multi-Purpose Logistics Module (MPLM)
Oct 4, 2001	UF-1	US Orbiter	STS-106 Multi-Purpose Logistics Module (MPLM); Photovoltaic Module batteries; Spares Pallet (spares warehouse)
Jan 2002	8A	US Orbiter	STS-108 Central Truss Segment (ITS S0); Mobile Transporter (MT)
Feb 2002	UF-2	US Orbiter	STS-109 Multi-Purpose Logistics Module (MPLM) with payload racks; Mobile Base System (MBS)
May 2002	9A	US Orbiter	STS-111 First right-side truss segment (ITS S1) with radiators; Crew & Equipment Translation Aid (CETA) Cart A
June 2002	ULF1	US Orbiter	Utilization and logistics Flight
Oct 2002	11A	US Orbiter	STS-112 First left-side truss segment (ITS P1); Crew & Equipment Translation Aid (CETA) Cart B
Oct 2002	9A.1	US Orbiter	STS-114 Russian provided Science Power Platform (SPP) with four solar arrays
Dec 2002	12A	US Orbiter	STS-115 Second left-side truss segment (ITS P3/P4); Solar array and batteries
Feb 2003	12A.1	US Orbiter	STS-117 Third left-side truss segment (ITS P5); Multi-Purpose Logistics Module (MPLM)
April 2003	13A	US Orbiter	STS-118 Second right-side truss segment (ITS S3/S4); Solar array set and batteries (Photovoltaic Module)
June 2003	13A.1	US Orbiter	Logistics and Supplies
Aug 2003	3R	Russian Proton	Universal Docking Module (UDM)
Aug 2003	5R	Russian Soyuz	Docking Compartment 2 (DC2)
Oct 2003	UF-4	US Orbiter	STS-127 Express Pallet Spacelab Pallet carrying «Canada Hand» (Special Purpose Dexterous Manipulator)
Nov 2003	10A	US Orbiter	STS-120 US Node 2
Feb 2004	1J/A	US Orbiter	STS-123 Japanese Experiment Module Experiment Logistics Module (JEM ELM PS) Science Power Platform (SSP) solar arrays with truss
April 2004	ATV		European Automated Transfer Vehicle
May 2004	1J	US Orbiter	STS-124 Kibo Japanese Experiment Module (JEM) Japanese Remote Manipulator System (JEM RMS)
June 2004	10A.1	US Orbiter	STS-121 Propulsion Module
Sept 2004	UF-3	US Orbiter	STS-125 Multi-Purpose Logistics Module (MPLM) Express Pallet
Oct 2004	1E	US Orbiter	STS-134 European Laboratory — Columbus Module
June 2005	2J/A	US Orbiter	STS-128 Japanese Experiment Module Exposed Facility (JEM EF) Solar Array Batteries; Cupola
Feb 2005	UF-5	US Orbiter	STS-131 Multi-Purpose Logistics Module (MPLM); Express Pallet
TBD	9R	Russian Proton	Docking and Stowage Module (DSM)
May 2005	14A	US Orbiter	STS-130 Science Power Platform (SPP) Solar Arrays; Zvezda Micrometeroid and Orbital Debris (MMOD) Shields
June 2005	UF-6	US Orbiter	STS-140 Multi-Purpose Logistics Module (MPLM); Batteries
July 2005	20A	US Orbiter	STS-133 US Node 3
Aug 2005	8R	Russian Soyuz	Research Module 1
Sept 2005	16A	US Orbiter	STS-141 Habitation Module
Oct 2005	17A	US Orbiter	STS-135 Multi-Purpose Logistics Module (MPLM); Destiny racks
Dec 2005	18A	US Orbiter	STS-136 Crew Return Vehicle (CRV)
Jan 2006	19A	US Orbiter	STS-137 Multi-Purpose Logistics Module (MPLM)
March 2006	15A	US Orbiter	STS-138 Solar Arrays and Batteries (Photovoltaic Module S6)
March 2006	10R	Russian Soyuz	Research Module 2
April 2006	UF-7	US Orbiter	STS-139 Centrifuge Accommodation Module (CAM)

Notes: Additional Progress, Soyuz, H-II Transfer Vehicle and Automated Transfer Vehicle flights for crew transport, logistics and resupply are not listed.

The ISS will provide a marked improvement in the level of international cooperation and in understanding the potential of space science and technology for solving the common problems of human civilization. As it is pointed out by NASA, «the ISS will afford scientists, engineers, and entrepreneurs an unprecedented platform on which to perform complex, long-duration, and replicable experiments in the unique environment of space. The ISS will maximize its particular assets: prolonged exposure to microgravity and the presence of human experiments in the research process» (*The International Space Station. The NASA Research Plan, an Overview, 1998*). The modern high technologies, such as telescience, will enable virtual access to the remote station laboratories to be realized. The ISS program envisages the following science and technology directions: biomedical research; medical care in space; advanced human support technology; biotechnology; combustion science; fluid physics; fundamental physics; materials science; gravitational biology and ecology; Earth sciences; space science; commercial product development. Several hundred thousand people at space agencies and various companies, as well as at scientific institutions of the whole world are involved in the ISS, contributing to the success of this project. Without doubt, this permanent station will also provide experience for further space exploration, in particular, the preparation of the Martian manned mission in 2015-2020. «When the Solar System is being conquered, the human beings will have new dimensions» (K. Tsiolkovskij).

I.2. UKRAINE'S PARTICIPATION IN THE ISS. STATUS OF THE UKRAINIAN RESEARCH MODULE

Ukraine's policy in the area of peaceful exploration of space is aimed at preservation and strengthening of the scientific schools and scientific-engineering potential of the space industry. Being one of the constellation of space-faring countries of the world, Ukraine is interested in the ISS project to conduct the national experiments onboard the ISS and to take part in international utilization of the space station.

Main objectives of Ukraine's participation in the ISS are the following:

- consolidate Ukraine's position of excellence in international scientific exploration of space;
- encourage development of space technology for progress of society;
- provide opportunities for Ukrainian scientists and engineers to participate in the national and international space missions;
- strengthen USA-Ukraine and Russia-Ukraine partnership in space exploration.

To meet these objectives the National Space Agency of Ukraine (NSAU) has included the Ukrainian Research Module (URM) project into the National Space Program for 1998-2002.

Status of the Ukrainian Research Module of the ISS

- URM should be the Space Station Element defined in Art. 3 of a Memorandum of Understanding between NASA and Russian Space Agency (RSA) as the Research Module incorporated into the Russian Segment;
- according to the Minutes of NSAU — RSA negotiations, the URM consists of the following main components:

— scientific and technological payload and specialized downlink for data transmission;

— basic complex for payload support (shared with the Russian Segment);

— set of maintenance equipment (shared with the Russian segment).

It is presumed that the Ukrainian Research Program to be implemented onboard the URM, will be harmonized with the ISS planning process and will benefit from performance of international experiments.

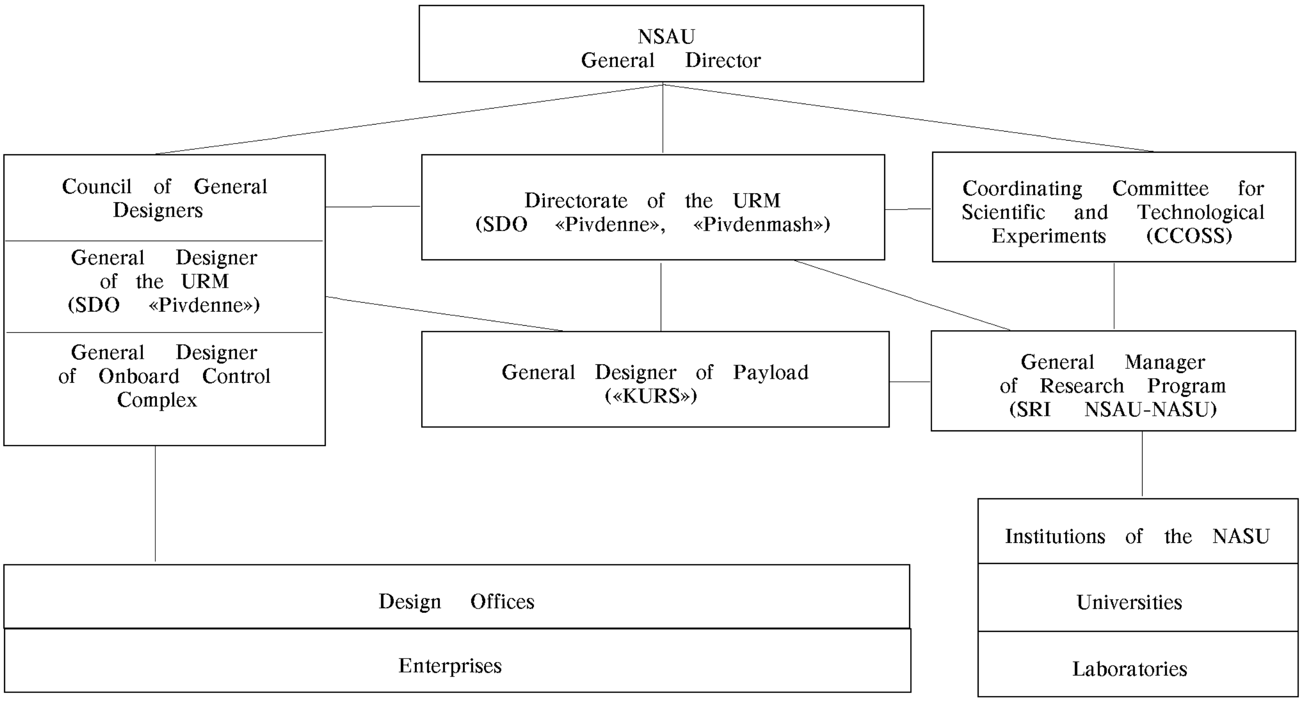


Fig. 1. Management Structure for Development and Construction of the URM

I.3. MANAGEMENT STRUCTURE OF UKRAINE'S PARTICIPATION IN THE ISS

Provisional **Management Structure** for development and construction of the URM includes the following Parties (see also Figure 1):

— Directorate of NSAU;

— Coordinating Committee for Scientific Research and Technological Experiments onboard the OSS;

— Directorate of the URM Program;

— Council of General Designers.

NSAU is responsible for general management of thee URM Program, for its financial and legal support, as well as for participation in the international planning process.

Directorate of the URM Program integrates the scientific and engineering proposals for development and construction of the URM.

Council of General Designers is responsible for design of the URM and for the flight planning.

General Designer of the URM is responsible for integration of scientific instrumentation, planning and development of scientific instrumentation.

General Manager of the URM Program is responsible for management of the URM Program.

To select scientific and technological experiments to be performed onboard the URM, a special coordinating committee was formed in October, 1997 by the National Academy of Sciences of Ukraine (NASU) and NSAU, namely the **Coordinating Committee for scientific research and technological experiments onboard the Orbital Space Stations (CCOSS).**

I.4. COORDINATING COMMITTEE FOR SCIENTIFIC RESEARCH AND TECHNOLOGICAL EXPERIMENTS ONBOARD THE ORBITAL SPACE STATIONS (CCOSS)

Main tasks:

— define a general strategy for Ukraine's participation in the ISS;

— distribute an announcement of opportunity for identifying the scientific and technological experiments to be performed onboard the URM;

— make an examination (peer review) of proposals received from scientific and engineering communities;

— select a set of experiments to be included into Instrument Definition and Development Program;

— work out the Ukrainian Program of Scientific Research and Technological Experiments proposed for the ISS;

CCOSS consists of Chairman, Vice-Chairman, Chairmen of Scientific Sections, Scientific Secretary, Members of Committee (see also Figure 2).

Members of the CCOSS:

Borys E. Paton	President of the NASU Director of the E. O. Paton Electric Welding Institute *Chairman*
Yaroslav S. Yatskiv	Director of the Main Astronomical Observatory, NASU *Vice-Chairman*
Elizaveta L. Kordyum	Deputy-Director of the Institute of Botany, NASU
Vsevolod M. Kuntsevich	Director of the Space Research Institute, NSAU-NASU
Leonid N. Litvinenko	Director of the Institute of Radio Astronomy, NASU
Volodymyr V. Nemoshkalenko	Director of the Institute for Metal Physics, NASU
Volodymyr F. Prisnyakov	Principal Research Scientist, Institute of Geotechnical Mechanics of the NASU *(Member of CCOSS up to 1999)*
Victor V. Pilipenko	Director of the Institute for Technical Mechanics, NSAU-NASU
Victor I. Trefilov	Director of the Institute for Materials Science Problems, NASU
Volodymyr J. Dranovsky	Chief of DO-3, the Yangel State Design Office «Pivdenne» *(Member of CCOSS from 1999)*
Oleg P. Fedorov	Chief of Division for Scientific Space Program, NSAU
Sergij N. Sedykh	Administration Secretary, Presidium of NASU

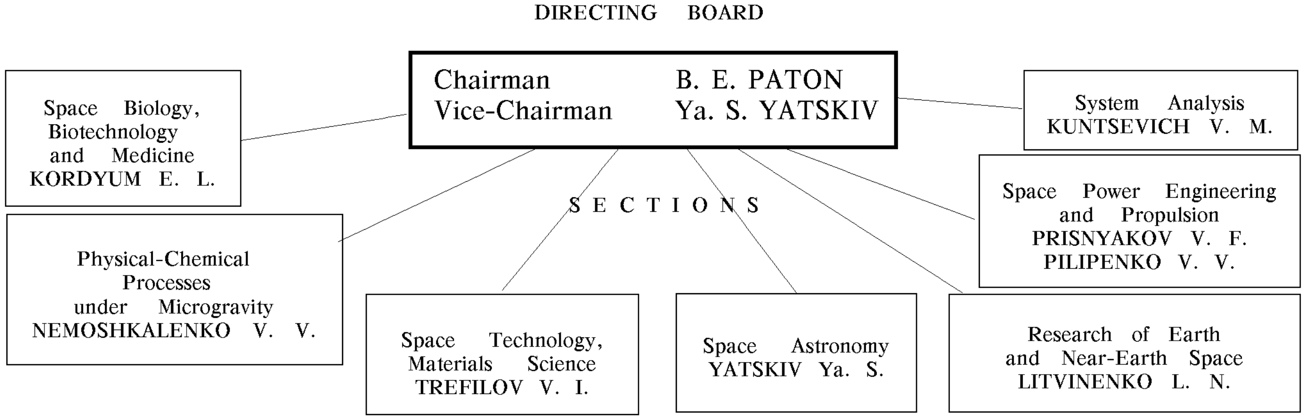


Fig. 2. Scientific Sections of the CCOSS

SCIENTIFIC SECTIONS of the CCOSS:

— **Space Technology and Materials Science** (creation of new types of materials; research of materials under microgravity; production of a limited number of samples of materials with unique properties; experiments on welding and soldering of materials in space);

— **Research of Earth and Near-Earth Space** (research of the ionosphere and lithosphere-ionosphere connection, as well as the Earth's surface);

— **Space Astronomy** (solar and Solar system physics; extragalactic astronomy);

— **Space Biology, Biotechnology and Medicine** (cell biology under microgravity; developmental biology (plants, animals) under microgravity and under the influence of altered gravity; functioning of the autotropic and heterotropic links of controlled ecological life-support systems of astronauts during a long-term flight; technology for production of biopreparations and biomaterials for fundamental sciences, medicine and agriculture);

— **Space Power Engineering and Propulsion** (development and improvement of space power systems); in 2000, this section was renamed as the «**Space Power Engineering and Analysis of Experiment Compatibility**»;

— **Physical-Chemical Processes under Microgravity** (research of the influence of gravity-driven phenomena on solidification and crystal growth of materials; processes of heat-mass transfer in liquids and gases; solidification of metals and alloys);

— **System Analysis** (optimal planning, removed control of experiments, system analysis).

I.5. ANNOUNCEMENT OF OPPORTUNITY FOR SCIENTIFIC RESEARCH AND TECHNOLOGICAL EXPERIMENTS ONBOARD THE UKRAINIAN RESEARCH MODULE (FIRST STAGE OF SELECTION)

In 1997 the CCOSS announced an All-Ukrainian competition of proposals from scientific and engineering teams for experiments onboard the URM of the ISS. The 266 proposals have been received from over 40 Ukrainian scientific and industrial organizations. Statistics of the proposals from scientific and engineering teams at the first stage of CCOSS's competition is presented in Table 1.

After examination by independent reviewers, CCOSS selected 70 proposals and recommended them to the NSAU for the First Stage of conducting the URM Program, the Assessment Study. These research teams received NSAU grants of about $1.3 million in 1998. The Assessment Study of the URM Program was completed at the beginning of 1999. Afterwards, in April, 1999, CCOSS summarized results of the projects completed by scientific and engineering teams to select the projects for the Feasibility Study.

Table 1. Statistics of the proposals for experiments onboard the ISS URM.

Section	Number of Proposals				
	Received	Positive Review	Negative Review	Others	Recommended for contract
Space Technology and Materials Science	75	42	13	20	10
Research of Earth and Near-Earth Space	44	28	15	1	10
Space Biology, Biotechnology, Medicine	70	25	22	23	15
Physical-Chemical Processes in Microgravity	17	5	8	4	5
Space Power Engineering and Propulsion	27	9	3	15	7
Space Astronomy	8	4	1	3	3
System Analysis	25	6	13	6	3
Total	266	119	75	72	53

Table 2. LIST OF PROJECTS TO BE REALIZED AT THE 2ND STAGE OF THE URM PROGRAM

	Title of Project (Name of Section)	Project Summary	Project Manager and Principal Institute
1.	PENTA - COMPLEX (Materials Science, Microgravity Science)	Effect of microgravity on liquid helium boiling and of space factors on the processes of friction and wear of materials, etc.	BONDARENKO S. I., POKHYL Yu. A. B. I. Verkin Institute for Low Temperature Physics and Engineering, NASU
2.	MATERIAL (Space Technology, Materials Science)	Experiments on production of new unique materials in space and development of special welding equipment, etc.	PATON B. E. E. O. Paton Electric Welding Institute, NASU TREFILOV V. I. I. N. Frantsevich Institute for Materials Science Problems, NASU
3.	DEGRADATION (Space Technology, Materials Science)	Degradation of metals and alloys under the effect of space factors	TREFILOV V. I. I. N. Frantsevich Institute for Materials Science Problems, NASU
4.	DIAGNOSTICS (Space Technology, Materials Science)	Methods and equipment for control of defectiveness and stressed state of constructions used in space	LOBANOV L. M. E. O. Paton Electric Welding Institute, NASU
5.	INFRAMON (Research of Earth and Near-Earth Space)	Research of the Earth's upper atmosphere by optical and mm-waves techniques.	MOROZHENKO O. V. Main Astronomical Observatory, NASU
6.	ENVIRONMENT (Research of Earth and Near-Earth Space)	Research of plasma and gas environments of large space constructions	BASS V. P. Institute of Technical Mechanics, NASU- NSAU
7.	SPACE (Research of Earth and Near-Earth Space)	Research of the Earth's ionosphere	YAMPOLSKI Yu. M. Institute of Radio Astronomy, NASU
8.	SURFACE (Research of Earth and Near-Earth Space)	Remote sensing of the surface and oceans of Earth	LYAL'KO V. I. Institute of Geological Sciences, Centre of Aerospace Research of Earth, NASU
9.	CONTEST (Space Astronomy)	Solar-oriented research	YATSKIV Ya. S. Main Astronomical Observatory, NASU
10.	GREENHOUSE (Space Biology)	Creation of Greenhouse and research of plants growth under microgravity	KORDYUM V. A., KORDYUM E. L. M. G. Kholodny Institute of Botany, NASU
11.	BIOLABORATORY (Space Biology, Biotechnology)	Biological experiments onboard the URM	KORDYUM E. L. M. G. Kholodny Institute of Botany, NASU
12.	ZOOMODULE (Space Biology, Medicine)	Effect of space factors on functioning and aging of living organisms	FROL'KIS V. V. M. G. Kholodny Institute of Botany, NASU
13.	BIOMEDCONTROL (Space Biology, Medicine)	Medical monitoring of astronauts and biological control in situ of the URM	KORKUSHKO O. V. M. G. Kholodny Institute of Botany, NASU
14.	MORPHOS (Physical-Chemical processes under Microgravity)	Processes of solidification of materials and composites under microgravity	NEMOSHKALENKO V. V. G. V. Kordyumov Institute of Metal Physics, NASU
15.	SYSTEM (System Analysis)	Development of a system for planning the experiments onboard the URM	KUNTSEVICH V. M. Space Research Institute, NASU-NSAU

I.6. ANNOUNCEMENT OF OPPORTUNITY FOR SCIENTIFIC RESEARCH AND TECHNOLOGICAL EXPERIMENTS ONBOARD THE UKRAINIAN RESEARCH MODULE (SECOND STAGE OF SELECTION)

Taking into account the recommendations of peer review of Reports by Project Managers, as well as the opinions of the Section Chairmen, CCOSS decided to recommend 15 Integrated Projects to NSAU for conducting the Feasibility Study under the URM Program. CCOSS identified 10 Institutes of the NAS of Ukraine, which will be Managers of these Integrated Projects. Some information on these Integrated Projects is given in Table 2.

In October 20-21, 1999 during the Russian-Ukrainian workshop on the current status of the Russian-Ukrainian co-operation in space science and industry, the representatives of the NASU, Russian AS, NSAU, and Rosaviakosmos discussed the project of an agreement between NSAU and Rosaviakosmos related to the URM. The Parties agreed the necessity of a joint discussion on the planned Ukrainian and Russian experiments to eliminate their duplication and to consider the technical compatibility of the experiments.

In October 8, 1999 the Government of Ukraine and the Government of the USA signed a Memorandum of Understanding on co-operation in the field of space research, and the US-Ukrainian Agreement on protection of technologies related to the Ukrainian carrier-rockets, rocket systems and technical data for the Sea Launch project, which are indicative of the high level of bilateral strategic partnership in this priority field. The signing of these agreements provided a new impetus to development of the space industry of Ukraine through implementation of joint research projects in co-operation with the US aerospace companies, in particular, under the ISS program. Legal protection of the Ukrainian rocket technology, technological equipment and technical documentation related to the Sea Launch project is also envisaged, as well as creation of a favourable investment climate for further development of space research. In 2000 NASA selected the projects, which will be conducted during 2001 within the framework of a Memorandum of Understanding, from those recommended by NSAU and CCOSS. Most of the projects are in field of space biology and materials science under microgravity, and part of them are in field of telemedicine and telecommunications. It should be also noted that in 2000 Ukraine became a regular member of the International Working Group on Space Biology, which is responsible for scientific program of the ISS in this field of research.

In the next Chapters we will provide a short description of the projects of scientific research and technological experiments recommended by CCOSS for implementation onboard the ISS.

II. UKRAINIAN SCIENTIFIC RESEARCHAND TECHNOLOGICAL EXPERIMENTS PROPOSED FOR THE ISS

II.1. SPACE TECHNOLOGY AND MATERIALS SCIENCE

Trefilov V. I.

I. N. Frantsevich Institute for Materials Science Problems, NAS of Ukraine
3 Krzhyzhanovsky St., Kyiv 03142 Ukraine
tel: (380) +44 +444 22 71, fax: (380) +44 +444 21 31, e-mail: dir@ipms.kiev.ua

Introduction. Production of materials and performance of technological experiments onboard the orbital space stations open new possibilities for development of national aerospace industry. They also provide the unique capabilities of solving the fundamental problems of space technology and materials science.

The two integrated «Material» and «Degradation» projects, which consist of several experiments, are proposed in this field of space science. It is important to accentuate that these experiments are interconnected from the point of view of developing more versatile equipment and optimal use of the available equipment. The third «Diagnostics» project deals with the methods and equipment for control of defectiveness and stressed state of space constructions.

The purpose of the majority of experiments is to study the influence of space factors on characteristics of elements and units of the ISS as well as on properties of various materials. The influence of space factors and microgravity on mechanical, tribotechnical, and optical-physical parameters of materials and coatings is studied in the integrated «Degradation» project. Special attention is paid also to development of new onboard scientific equipment, its power supply and thermostabilization systems (heat setting), as well as to ground-based simulation of the influence of space factors on various materials.

PRODUCTION OF NEW UNIQUE MATERIALS IN SPACE («Material» Project)

Paton B. E.

E. O. Paton Electric Welding Institute, NAS of Ukraine
11 Bozhenko St., Kyiv-150, 03680 Ukraine
tel: (380) +44 +2273183, fax: (380) +44 +2680486, e-mail: paton@iptelecom.net.ua; paton@i.kiev.ua

Trefilov V. I.

I. N. Frantsevich Institute for Materials Science Problems, NAS of Ukraine
3 Krzhyzhanovsky St., Kyiv 03142 Ukraine
tel: (380) +44 +444 22 71 fax: (380) +44 +444 21 31, e-mail: dir@ipms.kiev.ua

Introduction. Experiments of the «Material» project have a common purpose to make materials with new useful properties under microgravity conditions, which cannot be produced under the effect of terrestrial gravity. The processes of heating, melting, spraying, cooling, and crystallisation are used in all experiments for producing the samples. It involves a study of the dynamics of energy-mass transfer, structuring, and other micro- and macro-processes. However, tasks, methods, objects of study, and applied equipment differ essentially in these experiments. So, typical servicing equipment will be used to carry out the «Coating» and «Diffusion — Mono» experiments, whereas development of the new on-board equipment will be necessary for «Priority», «Levitechn», and «MGD-COSM» experiments.

Experiments can be classified in the following groups by the method of heating:

— *Radiation heating* ⟶ «Diffusion — Mono», «Priority», «Levitechn» experiments;

— *Laser heating* ⟶ «Levitechn» experiment;

— *Electron beam heating* ⟶ «Coating» experiment;

— *Induction high-frequency heating* ⟶ «Levitechn», «MGD-COSM» experiments;

— *Concentrated solar energy heating* ⟶ «Levitechn» experiment.

The diversity of these methods is due to the requirements of the technological processes to such parameters as temperature, heating rate, vacuum, gas-filling, spatial access, power-intensive operations, etc.

Various means and methods are proposed to keep samples in the molten and solid states in the experiments:

— *In containers* ⟶ «Diffusion-Mono», «MGD-COSM» experiment;

— *In glass ampoules, and also by surface tension forces and by the ends of an unmelted rod in floating-zone melting* ⟶ «Priority» experiment;

— *In levitators without containers* ⟶ «Levitechn», «Coating» experiment.

The latter method of keeping samples in levitators without containers is still little known. In the recent years the «ELF», «Tempus» and other levitator projects have been proposed in the West, and the «Levitechn» levitator has been considered in Ukraine. This method should be applied for the super pure and high-temperature technologies, which require contactless control of melt position, shape, and motion (i. e. for brazing and welding under microgravity). The measuring and registering systems for all the experiments are rather similar and can be unified, for example, as it is suggested in the «Technology» experiment.

The «Priority» experiment is of great commercial interest for Ukraine. For example, the weight of a matrix infrared receiver is 0.1 grams, and its cost is about several thousand US dollars. The volume of world sales of various infrared devices on the basis of hierarchical photodetectors with the narrow-band-gap $Cd_xHg_{1-x}Te$ semiconductor materials is more than $ 10 billion. Under the space conditions, it is possible to produce up to several hundred grams of this material with low power consumption, as well as reach a state of integration of the units of a matrix by 1 — 2 orders higher than that on the ground. Taking into account the small weight of these products, there is a high interest to organize their profitable manufacture in space.

«Diffusion-mono» Experiment

MICROSCOPIC MECHANISMS OF DIFFUSION IN MELTS UNDER MICROGRAVITY

Maiboroda V. P., Molchanovskaya G. M.

I. N. Frantsevich Institute for Materials Science Problems, NAS of Ukraine
3 Krzhyzhanovsky St., Kyiv 03142 Ukraine
tel: (380) + 44 +444 33 64, fax: (380) +44 +444 21 31, e-mail: maiborod@ipms.kiev.ua

The purpose of the experiment is to solve one of the principal problems of materials science. Does the distribution of dissolved elements in a fluid matrix obtained by melting of a monocrystal without modification of its outward form have the microscopically ordered character? In case of a positive answer to this question, the new effect of existence of the anisotropy of diffusion in metal melts will be discovered. Use of this effect will result in modification of practically all the space technologies of crystal growing and directional solidification, as well as production of glasses, alloys, composite materials and metastable phases in metal systems.

Similar experiments have been already conducted at «Salyut» and «Skylab» OSS.

Let us describe this effect. The crystal instability of Ga, In, Sn, Cu, Ag, Au, Pb, Zn was studied *in situ* at heating, melting and overheating of a melt by electron beams. The generated results on the structure of a melt at the atomic-lattice and cluster levels did not confirm a well-known notion of a fluid as the statistically non-ordered system with some near-range ordering. That is, microcrystals have been found to fragmentize spontaneously in the form of strip contrasts as soon as the Debay temperature was increased (Fig. 1). This spontaneous fragmentary structure was named the dissipative structure (DS). In our opinion, the melting of a metal monocrystal may be represented as the formation of a steady DS, which fragments a crystal into the sub-microscopic polydomain dynamical system. Being the unit of coherent dispersion, the minimal domain has the size of 2.5 — 10 nm [1]. This structure of a fluid was named the domain-dissipative structure [2]. The self-ordered structure of fluctuating waves of the localised anomalous displacements of plane atomic orderings arises in heating. Being a DS, such a structure is considered a new degree of freedom. The DS orientation is due to the symmetry of a crystal. Melting of a polycrystalline sample results in formation of the quasi-eutectic (colloidal) structure of a fluid. The colloidal structure is connected with different relative orientation of grains-monocrystals. It is supposed that the main arteries of inter-penetration of components in a fluid are the vacancy flows generated by the DS in colloids and inter-colloidal zones (Fig. 2). Study of self-diffusion of zinc at thermal gradient («Skylab» OSS, M558 experiment by A. Ukenva) has demonstrated that during 3600 seconds, penetration of ^{65}Zn isotope was equal to 1-2 cm. Such a value of penetration leads to overestimation of the coefficient of self-diffusion and can be connected with the looseness and thermal activity of inter-colloidal zones. To perform a more precise experiment in space, it is necessary to exclude not only the convective mass-transfer connected with the gravitation influence on a melt, but also the influence of inter-colloidal boundaries.

The purpose of the experiment is to study the microscopic mechanism of diffusion (self-diffusion) in heated crystals and melts under microgravity.

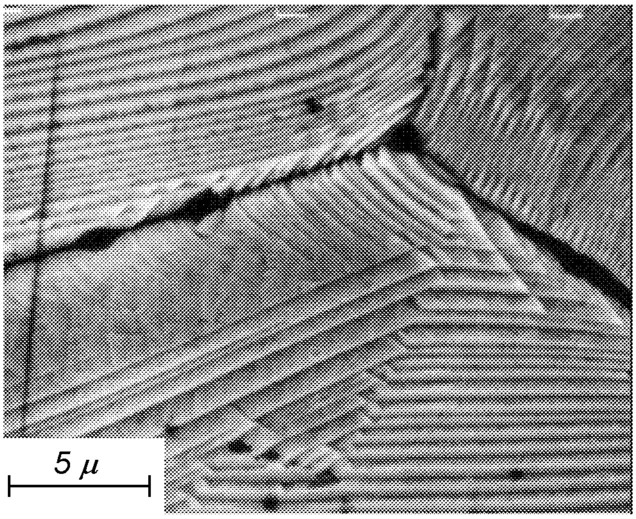
We have the following objectives:

— to define the preferential directions and planes of diffusion mass-transfer in solids and liquid metals;

— to work out methods of mass-transfer control for producing new materials and crystals with the given distribution of donor and acceptor additives, as well as for crystal growing and electrophoretic separation of substances.

It is suggested to produce a melt by melting a zinc monocrystal of two orientations (cylinder axis parallel and perpendicular to C axis). Melting will be conducted in the sealed-in ampoule having the form of sample and ^{65}Zn diffusant. The melt will be soaked in the thermal gradient field (similar to M558 experiment by A. Ukenva, «Skylab» OSS). Such conditions are necessary to validate the crystal-like mechanism of diffusion mass-transfer to large distances in liquid metals, and to define the level of macro-volume conservation of the translation motive of a fluid structure in the large molten monocrystal.

The resistive thermogradient unit with automatic sample-ampoule feed (Low Gradient Furnace) will



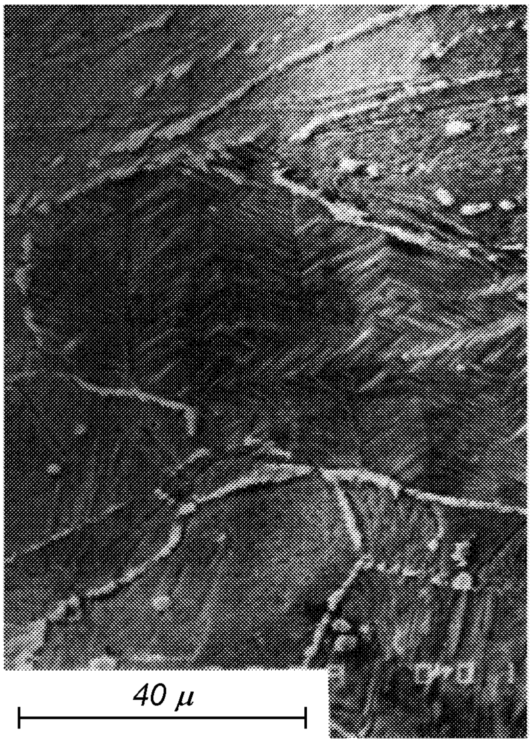


Fig. 1. Spontaneous fragmentation of microcrystals of copper at the temperature of 1065°C.

Fig. 2. Frozen structure of a boiling zinc melt.

be used for conducting this experiment onboard the ISS. The process of thermodiffusion will be studied at the temperature T = 450 ... 550°C. The volumetric distribution of the diffusant will be defined by the radiographic method.

The obtained results will be important for physics of monopropellant and multicomponent fluids, as well as for physics of complex fluids (colloids, jellies, foam) and processes of boiling. The worked out concept of the domain-dissipative structure of colloids and macrocolloids of overheated fluids will be useful for study of the formation of gaseous bubbles inside a volume and their behaviour during the thermo-temporal variations of a system. The obtained results can be also applied for the effective transfer of heat and energy flows, for the systems of cooling and energy conversion, and for the life-support control systems of fluids.

References

1. Maiboroda V. P. // Thin Solid Films.—1991.—**195**.—P. 357—366.
2. Maiboroda V. P., Trefilov V. I., Maximova G. A., Revo S. L. // Metallofizika i noveyshie technologii.—1997.—**19**, N 8.—P. 19—22. (in Russian).

«Priority» Experiment

ADVANCED SPACE MATERIALS AND RELATED TECHNOLOGY FOR THE INFRARED AND RADIATION-RESISTANT ELECTRONICS

Rarenko I. M.

Chernovtsy State University
2 Kotsubynsky St., Chernovtsy 58032 Ukraine
tel. (380) +0372 +59 84 75, fax: (380) +0372 +55 18 09, e-mail: microel@chdu.cv.com

Tkachenko V. G., Maksimchuk I. N.

International Center for Electronic Materials Science and Applied Problems of Aerospace Technology
3 Krzhyzhanovsky St., Kyiv 03142 Ukraine
tel. (380) +44 +444 11 90, e-mail: dep59@ipms.kiev.ua

Slunko E. I.

Chernovtsy Department of the I. N. Frantsevich Institute for Materials Science Problems, NAS Ukraine
5 I. Vilde St., Chernovtsy 58032 Ukraine
tel. (380) + 0372 +52 22 71, e-mail: slunko@impspas.chernovtsy.ua

Space experiments completed in the USA and the USSR starting from 1980ies revealed the low effectiveness of space technology for the unstable CdHgTe alloys because of the gradual Hg-induced decomposition of their inhomogeneous and cored semiconductive solid solutions. Moreover, the high Hg toxicity posed a threat for the astronaut's life. Obviously, in order to avoid the relatively rapid degradation of widely used microelectronic devices in solid-state microelectronics and to increase their stability, service life and radiation resistance, these Hg-doped alloys should be replaced by ecologically clean and Hg-free materials of a new generation, including the unique set of InSb-InBi solid solutions with regulated (to 0.1 eV) width of the exclusion zone. In addition, due to the presence of intrinsic stoichiometric vacancies the advanced semiconductors of A^3B^6 group have the radiation resistance, which exceeds that of Si-materials by more than 2-3 orders of magnitude in the wavelength range of 0.3...5.0 μm without changes of electrophysical properties. For example, it will be possible to obtain radiation-stable photoreceivers with the specific detectivity $D^* = 3\cdot10^{13}$ cm$\cdot$Hz$^{1/2}$W^{-1} at the wavelength of 10 μm on the epitaxial layers of PbSnGeTe<In> (10 μm thickness). This detectivity exceeds by more than two orders of magnitude the value for the currently available materials.

The structural perfection of a substrate determines also the maximum density of photosensitive elements in the matrix photodetectors. The technical characteristics of crystals on the basis of new materials will enable the integral density to be increased up to 104 elements (for the element size of 35×35 μm and step of 50 μm). Reduction of element size down to 3 μm (5 μm step) will provide the integration density of 10^6. Doping with 3rd-group and rare earth metals of alloys with the same composition allows production of materials with a high resistance $\rho \geq 10^3$ Ohm$\cdot$cm at the temperature T = 77 K.

However, it is practically impossible to produce homogeneous and structurally perfect InBiSb solid solutions by monocrystal growing under the terrestrial gravity because of the strong gravitational liquation of Bi. First experimental evidence indicates the principal possibility to produce the high-grade Hg-free materials by space technology ensuring the structural homogeneity of solid solutions and uniformity of a distribution of Bi.

The main purpose of the proposed experiments is to grow structurally homogeneous, perfect monocrystal of composite $InSb_xBi_{1-x}$ and PbMLTe solid solutions (where M is Ge, Mn; L is In, Ga, Yb) under microgravity ensuring a stability of mass and heat flows at the solidification front. To achieve the required structural perfection of monocrystals, it is necessary to significantly reduce the instability of magneto-hydrodynamic diffusion layer at the solidification front of an ingot. This is possible under the conditions of microgravity ($g < 10^{-3}$) at the vibration amplitude $g < 10^{-4}$, i. e. under the conditions of space flight. Computer simulation will be applied for comparison of the obtained results with the gravitational experiment in the magnetic field. It will be further used for definition of the optimum technological requirements for industrial production of materials.

«Levitechn» Experiment

CONTROLLED LEVITATORS WITH HELIO-HEATING FOR SPACE TECHNOLOGIES

Paslavsky E. S.

Space Research Institute, NAS of Ukraine and NSA of Ukraine
40 Akademik Glushkov Ave., Kyiv 03022 Ukraine
tel: (380) +44 +266 31 46, e-mail: phys@space. is.kiev.ua

Pasichny V. V.

I. N. Frantsevich Institute for Materials Science Problems, NAS of Ukraine
3 Krzhyzhanovsky St., Kyiv 03142 Ukraine
tel: (380) +44 +444 11 91, fax: (380) +44 +444 21 31, e-mail: pasich@ipms.kiev.ua

The purpose of the experiment is to study the controlled spaceborne levitators with helio-heating and to carry out operations with the electrically conducting bodies undergoing phase transformations (melting and solidification of metals, semiconductors, alloys, mixtures and so on). A levitator is a device, which allows containing the working media in a given space without mechanical contact.

The controlled spaceborne levitators can be used for realisation of the following technological processes and research:

1. Contact and contactless control of the movement, position and shape of the refractory and reactive melts; moulding in the «electromagnetic casting moulds and dies» («draw plates»)»; welding of the structural elements of space vehicles.
2. Development of novel perfect composites, gradients, foam and other materials, which cannot be produced in the ground-based conditions because of gravitational segregation (liquation).
3. Non-polluting production and processing of superpure materials, precision alloys, perfect monocrystals, elements of microelectronics and so on.

Substantiation of the need to carry out this experiment (including items 1-3) in space consists in the possibility to process such materials which cannot be processed contactlessly or do not levitate at all in the ground-based conditions.

Selection of a levitator design depends on its application, but its main parameters are determined by the value of the vector of relative acceleration of a working medium, which is due to the level of microgravity.

The possibilities for application of the existing contactless, spatially distributed levitation effects on a working medium (processed samples of materials), which are capable of balancing the microgravity, have been analyzed. The induction electromagnetic levitation effect in levitators intended for special metallurgy has been proved to be the most promising. It can provide the most necessary functions of contactless containment, automatic control and stabilisation of a working medium (sample).

Approximate calculations of parameters and operational modes of the controlled spaceborne levitators have been completed. These data were used to carry out comparative analysis of the main design parameters of spaceborne levitators and actual parameters of groundborne levitators. It turned out that the ratio of parameters of their main power, mass and overall dimensions is close to the value of $\gamma = g_k/g_0$ (g_k — size of microacceleration, g_0 — acceleration of gravity force on the Earth). The characteristic values of the main parameters of the devices, which ensure levitation process for containment of the mass less than the critical capillary mass (without heating and technological equipment), are the following:

— Weight:	several kilograms
— Overall dimensions:	several litres
— Power:	tens of watts

A levitator can be mounted in any technological system fitted with research equipment. The configuration of a levitator can change depending on the technological and heating requirements. Heating can be realized with an HF generator, laser, electron beam gun or concentrator of solar energy (helio-heating).

For helio-heating, at the first stage it is planned to use a very simple design of helio-concentrator, which is a metallic paraboloid made of sheet aluminium alloy with small-sized plane mirrors pasted to it. The intent is to supply a concentrated flow of radiant energy from the focal spot to the sample through optical light guides or a hollow focon. Experimental verification of the proposed design onboard the ISS should answer to the questions concerning the operating life of mirror helio-concentrator, selection of material for the light-reflecting coating, compatibility of a levitator with the helio-concentrator, and practicability of technological processes.

Direct use of the concentrated solar radiation for heating the levitating sample decreases the need for the scarce onboard electric power that eventually also reduces the mass load of the ISS (supply of solar batteries and converters).

«MHD-COSM» Experiment

DEVELOPMENT OF ELEMENTS OF PRINCIPALLY NEW MAGNETO-HYDRODYNAMIC TECHNOLOGY FOR MAKING ALLOYS WITH THE PEQULIAR STRUCTURE UNDER MICROGRAVITY

Dubodelov V. I., Kyryyevskyy B. A., Seredenko V. A.

Physical-Technological Institute of Metals and Alloys, NAS of Ukraine
34/1 Akademik Vernadsky Ave., Kyiv-142, 03680 Ukraine
Tel: (380) +44 +444 20 50, fax: (380) +44 +444 12 10, e-mail: metal@ptima.kiev.ua

Shcherba A. A.

Institute of Electrodynamics, NAS of Ukraine
56 Peremoga Ave., Kyiv-57, 03680 Ukraine
Tel: (380) +44 +446 01 51, fax: (380) +44 +446 94 94, e-mail: ashch@ied.kiev.ua

Space metallurgy is one of the important fields of space materials science. Use of metallurgical methods in space environment enables metals, alloys, composites and other materials with improved or principally new properties to be produced. Among such materials are pure metals, monotectic and eutectic alloys, alloys with intermetallics, composite alloys and foam metals, which can have special physical, chemical, electrical, magnetic, optical, mechanical and other properties. Conducting the melting in contactless apparatuses under microgravity, the characteristics of these materials can be improved, first of all, due to the absence of density segregation and the negligible natural convection in the liquid state.

Monotectic alloys, which are mixtures of phases with limited mutual solubility as in the solid, so in the liquid state, have been intensively studied under the space conditions. Melts of such alloys form a single-phase liquid at overheating above the critical temperature T_σ owing to the increase of mutual solubility, but reverting to the solid state they undergo the phase transitions of the first and second kind. An essential change of the characteristics of such alloys is observed in disperse and ultra-disperse phase states. However, there are problems concerning an ultra-dispersion of the second phase and a higher level of the uniformity of its distribution in the matrix. These problems are still unsolved either under the ground conditions or in space. There are also other problems of space production of such alloys. In particular, changes occurring during phase transformations greatly complicate the production of a finely dispersed structure of alloys. The top priority in development of space materials science has been given to the physics of weightlessness. The influence of the Earth's magnetosphere, where the majority of the key phenomena are determined by the fundamental processes of magnetic hydrodynamics (MHD), has been only partly taken into account. The action of magnetic fields on the liquid and solidifying alloys is the strongest during phase transformations and it is registered even in the weak ($1 \cdot 10^{-3}$ T) fields. The influence of a magnetic field on monotectic systems in phase transformations is still unstudied.

One of the objectives of the proposed experiment is to overcome the unfavourable effects appearing in production of monotectic alloys in space. Unlike the space experiments conducted in the past, we suggest to release a heat directly in the alloy for its further melting, as well as to apply a metallic cooler for achieving a higher rate of heat removal from the melt during its crystallisation. We would like to study the influence of magnetic field both on the nature of phase transitions in monotectic melts and on the parameters of crystallisation.

During the experiment, an external uniform constant magnetic field will be applied to the liquid monotectic alloy with the intensity greater than that of the geomagnetic field. During this impact under the conditions of space vehicle, the processes of a marked weakening of the natural thermo-gravitational convection ($g \leq 10^{-3}g_0$) and suppression of the convective flows of any nature promoted by the influence of the electromagnetic force in the melt, will be combined. Earlier experiments demonstrated that some kinetic problems hinder the homogenisation of a monotectic melt above temperature of the binodal. Taking into account these factors, we propose to use MHD methods for homogenisation of a single-phase fluid.

To optimise parameters of a given MHD-system for making monotectic alloys with a finely dispersed structure under microgravity, a comprehensive solution will be a combination of the following items:

— performance of mathematical and physical modelling;

— selection of potential variants and conducting experiments on the ground and in space;

— applying the technique of successive complication of the problem.

It is intended to start the research on optimization of a number of features of MHD-technologies from low-temperature «bismuth-gallium» alloy.

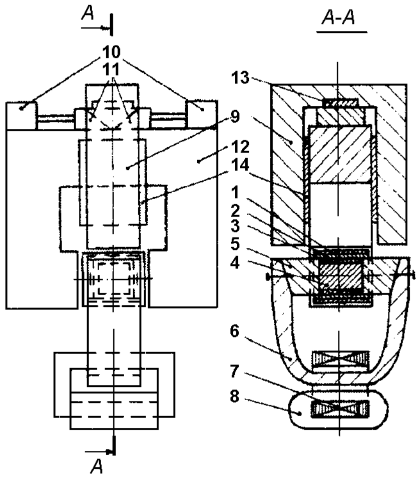


Fig. 3. Schematic of the technological unit (1 — copper capsule; 2 — ceramic cartridge; 3 — elastic heat insulator; 4 — alloy; 5 — copper electrodes; 6 — electrode bus; 7 — transformer core; 8 — transformer winding (primary); 9 — solid aluminium cooler; 10 — manipulator of the magnetic type; 11 — electromechanical cotter pin; 12 — permanent magnet; 13 — ferromagnetic lamina; 14 — slides of the cooler

The schematic of the technological unit is given in Fig. 3.

«MAGELLAN» Experiment

DIGITAL PRECISION SENSOR OF SUPERLOW ACCELERATIONS

Dem'yanenko P. A., Zinkovskiy Yu. F., Prokof'ev M. I.

National Technical University of Ukraine «Kiev Polytechnic Institute»
12 Polytechnichna St., NTUU «KPI», RTF, 17, Kyiv 03056 Ukraine.
Tel: (380) +44 +441 18 31, fax: (380) +44 +241 86 85 e-mail: pmi@ucl.kiev.ua

The accelerometer is based on the fiber-optic sensor (FOS) of superlow linear accelerations with time-pulse modulation of optical radiation intensity [1]. For a long time, the FOSs have attracted the attention of designers by their advantages in performance against the traditional (electric) sensors, but the poor metrological parameters of the classical (analogue) FOSs prevent their wide application.

Analysis of this problem has brought us to the following conclusion. To increase the accuracy of measurements using FOS, it is necessary to eliminate analogue modulation of the optical flow and use its discreet modulations, thus adding new, non-optical, parameters to the optical flow, which will serve as recipients of information. It permits preserving all the advantages of the FOSs, since the optical flow remains to be the carrier of information. Furthermore, the problem of measurement accuracy will not be connected with the problem of measurement of low-level intensity of the optical flow. It is transferred from the area of optical measurements into another, non-optical area, where these problems have been properly solved. We have developed a new class of precision FOSs (Fig. 4) with time-discrete (pulsed) modulation of the optical flow intensity. The target signal is the temporal sequence of optical signals. Information parameters of such a sequence are as follows:

— quantity of pulses as such (the process of measurement is reduced to calculation of pulses,

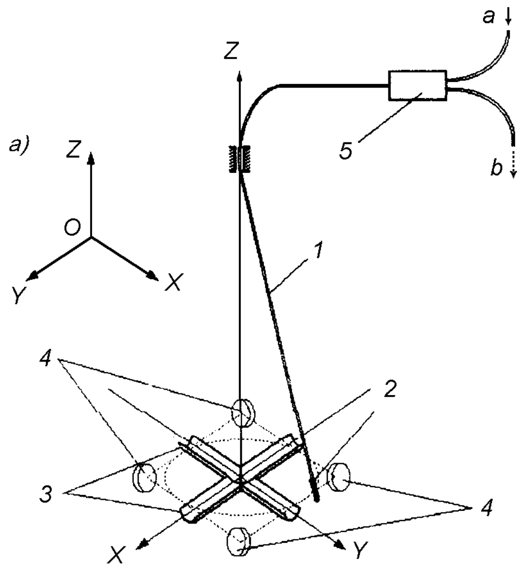


Fig. 4. Structure of pulsing FOS. *a*) Sensitivity axis orientation 1. Elastic element of pendulum suspension — quartz fiber optical gauge. 2. Inert mass — magnetically-soft material. 3. Transverse cylindrical mirrors. 4. Electoromagnets. 5. Fiber-optic splitter. Arrow *a* — Continuos radiation beam from an off-site source of light. Arrow *b* — Output pulse-modulated optical signal.

which can be done accurately);

— frequency of pulses (the process of measurement consists in calculation of the number of pulses per a unit of time; measurement of time intervals can be also done with the necessary accuracy);

— time intervals between pulses following each other in a sequence (the process of measurement consists in determination of the time intervals between the pulses and subsequent processing of the measurement results according to the algorithm accepted for the particular case), etc.

One more factor promoting achievement of a high accuracy of measurements by pulsing FOSs is the independence of their metrological parameters on any instabilities (time, temperature, etc.) of parameters of optical and electric elements. It is explained by fact that the measured (information) parameters in a target signal of pulsing FOSs are not the energy parameters of the optical flow (as in the case of analogue FOS), but the values of time intervals set by optical pulses.

In addition to providing a high accuracy of measurements, the FOSs of this class differ favourably from the usual analogue FOSs by a high threshold sensitivity and wide range of the measured values. Digital processing of a signal is the obvious advantage of pulsing FOS, which promotes higher precision and overall improvement of the quality of measurements. Deployment of digital chip processing permits adjustment of the measurement results, as well as neutralizing both the impact of natural obstacles to precise measurement (non-linear parameters, interference, etc.) and the inaccuracy of FOS manufacturing (non-perpendicular axes of mirrors, unmatched optical and geometrical axes). This ensures performance of precise measurements not in the FOSs but in the module of a signal processing [2]. This way, the technical requirements to FOS manufacturing may be lowered without decreasing the high level of requirements to the measuring accuracy.

Therefore, the higher precision measurements by the pulsing FOSs are ensured by precise measurement of time intervals between optical pulses and quartz super stable oscillating system, which is the sensitive element-modulator of the pulsing FOS.

References

1. Dem'yanenko P. A., Zinkovskiy Yu. F., Prokof'ev M. I. // Radioelectronika.—1997.—**40**, N 1.—P. 39—47.
2. Dem'yanenko P. A., Zinkovskiy Yu. F., Prokof'ev M. I. // Radioelectronika.—1998.—**41**, N 8.—P. 54—60.

INFLUENCE OF SPACE FACTORS ON PROPERTIES OF MATERIALS AND ORBITAL CONSTRUCTIONS («DEGRADATION» PROJECT)

Trefilov V. I.

I. N. Frantsevich Institute for Materials Science Problems, NAS of Ukraine
3 Krzhyzhanovsky St., Kyiv 03142 Ukraine
tel: (380) + 44 +444 22 71, fax: (380) +44 +444 21 31 e-mail: dir@ipms.kiev.ua

Introduction. The purpose of the experiments proposed in the «Degradation» project is to reveal the essential physical processes proceeding in materials and elements of space constructions under long-term exposure to outer space factors. Among such factors the following can be mentioned:

— high vacuum (10^{-7} torr),
— electromagnetic radiation of the Sun including UF-radiation (λ = (5...2500)10^{-9} m),
— fluxes of positive protons p^{+} and electrons e^{-} of natural and artificial radiation belts of Earth within the energy range of 30 KeV...10 MeV,
— variation of temperature in the range from 4.2 K up to 450 K,
— strong magnetic fields,
— strong electric fields with the strength of 20...30 kV arising due to the electrisation of a space vehicle,
— atomic oxygen, weightlessness, vibration, g-loading, etc.

Simulation of the influence of space factors on the ground usually requires the use of a great number of testing facilities. It means that it is practically impossible to study the entire set of space factors simultaneously. Moreover, the experimental data derived over the last few years on the ground-based simulation of space factors have a substantial disadvantage, as they do not permit any comparison to be made. In addition, simulation of the influence of some space factors on Earth may be even more difficult and expensive than under the conditions of a space flight. For example, about 15000 thermal cycles may affect a space vehicle during the flight, but only 500 thermal cycles per year were conducted on the ground. Besides, in order to obtain a flux of protons of the necessary magnitude, the experiment should be performed at an atomic power station and so on. Studying the influence of space factors under the space flight conditions, it is also necessary to know the correlation between the accelerated integrated simulation of space flight factors on Earth and the original experiments.

Experiments on degradation of materials and orbital constructions under the influence of space factors will be carried out by the entire international scientific community involved in utilisation of the ISS.

The objectives of the experiments of the «Degradation» project are as follows:

— development of a system («Degradation») of orbital equipment for study of the degradation of materials and elements of constructions of space vehicles under the influence of space factors;
— development of materials, as well as making test specimens and mocks-up for conducting experimental investigations on Earth and during the space flight;
— study of the influence of space factors on degradation of the properties of materials and constructions;
— issuing recommendations to improve the reliability and operational time of a space vehicle in orbit, as well as minimise its weight;
— prediction of normal operation of a space vehicle for the next 5-15 years.

«Resource» Experiment

DEGRADATION OF MATERIALS AND CONSTRUCTIONS UNDER THE INFLUENCE OF OUTER SPACE FACTORS

Trefilov V. I., Frolov G. A.

I. N. Frantsevich Institute for Materials Science Problems, NAS of Ukraine
3 Krzhyzhanovsky St., Kyiv 03142 Ukraine
tel: (380) + 44 +444 04 92, fax: (380) +44 +444 21 31 e-mail: frolov@alfacom.net

Surdu M. N.

State Scientific and Industrial Enterprize «Spetsavtomatika»
Tel: (380) +44 +2119246, e-mail: surdu@nbi.com.ua

Sitalo V. G.

Yangel State Design Office «Pivdenne»
3 Kryvoriz'ka St., Dnipropetrovsk 49008 Ukraine
Tel: (380) +562 +92 51 13, fax: (380) +562 +92 50 41

Non-metallic and polymeric composites (PC) are widely used for manufacturing space vehicles. In addition, space vehicles have been manufactured in the non-tight condition, which results in a long-term exposure of materials to all the space factors. Each of the space factors may disrupt the functions of a space vehicle. For example, the change of such mechanical characteristics as the coefficient of linear thermal expansion or the modulus of elasticity may change the geometrical parameters of orbital constructions made of PC, e. g., coal-filled plastic trusses and triplex panels for photo-converters, which are very important for the orientation accuracy and power supply of space vehicles. The usual thermal cyclic loads in a wide range of temperatures may destroy both the PC proper and structures including dissimilar materials.

The purpose of the proposed integrated experiment is to develop promising materials, coatings and structural elements intended for operation in outer space, as well as under the cryogenic temperatures, fine vacuum and radiation on Earth.

The objectives will be as follows:

1. To obtain test specimens of promising materials and coatings to study the influence of space factors on structural elements, friction units and power supply systems of space vehicle.
2. To develop techniques for adequate accelerated simulation of the influence of the space factors on materials on Earth and in space.
3. To test scientific equipment for conducting such studies in space.
4. To reveal the initial physical processes proceeding in materials and structural elements under the long-term influence of outer space factors.

It is intended to apply the following methods:

1. Long-term exposure of test specimens of the materials on the external side of the URM and control of the change of mass, charge accumulation, of the change in internal structure and surface temperature.
2. Experimental study of test specimens of the materials in the ground simulators using methods of adequate accelerated simulation of space factors.
3. Study of the influence of space factors on mechanical, tribotechnical, optical and physical properties of materials using the procedures developed in «Indentor», «Penta-Tribos», «Penta-Optics» and «Penta-Fatigue» experiments.
4. Monitoring the parameters of the vehicle's own environment and space factors, namely temperature, pressure, quantitative analysis of neutral and ionic components, density of atomic oxygen, density of power fluxes of positive protons, electrons and solar radiation.

The objects of study will be as follows:

- Non-metallic structural materials used for manufacturing space vehicles, e. g. carbon-filled plastics on the base of carbonic fillers LU-P*,

* Cyrillic abbreviator of name.

ELUR*, UKN-500* and epoxy resin such as EDT-10*; structural fiberglass plastics; cables coming in the set; lacquers, enamels, temperature-controlling and other coatings; adhesives such as VK-46*, VK-41*; plastic and rubber products.
(*authors:* Sitalo V. G., Tikhij V. G., Litvishko T. N., Primakov V. D. et al.);
- Mock-up of the solar battery frame with a photoelectric converter (FEC) consisting of the following layers: structural glass-reinforced or carbon-filled plastic — adhesive — honeycomb aluminium filler — adhesive — structural glass-reinforced or carbon-filled plastic — adhesive — FEC — optical adhesive — quartz glass and carbon-filled plastic truss

(*authors:* Sitalo V. G., Tikhij V. G., Primakov V. D. et al.);
- Metallic materials: cast and wrought aluminium alloys AL2*, AL4*, AL4C*, AMg6*, D16*; titanium alloy VT6*; high-alloyed steels 12Kh18N10T*, I654, EP56*, heat-resisting alloy E1868*

(*authors:* Kalinushkin E. P., Sinitcyna Yu. V.);
- Test specimens of reflecting coatings for a space-based helio-concentrator

(*authors:* Gudramovich V. S., Pasichny V. V., Stegnij A. I.);
- Metal and ceramic compounds with coatings based on transient metal borides, with high strength and resistance to radiation and temperature cycling

(*authors:* Podcherniajeva I. A., Panasiuk L. A.);
- New sealing, insulating and shielding materials on the base of thermally-expanded graphite reinforced by metal nets and strips for EVA operations.

(*authors:* Vishniakov L. R., Kosygin V. P., Moroz V. P., Kokhanyj V. A.);
- New polymeric composites for protection against the ionising radiation

(*authors:* Vishniakov L. R., Grudina T. V.);
- Radio-reflecting materials based on metal and metal-containing knitted reticulate structures for transformable structures and transformable aerials of space vehicles

(*authors:* Vishniakov L. R., Kokhanyj V. A., Kokhana I. N.);
- Self-lubricating anti-friction composite materials of a new generation on metal, polymeric, and glass-ceramic base

(*authors:* Kostornov A. G., Brodnikovskij N. P., Beloborodov I. I, Yuga A. I.);
- Test specimens of bearings, turbine rotors and other friction units from zirconia-based ceramics with magnesium stabilisation system (Mg-PSZ) and titanium intermetallic compounds for application in orbital devices

(*authors:* Firstov S. A., Vasil'ev A. V.);
- Compounds from titanium aluminides and high-temperature coatings based on Ti-Al system

(*author:* Oliker V. E.);
- Materials and designs for small-sized highly reliable on-board voltage converters on piezoelectric ceramics base for power supply to the space vehicle instrumentation

(*author:* Rud' B. M.);
- Thermal electric cells for conversion of solar energy into electric energy

(*author:* Goriachev Yu. M.);
- Module for solar energy accumulation on hydride base

(*authors:* Schur D. V. et al.);
- Materials on silicon carbide base for laser mirrors of information transmission in space

(*author:* Gnesin G. G.);
- Materials on rare-earth oxide base for coatings of laser mirrors of guidance systems and information transmission in space

(*authors:* Andrejeva A. F., Kasumov A. M.);
- New photoconductive materials with improved stability based on solid solutions of transient metal silicides for temperature-sensitive resistors exposed to outer space

(*author:* Dvorina L. A.);
- Hydrogen-containing compounds and ceramic materials activated with hydrogen, which are used as biological protectors against radiation and as the sources of hydrogen fuel

(*author:* Morosova R. A.).

The entire set of equipment of the experimental flight unit («Degradation») will be used to meet the objectives of such an integrated experiment by the mentioned methods. It is also planned to develop the following new scientific equipment.

- Space-based helio-concentrator

(*authors:* Skorokhod V. V., Gudramovich V. S., Pasichny V. V., Stegnij A. I., Frolov G. A.).

The mirror parabolic concentrator will be manufactured of eight all-metal nickel sectors by the method developed at the Institute of Technical Mechanics of the NASU-NSAU. Devices manufactured by this technology have already been used on «Ocean» (Yangel State Design Office «Pivdenne»), «Mars» (Lavochkin Scientific-Industrial Union), «Meridian» space vehicles, etc. The helio-concentrator will be equipped with precise tracking system for solar observations. This system will correct for the ISS's vibration and will be located on the outer platform of the URM. The characteristics of helio-concentrator are as follows:

— total power consumption is not more than 300 W;

— diameter of concentrator is up to 2 m;

— weight of mirror concentrator is up to 5 kg;

— focal distance is equal to 0.85 m;

— power concentration coefficient is about of 3000...5000;

— density of the heat flow in a focal spot of 0.01 m diameter is equal to 12000 kW/m^2.

- A complex of self-contained measuring instruments to control the loss of weight, charge accumulation, change of internal structure and surface temperature of test specimens of materials

(*author:* Surdu M. N.).

The measuring equipment developed by the State Scientific & Industrial Enterprise «Spetsavtomatica» is the hardware for system implementation, which may be integrated into a common information system by the onboard computer. The onboard computer should process the information in real time and compress it for telemetry. The measuring equipment is self-contained. Designed to vibration survival, the proposed measuring equipment will have the volume of about 150...200 cm^3 (excluding the volumes of the sensor and the studied test specimen), and the weight of not more than 100...200 grams. It will be able to operate within the temperature range of −40...+50°C and will bear g-loads during injection into orbit. The measuring equipment should be installed in a pressurised module.

- Fiber-optic sensor of atomic oxygen and radiation (designed by the Canadian Institute for Space Researches of the University of Toronto (UTIAS)). Upgrading of this sensor will be done by the Yangel State Design Office «Pivdenne».
- Space Ionic Micro-Analyser «SIMA»

(*author:* Cherepin V. T.)

On-board space ionic micro-analyser (SIMA) for local and layer-by-layer analysis of materials by the method of secondary ion mass spectrometry will have the following characteristics: total weight of up to 60 kg, power consumption of up to 60 W, localisation better than 10 microns, resolving power equal to 50 Ё and mass numbers in the range of 1...200. It will permit analysis of all the elements of the Mendeleev periodic system with up to 10 % response. SIMA will also permit remote-control analysis. This device is intended for conducting various materials science experiments, e. g., on study of corrosion under the actual space conditions, degradation of solar panels, nature and composition of various contamination on the ISS structural elements.

A ground-based facility will be used to improve the methods of study of the space factor influence on materials. It includes a 6-factor simulator of the KIPHK SDTO of the Institute for Low Temperatures Physics and Engineering (*author:* Abraimov V. V.), the helio-plant system of the I. N. Frantsevich Institute for Materials Science Problems in Kiev, and the Crimean Helio-Laboratory (authors: Trefilov V. I., Skorokhod V. V., Pasichny V. V., Frolov G. A., Stegnij A. I.).

«Astro» Sub-Experiment of the «Resource» Experiment

DEVELOPMENT OF BEARINGS AND TURBINE ROTORS AND OTHER FRICTIONAL PARTS MADE OF CERAMICS

Firstov S. A., Vasil'ev A. D.

I. N. Frantsevich Institute for Materials Science Problems, NAS of Ukraine
3 Krzhyzhanovsky St., Kyiv 03142 Ukraine
tel: (380) + 44 +444 02 94, fax: (380) +44 +444 21 31, e-mail: fsa@materials.kiev.ua, vasilev@ipms.kiev.ua

The purpose of the experiment is development of bearings and turbine rotors and other frictional parts for space industry, which are made of zirconia-based ceramics with magnesia and yttria stabilisation systems and of titanium intermetallic compounds.

Mechanical devices and moving parts are vital units for the actual and future space missions. Failures or degradation of such basic mechanical components as bearings and seals may impair a mechanism performance or interrupt a spacecraft operation. The designers consider zirconia-based ceramics as an ideal material for the space/vacuum applications in a wide temperature range, as well as for their application in severe conditions of corrosion (rocket fuel), abrasive (dust of planet surface) environments and thermal cycling. Equally important is application of ion conductivity of zirconia for electric power generation by the fuel cell technology and for air regeneration during the space missions.

That is why materials engineering for bearings and related devices of spacecraft mechanisms using zirconium ceramics should be considered as an innovation. It is known that NASA considered such a kind of projects as far back as 1995.

Intermetallic compounds based on titanium, like titanium aluminides Ti_3Al and TiAl, and on titanium strengthened with disilicides $Ti_5(SiAl)_3$ are promising materials for manufacturing various parts and components of spacecraft and mechanisms. Eutectic mixtures of these intermetallic compounds obtained by the conventional melting or granular powder metallurgy have the strength of 610—640 MPa at the temperature of 800°C and the fracture toughness K_{1c} of about 17—30 $MPa \cdot m^{1/2}$ at 20—800°C at the current stage of development. Their high hardness (460 HV) and hard silicide phase ensure a good abrasive stability. Their friction coefficient with no lubricant is about 0.28.

These innovations are relevant and important for solving the problems of long-time operation and reliability of different spacecraft mechanisms.

To prevent the smallest defects leading to a catastrophic failure at mechanical loading, we propose to make and to test those products under microgravity, which are based on zirconium ceramics and titanium intermetallic compounds. They are characterised by strengthening due to the phase transformations on the ground and, hence, by higher fracture resistance, tribotechnical and functional properties, as well as controlled heat conductivity.

The knowledge obtained during these space experiments will be used to create high-strength and abrasion-stable ceramics and intermetallic compounds for gas turbines, highly effective explosion engines, and artificial biological implants, like the hip joints and teeth.

Our confidence is based on the positive results of zirconium ceramics applications in bearings of chemical pumps, different rotating components of coal-mine equipment, drawing plates in aluminium wire production, pointed bearings of high-precision mechanisms and so on. Authors have a long-term experience in the field of R&D of zircon and other ceramics, for example various units of the explosion engine, such as pistons, valves, turbines and other structural parts, have been made using titanium intermetallic compounds.

«Protection» Sub-Experiment of the «Resource» Experiment

INFLUENCE OF SPACE FACTORS ON PROPERTIES OF METALLIC AND CERAMIC COMPOSITIONS WITH COATINGS

Oliker V. E.

I. N. Frantsevich Institute for Materials Science Problems, NAS of Ukraine
3 Krzhyzhanovsky St., Kyiv 03142 Ukraine
tel: (380) + 44 +444 10 90, fax: (380) +44 +444 21 31, e-mail: oliker@ipms.kiev.ua

Kresanov V. S.

National Technical University of Ukraine «Kyiv Polytechnical Institute»
12 Politechnicna St., Kyiv 03056 Ukraine
tel: (380) +44 +441 18 31, fax: (380) +44 +241 86 85

It is proposed to study properties of compositions on Ti-Al base with oxidation-resistant coatings (800—1000°C) used in aerospace industry, under the influence of various space factors.

The main disadvantage of similar alloys for coatings regarding the degradation of their fatigue life can be eliminated by development and application of a new kind of alloys. These alloys are based on gamma Ti-Al system modified by REM and Sc, which are able to change the reactivity of the Al/Ti components in the environment. As a result, an alumina will form on the surface of the alloy with saving of sufficient mechanical properties of the substrate (ultimate tensile strength is about 400—500 MPa at 800°C). The coatings have been formed by detonation spraying.

A special device will be designed to test the new material samples for fatigue strength. This unit consists of the loading device mounted on the outer side of the ISS, and of the automatic control and recording systems placed inside the ISS. The loading device is a carousel-type holder with 15 specimens, which are subsequently loaded in a cycle. Loading rollers are arranged in two circular rows in such a manner that the free ends of plane specimens are clipped for bending between them. The loading device is driven to rotation by a motor. The automatic control system records the holder revolutions, temperature, and time by the signal transducers mounted on the loading device.

«Accumulator» Sub-Experiment of the «Resource» Experiment

PROPERTIES OF METAL HYDRIDES UNDER MICROGRAVITY

Trefilov V. I., Schur D. V.

I. N. Frantsevich Institute for Materials Science Problems, NAS of Ukraine
3 Krzhyzhanovsky St., Kyiv 03142 Ukraine
tel: (380) + 44 +444 22 71, fax: (380) +44 +444 03 81, e-mail: shurzag@ipms.kiev.ua

The purpose of the experiment is to study the effect of microgravity on performance of energy conversion systems and other apparatuses based on metal hydride materials. This experiment also involves a study of hydrogen-sorbing materials production in space and of their physical and chemical properties. Such materials may be widely used in the future to design the space hydrogen power devices.

These data will be compared with the data obtained on the ground under the gravity conditions.

Experiment program includes the following stages:

- study of the peculiarities of the process of production of hydride-forming alloys;
- study of the influence of microgravity on physical-chemical transformations arising in application of hydrogen energy equipment;
- design, development, fabrication and testing of metal hydride storage facilities for hydrogen transformation and use onboard the OSS to perform scientific experiments;
- study of fatigue life, hydrogen capacity, structural and phase characteristics of alloys and of products of their interaction with hydrogen;
- production of various fullerenes under microgravity;
- comparative study of heat mass transfer and thermal-physical properties of metal hydride powders under the conditions of full gravity and microgravity;
- study of the influence of microgravity on the performance of a metal hydride electrode for batteries.

This work is carried out in wide co-operation with the institutions and laboratories in Ukraine (IPMS NASU; Institute for Problems in Machinery, NASU; State Scientific Industrial Enterprise «Zirconium»), Russia (Institute of New Chemical Problems, RAS; Institute of Chemical Physics, RAS), the USA (University of Central Florida; Allied Signal Inc. Aerospace Equipment Systems; Eastern Europe Linkage Institute), Canada (Ecole Polytechnique de Montreal), and Germany (Institute for Nuclear Energy and Energy Systems of the University of Stuttgart).

«Accumulator» Sub-Experiment of the «Resource» Experiment

PROPERTIES OF HYDROGEN-CAPACIOUS COMPOUNDS AND CERAMIC MATERIALS ACTIVATED WITH HYDROGEN

Trefilov V. I., Morozov I. A., Itsenko A. I., Kuprianova E. A., Morozova R. A., Panashenko V. M.

I. N. Frantsevich Institute for Materials Science Problems, NAS of Ukraine
3 Krzhyzhanovsky St., Kyiv 03142 Ukraine
tel: (380) + 44 +444 21 31, fax: (380) +44 +444 01 01,
e-mail: imorozov@materials.kiev.ua

Properties of hydrides and the field of their application depend on hydrogen content in the materials. Metal hydrides of the periodical system group IV are objects of great interest because of their high specific density of the hydrogen atoms. The maximum H/Me ratio in these materials does not exceed 2:1, which corresponds to MeH_2 formula where $N_H \approx \approx 9.1 \cdot 10^{22}$ at·H/cm^3.

The fundamentals of new synthesis technologies for metal hydrides (with high hydrogen content), as well as ceramic materials based on carbon, boron and aluminium have been developed for the first time at the I. N. Frantsevich Institute for Materials Science Problems of the NASU. Titanium, zirconium and hafnium hydrides with hydrogen contents of $MeH_{2.3}$ to $MeH_{3.7}$ have been obtained. Titanium hydride produced by our technology has the composition of $TiH_{3.7}$ ($N_H \approx 16.1 \cdot 10^{22}$ at·H/cm^3). Hydrides of such composition have quantitatively new characteristics: their thermal stability with respect to decomposition and oxidation is increased up to 250—300°; their irradiation resistance is improved 1.5-2.0 times. Changes of lattice structure of the hydrides with higher hydrogen contents have been also observed. A unique property of these hydrides to interact chemically with light inert gases, namely helium and argon, has been established.

In view of the good prospects for utilisation of aluminium and boron nitrides (as well as of compositions based on them) in space systems such as antenna windows and rocket fairing, it is interesting to study the influence of space factors on the physical-mechanical properties and structure of ceramics with improved characteristics, in order to determine their possible service life under these conditions.

The need to carry out experiments in open space (under the influence of cosmic radiation, long-term microgravity and very low pressure) is also due to the possibility of practical application of hydrogen-capacious materials and ceramics activated by hydrogen in space as:

1) powerful hydrogen source as ecologically pure fuel;
2) components of solid rocket fuel;
3) materials for protection from cosmic radiation;
4) biological protective materials for nuclear reactors;
5) regulators of fast neutron flows (zirconium hydride) in nuclear reactors;
6) antenna windows and rocket fairing (ceramics).

Intermetallic hydrogen accumulators can be used in this experiment in two aspects: 1 — as working materials — hydrogen sources, for ensuring the functioning of devices and life-support systems of a manned space station; 2 — as objects of study under the space conditions as promising materials of working elements of spacecraft in the future.

The principal task of this experiment is to study the influence of open space conditions (low pressure, cosmic radiation, and microgravity) on the following properties of the materials:

- for hydrides with increased hydrogen content:

1) hydrogen content as the main characteristic of hydrogen-capacious materials;
2) thermal stability of hydrogen-saturated materials;
3) structural lattice changes of hydrogen-capacious compounds;
4) changes of the electronic structure and chemical bonding of materials with an anomalously high content of hydrogen.

- for ceramics with improved properties:

1) chemical and phase composition of materials;
2) electrical insulation properties;
3) mechanical characteristics;
4) thermal stability;
5) chemical stability.

The following hydrogen-containing materials are planned to be used: a) 100×100×10 mm briquettes of up to 5 kg total weight, b) 40×40×10 mm ceramic briquettes of up to 2 kg total weight. The mentioned briquettes will be fixed in stainless steel frames. Containers with test materials should be located on the platform outside the ISS and should be exposed to all changes of space conditions during the whole operational period of the ISS.

Study of the influence of very low pressures, cosmic radiation and microgravity on the properties of hydride-forming materials undoubtedly is of prime importance for development of space materials science.

«Poplar» Sub-Experiment of the «Resource» Experiment

SOLAR THERMAL ELECTRIC POWER COMPLEX FOR ORBITAL SPACE STATION

Trefilov V. I., Goryachev Yu. M., Pasichny V. V., Kostornov A. G.

I. N. Frantsevich Institute for Materials Science Problems, NAS of Ukraine
3 Krzhyzhanovsky St., Kyiv 03142 Ukraine
tel: (380) + 44 +444 22 71, fax: (380) +44 +444 21 31, e-mail: dir@ipms.kiev.ua

The development and study of the Solar Thermal-electric Power Complex (STPC) is aimed at creation of a power source with higher efficiency, reliability and long-term life.

Realisation of the experiment is based on previous research carried out at the Institute for Materials Science of NASU and on the following main results obtained:

— Optimisation of high-temperature thermoelectric materials and thermoelectric element cascading permit increasing the temperature gradient, as well as decreasing the power degradation down to 5 % (after 10000 hours of operation);

— Use of a solar concentrator for heating of hot junctions of thermoelectric elements and of heat tubes for heat removal from the cold junctions permit intensifying the heat exchange and increasing the specific power up to 2 W/cm^2, and the efficiency up to 15 %.

The main purposes of the space experiment are the following:

— testing the performance of the power complex and its units and components when exposed to space radiation, vibration, and over-loading during putting into orbit and operation in space;

— studying the influence of weightlessness on the heat carrier transfer in heat tubes;

— determination of the functional effectiveness, reliability and fatigue of the STPC in space.

The experimental space system consists of STPC; two blocks BC-1, BC-2 for control, storing and processing of the data; platform for STPC and BC-1 assembled on the outer side of the OSS; cables; container for storage and transportation of STPC, BC-1 and BC-2. The STPC consists of three main units, namely solar concentrator, thermal battery and heat tubes.

The following main operations are provided:

— measurement of the irradiency in the focal spot of the solar concentrator;

— switching of two modes, namely no-load and short circuit (obtaining the volt-ampere characteristics (VAC));

— computer storage of the VAC data and pyrometer readings;

— processing the VAC data.

The work has been carried out within the framework of the International program of the USA, Russia, and Ukraine (NASA, RAS, NASU) for the ISS.

«Pipe» Experiment

SMALL-SIZED AND MINIATURE HEAT PIPES FOR COOLING SYSTEMS AND THERMAL STABILIZATION OF SPACE INSTRUMENTATION AND HARDWARE

Kostornov A. G., Shapoval A. A.

I. N. Frantsevich Institute for Materials Science Problems, NAS of Ukraine
3 Krzhyzhanovsky St., Kyiv 03142 Ukraine
tel: (380) + 44 +444 04 27, fax: (380) +44 +444 21 31, e-mail: dir@ipms.kiev.ua

Maintenance of normal thermal modes of space instrumentation and hardware is an important and difficult technological problem.

Problems of effective heat removal and maintenance of normal thermal modes of space vehicles have been solved by the following main methods: improvement of the extant heat engineering units, e. g. heat pipes. However, in terms of the thermal-physical aspect the conditions of heat pipes functioning in space are different essentially from those on Earth.

The IPMS NASU has designed heat pipes with high-performance metal-fibre capillary structures. Some of these pipes have been operating without failures since 1975 for thermal stabilization of orientation instruments mounted on space vehicles. In spite of the fact that these pipes have been used in space for a long time, an influence of microgravity on their parameters has not been studied.

On the other hand, the gravitation influence on thermo-physical processes occurring inside a heat pipe, leads to essential changes in the value of the pipe thermal resistance after long-time operation.

The anticipated results of heat pipes investigations under the space conditions would make a significant contribution to their theory. Results will be undoubtedly useful for design of cooling and thermal stabilization systems of space objects, satellite instrumentation, high-altitude aircraft, and rocket engineering as well as for development of high-performance heat-transfer units in the future.

«Indentor» Experiment

NEW METHOD AND INSTRUMENT FOR DEFINITION OF MECHANICAL PROPERTIES OF MATERIALS IN SPACE BY LOCAL LOADING WITH AN INDENTOR

Milman Yu. V., Ivaschenko R. K.

I. N. Frantsevich Institute for Materials Science Problems, NAS of Ukraine3
Krzhyzhanovsky St., Kyiv 03142 Ukraine
tel: (380) + 44 +444 30 61, fax: (380) +44 +444 21 31, e-mail: milman@ipms.kiev.ua

Exposure to space radiation, vacuum, and low temperatures, of materials and various instruments located on the external side of space vehicles (SV) results in the change of their structure and mechanical properties. Witness-specimens are currently used for control of the mechanical properties of materials. These specimens should be mounted on the SV shell, exposed to raw space and should be taken off before landing for further study on the ground. It is a very complicated and expensive operation, which does not provide any concrete control of the mechanical properties during the SV mission.

There is a necessity to analyse the mechanical properties and structure of materials on other celestial bodies, for example, on other planets during SV missions to them. However, right now it is only possible by specimens selection and their delivery to Earth for investigations.

The method of hardness and microhardness measurement has been widely used for many years for estimation of the mechanical properties of materials, both in research laboratories, and in industry. This method is the simplest, while being a highly sensitive one, and it does not require the production of any complicated specimens. Hardness measurement is performed without destruction of specimens, or damage of their surface; requires minimum expenses for microsections preparation and responds accurately enough to the finest changes of metals and alloys structure.

There exist many hardness measurement methods. However, the most convenient and versatile method is the Vickers hardness measurement, due to the application of a diamond pyramid and a new generation of devices for determination of micro- and nanohardness. Applying the loads from 1 mg to 500 g makes it possible to measure hardness both of the most brittle metals and of the microscopic bodies.

The capabilities of determination of the mechanical characteristics by the traditional methods are rather limited for nonplastic materials because of their brittle fracture at stress values close to the yield point or even lower. On the other hand, even with plastic materials, the traditional methods of determination of the mechanical characteristics require great expenses for sample preparation and a great number of samples that is unacceptable in some cases.

In tensile mechanical testing the specimens are used only once, whereas in microhardness measurement the number of measurements on one section is unlimited.

At local application of a rigid indentor even brittle nonplastic materials can be greatly deformed without macroscopic destruction. Over the last few years the method of local loading (MLL) of materials by a rigid indentor has been developed from a method of estimation of mechanical characteristics into a method of determination of the whole set of mechanical characteristics (yield limit, strength, plasticity, Young's modulus, cold brittleness temperature). Development of a procedure for determination of mechanical characteristics by the MLL method is especially important for brittle ceramic materials, for coatings and other surface layers. Only MLL allows determination of the yield limit of these materials, as well as comparison of the plasticity of materials, which demonstrate complete brittleness at mechanical tests by tension, compression and bending.

Considerable capabilities for determination of mechanical characteristics are provided by the method of hardness measurement by indentation depth, in which the dependence of the indentor load on the indentation depth is recorded. The hardness in depth Hh depending on the load is calculated from the loading diagrams. The diagrams of loading are also used for determination of Young's modulus and other characteristics. Thus, hardness and other mechanical characteristics will be determined for surface layers of materials (at different distances from a surface), which are damaged to the greatest extent by space radiation.

It is essential that application of this method eliminates the need for the indentation size measurement by the optical methods. This has opened a possibility to measure hardness at extremely small loads (nanohardness).

The purpose of the experiment is development of the new procedure of determination of the mechanical characteristics of materials during the ISS flight by periodic local loading of material models, exposed to outer space, with a rigid indentor, while recording the stress-strain curve.

The set objectives are as follows:

1. Determination of mechanical characteristics of surface layers of materials (at different distances from a surface), which are the most sensitive to outer space factors.
2. Study of mechanical characteristics of materials produced in space under the conditions of microgravity, namely monocrystals, composites, welded joints, and coatings etc.
3. Study of mechanical characteristics of non-plastic and brittle materials.
4. Measurement of hardness at extremely small loads (nanohardness) The indentation results will be presented as the indentation curves; numerical files; calculated values of the non-restored hardness in indentation depth and of restored hardness in an impression diagonal; modulus of elasticity (Young's modulus); plasticity characteristics; values of a material yield point.

Objects of research will be test specimens of different materials, including materials obtained under the flight conditions. The test specimens should have a cylindrical shape with the diameter up to 15 mm and the width up to 5 mm.

The following equipment will be used:

1. Device for the micromechanical tests of materials by a method of continuous impression of the indentor (60 cm × 45 cm × 45 cm size, up to 10 kg weight, energy consumption of up to 100 W during several minutes of the experiment).
2. High-resolution optical microscope connected to a computer to transfer images.

«Thermoemission» Experiment

THERMAL EMISSION ELEMENTS OF CATHODE — NEUTRALIZER FOR PLASMA THRUSTER OF SPACE VEHICLES

Paderno Yu. B., Fillipov V. B.

I. N. Frantsevich Institute for Materials Science Problems, NAS of Ukraine
3 Krzhyzhanovsky St., Kyiv 03142 Ukraine
tel: (380) + 44 +4441367, fax: (380) +44 +444 21 31, e-mail: paderno@ipms.kiev.ua

The application of electro-jet propulsion systems (EJPS) in space vehicles (SV) allows an essential increase in the life of the propulsion system (PS) simultaneously with its weight reduction compared to the chemical PS, that is especially important for long-term space flights and commercialization of space.

At present, one of the most effective and used EJPS is the stationary plasma thruster (SPT).

The SPT has a comparatively simple design of an accelerator and power supply system, as well as a wide range of thrust. It can be easy controlled by the rate of flow of a propulsive mass and accelerator voltage. The SPT has a possibility of precisely maintaining the trust at the required level, as well as a long service life (up to 10^4 hours and more), a great number of potential switching cycles (10^5).

One of the SPT blocks is the cathode-neutralizer, which has the greatest influence both on the service life and start-up rate, and possible number of switching cycles. The cathode-neutralizer should provide not only the initialization of plasma discharge in a thruster, but also the neutralization of volume charge at the PS outlet.

Since 1963 the development and manufacture of thermal emission elements from lanthanum hexaboride has been one of the areas of activity of the I. N. Frantsevich Institute for Materials Science Problems (IMSP). Starting from 1968 these thermal emission elements have been used in cathodes-neutralizers for development of SV thrusters. The customer for these thermal emission elements was the Special Design Bureau «Fakel» (Kaliningrad region, Russia). Thermal emission elements designed and manufactured in IMSP laboratory have been successfully used in the space programs of the Former Soviet Union. From 1982 the manufacture and supply of thermal emission elements for the regular thrusters of SV has been performed in keeping with the appropriate Specifications.

During this time the technology of both material production and thermoemitters treatment were optimised to improve the stability of their operating characteristics and service life. Extensive experience on modification of the structure of material and the configuration of the working channel of thermoemitters after SPT trials in the test installations has also been accumulated. However, there is a lack of results on comparison of the data obtained on Earth with the data obtained under the actual space conditions. It is known that the conditions of ground-based tests do not coincide completely those of space, especially in the SV vicinity. In particular, it concerns the composition of environmental gases, which is the determining factor both for the erosion rate of the thermal emission material and for its serviceability as a whole.

During 25 years (1972 — 1997) of EJPS service, more than 220 cathodes were operated in space, of which 104 cathodes are still operating. The total duration of their operation was 8950 hours until February 14, 1997, with the maximal duration of 976 hours for one cathode. At the same time, the service life of one cathode in the test installation reached 7500 hours (it is still in service now, and can be used for further experiments).

It is highly necessary to provide direct experimental confirmation of the fact that extension of the experience accumulated on Earth to the process of actual operation under the space conditions is well-grounded, in particular, taking into account most of the recent developments of PS for the orbital tow vehicles and manned flight to Mars. From this point of view, it is useful to conduct the investigation of structure and properties of materials (first of all, material for the thermoemitters) after SPT operation under the ISS Program. In addition, this experiment could provide also the lowering or practically complete compensation of the braking of the Earth's atmosphere due to the use of the SPT impulse.

At present, the modules having the thrust force from 3 grams up to 60 grams are designed and manufactured at the SDB «Fakel». It allows selection of the type of SPT, the schematic of their layout and modes of their operation so as to stabilise the orbit and orientation of the ISS and, therefore, to minimise the gravitational perturbations during performance of other scientific experiments. Considering that the energy of solar batteries is used for this type of PS, and only the propulsive mass (xenon) is consumed, this method of ISS orbit stabilisation is rather cost-effective one.

Within the framework of co-operation between the SDB «Fakel» (SPT manufacturer), the Rosaviacosmos and the IMSP, this experiment is accepted for feasibility study. It is intended to use the standard PS, namely the batch SPT-70 with the power of 700 W (1.5 kg mass) and SPT-100 with the power of 1350 W (3.5 kg mass). The consumption of the working gas (xenon) in the design mode is up to 2.8 mg/s for SPT-70 and up to 5.5 mg/s for SPT-100. It is also possible to use various tanks for the working gas depending on the purpose of the work (test of the cathode-neutraliser and/or compensation of the braking moment) and on the ability to replace them (for example: a) V = 1 l, M = 1 kg, M_{Xe} = 1.78 kg; b) V = 15 l, M = 6 kg, M_{Xe} = 1 kg; c) V = 50 l, M = 15 kg, M_{Xe} = 78 kg).

When SPT of other types are used, the power rang can be increased up to 1500 W (for each thruster).

For carrying out this study under the conditions of the ISS, it is possible to define the following two technical problems:

1) Study of the behaviour of the thermal emission elements made from lanthanum hexaboride. The initiation moment is the most critical for the serviceability and operating life of the cathode-neutraliser. From this point of view, it is desirable to provide the multiple switching on/off of the SPT with various modes of heating, operation and cooling. This will provide a substantiation for extension of the experience of ground-based tests to SPT operation under the space conditions.

2) Use of the EJPS for stabilisation of the orbit and/or control of the position of the ISS with the operation time of not less than 8000 hours.

«Optocoupling» Experiment

FIBER OPTIC ROTARY JOINTS FOR NON-CONTACT TRANSMISSION OF INFORMATION TO AND FROM ROTATING EQUIPMENT

Svechnikov S. V., Shapar V. N.

Institute of Semiconductor Physics, NAS of Ukraine
45 Nauka Ave., Kyiv 03028 Ukraine Tel: (380) +44 +2657081

The purpose of the experiment is to develop, study, and manufacture high-quality pilot models of the multipass fiber optic rotary joints (FORJs). The FORJs are designed for optoelectronic transmission of different digital and analog data from the rotating objects installed onboard the ISS to the stationary objects.

To date, the contact, capacitance, and inductance slip rings have been used for data transmission from rotating to stationary equipment. Contact slip rings have been mostly used as the simplest and cheapest ones. The advancement of information technologies has been accompanied by the impetuous increase of transmitted information scope and by introduction of fiber optic sensors and communication lines on rotating equipment. Due to this factor, the traditional application of electrical slip rings in modern facilities has become more and more problematic and in some cases impossible because of their principal disadvantages. For example, the number of physical channels in electrical slip rings for transmission of large volumes of information amounts to as much as several hundreds of channels because of lack of sufficient bandwidth. Thus, the weight of these devices can be up to several hundred kilograms. A high level of noise, as a result of friction and sparking of contacts, and a high sensitivity of contact slip rings to the electromagnetic barrier, cause serious problems in their use in equipment where strong electromagnetic fields are present. Besides, both sparking and the possibility of self-ignition of contacts create unsafe conditions for slip rings use in facilities where explosion hazard exists.

Development and introduction of fiber optic rotary joints instead of the traditional slip rings as their functional analog is the alternative solution of the problem of information transmission from rotating equipment.

The creation of FORJs is of great importance in such developed countries as the USA, Canada, Japan, and the United Kingdom. In the USA, the development of FORJs for instrumentation is one of the top priorities.

A considerable contribution to this field has been made at the Institute of Semiconductor Physics of the NASU [1-3]. It was developed a unique method of signal transmission between objects, which move relative to each other, by means of step-by-step compensation of velocities and directions of light beams (Invention certificate No 1832395, 1992). The developed method opens up the possibility to create multipass FORJs for dozens of optical fibers of different modifications. In addition, multipass FORJ on the basis of a graded-index optical compensator with unique characteristics has been designed (not less than 500 MHz bandwidth; not more than 2.5 dB insertion width; not more than 0.5 dB actual rotational variation; up to 10 channels; not more than 5...7 cm overall dimensions; less than 250... 300 grams weight).

A great bandwidth of a FORJ's channel, which is thousand times greater than that for an electrical channel, compactness and low weight, reliability and long service life, as well as no need for adjustment for several years are the principal advantages, which exactly meet the requirements to space equipment.

The most promising trends for the FORJ's usage onboard of a space vehicle are the following: space robotics, radar antennas, remotely operated vehicles, cranes and turrets, telemetry of rotary objects, and other fields, where there is a necessity to transmit information to and from the rotating equipment. The designed multipass FORJs and preliminary research allow us to confirm the applicability of the devices for the above purposes.

It is, however, necessary to study the influence of space emissions, high vacuum, as well as low temperatures on optical and operating characteristics of FORJs for their direct usage onboard the space vehicles. Investigation of these factors permits selection of the materials needed and development of special designs of FORJs for operation in a space environment.

References

1. Svechnikov G., Shapar V. // OE/FIBERS'91. SPIE International Symp.: Proc. SPIE.—Boston, Massachusetts, USA, Sept..—1991.—N 1589.—P. 24—31.
2. Svechnikov G., Shapar V. // OE/FIBERS'91. SPIE International Symp.: Proc. SPIE.—Boston, Massachusetts, USA, Sept..—1991.—N 1589.—P. 391—394.
3. Kyryluk L., Konyukhov S., Oleinik I., Shapar V. // Int. Sci. &Tech. Conf. «Advanced Radiolocation». — Kyiv: Sci. Research Inst. «Kvant», 1994.—P. 42.

«Factor» Experiment

PROSPECTS FOR STUDY OF STRENGTH OF STRUCTURAL MATERIALS AT THE OSS

Stryzhalo V. O., Skrypnyk Yu. D.

Institute for Strength Problems, NAS of Ukraine
2 Timiryazevska St., Kyiv 03014 Ukraine
Tel: (380) +44 +2962657, Fax: (380) +44 + 2961684

The near-earth space factors (NESF) adversely affect the strength of metal structural materials for space industry. These factors are classified into the following groups: vacuum, chemical composition of the atmosphere, corpuscular radiation, electromagnetic radiation, meteors and cosmic dust, and temperature. The NESF effect on structural materials is primarily exerted through their surface layers and also through the mechanisms of radiation damage. The simulation of the aforementioned set of NESF and its long-term confinement under the laboratory conditions is, in essence, an unsolvable problem. For this reason, there is a necessity to carry out mechanical tests directly in raw space using special equipment mounted on the outer surface of the OSS.

The goals of the experiment are as follows:

- qualitative and quantitative assessment of the NESF effect on the load-carrying capacity of structural elements during their long-term operation;
- development of specifications for design of load-carrying structures operating under space conditions for a long time;

- issuing recommendations for selection of structural materials to ensure the reliability of structures under space conditions taking into account the modes of mechanical loading and service life;
- development of the necessary industrial standards.

Integrated certification of such structural materials should include various procedures and testing equipment. Analysis of the actual methods for materials testing allowed us to select the method, which meets the basic requirements to experiments in space materials science. These requirements include some principal items: low power consumption during loading; larger surface area of experimental specimens exposed to the impact of destructive NESF; simulation of the most dangerous modes of loading of the actual structures; minimal overall dimensions and weight of experimental multi-specimen loading device; independent power supply source for this device; automatic control means.

In our opinion, the tests for cyclic alternating bending by specifying the kinematic displacement of the force application point, i. e. the strain-controlled loading, satisfy these requirements exactly. The low-cycle fatigue is a characteristic, which is very sensitive to short-term and long-term effects of NESF.

The Figure 5 illustrates the functional block diagram of the experimental unit being created. The experimental unit consists of loading device (LD) A, and of solar energy converter (SEC) B, which are mounted on the outer surface of the OSS, and of a system of automatic control and recording of experimental data (ACS) C, which is inside the station. The LD has holder 4 with circularly positioned specimens (about 24 pieces).

Each of the specimens is prepared in the form of a cantilever beam. It has equal resistance to bending and interacts with a ram, which reciprocates by loading rollers 3 during the holder revolution. In one revolution of the holder, each of the specimens is deformed according to a single symmetrical cycle composed of two half-cycles shifted in time. Being in the position between the rollers, the specimens are in the unloaded state. Special gauges 2 and 6 record their residual bending in a half-cycle, as well as the number of the holder revolutions. Taking into account the maximal loads and losses, the power of engine 1 for the holder revolution at the speed of 3 r.p.m. should be up to 30 W with the torque at the holder shaft of 100 N·m. The Stirling heat engine (external combustion engine) 8 with solar energy concentrator 7 in a hot zone of the engine and with emitter-radiator 9 in a cold zone, is used as a solar energy converter (SEC). Electric generator 10 generates power supplied to engine 1. The automatic control system includes transducers of signals from displacement pickups, holder revolution transducers, temperature gauges, generator current sensors, timer, and experimental data recording unit constructed on the basis of a microcomputer. In testing of one holder (24 specimens), the approximate number of the data recorded do not exceed 104, which requires up to 100 Kbytes of memory capacity.

In order to use the test unit in an independent power drive, a detailed design of the Stirling heat engine model has been developed. It has the following main rated characteristics: power at the pressure of the working medium of 105 Pa is equal to 20 W; power at the pressure of the working medium of $5 \cdot 10^5$ Pa is equal to 100 W; working medium is the air; temperature range of the thermal dynamic cycle is equal to 350...650 K; frequency is equal to

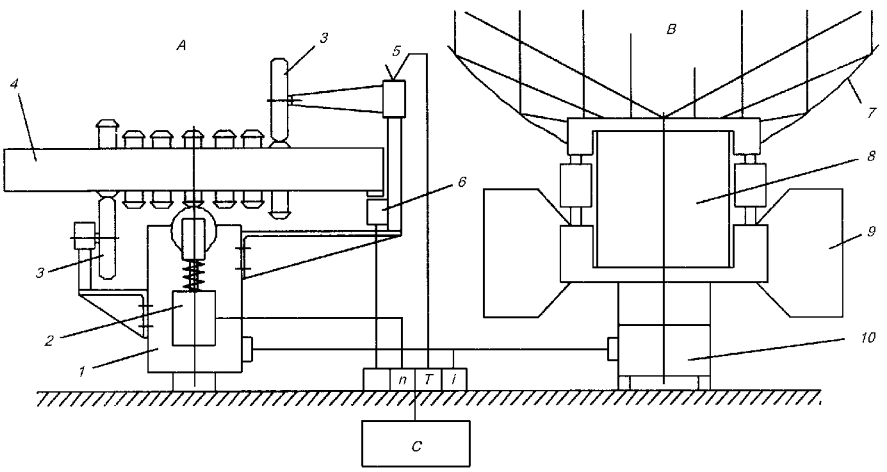


Fig. 5. Functional black diagram

10 Hz.

SPACE PROJECT «PENTA» COMPLEX

Eremenko V. V.

B. I. Verkin Institute for Low Temperature Physics & Engineering (ILTPE), NAS of Ukraine
47 Lenin Ave., Kharkiv 61164 Ukraine
Tel: (380) + 572 +308510, Fax: (380) +572 +322370, e-mail: ilt@ilt. kharkov.ua

Gavrylov R. V., Pokhyl Yu. A.

Special Research & Development Bureau for Cryogenic Technologies of ILTPE, NAS of Ukraine
47 Lenin Ave., Kharkiv 61164 Ukraine
Tel: (380) + 572 +320511, Fax: (380) +572 +322293, e-mail: sktb@ilt.kharkov.ua

«PENTA» project is devoted to creation of a complex workplace onboard the ISS, and is intended for realization of long-time on-board research experiments in the field of space materials science, space biology, and heat-mass transfer under the conditions of microgravity and influence of the factors of space flight.

«PENTA» experimental flight complex provides five independent experimental cells working in a consecutive-parallel mode. Three of them are intended for realization of the comparative study of the following tasks:

— processes of friction and wear of functional materials;

— characteristics of resistance to fatigue failure of various classes of structural and functional materials for space applications;

— optical and physical properties of thermo-regulating and protecting coatings, elements of solar batteries and on-board optical systems under the conditions of the actual space flight and ground-based laboratory simulation.

The fourth cell is intended for realization of space experiments on liquid helium boiling with artificially created variable relative level of microgravity (*HERUBIM experiment, chapter II.6, editor's remark*). And, finally, in the fifth cell the realization of long-time space experiments to study the influence of magnetic fields and microgravity on the dynamics of growth of vegetative objects is planned (*«Penta-Plant» experiment, chapter II.4, editor's remark*). The details of the proposed experiments are described in the subsequent articles.

Despite a variety of the tasks addressed by the «PENTA» complex, it is proposed to organize one flight work place for carrying out these experiments, as all the experiments imply quantitative control of the space factors and simultaneous measurements of physical characteristics of the objects under study. It will allow unification of complex blocks, which are carrying out common functions for all experimental cells. Such blocks include the power supply block, control instrumentation block (temperature, vacuum, radiation factors etc.), block of data accumulation and processing, control block, block of the interface with the on-board computer, platform for exposed samples in raw space, system of photo- and tele-visualization of objects etc.

Such a principle of construction of «PENTA» workplace combining a unified common power, measuring, information, and structural infrastructure with replaceable experimental cells, allows the equipment weight and overall dimensions to be reduced and the expensive flight time of the ISS to be used in the optimal manner.

Among others, the results obtained during scientific space experiments in «PENTA» research complex, will be used to solve the following tasks:

— ensuring long-term, reliable and safe operation of separate units and systems of space vehicles;

— improvement of the validity of calculation of the processes in two-phase «gas (vapour) — liquid» space systems of cooling and fuel systems under microgravity conditions;

— production of new structural and functional materials with a high efficiency;

— development of the methods for compensation of the negative influence of gravity force absence on biological objects and creation of biological systems of life-support of the crew during long-term space flights.

«Penta-Tribos» Experiment

STUDY OF THE ADEQUACY OF THE FRICTION AND WEAR DATA OBTAINED FOR ANTIFRICTION AND WEAR-RESISTANT MATERIALS DIRECTLY IN SPACE AT ORBITAL STATIONS AND IN LABORATORY CONDITIONS

Gamulya G. D., Ostrovska O. L., Yukhno T. P.

Special Research and Development Bureau for Cryogenic Technologies of the ILTPE, NAS of Ukraine
47 Lenin Ave., Kharkiv 61164 Ukraine
Tel/fax: (380) + 572 +322293, e-mail: sktb@ilt. kharkov.ua

The necessity of development of a new generation of space equipment which will be capable of safe and stable operation in near-earth orbit, as well as under the conditions of atmospheres of Solar system planets and in interplanetary space created a need for generation of valid information on friction-and-wear properties of structural materials and coatings intended for use in friction units of mechanisms and systems of space vehicles and OSS. Availability of such information is of special importance due to the fact that various faults and failures in spacecraft systems become increasingly frequent because of failures of friction conjunctions during the long-term flights. It is very difficult to implement tribological research of promising materials directly under the space conditions for technical and economic reasons. This circumstance has led to development of scientifically-grounded methods for determination of friction-and-wear characteristics of materials in ground-based laboratories, using special equipment for simulation of the influence of near-earth space factors on the friction pairs.

In this experiment, it is proposed to carry out a series of comparative tribological research under the flight conditions onboard the ISS and in a ground-based laboratory. Special on-board 6-module space tribometer will be used for this purpose.

Three tribometers will be used to realize one series of experiments. The astronaut-researcher will set up these tribometers one after the other on a special platform, which will be mounted on the external surface of the ISS. During one series of experiments it is planned to study 18 pairs of wear-resistant and antifriction materials and coatings. The duration of one tribometer operation is 3-5 hours (in the continuous or cyclic modes). Monitoring of experiments, recording of friction parameters and transmission of the results to Earth will be carried out with the help of a unified «PENTA» system for remote control and data processing.

When the program of experiments is completed, the tribometers are taken back to the Earth for diagnostic of the friction surface condition, establishment of wear parameters and mechanisms. Ground-based laboratory research will be carried out under the conditions of simulated space factors.

Comparative study of the data obtained in space and on the ground will allow revealing the adequacy of tribological research under various conditions.

Preliminary study and selection of materials, as well as development, manufacturing and testing of space tribometers, is planned in co-operation with specialists from the IMSP NASU and the Yangel State Design Office «Pivdenne».

The results obtained in «Penta-Tribos» experiment will permit prediction both the frictional behaviour of friction units and the safe and durable operation of space vehicles. This study will also allow certification of laboratory tribometers for space applications and will provide an opportunity for international certification of materials that are promising for use in spacecraft friction units.

«Penta-Fatigue» Experiment

INFLUENCE OF SPACE FACTORS ON FATIGUE FRACTURERESISTANCE OF STRUCTURAL MATERIALS

Pokhyl Yu. A., Yakovenko L. F., Aleksenko E. N., Lototskaya V. A.

Special Research and Development Bureau for Cryogenic Technologies of the ILTPE, NAS of Ukraine
47 Lenin Ave., Kharkiv 61164 Ukraine
Tel/fax: (380) + 572 +308551, e-mail: sktb@ilt. kharkov.ua

The long-term operation spacecraft (orbital stations, reusable space vehicles etc.) is experiencing multiple vibration loads while launches and landings, and in orbit as well (during docking/undocking with other spacecraft, while the orbit is changing, while technological experiments are conducted in space, etc.). To provide reliability and long-term durability of spacecraft, the structural materials of load-carrying parts of the body, antennae, solar cell batteries, and others units of the ISS should have not only high values of specific strength, but also high fatigue fracture resistance. The characteristics of fatigue fracture resistance of materials are the most sensitive to the influence of such outer space environment factors (SEF) as gas environment, some types of radiation, micrometeorite erosion. These factors mainly affect the material surface and sub-surface layers since the process of fatigue fracture is initiated in many cases from the surface. Experimental data obtained by simulation of several SEF in the ground-based laboratory show that the vacuum influence on fatigue fracture resistance is positive on the whole. While the low temperature impact can be different, depending on temperature values and on the type of structural material, the radiation impact on structural materials is mainly unfavorable.

To provide the long life and reliability of spacecraft structural components, it is necessary to solve the urgent task of a complete and integrated monitoring of SEF influence on fatigue fracture resistance of space structural materials. Nowadays this task is solved mainly by simulation of some SEF in the ground-based laboratories. The results obtained are extrapolated to the limit of the actual SEF parameters that does not guarantee their complete reliability.

A radical way for solving this problem, in the authors' opinion, is to install a special test module onboard the ISS for fatigue testing of structural and model materials under the real space conditions within the low- and high-cycle areas of fatigue curves.

To study the SEF influence on fatigue resistance of metals and polymeric materials, it is proposed to develop and manufacture «CYCLE-1» unit, as part of «PENTA» experimental complex for installation onboard the ISS. Such a study will be carried out in raw space for the first time. Having both applied and scientific significance, it allows evaluation of the structural materials durability under the space conditions for such important mechanical characteristic as fatigue resistance, and selection of the approved structural materials for space industry. At the same time, results of this space testing of materials in combination with the results of pre- and post-flight testing at the identical cyclic loading under the simulated conditions in the ground-based laboratory will enable determination of the adequacy of «simulated space environment factors». In case of their proximity, this will allow carrying out ground-based testing with less strict requirements to the set of simulated SEF and/or carrying out further research only in the ground-based laboratory. As regards the fundamental aspect, these results are important for establishing physical mechanisms of fatigue fracture under the conditions of integrated multi-factor space influence as well as for selection of scientifically-grounded criteria for producing new materials.

«Penta-Optics» Experiment

RESEARCH OF OPTIC-PHYSICAL PROPERTIES OF STRUCTURAL MATERIALS BY THE MONITORING OF THE FACTORS OF A SPACE FLIGHT

Solodovnik L. L., Verhovtzeva E. T., Yaremenko V. I.

Special Research and Development Bureau for Cryogenic Technologies of the ILTPE, NAS of Ukraine
47 Lenin Ave., Kharkiv 61164 Ukraine
Tel/fax: (380) + 572 +308551, e-mail: sktb@ilt.kharkov.ua

Implementing long-time space flights is one of the major problems at the current stage of development of cosmonautics. For solving this problem, there exist numerous rather strict requirements to reliability and service life of the spacecraft, including the structural materials used. In the course of a long-term orbital operation of a spacecraft, there occurs a degradation of thermo-controlling coatings. Investigations demonstrated different levels of optical materials stability in outer space. It is assumed that the most decisive factor in degradation of the mechanical and optical properties of TEFLON-FEP is the X-ray irradiation by solar flares.

Another important problem nowadays is related to identification of space contamination influence on optical properties of materials. It is universally known that substances being released into space environment as a result of outgassing and degradation of materials, are first absorbed on the material's surface, and then polymerized, thus resulting in increased Solar absorption coefficient.

Brief background and current status of the problem. Investigation of the actual changes in the optical properties of materials in long-term flights can be conducted by several methods for:

— employment of ground-based test facilities for simulation of space flight factors;

— implementation of experiments in a real space flight;

— implementation of experiments in a real space flight at simultaneous investigations in ground-based test facilities.

The first method is the most widely used, and is less expensive. However, the ground-based test facilities do not, in most cases, provide a simulation of the entire set of the actual space conditions. For instance, X-ray irradiation by Solar flares is not simulated in many test facilities, which is the factor, which may be the determining one in degradation of the optical and mechanical properties of a whole range of materials. In addition, in some cases of laboratory experiments, the simulation of individual factors of space is inaccurate. The researchers quite often neglect modeling of the spacecraft own exterior atmosphere, which, in particular, can contaminate the optical materials surface, thus deteriorating their optical properties. A certain ambiguity in interpretation of ground-based testing results arises in many cases from the lack of scientific justification of the «accelerated» testing procedure, i. e., shortening of test time at the expense of intensification of the acting factors. Therefore, the data on degradation of material properties generated in the ground-based test facilities may be different from the relevant data obtained in a real space flight.

Expediency of space experiment performance in space. The trustworthiest information about the change of material properties can be obtained from experiments staged in open space. The first spaceborne experiments were mainly dedicated to exposure of materials samples to outer space (and in many cases, without monitoring the space flight factors) with their consequent delivery back to Earth and a detailed comparative investigation of their properties prior to and after the flight. Current activities include such efforts as exposure of materials samples during a space flight with a simultaneous measurement of the optical characteristics (such as Solar-absorption integral coefficient, and materials emmissivity).

The most resultative are the investigations that combine both trends, i. e., exposure of materials in a real space flight with simultaneous investigations in the ground-based simulation test facilities. Irradiation of materials in the ground-based test facilities with subsequent investigations of their properties can be performed both by individual space environment factors and by all of them as a complex. This allows determination of the mechanisms of materials degradation.

Description of space experiment. Under this project it is proposed to create on-going scientific facilities onboard the ISS, as well as conduct integrated investigations of the spectral and integral transmission coefficients; reflection and absorption of Solar irradiation by materials under space flight conditions, with simultaneous control of its own external atmosphere parameters, such as:

— samples temperature,

— own exterior-atmosphere parameters (pressure or quantitative ratio of neutral and ion-components);

— space flight factors (fluxes of UV-, VUV- and USX-irradiation energy of the Sun, as well as fluxes of atomic oxygen and space rays).

It is intended to perform the investigations of the surface destruction and optical properties degradation in materials exposed to different outer space flight factors in the following manner.

First of mass and irradiation ability are measured, and analysis of materials surface according to the items specified during pre-flight experiments is performed in the ground-based laboratory. Next, part of the material samples is placed into a ground-based test facility to be subjected to «accelerated» impact of space factors both individually and as a whole set. Prior to irradiation, and in-between radiation sessions, the following optical characteristics are measured in site: spectral coefficients of directed transmission; adsorption coefficients; spectacular and total reflection coefficients (within working temperatures range), and the integral coefficients of transmission, adsorption and reflection of Solar radiation are determined.

In the process of irradiation, a mass-spectrometer is used for measurement of products of outgassing and degradation of materials. The above-described program of experimental work in the ground-based testing facility is done twice with:

a) clean surface of materials samples, and

b) monitored contaminations by a spacecraft's own exterior — atmosphere deposited on it.

Another part of materials (similar to the first one, but not irradiated), is placed into the sample-holders to be delivered aboard the ISS, mounted in the «Penta-Optics» research facilities and exposed to the outer space environment. After certain exposure time intervals, measurement sessions will be conducted to determine spectral coefficients of directed transmission, adsorption and spectacular and total reflection within 250...2500 nm wavelength range, along with photographing of the materials surfaces. The samples temperature, ISS exterior atmosphere parameters (pressure or quantitative ratio of neutral and ion components) and space flight factors (fluxes of UV-, VUV- and USX-irradiation energy of the Sun, as well as fluxes of atomic oxygen and space rays). The data obtained should be transmitted to Earth. After the period of materials exposure to the space environment (equivalent to 10000 Solar hours) is over, the materials in the sample-holder should be brought back to Earth, undergo a detailed investigation and analysis in after-flight experiments, as is described above). Generalization of the research results will form the physical basis for development of new promising optical materials for reliable and long-time functioning spacecraft in the space environment.

Novelty and quality-level assessment in comparison with analogous investigations accomplished in Ukraine and abroad. The scientific novelty consists of the following features:

— engineering a unique system of scientific equipment to allow performance onboard the ISS of complex investigations of the changes in surface topography and optical characteristics of transparent and non-transparent materials under the space flight conditions, along with simultaneous monitoring of space-medium parameters;

— obtaining new scientific information on degradation of optical and physical properties of materials in the space environment, as well as on degradation mechanisms;

— elaboration of a valid methodology for «accelerated» tests of samples inside imtegrated space simulation test facilities, by comparative analysis of the data on exposure of «twin»-samples to the raw space environment and of the measured characteristics;

— analysis of the data obtained, and determination of the physical principles for selection and development of advanced promising optical materials, to ensure a reliable and long-term functioning of a spacecraft under the flight conditions.

Expected results and anticipated applications. The subject of the proposed project, as well as the problems to be solved in it, are rather urgent, since relevant investigations results could facilitate creation of advanced optical materials with long-term performance capabilities in the space environment. The data to be obtained would make a significant contribution to fundamental knowledge, to creation of advanced optical materials with a longer life under the space environment conditions. These materials can be used in space engineering, in scientific instruments, and as cinema-photo-cameras lenses.

Division 3

METHODS AND EQUIPMENT FOR CONTROL OF DEFECTIVENESS AND STRESSED STATE OF CONSTRUCTIONS («Diagnostics» Project)

Lobanov L. M.

E. O. Paton Electric Welding Institute, NAS of Ukraine
11 Bozhenko St., Kyiv-150, 03680 Ukraine
tel: (380) + 44 + 2201775, fax: (380) + 44 + 2680486

«Diagnostics» Experiment

DEVELOPMENT OF METHODS AND COMPACT EQUIPMENT FOR CONTROL OF DEFECTS AND STRESSED STATE IN WELDED ELEMENTS OF STRUCTURES, WHICH OPERATE UNDER THE SPACE CONDITIONS

Lobanov L. M., Troitskii V. A., Pivtorak V. A., Zagrebelny V. I.

E. O. Paton Electric Welding Institute, NAS of Ukraine
11 Bozhenko St., Kyiv-150, 03680 Ukraine
tel: (380) + 44 + 2201775, fax: (380) + 44 + 2680486

Large-sized thin-walled welded structures, which should meet the requirements of high reliability and performance, are widely used now in construction of aerospace engineering systems.

Application of welding and brazing for repair and assembly of thin-walled elements of orbital stations has attracted increasing interest over the last years. In this connection intensive studies are carried out for development of effective methods of quality control and determination of residual stresses in welded joints of structures used under the space conditions.

The investigation methods should meet a number of requirements such as the possibility of defect visualization, validity of results, high sensitivity, contactlessness and accuracy of measurements and compactness of equipment. Traditional methods and means of structure diagnostics do not satisfy the above-mentioned requirements and do not provide any data on the features of the stressed state and quality of thin-walled elements under examination. Eddy current method and holographic interferometry — a new method of examination, meet these requirements.

The non-destructive testing method of holographic interferometry allows direct generation of the qualitative pattern of deformation distribution over the entire surface of an object to which certain forces are applied, without making any measurements of the interferogram being formed. Even without further analysis, this pattern provides very useful information for control purposes, thus permitting various defects to be detected easily.

The advantages of the new method are as follows: contactlessness of measurements; absence of harmful effect on the environment and attending personnel (ecologically clean method); feasibility of a simple visual observation of the interference fringe pattern over the whole field; applicability to examination of intricate objects; absence of special requirements to preparation of the surface of the objects to be examined; accurate quantitative determination of small values of the space vector of displacement over the surface of the object to be examined; simplicity

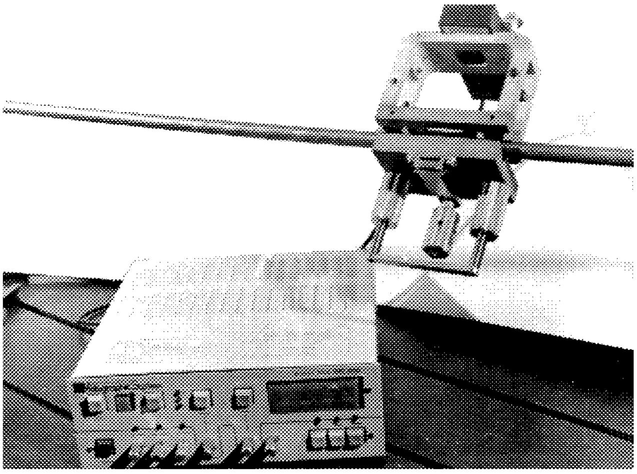


Fig. 6. General view of the mock-ups of holographic devices used for quality control of tubular elements

of interpretation of interference fringe patterns during quality control; absence of the effect of magnetic and electric fields on the accuracy of measurements; safety in operation; possibility of automation, etc.

The information on the quality of elements being examined was recorded by a developed compact thermoplastic recording camera, thus permitting to avoid chemical developing. This significantly increased the speed of information acquisition and shortened the time of hologram recording to 5-10 s.

The use of light guides in holographic quality control of the structural welded elements allows compact holographic instruments and devices to be developed, which are suitable for non-destructive examination in space.

In addition, the optical light guides can be sufficiently long for arranging the laser sources at a large distance from the holographic instrument.

On the basis of the developed procedures, operating mock-ups of holographic devices have been created for their testing, allowing evaluation of the possibility to perform non-destructive holographic control. Figure 6 presents general views of the operating mock-ups of holographic devices for quality control of tubular elements.

The interference fringe patterns, which characterize the quality of tubular specimens, are given in Figure 7.

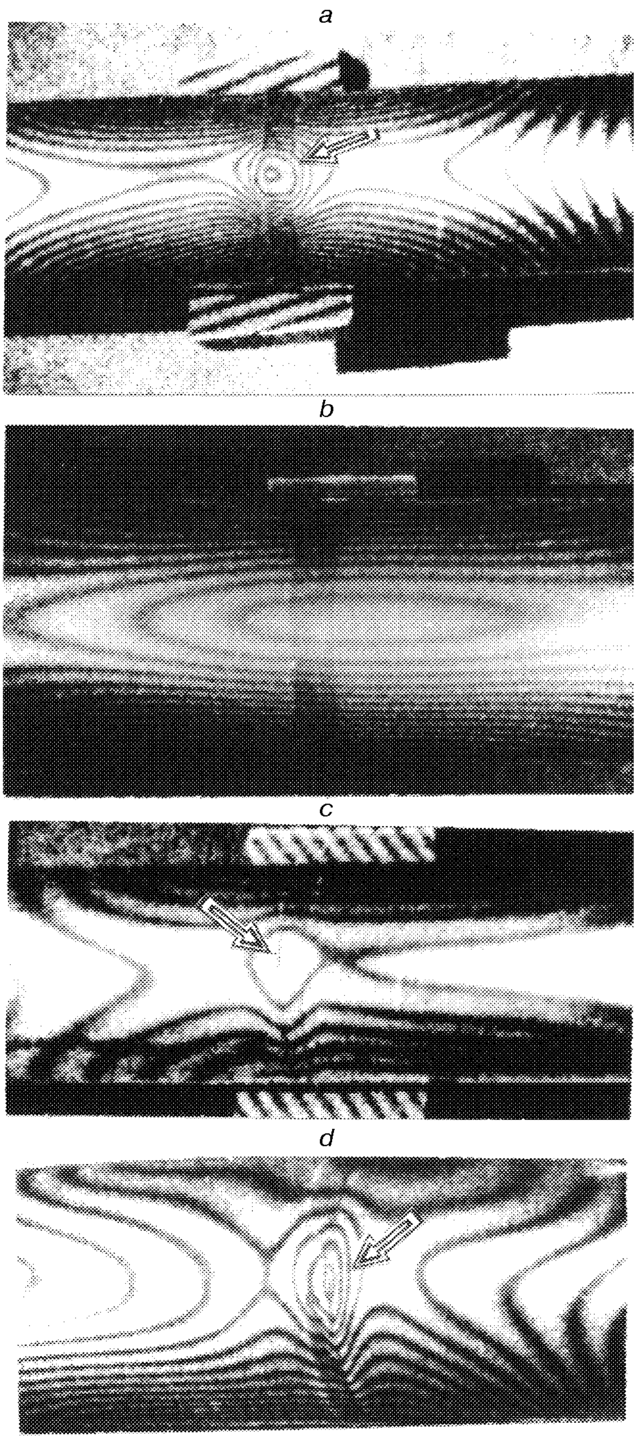


Fig. 7. Interference fringe patterns, which characterize the quality of tubular specimens

Fast analysis of the quality of welded tubular specimens showed the feasibility of applying the holographic method for non-destructive control of welds of thin-walled tubes used as technological piping at the orbital space station. In our opinion, one of the advantages of the method is visualization of control results, availability of photos, which are a document of the interference pattern that charac-

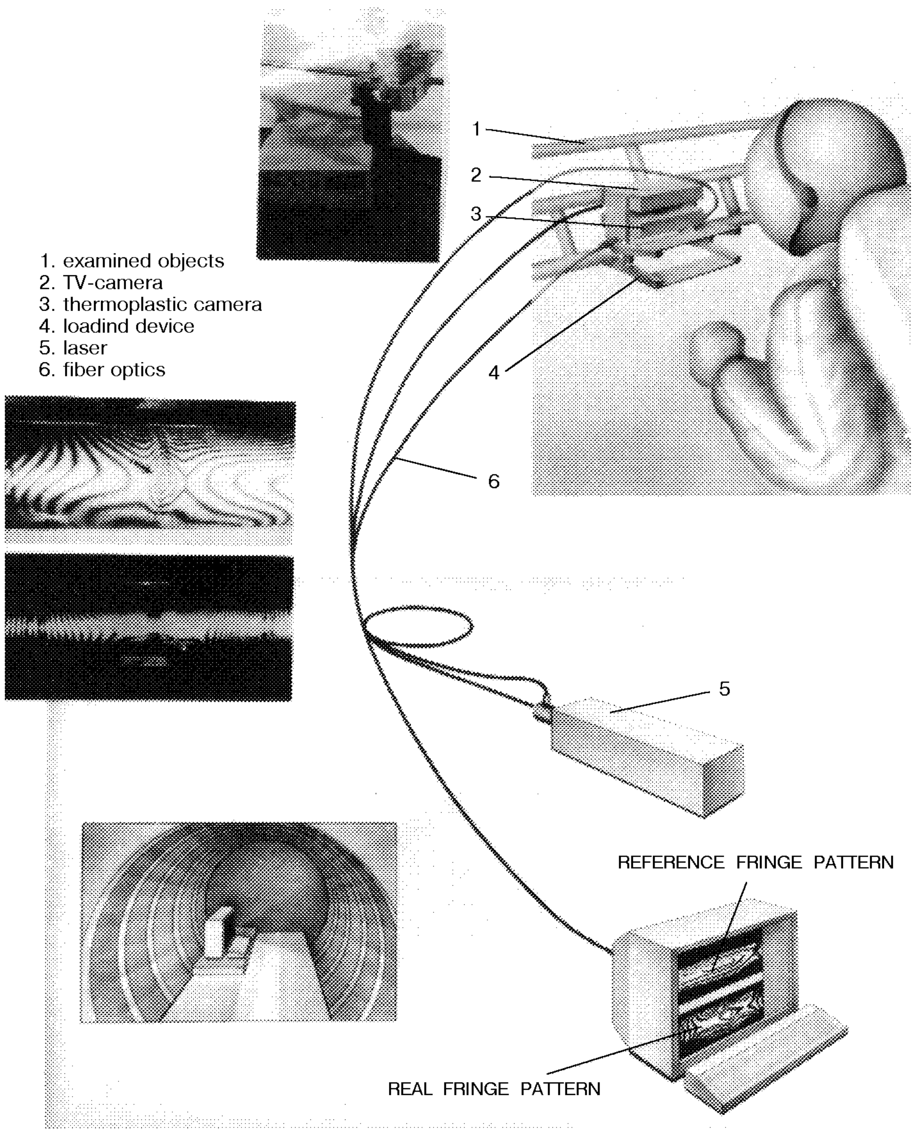


Fig. 8. Schematic of non-destructive quality control of structural elements under the space conditions.

terizes the quality of the object being examined. To identify all possible defects and causes of their initiation, it is necessary to obtain the reference fringe patterns, generated by a crack, lack of penetration, burn-through, changing of mechanical properties, etc.

Application of holographic non-destructive quality control of welded piping in vacuum, for example, in space, is most promising. The experiment on quality control in this case is performed in the following sequence.

After tube welding the astronaut takes a small-sized holographic device for quality control and mounts it on the tube in the weld zone being examined with the help of a simple clamp-holder (Figure 8). The small-sized laser source is located onboard the space station or in the casing of the holographic device. With the help of light guides the laser light is transmitted to a weld zone being examined. The weld interferogram is recorded and the image is transferred to the on-board computer monitor, which has a reference of the interference fringe pattern of a tubular sample stored in its memory. The computer compares the reference with

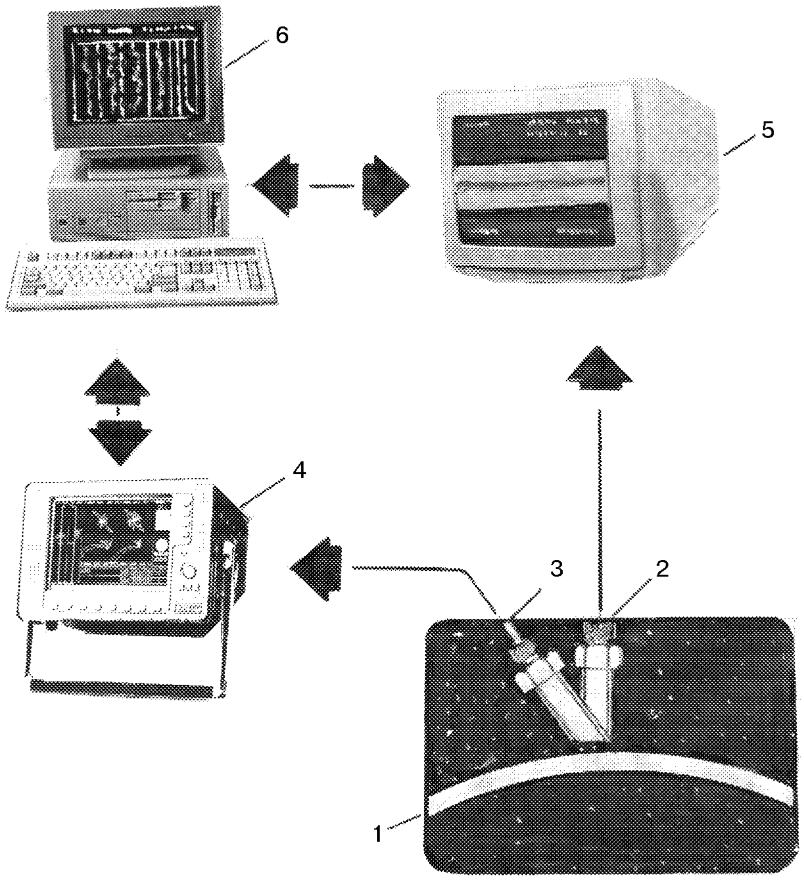


Fig. 9. Block-diagram of examination of welds in space using visual and eddy-current methods.

the interference pattern of the weld being examined. In case of a defect the computer sends a command about the weld being defective, or confirms its quality. In addition, the generated information can also be sent to Earth.

The version of visual comparison of the reference on the monitor with the interferogram of the examined weld by the operator is also possible. This can be done without using the computer. It should be noted that there is no need in any special complicated training of the operators.

Preliminary experiments on non-destructive contactless holographic control of the quality of thin-walled welded structural elements demonstrated its high efficiency and reliability.

Visual and eddy-current methods can also be used for non-destructive control of orbital station elements in space.

The first method provides information about the appearance of the welded joint, while the second (eddy-current) method — about its internal structure.

The block diagram of control of welds for space vehicles is given in Figure 9.

A combined scanning sensor (2, 3) which includes optical 2 and eddy-current 3 transducers moves along the weld and near-weld zone. Information from this sensor is transmitted to the space vehicle cabin where eddy-current flaw detector 4, video camera 5 and computer 6 are located. After scanning along the weld, the information stored in the memory is visualized and analyzed in the space vehicle cabin. Each of these methods (visual and eddy-current) can be also used independently, but their combination provides more valid information on the quality of the metal structure. The information entered for processing allows determination of the size of the defect, its location and evaluation of the probable hazard. Control is performed in real time. The most hazardous defects are marked by sound or light signals and are to be subjected to more careful examination with a repeated scanning of the hazardous zone.

The eddy-current flaw detector, in addition to a linear scanning image on the screen, provides the mode of a two-dimensional imaging of defective regions. In this mode, the point on the screen, which represents the end of a vector of a complex output voltage of the transducer, describes complex closed trajectories during the transducer movement with respect to the object of examination. The trajectory is memorized for a time required for analysis, which is set by the operator. The phase characteristics of the signal are determined from the trajectory position in a complex plane, while the defect can be identified from the trajectory.

The computer memory stores coded information on the typical internal and external defects that allows the classification analysis of defects to be made from the recorded scanning signals.

«Transformable Shells» Experiment

WELDED METAL TRANSFORMABLE SHELLS

Paton B. E., Samilov V. M., Pilishenko I. S.

E. O. Paton Electric Welding Institute, NAS of Ukraine
11 Bozhenko Sr., Kyiv-150, 03680 Ukraine
tel: (380) + 44 + 2273183, fax: (380) + 44 + 2680486

Progress in space science and technology, practical exploration of space, which has been started in the 60^s of the XX century, opened for the scientists and engineers the complicated, but challenging prospects of study and exploration of near-earth space and the nearest planets. Stations, which are equipped for an integrated study of the natural conditions, will enable the use of the resources of these planets for the benefit of mankind. The presence of scientific expeditions on the planets implies provision of comfortable conditions for work and rest of the crew. For this purpose, it is necessary to create living quarters, laboratories and production shops, stores, shelters, etc. Such constructions naturally have large volumes and their transportation from the Earth will be problematic, as there are contradictions between the required dimensions of structures and limited sizes of transport containers of rocket carriers.

Engineering thought has produced a number of approaches to overcome this contradiction, for example, folding of structures made from air-tight fabric and films, modular assembly, etc. The many-year practice showed that the use of metals is the most rational way to create space objects, but transformation of the overall constructions into compact packs is extremely difficult, the more so since

a b c

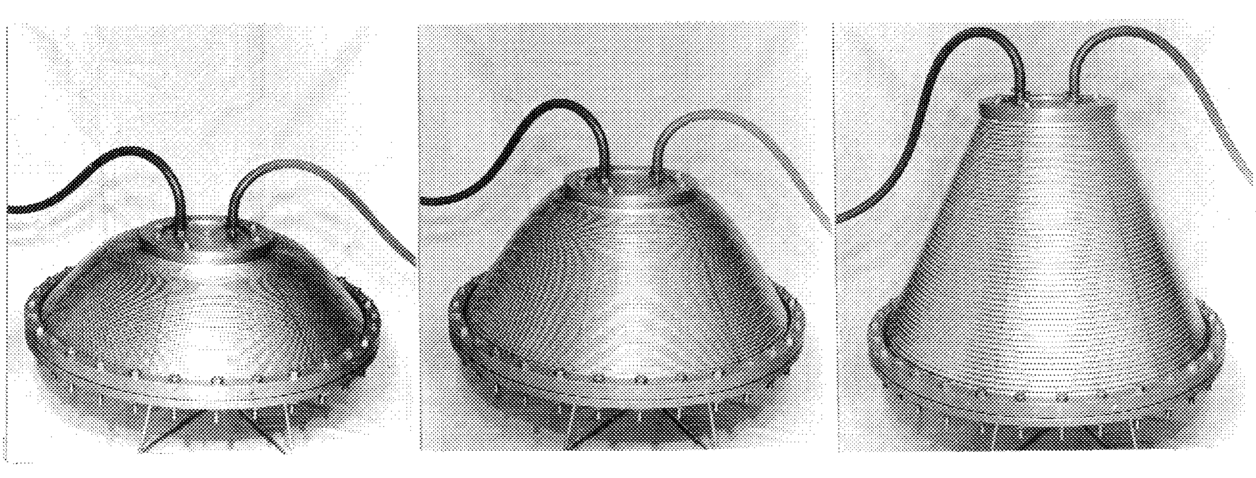


Fig. 10. Transformation of a corrugated disk into a conical shell at the initial (a), intermediate (b) and final (c) phases

the metal shell structures, which are to be transformed, should meet the following requirements:

— complete readiness for operation;

— air-tightness;

— minimum possible dimensions for transportation;

— simplicity of mounting after delivery;

— transformation pressure should be on the level of operating pressure in service.

Theoretical and laboratory analysis allowed to make a selection from a large number of variants, namely, the concept which is the most readily adaptable to fabrication is the transformation of a conical surface into a corrugated disk with circular corrugations. A theoretical model of transformation of closed surfaces is based on the principles of the theory of isometric bending and mirror reflection. The use of these principles allows the height of the cone to be decreased in the process of transformation of the shape within a very wide range (from 10 to 40 times).

Research carried out at the E. O. Paton Electric Welding Institute resulted in a unique, yet simple technology of transforming real metal shells with a conical surface into a corrugated disk. Investigations were performed on shells of 0.1 to 0.3 mm wall thickness and 400 mm diameter, made of titanium alloy VT1-1 and stainless steel Kh18N10T. Testing demonstrated good repeatability of the shell shape transformation, simplicity of the required equipment and a comparatively low cost. Transformation of a corrugated disk into a conical shell is shown in Figure 10 (a, b and c).

Joining the required number of corrugated elements into a single structure, which acquires the necessary dimensions and volume after transformation, provides a construction of a specified configuration and architecture.

Figure 11 shows a model of a 400 mm diameter structure with 65 mm height in a transportation state and with 2000 mm height in the operational state.

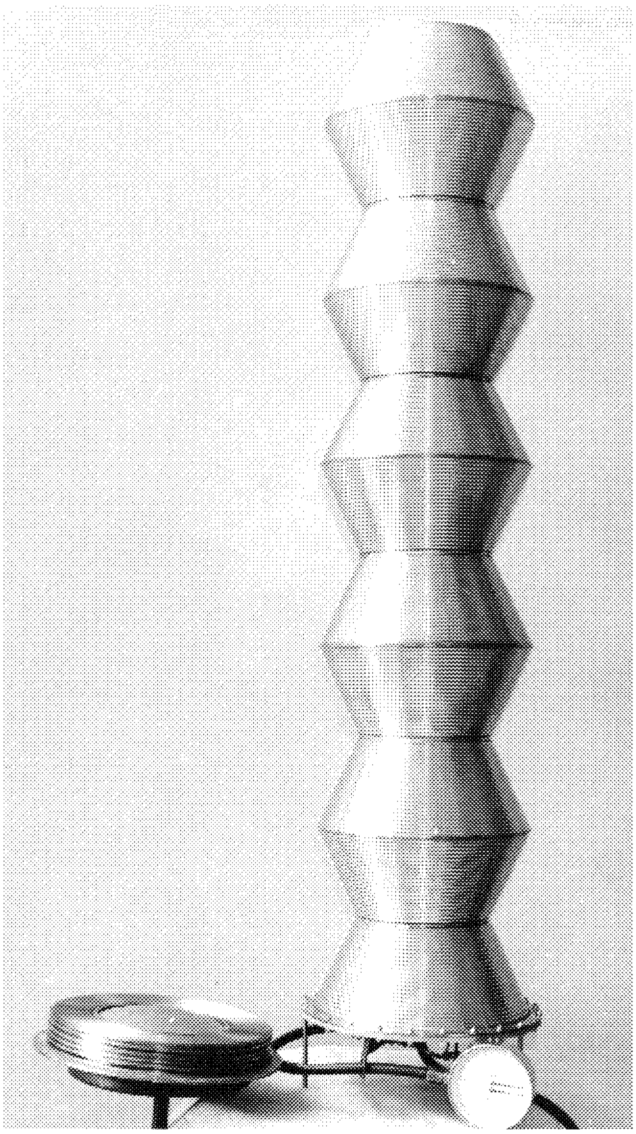


Fig. 11. Model of a 400 mm diameter structure in the transportation and operating states

The proposed structures allow manufacturing a wide range of space constructions, such as docking modules, modules for enlargement of the useful volume of the space vehicles and long-term stations, transition tunnels, multichannel rod aerials, rods for extending instrument modules, etc.

Designing a standardized module of transformable shell structures, which can be used as the basic one for creation of volumes of planetary stations, is also interesting in our opinion. The proposed structures can be used on the Earth for storage of liquid and bulky products, as water towers, fuel stores and granaries, etc. Within the scope of the project, it is intended to design and manufacture the transformable lock chamber and to perform an experiment on its deployment under the space conditions.

II.2. RESEARCH OF THE EARTH AND NEAR-EARTH SPACE

Litvinenko L. N.

Institute of Radio Astronomy, NAS of Ukraine
4 Chervonopraporna St., Kharkiv 61002 Ukraine
tel: (380) +572 +45 10 09, fax: (380) +44 +47 65 06, e-mail: lnl@ira.kharkov.ua

Introduction. For the present and the future there are, at least, three basic factors lending impetus to an orbital ISS-crew-aided research of near-Earth space:

a) planning of long-term operation of a manned orbital vehicle requires investigation and prediction of the influence of space factors on the functioning of the life support system, service lines, guidance, navigation systems, research complex, power supply, etc.;

b) operation of a manned vehicle is based on a long-term stay of numerous crew of cosmonauts and astronauts. Their functionability and psycho-visual condition are in many respects determined by the influence of space factors: by corpuscular and radiation activity of the Sun, magnetic field disturbance, etc.;

c) prospect of participation of numerous competent international teams of researchers in solving the problems of diagnostics of near-Earth space allowing performance of the sounding data analysis and interpretation directly on-board the ISS, that, in turn, opens possibilities for adaptation of experiments and development of a «Space Weather» system.

The proposed Ukrainian experiments concerning the diagnostics of the near-Earth space and Earth's surface are classified into the following 5 groups:

— contact diagnostics of the plasma and gaseous environment of the ISS;
— study of the Earth's upper atmosphere by the optical and millimeter-wave technique;
— study of the Earth's ionosphere;
— remote sounding of the surface and water area of Earth;
— active experiments in space and on the Earth's surface.

Analysis of the experiments allows us to propose a program of a permanently working laboratory of integrated near-Earth space research with active participation of a crew.

INVESTIGATION OF THE GASEOUS AND PLASMA ENVIRONMENT OF THE ISS BY MEANS OF CONTACT DIAGNOSTICS («Environment» Project)

Bass V. P.

Institute of Technical Mechanics, NAS of Ukraine — NSA of Ukraine
15 Leshko-Popel St., Dnipropetrovsk-5, 49600 Ukraine
tel: (380) +562 +47 25 88, fax: (380) +562 +47 34 13, e-mail: bass@pvv.dp.ua

Introduction. Interaction of space vehicles with plasma environment and solar radiation results in some effects which should be taken into account during the long-term operation of both the constructions of the ISS itself and of various electromagnetic systems of the station. Such effects include the following:

— polarisation of constructions;

— emission of a wide spectrum of the molecular constituents of structural materials due to bombardment by the solar corpuscular flow, as well as by flows of atmospheric gas and dust microparticles;

— appearance of glow in the ISS environment;

— development of perturbations of the electric and magnetic fields in the vicinity of the moving ISS and of the resultant plasma instability and a wide spectrum of heterogeneity;

— additional ionisation stipulated by chemical emissions of engine systems and by injection of charged particles, as well as by operation of radio transmission systems.

These phenomena call for an integrated approach to measurement and analysis of the basic parameters of gaseous and plasma environment of the station (concentration of particles, mass content, temperatures of electron and ion components, power spectra, effective scattering cross-sections, plasma potentials, pressure, electric and magnetic intensities, etc.).

Most of the above parameters could be measured by means of devices developed in Ukraine by the captive technology. In terms of sensitivity, the sensor devices made in Ukraine are on a par with the best world models and, in some cases, their performance is higher. The need for simultaneous measurements of the local and distant plasma parameters should be emphasised. Comparison of the parameters of the environment disturbed by the presence of the ISS with the natural background values, as well as with their spatial-temporal variations will permit solving technological and scientific problems of a long-term exploration of orbital stations.

«Environment» Experiment

STUDY OF ELECTROMAGNETIC ENVIRONMENT OF THE ISS

Korepanov V. E., Klimov S. I.

Lviv Center of the of Space Research Institute, NAS of Ukraine — NSA of Ukraine
5a Naukova St., Lviv-53 79601 Ukraine
tel/fax: (380) +322 +63 91 63, e-mail: vakor@isr. lviv.ua

Long-term operation of «Mir» OSS has revealed some effects connected with the heterogeneous distribution of charges on its surface and with the higher level of electromagnetic (EM) fields in its environment. A series of active experiments onboard the «Mir» and the STS-3 experiments onboard the Space Shuttle showed the existence of local wakes and turbulence, sometimes provoking the plasma heating and luminescence, etc. Due to non-homogeneous surface conductivity, the active processes onboard the station create local anomalous charges and high EM noises, which are dangerous both for the spaceborne equipment and human health. It is also important to localize the places with minimal noise/charge level along space stations for installation of scientific equipment.

The goal of the experiment is to ensure EM monitoring of the station environment, which will be necessary both for scientific research and for derivative control action. It is proposed to design automatic mini-buoys or nano-satellites with the fully autonomous and short-range telemetry. Various operational modes are envisaged, namely installation on the outer side of the station, free floating and tethered operation mode. The latter two mentioned modes offer the following advantage. It will be relatively easy to realize the extremely high EM sensor response onboard the nano-satellites that is not possible even using micro-satellites.

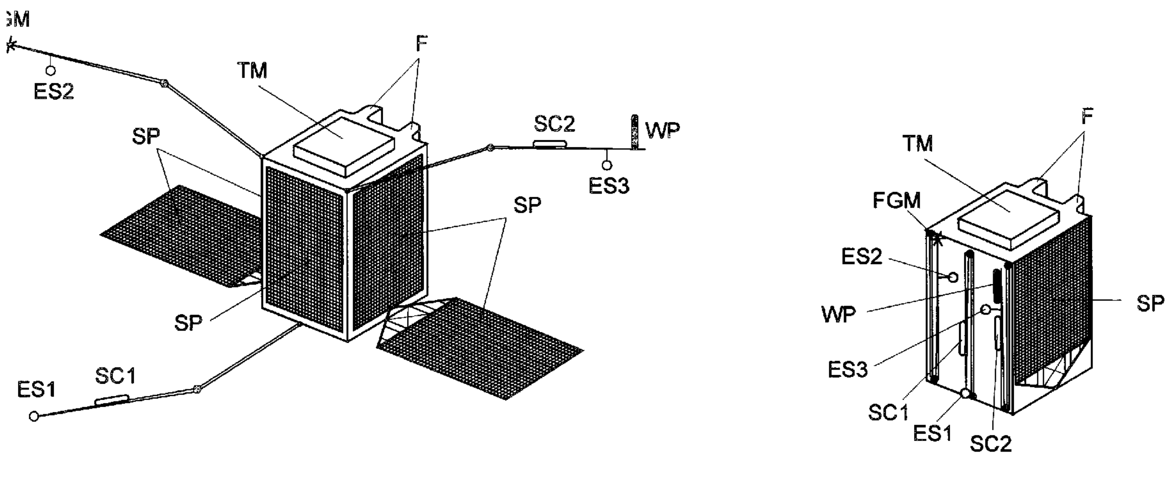
The reaction of non-conductive and semi-conductive surfaces of various structural materials to bombardment by space particles in the presence of highly non-homogeneous electric and magnetic fields and currents is not clear so far. Supposedly, these effects were the cause of the «Mir» cables insulation failure.

In addition to the technological purposes of the proposed experiment, it is very important to complete monitoring of the electric and magnetic fields in the ionosphere for solving some of the geophysical problems. Among such problems is investigation of plasma-wave processes developing as a result of solar-magnetosphere and atmosphere-ionosphere connections that is important for space weather study and forecast. A substantial factor also is to provide a long-term monitoring of these processes at least during one cycle of solar activity (11 years).

The methodology of electric and magnetic measurements onboard a spacecraft was developed intensively at the early stages of space research (see, for example, [1]). Some theoretical problems, however, concerning the interaction of large space constructions and space plasma, and the influence of active experiments are still to be studied. A break-through in our understanding can be achieved by the regular long-term investigation of these processes both in space and on the ground during at least one cycle of solar activity. The project proposed will allow making a significant contribution to such a study. The ISS crew during their extra-vehicular activity could search for locations-indicators of anomalous behavior and locations with a minimal level of interference for monitoring system installation.

We propose a new concept of space buoys or nano-satellites. This concept includes development of space-saving and fully autonomous measuring systems (up to 10 kg). Each of the systems will have the following units (Fig. 1, a): flux-gate magnetometer (FGM); search-coil magnetometers (SC); wave probe; electric sensors (ES); self-contained power supply (solar panels (SP) and inner long-term battery); short-range telemetry (TM); manually deployed booms and solar panels; one-side fixing arm (F).

Such a nano-satellite will take little space in the stowed position (Fig. 1, b) and could be easily delivered to the ISS as a piggyback cargo. Using the fixing arm (F), a nano-satellite can be con-



a) Deployed b) Stowed

Fig. 1. Sketch of a nano-satellite («Environment» experiment)

Table 1. Scientific payload proposed for the «Environment» experiment.

Device	Measurement	Weight
Wave probe WZ	Electric current density J: Frequency range 0.1 Hz ... 40 kHz, Noise 10^{-12} A/cm^{2}Hz$^{1/2}$ Magnetic field B: Frequency range 0.1 Hz ... 40 kHz Noise 10^{-13} T/Hz$^{1/2}$ Electric potential φ: Frequency range 0.1 Hz ... 40 kHz Noise 10^{-6} V/Hz$^{1/2}$	240 g
Electric probe ES	Electric field E: Frequency range 0.1 Hz ... 200 kHz Noise 10^{-6} V/Hz$^{1/2}$	120 g
Flux-gate magnetometer FGM	Frequency range DC — 20 Hz Noise 10^{-11} T	36 g
Search-coil magnetometer SC	Frequency range 10 Hz ... 200 kHz Noise 10^{-14} T/Hz$^{1/2}$	110 g

veniently placed in any location onboard the ISS by the astronaut. The nano-satellite booms should be manually deployed and the side (SP) should be oriented properly by the operator. The operation of a nano-satellite will be controlled by the ISS control system using short-range telemetry (TM). A set of such nano-satellites placed along and across the ISS will reproduce a spatial structure of the ISS electromagnetic environment and will allow localizing anomalous areas for further monitoring.

The nano-satellite design is a miniaturized copy of a micro-satellite structure [2]. Moreover, it will be simplified because no orientation system or automatic booms deployment system is needed. A special scientific payload will be manufactured (wave and electric probes, flux-gate and search-coil magnetometers). The main parameters of the scientific payload are given in Table 1. It should be noted that a wide frequency and dynamic range of measurements of the electromagnetic parameters ensures integration of the problems of local diagnostics and remote sensing. Short-range telemetry will be developed by the same principles as the already existing systems. The simplest embodiment seems to be based on the cellular phone technology. To avoid any additional electromagnetic interference, it is very attractive to apply the principles of infrared communication systems for development of the short-range telemetry. Such a possibility was already studied by the RSC «Energiya».

Use of such space-saving and cost-efficient nano-satellites is highly promising. It is subsequently planned to complement nano-satellites by the stellar imager and to use nano-satellites in the tethered or free-floating mode. It would enable the structure of electromagnetic environment of space stations, as well as the micro-formations in ionosphere, to be closely monitored.

References

1. Soprunyuk P. M., Klimov S. I., Korepanov V. E. Electric fields in space plasma. — Kyiv: Naukova dumka, 1994.—190 p. (in Russian).
2. Gladilin V., Korepanov V. Small satellites for Earth Observation // Digest of the Int. Academy of Astronautics.—1996.—Nov. 4–8.—P. 437—440.

«Aeros» Experiment

PHYSICAL AND AERONOMICAL EXPERIMENTS ABOARD THE ISS

Bass V. P.

Institute of Technical Mechanics, NAS of Ukraine — NSA of Ukraine
15 Leshko-Popel St., Dnipropetrovsk-5, 49600 Ukraine
tel: (380) +562 +47 25 88, fax: (380) +562 +47 34 13, e-mail: itm@csaitm.unity.dp.ua

The purpose of the «Aeros» experiment is to conduct a series of basic physical and aeronomical experiments on study of gas and plasma environment of the ISS by means of space-borne mass-spectrometric (MS), spectrophotometric (SP) and other measuring instruments [3]. The main objectives of these experiments are as follows:

— study of effective cross-sections of scattering of the atoms and molecules of various gases in the multi-component free stream of the Earth's upper atmosphere;

— study of the mechanisms of the ISS glow and of its influence on the spacecraft systems operation;

— study of variations of the molecular content of the upper atmosphere during the maximum of solar activity;

— study of physical processes in the upper atmosphere and ionosphere to reveal the factors, which could be messengers of earthquakes and of other cataclysms.

Numerous theoretical and experimental results on studying the short-range intermolecular forces were accumulated over the past three decades. The principal results of measurement of the scattering cross-sections were obtained in experiments with high-energy beams ($E \approx 1$ KeV) in accelerators. The medium energy region ($E \approx 10$ eV), which is responsible for the interaction of the spacecraft with the atmospheric free stream, is not fully studied, whereas most of the theoretical and applied problems of rarefied gases kinetics require accurate data on potentials of intermolecular forces exactly in this energy region. The problem of formation of a proper external atmosphere in the vicinity of a spacecraft at high altitudes could be classified among this kind of problems [2].

Collision processes are largely responsible for the luminescence in the Earth's atmosphere and above the spacecraft surface in the shadow parts of the orbit. There is convincing data from satellite experiments on anomalous luminescence of the atmosphere in various wave ranges, which precede the earthquakes. The total seismicity of Earth, as well as the seismicity of its individual regions depends on 11-year cycle of solar activity. The frequency of the most powerful earthquakes (magnitude > 7.5) is increased in the maximum of the cycle, while the periods of their occurrence are connected with the active processes in the Sun.

Spacecraft glow gives rise to adverse effects on space-borne systems of optical sensors. Just the first steps are currently taken to provide a quantitative description of these phenomena [5].

Properties of rarefied gas of the upper atmosphere are defined by the solar energy transfer through the interrelated «magnetosphere — thermosphere — lower atmosphere» system. This circumstance is responsible for the complexity and inadequacy of analysis of the available experimental data. Therefore, further space experiments are needed to revise theoretical concepts of the nature of physical-chemical processes in the upper atmosphere. Even the most adequate models of the upper atmosphere developed abroad and in our country (MSIS-77, CIRA-72-78-86, DTM*, AEROS, GOST-74*) are still far from the optimal description of variations in the content and density of the upper atmosphere. In particular, it concerns the conditions of the high solar and geomagnetic activities, as these models have been developed with use of the data from the American «Atmospheric-Explorer» program conducted in 1973-1990 years (minimum of solar activity). The best currently available models are approximately equally valid and differ by the value of relative error of about 20-30 %. However, the error of the models can reach 50-100 %, when sporadic disturbances are arising in the atmosphere (solar flares, geomagnetic storms).

The first experiments onboard the ISS will be performed during the period of maximum of solar activity (2001-2002 yrs). So, there is a unique opportunity to study also the solar-terrestrial links under the extreme conditions of the active Sun.

Conception and methods of measurement. The following algorithm is proposed to determine the effective scattering cross-sections and parameters of the station glow:

— a controlled source of working gases is installed onboard the ISS (the parameters of the flow from this source should be known with high accuracy);

— the selected working gases should be those, which are absent in the upper atmosphere and which have essentially different molecular weights, for instance, Ne, Kr, Xe;

— a sensitive MS device is mounted onboard the ISS, which registers both the flows of atmospheric components at a given altitude and the re-entered flows of injected gas which is scattered on the multi-component free stream;

— a SP device is also mounted onboard the ISS, which registers the radiation from the region of the station glow;

— the sought cross-sections from the selected model of intermolecular interaction and matching photometric characteristics will be determined by on-board measurements and by the results of numerical simulation of this experiment to obtain the desired apparatus functions.

We have extensive experience of laboratory measurements of the total cross-sections for scattering of inert gases in the region of relative energies of interaction of about 7-17 eV [1] as well as verified algorithms of mathematical simulation of the flows of rarefied gas [4]. It will enable several procedures to be proposed for determination of cross-sections for scattering of gaseous particles in the full-scale experiment at the altitude of 200-500 km [3].

The experiment will be conducted with application of the instrumentation developed at the Physics and Engineering Institute for Low Temperatures of

* Cyrillic abbreviator of name.

the NAS of Ukraine (Fig. 2). This kind of instrumentation has been used in experiments onboard the «Kosmos-1643» and «Kosmos-2007» satellites. An integrated laboratory study of the following parameters should be performed before setting up the proposed experiment in the URM:

— response angle coefficients of space-borne instrumentation at interaction with a running gaseous flow with the energy of 7-17 eV against the background of intensive UV radiation; calibration of instrumentation;

— parameters of outgassing of a full-scale model of a spherical shell (r = 0.3 ... 0.4 m) made of a porous material;

— parameters of the atmosphere both inside of a spherical shell volume and in its vicinity for the rate of the flow levels of the known gases (Ne, Ar, Kr, Xe, etc.);

— parameters of permeability of a spherical shell and evaluation of stability of these parameters.

The dynamic calibration of instrumentation will be completed using the supersonic Vacuum Aerodynamic Plant (VAP-2M) and a cryogenic pumping down system. The VAP-2M belongs to the Institute of Technical Mechanics of the NAS and NSA of Ukraine.

References

1. Abramovskaya M. G., Bass V. P., Petrov O. V. Definition of integral cross-sections for scattering atoms and molecules. — Patent N 1584583, 04/28/1990.
2. Bass V. P. Gas-dynamic aspects of formation of the external atmosphere of spacecraft moving in the Earth upper atmosphere // EAS observations. — M.: Astrosovet AS USSR, 1986.—N 24. (in Russian).
3. Bass V. P. // Tech. Mechanics.—1999.—**1**.
4. Bass V. P., Brazinsky V. I. // Zh. Vych. Mat. & Mat. Fiz.—1988.—**28**, N 7.
5. Bass V. P., Brazinsky V. I., Zabluda S. M., Fridlender O. G. // Tech. Mechanics.—1998.—**8**.

«Diagnostics» Experiment

DIAGNOSTICS, MONITORING, AND STUDY OF A SET OF PARAMETERS OF THE IONOSPHERIC PLASMA AND ENVIRONMENT NEAR THE ISS

Shuvalov V. O.

Institute of Technical Mechanics, NAS of Ukraine — NSA of Ukraine
15 Leshko-Popel St., Dnipropetrovsk-5, 49600 Ukraine
tel: (380) +562 +47 24 88, fax: (380) + 562 +47 34 13, e-mail: itm@meh.vidr.dp.ua

The ionospheric plasma is highly sensitive to the influence of external sources of solar, space, technogenic, and anthropogenic origin. The ionosphere responds to the solar and seismic activity, cyclones, magnetic storms, power explosions, volcanic activity, pollution of the troposphere, as well as active experiments during launches and flights of rockets and satellites. This is manifested as the periodical and non-periodical fluctuations of the main kinetic parameters of the ionospheric plasma, namely concentration of charged and neutral particles, pressure and degree of ionization, temperature of charged and neutral particles, electric and magnetic field strengths, energy spectrum of charged components, plasma potential.

The purpose of the experiment is to monitor and to study the ionospheric plasma by the contact methods for solving the inverse task, namely, to localize the sources of natural cataclysms by identifying the fluctuations of the main plasma kinetic parameters. We are also planning to develop methods and models of ecological and anthropogenic monitoring and forecasting.

The considered problem has two components. The first one is connected with implementation of the direct contact plasma diagnostics in the F_2-region of the ionosphere. The second component is connected with such items as interpretation of the measurement results, establishment of interconnection of periodic and non-periodic fluctuations of the ionospheric plasma parameters with spatial-temporal localization of the sources of external effects, as well as identifying their characteristic features and origin. The spatial-temporal synchronism of the external influence, event, and measurement can be ensured only in a manned spacecraft.

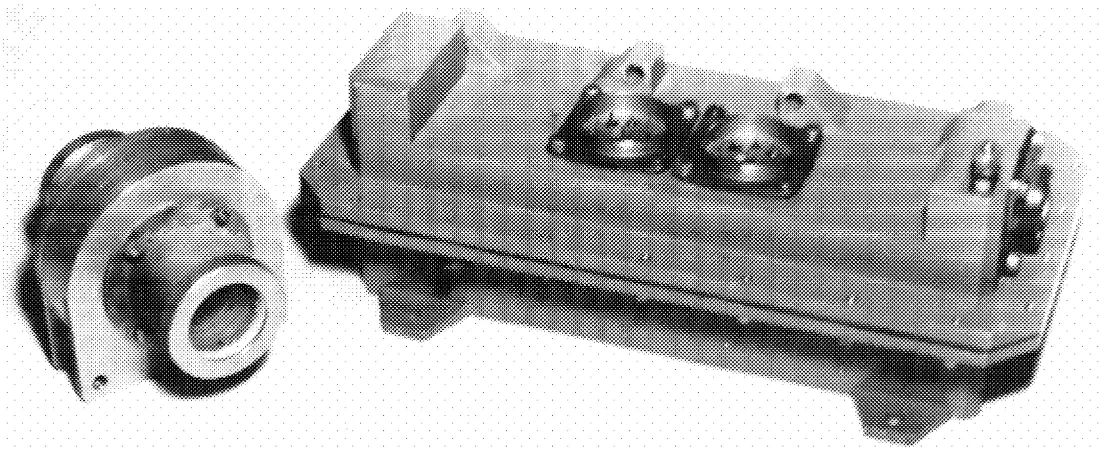


Fig. 3. «BMC» unit (sensor is shown on the left; modules for control, analysis, and processing of the data are on the right)

The experiment proposed will be realized with application of the new «BMC» unit (block for measurement and control). The operating characteristics of this unit are the best suitable to measure the above parameters of low-density ionospheric plasma in a wide range. The «BMC» combines the properties of the inverse-magnetron converter of the transit type and two multi-electrode probe energy-analyzers (ion and electron). The «BMC» unit consists of the sensor, modules for control, analysis, and processing of the data (see Fig. 3). The sensor dimensions are $D = 0.08$ m, $L = 0.1$ m, and its mass is equal to $M = = 0.8$ Kg. The experiment will be completed with the use of two sensors. They are installed on the boom of a modifiable length, which provides two fixed positions (at the distance $l_1 = = 1.0$ m and $l_2 = 10 \ldots 15$ m from the station surface). The parameters of the ISS own external atmosphere are measured in the first position and the parameters of the non-disturbed ionospheric plasma — in the second position. To minimize the influence of ionospheric plasma disturbances, the boom with sensors should be installed on the front (exposed to the «wind») side of the ISS. The symmetry axis of one sensor is oriented along the ISS movement, and the symmetry axis of the other sensor is perpendicular to the velocity vector of the plasma flow. The experiment is practically fully automated. The device offers the advantages of design simplicity, small power consumption, higher reliability, and resistance to the influence of reactive and toxic components.

During 1987-1992 a simplified variant of the unit proposed, namely the inverse-magnetron converter, was operated in the «Kvant» module of the «Mir» station [1]. The ion multi-electrode probe was used in the «Alfa-2» complex on the tail and auroral sondes [2] for measurement of the local parameters and study of the spatial plasma distribution.

References

1. Guzhva E. G., Nikitskii V. P., Shuvalov V. A., et al. Results of the study of the external atmosphere in the vicinity of «Mir» orbital complex // Proc. of the X-th All-Union Conf. «Dynamics of rarefied gases». — M, 1989.—P. 198. (in Russian).
2. Bezrukih V. V., et al. Study of the low-energy plasma in the Earth's magnetosphere with the tail and auroral sondes // Kosmich. Issled.—1998.—**36**, N 1.—P. 33—41. (in Russian).

Division 2

RESEARCH OF THE EARTH'S UPPER ATMOSPHERE BY THE OPTICAL AND MILLIMETER-WAVE TECHNIQUE («Inframon» project)

Morozhenko O. V.

Main Astronomical Observatory, NAS of Ukraine
Golosiiv Kyiv-22, 03650 Ukraine
tel: (380) + 44 +266 47 61, fax: (380) +44 +266 21 47, e-mail: morozhenko@mao.kiev.ua

Introduction. The project deals with continuous and long-term monitoring of the events occurring on the Earth's surface, in the atmosphere and in the near-Earth space. The apparatus proposed by the authors can be incorporated into a common measuring complex allowing research to be completed simultaneously in the high-frequency range of the electromagnetic wave spectrum. Moreover, an integrated method of the passive control (without any influence on the studied object) is used, namely the radiometry of thermal radiation.

«BIT» Experiment

ON-BOARD INFRARED TELESCOPE

Shulman L. M.

Main Astronomical Observatory, NAS of Ukraine
Golosiiv Kyiv-22 03650 Ukraine
tel: (380) + 44 + 266 47 69, fax: (380) + 44 + 266 21 47, e-mail: shulman@mao.kiev.ua

Melenevsky Yu. A.

Special Research and Development Bureau for Cryogenic Technologies of the ILTPE, NAS of Ukraine
47 Lenin Ave., Kharkiv 61164 Ukraine
Tel/fax: (380) + 572 +32 22 93, e-mail: sktb@ilt.kharkov.ua

The principal idea of the «BIT» experiment is to determine the temperature distribution over the field of view with the spatial and temperature resolution that is good enough to localise the sources of any toxic or harmful outbursts (such as smokes and hot gases), and to study their vertical distribution and global migration. Taking into consideration the absence of precise stabilisation of the ISS, the instrumentation of the on-Board Infrared Telescope (BIT) is based on a highly sensitive matrix image sensor that, in contrast to any scanner, is able to produce an image with a short enough exposition to avoid the blurring caused by space instability of the ISS. Both the temperature and the emission distribution within the field of view can be calculated, if a possibility is provided to compare two images obtained almost simultaneously in the different spectral ranges.

The main objective is to monitor the terrestrial atmosphere and near space. The monitoring should be carried out with a set of instrumentation attached to an on-board infrared telescope for imaging in one or more spectral bands in the range from 1 to 5 μm. The experiment is oriented to the problems of ecology and investigation of the Earth's atmosphere, in order to detect the effects of industrial and natural factors on the environment and climate.

On-board infrared telescope consists of the following units:

— Full steering platform for pointing the telescope onto the object.

— Two mirror telescopes with an aperture of at least 300 mm.

— Beam splitter to divide the input radiation flux between the visible and infrared cameras.

— TV monitor.

— Interface device to link the telescope to the on-board computer.

The Special Research and Development Bureau for Cryogenic Technologies (SR&DBCT) of the ILTPE of the NASU has experience in development of an on-board infrared telescope and highly sensitive infrared sensors, as well as cryogenic equipment. A brass board model of a cryogenic on-board infrared telescope was made in 1980s. It is important to note that SR&DBCT ILTPE possesses all the necessary equipment and technology to test such an instrumentation including outer space conditions simulators. This Research and Development Bureau is the principal manufacturer of the experimental sample of the telescope.

Three operational modes are envisaged:

— the passive mode, when the optical axis of the telescope is permanently directed to the chosen point, e. g. to the limb of the Earth, and images are obtained by a pre-set program;

— the automatic mode, when a sequential pointing program to a programmed list of co-ordinates is running;

— the manual control mode, when the cosmonaut points the telescope manually.

Since the ISS is to be visited by astronauts time after time, there is a possibility to repair the telescope and prolong its cryogenic resource. Therefore, the duration of the experiment is limited only by the lifetime of the ISS itself.

The team that has set up the experiment will own the raw experimental data. The raw data, i. e., the brightness distribution in different parts of the spectrum, need rather complicated professional processing to derive the final results such as detection of the sources of ecological damage, as well as some geophysical information, where the data on global climate phenomena are of a great importance. The final result includes the co-ordinates of the sources of ecological damage together with quantitative estimates of this damage parameters. The potential users of these data are as follows: meteorology, ecological services, the industries that create environmental pollution, and all the authorities concerned.

The project is open to any international co-operation. At present, co-operation with the Russian manufacturers of infrared image sensors has been arranged.

«Climate» Experiment

INFRARED MONITORING OF THE EARTH'S ATMOSPHERE

Morozhenko O. V.

Main Astronomical Observatory of the NAS of Ukraine
Golosiiv Kyiv-22, 03650 Ukraine
tel: (380) + 44 + 266 47 61, fax: (380) + 44 + 266 21 47, e-mail: morozhenko@mao.kiev.ua

Study of the influence of anthropogenic activity of humanity and natural harmful factors on the Earth's atmosphere is an urgent task to understand the causes of variations of the ozone layer, and to construct a model of the thermal state of the atmosphere, as well as to evaluate the water resources in the atmosphere.

The main purpose of the experiment is to monitor gaseous and aerosol pollution of the Earth's atmosphere and their vertical structure and temperature distribution. To accomplish this, we intend to use the absorption spectra of the Earth's atmosphere in the thermal region of the spectrum and spectral polarimetric properties of backscattered light in the spectral range of 200 — 350 nm. The data on the intensity of absorption bands of about 20 gaseous components of the Earth's atmosphere, as well as the parameters of polarization properties and particle size distribution of stratospheric aerosol at the altitudes over 30 km will be obtained.

To meet these goals, we propose placing two observation complexes onboard the ISS. The first one is intended to monitor the composition of the Earth's atmosphere on the global scale and the aerosol physical properties at the altitudes over 30 km. It consists of two Fourier-spectrometers

(λ = 1 — 5 μm; λ = 4 — 11 μm) with the spectral resolution of about 2 cm^{-2} and 1:1 illumination, and a spectropolarimeter (λ = 200 — 400 nm) with the spectral resolution of about 5 nm. This complex is designed to measure the heat spectrum of Earth and solar radiation reflected diffusely by the Earth's atmosphere. The second complex consists also of two Fourier-spectrometers with the same parameters but with illumination of about (1/10)—(1/20). It will be used for study of vertical distributions of temperature, molecule concentration of various gases and aerosols, as well as of their day-night variation. The solar and lunar radiation against the Earth's atmosphere will be observed with the step of 1 — 2 km at different attitudes above the Earth's limb.

Observations should be carried out one or two times per month on round-the-clock basis in the automated mode to reveal the seasonal and 24-hourly effects.

The results will be used to model the heat regime of the atmosphere and to establish the causes of the ozonosphere variations, to construct the maps of ecological state of various regions of Earth and to estimate the water resources, etc.

«Vertical» Experiment

SPACE-BORNE MILLIMETRE-WAVE NADIR OZONE SOUNDER (SMNOS)

Eru I. I., Myshenko V. V., Shulga V. M.

Institute of Radio Astronomy, NAS of Ukraine
4 Chervonopraporna St., Kharkiv 61002 Ukraine
tel: (380) + 572 + 44 85 91, fax: (380) + 572 + 47 65 06, e-mail:shulga@rian.ira.kharkov.ua

The principal method to study the atmospheric composition is the molecular spectroscopy of constituent gases. The majority of intense rotational transitions of these gases fall into the millimetre and sub-millimetre wave bands [1].

The purpose of the experiment is to develop a space-borne millimetre-wave spectral complex (SMNOS) for monitoring the global distribution of the total content of the atmospheric ozone. A characteristic feature of the SMNOS complex is its capability to monitor the atmospheric ozone distribution from a satellite orbit not along the line tangent to the atmosphere but vertically down (in the nadir direction). Such an approach eliminated the need for a large antenna system, which would have to meet a number of strict requirements to the design of the complex.

The sounder input is a scalar horn antenna with the diameter of 10 cm. The stable local oscillator will operate near the frequency of 142 GHz with the output power of 10 mW and the frequency stability of 10^{-7}. The uncooled balanced diode mixer with beam leads combines RF signal from the antenna and LO signal to give IF signal at the frequency of 1.5 GHz. The loss by insertion is about 6.1—6.6 dB. The gain of the uncooled low-noise IF amplifier is equal to 60 dB and its noise temperature is 50 K. The noise temperature of this heterodyne down converter is equal to 700 K (DSB). The complex is connected with the recording device, which is capable of operating in a wide frequency range (bandwidth of 500 MHz), as well as in the multi-channel filterbank mode (10 channels, each with 100 kHz bandwidth). The difference of optical thickness in the spectral channels and the wide-band (reference) channel is used to detect the spectral ozone line against the background of the ascending thermal radiation from the Earth's surface and the atmosphere.

The complex operation is carried out by periodical calibration of its sensitivity against two blackbody radiators (300 K and 100 K). The entire SMNOS complex is thermostated with the accuracy of 1 K. The on-board computer will control its operation.

Analysis shows that the sensitivity of the SMNOS complex can be sufficient for detection of the ozone contained in the atmosphere at the level of 10^{15} mol·cm^{-2}. This is two orders of magnitude lower than the average level of the full ozone content in the Earth's atmosphere.

Reference

1. A Parrish «Millimeter-wave Environment Remote Sensing of Earth's Atmosphere» // Microwave J.—1992.—**35**, N 12.—P. 24—57.

«Modul» Experiment

CONCEPT OF A MULTICHANNEL SYSTEM INSTALLED AT THE ISS FOR STUDY OF THE EARTH'S SURFACE AND ATMOSPHERE

Kuz'kov V. P., Eremenko N. A.

Main Astronomical Observatory, NAS of Ukraine
Golosiiv Kiev-127, 03680 Ukraine
Tel: (380) +44 +266 47 69, fax; (380) +44 +266 21 47, e-mail: kuzkov@mao.kiev.ua

Khymenko O. A., Kugel V. I.

State Research Center «Fonon»
37 Peremoga Ave., Kiev 04056 Ukraine
tel: (380) +44 +2463811, fax: (380) + 44 +2191970, e-mail: khymenko@fonon.kiev.ua

Yatsenko V. A.

Space Research Institute, NAS of Ukraine — NSA of Ukraine
40 Akademik Glushkov Ave., Kyiv 03022 Ukraine
Tel: (380) +44 +2663146, e—mail: yat@d310.icyb.kiev.ua

The concept of a multichannel system for the synchronized observations in the IR, sub-mm and mm wavelengths is developed to carry out investigations of the Earth's surface, atmosphere and ionosphere. The system envisages both scanning the atmosphere up and down from 15 up to 120 km per orbit and long view pointing towards an astronomical object.

The multichannel system will be connected with the Cassegrain type telescope and scanning system. The optical axis of the telescope will be oriented to the velocity vector. The mirrors will be made of a lightweight metal. The field of vision of the scanning mirror will be equal to 60°; the micro scanning mode will be also possible. The rotation system will provide 270°-slowing in the plane, which is perpendicular to the axis of the telescope. The fast scanning system will ensure stereoscopy observations and integration of signals from various points of the Earth's surface. The rotation system will also provide telescope orientation for atmospheric and space research, and will make pointing available on the ground stations for communication experiments [1]. We are planning to make four instrumental modules, assuming their modification for other tasks. The experiment pursues the following objectives.

Study of the Earth's surface

- Scanning the Earth's surface in the visible and near IR range by photometer and spectrophotometer with the resolution of 15 — 20 m to carry out water control, land and surface temperature measurements, fire and environmental monitoring, estimation of agricultural crop, as well as gas-field and oil-field prognostication.

Study of the Earth's atmosphere and ionosphere

- Measuring the temperature of the atmosphere to construct the distribution of the atmospheric gravity waves connected with the processes on the Earth's surface.
- Measuring the content of CO and CO_2 molecules in the atmosphere for estimation of the «hothouse» effect.
- Measuring the stratospheric ozone to study the «ozone hole» region and its influence on the processes in the ionosphere.
- Studying the mechanisms which provide coupling between the upper and lower atmosphere; studying the influence of the processes on the ground and in the lower atmosphere on the processes in the upper atmosphere and ionosphere.
- Investigation of the influence of turbulent transport and corpuscular radiation on the processes in the atmosphere and ionosphere.

Astronomy

- Detailed study of the physics and chemistry of comets, planets, bright stars, interstellar molecular clouds, namely the following classes of objects will be targets for observations:

— Comets: water outgassing, size of active regions, density of molecules in short-period and long-period comets.

— Planets: seasonal variations in the atmospheres of planets-giants.

— Detection of protostars: dynamics of circumstellar envelopes and interstellar extinction.

— Giant molecular clouds and nearby dark clouds: molecular distributions in comparison with those in the envelopes of stars.

To meet these objectives, the following instrumental basis will be developed.

Telescope

The diameter of prime mirror is equal to 400 mm with the f/D ratio of 15. The scale level in the focal plane will be equal to 1 mm = 35 arcsec with the equivalent focus of the telescope of 6000 mm. The actual field of vision of the telescope will be about 1°. Depending on the change of the orbit altitude of the ISS from 300 km to 450 km, the viewing spot on the Earth's surface will change from 5.2 km to 7.8 km in diameter. Use of 256 element 1D array of detectors in the focal plane will provide the surface resolution of 20 — 30 m in the IR band with subsequent improvement by the factor of 2 with the use of 512 element array. The visual CCD or CMOS camera with the guide small telescope will be used for trace recognition. Cooling of detectors in the focal plane of the telescope is envisaged to provide a sufficient sensitivity. Cryo-cooler will be used to cool the IR and sub-mm detectors and mixer of mm-band to the temperature of 70—90 K. Only the thermoelectric coolers can be used to cool the detectors for short wave IR band to the temperature of 200 K.

The optical system configuration [2]

The optical system configuration is shown in Fig. 4. The four optical channels are separated by dichroic elements. One of the variants of dichroic elements is the photolitography grating performed on the substrate.

IR channel.

We intend to use the following devices in the IR channel:

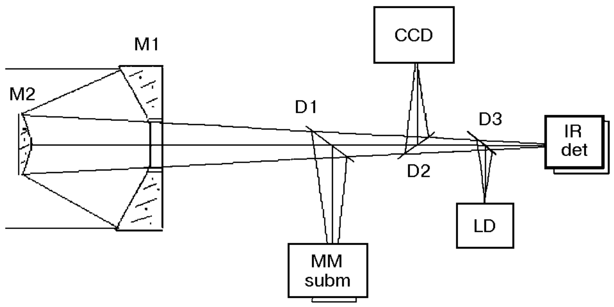


Figure 4. The schematic of optical channels: M1, M2 — mirrors of the telescope; D1, D2, D3 — dichroic elements; MM — millimeter channel; SUBMM — sub-millimeter channel; IR — infrared channel; LD — laser diode

— photometer-grating spectrophotometer for the spectral range of 1 — 2.5 μm with the spectral resolutions of 3 cm^{-1} in the spectrophotometer mode;

— photometer for the spectral range of 2.5 — 16 μm. HgCdTe 1D array with cooling to 77—100 K will be also used.

— spectrophotometer for the spectral range of 16 — 60 μm with scanning grating and 2×2 element YBaCuO superconducting bolometers at the temperature of 77 K;

— 256 or 512 element InGaAs 1D arrays for the spectral range of 1 — 2.5 μm with cooling to 77 — 200 K by the closed-cycle cooler and thermoelectric battery. With the field of vision of the telescope of 1° and the scanning surface width of 5 — 7.8 km, it will provide the surface resolution of up to 10 — 20 m.

Sub-mm channel

In the sub-mm channel we are planning to use a spectrophotometer for the spectral range of 60 — 120 μm with scanning grating and 2×2 element YBaCuO superconducting bolometers at the temperature of 77 K. The low temperature bolometer at the temperature of 4.2 — 30 K will be also applied. Epitaxial $YBa_2Cu_3O_{7-x}$ films with the thickness of 0.1 — 0.25 μm are formed by pulsed laser deposition technique on various substrates. However, the working points of the superconducting bolometer films are destabilised, because of the positive thermal feedback in these films. Working modes and procedures will be implemented to stabilise the working points of the superconducting bolometers, to provide a broader dynamic range, and to ensure the longer total duration for useful signals.

MM channel

The mm channel will be used for radiometer observations of the atmosphere and ionosphere in the spectral ranges of 118 — 119 GHz (O_2), 115 GHz (CO), and 96.2 — 101.7 GHz (O_3). The mm radiometer is equipped with a cooled Schottky diode mixer, phase-locked Gunn oscillator and IF amplifier. Cooling will be provided by the closed-cycle cooler to the temperature of 70 — 90 K or by the thermoelectric battery to 200 K. The HEMT transistor preamplifier allows the system temperature to be lowered to 300 K at 119 GHz. A digital autocorrelator (A-C) will be also used.

Control system software

A hybrid technology is being developed, which will be applied to perform on-board processing of the remote sensing data, algorithms and programs, as well as to pre-process results of the remote sensing in mm and IR ranges, and to apply purpose-oriented signal processors that can be incorporated into the observation system. Image processing methods based on the neural networks will be created [3].

References:

1. V. P. Kuz'kov, N. A. Eremenko, O. A. Khymenko, V. I. Kugel, V. A. Yatsenko. The Concept of a Multichannel System for Surface, Atmosphere Investigations of the Earth and Near Space Observations // Proc. Int. Symp. «Interball». — Kyiv, 2000.—P. 77—80.
2. Kuz'kov V. P., Kudelja A. M., Larkin S. Yu., Multichannel System for Infrared and MM Wave Synchronized Observations // Proc. ESA Symp. «The Far Infrared and Submillimetre Universe», Grenoble, France, 1997. — ESA SP-401.—P. 297—299.
3. Yatsenko V. A., Neurosensors for operation in water and in the atmosphere // Proc. European Symp. «Optics for Environmental and Public Safety», Munich Fairgrounds, Proc. 2508, Rep. 2505-22.

«Choven» Experiment

SCIENTIFIC HARDWARE AND METHODS FOR THE REMOTE MONITORING THE EARTH'S ATMOSPHERE AND SURFACE BY MILLIMETER WAVELENGTH RADIOMETRY

Ruzhentsev N. V., Churilov V. P.

Institute of Radio Astronomy, NAS of Ukraine
4 Chervonopraporna St., Kharkiv 61002 Ukraine
tel: (380) + 572 + 44 11 27, fax: (380) + 572 + 47 65 06, e-mail:vch@rian.ira.kharkov.ua

Further progress of such important research fields as climatology, meteorology, and environmental monitoring largely depends on understanding the regularities of the origin and phase redistribution of atmospheric moisture.

Practically approved radiophysical methods of remote monitoring of the Earth's surface and atmospheric parameters have led to a marked improvement in the efficiency of global and regional monitoring.

At the same time, the problem of negative influence of atmospheric inhomogeneity in the cases of Earth's surface (especially of the ground) sounding, as well as negative influence of the Earth's landscape irregularities during atmosphere monitoring, has not been solved yet. At present, the satellite systems operating in the mm-wavelengths radiometric channels (Cosmos-1610, Nimbus, SSM/I, TRMM, and others) are used.

The proposed «Choven» experiment will deal with development of hardware and methods to conduct remote monitoring of the Earth's surface and atmosphere, as well as with development of new methods for data interpretation. The project pursues the following objectives:

— ensuring higher sensitivity and improving equipment configuration as compared with, e. g., the best US-Japanese counterpart satellite «TRMM», which provides the tropical zone monitoring;

— covering other latitudes with monitoring;

— obtaining information, which is currently lacking for implementation of the ideas earlier set forth by the authors with respect to development of new methods and approaches in processing the remote sounding data [1, 2].

The scientific novelty of the planned space research underlies the significance of this experiment. It is based on development of new methods and approaches capable of achieving higher accuracy in interpretation of the meteorological parameters and improved quality of the Earth's surface radio images in mm-range of wavelengths. With respect to the applied science, the novelty of the experiment lies in continuous generation of current information on water content in the atmosphere, as well as on the phase composition of cloudy moisture using the regular and new methods developed during performance of this research project. These data are necessary for obtaining new climatic, meteorological and general physics estimates.

Facility. The first stage of the experiment envisages the use of a five-band radiometric scanning system operating as a part of the measuring equipment system of the Ukrainian Research Module onboard the ISS (boosted into a circular orbit at 350 km). The system will provide reception of thermal radiation in the ranges of 19 GHz, 22 GHz, 34 GHz, 55 GHz and 94 GHz in the two-polarization mode. The radiometers will operate with a common scanning antenna providing 800 km survey zone. The sensitivity of uncooled radiometers will be equal to 0.0150—0.030 K, and the space resolution of the antennas will be equal to 0.20°—0.90° (depending on the frequency range). The system power consumption will be 80 W, and its gross weight will be 50 kg.

The main results of the experiment will be as follows:

— development of a space-based measuring-computing complex and related software and methods, as well as evaluation of their reliability and performance, that will be important for fulfillment of some subsequent satellite (unmanned) projects;

— development of new data processing methods and obtaining new data for making climatic and meteorological estimates, as well as for acquiring general physical knowledge and development of new concepts;

— development of an access system for domestic and foreign users aimed at retrieving the primary and secondary data on remote monitoring of the Earth's atmosphere and surface;

— creation of an international network for sub-satellite support and participation in new international research projects;

— definition of the subsequent problems and ways for their further solution to meet and develop the experiment's goals.

References

1. Antonov A. V., Gerasimov Yu. M., Ruzhentsev N. V., Churilov V. P. About possibility of selection of parameters of frontal cloudy derivations // Radiophysics & Radio Astronomy.—2000.—5, N 2.—P. 131—136.
2. Ruzhentsev N. V., Antonov A. V., and Gerasimov Yu. M. About possibility of reduction of mutual influence of the Earth's surface and clouds to problem of atmosphere radiomapping // Proc. of URSI Commission F Int. Symp. «Climatic Parameters on Radio Waves Propagation (CLIMPARA'98)», 1998, Ottawa, Canada.—P. 216—219.

Division 3

RESEARCH OF THE EARTH'S IONOSPHERE («Space» Project)

Yampolski Yu. M.

Institute of Radio Astronomy, NAS of Ukraine
4 Chervonopraporna St., Kharkiv 61002 Ukraine
tel: (380) + 572 + 45 10 09, fax: (380) + 44 + 47 65 06, e-mail: yampol@rian.ira.kharkov.ua

«Space» Experiment

SPACE-BORNE IONOSPHERE RADIO SOUNDING BY SIGNALS OF THE GROUND-BASED HF AND VHF BROADCASTING STATIONS

Yampolski Yu. M.

Institute of Radio Astronomy, NAS of Ukraine
4 Chervonopraporna St., Kharkiv 61002 Ukraine
tel: (380) + 572 + 45 10 09, fax: (380) + 44 + 47 65 06, e-mail: yampol@rian.ira.kharkov.ua

The experiment proposes a new procedure of global near-Earth plasma monitoring with the method of radio sounding by signals of the ground-based HF and EHF broadcasting radio and television stations, received onboard the orbital space station (OSS). The possibility for tomographic ionosphere reconstruction with the proposed measurement procedure is analyzed, and the methods of determination of the local value of electron concentration in the OSS vicinity and the ionosphere penetration frequency are suggested.

During the almost 80 years of ionospheric research, the knowledge of physical processes in formation and dynamics of near-Earth plasma, development of the methods of ionosphere condition diagnostics and prediction, study of ionosphere influence on the performance of different radio systems, etc., have advanced considerably. However, sounding of the near space, i.e., the Earth's ionosphere and magnetosphere, still remains one of the most pressing problems in modern radio physics, for a number of reasons.

Firstly, the ionospheric channel is, probably, the most «overloaded» with signals of the ground-based and space-borne radio systems (long-haul radio, radar, navigation, telemetry and others). More and more detailed knowledge of the ionosphere parameters is needed to meet the ever-growing accuracy and operational reliability requirements for such systems, alongside with the problem of achieving their best performance.

Secondly, the upper atmosphere is the region where the basic interaction occurs between the radiation and corpuscular energy of the Sun and the gas envelope of the Earth. The energy fluxes of exospheric origin (solar flares and particle eruption) are hazardous for the control systems of space vehicles, frequently resulting in decoupling of space and ground radio communication channels, and are harmful for the human beings.

Thirdly, rapid progress of technology has led mankind to further expanding its environment, which now already covers the near space. Eventually, the man-made energy fluxes (powerful explosions, chemical deposits, space launches, electromagnetic pulses of powerful transmitters, industrial accidents, etc.) became comparable with those of natural origin (earthquakes, tsunami, typhoons, hurricanes, etc.), and in some cases even exceed the latter. The ionosphere, as a kind of delicate «pitchfork» responding to powerful energy release both of natural and artificial origin, can be used to reveal such processes when solving the problem of environmental monitoring and prediction of natural disasters.

Fourthly, the experiments proving the connection of the processes in the near space with the tropospheric and stratospheric meteorological processes, and phenomena occurring in the Sun and in the interplanetary medium, as well as on the surface and in depth of the Earth, open a prospect for creation of a self-consistent model — the concept of «space weather», being rapidly developed recently.

The project is aimed at development of a new procedure of global monitoring the near-Earth's plasma using the ISS-mounted HF and VHF receiver complex and applying the method of radio sounding with signals of the ground-based broadcasting and television stations. The tomographic methods are proposed for reconstruction of the ionosphere, which find ever-new applications in various areas of science and engineering. Despite rather detailed algorithms available for tomographic reconstruction of the ionosphere, they cannot be immediately incorporated into the suggested procedure. The point is that the conventional methods for measurement of linear integrals (total electron content (TEC) along the line of sight) imply arrangement of special transmitters onboard the space vehicle, while the transmitted signals are received on the Earth's surface.

Therefore, the experiment considers non-traditional methods for radio-tomographic reconstruction of the ionosphere by using the polarization patterns of the sounding signals. Apart from the tomographic reconstruction of the ionosphere, the intent is to use some other diagnostic capabilities of the said radio sounding procedure. It allows, for example, to fairly easily measure the local value of electron concentration in the space vehicle vicinity.

On-board equipment includes:

— HF and VHF antenna systems based on small-sized orthogonally polarized broadband dipoles;

— multi-range, coherent, program-driven receiver complex supplied with a panoramic scanner and multichannel sub-band recorders;

— fast analog digitizer;

— computing hardware coupled with the systems of data visualization, accumulation and transmission;

— applied software package ready for quick data processing, visualization and analysis onboard the ISS.

The above assumes close interaction with the ground-based diagnostic centers located in the space vehicle's sub-radar point. Application packages for data processing, storage and visualization will be developed on the basis of the built diagnostic algorithms. Computer simulation is suggested for testing and finalizing the method. Alongside with implementation of these items, analysis of a global net of transmitting centers will be done to select the radio sounding frequency, space and time ranges matching the ISS position in orbit. After manufacture of the prototype and flight models of a receiving-measuring complex, the ground observatory-based full-scale measurements will be performed.

The final result of the experiment is to manufacture an on-board unit with the appropriate software. Thus, due to a large number of HF and VHF stations, the suggested procedure of diagnostics will enable practically continuous global monitoring the near-Earth's plasma to be completed.

«Synthesis» Experiment

FEASIBILITY OF MAGNETOHYDRODYNAMIC INTERFEROMETRY IN THE MAGNETOSPHERE

Sinitsin V. G.

Institute of Radio Astronomy, NAS of Ukraine
4 Chervonopraporna St., Kharkiv 61002 Ukraine
tel: (380) + 572 + 451009, fax: (380) + 44 + 476506, e-mail: rai@ira.kharkov.ua

The transfer of energy and information between different parts of the «magnetosphere — ionosphere» system is largely determined by magnetohydrodynamic (MHD) waves, which are low frequency vibrations ($\omega < \Omega_i$) of the electric and magnetic fields, as well as by charged particle displacements and velocities in the interplanetary and terrestrial plasma. The conditions for MHD wave propagation through the geospace depend essentially on structural features of the magnetosphere and physical processes occurring in the magnetospheric/ionospheric plasma. This suggests a possibility of MHD diagnostics, i. e., determination of the propagation medium parameters from observed variations in the geomagnetic field. Measurement of the geomagnetic disturbances falling into the class of micropulsations ($\omega \approx 0.01$—5 Hz), allows estimation of the plasma density, energy and location of energetic particles, position of the magnetopause, cross-field conductivities of the lower ionosphere and other parameters of the geospace [1, 2]. The micropulsations can be observed with a variety of techniques, however most of these are indirect methods as long as MHD waves in the plasma are concerned. That is, ground-based observations of the ULF (ultra-low frequency) electric or magnetic field variations actually refer to components of the «secondary» electromagnetic response produced by the lower ionosphere under the impact of an incident MHD wave. The MHD waves proper are observable in or above the ionosphere, either with HF/VHF radars or satellite-borne magnetometers [3, 4]. Spatial characteristics of the magnetospheric pulsation signatures (localization near a certain magnetic shell, cross-phases for a few observation points, state of polarization and angular spectrum) can be studied only through multiple point measurements. (The ESA Project Cluster [5] envisaged direct simultaneous observations of geomagnetic field components at a few points in the magnetosphere with provisions for the temporal and spatial resolution, which enabled calling the facility a «wave telescope»). A MHD wave telescope implements the idea of spaced or interferometric reception at pairs of observation points. If an ensemble of such pairs is available, where the baselines differ in length and orientation, it should be possible to restore the amplitude and phase distribution of the wave field and angular spectrum of the signal received. Some of the baselines might not be real but rather synthesized, based on the orbital motion of the satellite carrier.

References

1. Guglielmi A. V. Geomagnetic pulsations of extramagnetospheric origin // Geomagnetism and upper atmospheric layers (Advances of Science and Technology, Vol. 7). — Moscow: VINITI, 1984.—P. 114—151 (in Russian).
2. Sinitsin V. G., Kelley M. C., Yampolski Y. M., et al. // J. Atm. Solar-Terrestr. Phys.—1999.—**61**.—P. 903—912.
3. Menk F. W. // Planet. Space Sci.—1992.—**40**, N 4.—P. 495—507.
4. Glassmeier K.-H., Motschmann U. and von Stei R. // Ann. Geophysicae.—1995.—**13**.—P. 76—83.
5. Neubauer F. M. and Glassmeier K.-H. // J. Geophys. Res.—1990.—**95A**.—P. 19115—19122.

«Reliability» Experiment

INFLUENCE OF LOW-FREQUENCY ATMOSPHERIC ELECTRICAL PROCESSES AND NEAR-SPACE ELECTROMAGNETIC SIGNALS ON THE CENTRAL NERVOUS SYSTEM FUNCTIONAL CONDITION OF A MAN MAINTAINING SPACE SYSTEMS

Sukhorukov V. I., Serbinenko I. A., Korsunov A. N., Bovt Yu. V., Zabrodina L. P.

Ukrainian Research Institute for Clinical and Experimental Neurology and Psychiatry:
46 Akademik Pavlov St., Kharkiv 61068 Ukraine
tel: (380) + 572 + 263146, fax: (380) + 44 + 263387, e-mail: postmaster@neuro. kharkov.ua

Litvinenko L. N., Budanov O. V., Lazebny B. V., Paznukhov V. E., Rokhman A. G., Aristov Yu. V.

4 Chervonopraporna St., Kharkiv 61002 Ukraine
tel: (380) + 572 + 451009, fax: (380) + 44 + 476506, e-mail: rai@ira.kharkov.ua

The natural low-frequency radiation corresponds to «a noise» initiating thunderstorm activity, Earth's emissions, etc. The noise spectrum always possesses the frequencies (8, 14, 20 and 26 Hz), which are attributed to the «Earth-ionosphere» resonance system. Thus, the man on Earth permanently exists in a species of resonator. There is no resonator influence in near space, as no resonances are observed in the spectrum of electromagnetic radiation, so in this case a man goes through a different electromagnetic environment.

There is no authentic information on the character of influence of natural low-frequency electromagnetic fields on the human organism. On the other hand, the knowledge of particular effects of low-frequency radiation on the central nervous system (CNS) functional condition of people with various individual-typical natures (defining their adaptation capability, etc.) is necessary. It will allow increasing the reliability of «man + space vehicle» and «man + ground control system», as well as other similar systems, since the final goal may be establishment of the criteria to select experts maintaining these systems and to develop methods for optimizing the adaptation process under the above-mentioned conditions.

Our experiment deals with definition of the character and dynamics of the CNS functional condition of people with various individual-typical natures under the effect of low-frequency electromagnetic radiation. To reach this purpose, we set the following objectives:

1) analysis of parameters of the electromagnetic environment;

2) development of an experimental model of parallel recording of parameters of the electromagnetic radiation and the CNS functional condition characteristics with further definition of their correlation;

3) working out the criteria defining the influence of the electromagnetic radiation on the men with various individual-typical nature (in particular on those possessing various adaptation capabilities).

Research methods:

The following equipment has been developed: medical and radio physical equipment, and processing complex. The medical equipment includes the following devices: electroencephalograph, reograph, cardiac contractions rate and arterial pressure recorders. The radio physical part of equipment includes low-frequency receivers, calibration units, computer complex for the data input.

The fulfillment of the «Reliability» experiment envisages the following scheme: a) development of a technique for joint measurements of a frequency-amplitude spectrum of the cerebrum brain bioelectric activity and low-frequency radiation, b) test experimentation, c) full-scale research, d) processing and analysis of the data obtained, e) development of a flight and experiment techniques, f) substantiation of medical recommendations on improving the human adaptation to the changing electromagnetic environment.

The preliminary research has shown [1—2] that the electromagnetic radiation intensity growth correlates with the increase of spectral power of all bioelectric rhythms (alpha, delta and theta), with the power and rate reorganization of rhythms in the alpha-range (in most cases the peak is being formed at the frequency of 10 Hz), as well as with the increase of the left cerebral hemisphere domination on the electroencephalogram. Our methodical approach has shown the effectiveness of these results, and so, it can be recommended for performance of the experiment onboard the OSS.

References:

1. Sukhorukov V. I., Serbinenko I. A. A new method of adaptation management in psychoneurology // Ukrainian psychoneurologic bulletin, Kharkiv.—1995.—**III**, N 1.— P. 37—40. (in Russian).
2. Lytvynenko L. M., Aristov Yu. V., Bliokh P. V., et al Influence of super-low-frequency electromagnetic fields on the cerebrum brain bioelectric activity // Radio physics & radio astronomy.—1998.—3, N 3. (in Russian).

REMOTE SENSING OF THE SURFACE AND WATER AREA OF EARTH («Surface» Project)

Lyalko V. I.

Centre for Aerospace Research of the Earth, Institute of Geological Sciences, NAS of Ukraine
55b, O. Gonchar St., Kyiv-54 01601Ukraine
tel/fax: (380) +44 +216 94 05, e-mail: casre@casre.kiev.ua

«Surface» Experiment

REMOTE SENSING OF THE SURFACE AND WATER AREAS OF EARTH BY THE UKRAINIAN ON-BOARD RADAR COMPLEX AND THE DATA FROM MULTI-SPECTRAL SURVEYS AND TESTING AREAS IN THE TERRITORY OF UKRAINE

Lyalko V. I., Fedorovsky A. D.

Centre for Aerospace Research of the Earth, Institute of Geological Sciences, NAS of Ukraine
55b, O. Gonchar St., Kyiv-54 01601, Ukraine
tel/fax: (380) +44 +216 94 05, e-mail: casre@casre.kiev.ua

Dovgij S. A.

Environment and Resources Research Institute of Ukraine,
National Security and Defense Council of Ukraine
Tel: (380) +44 +241 77 24

Bakan G. M.

Space Research Institute, NAS of Ukraine — NSA of Ukraine
40, Akademik Glushkov Ave., Kyiv 03022 Ukraine
tel/fax: (380) +44 +266 41 24, e-mail: iki@spase.is.kiev.ua

Korotaev G. K.

Marine Hydrophysical Institute, NAS of Ukraine
2 Kapitans'ka St., Sevastopol 99000 Ukraine
tel: (380) +692 +54 72 79, fax: (380) +692 +55 42 53,
e-mail: omnet-mhi.sevastopolrelcom-ocean@mhi2.sebastopol.us

Tcymbal V. N.

A. I. Kalmykov Centre for Radio Physical Sensing of Earth, NAS of Ukraine — NSA of Ukraine
12 Akademik Proskura St., Kharkiv 61085 Ukraine
tel/fax: (380) +572 +44 83 97, fax: (380) +572 +44 10 12, e-mail: kalmykov@ire.kharkov.ua

The Earth Remote Sensing (ERS) allows studying a lot of important problems, i. e. the global energy-mass transfer and weather forecasts, the local ecological control and mineral resources surveillance.

Development and introduction of effective ERS methods is especially important for Ukraine because of the strained ecological and economic situation. Large-scale international cooperation in the form of collaboration for creation of the ISS, could be of great benefit for Ukraine in this field of research.

Installation of the ERS complex on-board the orbital station has advantages over single satellites accomplishing the ERS in the self-contained mode. The principal advantages are as follows:

— Control over experimental conditions; active analysis of the visual and concurrent information to determine the time of turning on the measuring instruments; possibility to correct the observational conditions.

— Integrated nature of the experiments; possibility of using dissimilar and diverse measuring instruments simultaneously.

— Active control over the satellite and ground-based blocks of the experiment during the sub-satellite measurements.

«Surface» project deals with a series of experiments to study the natural environment of Earth in optical, infrared, millimeter, centimeter, decimeter, and a meter ranges of waves and to improve the existing ERS methods of measurement. It is supposed that this project will enable meeting the following objectives:

— Ensuring a sufficiently active reaction of the astronaut to extraordinary processes and phenomena on the Earth's surface (earthquakes, floods, fires, landslides) by their surveying in various ranges of the electromagnetic radiation and preliminary physical interpretation of the data obtained.

— Repair and upgrading of on-board surveying apparatus.

— Optimization of the on-board surveying apparatus set without duplication of the appropriate apparatus of other satellites, as well as taking into account the limitations on power supply, overall dimensions, and electromagnetic compatibility with other on-board devices.

— Ensuring that the ISS surveying and surveying from other satellites (LANDSAT, SPOT, ERS, JERS, Radarsat, IRS, Resurs, Ocean-O, etc.) complement each other in terms of their orbits, seasons, phenophases of vegetation development, etc.

— Substantiation of the requirements to the testing grounds for ground-based calibration and certification of the ERS results and development of procedures for external monitoring of the surveying apparatus of the ISS.

— Creation of the methods for improving the information content and definition of the tasks by overlap processing of the results in various ranges of the electromagnetic waves on the basis of synergetic principles.

Taking into account the experience of the Ukrainian institutions on the use of radio physical methods for the ERS, we also propose development of on-board radar and radiometric systems with greater information content. This problem has two aspects. The first of them concerns the combined ERS active-passive method to improve the reliability of data interpretation for oceanographic and glaciological tasks. The proposed complex will have a wide survey band, devices for data processing and subsequent data transmission in the form of synchronous radar and radiometric images of the same regions of Earth. The provided modes of on-board calibration of all channels of the complex significantly increase the stability and absolute accuracy of results. The second aspect envisages creation of the two-mode radar system (RLS). We have elaborated a new approach to the RLS apparatus, based on optimization of the parameters of the designed antennas and on a wide use of microprocessor equipment.

Metrological traceability of measurements performed by the ground-based instruments, from the aircraft and satellite is one of the most difficult requirements. To meet this requirement it is necessary to reference the power scales and spectral channels of the instruments using standardized test facilities and standards by a common procedure. Hence the need for validation of space information in the specially selected ground-based testing areas. Not all the objects present in the metrological testing areas are fit to be the test objects for metrological purposes, but only those, whose spectral lines are stable enough during a certain period. Systematic observations and measurements of parameters should be performed in the testing areas, in order to record the change of state of the tested ground-based objects and related changes of the spectral characteristics. Using this approach, we have worked out a system of criteria for the testing areas and have defined the main purpose of the testing area network for the agricultural industry.

The most important part in technical embodiment of the instrumentation concept is to ensure the maximal achievable accuracy of absolute measurements. Therefore, both the preliminary matching of the tactical-technical parameters of a radio physical complex and its final specification, and the whole range of technological, design, and metrological decisions concerning the development and certification of the complex, as well as its launching into orbit and subsequent operation, should meet this requirement.

The proposed scanning radiometric complex will allow measurement of spatial distribution of the radio brightness temperatures of the Earth-atmosphere

Table 2. Required performance attributes for radar complex ISS

Performance Attributes	Space-born Radar Complex Components			
	mm-band	cm-band	dm-band	m-band
Operating mode	SLAR	SAR, SLAR	SAR	SAR
Wavelength	8 mm	3.2 cm	23 cm	2m
Emitted and received polarization	VV	VV	VV, HH, HV, VH	VV, HH, HV, VH
Field of view band, (at less)	500 km		700 km	700 km
- amplitude regime		750 km		
- SAR-regime		700 km		
Cover band			90 km	90 km
SAR-regime (at less)		90* (300)** km		
Resolution	1–2 km		10–20 m	10–20 m
- SLAR-regime		1–3 km		
- SAR-regime		5-15* m, (100–150)** m		
Contrast-background sensitivity (at less)	1 dB	1 dB (SLAR)		
Field of view number		4	4	4
Antenna type	Periodical scheme	Reflector-type	APHA	PHA
Antenna size				
movement direct	4–5m	12–15m	10m	4 m
across movement		1 m	3 m	
Antenna pattern	$cosec^2$	$cosec^2$		
Power supply				
- uninterrupted regime	150 Watt			
- on the survey (10 min)	550 Watt			
Equipment weight	200 kg			

* — focused aperture high resolution SAR-regime,

** — unfocused aperture average resolution SAR-regime

system in the six frequency intervals of the super high frequency range within the given radar scanning band. As regards the majority of its parameters, this complex is not inferior to the foreign analogs of space radiometric complexes such as the SSM/I, AMSR/AMSU in the ERS, DMSP, and NOAA systems, and is even superior to them in some parameters (see Table 2).

The complex of radio physical instruments operating in the wave range from several millimeters up to tens of meters with different polarization and spatial resolution from 2 km to 10 m, will allow not only solving the traditional problems (flood and storm monitoring, etc.), but also studying the internal geological structure of Earth.

Multi-frequency radar ERS complex will consist of 4 radar stations of lateral scanning, which are working simultaneously in the overlap scanning bands at the wave lengths of 8 mm, 3 cm, 23 cm, and 1.8 m. The radar station of 8-mm range should operate in the mode of radar lateral scanning (amplitude mode). The radar station of 3-cm range should operate in the mode of radar lateral scanning and in the mode of aperture synthesis. Other radar stations should operate only in the aperture synthesis mode. The lock-in bands of some stations depend on the operational modes and make up from 100 km to 700 km. The spatial resolution of low, middle, and high type is also dependent on the operational mode (see Table 2).

The «Surface» project pursues the following scientific objectives:

- Study of the morphology of the underlying surface of Earth by radar methods;
- Study of the dielectric properties of the underlying surface using the data of the microwave range;
- Study of the properties of the upper layer of the Ocean using the data of thermal and optical surveying and the data of dedicated research of space altimetry and gravimetry;
- Study of the ozone distribution in the atmosphere;
- Modeling the energy-mass transfer processes in the geosystems;
- Creation of a database on the general view of

Table 3. Basic requirements to the equipment and surveying conditions for Ukraine's module of International Space Station

№ Items	Objectives	Surveying equipment			
		Ranges Spatial resolution, m / Channels			Foreign analogues on Spaceship / Spaceship equipment
		visible	infrared	radio-wave	
1.	**The most essential for Ukraine's objectives are:**				
1.1.	Assessment and control of territory and water area contamination as to toxicants (radionuclides, heavy metals, pesticides, etc.) on the basis by recording of vegetation spectral anomalies in a visible range. *	8-20 / 3	-	-	SPOT-4 / HRVIR (France) IRS-1C / LISS-III (India)
1.2.	Prospecting of oil-gas deposits on the land and shelf areas by recording and interpreting of spectral, thermal, optical density anomalies in visible, infrared and radio-wave ranges.**	20-100 / 3	250 / 1 (10-12 μm)	10-2000 *** / 4 (mm, cm, dm, m)	SPOT-4 / HRVIR (France) Ocean-O / MSU-V (Russia, Ukraine) ERS-1 & 2 / AMI-SAR (ESA) [Weight 200 kg; Overall dimensions antennas 15 m × 3 m; Power supply: 150 Watt (uninterrupted regime), 550 Watt (10 min-survey); Leading Contractor: CRSE NSAU-NANU; Participating bureaus: IRE NANU, IRA NASU]
1.3.	Examination of angular structure of optical irradiation under different hydro and meteo conditions to increase reliability and accuracy of weather forecast.*	20-100 / 3 20-100 / 3	250 / 1 (10-12 μm)	- -	SPOT-4 / HRVIR (France) Ocean-O / MSU-V (Russia, Ukraine)
1.4.	Examination of «supervision» effects from spaceship through the sea water mass in visible range that allows for the first time to explain this phenomenon. *	20-100 / 3 50-100 / 6	250 / 1 (10-12 μm)	- -	SPOT-4 / HRVIR (France) Ocean-O / MSU-V (Russia, Ukraine) IRS-1C / LISS-III (India)
2.	**Earth cover research**				
2.1.	Monitoring of vegetation cover condition, including plantings development dynamics and forecasting of crops yielding capacity. *	20-100 / 3 50-100 / 6	- - 250 / 1 (10-12 μm)		SPOT-4 / HRVIR (France) IRS-1C / LISS-III (India) Ocean-O / MSU-V (Russia, Ukraine)
2.2.	Ecological monitoring of condition and dynamics of development of forest ecosystem	-"-	-"-		-"-
2.3.	Monitoring of condition and soil moisture including erosion dynamics.**	-"-	-"-	10 / 3 (cm, dm, m)	ERS-1 & 2 / AMI-SAR (ESA) (For parameters of radiophysical equipment see Table 2)
2.4.	Estimation of meliorative systems condition, monitoring of swamped areas.**				
2.5.	Survey aiming to update topographic maps as well as land and water cadastre compiling*	8-20 / 3		10 / 3 (cm, dm, m)	SPOT-4 / HRVIR IRS-1C / LISS-III ERS-1 & 2 / AMI-SAR

Technology of the survey and thematic interpreting of the data acquired		Operational conditions for the survey				Projects (organizations), competing for International Space Station complement that could cooperate to solve the objectives	Departments, concerned with task accomplishment
Leading Contractor	Participating bureaus	Observation periodicity	Observation condicions	Angle of the Sun rising	Air and ground proofing		
CASRE NANU	ERRIU of Nat. Security and Defense Council, SRI NSAU-NASU	March-Oct. (1 time per 10 days)	Cloudless sky	>35°	Aerial survey from Flying Lab., sampling of vegetation in the test areas	«Inframon» (MAO NASU), «Sova» (Inst. of Physics, NASU), «Choven» (IRA NASU), «Module» (Res. Centre «Fonon»)	State Administration, Ministry of Agriculture, Min. of Forestry, State Com. for Water Manag., State Com. on Land Use, Min. of Ecology, Ministry of Emergence Situations
CASRE NANU	CRSE NSAU -NANU, MHI NASU	March-Oct. (1 time per 10 days) - The whole year round once a month	Unclouded sky - All-weather	>35°	Aerial survey from Flying Lab, ground vegetation and water sampling	-"-	Nat. JSC «NAFTOGAZ Ukrainy», Geological Survey of Ukraine, SGE «Chemomorneftegaz», JSC «Ukrnafta», Foreign oil companies
MHI NASU	CASRE NANU, CRSE NSAU -NANU	The whole year round (1 time per 10 days)	All-weather		Aerial survey from Flying Lab., ground measure-ments	-"-	State Com. on Hydrology and Meteorology, State Com. for Water Manag., Dept. of Marine and River Fleet, Hydrographic Survey of Ukraine's Min. of Defense
MHI NASU	Hydro-graphic Survey of Ukraine's Ministry of Defense	The whole year round (1 time per 5-10 days in different light conditions)	Unclouded sky		Aerial survey from Flying Lab., ground measure-ments	-"-	-"-
CASRE NASU	ERRIU of Nat. Security and Defense Council, Ministry of Agriculture	March-Oct. (1 time per 10 days)	Cloudless sky	>35°	Survey by Flying Lab., sampling of vegetation in the test areas	«Inframon» (MAO NASU), «Sova» (Inst. of Physics, NASU), «Choven» (IRA NASU), «Module» (Res. Centre «Fonon»)	Ministry of Agriculture, State Dept. of Statistics, State Administration
CASRE NASU	Ministry of Forestry, Ministry of Emergence Situations	-"-	-"-	-"-	-"-	-"-	Ministry of Forestry, Ministry of Emergence Situations, State Administration
CRSE NSAU-NASU		The whole year round (1 time per 10 days)	All-weather		Survey by Flying Lab., soil sampling in the test areas	-"-	Ministry of Agriculture, State Com. for Water Manag., Ministry of Ecology, Ministry of Emergence Situations
CASRE NASU	UkrGeodez-Kartographia	4 times a year (seasonally)	Cloudless sky All-weather	>35°	Survey by Flying Lab., location survey of test areas by GPS	-"-	UkrGeodezKartographia, State Com. on Land Use, Ministry of Forestry, State Com. for Water Manag., State Administration

Cont. of Table 3.

№ Items	Objectives	Surveying equipment			
		Ranges Spatial resolution, m / Channels			Foreign analogues on Spaceship / Spaceship equipment
		visible	infrared	radio-wave	
2.6.	Accident area monitoring.**	8-20 / 3 50-100 / 6	250 / 1 (10-12 μm)	10 / 3 (cm, dm, m)	SPOT-4 / HRVIR (France) IRS-1C / LISS-III (India) Ocean-O / MSU-V (Russia, Ukraine) ERS-1 & 2 / AMI-SAR (ESA)
3.	**Sea and ocean water monitoring: ** **				
3.1.	Determination of the parameters of sea-wave spectrum and near-surface wind field.	50-100 / 6			Ocean-O / MSU-V (Russia, Ukraine) ERS-1 & 2 AMI-SAR
3.2.	Storm, squall areas detection.				
3.3.	Monitoring of energetically active interaction processes in «ocean-atmosphere», including detection and parameters determination of hurricanes, typhoons.		250 / 1 (10-12 μm)		
3.4.	Location of frontal zones, currents, upwelling, internal waves, etc.			10-2000 / 4 (mm, cm, dm, m)	(For parameters of radiophysical equipment see Table 2)
3.5.	Ecological monitoring of petroleum products pollution in marine economic zones, and liquidation of oil spills.	-"- -"-	-"-	-"-	-"-
3.6.	Estimation of fish resources in marine economic zone, and detection of ships carrying a braconnier fishing.	-"-	-"-	-"-	-"-
4.	**Marine ice, glaciers diagnostics:** **				
4.1.	Age (thickness) and marine ice continuity determination.	50-100 / 6			Ocean-O / MSU-V (Russia, Ukraine)
4.2.	Determination of channels and open-water in marine ice.				
4.3.	«Ice-water» boundary ecological monitoring.		250 / 1 (10-12 μm)		ERS-1 & 2 / AMI-SAR
4.4.	Glacier debacles monitoring, detection of the early stage of blocks of ice and iceberg splitting.				
4.6.	Limnic ice condition and permafrost areas monitoring.			10-2000 / 4 (mm, sm, dm, m)	(For parameters of radiophysical equipment see Table 2)

* — Surveys will be carried out by the equipment provided by other countries and installed onboard the ISS. Ukrainian party provides techniques for calibration and verification on test proving ground and thematic interpretation of the survey results.

** — In radio-wave range surveys will be carried out using domestic equipment, calibration and verification on test proving ground and thematic interpretation of surveys results.

*** — Detailed operating characteristics of this radar complex is shown in Table 2.

the surface studied, i. e., using the SAR data and higher resolution optical data.

The «Surface» project envisages the following applied tasks:

Monitoring the surface of the sea and ocean

— Analysis of the field of the wind near the water and parameters of the roughness spectrum;
— Revealing the storm and tornado zones;
— Control over energy interactive processes in the ocean — atmosphere system, i. e. revealing, monitoring and measuring the parameters of hurricanes and typhoons;
— Revealing the frontal zones, currents, and internal wave manifestation, etc.;
— Ecological monitoring of the marine economic zone; revealing the pollution by oil products and ensuring their liquidation;
— Revealing the shoals of fishes and estimation of fish reserves in the marine economic zone; detection of the poacher fishing-boats;

Technology of the survey and thematic interpreting of the data acquired		Operational conditions for the survey				Projects (organizations), competing for International Space Station complement that could cooperate to solve the objectives	Departments, concerned with task accomplishment
Leading Contractor	Participating bureaus	Observation periodicity	Observation condicions	Angle of the Sun rising	Air and ground proofing		
		The whole year round (1 time per day)	Cloudless sky All-weather		Survey by Flying Lab. On-land certification of the survey results	-"-	Ministry of Emergence Situations, State Administration
MHI NASU	CRSE NSAU-NASU	The whole year round (according to users requests)	Cloudless sky All-weather	>35°	Survey from Flying Lab. and ship's measure-ments	«Inframon» (MAO NASU), «Sova» (Inst. of Physics, NASU), «Choven» (IRA NASU), «Module» (Res. Centre «Fonon»)	Dept. of Marine and River Fleet, Ministry of Ecology, Ministry of Fishery, State Com. on Hydrology and Meteorology, State Administration
-"-	-"-	-"-	-"-	-"-	-"-	-"-	-"-
-"-	-"-	-"-	-"-	-"-	-"-	-"-	-"-
CRSE NSAU-NASU	MHI NASU	The whole year round (according to users requests)	Cloudless sky All-weather	>35°	Survey from Flying Lab and ship's measure-ments	«Inframon» (MAO NASU), «Sova» (Inst. of Physics, NASU), «Choven» (IRA NASU), «Module» (Res. Centre «Fonon»)	Dept. of Marine and River Fleet, Ministry of Ecology, Ministry of Fishery, State Com. on Hydrology and Meteorology, State Administration

— Search of the potential oil and gas bearing areas in the shelf zone.

—

Diagnostics of the marine ice and glaciers

— Determination of the age (thickness) and solidity of the marine ice;
— Detection of the channels and patches of ice-free water in the ice;
— Ecological control of the «ice-water» line;
— Monitoring the ice motions; detection of the splits of ice-floes and icebergs at an early stage;
— Monitoring the state of freshwater ice and permafrost zones.

Study of the topsoil

— Monitoring the state of vegetation topsoil, i. e., the dynamics of development of agricultural crops; prognostication the crop yield;
— Monitoring the state of soils and its mineralization and moisture, i. e. dynamics of soil eroding;

— Analysis of the state of meliorated systems; control of the swamping lines;
— Ecological monitoring of the state and dynamics of development of the timber ecosystems;
— Subsurface sensing of the arid areas; control over the processes of desertification; study of the manifestations of geological and hydrogeological structures;
— Survey for mapping the territory (more precise definition of the topographic maps) and for the land, timber, and aquatic cadastre;
— Monitoring the regions of emergencies.

We envisage the following tasks as the most urgent ones for study from the ISS:

— Estimation and monitoring of pollution of the Earth water area and surface by toxicants, radio nuclides, heavy metals, herbicides, etc. on the basis of recording the spectral anomalies of vegetation, i. e. for the Chernobyl zone and the Black Sea;

— Search for the oil and gaseous fields on land and in the shelf zones by recording the spectral and thermal anomalies of the underlying surface;

— Analysis of angular structure of optical radiation under various hydrometeorological conditions;

— Study of the «supervision» effect (space observations of locations of some underwater mountain ridges and mountains situated at the depth of several kilometers), which is explained hypothetically by variation of the transparency (color) of the subsurface layer of water at a depth of several tens of meters;

— Study of the radar and optical contrasts in the regions of the atmospheric and sea fronts;

— Study of the meso-scale structure of the field of wind and roughness in coastal regions.

The main requirements to the on-board surveying instruments of the ISS and satellites are given in Table 3.

Division 5

ACTIVE EXPERIMENTS IN SPACE AND AT THE EARTH'S SURFACE

«Ablation» Experiment

MODELING OF THE PROCESSES AND PHENOMENA IN THE NEAR SPACE USING THE COMPLEX OF CHARGE-PARTICLE SOURCES AND EHF-GENERATOR

Egorov A. M., Fainberg Ya. B., Karas' V. G., Kharchenko I. F.

Institute of Plasma Electronics and New Methods of Acceleration,
NSC «Kharkiv Physical-Technical Institute»
1 Akademichna St., Kharkiv 61108 Ukraine
tel: (380) +572 +356140, fax: (380) +572 +353564, e-mail: egorov@kipt.kharkov.ua

Nazarenko O. K.

E. O. Paton Electric Welding Institute, NAS of Ukraine
11 Bozhenko St., Kyiv-150, 03680 Ukraine
tel/fax: (380) +44 +2654319

Sitalo V. G.

Yangel State Design Office «Pivdenne»
3 Kryvoriz'ka St., Dnipropetrovsk 49008 Ukraine
Tel: (380) +562 +925113, fax: (380) +562 +925041

Nowadays the problem of the debris removal from the near space and protecting the Earth from asteroids has assumed great importance. The great number of debris of different origin, even when their mass is small, become highly dangerous because of their high velocities (about the first space one), for launching and normal operation of spacecraft in the future.

We consider the laser to be a rather efficient technique of the orbital debris elimination. It was proposed by the scientific teams from Los-Alamos National laboratory (G. Canavan, J. Solem, J. Rother, R. Hunter, C. Patel et al.), NASA (J. W. Campbell et al.), Tauson University (H. E. Bates), Shtutgard Institute of Technical Physics (W. O. Shall) and others. The main idea of these proposals consists in changing the small space object orbits by the laser ablation.

The goal of the «Ablation» experiment is to model some phenomena and processes in the near space based on the developed and built system of charge-particle sources and powerful Expremely High Frequency (EHF) generator. The intent is to perform a number of theoretical and laboratory experiments and optimization of the laser radiation parameters, in order to use the advantages of the charge-particle beams and avoid their disadvantages in transmitting a pulse to an object through ablation. Taking into account the nature of interaction of the regular and stochastic radiation with the environment, the advantages of each of them in identification of the space objects will be also studied.

The following results of the project are anticipated:

— scaling of the orbit change due to ablation of the object irradiated by the laser and electron, ion and neutral particle beams;

— modeling the collisions of space objects moving at hypersonic velocities by means of charge-particle beams;

— identification of space objects using regular and stochastic radiation produced by a plasma-beam EHF-generator.

The on-board experimental unit will include the electron accelerator generating beams with electron energies $E_b = 1$ MeV, electron current $I_b = 25$ kA, and pulse duration $\tau = 15$ ns. The beams will have the following main parameters: beam cross-section $S_b = 1$ cm^2; beam power $P_b = 25 \cdot 10^9$ W; beam energy per impulse $W_b = 375$ J. The efficiency of the electron accelerator is $\eta = 50$ %. The total energy, which is necessary for producing 10 pulses, is $W_s = 7.5$ KJ.

We suggest that a plasma channel can be used for transfer of a powerful relativistic beam to the object. This plasma channel will be immediately created by the electron beam during its propagation in the gaseous medium. We propose using a metallic tube to provide the optimal current and charge compensation. It should be filled by gas with the pressure of 1-2 Torr and should have the diameter larger than the beam diameter. Such conditions of the experiment will also prevent charge accumulation in the spacecraft, where the electron accelerator is situated. If this tube is made of duraliminium, the application of the electron beam under the above conditions will provide the needed pulse of $J = 0.06$ N·s. The above parameters allow achieving the most efficient energy conversion of the electron beam into vapours which ensures the maximal recoil momentum.

References:

1. Antonov A. N., Bliokh Yu. P., Dekhtyar Yu. A., et al. Plasma beam generator based on the interaction between charge-particle beams and plasma-wave structure of a chain of inductively coupled resonators // Plasma Physics.—1994.—**20**, N 9.—P. 777—781.
2. Karas' V. I., Moiseev S. S. On the possibility of resonance effect of laser radiation on solid bodies // Voprosy Atomnoj Nauki i Tekhniki, KhPTI.—1977.—P. 77—17, 13—18.
3. Golota V. I., Karas' V. I. Excitation mechanisms of elastic oscillations by charge-particle beams // Ukr. Phys. Zhur.—1985.—**30**, N 7.—P. 1093—1097.
4. Bludov S. B., Gadetskij N. P., Kharchenko I. F., et al. Ultrashort microwave pulse generation and its effect on electronic devices // Plasma Physics.—1994.—**20**, N 7.—P. 712—717.

«Approach» Experiment

APPROACH OF SPACE DEBRIS TO THE ORBITAL SPACECRAFT

Khizhnyak A. I.

Institute of Applied Optics, NAS of Ukraine
10-G Kudryavska Sr., Kyiv 03053 Ukraine
tel: (380) +44 +2122158, fax: (380) +44 +2124812,
e-mail: knizh@lomp. ip.kiev.ua

Didkovskij L. V.

Crimean Astrophysical Observatory, Ministry for Education and Science of Ukraine
Naukove, Bakhchisarai, 98409 Crimea, Ukraine
Tel: (380) +6554 +71161, Fax: (380) +6554 +40704,
e-mail: postmaster@crao.crimea.ua

Dangerous approach of space debris to the «Mir» OSS and catastrophic damage to the French «Ceriese» spacecraft (1996), give evidence of practical necessity of prediction of such phenomena, especially in the cases of manned missions and nuclear sources presence onboard the spacecraft. Radar observations permit prediction of only the dangerous approaches (< 3 km) of large space debris (> 10 cm). However, collisions with centimeter-sized objects can also have a disastrous effect, taking into account their multiplicity and velocity. Ground-based registration of these objects using optical electronics is possible, but creation of a database (similar to that existing for the large space objects) suitable for accurate prediction of their motion, is considered to be unrealistic. These data can be used only for statistical models, which describe the motion of a group of bodies as a Poisson's random process, and give results, which are too rough to be used for estimation of the hazard of collision of individual objects.

Analysis of models leads to the conclusion that the strict deterministic models cannot be supported by the input experimental data, but on the other hand the available statistical data do not provide acceptable estimates of the risk of approach. In addition to these two classical models of motion of the orbital objects, there are the so-called «semi-deterministic» models, which allow obtaining the same parameters as those derived from the deterministic models. The distribution of the minimal distances between the approaching objects is one of such parameters. This characteristic is regarded to be the main index of space debris population. Obviously, if a means were provided for measuring this index, the hazard of collisions between space debris and operating satellites could be predicted more precisely.

The main goal of the experiment is to develop a technique for experimental research of orbital object characteristics, which evaluates the risk of operating spacecraft being damaged by space debris. An important feature of the experiment is to obtain not only the spatial distribution of the objects around a spacecraft orbit but also the distribution of minimal distances to these objects during their approach to the ISS.

Small space objects move in clusters formed by explosions and destruction. Ground tracking station control gives evidence that some orbital parameters of the objects forming the cluster are highly localized. These data are related to the catalogued objects (> 10 cm), but the degree of localization of small-sized (several centimeters in size) objects can be also assessed, when the available models of explosion and destruction, as well as of evaluation of debris orbits are applied. Our approach is based on a priori data on localization of orbital characteristics of space objects. Knowing the region of space debris parameter localization, it is possible to determine a set of angles of approach of the objects to the spacecraft and their relative velocities. The relative velocities obtained permit the distance to the objects to be estimated using just the results of positional measurements.

The experimental complex will consist of a wide-angle optical system (telescope) equipped with a CCD camera to detect object images and with instruments to process the coordinate measurement results. The control system software will provide orientation of this system, taking into account the dependence of the direction of an object approach on time.

The proposed experimental complex will enable all the dangerous objects in the vicinity of a 5-km zone of the ISS to be recorded.

«Lightning» Experiment

DIAGNOSTICS OF ACTIVE EXPERIMENT DISTURBANCES IN THE NEAR-EARTH SPACE

Tyrnov O. F., Tsymbal A. M.

Kharkiv National University
4 Svoboda Sqr., Kharkiv 61077 Ukraine
tel: (380) +572 +47 10 12, fax: (380) +572 +47 18 16, e-mail: Oleg.F.Tyrnov@univer.kharkov.ua

At present active experiments which affect the space environment through powerful radio emissions, charge carrier injection, chemical agent ejection and some side effects accompanying launches and flights of the space rockets, industrial explosions, on-board technological operations are the main methods for studying the physical processes in near-Earth space. These methods allow simulation and triggering of the natural phenomena, which occur during various geophysical disturbances and plasma diagnostics.

The goal of the experiment is to develop on-board active experiment procedures and carry out monitoring of the disturbances initiated by these experiments. It will allow simulation and study of mechanisms of their formation and evolution.

This research will be based on the following idea. A powerful artificial local influence on the near-Earth space can lead to release of energy present in the radiation belts, as well as to large-scale and global disturbances in the ionosphere and magnetosphere. The disturbance velocity can be up to 100 km/s.

Complete diagnostics of artificial disturbances in the near-Earth space will be performed using different remote sensing instrumentation, namely the partial reflection complex with the antenna of 300 by 300 m, the unit of active Doppler monitoring in the range of 1.5-30 MHz, systems for passive Doppler monitoring in the range from 30 kHz to 30 MHz, radio receiver devices of the «Transit» and «Czikada» systems for receiving signals of the navigation satellites, ionosphere stations, magnetometers. They allow diagnostics of the disturbances in the altitude range from 60 to 1000 km.

References:

1. Rozumenko V. T., Tyrnov O. F. et al. Studies of global and large-scale ionospheric phenomena due to sources of energy of different nature // Turkish J. of Physics.—1994.—**18**, N 11.—P. 1193—1198.
2. Hysell D. L., Tyrnov O. F. HF radar observations of decaying artificial field aligned irregularities // J. Geophys. Res.—1996.—**101**, N 12.—P. 1864—1876.

«Control» Experiment

GENERATION OF ARTIFICIAL PLASMA FORMATIONS IN SPACE AND MONITORING OF THEIR LOCAL PARAMETERS

Stepanov K. N., Buts V. A.

NSC «Kharkiv Physical-Technical Institute»
1 Akademichna St., Kharkiv 61008 Ukraine
tel.: (380) +572 + 404414, E-mail: abuts@kipt.kharkov.ua

Creation of artificial plasma formations in near space and modification of their parameters, as well as parameters of the ionosphere are important both for better understanding of the electrodynamic properties of the near space and for many practical purposes, such as communications, energy transmission from one space object to another, etc. The process of plasma generation in space is limited because of power-intensity, overall dimensions and weight of a plasma source.

Within the framework of this experiment, new mechanisms and techniques are proposed for plasma generation and parameter control of both the artificial plasma formations and the ionosphere. Use of on-board helicon plasma sources is proposed for producing plasma formations with densities of up to 10^{12} cm^{-3} and electron temperature of 3-5 eV in the continuous-wave and pulsed modes. Experiments completed in the US have demonstrated that such a source with the diameter of about 15-20 cm and length of 20-30 cm requires the magnetic field of about 50 oersted and HF-generator of about 1 kW power at the frequency of 13.56 GHz. Due to the fact that the velocity of the plasma flow for such a helicon generator is equal to 10^6 cm/s, it is impossible to study the temporal evolution of the plasma clots inside a limited volume of a laboratory facility.

In previous experiments modification of parameters of plasma formations in the near space was generated by explosions of atomic devices («Argus» program) or by the charge-particle beam injections («Araks», «Zarnitsa» projects), or by the action of powerful fluxes of electromagnetic radiation directed from the ground-based sources. In the latter case the elementary mechanisms of heating of charged particles are the pair collisions of plasma particles. This is a rather slow process. It is also accompanied by excitation of a wide spectrum of turbulent plasma pulsations, as well as by small changes of plasma temperature.

We propose using the process of local stochastic motion instability of the charged particles in the field of a few electromagnetic waves for plasma heating. According to analytical estimation and numerical simulation, the evolution of such an instability results in faster plasma heating (about 100 periods of electromagnetic waves). In addition, heating up to much higher temperatures is achieved (mean electron energy is over 1 MeV) and plasma turbulent pulsations are smaller, than those in the cases of other types of heating.

It is known that explosion of an atomic device with the power of 1 megatons generates approximately 1026 electrons. This is consistent with transformation of 1 kg of a material into plasma. A helicon plasma source can create more than 1024 electrons during one hour. Obviously, the power distribution of these particles differs substantially from the distribution of those at an atomic explosion. However, the distribution created by a helicon source can be controlled, and the generated plasma formations will remain compact over a long period of time, due to the low electron energies. With stochastic heating, the electron energy can be rapidly changed in a wide range and can be described as the distribution of particles at an atomic explosion. So, using a helicon source and stochastic heating, it is possible to simulate some processes, which are occurring at explosion of atomic devices in near space.

Other objectives of the experiment are selection of helicon plasma sources, which are the most suitable for on-board operations, and of HF-generators intended for heating the plasma and for deriving the desired function of its particle distribution. A series of laboratory experiments and theoretical modeling of the space plasma parameters will be completed too.

References

1. Mykhailenko V. S., Stepanov K. N. The theory of the low-parameter turbulence of plasma // JETF.—1984.—**87**, N 1.—P. 161.
2. Ahiezer A. I., Mykhailenko V. S., Stepanov K. N. Ionosound turbulence of plasma with transverse current in the magnetic field // UFJ.—1977.—**42**.—P. 990—995.
3. Balakirev V. A., Buts V. A., Tolstoluzskij A. P., Turkin Yu. A. Dynamics of the charged-particle motion in the field of two electromagnetic waves // JETF.—1989.—**95**, N 4.—P. 1231—1245.
4. Buts V. A., Stepanov K. N. Stochastic plasma heating by the field of laser radiation // Lett. JETF.—1993—**58**, N 7.—P. 57—62.
5. Buts V. A., Krivoruchko S. M., Stepanov K. N. Controlling the structure of the spectrum of oscillations excited by electron beams in a plasma // Plasma Physics Reports.—1996.—**22**, N 11.—P. 927—931.

II.3. ASTROPHYSICS AND EXTRATERRESTRIAL ASTRONOMY

SOLAR-ORIENTED RESEARCH («CONTEST» Project)

Yatskiv Ya. S.

Main Astronomical Observatory of the NAS of Ukraine
Golosiiv, Kyiv-22, 03680 Ukraine
Tel: (380) +44 +2663110, fax: (380) +44 +2662147,
e-mail: yatskiv@mao.kiev.ua

Introduction. In the second half of the 20th century due to progress of space technology and engineering, astronomy has expanded to cover all the wave ranges of the electromagnetic radiation. New observational data concerning particular celestial objects and the Universe as a whole has been collected during the last decades. With advances in space observational techniques (Hubble Space Telescope, Infrared Space Observatory, etc.) the amount of data is continuously growing. Nevertheless, a short duration of space experiments is a substantial disadvantage, not allowing the long-term processes in the near-Earth space and in the Universe to be studied. Therefore, astronomical experiments onboard the ISS could solve some of these problems.

Studying the Sun astronomers encounter both quite specific and typical problems. It was found that processes occurring in the solar interior and in near-Sun space are typical for the other space objects. For examples, solar type phenomena were found in the stars, namely stellar oscillations, spots, flares, corona and wind. The Sun and heliosphere are a unique laboratory for conducting observations and experiments to verify scenarios and models of stellar evolution and for studying fundamental problems of magnetohydrodynamic, atomic physics and cosmology. During the last years significant data indicative of the correlation between the phenomena across the wide range of heights of the solar atmosphere has been amassed.

Observations of the solar plasma intensity in the temperature range from 10^3—10^6 K and higher, and subsequent theoretical analysis of the data, as well as study of non-thermal processes are necessary to understand the real nature of various solar formations. To progress toward these goals, simultaneous observations across broad wavelength bands from the extreme UV to radio wavelength range should be carried out. These observations can not be performed by the ground-based instruments due to the Earth's atmosphere interference.

Spectral observations of the Sun in the range of 10.0 — 160 nm to determine the physical parameters of various solar formations have not been yet conducted. Therefore, observations of the Sun carried out onboard the ISS in this wavelength range will provide the basis for extensive studying the active and non-active regions of the Sun and their evolution over a wide range of spatial and temporal scales.

«SOT» Experiment

SOLAR-ORIENTED TELESCOPE

Gopasyuk S. I.

Crimean Astrophysical Observatory, Ministry for Education and Science of Ukraine
Naukove, Bakhchisarai, 98409 Crimea, Ukraine
Tel: (380) +655 +471166, Fax: (380) +655 +471754, e-mail: gopasyuk@crao. crimea.ua

Observations of magnetic field and plasma conditions of various formations on the Sun with the high resolution up to 0.2″, which has been never reached in previous experiments, are the purpose of the «SOT» experiment. The solar Gregory telescope with $D \approx 300$ mm (equivalent focal distance of 11 m) for carrying out observations in UV wavelengths (90—160 nm) will be manufactured and equipped with a spectropolarimeter with CCD camera. It allows detection of the processes involving high-energy release, and thus, provides a better understanding of the mechanisms of plasma heating and acceleration of particles up to high energies. The spectral measurements in Liaman continuum will be carried out as well to determine the density, temperature and small-scale structure of the plasma in solar flares.

«SOT» experiment pursues the following main objectives:

— manufacturing the UV telescope equipped with a spectropolarimeter incorporating a CCD camera together with guiding and solar disk scanning system;
— observations of the magnetic field, brightness and velocities in the solar formations at different spectral lines with high spatial and temporal resolution.

The Gregory telescope will monitor the solar disk on the slit of a spectropolarimeter with CCD camera designed for spectral and magnetic measurements. Polarization properties of Zeeman components will be determined to measure the magnetic field.

The afocal Gregory telescope has two sital mirrors with the special coating that provides considerable reflection of the UV radiation. The primary mirror diameter is equal to 300 mm. The telescope equivalent focal distance is $f_{eq} \approx 11$ m, the spatial resolution on the polarimeter slit is of about 0.2″.

Spectropolarimeter consists of diffraction grading, collimator and several chamber mirrors. Guiding and solar disk scanning systems employ the light reflected by the spectropolarimeter slit. The spectrometer slit coincides with the focal plane of the telescope. The light beam passes through the polarimeter set behind the slit to the collimator mirror, grading and chamber mirrors, consecutively. Spectral resolution of the spectropolarimeter equals a pixel of a CCD chip.

Registration system employs a CCD chip with 1024×1024 sensitive pixels for the spectropolarimeter and the one with 512×512 pixels for obtaining H_α images of the Sun. An onboard data acquisition system will be necessary, in view of the total duration of one set of observations of about 5 hours and overall amount of information of about 2 Gb.

A scientific data management system provides data acquisition, data reduction procedure and computer interface in two operating modes:
— data obtaining in real time and by the recording and reproducing system (RRS) simultaneously;
— data recording by the RRS only.

SOT control system has two operating modes:
— manual control (MC) of the unit by a ground-based observer or an astronaut; a video camera is envisaged for transmitting solar image to the Earth in the real time;
— automatic control (AC) in accordance with a preset program.

Being in AC mode, the control system will ensure to direct the telescope at any point of the solar disk with the accuracy of about 5″. The accuracy of stabilization is of about 0.5 arcsec/s. By using additional means the accuracy of the automatic stabilization of the Sun's focal image will be of about 0.001 arcsec/s during each set of observations (200 — 300 s). Scientific equipment control will be carrying out permanently by ground-based observers using relay control commands or code words.

Telescope optics weight is equal to 10 kg, total complex weight is 150 kg, and power of the scientific equipment is of about 1 Chat. The entire complex should be thermally insulated, and the optics should be protected from the influence of gaseous environment (mainly, from oxygen atoms and ions).

The most interesting active regions of the Sun, where instabilities could occur, as well as the non-active regions with the areas of high energy releases (bright knots), protuberances and filaments will be the objects of observations by the SOT. The SOT objects will be chosen from ground-based observations.

Successful performance of the SOT experiment will permit magnetic field and solar plasma observations in various formations of the Sun with the spatial resolution as high as 0.2″. Among others, the obtained data could detail the following:

— small-scale magnetic field and plasma activity;
— connection between the origin and evolution of non-stationary processes as powerful as for example, solar flares, and the magnetic field destabilization;
— problem of electric current generation in the outer solar atmosphere;
— role of small-scale magnetic activity and plasma instability in heating the plasma;
— acceleration of particles up to high energy, and energy transfer in magnetic structures.

«SOYA-M» Experiment

SOLAR BRIGHTNESS OSCILLATIONS MEASUREMENTS

Bruns A. V.

Crimean Astrophysical Observatory, Ministry for Education and Science of Ukraine
Naukove, Bakhchisarai, 98409 Crimea, Ukraine
Tel: (380) + 655 + 471166, Fax: (380) + 655 + 471754, e-mail: bruns@crao.crimea.ua

Most of our knowledge about the Sun has been derived from observations of visible solar surface layers: the photosphere, chromosphere and corona. One of the main problems of the modern solar physics is to develop the techniques for studying physical conditions in the solar interior and conduct continuous observations. Helioseismological research is one of the powerful means for studying the internal structure of the Sun by observations of its proper global oscillations. In many respects it has analogy to the seismological research of the Earth's internal structure.

Study of the internal structure of our nearest star, the Sun, is the goal of the SOYA-M experiment.

To meet the requirements of precise measurement of the proper frequencies of oscillations of a solar surface, it is necessary to provide a higher signal/noise ratio as well as continuity and long duration of observations. The experiment is intended for long-term measurements of the solar radiation flux with the subsequent calculation of the proper frequencies of its oscillations. The relative amplitudes of these oscillations are equal to $(1 - 10)\cdot 10^{-5}$. Stringent metrological requirements for stability of parameters of the radiation sensor and for the time interval precision are imposed to detect such a weak signal. Due to the atmospheric disturbances, measurement of such small brightness oscillations is possible only from a space station.

SOYA-M is the modified SOYA unit that was installed in «MARS-96» spacecraft, but this experiment was not realized by the reason of unsuccessful launch. It is a precise photometer measuring the solar radiation flux in a narrow spectral interval. Accuracy of discrete reading is up to 10^{-6} of the whole scale. Thermostabilization of measurement of circuits is used to decrease the drift of the photometer parameters because of the change of its temperature. Phase and amplitude of solar brightness oscillations strongly depend on the wavelength used. Choosing the wavelength for observations, the authors proceeded from their previous experience with a similar IRIR unit installed onboard the «FOBOS» satellite. Data processing revealed a strong degradation of filters in blue and green spectral regions and its absence in the red one. Thus, the interferential filter at λ = 800 nm will be applied in SOYA-M.

The ISS orientation system will introduce an additional error (modulation) in the measurements with the value of up to $(2 - 4)\cdot 10^{-3}$ of the whole scale (i. e., it exceeds the amplitude of oscillations studied by one or two orders). To correct this error during posterior processing of the data, SOYA-M will be equipped with a detector for measuring two coordinates of the Sun in the field of view of the polarimeter with the accuracy of about 0.01 arcdegree. The signal accumulation time is equal to 0.5 min. The duration of the experiment is from eight months up to the total operational life of the unit (≈ 3 years). The unit is fully automated.

The program is intended for providing data from the ISS and simultaneous observations in the Crimean Astrophysical Observatory. Continuous onboard measurements, which are free of atmospheric disturbances, will permit determination of the solar oscillation spectra with high accuracy. The ground-based observations may allow establishing a correlation between the phenomena observed on the solar surface and the processes in the solar interior.

Data obtained will be in some way a continuation of the research conducted onboard the «FOBOS». They will provide a database for further studying the structure, chemical composition, and distribution of physical parameters of the solar interior.

Conducting the SOYA-M experiment will complement the FOBOS and SOHO data. Taken together, they will provide observations of the 11-years solar activity cycle.

II.4. SPACE BIOLOGY, BIOTECHNOLOGY AND MEDICINE

Kordyum E. L.

M. G. Kholodny Institute of Botany, NAS of Ukraine
2 Tereschenkivska St., Kyiv 01601 Ukraine
tel/fax: (380) +44 +2123236, e-mail: ekord@botan.kiev.ua

Introduction. The program on space biology, biotechnology and medicine envisages:

— gaining principally new scientific knowledge about mechanisms of biological effects of microgravity on the population, organism, cellular and molecular levels;

— developing concepts on cell gravisensitivity and growth, development, reproduction, and resistance of organisms in microgravity.

It will promote creation of the space cell biotechnology for medicine and agriculture, express-methods for ecological monitoring of the biosphere, as well as development of new technologies for the Controlled Ecological Life-Support Systems (CELSS). These priorities of the program are based on the statement that proliferating and actively metabolising cells are the most sensitive to the influence of microgravity.

According to the conception on gravitational decompensation:

— cytoplasmic membrane is the primary site of the microgravity action;

— changes of the cytoplasmic membrane surface tension under essential lowering or absence of hydrostatic pressure can play an inductor role in modification of membrane's physical-chemical properties.

These changes modify membrane's permeability and receptors' functioning, as well as activity of membrane-bound enzymes, that, in its turn, leads to further metabolism changes resulting in physiological responses of cells and organisms to the microgravity action. A considerable attention is paid to space medicine directed to protection of human health, improvement of the quality and duration of the astronauts' life in a long-term space flight.

Space biology and medicine are the most important in the system of space sciences. Studying the biological effects of space flight factors, especially of microgravity and heavy charged space particles, the space biology obtains principally new scientific knowledge for solving fundamental problems of modern biology, namely:

— role of gravity in vital activity of organisms on Earth;

— influence of microgravity at the organism, cellular and molecular levels;

— establishment of the range of damage effects of heavy charged particles and ways of their reparation;

— working out the CELSS in long-term space flights and prediction of their functioning;

— development of the cell biotechnology in space.

During the last 25 years, complex research of bacteria, lower and higher plants, animal and plant organ, tissue and cell cultures has been performed on board the biosatellites, spaceships and orbital stations. It was conducted by the cytological, biochemical, biophysical and molecular-biological methods. Electron microscopic method was used in Ukraine for the first time in the world for evaluation of the influence of space flight factors on cells. As a result of this integrated research, the following conclusions have been made:

— lower and higher plants grow and develop in microgravity during a certain time;

— morphogenesis, division and differentiation of cells occur without essential deviations from the norm under microgravity;

— microgravity has an essential effect on cell metabolism; modifications of metabolism are reflected as rearrangements of cell ultrastructure, i. e., the cell is sensitive to gravity;

— microgravity upsets the intracellular calcium balance;

— changes in metabolism under microgravity lead to acceleration of cell differentiation and ageng;

— microgravity belongs to such alteration factors, which do not prevent the adaptive reactions at the cellular and organism levels in the range of physiological response, i. e., within the scope of genetically determined program of ontogenesis.

The following directions of contemporary space life sciences should to be noted: 1) gravitational biology, 2) radiation biology, 3) planetary biology and prebiotic synthesis, and 4) natural and artificial ecosystems. The principal investigations of Ukrainian space biologists have been carried out in the field of gravitational biology. For this reason, a significant number of biological experiments on board the URM are intended to verify the conceptual ideas of Ukrainian scientists in this field. New methodological approaches to performance of the space and ground-based experiments with clinostats and centrifuges are considered as well.

Experiments proposed in the field of life sciences on board the URM are arranged in accordance with divisions of the Program and are presented below.

Division 1

BIOLOGY OF A CELL UNDER MICROGRAVITY; CYTOSKELETON ARRANGEMENT, CALCIUM HOMEOSTASIS, MECHANISMS OF GRAVISENSITIVITY OF LIVING SYSTEMS AT THE CELLULAR AND MOLECULAR LEVELS («Biolaboratory» Project)

Kordyum E. L.

M. G. Kholodny Institute of Botany, NAS of Ukraine
2 Tereschenkivska St., Kyiv 01601Ukraine
tel/fax: (380) +44 +2123236, e-mail: ekord@botan.kiev.ua

Introduction. A discovery of cell gravisensitivity, including plants, has attracted attention to elucidation of the mechanisms of biological effects of microgravity at the cellular, subcellular and molecular levels and understanding how organisms grow, develop and reproduce in the absence of gravity. The conception, which consists in that proliferating and actively metabolizing cells are the most sensitive to the influence of altered gravity, has been assumed proceeding from experimental data on the changes in cell metabolism under microgravity. Simultaneously, this conception propounds the following questions. What are the primary events underlying metabolism changes under microgravity? What are the second messengers taking part in transfer of the primary signals of microgravity? Does the gene expression undergo changes in microgravity? What peculiarities of cell metabolism regulation can be present in microgravity? Why the carbohydrate and lipid metabolism is the most sensitive to the influence of microgravity? Do the parameters of a cell cycle and proliferation activity change in microgravity? How are the changes in metabolism under microgravity integrated into physiological responses in the cells of different types connected directly with realization of their functions?

Trying to provide answers to these questions, a hypothesis of gravitational decompensation was assumed. According to this hypothesis, a change in the surface tension of the cytoplasmic membrane can play an inductor role in rearrangements of its physical-chemical properties under reduction or absence of hydrostatic pressure. The effect of such an inductor increases owing to its heterogeneity over the length of the cytoplasmic membrane. In the gravitational field, the surface tension and gravitational force are summed up, if they act in the same direction and are subtracted if their directions are opposite. In the absence of gravity, only the surface tension is present (gravitational decompensation). Under the conditions of a clinostat, the resulting action of these two forces is continuously changed in each point of the membrane. The rearrangements in the physical-chemical properties of the cytoplasmic membrane underlie the changes in its permeability, receptors' functioning, membrane-bound enzyme activity. This, in its turn, leads to the subsequent metabolism changes, eventually resulting in physiological responses of cells and organisms to the influence of microgravity. New approaches concerning the ion and water transport examination under microgravity are revealed, due to the currently available data on the presence of mechanically-sensitive calcium channels and highly selective water channels (proteins-aquaporins) in the cytoplasmic membrane. Investigations of the topography of cytoskeleton elements as a supportively motive apparatus are directed to clarifying the role of cytoskeleton (tubulin microtubules and actin microfilament complexes) in cell responses to the influence of microgravity.

Comprehension of mechanisms of pathological changes in excitable cells (nervous and endocrinal) at the subcellular and molecular levels in a space flight, will contribute to a more profound understanding of rearrangements of the physiological processes, which arise in mammals under these conditions. It will also facilitate working out prophylactic recommendations and pharmacological preparations for prevention of pathological changes in human health.

A decrease in bone minerals content in astronauts during the space flight has been established, as well as a tendency to redistribution of mineral substances in the skeleton. The experiments with mammals and birds gave evidence of a reduction in the intensity of growth and osteoplastic processes in skeleton bones, as well as of a loss of bone mass and osteoporosis. So, study of structural and metabolic rearrangements in bone tissue cells, will require further examination of cytological mechanisms of gravi-dependent changes in developing and mature bone skeleton under microgravity.

Study of the influence of microgravity on the immune system of the astronauts and test animals has shown a depletion of immune cells and lowering of the general competence of the immune system. At the same time, it remains unknown, what stages of an immune response that is a complex process, are the most sensitive to microgravity. Revealing the stages of an immune response is planned to be carried out on test animals in vivo and with utilization of cell cultures in vitro.

Diverse model systems were chosen for study of the influence of microgravity at the cellular and molecular levels. Among them are the artificial phospholipid (liposomes) and biological membranes; tip-growing plant cells; photosynthetic cells and photosynthesis process; endocrine cells of different types; neurites and their growth; isolated central and peripheral neurons and their maturing; unicellular and coenobial algae; moss protonema; annual higher plants and small animals; tumor cells of plant and animal origin; proliferation and differentiation processes of transformed nervous cells induced by the nervous growth factor, as well as crown galls induced by Agrobacterium tumefaciens, processes of their induction and efficiency of anti-tumor preparations.

«Calcium-cytoskeleton» Experiment

IMPACT OF ALTERED GRAVITY ON THE CYTOSKELETON DYNAMICS AND CALCIUM HOMEOSTASIS DURING DEVELOPMENT OF GRAVIPERCEIVING AND GRAVIRESPONDING ROOT CELLS

Kordyum E. L.

M. G. Kholodny Institute of Botany, NAS of Ukraine
2 Tereschenkivska St., Kyiv 01601Ukraine
tel. /fax: (380) +44 +2123236, e-mail: ekord@botan.kiev.ua

Research on development and functioning of plant cells in altered gravity is proposed. The following objectives are to be achieved:

— to locate the cytoskeleton arrangement during development of graviperceiving (root cap) and graviresponding (epidermis and cortex) cells under altered gravity (actin, tubulin and myosin components of cytoskeleton);

— to study the calcium homeostasis in graviperceiving and graviresponding cells during their development and to define the role of calcium ions in specification of these cells;

— to establish the impact of altered gravity on the cytoskeletal protein genes expression during development of graviperceiving and gravіresponding root cells;

To met these objectives, the following methods will be applied: electron, light and fluorescent microscopy, dot and in situ hybridization techniques, immunohistochemistry and fluorescent dyes staining.

This research will be carried out for the first time. The intent is to obtain comparative characteristics of cytoskeleton arrangements in two cell lines originating from two different types of root meristem (root cap meristem and apical root meristem, accordingly). It will be important for establishment of the role of cytoskeleton in histogenesis of graviperceiving and graviresponding root sites and, consequently, in the process of gravisensing. Study of calcium homeostasis during the specification of graviperceiving and graviresponding plant cells, as well as study of expression of cytoskeleton genes will promote the definition of the signal-transducing pathway for gravity in plant roots.

«Membranes» Experiment

PHYSICAL-CHEMICAL PROPERTIES OF BIOLOGICAL MEMBRANES UNDER MICROGRAVITY

Polulyakh Yu. A.

M. G. Kholodny Institute of Botany, NAS of Ukraine
2 Tereschenkivska St., Kyiv 01601Ukraine
tel/fax: (380) + 44 +2123236, e-mail: ekord@botan.kiev.ua

Przhonska O. V.

Institute of Physics, NAS of Ukraine
46 Nauky Ave., Kyiv 03039 Ukraine
tel: (380) +44 +2656713, fax: (380) +44 +2651589, e-mail: olga@iop.kiev.ua

The experiment is aimed at performance of complex investigations of physical and chemical properties of the cytoplasmic membrane of plant cells at the molecular level under altered gravity and understanding the mechanisms supporting its microviscosity within certain limits under altered gravity, i. e., homeoviscous adaptation of plant cells to altered gravity.

The main objectives are the following:

— to develop a new method of fluorescence probes, which will allow measurement of the dynamic changes in microviscosity of the model and native biomembranes;

— to develop new highly sensitive and specific fluorescence probe-molecules for their incorporation into biomembranes;

— to develop a special and original mini-device for measuring microviscosity on board the space station;

— to work out procedures of recurrent measurement of biomembrane's microviscosity during a space flight according to a special program;

The methods of ultracentrifugation, extraction, fractionating, thin-layer chromatography, gas-liquid chromatography, and modified fluorescence probes will be used. The results obtained will promote an understanding of the physical-chemical properties of biomembranes under altered gravity, and the mechanisms of homeoviscous adaptation of plant cells to microgravity.

«Liposomes» Experiment

INFLUENCE OF MICROGRAVITY ON STRUCTURAL AND FUNCTIONAL PROPERTIES OF ARTIFICIAL PHOSPHOLIPID MEMBRANES

Borisova T. A.

O. V. Palladin Institute of Biochemistry, NAS of Ukraine
9 Leontovych St., Kyiv 01030 Ukraine
tel: (380) +44 + 2243254, fax: (380) +44 +2296365, e-mail: tborisov@paladin.biochem.kiev.ua

The main purpose of the experiment is to study the influence of microgravity on the properties of model biological membranes. Application of artificial phospholipid vesicles (liposomes) as models of biomembranes for research of lipid bilayer state is planned. Several unique advantages make liposomes a powerful experimental model to study the properties of biomembranes. Influence of gravity on the molecular mechanisms can be easily investigated in such simplified model systems as liposomes.

The liposomes to be used in the experiment will be obtained directly on board the station. The interaction of liposomes with ribosomes, process of liposome's fusion, as well as the binding of liposomes with various proteins will be studied. The fluorescent «fusion-reporting» probe — *octadecyl Rhodamine B-chloride* (R18) will be used for this purpose. This probe will be incorporated both into the membranes and ribosomes. The same experiment will be carried out under the conditions of gravity (in the ground-based laboratory).

Comparison of the results obtained in space and in the ground-based laboratories will allow selection of parameters of a quantitative nature from the wide parameter range. Results will provide a much more profound insight into the fundamental mechanisms of membrane interaction with ribosomes and proteins, as well as the membrane fusion process. The experiment will also enhance our understanding of the changes occurring in membranes during the space flight, as well as the role of gravity in the maintenance of normal cell activity.

«Messengers-1» Experiment

FUNCTIONING OF SECOND MESSENGERS (Ca^{++}-CALMODULIN, ADENYLATE CYCLASE)

Yavorska V. K.

Institute of Plant Physiology and Genetics, NAS of Ukraine
31/17 Vasylkivska St., Kyiv 01022 Ukraine
tel: (380) +44 +2635160, fax: (380) +44 +2635150

In this experiment it is planned to study adenylate cyclase system functioning under altered gravity. It is assumed that system of cAMP and Ca^{++}-homeostasis system take part in signal transduction. Following this hypothesis, the molecular mechanisms of gravity stimulus transduction into plant cell under altered gravity will be clarified.

Objects of investigation will be the seven- and eight-day old rye seedlings. The methods of thin-layer chromatography and high performance liquid chromatography, gel-chromatography, ion-exchange chromatography (DEAE-cellulose), and of affinic chromatography will be used. It is intended for the following items:

— to determine the cAMP content,

— to study PDE properties under the action of Ca^{++}-calmodulin, phytohormones and other allosteric regulators under microgravity,

— to study the mechanism of interaction of two systems of second messengers under microgravity using adenylate cyclase system modulators and Ca^{++}-metabolism antagonists.

«Messengers-2» Experiment

ROLE OF POLYPHOSPHATIDYLINOSITOLS IN SIGNAL TRANSDUCTION IN MICROGRAVITY

Kravets V. S.

Institute of Plant Physiology and Genetics, NAS of Ukraine
31/17 Vasylkivska St., Kyiv 01022 Ukraine
tel: (380) +44 + 2633108, fax: (380) +44 +2635150, e-mail: KVS@ifrg. freenet.kiev.ua

The purpose of the experiment is to clarify mechanisms by which plants perceive several environmental stimuli, especially gravity, and respond to them. It is important from this point of view to clear up the primary biochemical processes occurring with phosphatidylinositol sensor signal system under altered gravity and during the adaptation to microgravity. The metabolic changes of key components of phosphatidylinositol cycle — PI(4)P and PI(4, 5)P2, as well as changes of their hydrolyzing products content — Ins(1, 4)P2 and Ins(1, 4, 5)P3 in response to gravity will be studied, in order to determine the role of phosphatidylinositol cycle in the primary reactions of gravity perception. Changes in phospholipase mRNA in the plant cells will be also studied in microgravity.

Objects of investigations are the etiolated seedlings of wheat and maize. Use in vivo of radiolabelling, as well as thin layer chromatography, anion exchange chromatography and autoradiography is proposed.

The influence of microgravity on the milestones of phosphatidylinositol signal pathway and lipid metabolism will be established.

«Photosynthesis-1» Experiment

INFLUENCE OF MICROGRAVITY ON PHOTOSYNTHESIS PROCESS

Volovik O. I.

Institute of Plant Physiology and Genetics, NAS of Ukraine
31/17 Vasylkivska St., Kyiv 03022 Ukraine
tel: (380) +44 +2635160, fax: (380) +44 +2635150

The purpose of the experiment is to study the effects of microgravity on the efficiency of functioning of the electron transfer chain of chloroplasts and on the formation of light-stage photosynthesis products, ATP and NADPH in the chloroplasts and their accumulation in leaves of pea and barley plants. The main objectives are the following:

— to establish interrelations between the formation of ATP and NADPH and the direction of the dark carbon metabolism (14CO2 incorporation into primary photosynthesis products) and the quality of plant biomass as well;

— to compare changes of primary photoprocesses with changes in the chloroplast ultrastructure and the ratio of main pigment-protein complexes as well;

— to study peculiarities of regulation of the light photosynthesis stage at the level of separate electron transfer chain components (water-splitting complex, QB-centers, plastoquinones, cytochrome b/f complex), as well as changes in electron transfer rates and ATP synthesis induced by the phosphorylation of thylakoids membrane proteins.

The methods of polarography, spectrophotometry, bioluminescence, biochemistry, isotope and inhibitory analyses will be used.

The experiment will permit revealing the elements of the photosynthetic process, which are the most sensitive to space flight factors. Research will result in modification of the plant cultivation technology in long-term space flights.

«Photosynthesis-2» Experiment

INFLUENCE OF MICROGRAVITY ON OXYGENIC PHOTOSYNTHESIS

Zolotareva H. K.

M. G. Kholodny Institute of Botany, NAS of Ukraine
2 Tereschenkivska St., Kyiv 01601Ukraine
tel: (380) +44 + 2123231, fax: (380) +44 + 2123236, e-mail: ezol@botan.kiev.ua

The purpose of the experiment is to study the polypeptide composition, content of tightly and loosely bound manganese and calcium in OEC, as well as the role of three peripheral polypeptides with molecular masses of 33, 24 and 18 kDa in the process of oxygen evolution during cultivation of plants on board the space station.

The main objectives are the following:
— to estimate oxygen evolving activity of the PS II particles using Clark-type electrode and phenyl-p-benzoquinone as electron acceptor;
— to perform spectroscopic analysis of the PS II particles (samples will be analysed in oxidised and reduced forms);
— to carry out electrophoretic and chromatographic analysis of the polypeptide composition of the PS II;
— to determine manganese and calcium content using EPR spectrometry and fluorescent Ca probe, respectively;
— to study susceptibilities to proteinases (trypsin and chemotripsin) of two classes of the OEC manganese.

The methods of polarography, spectrophotometry, gel-electrophoresis, chromotography, EPR spectrometry will be used.

Principal result of this experiment will be the new data on peculiarities of the oxygen evolution process in microgravity.

«Ethylene» Experiment

ROLE OF ETHYLENE AND ABSCISIC ACID IN BIOLOGICAL EFFECTS OF MICROGRAVITY

Kurchii B. A.

Institute of Plant Physiology and Genetics, NAS of Ukraine
31/17 Vasylkivska St., Kyiv 03022 Ukraine
tel: (380) +44 +2635160, fax: (380) +44 +2635150, e-mail: Bogdan_Kurchii@yahoo.com

The purpose of the experiment is to study the influence of microgravity on the endogenous levels of ethylene and abscisic acid in radish, potato and onion plants during a long-term space flight. It is supposed that ethylene and abscisic acid can participate in plant responses to the action of microgravity.

Seeds of radish and onion, the onion bulbs and potato tubers will be used. Bulbs, potatoes and seeds will be germinated in the greenhouse on board the URM. Ethylene production rate will be monitored daily by taking air into flasks sealed with rubber serum caps. Ethylene concentration in flasks will be analysed by withdrawing a gas sample with a syringe and injecting it into a gas chromatograph. To determine ABA, the plant material from leaves will be collected, extracted by ethanol and stored till the end of experiment. ABA levels will be determined by HPLC. A part of these plants will be taken at the end of experiment and sent back to the ground-based laboratory for further study.

New data concerning the growth and development of plants in microgravity, in particular, the anticipated participation of ethylene and ABA in plant gravisensitivity, will be obtained.

«Meristem» Experiment

INFLUENCE OF MICROGRAVITY ON KINETICS AND NUTRITION OF PLANT MERISTEM

Grodzinsky D. M.

Institute of Cell Biology and Genetic Engineering, NAS of Ukraine
148 Zabolotny St., Kyiv 03143 Ukraine
tel: (380) +44 +2636167, fax: (380) +44 +2671050, e-mail: dmgrod@ukrpack.net

The impact of microgravity on kinetics and nutrition of meristem and reproductive ability of plants in long-term space flight will be studied.

The main objectives are as follows:

— to study patterns of distribution of assimilates and the trophic supply of meristems in altered gravity;

— to study the donor-acceptor connections in plants with C-3 & C-4 -photosynthesis in altered gravity;

— to study the structure and kinetics of root apices;

— to check a possibility of pre-adaptation of plants to long-term space flight;

— to develop modes of correction of morphogenetic abnormalities arising in altered gravity.

The methods of light microscopy, histochemistry, morphometry, photoshooting and chromatography will be used.

Study of these systems in several generations will allow to answer the questions, whether the microgravity has an effect modifying the meristem structure and kinetics, what are the effectiveness and duration of the gravitational memory, and what is the role of microgravity in supply of meristems by assimilation nutrition.

«Starch» Experiment

STRUCTURAL-METABOLIC ASPECTS OF CARBOHYDRATE METABOLISM IN MICROGRAVITY

Kordyum E. L., Nedukha O. M.

M. G. Kholodny Institute of Botany, NAS of Ukraine
2 Tereschenkivska St., 01601Kyiv Ukraine
tel/fax: (380) +44 +2123236, e-mail: ekord@botan.kiev.ua

Authors propose the use of an ideal model system (potato minitubers) to study carbohydrate metabolism in plants under altered gravity. The following objectives are defined:

— to carry out phenomenological observations of minituber formation both in control and in altered gravity; to obtain data on sizes and forms of minitubers as well as on formation rate;

— to study anatomical organisation of minitubers and ultrastructure of storage parenchyma cells;

— to determine localisation and relative content of calcium in minituber cells;

— to determine localisation and activity of selected enzymes of starch and saccharose synthesis in storage parenchyma cells;

— to study expression of some genes of starch synthesis and hydrolysis enzymes;

— to determine content and quality of starch synthesised in minitubers under the influence of altered gravity.

The methods of light and electron microscopy, cytochemistry, biochemistry and molecular biology will be used.

The obtained data will allow defining structural-functional features of storage parenchyma cell formation in potato minitubers, which is a basis for understanding the mechanisms of changes in carbohydrate metabolism under microgravity.

«Spirulina» Experiment

INFLUENCE OF MICROGRAVITY ON STRUCTURAL-FUNCTIONAL ORGANIZATION OF CYANOBACTERIA

Zolotareva H. K., Shnyukova E. I.

M. G. Kholodny Institute of Botany, NAS of Ukraine
2 Tereschenkivska St., Kyiv 01601 Ukraine
tel: (380) +44 +2123220, fax: (380) +44 +2123236, e-mail: ezol@botan.kiev.ua

The purpose of the experiment is to study the microgravity effects on growth, morphology, ultrastructure, biochemical parameters and photosynthesis of cyanobacterial cells of *Spirulina platensis* and *Nostoc linckia.* Such a research is important for understanding the carbon dioxide transport into living cell under microgravity. Cyanobacteria will be grown in the presence of different concentrations of bicarbonate. The microgravity effect on carbonic anhydrase activity will be studied, and the correlation between activity of this enzyme and growth of cyanobacteria, amount and dimensions of gas vacuoles, which are responsible for motion of cyanobacteria in gravity, will be established.

Cyanobacteria grown in space flight and in the ground control will be analysed by light and electron microscopy (trichome dimensions, degree of growth, ultrastructural changes, amount and size of gas vacuoles). Biochemical analysis will be performed by TLC and HPLC chromatography, polarography, and electrophoresis, as well as by enzymatic analysis of carbonic anhydrase activity.

The obtained results will allow understanding how microgravity affects primitive organisms of cyanobacteria. The role of gas vacuoles in gravity perception and adaptation of cyanobacteria to microgravity will be established, and the mechanism of carbon dioxide transport into living cell realized under microgravity, will be revealed.

«Polymorphism» Experiment

INFLUENCE OF MICROGRAVITY ON STRUCTURAL-FUNCTIONAL ORGANISATION OF UNICELLULAR AND COENOBIAL GREEN ALGAE

Tsarenko P. M.

M. G. Kholodny Institute of Botany, NAS of Ukraine
2 Tereschenkivska St., Kyiv 01601 Ukraine
tel: (380) +44 +2245157, fax: (380) +44 +2241064

The influence of long-term microgravity on cell structural and functional characteristics of some algae species, as well as a possibility of their usage in CELSS will be studied. The main objectives are the following:

— search of potential objects for utilization in manned space system, where algae will have a regenerative role (primarily, morphological and reproductive characteristics of algae);

— study of behaviour, structural and functional peculiarities of potential objects in altered gravity for biotechnological applications;

— study of the microgravity effects on growth and development of green algae species.

To meet these objectives, use of green algae *Scenedesmus armatus (Chod.) Chod.* and *Pediastrum boryanum (Thurp.) Menegh.* is proposed. These species of algae, which are successfully used in biotechnology, have never been studied in space. The methods of light and electron microscopy will be used.

The data obtained in this experiment will greatly enhance our knowledge in the field of theoretical and applied psychology, taxonomy, biotechnology and space botany.

«Protoplast» Experiment

INFLUENCE OF MICROGRAVITY ON DIVISION CAPABILITY AND EXPANSION GROWTH OF PLANT CELLS INVITRO

Klymchuk D. A.

M. G. Kholodny Institute of Botany, NAS of Ukraine
2 Tereschenkivska St., Kyiv 01601 Ukraine
tel/fax: (380) +44 +2123236, e-mail: ekord@botan.kiev.ua

The gravisensitivity of plant cells *in vitro* will be studied. The protoplast and culture of single cells growing in altered gravity will be the objects of experiment. The main objectives are the following:

— control of the growth and behavior of protoplasts and cultured single cells;

— study of cell proliferation and cell expansion rate, microcallus formation, genetic stability and cell differentiation;

— determination of the calcium ion concentration during cell wall regeneration by protoplasts and in microcallus cells;

— study of structural and biochemical features of a regenerating cell wall;

— study of the cytoskeleton topography in protoplasts and microcallus cells.

The methods of light, fluorescence and electron microscopy, cytochemistry, immunocytochemistry and morphometry will be used.

To meet these objectives, the simplified and inexpensive approaches are proposed. The obtained data on the influence of altered gravity on basic processes of plant cell functioning will be helpful for understanding the mechanisms of cell gravisensitivity.

«Plant Tumors» Experiment

STUDY OF MICROGRAVITY EFFECTS ON TUMOR FORMATION IN PLANTS BY THE MODEL OF CROWN GALL INDUCTION WITH AGROBACTERIUM TUMEFACIENS

Sarnatzkaya V. V.

Institute of Plant Physiology and Genetics, NAS of Ukraine
31/17 Vasylkivska St., Kyiv 03022 Ukraine
tel: (380) +44 +2635160, fax: (380) +44 +2635150

The purpose of the experiment is to study the influence of microgravity on induction and development of crown gall tumors on explants of plant storage tissue cultivated in vitro. The main objective concerns the relation between the efficiency of the process of tumor induction and cell metabolism in altered gravity (namely, the effect of modification of Ca^{++} metabolism on tumor induction, enzyme activity and pathogenesis-related protein formation). This model is also applied for screening anti-tumor preparations and for study of the mode of their action. For this reason, it is important to study the effectiveness of anti-tumor substances, which affect just the nuclei and cell membranes, under microgravity. Both normal and inoculated with Agrobacterium tumefaciens explants of Jerusalem artichoke and potato bulbs will be used as objects of this investigation.

The methods of tissue culture, evaluation of crown gall tumor induction and development, as well as cytological (investigation of mitotic and proliferative activity, cytofluorimetry) and biochemical (ion-exchange chromatography and gel-electrophoresis of proteins) methods will be applied.

«Expression» Experiment

GENE EXPRESSION IN PLANTS IN MICROGRAVITY

Prima V. I.

Institute of Molecular Biology and Genetics, NAS of Ukraine
150 Zabolotny St., Kyiv 03143 Ukraine
tel: (380) +44 +2661139, fax: (380) +44 +2660759

It is known that specific genes of many plants are to be activated by extreme factors. It allows plants to survive and to adapt to the environmental stresses. Some of these genes have already been selected and cloned. There is evidence that altered gravity acts similar to an extreme factor producing a shock effect at the cell level. It is suggested that changes in gene expression can also ensure an adaptation to microgravity.

The purpose of experiment is to examine plant tissues for the intermediates in signal transduction pathways after space flight and clinostating in comparison with unit gravity conditions. It is important also to determine the cellular content of high and low molecular weight proteins and specific RNA or RNP, which are coded by various types of stress-related genes, in particular, c-myc, c-fos, hsp 70, SOD, SAUR and ubiquitin genes. Correlation of different types of nuclear RNP (mRNP, rRNP, regulatory RNP), cytoplasmic RNP (mRNP, rRNP) and the poly(A)+RNA «spectrum» will be also studied.

The methods of purification and quantification of nucleic acids from plant seedlings, PCR technique for generation of probes for stress-related genes, DNA fractionation and agarose gel electrophoresis, Northern-blot hybridization, Western-blot hybridization and electrophoresis in polyacrilamide gels will be used to meet these objectives. Comparative analysis of results obtained during this experiment and those obtained before in flight and clinostat experiments will be done.

This integrated research will reveal interrelations between various links of the process of gravity perception, signal transduction and generation of biochemical and physiological responses of plant cells to altered gravity.

«Chaperones» Experiment

INFLUENCE OF MICROGRAVITY ON PROTEIN BIOSYNTHESIS

Kravets V. S.

Institute of Plant Physiology and Genetics, NAS of Ukraine
31/17Vasylkivska St., Kyiv 01022 Ukraine
tel: (380) +44 + 2633108, fax: (380) +44 +2635150, e-mail: KVS@ifrg. freenet.kiev.ua

The role of molecular chaperones in plant cell reactions to the action of microgravity will be studied in this experiment. It is proposed to test the hypothesis which consists in that rearrangements in protein synthesis processes at the cellular and subcellular levels in microgravity can be adaptively significant and can change the reaction of plants to other types of abiotic stresses.

Proposed experiments with plants grown in altered gravity will include identification of changes in protein synthesis by means of PAGE and immunoblot-analysis of organelle proteins. Specificity of the synthesis and transport into mitochondria and nuclei of the hsp70 and members of other molecular chaperones families at the different stages of maize caryopsis germination and seedlings development in microgravity will be also studied. This research will include an identification of molecular chaperones in different cell fractions. In view of the technical impossibility to study the protein de novo formation under space flight conditions, we intend to apply the methods of metabolic radiolabelling in the laboratory experiments only.

The data concerning the influence of altered gravity on gene expression, protein synthesis and transport of newly synthesized polypeptides to cellular compartments will be obtained.

«Lipas» Experiment

LIPID PEROXIDATION INTENSITY AND ANTIOXIDANT SYSTEM STATE IN PLANTS UNDER MICROGRAVITY

Baranenko V. V.

M. G. Kholodny Institute of Botany, NAS of Ukraine
2 Tereschenkivska St., Kyiv 01601 Ukraine
tel/fax: (380) +44 +2123236, e-mail: ekord@botan.kiev.ua

Effects of altered gravity on lipid peroxidation intensity and state of antioxidative defence system in pea seedlings will be studied. The main objectives are the following:

— to study lipid peroxidation intensity in the leaf and root homogenates of pea seedlings and in the cell compartments (chloroplasts, mitochondria and cytosolic fractions) under altered gravity;

— to study the activity of enzymatic antioxidants such as superoxide dismutase and catalase;

— to study the activity of the low molecular weight antioxidants such as glutathione and carothenoids.

The level of lipid peroxidation will be measured both in terms of malonic dialdehyde content and by chemiluminescence. An activity of enzyme and non-enzyme antioxidants will be determined by the methods of biochemistry and spectrophotometry.

The features of lipid peroxidation processes, as well as a state of the defence system in plant tissues under conditions of the real and simulated microgravity will be established. Recommendations will be worked out on enhancement of the plant resistance in space flight using the exogenous antioxidant.

«Fragmentation» Experiment

INFLUENCE OF SPACE FLIGHT FACTORS ON THE INTEGRITY AND ORGANIZATION OF NUCLEAR DNA

Sorochinsky B. V.

Institute of Cell Biology and Genetic Engineering, NAS of Ukraine
148 Zabolotnyogo St., Kyiv 03143 Ukraine
tel: (380) +44 +2661081, fax: (380) +44 +2521786, e-mail: bvs@phyto.kiev.ua

This study concerns the influence of microgravity and physical modification on plant's DNA pattern. DNA single- and double brakes will be analyzed both for embryos in seeds and for proliferative tissues of maize and pine seedlings. The material of plants will be fixed in different periods during the ISS flight for further analysis after landing. Hydroxylapatite chromatography and pulsed-field electrophoresis will be used to detect DNA damage. Obtained results will be necessary to determine genotoxicity depending on the space missions duration.

«Impulse» Experiment

INFLUENCE OF MICROGRAVITY ON THE NERVOUS SIGNAL TRANSMISSION

Himmelreich N. H., Borisova T. A.

O. V. Palladin Institute of Biochemistry, NAS of Ukraine
9 Leontovych St., Kyiv 01030 Ukraine
tel: (380) +44 +2243254, fax: (380) +44 +2296365,
e-mail: ninahimm@paladin.biochem.kiev.ua, tborisov@paladin.biochem.kiev.ua

A long-term stay under the conditions of space flight leads to the pathological changes of a wide variety of neuronal systems ranging from motor to hypothalamic function. Such changes are likely to involve both functional and morphological alterations in the brain. The underlying mechanisms are still unclear.

The objective of the proposed research is to identify the alterations in synaptic transmission characteristics, which correlate with the process of adaptation to microgravity. A comparative analysis will be performed on rats exposed to micro- and hypergravity. Special attention will be paid to the two main stages of this process, namely the excitation and neurosecretion. The effect of microgravity on the potential-dependent calcium channels and process of neurosecretion in nerve terminals will be studied. The nerve terminals (synaptosomes) used in this experiment will be purified from rat brain.

Three sets of ground-based and space-based experiments are planned: 1) analysis of the presynaptic membrane calcium permeability; 2) monitoring the cytoplasmic Ca^{2+} concentration; 3) study of uptake and release of neurotransmitters.

These studies will allow recognition of neurochemical bases for the synaptic plasticity, which accompanies CNS responses to altered gravitational environment. They will provide insight into the molecular changes, which may occur in the brain during exposure to space flight, and will advance our understanding of the role of gravity in the maintenance of normal nervous signal transmission.

«Netcells» Experiment

INFLUENCE OF MICROGRAVITY ON GROWTH, STRUCTURE, AND FUNCTIONS OF NERVOUS, ENDOCRINE AND TRANSFORMED CELLS

Kostyuk P. G.

O. O. Bogomolets Institute of Physiology, NAS of Ukraine
4 Bogomolets St., Kyiv 01024 Ukraine
tel: (380) +44 +2932909, fax: (380) +44 +2536458, e-mail: pkostyuk@serv.biph.serv.kiev.ua

The purpose of the proposed experiment is to study the cellular and molecular mechanisms of changes in functioning of the nervous and endocrinal systems, induced by long-term staying in an orbital station. The latter may be important for development of prophylactic recommendations and usage of pharmacological preparations to prevent pathological changes in human health. It is planned to use a large set of methods for testing the morphological and functional changes of excitable cells under the conditions of orbital flight. It will be possible to conduct microphotoshooting of development of either normal or transformed cells under low gravity during the flight. The detailed analysis of data, as well as comparative electrophysiological and microfluorimetric investigations of the cells, which have been exposed to space flight factors, will be conducted after space mission in a ground-based laboratory. For this ground-based experiment, the isolated cultivated cells kept under sterile conditions in a microincubator will be used, and the cells from rats, which were in the orbital station, will be tested in parallel.

The following methods will be used: cell cultivation, microphotography, computer morphometric analysis, electron microscopy, electrophysiological and electrochemical investigations.

This complex space-based and ground-based research will allow clarifying the nature of morphological and functional changes, as well as changes in development of the corresponding cells.

«Immunity» Experiment

IMMUNE RESPONSE IN MICROGRAVITY

Skok M. V.

O. V. Palladin Institute of Biochemistry, NAS of Ukraine
9 Leontovych St., Kyiv 01030 Ukraine
tel: (380) +44 +2243354, fax: (380) +44 +2296365, e-mail: skok@biochem.kiev.ua

Space flight factors, primarily, microgravity, affect all the functional systems of an organism. One of the most sensitive is the immune system.

The experiment will study microgravity effects on the immune response of test animals. Immunological approach to analysis of cellular processes occurring under microgravity will be used. The main objective is to identify the most vulnerable elements of the immune response in microgravity.

For this purpose, in the first set of experiments, it is planned to send on board the URM several groups of mice with different degrees of immunisation, and to study their immune response to the model antigens compared to control groups. Such an approach will enable following the effect of microgravity at different stages of the immune response: antigen presentation and primary recognition, germinal centre and memory cell formation, as well as secondary immune response. In the second set of experiments, the cultivable antibody-secreting cells and hybridomas will be delivered to the space station. The rate of the antibody production, as well as the proliferation processes occurring under microgravity will be studied. In addition, the blood sera of both test animals and astronauts will be examined for the presence of natural antibodies.

The modern experimental techniques, such as immunoenzyme assays and immunoblotting will be used to determine the quantity and specificity of the antibodies produced. The expected results will help to determine the exact stages of the immune response, which are the most sensitive to the effect of space flight factors.

«Oblast» Experiment

INFLUENCE OF MICROGRAVITY ON OSTEOGENESIS

Rodionova N. V.

I. I. Shmalhauzen Institute of Zoology, NAS of Ukraine
15 B. Khmelnytsky St., 01601 Kyiv Ukraine
tel: (380) +44 +2259084, fax: (380) +44 +2241569, e-mail: root@iz.freenet.kiev.ua

The purpose of the experiment is to study the cytological mechanisms of gravity-dependent changes in the developing and mature bone skeleton under the space flight conditions for devising methods to correct them. The main objectives are the following:

— to study peculiarities of proliferation, differentiation, specific functioning and metabolism of osteoblasts, osteocytes and osteoclasts, as well as their morpho-functional interactions during osteogenesis and resorption;

— to study intensity of osteoplastic and resorptive processes in bones using ultrastructural criteria worked out by the author;

— to define peculiarities of specific metabolism of the osteogenic cells (including changes in Ca^{2+}-balance);

— to study organisation of the vascular-cellular complexes in osteogenic and resorptive zones and bone compact substance;

— to establish mechanisms of correction of the osteoporotic remodelling by biphosphonates or other protectors.

Objects of investigation will be the bones of white rats or mice (3-4 weeks old), which were at the space station for 7-14 days and have been returned to the Earth. The methods of histology, electron microscopy, autoradiography (with 3H-thymidine, 3H-glycine, 45Ca), cytochemistry, osteodensitometry will be used.

Obtained data on cytological mechanisms of gravity-dependent changes in the bone tissue will be important for working out recommendations as regards their correction.

«Regeneration» Experiment

REGENERATION OF FISH DERMOSKELETON IN MICROGRAVITY

Pegueta V. P.

I. I. Shmalhauzen Institute of Zoology, NAS of Ukraine
15 B. Khmelnytskogo St., Kyiv 01601 Ukraine
tel: (380) +44 +2648406, fax: (380) +44 +2241569, e-mail: Gennady@concord.kiev.ua

The purpose of the experiment is to study the influence of microgravity on periosteal ossification in order to determine the cause of the bone calcification disturbance.

From this point of view, a study of the influence of microgravity on development of the dermoskeleton is the most important, because its bone elements (rays of fins and scales) are of periosteal origin.

A convenient object of investigation is a dermoskeleton of the small aquarium fish Poecilia reticulata. Two approaches can be used to meet this objective, namely:

— to experiment with the larvas, which have no bone skeleton yet. Study of the structure of dermoskeleton elements after landing will permit clarifying the influence of microgravity on initiation of ossification and development of dermoskeleton elements.

— to experiment with the adult fishes with partly (2/3) amputated caudal fins. A comparative analysis of the amputated part of fins and their regenerates after landing will permit to find out the influence of microgravity on periosteal ossification.

Histological, histochemical and electron-microscopy methods will be used.

Division 2

DEVELOPMENTAL BIOLOGY IN MICROGRAVITY («Greenhouse», «Biolaboratory» Projects)

Kordyum V. A.

Institute of Molecular Biology and Genetics, NAS of Ukraine
150 Zabolotny St., Kyiv 03143 Ukraine
tel/fax: (380) +44 +2662024, e-mail: alf@imbg.kiev.ua

Kordyum E. L.

M. G. Kholodny Institute of Botany, NAS of Ukraine
2 Tereschenkivska St., Kyiv 01601, Ukraine
tel/fax: (380) +44 +2123236, e-mail: ekord@botan.kiev.ua

Introduction. The currently available experimental evidence concerning the generative development of higher plants in microgravity does not provide an answer to the problem of obtaining the second and next generations of fertile plants in orbit. This issue is of paramount importance, because higher plants are an indispensable component of CELSS. The attempts to obtain the second generation of fertile higher plants in orbit, i. e., fruiting and forming viable seeds, were futile. The causes of failure could be the following: 1) disturbance of hormonal balance in plants in space flight, especially at the stage of transition to generative development; 2) lack of the optimal conditions for plant growth, first of all, aeration and water regime for the root system growth.

Therefore, development and creation of a space green-house of a new generation is absolutely necessary for growing higher plants and selection of other species of dicotyledons and monocotyledons for long-term space flight experiments. All this will enable studying the peculiarities of seed reproduction of higher plants in microgravity. The higher plants (wild and cultivates) have a different ecology and diverse types of the root system. They differ by the peculiarities of generative development, in particular, by the types of embryo- and endospermogenesis. Due to these features, the various species of higher plants will adapt to microgravity in different ways. The chief objective of experiments proposed below is to realize all the stages of generative development (budding, flowering and fruiting) for formation of viable seeds of the second and next generations in orbit.

«Seed» Experiment

INFLUENCE OF MICROGRAVITY ON VEGETATIVE AND GENERATIVE STAGES OF ONTOGENESIS AND PLANT SEED REPRODUCTION

Kordyum E. L., Popova A. F.

M. G. Kholodny Institute of Botany, NAS of Ukraine
2 Tereschenkivska St., Kyiv 01601 Ukraine
tel/fax: (380) +44 +2123236, e-mail: ekord@botan.kiev.ua

The purposes of this experiment are to study the reproductive development of annual higher plants in microgravity and to obtain a full plant cycle from seed to seed as the basis for working out the technologies of space planting for CELLS. The main objectives are as follows:

— to obtain an «embryological diagram» of annual plants in microgravity (characteristics of anther and ovule formation, micro- and macrosporogenesis, male and female gametophyte development, processes of pollination and fertilization, embryo- and endospermogenesis, the peculiarities of reserve substance accumulation during seed formation);

— to try to obtain the second generation of higher plants in microgravity. The methods of light microscopy, transmission and scanning electron microscopy, cytochemistry, and morphometric analysis will be used.

The obtained data will be important for understanding the role of gravity in plant seed reproduction system formation and for revealing the stages in plant generative development, which are the most sensitive to the influence of microgravity.

«Orchids» Experiment

INFLUENCE OF MICROGRAVITY ON GROWTH AND DEVELOPMENT OF ORCHID PLANTS

Cherevchenko T. M.

M. M. Grishko National Botanical Garden, NAS of Ukraine
1 Tymyryazevska St., Kyiv 01014 Ukraine
tel: (380) +44 +2954105, fax: (380) +44 +2952649, e-mail: cher@botanicalgarden.kiev.ua

The purpose of the experiment is to define a sensitivity of different orchid species to the microgravity effect, depending on their anatomical and morphological features and development phases to devise methods of plant cultivation in a space flight.

The main objectives are as follows:

— to study the effect of clinostating and microgravity on physiological and biological processes in plants;

— to make a comparative analysis of the anatomical structure of the leaf surface in epiphyte and terrestrial orchid species in microgravity.

— to work out the technology of plant growing in the artificial soil substitutes using the mineral nutrition balance system.

Epiphyte and terrestrial orchid species with monopodial and sympodial types of shoot system broaching and various photosynthetic types of metabolism were chosen as the experimental samples. Use of the callus cultures in the solid nutrient medium is also planned.

The integral parameters of morphological, anatomical and physiological changes in orchid species will be studied, to define the functional state of plants under clinostating and microgravity. The amino acid analyser will determine the content and composition of free aminoacids. Photosynthetic pigment content and activity of oxidising, as well as respiration enzymes will be evaluated by the methods of spectrophotometry. Biogenous element level in plant organs will be assessed by the atomic-absorptive gas analyser. Phytohormone compounds will be evaluated by the chromatography method and biotests.

Results obtained will promote development of the cultivation technology of plants with different morphological and ecological types in microgravity. The structural model for the microgravity conditions will be elaborated.

«Protonema» Experiment

GROWTH AND MORPHOGENESIS OF MOSS PROTONEMA IN MICROGRAVITY

Demkiv O. T.

Institute of Ecology of the Carpathians, NAS of Ukraine
4 Kozelnytska St., Lviv 79036 Ukraine
tel: (380) +322 +725809, fax: (380) +322 +427430, e-mail instecoc@cscd. lviv.ua

The objectives of the experiment are to study the role of gravity in realization of growth and form-developmental processes in mosses. We plan to:

— study the role of gravity in plant movements;

— study the interaction of different stimuli, i. e., endogenous (structural and genetic determination) and exogenous (light and gravity) in realization of these processes;

— select and test new systems (different moss species and mutants).

Three well-known moss species, *Ceratodon purpureus (Hedw.) Brid.*, *Pottia intermedia (Turn.) Fürnr.* and *Pohlia nutans* (Hedw.) Lindb. will be used in experiments with protonemata. The specific moss capsules *Bryum argenteum* Hedw. and *Funaria hygrometrica* Hedw. will be also used to study the role of gravity in formation of species. We intend to use microscopic analysis, measurement of gravity bending of protonemata, cytochemical analysis of α-amylase and glucose-6-phosphatedehydrogenase activity; cytofluorometrical analysis of free and membrane-bound Ca^{2+} and intracellular pH, immunofluorescent analysis of microtubule distribution, electrophoresis of multiple molecular forms of enzymes.

New data will be obtained, concerning the nature of sensing the gravi-stimulus and its transduction into growth and form-developmental processes, as well as the influence of gravity and light on complex transformation of an apical protonema cell into three-dimensional gametophore bud.

«Greenhouse» Experiment

GREENHOUSE OF MODULAR DESIGN FOR SHORT-TERM AND LONG-TERM GROWING OF HIGHER AND LOWER PLANTS

Kordyum V. A.

Institute of Molecular Biology and Genetics, NAS of Ukraine
150 Zabolotny St., Kyiv 03143 Ukraine
tel/fax: (380) +44 +2662024, e-mail: alf@imbg.kiev.ua

It is planned to manufacture the modular greenhouse of a variable configuration and sizes depending on requirements to experiments.

The modular greenhouse with the variable geometry will consist of three devices — «lower», «middle» and «upper». These devices will be functioning both as one unit and as separate units. The «lower» device will consist of the panel with joints. The trays will be connected at right angles to the panel. The replaceable modules for cultivation (hardware for growing the plants) will be placed on the trays. The units of fastening of these modules will be joined to the power and telemetry systems connectors. The number and configuration of the trays will depend on the number of experimental modules placed on them. The «middle» device will be equipped with two joined cantilevers for connection to the consoles. The power supply and telemetry lead, which come to the joints, will be placed inside the cantilevers. Each of the consoles will be equipped with two fastening units for joining the greenhouse blocks. All the power systems for the greenhouse blocks will be fastened on the lateral sides of the consoles. The greenhouse blocks will incorporate the ware for the raising. The «middle» device will be used to fulfil (monitor) various technological tasks and to prepare the planting material for the third device. The «upper» device will consist of the panel with one unit of fastening for one console with one greenhouse cell. The service lines for the greenhouse block will be placed at lateral sides of console. The technological greenhouse hardware will allow creating the green plant raising conveyer for the crew nourishment.

The modular greenhouse with the variable geometry is intended to experiment with plants and to optimise the technology of the fresh green nourishment.

«Homeostasis 1» Experiment

INFLUENCE OF HYPERGRAVITY, MICROGRAVITY AND IONIZED RADIATION ON THE STATE OF OXIDANT-ANTIOXIDANT HOMEOSTASIS OF RATS

Baraboj V. A., Zinchenko V. A.

Institute of Oncology and Radiology, Ministry for Health Protection
33/43 Lomonosova St., Kyiv 03022 Ukraine
tel: (380) +44 +2633062, fax: (380) +44 +2660198

The purpose of the experiment is to examine the activity of antioxidant (AO) systems of the organism, as well as intensity of peroxidation of lipids (POL) in organs and blood of the rats in different periods after the space flight. The complex of antioxidants containing a dietary supplement (β-carrotin, α-tokoferol, complex of catecholamines and ascorbic acid) and/or parenterally injected drugs will be used as a means for normalization of oxidant-antioxidant homeostasis of rats during a space flight.

The intent is to examine the indices of oxidant-antioxidant homeostasis in blood and organs (brain, liver, spleen, small intestine) of rats: content of TBA-active products of POL, oxidant hemolysis of erythrocytes, activity of AO-enzymes (superoxide-dismutase, catalase, glutathion-reductase), content of α-tokoferol and restored glutathione, as well as non-protein thiol groups. Impact of hypergravity on the same indices in blood and organs of rats will be studied in the ground-based laboratory.

The results of the experiment will be helpful to optimize the vital functions of astronauts during space flights.

INTERACTION OF EUKARYOTIC (PLANTS, ANIMALS, HUMAN), PROKARYOTIC (PATHOGENIC, SYMBIOTIC AND ASSOCIATED) ORGANISMS AND VIRUSES IN MICROGRAVITY; CHANGES OF MICROFLORA AND ITS PATHOGENIC PROPERTIES IN THE CABIN OF SPACE VEHICLES
(«Biolaboratory» Project)

Kordyum E. L.

M. G. Kholodny Institute of Botany, NAS of Ukraine
2 Tereschenkivska St., Kyiv 01601 Ukraine
tel. /fax: (380) +44 +2123236, e-mail: ekord@botan.kiev.ua

Introduction. Changes of interrelations of pathogenic fungi and prokaryotic organisms with eukaryotic ones under microgravity intensify the infection process. Therefore, it is necessary to clarify the mechanism of this phenomenon, i. e., possible decrease of the immunity of plants, animals and humans and/or increase of the aggression of pathogenic organisms. It will be important for prognosis of a sanitary-hygienic situation in a cabin of space vehicles and for working out methods of protection of plants and animals from different diseases. The influence of space flight factors on adenoviruses, plant viruses, pathogenic bacteria and fungi, phage induction in plant bacterial diseases, level of spontaneous induction of temporal viruses and their genome expression, development of pathogenic processes, will be also studied in the experiments proposed in this division of the Program.

«Virus» Experiment

INFLUENCE OF SPACE FLIGHT FACTORS ON DNA AND RNA GENOMIC VIRUSES AND THE «VIRUS — CELL» SYSTEM

Dyachenko N. S.

D. K. Zabolotny Institute of Microbiology and Virology, NAS of Ukraine
154 Zabolotny St., Kyiv 03143 Ukraine
tel: (380) +44 +2666168, fax: (380) +44 +2662379,
e-mail: dyachenko@serv. imv.kiev.ua povnitsa@mail. ru

The purpose of the experiment is to study the influence of space flight factors on viruses and their interaction with cells. The main objectives are as follows:

— to study the influence of the space flight factors on the biological properties, structure, antigenic composition and infection of viruses;

— to study the influence of microgravity on the «virus-cell» system: reproduction of adenoviruses (AD) in cells (epithelium cells and lymphocytes) and reproduction of Curly Potato Dwarf Virus (CPDV) in plants after space flight.

Why shall we use AD and CPDV as objects of study? AD have some unique properties and a wide spectrum of pathogenicity at the cellular and organism levels. AD are widely spread pathogens for human. They have such biological features as a capacity to be in the latent state, to infect the lymphocytes and to suppress the immunity. CPDV belongs to the family of rhabdoviruses, which unites some viruses of human, animals and plants.

The methods of virology and molecular biology will be applied.

«Resistance» Experiment

PHYTOVIRUSES AND VIRUS-INFECTED PLANTS (WHEAT, TOBACCO) UNDER MICROGRAVITY

Boyko A. L., Mischenko L. T.

Taras Shevchenko National Kyiv University
64 Volodymyrska St., 01033 Kyiv, Ukraine
tel: (380) +44 +2669668

The purpose of the experiment is to study how the factors of space flight affect healthy and virus-infected wheat plants.

The main objectives are the following:

— to study viral reproduction and properties of viruses in the leaves of wheat;

— to study ultrastructural, physiological and biochemical characteristics of healthy and infected plants (photosynthetic pigments; photochemical activity of chloroplasts; content of the main macro- and microelements, carbohydrates and dried substance; morphometry);

— to study the features of a tobacco mosaic virus (TMV);

— to determine the presence of the other latent viruses.

The immune-enzymic and immune-fluorescent methods, as well as the methods of atomic-adsorptive analyses, spectrophotometry, light and electron microscopy and morphometry will be used.

It is planned to create a database on physiological and ultrastructural features of cells of healthy and virus-infected plants in microgravity. Revealed features of the mechanism of interaction of the «plant cell-virus» system will be used to increase the resistance of plants to viral infections and to improve life-support systems in space flights.

«Bacteriophage» Experiment

VIRUSES OF PHYTOPATHOGENIC BACTERIA (BACTERIOPHAGES) IN MICROGRAVITY

Gvozdyak R. I.

D. K. Zabolotny Institute of Microbiology and Virology, NAS of Ukraine
154 Zabolotny St., Kyiv 03143 Ukraine
tel: (380) +44 +2665578, fax: (380) +44 +2662379, e-mail: root@phyto. imv.kiev.ua

Most of all the bacterial cultures are infected by phages. The phage DNA is incorporated in the DNA of a bacterial cell. Prophage is released from a cell as mature phage particles under the influence of various natural and chemical factors. There is evidence that a plant can act as an inductor of prophage transformation in viruses of bacteria. From this point of view, the purpose of the experiment is to study the interaction between macro- and microorganisms under extreme conditions of space flight.

The main objectives are as follows:

— to select the test-cultures of bacteria for revealing the lytic agents;

— to reveal the bacteriolitic agents in the struck tissues of plants;

— to extract phages in the lytic agents;

— to study an impact of phages on phytopathogenic, relative pathogenic and saprophytic microflora.

The classical methods of microbiology and virology will be used.

This integrated ground-based and space flight experiment will enable revealing new interrelations between bacteria and phages in the presence of plants, as well as a role of phages in infection process of plants.

«Pathogen-1» Experiment

AGGRESSION OF PATHOGENIC BACTERIA IN MICROGRAVITY

Gvozdyak R. I.

D. K. Zabolotny Institute of Microbiology and Virology, NAS of Ukraine
154 Zabolotny St., Kyiv 03143 Ukraine
tel: (380) +44 +2665578, fax: (380) +44 +2662379, e-mail: root@phyto. imv.kiev.ua

Considering that aggressiveness of bacterial populations depends on many factors of bacteria habitat, it is planned to study the influence of space flight factors on aggressiveness of the pathogen bacterium population.

The main objectives are as follows:
— to select the struck plants;
— to identify activators of diseases of plants;
— to identify phytopathogenic isolates;
— to select plants-indicators to establish pathogenicity of bacterial isolates;
— to study the aggressiveness of both the bacterial populations, which cause the given diseases, and the pathogenic strains clones.

The classical methods of microbiology and plant pathology will be used.

Obtained data will enrich our knowledge on the mechanisms of changes in aggressiveness and pathogenicity of the microbial populations. These data will enable working out the methods of restriction of development of plant diseases not only in space flight but also on Earth.

«Pathogen-2» Experiment

AGGRESSION OF XANTHOMONASCAMPESTRISIN MICROGRAVITY

Nedukha O. M.

M. G. Kholodny Institute of Botany, NAS of Ukraine
2 Tereschenkivska St., Kyiv 01601 Ukraine
tel/fax: (380) +44 +2123236, e-mail: ekord@botan.kiev.ua

The purpose of the experiment is to study the influence of microgravity on rice plants infected with *Xanthomonas campestris* [1, 2].

The main objectives are as follows:
— to study the ultrastructure of epidermal, xylem and mesophyll cells of rice plants infected with *X. campestris*;
— to determine a relative content of callose and cellulose in cell walls of leaf tissues;
— to study the Ca^{2+} localisation and its relative content in plant cells;
— to study activity and localisation of peroxidase and 1, 3-β-glucanase in plant cells.

The methods of light microscopy, electron microscopy, cytospectrophotometry, immunocytochemistry and molecular biology will be used.

The responses of induced defence of rice plants infected with *X. campestris* will be established at the tissue, cellular and molecular levels, in order to understand the mechanisms of interactions of a plant cell and pathogen in microgravity.

References:

1. Guo A., Leach J. // Phytopathology.—1989.—79, N 4.—P. 433—436.
2. Chambers A., Ryba-White M., Hilaire E., et al. // Gravitational and Space Biol. Bulletin.—1998.—12, N 1.—P. 19.

«Induction» Experiment

INFLUENCE OF MICROGRAVITY ON THE LYSOGENIC CYANOBACTERIA

Mendzhul M. I.

D. K. Zabolotny Institute of Microbiology and Virology, NAS of Ukraine
154 Zabolotny St., Kyiv 03143 Ukraine
tel: (380) +44 +2662309, fax: (380) +44 +2662379

The purpose of the experiment is to study the influence of microgravity at the level of prophage induction and peculiarities of their lytic development in lysogenic cyanobacterium culture. The main objectives are as follows:

— to study the influence of standard and space flight factors on growth characteristics of the lysogenic culture and level of prophage induction;

— to carry out analysis of physical-chemical properties of virus particles and DNA of induced prophages, as well as molecular-biological characteristics of their excision.

The cloned lysogenic culture of filamentous cyanobacterium *Plectonema boryanum* CALU 465 and the test culture will be used as a model for determination of the level of induction and accumulation of virus particles.

The methods of molecular virology will be applied, e. g., the electron microscopic analysis of morphology of virus particles, determination of kinetic and thermodynamic parameters of adsorption, physical-chemical characteristic of virions, polymorphism of restriction fragments length, genome hybridization, HPLC-analysis of the modified bases, creation of data bases and statistical data processing.

Obtained results will be a basis to develop the general concept for evaluation of reliability of a system of stabilisation of the intergenomic virus — host cell interactions for a wide range of living systems.

«Gentrans» Experiment

EXCHANGE OF GENETIC INFORMATION BETWEEN BACTERIA IN MICROBIOCENOSIS UNDER MICROGRAVITY

Kozyrovska N. A.

Institute of Molecular Biology and Genetics, NAS of Ukraine
150 Zabolotny St., Kyiv 03143 Ukraine
tel: (380) +44 +2665596, fax: (380) +44 +2660759, e-mail: kozyr@imbg.kiev.ua

The purpose of the experiment is to study the exchange of genetic material between bacteria in microbiocenosis during space flights. The endophytic bacteria have a set of beneficial properties for plants, e. g., nitrogen fixation, phytohormone production, etc. They will be genetically modified and applied to simulate the exchange of genetic information between them and recipients during interaction with plants in space- and ground-based experiments.

The objectives are the following:

— monitoring of genetically modified bacteria (GMB) in microcosm system;

— study of the influence of microgravity on plant — bacteria interrelations in flight;

— study of the mechanism of endophytes penetration into the plant root tissue;

— design of devices needed for seed inoculation and bacteria cultivation in space flight.

Obtained results will allow elaboration of a predictive model of genetic material transfer between bacteria, as well as a model of GMB spreading in the microcosm during the space flights.

USE OF THE MAGNETIC FIELD TO STUDYTHE PLANT GRAVIPERCEPTIVE APPARATUS («Greenhouse» Project)

Kordyum V. A.

Institute of Molecular Biology and Genetics, NAS of Ukraine
150 Zabolotny St., 252143 Kyiv, Ukraine
tel/fax: (380) +44 +2662024, e-mail: alf@imbg.kiev.ua

«Gradient» Experiment

EFFECT OF THE GRADIENT MAGNETIC FIELD ON PLANTS UNDER THE CONDITIONS OF THE GRAVITATIONAL FIELD WEAKENING

Bogatina N. I.

Special Research and Development Bureau for Cryogenic Technologies
of the B. I. Verkin Institute for Low Temperature Physics and Engineering, NAS of Ukraine
47 Lenin Ave., Kharkiv 61164 Ukraine
Tel/fax: (380) +572 +322293, e-mail: sktb@ilt.kharkov.ua

Kordyum E. L.

M. G. Kholodny Institute of Botany, NAS of Ukraine
2 Tereschenkivska St., Kyiv 01601, Ukraine
tel. /fax: (380) +44 +2123236, e-mail: ekord@botan.kiev.ua

A universal mechanism of the influence of the magnetic, electric and gravitational fields on biological objects was suggested by one of the authors [1].

The following evidences were taken into account to develop a model. As each of these fields produces the ion concentration gradient, they affect the ion permeability of membranes in the same way. The change in the ion concentration is equal to 10^{-10} — 10^{-11} of the initial value, i. e., it is negligible due to the negligibility of the magnitude of these fields. It is known, however, that even such slight changes could result in changes of the ion transport through the membrane and changes of growth rate of plants as well. Calculations carried out by such a model [1] were in fairly good agreement with the experimental evidence on the threshold values for all the three fields. So, we advanced a hypothesis that substitution of an absent field (for example, the gravitational field) by another field (for example, the magnetic field) may compensate a negative effect of the absence of gravity on plants during the space flight.

We have carried out a set of ground-based experiments concerning the effect of a gradient magnetic field on the growth rate and root orientation of wheat seedlings under simulated microgravity.

The following valid results were obtained:

— Weakening of the magnetic field induction to the level of $2 \cdot 10^{-3}$ T increases the growth inhibition caused by weakening of the gravitational field.

— The gradient magnetic field with magnetic induction of about 10^{-3} T and the gradient magnetic induction of about $2 \cdot 10^{-2}$ T/m, could partially compensate the negative effects caused by simulated microgravity.

— The magnitotropism of the wheat roots is observed only under the conditions of weakening of the gravitational field.

We have applied two methods of simulated microgravity, namely, sprouting of plants in the water and rotation of plants on the clinostate. Neither of the methods resulted in complete weightlessness of all the parts of the plant simultaneously. Therefore, no conclusions can be made so far either on the possibility of compensation of the absence of gravity by means of a gradient magnetic field, or on the mechanism of its influence. For this reason, we are planning to carry out the same experiments under the actual microgravity conditions on board the space station at the acceleration level below the threshold value, i. e. $10^{-5}g$.

References:

1. Bogatina N. I. // Electronnaya obrabotka materialov.—1986.—N 1.—P. 64.

«Magnet» Experiment

USE OF THE MAGNETIC FIELD FOR EVALUATION OF THE PLANT GRAVIPERCEPTIVE APPARATUS AND FOR COMPENSATION OF THE ABSENCE OF THE VECTOR OF GRAVITY

Kondrachuk A. V.

Institute of Physics, NAS of Ukraine
46 Nauka Ave., Kyiv 03039 Ukraine
tel: (380) +44 +2650823, fax: (380) +44 +2651589

Belyavskaya N. A.

M. G. Kholodny Institute of Botany, NAS of Ukraine
2 Tereschenkivska St., Kyiv 01601 Ukraine
tel/fax: (380) +44 +2123236

It is suggested that the influence of the high-gradient magnetic field (HGMF) on a plant is determined by the displacement of starch statoliths in the statocytes by ponderomotive forces generated by HGMF. For this reason, it is highly useful to implement the HGMF for study and simulation of the root gravitropic response in microgravity.

The purpose of the experiment is to study the role of statolithic and non-statolithic mechanisms in gravisensitivity of higher plants. The purposeful stimulation of statocytes by HGMF under gravity (1*g*) and microgravity will be applied.

The main objectives are as follows:

— to develop the optimal HGMF configurations with the uniform spatial distribution of the high-intensity ponderomotive force;

— to study mechanisms of the gravitropic response using the HGMF effects;

— to design equipment for HGMF application to stimulate gravisensitive cells in microgravity.

It is proposed to use the graviresponsive primary roots of cress and pea as convenient objects for such a study. The following indices, which are affected by the HGMF, will be analysed by various methods, including the electron microscopy and electron cytochemistry:

— dynamics of root curvatures and root elongation;

— spatial distribution of pH along the roots;

— topography of cellular organelles;

— distribution of calcium ions.

The data on the ultrastructural changes in statocytes and their interrelation with calcium balance in HGMF under microgravity will be obtained. It will allow checking the statolith and non-statolith mechanisms of graviperception in higher plants and the signal role of calcium in statocytes. These data will be also useful to design equipment for HGMF application for stimulation of gravisensitive cells in microgravity and for simulation of the microgravity effects in these cells during ground-based experiments.

WORKING OUT SPACE CELL BIOTECHNOLOGY, THE METHODS OF SPACE PLANTING, WASTE UTILIZATION, AND EQUIPMENT MONITORING
(«Biolaboratory», «Biomedcontrol» Projects)

Kordyum E. L.

M. G. Kholodny Institute of Botany, NAS of Ukraine
2 Tereschenkivska St., Kyiv 01601 Ukraine
tel/fax: (380) +44 +2123236, e-mail: ekord@botan.kiev.ua

Korkushko O. V.

Institute of Gerontology of the AMS of Ukraine
67 Vyshgorodska St., Kyiv 04114 Ukraine
tel: (380) +44 +4304068, fax: (380) +44 +4329956

Introduction. Space biotechnology is one of the promising fields of space technology. The unique conditions of microgravity open up a prospect for obtaining a better separation of cell and biologically active substances, as well as growing protein crystals and other biopolymers. However, manufacturing biopolymer crystals in orbit is the only short-term practical benefit, which may be derived from space biotechnology. All the other areas require profound basic research carried out in close cooperation of biologists, mathematicians and designers.

Having an experience of performance of biotechnological experiments at Salyut and Mir orbital stations, Ukrainian scientists propose new basic and applied research for experiments on board the URM.

In order to meet some priority objectives of CELSS creation, Ukrainian scientists propose the following:

— working out space technologies for alga cultivation on orbit;

— selection and testing of inert organic and mineral materials with different additives of bioactive compounds and fertilizers with a prolonged effect, as substrates for plant growing in space;

— use of oligochaetae (Californian worm) for food waste utilization;

— use of daphnia as a biotest for control of general toxicity and mutageneity of the environment, in particular, water and air in a cabin of space vehicles.

«Daphnia» Experiment

DAPHNIA AS BIOTEST ON GENERAL TOXITY AND MUTAGENEITY OF ENVIRONMENT IN SPACE VEHICLES

Moiseenko K. Ya.

Institute of Management Problems and Ecology, NAS of Ukraine
6 Moskovska St., Dnipropetrovsk 49000 Ukraine
tel: (380) +56 +7785920, fax: (380) +56 +7447192

The purpose of the experiment is to create a system for biological control over total toxicity and mutageneity of the environment in space vehicles. The main objective is to develop a semi-automatic device for daphnia-biotest. The device output will be connected to a computer for estimation of the total toxicity and mutageneity of the environment inside space vehicles under the influence of microgravity and high-energy radiation.

Drinking and service water, aero- and gaseous mixtures, food-stuffs, beverages, bioactive substances reproduced and manufactured under microgravity and cosmic radiation, and unknown compounds will be tested in the experiment.

An express method of instrumentation application for estimation of the total toxicity of the samples and the environment will be worked out. The essence of our approach lies in the use of daphnia metabolism changes in response to the influence of deleterious substances dissolved in water. The basic idea of the method is to register the chemiluminescence of exometabolites in daphnia's habitat, which is altered under the influence of the above changes. The mutagenic changes of daphnia (changes of eggs, hereditary traits transmitted to offspring) will be estimated visually.

The obtained results will allow identifying the presence and nature of toxicants in the tested objects, as well as their activity compared to the standard.

«Utilization» Experiment

INFLUENCE OF MICROGRAVITY ON THE PHYSIOLOGICAL STATE AND REPRODUCTIVE ABILITY OF OLIGOCHETAE

Evtushenko N. Yu.

Institute of Hydrobiology, NAS of Ukraine
12 Heroev Stalingrada Ave., Kyiv 04210 Ukraine
tel: (380) +44 +4183565, fax: (380) +44 +4182232

The main objectives of the experiment are as follows:

— to study the nature of metabolism in invertebrates (hybrid red californian worm) in microgravity;
— to study reproductive ability of oligochetae in microgravity,
— to evaluate the influence of space flight factors on the resistance of oligochetae and efficiency of food utilization.

The level of plastic metabolism is evaluated by the contents of total proteins, lipids, carbohydrates (glycogen), nucleic acids (DNA and RNA) and their ratio in worm tissues. Contents of adenine nucleotides and activity of appropriate enzymes in worm tissues will allow determining the level of energy-related metabolic processes. The mineral exchange will be evaluated by studying the accumulation of macro- and microelements in worm tissues. The adaptation and resistance of worms will be assessed during investigation of the free radical processes, dienic conjugate concentration, lipid hydroperoxides, and malonic dialdehyde in mitochondrial fractions of worm tissues. Reproductive ability will be estimated by counting the quantity of adults, young specimens and cocoons. Changes in the chemical structure of a substratum will be studied by recording the concentrations of protein, crude fat, cellulose, ash, macro- and microelements.

Data obtained will allow a physiological state of worms to be evaluated. This, in its turn, will provide new theoretical knowledge of the mechanisms of biological influence of microgravity on invertebrates, as well as on the adaptability and reproductive ability of invertebrates for CELSS.

«Sensor» Experiment

APPLICATION OF THIN-FILM SENSORS IN SPACE BIOLOGICAL EXPERIMENTS

Vojtovich I. D.

V. M. Glushkov Institute of Cybernetics, NAS of Ukraine
40 Academika Glushkova Ave., Kyiv-187, 03680 Ukraine
tel: (380) +44 +2660128, fax: (380) +44 +2663348

The main objectives of the experiment are the following:

— development and manufacture of monitoring systems based on the thin-film sensors;
— development and manufacture of chambers for ecobiosystems, which will be equipped with monitoring systems functioning in microgravity.

The experiment will include a study of thin-film resistance thermometers based on the high-purity films, as well as a study of gaseous sensors based on the thin-film technology. The proposed electronic and program support of the sensor complex provides a means for «operator — monitoring system» dialogue, as well as data processing and displaying.

Application of monitoring systems, which are based on the thin-film sensors, will be one of the methods of monitoring and maintaining the optimal environmental parameters during the technological and biological experiments on board the space station.

«Biosorbent» Experiment

BIOSPECIFIC CARBON SORBENTS AND THEIR APPLICATION FOR MEDICINE AND BIOTECHNOLOGY

Bakalinskaya O. N.

Institute for Sorption and Problems of Endoecology, NAS of Ukraine
13 Generala Naumova St., Kyiv 03164 Ukraine
tel: (380) +44 +4529325, fax: (380) +44 +4529327

The purpose of the experiment is to study the degree of affinity of biospecific sorbents on the base of granular and filament carbon matrices.

The main objective is to study the affinity of a set of sorbents for evaluation of their effectiveness against antibodies, free haemoglobin, and lipoproteins from biologic fluids (blood plasma, blood replacements, and model liquids).

These results will form the base of a new treatment procedure of the efferent type, namely, extracorporal detoxification of patients after long-term space flight (raising the titre of IgG, free haemoglobin, lipoproteins of low density, etc.).

The results could be used in biotechnology for affine isolation of biological substances under microgravity. The «affine sorbent — biological liquid» systems will be studied in microcolumn flow experiment both in gravity and microgravity. The kinetic study of titre variation of metabolites in the liquid phase will be carried out.

«Biomineralisation» Experiment

MICROALGA BIOMINERALISATION UNDER MICROGRAVITY

Estrela-Liopis V. R.

F. D. Ovcharenko Institute of Biocolloid Chemistry, NAS of Ukraine
42 Akademik Vernadsky Ave., Kyiv 03142 Ukraine
tel/fax: (380) +44 +4448078

Popova A. F.

M. G. Kholodny Institute of Botany, NAS of Ukraine
2 Tereschenkivska St., Kyiv 01601 Ukraine
tel/fax: (380) +44 +2123236

The purpose of the experiment is to study the effect of microgravity on microalga biomineralisation phenomena in processes related to the metal ion transformation in two ways, namely by exobiopolymers during crystal formation and by the cell itself in the course of transport and assimilation of metal ions — microelements of nutritional medium in autotrophic and heterotrophic regimes.

The main objective is to study microgravity effects on the following processes:

— monocrystal synthesis (for example, gold and platinum) with application of water soluble biopolymers — exopolysaccharides of microalgae *Chorella vulgaris*, strain LARG-3, as reducers;

— alteration of cytoplasmic membrane configuration in the course of microalga growth and development on a space station in altered gravity.

The absence of gravitational convection in microgravity results in unlimited growth (without mixing) of diffusion layer of microalga cells exometabolites and, probably, in diffusion restrictions on microelement transport to a cell. This hypothesis will be checked in experiment.

The methods of electron microscopy and X-ray diffraction will be used.

Results obtained will allow recommending new biotechnological methods of perfect monocrystal synthesis in microgravity.

PREBIOTIC SYNTHESIS IN OPEN SPACE AND EXOBIOLOGY («Biolaboratory» Project)

Kordyum E. L.

M. G. Kholodny Institute of Botany, NAS of Ukraine
2 Tereschenkivska St., Kyiv 01601 Ukraine
tel/fax: (380) +44 +2123236, e-mail: ekord@botan.kiev.ua

Introduction. It is known that proteins, which were formed from amino acid remnants, are the chemical basis of all the known life forms. The origin of amino acid on Earth is elucidated by model experiments and analysis of natural objects of terrestrial (volcanic samples) and cosmic origin (meteorites, Lunar and Martian rocks). However, the issue of the mechanisms of abiogenic origin of peptide and protein molecules is still debatable and cannot be solved without performing preliminary model experiments and analysis of organic compounds by special oversensitive methods.

Experiments proposed on board the ISS contemplate:

— establishment of cardinal paths of abiotic transformations of proteinogenic amino acids adsorbed on the surface of highly-dispersed silicon as a model of cosmic dust;

— study of possible modes of peptide bond formation under the influence of outer space factors and further verification of the established regularities.

It is a known fact that organisms being in active physiological state do not survive in outer space. Proposed experiments will allow studying the protective capabilities of organisms against solar radiation outside the ozone layer. Utilization of lichens in experiments in outer space will be a new approach to this problem.

«Biomolecules» Experiment

STUDY OF PREBIOTIC SYNTHESIS IN OUTER SPACE CONDITIONS

Pokrovsky V. A.

Institute for Surface Chemistry, NAS of Ukraine
31 Nauky Ave., Kyiv 01028 Ukraine
tel/fax: (380) +44 +2686871

It is known that cosmic dust microparticles could have an important role in the origin of life on Earth. As one of the models of organic substances origin in outer space, we propose studying the intermolecular mechanism of proteinogenic amino acids interaction in the surface layer of superfine silica, resulting in peptide bond formation.

The intent is to establish the cardinal pathways of abiotic transformations of proteinogenic amino acids on an inorganic surface and possible ways of peptide bond formation under the effect of specific factors of outer space.

We will apply the methods of mass spectrometry, IR-spectroscopy and liquid chromatography to identify the products obtained. Sample analysis will be carried out by mass spectrometric recording of volatile products during temperature-programmed desorption. Non-isothermal methods will be also applied for evaluation of the energy of activation and pre-exponential factor for heterogeneous surface reactions, causing peptide bond formation.

«Lichens» Experiment

PROTECTIVE PROPERTIES OF FUNGUS STRUCTURES (LICHEN) IN OUTER SPACE

Kondratyuk S. Ya.

M. G. Kholodny Institute of Botany, NAS of Ukraine
2 Tereschenkivska St., Kyiv 01601Ukraine
tel: (380) +44 +2254041, fax: (380) +44 +2241064

The purpose of experiment is to study protective features of the unique live organism-systems, namely the lichens, under the conditions of outer space. Lichens as an extremely ancient historical formations, could open up a new era for study of direct influence of outer space factors on live tissues.

Lichens are a unique biological group formed by two or three (seldom four) components — fungi, algae and cyanobacteria. Their unique nature allows them to survive in an environment, which is hostile to other forms of life.

Experiments proposed are of great importance for basic research of the resistance of various plants and fungi in the natural (non-extreme) conditions of ancient epochs. These experiments are also of applied importance for the problem of a survival of the live organisms under the conditions of the global changes on Earth, e. g. changes of the ozone layer.

Obtained data will allow selecting the most protective structures of the cortical layers of lichens, which are characterized by the highest tolerance to extreme solar radiation.

LIFE SPAN AND AGING IN MICROGRAVITY
(«Zoomodule» Project)

Frolkis V. V.

«Ageing» Experiment

GRAVITY EFFECTS DURING SPACE FLIGHTS UPON AGING AND LONGEVITY OF THE LIVING ORGANISMS: MODELING THE GRAVITY OF SOLAR SYSTEM PLANETS

Frolkis V. V., Muradjan Kh. K.

Institute of Gerontology of the AMS of Ukraine
67 Vyschgorodska St., Kyiv 04114 Ukraine
tel: (380) +44 +4304068, fax: (380) +44 +4329956, e-mail: direct@geront.freenet.kiev.ua

In long-term space flights, e. g. interplanetary ones, the issues pertaining to their influence on living organism's ageing and longevity acquire a special importance. It will ultimately determine the duration of manned mission to other planets. There are also other gravity effects during space flights. First of all, an astronaut is exposed to considerable hypergravity during the launch of a space vehicle. Secondly, an astronaut is exposed to microgravity in a prolonged space flight.

All this has led to an attempt to study the gravity effects on the living organisms. Some of these values of gravity may be identical to those that may be encountered during the planned interplanetary flights. In this experiment, for the first time we propose to study the gravity effects, which are peculiar to all planets of the Solar system, on the longevity of the terrestrial organisms.

To meet this major objective, we are planning to stow a centrifuge of a certain diameter inside the URM. Depending on placement relative to the center of this centrifuge, the test animals will be exposed to different values of gravitational acceleration. In addition, the emerging gravity will simulate the gravitational forces of all the Solar system planets.

The best objects for this research are laboratory animals, namely the female and male drosophilas, as well as mice. We will examine the following parameters: mortality rates and longevity, sexual and physical activity, intensity of oxygen consumption, as well as a number of biochemical indices.

Results are anticipated to allow evaluation of various gravity effects on aging and longevity of the living organisms. This will further permit prediction of the consequences of changes that may develop in the organism during the interplanetary flights.

SPACE MEDICINE
(«Biomedcontrol» Project)

Korkushko O. V.

Institute of Gerontology of the AMS of Ukraine
67 Vyshgorodska St., Kyiv 04114 Ukraine
tel: (380) +44 +4304068, fax: (380) +44 +4329956

Introduction. The long-term flights in outer space and the further interplanetary missions pose the problems of space medicine as the principal issues. Some of these problems are:

— to elaborate telemetric methods allowing evaluation of the organism functional state and its adaptation to the influence of space flight factors;

— to study the peculiarities of development of regulatory deviations and pathological states in microgravity using test models and members of a crew;

— to study the peculiarities of pharmacological drugs under space flight conditions;

— to work out prophylactic countermeasures and treatment of a pathological state caused by long-term stay in space;

— to perform long-term research for evaluation of the biological age and dynamics of health state of space mission participants.

— to study the influence of space flight on aging tempos and development of age pathology;

— to provide the psycho-physiological monitoring of the astronauts' working capacity and to create an onboard system for performance of such a monitoring in a space flight. Specal attention will be given to study of the influence of micro- and hypergravity, as well as hypodynamism on the state of microcirculatory system and rheological properties of astronauts' blood, regulation of thrombus formation and thrombolysis, as well as to elaboration of measures to correct the possible disturbances in the studied systems, which cause the pathological processes and, as a result, a faster ageing of the astronauts.

The current system includes individual adaptive models of astronaut's working capacity and evaluation of astronaut's pre-flight state.

«Biominerals» Experiment

MECHANISMS OF PROPERTY CHANGES OF BIOMINERALS IN MICROGRAVITY AND METHODS FOR REDUCTION OF BONE DEMINERALISATION IN A SPACE FLIGHT

Vozianov A. F.

Institute of Urology and Nephrology of the AMS of Ukraine
9A Kotzubynsky St., Kyiv 04053 Ukraine
tel: (380) +44 +2166731

Brik A. B.

Institute of Geochemistry, Mineralogy and Ore Formation, NAS of Ukraine
34 Palladin Ave., Kyiv-142, 03680 Ukraine
tel: (380) +44 +4441570, fax: (380) +44 + 4441270

Solution of bone demineralization problem is impossible without development of new methods and emergence of new scientific ideas.

We propose new methods for reduction of bone demineralization processes and decrease of bone mass loss in a space flight. To study biominerals, we have introduced a notion of the «mineral-organic nano-associated» (MONA) systems. These systems have some special features. The important feature of the MONA systems is their capability of creating the nano-dimensional piezoelectric effect (NPE). Due to NPE, mechanical stress causes a gradient of electric charges in biominerals. The electric forces, induced by mechanical pressure, control the ion diffusion in the mineral component of biominerals. The efficiency of mechanical-electrical mechanism of diffusion is decreased under microgravity that leads to bone demineralization.

Human and rat bones will be used in the ground-based experiments. We will apply the methods of electron paramagnetic resonance, nuclear magnetic resonance, electron nuclear double resonance, as well as other methods. The intent is to implant special paramagnetic markers in the rat bones and to expose these animals to various external influence, including the immobilization, centrifugation, electric and acoustic fields. We will also control rats with paramagnetic markers in their bones during the flight experiments. Study of the markers after returning the rats to Earth should provide new data about bone demineralization processes in micro-gravity.

«Osteoprotection» Experiment

SKELETAL EFFECTS OF MICROGRAVITY AND PROTECTOR EFFECTS OF INTERMITTENT GASEOUS MIXTURES WITH LOW OXYGEN CONTENT ON OSTOPENIA

Berezovsky V. A.

O. O. Bogomoletz Institute of Physiology, NAS of Ukraine
4 Bogomolets St., Kyiv 01024 Ukraine
State Research and Development Medical-Engineering Center «NORT», NAS of Ukraine
45 Vasylkivska St., Kyiv 03039 Ukraine
tel/fax: (380) +44 +2562477, e-mail: vadber@serv. biph.kiev.ua

The aim of experiment is to evaluate skeletal effects of weightlessness and to study preventive and corrective effects of gaseous mixtures with low oxygen content on weightlessness-induced osteopenia;

The principal objectives are the following:

— to carry out the structure analysis of crystalline framework of animal bones (both trabecular and compact ones) before and after mechanical unloading and weightlessness;

— to study the influence of weightlessness on strength of the trabecular and compact bone (by microstrength measurement);

— to study the influence of weightlessness on electric and dielectric properties of long tubular bones of animals;

— to study the influence of weightlessness on mineral and organic components of animal bones (both trabecular and compact bone tissues);

— to assess preventive and corrective effects of intermittent gaseous mixtures on osteopenia generated by exposure to natural weightlessness.

Objects of this study are the tubular and trabecular bones of adult Wistar rats. Biochemical determination of bone remodelling, calorimetric determination of calcium and phosphorus in bone and blood will be performed. A gas-mixtures generator will be used, which is based on «molecular sieves» principle, i. e., on physical-chemical separation of ambient air components by passing them through polymer capillary gas-separation modules.

It is assumed that application of gaseous mixtures with low oxygen content in weightlessness may prevent weightlessness-induced osteopenia.

«Telediagnostics» Experiment

STUDY OF THE INFLUENCE OF IONIZING RADIATION AND OTHER SPACE FACTORS ON A HUMAN ORGANISM BY TELEMEDICINE AND COMPUTER DIAGNOSTIC TECHNIQUE

Cheban A. K.

Ukrainian Research Center for Radiation Medicine, AMS of Ukraine
53 Melnikov St., Kyiv 04050 Ukraine
tel: (380) +44 +2130637

Development and testing of a new model of medical monitoring of astronauts is proposed.

We will apply telemedicine technology, namely teletransfer of primary information (ultrasonic images, ECG, EEG etc.) on medical condition of astronauts to the ground-based laboratory for further analysis, creation of databases and computer diagnostic systems.

Telemedicine technology for remote analysis of the state of a human organism, e. g. neuro-psychiatric, cardiovascular, endocrinal and hematogenic systems, will be developed. We are planning to test such a technology for monitoring the medical condition of people living and working in 30-km zone of Chernobyl, at the «Shelter» object and SE «Radek», as well as Chernobyl power plant.

The integrated program developed in this experiment will be applied for monitoring the nervous, endocrinal and circulatory systems of persons living in the Chernobyl power plant zone and exposed to the long-term influence of small dozes of ionizing radiation.

«Thrombocytes» Experiment

INFLUENCE OF SPACE FLIGHT FACTORS ON PROCESSES OF THROMBUS FORMATION AND DESTRUCTION IN HUMAN BLOOD

Komissarenko S. V.

O. V. Palladin Institute of Biochemistry, NAS of Ukraine
9 Leontovych St., Kyiv 01030 Ukraine
tel: (380) +44 +2245974, fax: (380) +44 +224 6365, e-mail: secretar@biochem.kiev.ua

The purpose of the experiment is to study the influence of space flight factors on the blood coagulation processes and the blood clot enzyme destruction. These processes are the basis of regulatory mechanisms of the thrombus formation and thrombolysis.

The main objectives are the following:

— to reveal the direction and essence of simultaneous influence of space flight factors on the velocity of fibrin clot formation and of its enzyme destruction, as well as on separate steps of these processes;

— to study the microgravity influence on factors VII, IX, X, II, I, protein C, plasminogen, plasminogen activators and plasmin inhibitor concentration, integral parameters of the blood coagulation and fibrinolysis systems in blood plasma of astronauts;

— to study possible changes of the protein — protein interactions in microgravity and adaptive ability of two equilibrium systems of blood plasma — blood coagulation and fibrinolysis.

Integral parameters of blood coagulation and fibrinolysis system will be determined by the immunological methods with standard tests.

The results will be used in the field of space medicine for astronauts' screening and for choice of prophylactic measures in long-term space flights.

«Microcirculation» Experiment

INFLUENCE OF SPACE FLIGHT FACTORS ON BLOOD MICROCIRCULATION AND ITS RHEOLOGICAL PROPERTIES IN HUMAN

Korkushko O. V.

Institute of Gerontology of the AMS of Ukraine
67 Vyshgorodska St., Kyiv 04114 Ukraine
tel: (380) +44 +4304068, fax: (380) +44 +4329956

The purpose of experiment is to study the effects of micro- and hypergravity, and hypodynamics on the skin and bulbar microcirculation, oxygen tension in subcutaneous cellular tissue, and rheological properties of blood in astronauts before and after space flights. The duration of experiment will consist of pre-flight training period, period spent on board the space vehicle and period after landing, both in the next hours and in a more remote period of time.

We will study systems of microcirculation and oxygen provision of tissues both in almost healthy people of various age and in patients with diseases of cardiovascular and nervous systems. Experiment will be performed with the laser Doppler flowmeter for noninvasive determination of the volume of blood flow in microvessels and with the transcutaneous monitor for noninvasive determination of oxygen and carbon dioxide tensions in tissues and media of the organism.

Results obtained will facilitate developing a set of measures both for preventing the disturbances in functioning of microvessels in astronauts under the influence of space flight factors and making the human organism more adaptable to the conditions of a space flight.

«Homeostasis-2» Experiment

EVALUATION OF OXIDANT AND IMMUNE HOMEOSTASIS IN PERSONS EXPOSED TO ADVERSE INFLUENCE OF SPACE FACTORS. PROPHYLAXIS AND CORRECTION OF PATHOLOGICAL CHANGES

Chumak A. A., Ovsiannikova L. M.

Ukrainian Research Center for Radiation Medicine of the AMS of Ukraine
53 Melnikov St., Kyiv 04050 Ukraine
tel: (380) +44 +4319838, fax: (380) +44 +4319838, e-mail: chumak@kpi.kiev.ua

The purpose of experiment is to develop recommendations for protection of the immune system and oxidative homeostasis of persons exposed to the negative influence of a space flight. The main objectives are as follows:

— to study the oxidative homeostasis and immune state of people under the influence of various doses of ionizing radiation;

— to study the immune-modulating and anti-oxidative substrates for prevention and correction of the negative influence of a space flight.

Investigation of peripheral blood mononuclear cells will be carried out by the methods of flow cytometry with antibodies. The enzyme and non-enzyme indices of antioxidant system, primary and final products of lipid peroxidation will be also determined.

Recommendations on improvement of the immune and anti-oxidative state of astronauts and persons, which are working under adverse conditions, will be proposed.

«Neuroprotection» Experiment

MAINTENANCE OF A CAPACITY FOR WORK OF ASTRONAUTS DURING A SPACE MISSION: NEW TECHNOLOGY BASED ON SELECTED GASEOUS MIXTURES

Berezovsky V. A.

O. O. Bogomoletz Institute of Physiology, NAS of Ukraine
4 Bogomolets St., Kyiv 01024 Ukraine
State Research and Development Medical-Engineering Center «NORT», NAS of Ukraine
45 Vasylkivska St., Kyiv 03039 Ukraine
tel/fax: (380) +44 +2562477, e-mail: vadber@serv. biph.kiev.ua

The objective of experiment is to work out a method for maintenance of the high stress resistance and high capacity for work of astronauts. To meet this objective, we are planning to carry out the following:

— to enhance a level of antioxidant protection of a human body by restriction of electron acceptors in the chain of biological oxidation;

— to ensure the activation of alternate paths of energy metabolism of the central nervous system;

— to develop equipment for maintenance of dosed oxygen deprivation;

— to develop medical technology providing the oxygen deprivation in short-term and long-term space flights and on Earth.

Equipment designed specially for maintenance of dosed oxygen deprivation on board the space station will be a modification of the membrane gas-separation device. The particular response pattern of an individual will be taken into consideration to develop a special medical technology for enhancement of a capacity for work of astronauts. The mental capacity for work of astronauts will be monitored by medical equipment, which is usually used for this purpose on board the space station. The healthy young persons and those of an older age will be objects of this study. We are planning to apply PNN-4 computer system to study the mobility of nervous processes in the central nervous system, as well as the selective membrane gaseous separation or compressed gases (on board the station) for creation of gaseous mixtures.

We assume that the dosed oxygen deprivation in a special mode can allow maintaining a higher level of the capacity for work and stress resistance of astronauts under microgravity and influence of other factors during the long-term space flight.

«Comfort» Experiment

PSYCHOPHYSIOLOGICAL MONITORING OF ASTRONAUTS

Kundiev Yu. I.

Institute for Occupational Health, AMS of Ukraine
75 Saksagansky St., Kyiv 01033 Ukraine
tel: (380) +44 +2208030, fax: (380) +44 +2206677, e-mail: peter@vitte-joh.kiev.ua

The purpose of the experiment is development of an onboard system for the psychophysiological monitoring of astronauts during a space flight.

This system will ensure evaluation of the current state and capacity of astronauts for work.

The main objectives are as follows:

— to develop new methods for the psychophysiological monitoring of a capacity of the crew for work;

— to develop new methods for analysis of synchronization of psychological and physiological parameters of the human capacity for work;

— to develop an algorithm for construction of a psychophysiological model of the human capacity for work;

— to design a system, which will execute such an algorithm;

— to examine the efficiency of such a system;
— to modify the system by the results of examination.

We will apply the following methods: measurement of psychophysiological indices of the capacity of an operator for work; mathematical simulation of psychophysiological reliability of the operator capacity for work; psychophysiological analysis of the system reliability; analysis of biorhythms; development of the recursive algorithms and predictive models; software development. Computer recording of an electrocardiogram and sphigmogram is envisaged in the experiment.

«Microflora» Experiment

INFLUENCE OF SPACE FLIGHT FACTORS ON BIOLOGICAL PROPERTIES OF HUMAN RESIDENT MICROFLORA: EXPERIMENTS IN VIVO AND IN VITRO

Vozianov A. F.

Institute of Urology and Nephrology of the AMS of Ukraine
9A Kotzubynsky St., Kyiv 04053 Ukraine
tel: (380) +44 +2166731

The purpose of experiment is to study the influence of space flight conditions on the biological properties of representatives of the normal (resident) human microflora and to evaluate their ability to manifest the potential pathogenic properties under extreme conditions.

The main objectives are as follows:
— to develop and apply the method of integral evaluation of vitality and functional state of microorganisms belonging to the resident human microflora;
— to study the vitality of bacteria, their functional state and features of interaction with eukaryotic cells in a space flight;
— to study the virulence of some microorganisms (in control before and after the microgravity influence) in ground-based experiments.

The test objects will be the representatives of resident human microflora (*Proteus mirabilis, Mycoplasma hominis*) and the test animals (mice of Balb line and mongrel white mice). The microbiological, serological, immunological, histological, morphological, biophysical, genetic and electronic microscopy methods will be used.

Experiments carried out *in vitro* and *in vivo* will facilitate studying the structural and functional state of bacteria under the influence of space flight factors. Results obtained will promote substantiation of biological protection of astronauts from the aggressive effect of resident microflora.

«Electromagnetic Radiation» Experiment

STUDY OF THE NEGATIVE INFLUENCE OF ELECTROMAGNETIC RADIATION PRODUCED BY RADIO ELECTRONIC DEVICES ON BOARD THE ISS ON THE HOMEOSTATIC SYSTEM OF ASTRONAUTS

Tsutsaeva A. A.

Joint-Stock Company NIIRI
271 Academik Pavlov St., Kharkiv 61054 Ukraine
Tel: (380) +572 +265200, fax: (380) +572 +264112
Institute for Problems of Cryobiology and Cryomedicine, NAS of Ukraine
23 Pereyaslavska St., Kharkiv 61015 Ukraine
tel: (380) +572 +720126

The purpose of experiment is to study the influence of electromagnetic radiation (EMR) produced by radio electronic devices aboard the orbital stations on the homeostatic system of astronauts

The main objectives are as follows:

— to study biotropic effects resulting from combined influence of electromagnetic radiation and other space flight factors on the stability of a human homeostasis;

— to develop methods for enhancement of astronauts' resistance to the adverse influence of the space flight factors.

CONCLUSION
TO THE «SPACE BIOLOGY, BIOTECHNOLOGY, AND MEDICINE» CHAPTER

The Ukrainian Research Module of the ISS will be used for performance of more than 50 experiments in the field of space biology, biotechnology and medicine. These series of experiments will create the necessary basis for obtaining principally new fundamental knowledge on the biological role of gravity and geomagnetic field acting permanently on Earth. These experiments will enable the original ideas on growth, development, and vital activity of living systems to be verified under the influence of various space factors. This basic research will allow development of space cell biotechnologies and methods for functioning of the autotrophic and heterotrophic links of CELSS for astronauts during their flights in far space and visits to Moon and Mars. The long-term orbital flight of the URM will give us a unique possibility both to test the reliability of newly created biotechnologies and to develop self-sufficient onboard technological processes for production of biopreparations and biomaterials.

Research and testing performed in the URM will facilitate a wider integration of Ukraine into the international co-operation in the field of space life sciences.

SOLAR POWER ENGINEERING (Subproject of the «Environment» Project)

Prisnyakov V. F.

Institute of Geotechnical Mechanics, NAS of Ukraine
2a, Simferopol'ska St., Dnipropetrovsk-5, 49600 Ukraine
Tel: (380) +562 +46 51 05, fax: (380) +562 +46 24 26, e-mail: nanu@igtm.dp.ua

Pilipenko V. V.

Institute of Technical Mechanics, NAS of Ukraine — NSA of Ukraine
15 Leshko-Popel St., Dnipropetrovsk-5, 49600 Ukraine
Tel: (380) +562 +45 12 38, fax: (380) +562 +47 34 13, e-mail: pvv@pvv.dp.ua

Introduction. This integrated project in the field of space solar power engineering pursues the following objectives:

— further development of the theory of processes of solar energy conversion into electric energy and its transmission to remote users in the space environment;

— creation of adequate mathematical models and study of the dynamics of advanced technological structures in solar power engineering as specific mechanical systems.

«Cable-Tether System» Experiment

STUDY OF THE BASIC VARIABLES OF A CABLE-TETHER SYSTEM INTENDED AS AN ELECTROMECHANICAL LINKAGE BETWEEN SPACE VECHICLES

Alpatov A. P., Pirozhenko A. V., Voloshenjuk O. L.

Institute of Technical Mechanics, NAS of Ukraine
15 Leshko-Popel St., Dnipropetrovsk-5, 49600 Ukraine
Tel: (380) +562 +472574, fax: (380) +562 +473414, e-mail: alpatov@pvv.dp.ua

Khoroshilov V. S.

Yangel State Design Office «Pivdenne»
3 Krivorizska St., Dnipropetrovsk 49600 Ukraine
tel: (380) +562 +92 51 13, fax: (380) +562 +77 0 01 25

One of the trends in space power engineering is isolation of power modules of a space vehicle as a self-contained power space vehicle. Power transmission from such a «power space vehicle to the space vehicles-«users» could be carried out by cables or with wireless technology. The latter method represents the more advanced technology. However, the efficiency of power transmission, which can be achieved with the wireless technology, is low. The mentioned wire technology of power transmission can be realized by means of a cable-tether linkage. On the other hand, implementation of this cable-tether linkage requires solving the problems of space electrical engineering and control of such a mechanical tether configuration as «power space vehicle — cable-tether system — space vehicle-user». The electromechanical coupling can be also used for transfer of pull impulses to compensate for the aerodynamic effect or for transporting the space vehicles to other orbits. The proposed space experiments are aimed at solving some of the above problems.

A. The basic variables of a cable-tether system. Functioning of the «power space vehicle — cable-tether system — space vehicle-user» system requires dynamic isolation of the space vehicles. A constraining tether will transfer not only the legitimate forces but also forces upsetting the stabilization of a vehicle. The dynamics of the tether proper will also have an essential influence. Analysis of the dynamic problems of such a system shows the necessity to develop special fastening unit for the areas of the cable-tether attachment to the space vehicles. On the one hand, this unit will provide the vibrational isolation of the space vehicle, and, on the other hand, it will ensure the accuracy of orientation of the space vehicle and the system as a whole. Other problems of functioning of the «power space vehicle — cable-tether system — space vehicle-user» system are degradation of the mechanical and electrical properties of the cable-tether during its operation and interaction of the extended cable-tether with the environment.

The following experimental procedure is envisaged. At the beginning of the experiment, the unit with the folded cable-tether is moved by the cosmonauts to the exit port. Then, the unit is installed on a platform outside the URM by the mechanical manipulator. After this, the cable-tether is extended for 20 m from its folded condition by a special deployable mechanism. The stretching force and the voltage of about 25 kV are applied to the cable-tether. Mechanical vibrations are periodically excited at one end of the cable-tether by a drive-vibrator. After 3 to 5 years of service, the cable-tether system is delivered to the Earth for further study.

The following basic variables of the cable-tether system will be measured during this experiment: resistance of insulation, surface temperature of the cable-tether, voltage, and current. It is also planned to determine the equilibrium configurations of the tether at small loads and its dynamic parameters, the level of vibrations damping when passing through the tether and the unit of fastening to the URM and station, the cable-tether rigidity from vibration characteristics, and the serviceability of the stabilization system.

B. Dynamics of the «power space vehicle — cable-tether system — space vehicle-user» system. The space-tethered system (STS) of «power space vehicle — cable-tether system — space vehicle-user» includes the cable-tether as the principal and novel system element. From this point of view, study of the dynamics of the current-conducting tether at small loads, of its equilibrium configurations and interaction with the environment is of great importance. It appears to be expedient to carry out this study in two stages. The first stage will consist of an experiment on the dynamics of the tether deployment and initial retrofitting of the deployment system. A small self-contained STS with the mass of about 5 Kg and with tether length of about 100 m will be deployed. The tether tension and stabilization of motion of such a system will be implemented by imparting to the system a torque about the center of masses. This experiment would enable a large-scale experiment with the model of a space vehicle-user to be performed. The second stage will consist of an experiment on deployment of an STS mock-up to testify the stability of its radial configuration and stabilization of its motion.

The following experimental procedure will be used. Spring pushers with two spherical bodies are installed on the external side of the URM. The deployment system is located inside one of these bodies. The spherical bodies are separated from the URM after the spring pushers come into action. The difference between the two stages of the experiment is as follows. The mock-up of the space vehicle will be one of these bodies and the tethered system will be deployed only with this one body. A special device will be used to separate the mock-up of the space vehicle from the URM. This device will be designed along similar lines as the device for separation of the sub-satellite from the space vehicle, developed in the Yangel SDO «Pivdenne» under the «Warning» space project. Special sensors will follow the process of deployment of the tethered system and will transmit these data aboard the URM. Upon completing these experiments, the equipment will be separated from the URM and will move separately until entering the atmosphere.

The tasks defined in this experiment undoubtedly have a scientific novelty. Their solution is of great importance for development of promising space tethered systems, orbital space stations, creation of the «space vehicle — tether — sub-satellite (micro-satellite)» system, development of space electrical engineering and power engineering, as well as of orientation and stabilization systems.

«Concentrator» Experiment

PROCESSES OF SOLAR ENERGY CONVERSION INTO ELECTRIC ENERGY IN THE ADVANCED MULTIPLAYER PHOTO CELLS IN A COMPLEX WITH SOLAR RADIATION CONCENTRATORS

Alpatov A. P., Fokov O. A.

Institute of Technical Mechanics of NAS of Ukraine
15 Leshko-Popel St., 49600 Dnipropetrovsk, Ukraine
Tel:(380) + 562 + 472574, fax:(380) + 562 + 473413, e-mail: alpatov@pvv. dp.ua

Statsenko I. M.

ISR «Energetika» of the Dnipropetrovsk State University
13 Naukova St., 49050 Dnipropetrovsk, Ukraine
tel:(380)+562+433145

Rassamakin B. M., Shmireva A. H.

National Technical University of Ukraine «Kyiv Polytechnic Institute»
6 Politekhnichna St., 04056 Kiev, Ukraine
tel/fax: (380) +44 +241 86 66, e-mail: lab_hp@tefntuu.kiev.ua

Belov D. G., Medvednikov S. V., Tarasov G. I., Perekopskiy I. I., Khoroshilov V. S.

Yangel State Design Office «Pivdenne»
3 Kryvorizska St., Dnipropetrovsk 49600 Ukraine
tel: (380) +562 +92 51 13, fax: (380) +562 +77 0 01 25

The use of advanced solid-body photo-voltaic (PV) converters and PV converters with solar energy concentrators allows reducing the solar arrays cost, increasing their resistance to performance degradation under the impact of the space environment factors, and improving their efficiency. Development of efficient PV converters is hindered by insufficient knowledge of physical phenomena of solar energy conversion under the space environment conditions. Application of concentrators is limited by the need to maintain the required thermal mode of PV converters exposed to concentrated radiation. This implies the urgency of studying new physical phenomena in solid-body PV converters and of solving the problem of heat removal.

The purpose of the experiment is to study the physical phenomena that occur in the solar array structures under the complex influence of space factors and to determine the maximum permissible degree of solar radiation concentration for PV converters of different structure and with different methods of heat removal.

The results of the experiment will allow verification of the calculated data and design solutions aimed at decreasing the degradation, as well as selection of coatings and materials both for PV converters and concentration systems, and for heat removal systems. Novel technologies will be developed to improve the solar arrays both for space and ground applications.

«Dynamics» Experiment

CHECK OF ADEQUACY OF MATHEMATICAL MODELS OF THE DYNAMICS OF HIGHLY DEFORMABLE LOW-ELASTIC LARGE-AREA SURFACES UNDER MICROGRAVITY

Alpatov A. P., Delyamoure V. P., Khramov D. A., Belonozhko P. P.

Institute of Technical Mechanics of NAS of Ukraine
15 Leshko-Popel St., Dnipropetrovsk-5, 49600 Ukraine
Tel: (380) +562 +472574, fax: (380) +562 +473414, e-mail: alpatov@pvv.dp.ua

One of the most important technical trends in solar power engineering is development of large-area solar arrays. Being one of the types of large space structures (LSS), these structures are characterized by an extremely low ratio of thickness to linear surface dimensions. The development of this trend is retarded by a lack of experimental data, which would enable the adequacy of the known and developed mathematical models of LSS dynamics to be checked.

The purpose of the experiment is to obtain experimental data on the parameters of LSS dynamics. From this point of view, the primary objective is to determine the deformations and displacements of the LSS. Study of this problem on the ground is impossible. The reason is that the dynamics of such a model is completely distorted by the Earth's gravitational field. Therefore, this experiment should be carried out under microgravity. It is assumed to model the large-area solar arrays as a mechanical large-area system with the extremely low ratio of thickness to linear surface dimensions by a thin low-elastic plate with the low bending resistance. The set of parameters will be defined with use of a video filming and remote modes during the exposure of a model in the experimental zone.

The results of the experiment will be used to establish the adequacy of mathematical model of the dynamics of essentially deformable low-elastic large-area surfaces as the basic structural elements of solar arrays. At the same time, the results of the planned experiment may be helpful for numerous researchers in the field of LSS dynamics and, thus, may be of great scientific value.

II.6. PHYSICAL-CHEMICAL PROCESSES UNDER MICROGRAVITY

PHYSICAL-CHEMICAL PROCESSES UNDER MICROGRAVITY («Morphos» Project)

Nemoshkalenko V. V.

G. V. Kurdyumov Institute of Metal Physics of the NAS of Ukraine
36 Academik Vernadsky Blvd., Kyiv-142, 03680 Ukraine
tel: (380) +44 +4441005, fax: (380) +44 +4442561,
e-mail: metall@imp.kiev.ua

Introduction. The Ukrainian Program for study of the physical-chemical processes under microgravity proposed for the ISS, concerns the basic problems of physics of liquid and materials science.

The Program contains six experiments, where authors propose not only the newest advanced theoretical conceptions but also the original technological ideas. Despite the fact that now these experiments are at different levels of flight maturity of the experimental installations they will provide new knowledge after their implementation onboard the ISS.

The proposed experiments can be conditionally divided into three groups depending on the subject and on the role, which the microgravity factor plays in the processes to be studied.

«HERUBIM» experiment to study the microgravity influence on parameters of heat exchange and dynamics of the vapour phase in boiling of liquid helium is included in the first group of experiments, namely the physics of liquids under microgravity conditions. The authors intend also to correct the methodological errors of space experiments carried out earlier in this field.

The next experiments belonging to the second group, namely the materials science under microgravity, can result in new technological solutions in space production of materials.

The proposed «Morphos» experiment concerns the process of directional crystallization under microgravity with three-dimensional preparation. It allows overcoming a number of difficulties appearing in interpretation of results for quasi-two-dimensional preparations.

The conception of an on-board installation to study the processes of manufacturing the composite materials from immiscible components (Zn-Pb, Al-Pb, Ag-Fe, Al-W) is proposed in the «Sound» experiment. Such materials have unique physical and mechanical properties. The authors use the method of ultrasonic excitation for compensating the deleterious effects introduced by Marangoni convection and other processes.

The next experiment in this group is to study the processes of manufacturing the eutectic alloys of Ni-Nb-C system by the method of electron beam zone melting. An original concept of the unit for carrying out this research is proposed.

The processes of soldering composite ceramics and glasses with molten metal solders are studied in «Brazing» experiment.

«HERUBIM» Experiment

SPACE-BORNE CRYOGENIC FACILITY TO STUDY THE LIQUID HELIUM PHENOMENA UNDER MICROGRAVITY AND THE RELEVANT EXPERIMENTAL PROGRAM

Bondarenko S. I., Melenevsky Yu. A., Rusanov K. V., Scherbakova N. S.

Special Research and Development Bureau for Cryogenic Technologies
B. I. Verkin Instituite for Low Temperature Physics and Engineering of NAS of Ukraine
47 Lenin Ave., Kharkiv 61164 Ukraine
Tel/fax: (380) +572 + 322293, e-mail: sktb@ilt.kharkov.ua

A cryogenic liquid helium facility has been developed to study the basic problems related to the liquid helium phenomena under microgravity (MG). This facility will provide acceleration within $(1—10^{-4})$ micro-g acceleration range (g is gravity acceleration of the Earth) with the pre-assigned vector values and directions. It will also provide visualisation of this physical experiment and measurement of such main parameters as acceleration, pressure, and temperature.

Experimental and theoretical research in the field of liquids-boiling physics within mass-force fields of various intensity (i. e. phenomenon of liquid helium boiling) has been carried out in the Special Research and Development Bureau for Cryogenic Technologies, ILTPE of the NAS of Ukraine since 1960s. The heat transfer theory developed in this Bureau has been proven by numerous experiments in intensive fields of centrifugal forces and by various techniques for microgravity (MG) simulation within 2.700 g to 10.000 micro-g acceleration range.

The experiments implemented by H. Merte, USA, and J. Straub, Germany, aboard the Shuttle spacecraft in 10...100 micro-g acceleration range, have shown that boiling of non-cryogenic liquids under MG conditions reveals a series of novel effects, being outside the philosophy of the existing theories. As we may surmise, these effects are not related to the impact of MG proper, but to these tests failing to satisfy certain requirements. In particular, these requirements concern the constancy of a ratio of linear dimensions of a test-cell and experiment duration versus internal linear and time scales of the boiling process, as the scales of the boiling process are significantly increased under MG conditions.

Helium should be used as the working fluid to correctly verify the theoretical concepts of the MG influence on boiling physics, and to identify ever-new phenomena related to the MG effect as such. Our estimations have shown that the optimal MG level for this kind of experiment is 100 micro-g, and that the acceleration vector should be constant both in its magnitude and in direction relative to the boiling surface. Developing our helium cryogenic facility for installation onboard the space station, this latter requirement has been taken into account. The facility is a cryostat (filled with liquid helium) being spinned at 0.3 r.p.m. velocity during the entire experiment course. It is intended to mount this 100-litter helium cryostat on a rotating platform on the external side of the URM aboard the ISS. The recorders and measuring instruments will be installed in the manned compartment of the ISS. It will be possible to monitor this experiment by video cameras through the optical windows on the cryostat body.

The goal of HERUBIM (Helium Rotating Unit-Boiling In Microgravity) experiment is to study the MG influence on the vapour phase dynamics in boiling and barbotage, the main heat transfer parameters, stability of boiling regimes against local disturbances, and the dynamics of critical transitions in going from the nucleate boiling to the film boiling regime.

The experiment will result in radically new data on the influence of the acceleration vector controlled by magnitude and direction, on the parameters of helium boiling over a comparatively wide (relative to the scale of the internal boiling process) solid surface. These data will allow a conclusion to be made about the feasibility of extrapolation of the boiling theory to the yet unstudied range of accelerations, as well as identifying novel physical effects. In addition, the MG influence on the phenomena of stability and on dynamics of critical transitions in boiling will be studied for the first time.

The expected results will be not only of theoretical importance but will also find engineering application for improving the on-board cooling systems (using the effect of phase transition), cryogenic fuel storage and pumping-over systems.

The second stage of HERUBIM scientific experiments is dedicated to quantum effects in superfluid helium physics under MG conditions. A relevant program of experiments is being worked out by the ILTPE experts.

«Morphos» Experiment

EXPERIMENTAL STUDY OF SOLID-LIQUID INTERFACE IN TRANSPARENT SUBSTANCES

Nemoshkalenko V. V., Fedorov O. P., Zhivolub E. I., Bersudsky E. I., Chemerinsky G. P.

G. V. Kurdyumov Institute of Metal Physics of the NAS of Ukraine
36 Academik Vernadsky Blvd., Kyiv-142, 03680 Ukraine
tel: (380) + 44 + 4441005, fax: (380) +44 + 4442561, e-mail: metall@imp.kiev.ua

Experimental study of crystallization processes under microgravity is one of the priority fields of materials science in space. It will take one of the most prominent places in the ISS program. The peculiarities of the solidification process are determined largely by the level of gravity convection. In view of the almost complete absence of this type of convection under microgravity, it is important to conduct experiments for study of fundamental physical mechanisms of the solid phase formation from the melt. Further development of the ground technologies of manufacturing single-crystal materials, composites, foundry, etc. is impossible without valid experimental data on the influence of gravity convection on structurally sensitive properties of the crystalline materials. One of the goals of the experiments is application of transparent model substances for study of the crystal growth process and, in particular, of the morphology of the crystallization front during directional solidification [1—4].

A complex of problems related to directional crystallization of transparent model substances in a three-dimensional sample under microgravity conditions studied in this work is proposed for the first time. Directional crystallization is the basic method of future production of materials under the space conditions due to comparative simplicity of the technique, possibility of maintaining a stable growth environment, as well as due to numerous applications, i. e. growing single-crystals of various materials and production of composites and metal alloys.

Since the first studies [5, 6], ground-based experiments with quasi-two-dimensional samples have been a widely used methods. Improvements proposed in these studies, allow investigation of transparent single-crystals and various crystallographic directions of growing, as well as comparison of the data of laboratory model experiments with the data on the actual processes and structure of metal single-crystals.

The following logic step in this direction is complete reproduction of the solidification process in a three-dimensional sample with a model substance. It will provide direct data on development of unstable crystallization front, typical sequence of the morphology change at variation of the growth conditions (in particular, increase of growth rate) in the actual three-dimensional sample where the processes of convective heat-mass transfer are one of the controlling factors.

An important problem is the interaction of the crystallization front with gaseous inclusions. As is known, there is no outgassing from the material being crystallized under microgravity and, therefore, direct observation of the interaction of the crystallization front in the melt bulk with the gas bubble which does not float at the crystal growing in space is possible. Earlier such experiments were completed only in two-dimensional preparation, where a number of unexpected effects have been revealed, in particular, accelerated growth of crystals (dendrites and cells) along the gas-melt interface, compared to their growth in melt far from the interface [7]. However, it is still not clear whether the mentioned and some other effects are related to the peculiarities of crystal growth in a thin preparation or whether they result from fundamental properties of three-phase crystal-melt-gas interface. A correct experiment on establishing the parameters of the crystallization front interaction with a gas bubble can only be conducted under microgravity, where direct observation of the three-phase crystal-melt-gas interface is possible, without applying an external force to hold a gas bubble at the interface.

Aging (or coalescence) of dendrites is the major component of the solidification process, which is of the greatest importance for the technology of production of metal ingots and which is controlled essentially by the melt stirring process. For the latter reason, extensive experimental and theoretical research and, in particular, space research, is devoted to coalescence of dendrites. The essence of this process is described in detail in metallurgical literature, for example in [8]. It causes vanishing (dissolution) of thin branches and thickening of large ones. For metals the coalescence results in formation of the so-called plate-like structure which is a casting defect. In the absence of macro-stirring (convection), the described process is governed only by diffusion. Therefore, it is possible to understand the mechanism of the process and to study its kinetics only under microgravity conditions, excluding convection. Hypothesizes and assumptions in this respect have been verified experimentally in our ground-based research, where isothermal conditions were created and there was practically no convection [9, 10]. The final verification of assumptions made, and the search for the final answers as regards the conditions of separation of the branches and refinements of the cast structure require a carefully formulated space experiment.

Furthermore, the most informative and correct method of research is direct observation of the process on transparent models in the absence of convective stirring.

The feature of the authors' approach consists in parallel study of substances characterized by various mechanisms of crystal growth from the melt, namely continuous and layer-by-layer. That is, the same effects are investigated in so-called metal-like substances (succinonitrile and its alloys) and in faceted crystals modeling crystallization of semiconductor substances (benzophenone and its alloys).

Solving the defined scientific problems is united by one technique, namely the directional crystallization of transparent alloys by Bridgeman and recording of the structural elements of the crystallization front by the optical methods. The main part of the experiments is focused on observation and recording of the solid-liquid interface.

The experiments to be carried out using the «MORPHOS» installation intend to grow crystals of model transparent substances by directional crystallization with video recording of the morphology of solid-liquid interface during the entire growing process under microgravity conditions.

The experiment runs in the automatic mode. Operator interference is assumed in the stages of preflight preparation and on completion of the flight.

The installation design provides a possibility to realize preliminary ground-based experiments with working samples at the vertical position of the sample axis (heater from above, cooler from below) for minimizing the convective flows in the liquid phase.

A separate ground variant of the installation with the vertical arrangement of the elements similar to those mounted in the flight unit will be created.

References

1. Jackson K. Main concepts of crystal growth // Problems of crystal growth. — M.: Mir, 1968.—P. 13—26.
2. Glicksman M. E., Schaefer R. J., Ayers J. D. Dendritic growth — a test of theory // Met. Trans. A.—1976.—7, N 11.—P. 1747—1759.
3. Huang S. C., Glicksman M. E. Fundamentals of dendritic solidification. II // Acta met.—1981.—**29**, N 5.—P. 717—734.
4. Trivedi R., Tiller W. A. Interface morphology during crystallisation. I. Single filament unconstrained growth from a pure melt // Acta met.—1978.—**26**, N 5.—P. 671—679.
5. Borisov A. G., Fedorov O. P., Maslov V. V. Features of dendritic and cellular morphology of the front in crystals growing in different crystallographic orientations // Crystallography.—1991.—**36**, N 5.—P. 1267—1274.
6. Fedorov O. P. Cellular pattern during directional growth of a single crystal in a quasi-two-dimensional system // J. Crystal Growth.—1995.—**156**.—P. 473—479.
7. Fedorov O. P. Interaction between growing crystals and inclusions in the melt // J. Crystal Growth.—1990.—**102**.—P. 857—861.
8. Flemings M. Solidification processes. — M., 1977.—423 p.
9. Fedorov O. P. Interaction of crystals growing from the melt with inclusions and concentrational inhomogeneity // Crystal growth. — M.: Nauka, 1990.—**18**.—P. 197—214.
10. Fedorov O. P., Ovsienko D. E., Krivoshei M. B. On the mechanism of transformation of dendrite branches of a binary alloy under isothermal conditions // Metallofizika.—1987.—**9**, N 2.—P. 68—75.

«Sound» Experiment

DEVELOPMENT OF A NEW METHOD OF PRODUCING THE MATERIALS UNDER MICROGRAVITY USING ULTRASONIC FIELD

Nemoshkalenko V. V. Kozlov A. V.

G. V. Kurdyumov Institute of Metal Physics, NAS of Ukraine
36 Academik Vernadsky Blvd., Kyiv-142, 03680 Ukraine
tel: (380) + 44 + 4441005, fax: (380) +44 + 4442561, e-mail: metall@imp.kiev.ua

Modern industry requires materials with advanced properties, namely high magnetic characteristics, high heat resistance, wear resistance, etc. Such materials can be obtained from aggregates that do not dissolve in each other, namely from a disperse system. The specific mechanical and electrical properties can be achieved, when particles with the diameter of 0.1 micron are used and the distance between the particles is 1 micron, that corresponds to the order of volumetric content of dispersed component of 10 %. Such systems can be illustrated by the following examples: 1) systems where disperse particles considerably raise the durability (especially at high temperatures for turbine blades); 2) systems, where the self-lubricating bearings — disperse particles of graphite, tin, lead are applied in the Al matrix; 3) materials for electrical contacts with high wear resistance represented by aggregates based on dispersions of solid particles (*W* or oxides) in a metal matrix with a good conductivity, low hardness and yield stress. The alloy for constant In-Al magnets, where the high values of coercive force were obtained, is also a disperse system. Usually, however, it is impossible to obtain high-quality disperse alloys under the regular conditions, because of sedimentation and fast stratification of liquid components.

The research under microgravity provides new possibilities to study these systems. Under microgravity the velocity of coalescence and sedimentation is considerably lower, allowing metastable disperse phases to be produced, that is practically impossible under the normal conditions. Emulsions are 10 times more stable under microgravity and velocity of coalescence is 10^{-6} lower, than under the usual conditions [1]. At the same time, in spite of the fact that during space experiments the acceleration was practically absent, attempts to obtain homogeneous composite alloys with small size particles (micron) have not been successful. Instead, rough dispersions and alloys with coarse inclusions of one component surrounded with the other component, were obtained. In some experiments a complete separation of phases caused by the low mutual wettability of components was observed. Among the basic requirements to disperse compositions are small sizes of disperse particles and their uniform distribution, as well as wettability of disperse particles with the molten alloy.

We anticipate that the combination of microgravity and ultrasound will enable slowing down the processes of coagulation and sedimentation of insoluble components in disperse systems. Cavitation in a molten alloy caused by intensive ultrasound increases the wettability of insoluble components of the alloy [2], while intensive dispersion takes place, which in combination with slowed down diffusion and lack of stratification under microgravity yields finely dispersed homogeneous composite materials with new physical properties.

Wettability plays a special role. When dipped into the matrix molten alloy, disperse particles do not exhibit any tendency to separation until they are wetted with liquid matrix [3]. It has been pointed out [4, 5] that inhomogeneous distribution of disperse particles changes to a homogeneous one in the case if they are first metallized with the molten alloy, i. e., if disperse particles are initially wetted. Ultrasound increases the wettability of disperse particles as a result of a local raise of temperature and pressure on the boundary between disperse particles and molten alloy mainly due to cavitational bubble shocks. In addition, the impact of powerful ultrasound on a molten alloy with disperse particles or liquid drops causes intensive dispersion of these particles and drops. Acoustic mixing of Zn-Pb system under microgravity conditions was used in [6]. Coalescing drops in the molten alloy were dispersed by ultrasound, and well-dispersed structures were obtained; however, these experiments were carried out only at small concentration of Pb and at low ultrasound intensity.

The intent is to carry out these experiments at disperse components concentration of more than 10 %, i. e., at such a concentration, when the processes of coagulation of dispersions predominate under the usual conditions. Such zero gravity experiments on model systems with the low melting point of the matrix will allow us to develop methods of obtaining especially fine dispersions, and they will also help to clarify the mechanism of crystallization of disperse systems with application of ultrasound.

The knowledge obtained during the project will provide a physical background for development of the technology of producing new composite materials for aerospace and electronic engineering.

The developed ultrasonic equipment will be also used in the experiments of an independent biological project of the Institute of Biochemistry of the NAS of Ukraine. This project is devoted to the study of functional abilities of diaphragms under the conditions of microgravity to obtain suspensions of one-molar liposomes, which is achieved by destruction of large multilayer vesicules with ultrasound.

The Institute of Metal Physics is planning to make a flight unit for obtaining the composite materials using an ultrasonic field under microgravity onboard the Ukrainian Research Module of the ISS. The unit is designed for performance of the above-mentioned and other research.

References

1. Space materials science. — M.: Mir, 1989.—478 p.
2. Abramov O. V. Crystallization of metals in ultrasonic field. — M.: Metalurgia, 1972.—256 p.
3. Achievements in the field of composite materials / Ed. by J. Piatty. — M.: Metallurgy, 1982.—304 p.
4. Teryokhina T. A., Pirogov S. Y., Sokolov V. F. Interaction of some refractory alloys with Ni-Cr-Si-B molten alloy // Powder metallurgy.—1980.—N 8.—P. 53—57.
5. Revun S. A., Muravyova E. L. About the mechanism of forming of macrostructure at metallization and melting of composite coatings // Physics and Chemistry of Materials Processing.—1998.—N 3.—P. 65—69.
6. Schonholz R., Dian R., Nitsche R. // Proc. 5th European Symp. on Material Science under Microgravity: Schloss Elman, Nov., 1984. — ESA SP-22, 1984.—P. 163—167.

ELECTRON BEAM ZONE MELTING OF Ni-BASE EUTECTIC

Barabash O. M., Nemoshkalenko V. V.

G. V. Kurdyumov Institute of Metal Physics, NAS of Ukraine
36 Academik Vernadsky Blvd., Kyiv-142, 03680 Ukraine
tel: (380) + 44 + 4441005, fax: (380) +44 + 4442561, e-mail: metall@imp.kiev.ua

One of the promising methods of obtaining the modern composite materials is the unidirectional solidification (DS) of the eutectic alloys by means of electron beam zone melting. The characteristic property of this method is gradual solidification of the sample by moving the melt zone. Under these conditions, a perfect structure designed and oriented in the specific crystallographic direction is formed in the sample. Existence of such a structure leads to the unique physical-mechanical properties of a sample. The advantages of this method of obtaining the composite materials are the one-stage processes controlling the morphology of the phases and perfection of the material structure. The number of investigations concerning the influence of microgravity, in particular, on the process of solidification, has considerably increased, as they offer outstanding possibilities of the material structure control.

Among the composite materials currently obtained by electron beam zone melting, the most promising are Ni-base eutectic alloys reinforced by refractory metal carbides, in particular, the alloys of Ni-Nb-C system. It was this system which formed the base for development of the currently used alloys for the turbine blades. Alloys proposed for this experiment are being currently manufactured. They have a relatively low melting temperature (full power for maintaining the liquid zone during electron beam zone melting is 200 W). The authors have carried out calculations and ground-based experiments with alloys of this simple system. The basic mechanism of formation of a perfect oriented composite structure has been worked out [1, 2]. At present the eutectic composites are being improved by making them more complex. To this end, variation in the number and concentration of the alloying elements is accompanied by changing the temperature-concentration parameters of the eutectic transformation and by decreasing the DS velocity. In order to design advanced superalloys, it is necessary to know how the DS parameters (DS velocity, temperature gradient on the crystallisation front) and characteristic properties of each alloying element affect the structure of the composites. The decrease in the gravity level should change the macro- and microstructure of composites.

Production of DS eutectic alloys by zone melting has some difficulties under the ground conditions. On the one hand, a liquid zone is overheated by the electron beam that is necessary to obtain high temperature gradients, and at the same time it is limited by the flowing quality of the melt. On the other hand, the overheating of a melt generates the thermoconvection process, which upsets the planar front stability and causes an increase of the number of structural defects. DS under microgravity will enable stabilisation of the influence of these factors for creation of a perfect eutectic structure.

The experiment will be carried out in two stages. At the first stage, a series of technological DS experiments with the Ni-Nb-C alloys will be performed under microgravity. They are intended to study the composite growth field of alloys in the direction of the increase of the strengthening phase content. At this stage, a great number of sub-experiments will be conducted with various solidification velocities to establish the maximum velocity during the existence of the planar front. At the second stage, DS experiments with complex alloying (6—10 alloying elements) will be carried out. These experiments are intended to determine such a segregation level of various elements where the composite structure formation is slowed down. It is also proposed to assess the influence of overheating of a melt zone and convection on the planar front stability.

The obtained data will allow us to work out recommendations for the eutectic and non-eutectic DS on the ground.

References

1. Gridnev V. N., Barabash O. M., Buria I. V., Legkaya T. N. Crystallographic features of growth and structural perfection of a two-phase Ni-Nb-C eutectic alloy, depending on the directional solidification velocity // Kovove materialy.—1989.—N 2.—P. 129—136.
2. Barabash O. M., Legkaya T. N. Phase transformations and formation of the oriented γ/γ'-Mo_2C structure in the Ni-Mo-Al-C system // Met. Phys. Adv. Techn.—1996.—18.—P. 993—999.

«Brazing» Experiment

CAPILLARY PROPERTIES OF METAL MELTS, NON-METAL MATERIALS AND PROCESSES OF WETTING AND BRAZING UNDER MICROGRAVITY

Najdich Yu. V., Gab I. I., Zhuravlev V. S.

I. N. Frantsevich Institute for Materials Science Problems, NAS of Ukraine
3 Krzhyzhanovsky St., Kyiv-142, 03680 Ukraine
tel: (380) + 44 +4443017, fax: (380) +44 +4440181, e-mail: naidich@ipms.kiev.ua

The experiment pursues two main objectives.

The first one is to test one of the fundamental laws of physical chemistry on the surface phenomena, namely the second capillarity law about the independence of wetting contact angle on gravity [1, 2]. It is intended to carry out measurements of wetting contact angles under normal conditions and microgravity in low-temperature systems, where both wetting ($\Theta < 90°$) (water, glycerine — polyvinylchloride, nylon) and non-wetting ($\Theta > 90°$) (water, glycerine — paraffin, teflon) are observed. The solution of this problem will provide an answer to the fundamental question of whether Young's equation (1), which has been used for almost two centuries now, holds true or whether wetting contact angles and all the related processes depend on gravitation:

$$\cos\Theta = (\sigma_{sg} - \sigma_{sl})/\sigma_{lg} \qquad (1)$$

(Θ is the contact angle; σ_{sg}, σ_{sl} and σ_{lg} are the surface tensions at solid-gas, solid-liquid and liquid-gas interfaces, respectively).

This answer will allow not only a correct interpretation of the obtained results, in particular concerning liquid phase sintering, but also developing experiments and technological processes with use of a liquid phase both in space and on Earth, as well as predicting their results.

To conduct this experiment, it is intended to develop a compact device equipped with a photosystem for photographing the drop profile on photographic film. The working chamber of the device is titanium or steel box (3—5 litre volume). Two optical windows of about 50 mm diameter are mounted in two opposite walls of the box. A manometer for gas pressure measurement and a valve for inert gas supply are fastened on the chamber cover. The table and the studied substance supply system consisting of a syringe feeding liquid onto the substrate surface will be installed inside the chamber.

The second objective would be to obtain experimental data on the following issues:

— behavior of metal melts in broad (6 — 10 mm; non-capillary for Earth conditions) high (50 mm and more) gaps between metal and glass or ceramics;

— crystallization of these melts in the indicated gaps under microgravity;

— standard brazed samples as such [3].

The obtained data will be very important for further study and development of the surface phenomena theory. They will provide both an understanding of the physical-chemical processes occurring under the mentioned conditions and modifying the present technologies for non-metals/metals brazing. It is impossible to carry out similar experiments on Earth because of the metal melt flowing out of a broad gap. The role of gravity in the described processes can be investigated only under the conditions of long-term weightlessness.

It is intended to conduct this study in a small-sized periodic-action vacuum device located at the ISS either inside the URM or in the ISS lock chamber. The equipment includes a small-sized vacuum pump of turbomolecular, getter-ion or magnet-charge type, a vacuum chamber with the heater and viewing window, and the control panel.

The essence of the experiment consists in measuring the contact angles of wetting of solids by liquid solders under microgravity during an orbital flight and in studying the conditions of liquid solder containment in a broad brazing gap. It is planned to measure the contact angles of liquid metals (low melting alloys based on Sn, In, Pb, etc.) on non-metal substrates (quartz) in the high vacuum under microgravity. The contact angle measurements will be performed using the same systems both on the Earth and onboard the space vehicle. The results of ground- and space-based experiments will be compared.

References

1. Tatarchenko V. A. Peculiarities of Crystallisation in Capillary Shape Formation in Space // Technologicheskie Experimenty v Nevesomosti. — Sverdlovsk: AS USSR, Ural Sci. Centre, 1983.—P. 101—115. (in Russian).
2. Space Materials Science. Introduction to Space Technology Scientific Background / Eds B. Foierbaher, G. Hamaher, R. I. Nauman. — M.: Mir, 1989.—P. 478 p. (in Russian).
3. Chicu Ph. U. U. S. Astronaut Experiment with Soldering in Space // Weld. J.—1993.—N 10.—P. 47—48.

«Technology» Experiment

NEW CAPABILITIES OF GROWING SEMI-CONDUCTOR MATERIALS BY THE METHOD OF ELECTRON BEAM CRUCIBLELESS ZONE MELTING UNDER MICROGRAVITY

Paton B. E., Asnis Yu. A., Zabolotin S. P.

E. O. Paton Electric Welding Institute, NAS of Ukraine
11 Bozhenko St., Kyiv 03650 Ukraine
Tel: (380) + 44 +227 31 83, fax: (380) +44 +268 04 86

Baranskii P. I., Babich V. M.

Institute of Semiconductor Physics, NAS of Ukraine
45 Nauka Ave., Kyiv 03028 Ukraine
Tel: (380) + 44 +265 55 85, fax: (380) +44 +265 83 42, e-mail: mickle@semicond.kiev.ua

Improvement of the quality of semi-conductor materials is one of the priority tasks for all the industrialised countries. An essential obstacle in this path is the presence of the gravitational field of

Earth. There are well-grounded reasons to believe that the materials, which will be produced using perfect technology under microgravity (MG), will be characterised by parameters close to the theoretically anticipated ones.

A promising method for production of semi-conductors in space is the crucibleless zone melting (CZM) with a disc-shaped electron beam, which is based on the extremely clean conditions of the molten zone formation.

The principle of operation of such a unit and its main operational parameters are presented in detail by the authors in [1]. The principally important advantages which are characteristic of the electron beam method of CZM (compared to other methods), are described in detail in [2]. It should be noted that our main attention was recently focused on the search for and practical implementation of the modes of conducting CZM, which provide the formation of the solidification front quite close to the plane one in its shape. This is exactly that is indicated by the data in [3]. Considering that the plane solidification front whose provision is one of the most important and necessary conditions of formation of perfect and homogeneous crystals turned out to be quite achievable with the above method, we can see good prospects for its use under MG for production of perfect semi-conductor materials.

A characteristic feature of the molten zone under the conditions of electron beam CZM is the high effectiveness of the solidification front ousting the donor type additives (phosphorus) typical for n-Si. In Si crystals it is characterised by a segregation coefficient which essentially differs from a unity [3].

The influence of rotation of the ingot being grown relative to the melt on the shape of the solidification front and other characteristics of the crystals, was studied at different times and by different researchers under the conditions of terrestrial experiments using CZM with resistance heating. However, under the conditions of $1g_0$ no essential influence on the solidification results was found. It is probable that at $1g_0$ the regular hydrodynamic convection is too effective, compared to the melt mixing as a result of the ingot rotation.

Investigations performed by the authors on the influence of the ingot rotation on the degree of cleaning in electron beam CZM showed that in this case there is a tendency of improvement of the degree of cleaning.

Under MG during zone melting by the electron beam, the melt mixing in the zone will be practically due only to Marangoni convection.

Therefore, the melt mixing in the zone as a result of the sample rotation can prove to be competitive against Marangoni convection or even superior to it in its importance. However, only comparative studies can provide an unambiguous answer to this question, which should to be conducted at $1g_0$ and at MG.

We are also working to acquire the ability to effectively use the increase in the molten zone height under MG, to provide its additional cleaning from additives under the action of an electric field superposed on the crystal in its growth direction.

The electric current which is generated by this field, enables a purposeful change (i. e. regulation and stabilization) of the thermal mode directly on the solid-liquid interphase due to Peltier effect developing on this interphase at current passage along the crystal during its recrystallisation. All this will create the required technological support for investigation of a number of fundamental issues of the physics of solidification and phase transformations under MG, which cannot be performed at all on Earth.

The research data obtained in this experiment will allow optimisation of the processes of heat and mass transfer and of the directly related to them technologies of semi-conductors melting on Earth.

The E. O. Paton Electric Welding Institute is currently making a flight unit for conducting the electron beam CZM under microgravity onboard the URM of the ISS. It is planned to perform in this unit the above-mentioned and other research related to space materials science.

References

1. Paton B. E., Asnis E. A., Zabolotin S. P., et al. Features of production of semi-conductor materials under microgravity // Avtomat. Svarka.—1999.—N 10.—P. 97—99.
2. Paton B. E., Lapchinskii V. F., Asnis E. A., et al. Urgent tasks of production of materials for electronic devices under microgravity // Space Science and Technology.—1998.—**4**, N 5/6.—P. 95—98.
3. Paton B. E., Asnis E. A., Zabolotin S. P., et al. Crucibleless zone melting of silicon single-crystals using the electron beam // Reports of the NAS of Ukraine.—1999.—N 7.—P. 108—112.

PLANNING AND MANAGEMENT OF THE EXPERIMENTS («System» Project)

Kuntsevich V. M.

Space Research Institute, NSA of Ukraine — NAS of Ukraine
40 Akademik Glushkov Ave., Kyiv 04022 Ukraine
tel./fax: (380) +44 + 266 41 24, e-mail: vmkun@d305. icyb.kiev.ua

PLANNING AND MANAGEMENT OF ON-BOARD EXPERIMENTS AT THE SCIENTIFIC ORBITAL LABORATORY IN THE STRUCTURE OF THE ISS

Cherepin V. T.

Physical Engineering Teaching-Research Center, NAS of Ukraine
36 Akademik Vernadskij Blvd., Kyiv-142 03680 Ukraine
tel: (380) +44 +444 32 20, fax: (380) +44 + 444 82 50, e-mail: cherepin@imp.kiev.ua

Kamelin A. B.

National Space Agency of Ukraine
11 Bozhenko St., Kyiv 03022 Ukraine
tel: (380) +44 +227 89 57, fax: (380) +44 +269 50 58

Kuntsevitch V. M., Lychak M. M.

Space Research Institute, NAS of Ukraine — NSA of Ukraine
40 Akademik Glushkov Ave., Kyiv 03022 Ukraine
tel/fax: (380) +44 +266 41 24, e-mail: vmkun@d305. icyb.kiev.ua

Introduction. Various research modules (RM), i. e., scientific orbital laboratories, are assumed to function as the components of the ISS. It is also assumed that a considerable number of simultaneous experiments should be completed at every RM, while a relatively small number of astronauts are participating aboard. In addition, a RM operating term is supposed to be long in orbit, and long-term experiments are intended to be carried out by astronauts in accordance with a program, which is quite complicated and changes periodically.

These features show that planning and implementation of experiments should be arranged in a new way. The possibility to create a mode of virtual on-board presence of the authors of these experiments at the RM, in order to provide efficient control of the experiments up to implementation of a telecontrol mode, is of importance.

The problem of the virtual presence of an expert close to the experimental installation, which may be located at a long distance from a researcher for some reason, and the problem of an expert's ability to be involved in an experiment, are urgent. The users and designers of experimental installations are just beginning to realize this importance. The virtual presence of the authors of the experiments means in many cases a possibility to revise the conditions, under which these experiments are carried out, and to essentially broaden the scientists' abilities. In this case, a space crew, working at the RM, seems to become more numerous, including ground-based experts, whose virtual presence during the experiments staged by themselves, may make the scientific level of these experiments substantially higher and may increase their efficiency. There is every reason to believe that creation of virtual systems used for management of space experiments is now emerging as a new field of science.

At present, the activities aimed at creation of the systems performing telecontrol of scientific investigations and technological processes already take place in the majority of the space-faring countries. For instance, the Levis Research Center of NASA has now created the Telescience Support Center, in order to support scientific on-board experiments at the ISS. In addition, the telecontrol mode (telescience) is supposed to be implemented practically in all the experimental installations, created within the framework of ESA Columbus Program (European part of scientific and technological on-board experiments at the ISS, including a biolaboratory, laboratories, studying the features of solids and liquids, and a module, studying physiological effects) [3].

PLANNING AND MANAGEMENT OF SCIENTIFIC AND TECHNOLOGICAL ON-BOARD EXPERIMENTS: SYSTEM DESIGN

Specialists working at the Space Research Institute, NASU — NSAU, and at the NSA of Ukraine have developed the design of the system for planning and management of scientific and technological on-board experiments, performed at an assumed Ukrainian Research Module (URM) of ISS [2].

According to a preliminary estimate, about 8-10 simultaneous on-board experiments are planned to be conducted at the URM. The hierarchical control system designed is shown in Figure 1. The URM is assumed to contain the workplaces of the researchers with local control systems, which comprise the lower hierarchy level (Level 1). The upper hierarchy level (Level 2) includes a central experiment control system, a space communication channel (CC) of the URM and a space crew. The workplaces of researchers, where the authors of experiments are present, are on the ground. The mission and experiment control center (MECC) creates their virtual on-board presence, when respective experiments are carried out at the URM, and this is done by the ground-based part of experiment planning and management system through the MECC CC or

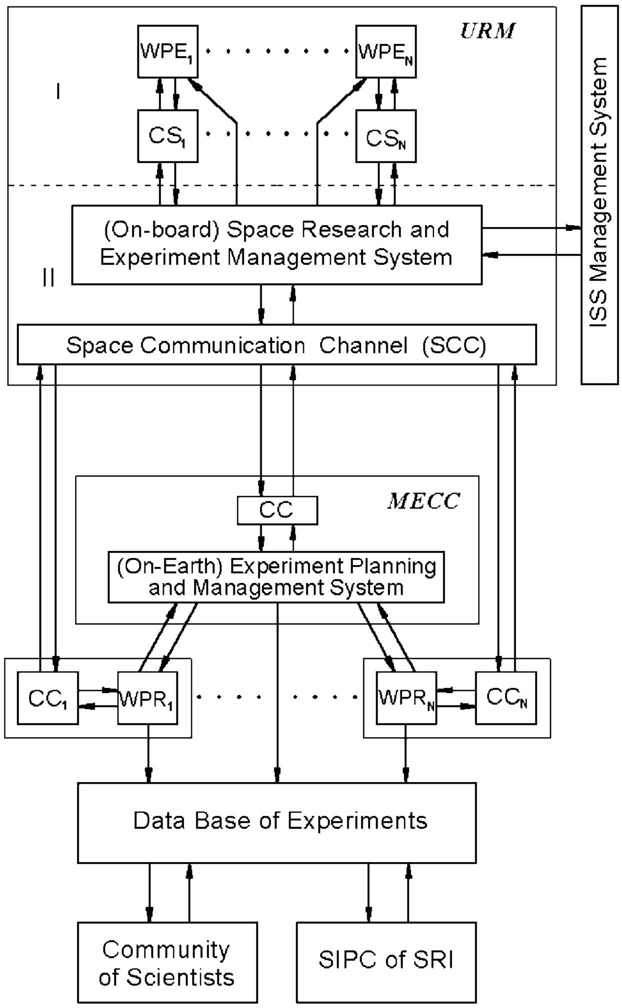


Fig. 1. WPE_i — (on-board) workplace of experimentalists, CS_i — (on-board) local control systems, CC — communication channel, MECC — mission and experiment control center, WPR_i — (on-Earth) workplaces of researchers, SIPC — Scientific Information Processing Center, ISS — International Space Station, SRI — Space Research Institute, URM — Ukrainian research module

through its own CC. This paper proposes creation of such a database system, which would contain the results of the total set of on-board experiments performed at the URM. This may be realized, for instance, on the basis of the Redundant Array of Inexpensive Disks (RAID) technology in the form of the shared data RAID-repository, accessible to Scientific Information Processing Center, to Space Research Institute and to the international scientific community.

CONDUCTING A SET OF ON-BOARD EXPERIMENTS: PLANNING METHODOLOGY

The Program, concerned with scientific and technological experiments, carried out in the URM, includes 6 priority areas. First of all, the Program considers 15 integrated projects, which include, in their turn, almost 100 separate experiments. For example, Section 1 of the Program, i. e., «Space Biology, Biotechnology and Medicine» consists of 4 integrated projects («Greenhouse», «Zoomodule», «Biolaboratory», and «Biomedcontrol») and «Greenhouse» project consists of about 20 experiments.

The specific feature of the onboard experiments conducted at the URM is that a set of experiments is to be simultaneously performed in the single orbital laboratory. Various scientific installations and instruments should be mounted and should operate in parallel to perform these experiments. Therefore, when an initial experiment set structure and a further current renewal are planned then restrictions imposed onto the volumes, weights, energy and information exchange intensity should also be taken into consideration. In addition, it is necessary to provide a compatibility of experiments during their performance with the ISS technological operation modes and between the experiments themselves. For instance, when the solar batteries of the ISS are reoriented, vibrations are probable, and a level of microaccelerations caused by them, may exceed a level admissible for separate types of experiments. Thus, planning the experiment duration the possibility of simultaneous performance of the technological mode of reorientation should be eliminated, or, to realize an experiment, the vibration level should be measured and an appropriate protection from vibration should be envisaged in an installation. Much the same situation is probable during parallel operation of scientific installations and instruments, because of electromagnetic radiation, irradiation, thermal or other flows, which take place in this case and which may have a great influence on performance of a separate experiment. Therefore, appropriate means should be provided for protection from these influences and their intensity should be measured.

Experiments will be conducted at special workplaces of specific design, accommodating the main and auxiliary equipment for performance of these experiments. The number of these workplaces, R, is limited, and the number of experiments, N, is much higher than R. Hence, a nontrivial problem emerges here concerned with the choice of top-priority R experiments out of N experiments, as well as the problem concerned with ordering the rest of these experiments.

The main criterion of selection of R experiments consists in their scientific value and technological novelty. Proceeding from this criterion, such a selection is performed by experts and, first of all, by the members of the CCOSS and by the experts working at the NSA of Ukraine. In this case, those research areas are highlighted, in which top-priority experiments should be performed, and natural restrictions are introduced which are imposed on their number. The experts will have to select a number of candidates for top-priority experiments, which is larger, than a number defined by the introduced restriction, and this selection is made for each area. Therefore, we have $N_1 < N$ experiments, from which R experiments are to be selected. It is necessary to make up N_2 combinations from N_1 selected experiments for R different experiments. In this case, upper constraints should be taken into account in each research area. In this case, the experts may also introduce the lower constraints on a number of workplaces in every area, for example, in order to locate no less than two on-board research installations at the URM, which are to support the experiments, carried out in one of these areas. Thus, the procedure of choosing the possible combinations becomes easier.

Further selection of the said combinations, pretending to their top priority as to performance, is to be made by means of a computer program. The abovementioned restrictions imposed onto a possibility to perform the considered set (combination) of R experiments should be taken into account.

When experiments are planned at the URM, the human factor should also be taken into consideration. If an astronaut serves the set of R experiments, then he must be checked for his ability to do this, as well as for his professional level for each experiment, i. e. the extent to which they are computerized, duration required for their performance, fatigue and different factors (in particular, microgravity) influencing the efficiency of his work. All these factors can allow making the set of possible top-priority experiments even smaller.

It should be noted that when scientific and technological investigations are planned and performed at the URM, one should be fully aware of the fact that a specific human-computer system is in place here. The problem related to construction of high-performance human-computer systems is not solved yet despite the rich history of the investigations carried out in this area. It is only evident that, in view of the specific conditions of the astronaut's activity, one should try to avoid as much as possible, entrusting him with execution of those operations, which can more or less successfully be carried out by computer-aided control systems. He should perform only those operations, which, for certain reasons, are rather complicated for implementation or which cannot be realized by technical means. In addition, his main function should be participation in the case when problems are to be solved in an emergency.

The state-of-the-art of information technologies and telecommunication systems allows implementation of the mode of virtual presence at the URM of a ground-based scientist who is an author of an experiment, and the distribution of duties in such a human-computer system becomes substantially modified. There is every reason to believe that when every constraint, both purely technical and associated with the human factor, is taken into account, a computer-aided selection will result in a relatively small number of sets of R experiments, pretending to their top-priority performance.

METHODOLOGY OF COMPUTER-AIDED SELECTION: VOLUME AND POWER RESTRICTIONS FOR A SET OF EXPERIMENTS

Problem Statement. Let there be N on-board experiments (projects), which are to be realized at the URM.

Let us assume that an equipment (instrument) set, consisting of σ_i units, is necessary for realization of each i-th project. A qualitative composition of equipment for each i-th project is characterized by a vector X^i, where $\dim X^i = \sigma_i$. Vectors X^i consist of a number of unique components, required only for realization of some i-th project, as well as of a number of the components, participating also in the realization of other projects. The total set of equipment components x_k, $k = 1,...M$, participating at least in one project out of N projects, is characterized by the vector:

$$\mathbf{X} = \| x_k \|_{k=1}^{M}, \tag{1}$$

where x_k is the number of some k-th instrument. Therefore, vectors X^i, $i = 1,..., N$, may be considered as selections from σ_i components of $\mathbf{X}$, i. e.

$$X^i = S^i X,\ S_i = \| s_{ln}^{i} \|_{l,n=1}^{l=M,\ n=\sigma_i}, \tag{2}$$

where S_i is some $(M\times\sigma_i)$-dimensional matrix. One element of this matrix is equal to a unity in each row, i. e., this condition means that the l-th component of $\mathbf{X}$ is used in the i-th project, and all the other elements of the same row are equal to zero. S^i are the exhaustive characteristics of an equipment set, needed for implementation of some i-th experiment.

Let us assume also that a volume ν_k is required to accommodate each k-th instrument. Then, to realize some i-th project, the volume

$$V^i = \sum_k \nu_k,$$

is needed, where the index k runs through every value of the vector X^i.

Suppose, that a total volume

$$\overset{o}{V} = \sum_{i=1}^{N} V^i,$$

required for location of the entire equipment, when all the N projects are realized simultaneously, exceeds a given volume $\overset{*}{V}$, i. e.:

$$\overset{o}{V} > \overset{*}{V}.$$

If inequality (3) exists, it is impossible for all the N experiments to be realized simultaneously. Hence, the following problem: it is necessary to establish such a parallel-serial schematic for delivery of equipment and for its arrangement on board the URM, and to perform such a combination of experiments that an amount of equipment is involved at every moment of time t, for which the inequality

$$\widetilde{V}_t \le \overset{*}{V},\quad t \in [0, T] \tag{3}$$

is met during the whole time interval $[0,\ T]$, providing for performance of a specified number of experiments.

In this case, $\widetilde{V}_t$ is the total volume, i. e., an amount of equipment used at a moment of time t.

Let us suppose now, that p_i energy units are needed to perform each i-th experiment. In this case, to simplify the solution to the problem, concerned with the definition of the required experiment realization scheme, let p_i = const, i = 1,..., N, i. e., the power consumed during some i-th experiment does not vary in time. Denote the amount of energy, available for consumption, by $\overset{*}{P}$. Then, the scheme for which a total consumed energy $\widetilde{P}(t)$ does not exceed P, i. e.

$$\widetilde{P}(t) \le \overset{*}{P},\quad t \in [0; T], \tag{4}$$

is considered to be a serial-parallel experiment realization scheme, admissible by the power indices.

Such a parallel-serial experiment performance scheme, for which inequalities (3) and (4) are met simultaneously, is hereafter referred to as an admissible scheme. To solve the problem of experiment performance scheme definition, the experiment performance conditions should be clarified and some cost considerations should be pointed out. Let us assume, first of all, that to prevent the equipment duplication, it is necessary to consecutively use the same equipment unit x_i for performance of different experiments. Those instruments that were already used to realize a project and which are not needed for realization of the remaining projects, are «annihilated», and, therefore, a place, where new instruments must be mounted, is free for the latter.

Let each i-th experiment be realized during a time interval τ_i. To simplify the solution of the problem of definition of an admissible experiment performance plan, let there be no space-time constraints, imposed onto experiments, i. e., they can be realized at an arbitrary moment of time $t \in [0; T]$ and in any position of the ISS with respect to the Earth. Let us take the totality of experiments and consider such a group of them equal to $\overline{N}$, for which $\tau_i = T$.

The structural and energy resources ($\overset{*}{V}$ and $\overset{*}{P}$, respectively) are specified. Then, consider their portions $\Delta\widetilde{V}$ and $\Delta\widetilde{P}$, needed for experiments, realized during the whole time interval T under consideration, i. e., for an experiment, when $\tau_i = T$, and reject them from further consideration. Let us introduce the following denotations:

$$\overline{P} = \overset{*}{P} - \Delta\widetilde{P}; \quad \overline{V} = \overset{*}{V} - \Delta\widetilde{V} > 0 \qquad (5)$$

for the remaining resources. Let us denote a number of experiments, remaining for consideration, as $\overline{M} = M - \Delta M$. The scheme definition problem, when $\overline{M}$ experiments are accomplished and for which resources $\overline{P}$ and $\overline{V}$ are provided, is dealt with further on.

Defining an Experiment Performance Plan: Problem Solution Scheme. The experiments X^i, repeated in a cyclic manner q_s^i times are considered to be q_s^i independent experiments that need the same equipment structure. Each i-th experiment in the 3D-space $\{t, v, p\}$ is characterized by its triad («generalized volume») $\omega = \tau_i \times V^i \times p_i$. Therefore, at contents level, the problem, related to checking how inequalities (4) and (5) are met, is similar to the known problem of «box packing» into a specified 3D box $W = T \times \overline{V} \times P$. However, there is the following essential difference between these two problems: a group of triads ω_i that are to be packed into W, is not specified in advance, but it is to be determined. The number of possible combinations of instruments in N projects is

$$C_\sigma^N = \frac{N!}{\sigma!(N-\sigma)!}.$$

The value of C_σ^N is equal to 10^5 — 10^7 at $N = 50...100$ and at average $\sigma_i = \sigma = 4...5$, and, evidently, the problem of definition of an admissible experiment performance scheme is a complicated combinatorial problem that is rather difficult to be solved «manually». It is also evident that this combinatorial problem has no single solution. Therefore, for excluding this non-singularity and for reducing the number of variants analysed, which are further on checked for satisfying inequalities (4) and (5), let us introduce one more characteristic, i. e., the project priority degree. Without losing the generality, let us assume that, when a project ordinal number is decreased, a project priority degree increases. Then the following problem solution scheme may be proposed.

Starting from the first project, characterized by the matrix S^1, the projects, compatible with the first one are stated according to the matrices S^i and to the order of their numbers increase, and the volumes V^i and energy resources P^i, which are needed for their implementation, are determined and summed up. This process of increasing the number of simultaneously realized projects, goes on until a violation of one of inequalities (4) and (5) is observed. After this, the last project, the addition of which for forming the group of simultaneously realized projects has resulted in violation of one of inequalities (4) and (5), is rejected, and the set of projects, derived in this way, is admissible.

Then, when a project with a minimum duration is terminated, the equipment, already used for its realization is annihilated, if it is not used in the rest of the projects. For filling up an extra volume formed in accordance with the already described methodology, let us determine those additional projects in the order of decreasing numbers, which are compatible with the rest of the projects, not completely realized yet. The project compatibility is checked by the lack of elements not equal to zero, in the respective rows of S^i.

Then, when some next-shortest project is terminated, the above procedure is repeated until the answer is provided as to whether a specified time interval $[0; T]$ is sufficient for realization of the total number of projects or not. It should be admitted in the latter case that a proposed project totality is not realizable within the provided resources and that the number of projects must be made smaller.

Some Generalizations. Consider now some generalizations for the above method, in which an admissible parallel-serial experiment performance scheme is defined. It was assumed above that each experiment can be realized at some arbitrary moment $t \in [0; T]$. Generally speaking, however, if a set of N experiments is planned, space-time restrictions may be imposed onto some of them by virtue of many reasons, ultimately requiring these experiments to be performed, starting at the time moments $t^j \geq 0$ during the time τ_j. Take the highest priority for this experimental portion and combine these experiments with the ones, performed during the entire time interval T. Denote the resources, needed for realization of the experiments with time restrictions, as $\hat{V}(t)$ and $\hat{P}(t)$. Then, the reserve of the resources, necessary for realization of all the remaining experiments in $\tau_i < T$ is

$$\overset{\circ}{V}(t) = \overset{*}{V} - \Delta V - \hat{V}(t), \tag{6}$$

$$\overset{\circ}{P}(t) = \overset{*}{P} - \Delta P - \hat{P}(t), \tag{7}$$

Therefore, instead of checking inequalities (4) and (5) with the constants in their right sides, in the case under consideration one should bear in mind that the right sides of inequalities (6) and (7) are the specified functions of time. Much the same situation is also in place, when either initial energy resources depend on time for some reason, or if the energy resources, required for realization of some experiments, vary in time.

For simplicity sake, everywhere above it is assumed that when a volume, needed for the realization of some experimental totality, is determined, this volume is equal to the sum of volumes required for performance of each such experiment. The actual situation, however, is different, since for a number of structure-related reasons, the total RM volume falls into a certain number s of standard racks of equal volumes, and each such rack consists, in its turn, of a specified number q of standard cells of a volume equal to Δv. Thus, the total module volume is discretized at two levels: at an upper level and at a lower level, i. e., at a level of racks and a level of cells, respectively. Therefore, if total volume V_σ, necessary for realization of a set of experiments, consisting of σ experiments, is determined, it should be not the sum of the volumes V^i for each i-th experiment, but the sum of the values

$$\overset{*}{V^i} = \mathrm{Ent} V^i, \tag{8}$$

where Ent$X$ is the nearest larger integer number of the scale of volumes Δv.

A SYSTEM FOR TELECONTROL OF AN EXPERIMENTAL ON-BOARD INSTALLATION

Another important function, performed by the system of planning and management of scientific and technological on-board experiments at the URM of the ISS, consists in realization of the experiment telecontrol mode. The co-executor of the Space Research Institute in the sphere of experiment telecontrol design and implementation is the Physical Engineering Teaching-Research Center (PETRC) of the NAS of Ukraine, which took part in the International Project on design of MIGMAS, an on-board space ion microanalyzer jointly with the Austrian Research Center (Seibersdorf) and «Energia» Russian Space Corporation [4]. To control MIGMAS, PETRC has developed SIMSCAN [5], the hardware-software system, which by means of a computer enables performance of all the instrument adjustment operations, testing its condition and carrying out information acquisition, processing and documenting.

The main idea of telecontrol is to share control functions between several systems with different levels of intelligence, interconnected by communication facilities, and to minimize data flows between these systems.

In the majority of the present-day analytical instruments, a considerable number of the analysis process computerization operations are executed by a computer or by an instrument controller. The man's task is to generate a sequence of macrocommands for this computer or controller. Evidently, such a macrocommand sequence can be generated also at a distance from this analytical instrument, if a man has complete information about an instrument state at the decision-making moment.

It has become possible to solve this problem due to development of the communication means, capable of providing a sufficient data transfer rate. The examples here may be Internet, telephony, video conferences in the Internet. Nevertheless, considering the distance from the Earth to the ISS and the continuous motion of the ISS with respect to the Earth, the information flows should be minimized, the high speed and integrity of control

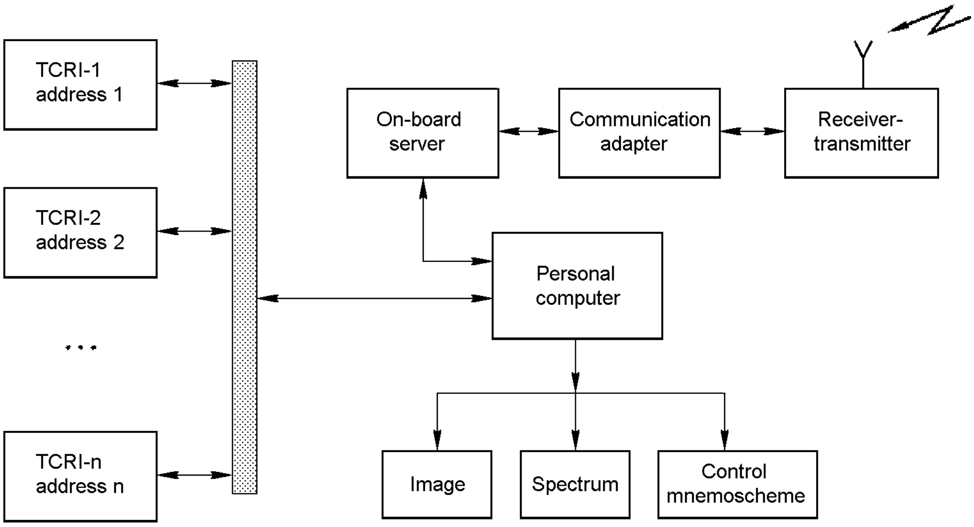


Fig. 2. ABEL — Automatic On-Board Experimental Laboratory: A Flowchart

programs transfer aboard the ISS should be provided, as well as transfer of the system state parameters and measurement results to the flight control center (FCC).

In contrast to commercial analytical instruments, where measurement processes and measurement procedures are strictly standardized, a scientific instrument, created as a separate specimen, must readily allow making changes in the hardware configuration and analysis procedures. Therefore, those systems, which are aimed at computerization of such instruments, should also be universal and not developed for a particular instrument.

Figure 2 shows a flowchart of an automatic on-board experimental laboratory (ABEL). This control system level is constructed on the basis of a computer, which controls the operation of several telecontrolled research installations (TCRI), connected to it in one of the usual ways, for instance, by the USB- or IEEE 1394 (Firewire) buses. A really multiproblem operation system, for example, Windows NT or UNIX, should be installed in this computer. Control programs should always be present in the computer memory and provide a continuous monitoring of the parameters of every TCRI. The software should enable entering the control instructions and displaying the experimental results and current information on the operational modes of the selected instrument. The computer must be connected to the on-board information network of ISS, in order to send data to the Earth.

The upper (ground-based) telecontrol system level in the ABEL (Figure 3) is based on the standardized

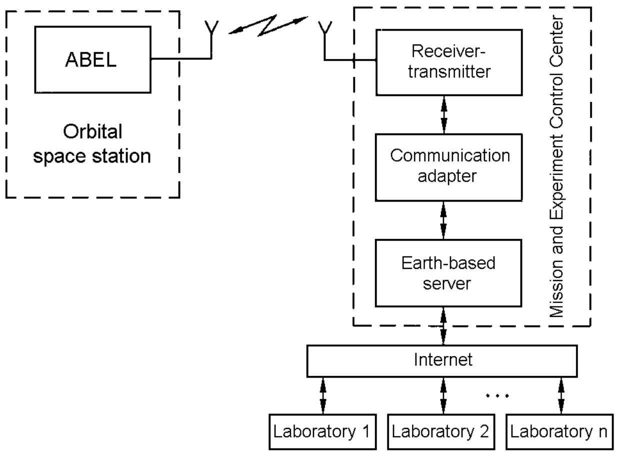


Fig. 3. Telecontrol System: A Flowchart

Internet technologies. The FCC incorporates the system server, which envisages the following:

— transfer of the instrument control commands;

— receiving all the operational and analytical information from the ABEL;

— making protocols of ABEL instrument operation;

— structuring and storing the obtained information;

— proving authorized scientists' access to the obtained information;

— providing virtual contact between the experts.

Since the analog sensor signals must be digitized

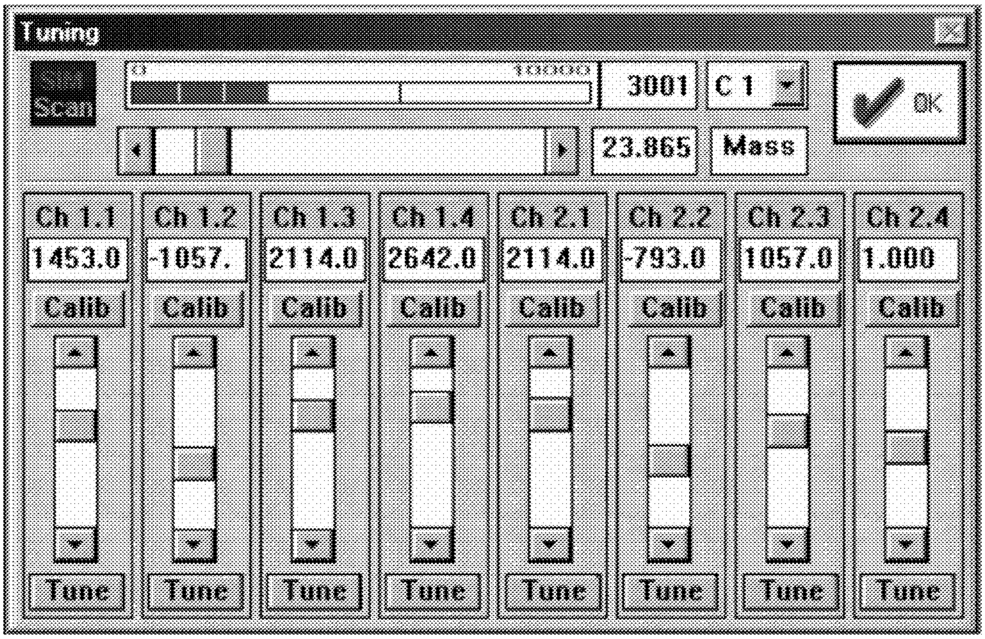


Fig. 4. A Displayed Virtual Instrument

during performance of an experiment, the system must be supplied with a set of AD converters. The control analog signals must be generated by a set of DA converters, whose capacity and operating speed are determined by the measurement and control system features.

The concept of construction of remote control of an experiment is based on the client-server methodology. A server exports some resources (equipment access in our case), and clients use these resources. A server communicates with clients through a computer network, to be created via Internet and Intranet. A client provides a transfer of queries and control from a researcher to a server, which converts these data into instructions of installation control, of reading the output data of physical measurements, as well as of sending them to a client. A client visualizes these data for a researcher. It is rational to construct the software using Java that is simultaneously a medium and an execution environment, supported by every operation system and now also supported by the hardware [1].

The system of telecontrol of scientific and technological experiments, performed at the URM of the ISS, has passed its ground-based pilot design stage, and has been tried out in the case of remote numerical control of the secondary-ion mass-spectrometer. SIMSCAN-3, the mass-spectrometer computerization system, performs complete parameter control and instrument adjustment, records the primary and secondary mass-spectra, ion and electronic images, and conducts the depth profiling. It is a Eurostandard crate of a half-height, containing a set of functionally independent modules and connected to an IBM PC computer by a specially designed parallel interface, incorporating a bi- directional 8-bit data bus, an 8-bit address bus and a control bus. The maximum data exchange rate is about 500 Kbytes/sec. SIMSCAN consists of the following modules:

— A high-voltage operational amplifier module. It consists of 4 amplifiers, used to control a system of deflection of a primary ion beam. Maximum output voltage is ± 130 V; bandwidth is 200 kHz.

— A deflection system DA converter module. It contains the following converters: two 13-bit DA converters (12 bits + a symbol) and one 11-bit DA converter (10 bits + a symbol). It is used to control the high-voltage operational amplifier module.

— A module for Wiener filter control. It incorporates one 16-bit precision DA converter and is used to control the power supply unit of Wiener filter magnet.

— An AD converter module. It contains one 13-bit DA converter with a switch for 8 channels (12 bits + a symbol). Conversion time is 100 mcs. It is used to measure the current at different column points, the source temperature and so on.

— A timer-counter module. It incorporates one 32-bit timer and two counters (a 32-bit counter and a 16-bit counter). It is used to register the pulses from a secondary-electron and secondary-ion channel outputs.

— A DA converter module. It contains four 12-bit DA converters. It is used to control the high-voltage power supply units of accelerating, extracting and focusing voltages, as well as the source temperature, energy and type of secondary ions.

Such a set of modules, used for control and monitoring purposes, makes the system flexible for adaptation to performance of any experiments on microanalysis and/or microprocessing. The information basis of the whole instrument is special-purpose software that allows implementation of all the functions of this instrument, namely:

1. Generating control signals for the analyzer beam scanning (deflection) over the surface of the object being analyzed, to provide a raster allowing a broad variation of the raster dimensions, scanning amplitude, number of pixels, contrast gradation, scanning time, choice of sectors or scanning lines. These systems are typical for raster electronic microscopes, electronic and ion microprobes, scanning tunnel microscopes, microscopes of atom forces, acoustic and laser microscopes.
2. Generating a control signal for analyzer scanning. Such a signal usually varies in time by a linear law and is formed by DA converters with a high resolution (16 bits).
3. Registering an output signal in analog or counting modes in the frequency band of $1...10^7$ Hz.
4. Control of the main circuits providing the analyzer operability through DA converters.
5. Display of the main parameters characterizing the system state.
6. Analyzer calibration for scale linearization purposes.
7. Recording the derived images, spectra and current parameters.

The instrument software, namely the control program called SIMSCAN.EXE, functioning in the MS Windows environment, is developed using the object-oriented approach and implemented in the C++ and Assembler languages. The software module is created, which directly controls the system in a computer-aided operational mode and in the virtual instrument mode. The instrument controls are displayed as mouse-controlled potentiometer slides, with indication of the current values of the controlled parameters. The program allows calibration of each channel. Measured signals are displayed as a bar indicator and as an intensity meter (see Figure 4).

The results of testing the mock-up of the system for remote control of the secondary-ion mass-spectrometer demonstrate the system operability and efficiency. This opens up the possibilities for development of other systems on its basis, which are capable of performing telecontrol of other sophisticated on-board experimental installations and instruments in the orbital scientific laboratory within the ISS.

References

1. Weber J. Using Java, 2nd Edition. Transl. from English // BHV Dusseldorf, Kiev, Moscow, St. Petersburgh, 1999.— 1104 p. (In Russian).
2. Kuntsevich V. M. Space Science in Ukraine: Current Trends and Future // News of NAS of Ukraine.—1998.—N 11-12.— P. 45—52. (In Ukrainian).
3. Reibaldi G., P. Behrmann G., J. Ives G., et al. The Microgravity Facilities for Columbus Programme // ESA Bulletin.—1977.—90.
4. Rudenauer F., Riedler W., Cherepin V. T. MIGMAS — an Analytical Ion Microprobe for the Space Station MIR // Advances in Mass Spectrometry. — Amsterdam: Elsevier Sci. Publ., 1998.—**14**.—P. 705—711.
5. Zotov I. A., Cherepin V. T., Rudenauer F. G. SIMSCAN — New System for SIMS-Data Acquisition and Processing // Secondary Ion Mass Spectrometry, SIMS-10. — Chichester-New York: Wiley, 1997.—1023 p.

CONCLUDING REMARKS

Scientific research and technological experiments presented in this special issue is an important contribution of Ukrainian scientists and engineers into the ISS project.

These experiments will give principally new knowledge in such fields as space technology and materials science, Earth sciences, solar astrophysics, space biology and biotechnology, space medicine, solar power engineering, study of the physical-chemical processes under microgravity, planning and management of on-board experiments in the orbital complex.

The *«Space technology and materials science»* Chapter contains information on three integrated projects aimed at study of the influence of space factors on characteristics of the ISS elements and units as well as on properties of various materials.

The experiments of the «Material» project have a common purpose to make materials under microgravity conditions with new useful properties, which cannot be produced under the effect of terrestrial gravity. The processes of heating, melting, spraying, cooling, and crystallisation are used for producing the samples. However, tasks, methods, objects of study, and applied equipment differ essentially in these experiments. The measuring and registering systems for all the experiments are rather similar and can be unified.

The influence of space factors and microgravity on mechanical, tribotechnical, and optical-physical parameters of materials and coatings is studied in the integrated «Degradation» project. Special attention is paid also to development of new on-board scientific equipment, its power supply and thermostabilization systems (heat setting), as well as to ground-based simulation of the influence of space factors on various materials.

The third «Diagnostics» project deals with the methods and equipment for control of defectiveness and stressed state of space constructions.

The *«Research of the Earth and near-Earth space»* Chapter contains five integrated projects, which are related to contact diagnostics of plasma and gaseous environment of the ISS, study of the Earth's upper atmosphere by the optical and millimeter-wave technique, study of the Earth's ionosphere, remote sounding of the surface and water area of Earth, active experiments in space and on the Earth's surface.

An integrated approach to measurement and analysis of the basic parameters of gaseous and plasma environment of the station (concentration of particles, mass content, temperatures of electron and ion components, power spectra, effective scattering cross-sections, plasma potentials, pressure, electric and magnetic intensities, etc.) is proposed in the «Environment» project.

The «Inframon» project deals with continuous and long-term monitoring of the events occurring on the Earth's surface, in the atmosphere and in the near-Earth space. The apparatus proposed by the authors can be incorporated into a common measuring complex allowing research to be completed simultaneously in the high-frequency range of the electromagnetic wave spectrum.

In the «Space» project a new procedure of global near-Earth plasma monitoring with the method of radio sounding by signals of the ground-based HF and EHF broadcasting radio and television stations, received on board the ISS is proposed.

The «Surface» project deals with a series of experiments to study the Earth, water area and natural environment of Earth in optical, infrared, millimeter, centimeter, decimeter, and meter ranges of waves and to improve methods of the Earth Remote Sensing.

This Chapter also contains a description of active experiments in space, including such an important task as a development of a technique for experimental research of orbiting object characteristics, which evaluates the risk of operating spacecraft being damaged by space debris.

Two experiments described in the *«Astrophysics and extraterrestrial astronomy»* Chapter are in the field of solar astrophysics. One of the experiments deals with observations of magnetic field and plasma conditions of various formations on the Sun with the high resolution up to 0.2″, which has never been reached in previous experiments. The second experiment is intended for long-term measurements of the solar radiation flux with the subsequent calculation of the proper frequencies of its oscillations. The relative amplitudes of these oscillations are equal to $(1—10)\cdot 10^{-5}$. Stringent metrological requirements for stability of parameters of the radiation sensor and for the time interval precision are imposed to detect such a weak signal.

The program on space biology, biotechnology and medicine described in the *«Space biology, biotechnology and medicine»* Chapter envisages gaining of principally new scientific knowledge about the mechanisms of biological effects of microgravity at the population, organism, cellular and molecular levels as well as development of concepts on cell gravisensitivity and growth, development, reproduction, and resistance of organisms in microgravity. It will promote creation of the space cell biotechnology for medicine and agriculture, express-methods for ecological monitoring of the biosphere, as well as development of new technologies for the Controlled Ecological Life-Support Systems (CELSS). These priorities of the program are based on the statement that proliferating and actively metabolising cells are the most sensitive to the influence of microgravity.

The principal investigations of Ukrainian space biologists have been carried out in the field of gravitational biology. For this reason, a significant number of biological experiments on board the URM are intended to verify the conceptual ideas of the Ukrainian scientists in this field. New methodological approaches to performance of the space and ground-based experiments with clinostats and centrifuges are considered as well. A considerable attention is also paid to space medicine directed to protection of human health, improvement of the quality and duration of the astronauts' life in a long-term space flight.

The project of the *«Space solar power engineering»* pursues further development of the theory of processes of solar energy conversion into electric energy and its transmission to remote users in the space environment as well as creation of adequate mathematical models and study of the dynamics of advanced technological structures in solar power engineering as specific mechanical systems.

The experiments described in the *«Physical-chemical processes under microgravity»* Chapter are concerned with the basic problems of physics of liquids and materials science. The first described experiment deals with study of the microgravity influence on parameters of heat exchange and dynamics of the vapour phase in boiling of liquid helium. Other experiments deal with producing new materials under microgravity, i.e. composite materials from immiscible components with use of the method of ultrasonic excitation and the eutectic alloys of Ni-Nb-C system by the method of electron beam zone melting. Experiments on processes of directional crystallization under microgravity with three-dimensional preparation and of soldering composite ceramics and glasses with molten metal solders are performed too. A promising method for production of semi-conductors in space is the crucibleless zone melting (CZM) with a disc-shaped electron beam, which is based on the extremely clean conditions of the molten zone formation. This method will be used in the unique «Technology» experiment for making a flight unit to conduct the electron beam CZM under microgravity on board the ISS.

The *«System analysis»* deals with planning and management of on-board experiments at the scientific orbital laboratory in the structure of the ISS.

The projects of scientific research and technological experiments described in this issue have been recommended by the CCOSS for realization onboard the Ukrainian Research Module of the ISS. They could also serve as the database for preparing joint international proposals. As the first step in this path the appropriate American and Ukrainian organizations have selected several bilateral projects, which will be funded by the USA according to a Memorandum of Understanding signed in 1999. Negotiations are now in progress between the Russian and Ukrainian specialists for specifying joint Russian-Ukrainian projects.

Not with standing the prospect of the Ukrainian Research Module, the authors hope that their vision of conducting the scientific research and technological experiments onboard the ISS will be useful for the ISS community, and that the great ISS project will be realized for benefit of mankind.