ANNEX I

Work Plan

I. Summary Project Information

1. Project Title

New Technology of Obtaining of Thermoregulating Coatings for Space Vehicles

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3. Participating Institutions

3.1. Leading Institution

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3.2. Other Participating Institutions

Participant Institution 1

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None

4.2. Partners

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5. Project Duration

24 months

6. Project Location and Equipment

Institution	Location, Facilities and Equipment
Leading Institution- IGIC NAS RA	The “Complex treatment of aluminosilicate rocks and inorganic polymers” laboratory of the Institute of General and Inorganic Chemistry of the National Academy of Sciences of the Republic of Armenia (IGIC of NAS RA) is equipped for the works at hydrothermal conditions. The laboratory rooms have drawing and input ventilation. The laboratory is provided by main electric, mechanical and glass equipment for hydrothermal-microwave treatment and synthesis of silicate materials. There are special autoclave lines for the work at the pressure of up to 40 bar (T = 250 ^{0}C).The laboratory is served by the special laboratories of physico-chemical investigations and by analytical laboratories as well. The work conditions and personnel qualification permit to proceed to the investigations immediately. During the works it is possible to provide a current preventive repair of some part of the equipment. The laboratory rooms are equipped with the following main scientific equipment: Atomic absorption spectrophotometer AAS-1 (Germany); IR spectrophotometer “Specord-75 IR”; “Specord-M80” (Germany); Derivatograph “OD-103” (Hungary); Diffractometer URD-63 (Germany); Dilatometer “DKV-5A” (Russia); Microwave furnase CE 1073AR; Electric high-temperature furnace “Nabertherm” LHT 08/17; Electric muffle furnace “Nabertherm” N 11/H. The necessary new equipment to be purchased is listed in the Table 9.1.2.
Participant Institution 1 - YerPhI	The laboratory of radiative solid state physics and optics of A.Alikhanyan National Laboratory (Yerevan Physics Institute) is placed in #58 building. The equipment of Institute to be used for the Project implementation, is as follows: 4, 10 MeV Linear electron accelerators; UV-irradiation generator; XRF- ARL QUAN, X-Spectrometer; 18 MeV proton cyclotron; Optical spectral installations for investigations in UV-IR ranges; Low-temperature vacuum chamber for materials irradiation; Low-background gamma-ray spectrometric installation with NaI cell and software; Low-background gamma-ray spectrometric installation with germanium cell and software. The necessary new equipment to be purchased is listed in the Table 9.1.2.

II. Specific information

1. Introduction and Overview

The Project aim. Developments of new compositions of thermoregulating coatings for space vehicles (SV) and new technology of their obtaining by original and perspective method, hydrothermal-microwave synthesis, are planned within the framework of the Project.

Situation in the field of research. Thermoregulating coatings are used in SV for the purpose of maintenance of their thermal regime. Stability of SV thermal regime is one of the main factors determining safety and durability of SV, because the SV optics and electronics works in a definite temperature mode. A part of hardware thermoregulation system are various thermoregulating coatings (TRC) that ensure a balance between the heat liberation in the SV interior, the energy absorbed from the space, and the energy reradiated in the space. Nowadays it is provided with enamel and ceramic thermoregulating coverings of “solar reflectors” type on the basis of oxide white pigments. As the previous experience shows, a number of SV could not perform the planned schedule in view of overheating as a result of increaseed TRC’ absorption coefficients of solar irradiation in the passive thermoregulation system. Examination of the existing TRCs indicates that they can not provide increase in active lifetime up to 15 years, especially for SV operated at high elliptical and geostationary orbits, because spectroscopic characteristics of the coatings are changed under the impact of space factors during long-term orbital missions of SV. This leads to destabilization of radio-electronic hardware operation, on-board systems failure and abortion, and thereby results in reduction of SV active lifetime. Therefore, creation of TRC of “solar reflectors” type having stable thermo-radiation characteristics and simultaneously antistatic properties at long-time operation in the space with low out-gassing is one of the main tasks of cosmonautics of XXI century. Development of such coatings will permit to minimize deviation of the predetermined thermal regime, to decrease works failure and abortion of highly sensitive optic and radio-electronic hardware, giving a possibility to increase the SV' active lifetime up to 15 years and more. Prospective directions for the solution of the mentioned task are as follows:

- Development of methods for increasing the pigments' photo- and radiation stability;
- Selection or development of effective stabilizers of degradation under the impact of the space;
- Development of new composites of pigments, including those with high electro-conductivity, stable to long-term impact;
- Development of new composites of thermoregulating coatings;
- Development of composite or modified thermo-stable and radiation-stable binding agents with low out-gassing.

These problems in the world experience are being solved by various methods: new compositions of thermoregulating coatings are being elaborated, radiation characteristics of known materials are being improved by their structure modification using various methods [1,2]. The ability of pigments to absorb and reradiate solar irradiation in near UV-irradiation, etc., is predetermined by their chemical composition and structure. When absorbing radiation with relatively high energy, some structural transformations related to the change of energy state of atoms and ions take place in pigments. Here, total absorption of radiation by coating is a sum of own absorption and absorption caused by the presence of elements with variable valence (d and f elements). The existed thermoregulating coatings of “solar reflectors” type are enamel and ceramic composites on the basis of oxide white pigments. As pigments for this coatings type, ZnO, ZrO_2, TiO_2, Zn_2TiO_4 etc. powders [3-7] have found the most use as more stable under the impact of charged particles and quanta of solar vacuum and near UV-irradiation. The mentioned materials are obtained on the basis of expensive high-purity chemical substances; the process of their obtaining is multi-stage and long-term and is carried out at high temperatures. Analysis of scientific and technical information on the problem of obtaining materials for SV coatings has shown that as for of oxide ceramics, it is possible to change essentially physical properties of ceramic materials and to improve their mechanical characteristics by reducing the size of initial powder particles down to nanometers [8-10]. Modification of oxides by nanopowders of definite composition is carried out at high temperatures. In recent years, unique abilities of microwave treatment have found application for obtaining of nanopowders and modification of their structure [11-14]. Our preliminary analysis of scientific and technical information, experience and investigations in the field of synthesis of high-purity materials have shown that nanopowders of silicates of zirconium, zinc, titanium doped with atoms of rare earth elements (REE) - yttrium, cerium, etc. - can be successfully used as pigments for solar reflectors[13-14]. Application of REE in ceramics is studied a little, however detailed analysis of their physico-chemical properties and a special electron structure of REE atoms suggests that it will enlarge considerably the pigments lighting parameters and increase their thermal stability [4,6,7]. The TRC on the basis of the stated materials will provide their long-term operation in the space as they have high chemical stability and do not deteriorate under the impact of space; the outgassing is excluded as well, which is observed when using oxide ceramics and organic binders (due to some chemical reactions). The silicate pigments compositions with decreased UV-transmittance may vary in rather wide ranges. Nowadays the use of silicate pigments for TRC is limited due to complicated technology of their obtaining. The process of obtaining of nanocrystalline powders, as well as high-purity silicates of zirconium, zinc, etc. is multi-stage and prolonged, it should be carried out at high temperatures [15-17]. The development trend in this field is aimed to provide high failsafety of passive thermoregulation systems functioning at high orbits, to increase lifetime of products due to increasing radiation stability of their coatings. With this end in view, new compositions of TRC are being elaborated, radiative properties of known materials are being improved using their structure modification by various methods. Analysis of scientific-and-technical literature on obtaining of materials for SV coatings has shown that there are considerable achievements in this field. However, the known methods of synthesis of the stated materials are mainly solid state or sol-gel method. The initial materials are mainly oxides, carbonates, nitrates or sulphates that pollute environment at thermal treatment. The substances modified in solid state synthesis conditions, do not provide homogeneous structure, which is very important for obtaining of pigments with definite thermo-radiation characteristics. The stated materials are obtained on the basis of expensive high-purity chemical substances modified by nanopowders of definite compositions at high temperatures. The process of their obtaining is multi-stage and long-term. Therefore, there is a necessity for fundamentally new methods of their obtaining and cheaper materials for TRC production. It is possible to develop new pigments composition using scientifically grounded approach based on our investigations in the field of synthesis of high-purity materials. Our investigations in this area have shown that nanopowders of silicates of zirconium, zinc, doped with oxides of ittrium, cerium, etc. can be successfully used as pigments for solar reflectors. Thermoregulating coatings on the basis of these materials will provide their long-term operation in the space. Obtaining of silicate solutions and co-precipitation of silicates by hydrothermal-microwave treatment is an effective method for production of complex nanocrystalline silicates in comparison with the solid state reactions methods. The proposed technique gives an opportunity to use silica containing rocks as raw materials. We have elaborated a new original hydrothermal method, a hydrothermal-microwave method for obtaing of solutions of sodium, potassium and lithium silicates from rocks, and a method for purification of the obtained silicate solutions [18,19], as well as low-temperature (200-250ºC) synthesis of nanocrystalline silicates doped with various components. Using the elaborated method, alkaline silicates solutions ($Na_2O{\cdot}nSiO_2$ or $K_2O{\cdot}$ $nSiO_2$ n=l-3,8) have been obtained from silica containing rocks (perlite, diatomite, quartzite, quartz sand) after hydrothermal-microwave treatment. Hydrothermal-microwave treatment of rocks accelerates the obtaining of silicate solutions by a factor of 3-5 in comparison with hydrothermal method. Then silicates of elements entering into the composition of the pigment, are precipitated on the basis of alkaline silicate solutions and watersoluble compounds. The proposed method provides both the silicate formation reactions and mixture homogeneization at the process of composite preparation. Co-precipitation of silicates using hydrothermal-microwave treatment is an effective method for synthesis of nanocrystalline silicates and their doping in the course of synthesis in comparison with the solid state reactions methods. The microwave technology combined with hydrothermal treatment is an effective method for obtaining of inorganic materials as well as doped nanoparticles of reaction products due to uniform and rapid heating, process time control and high-purity conditions. Energy concentration at microwave heating can be used for annealing of the synthesized nanocrystalline silicates, providing achieving a high degree of structural arrangement in a short time, when the grain sizes remain the same nano-range. The use of dense and monodisperse particles having phase uniformity is a crucial factor in obtaining ceramics for thermo-regulating coatings. As a binding agent in the formation of thermo-regulating coatings, it is proposed to use potassium or lithium liquid glass. In the process of hydrothermal treatment of perlite by NaOH or KOH solutions, ferrous compounds (up to 0,03%) pass into silicate solutions. In this connection the necessity for effective methods of purification of silicate solutions from ferrous compounds comes up. In this connection, a novel effective hydrothermal-microwave method for purification of silicate solutions from ferrous compounds has been developed by our team. The method allows to decrease their content down to 0.0001% and lower. The Project participants have experience in investigations and developments related to the synthesis of silicates from perlite, diatomite, quartzite, etc., in hydrothermal treatment, as well as in study of radiation characteristics of solids [20-53].

The suggested technology of obtaining TRC on the basis of rocks is nonwaste. In addition to obtaining TRC, it permits to obtain such products as liquid glass, various silicates, silica, complex glass charge, zeolites, adsorbents, catalysts supports, etc.

Preliminary comparative analysis of the integrated factor of sunlight absorption (α_s) and factor of reflection (ε) has shown that, TRC on the basis of the specified silicates has $\alpha_s \leq 0.12$ and $\varepsilon \geq 0.92$, while conventional TRC for SV are characterized by $\alpha_s \leq 0.20$ and $\varepsilon \geq 0.90$.

It is reasonable to note that the proposed hydrothermal-microwave method of obtaining of the mentioned silicate products is economically sound in comparison with the known methods of obtaining of concurrent materials: preliminary calculations show that cost saving will make 60 % and more.

Analysis of patents and scientific publications and our preliminary investigations have shown that application of new thermoregulating coatings for SV will provide:

- High stability to destruction at "heating-cooling" thermal cycling;
- Increased radiation and chemical stability;
- Long-term operations;
- Low out-gassing.

The developed technology allows obtaining of various silicate materials that will find a wide application in glass, ceramics, chemical, petrochemical, light, etc. industries.

The use of hydrothermal-microwave method for obtaining TRC from silica containing rocks is a new direction in space materials science and appears as patentable. It is supposed that engineering solutions related to the obtaining of new amorphous and crystalline high-purity nanodisperse silicates will be patentable as well.

In terms of science, achievement of the Project aims supposes conducting of significant theoretical and experimental investigations in the field of silicate pigments by unconventional methods.

The synthesized materials will be tested thoroughly in different laboratories and enterprises.

The proposed Project implementation will offer an opportunity to systematize the obtained results and for the first time to develop a technology of obtaining of pigments and TRC on the basis of silica containing rocks using hydrothermal-microwave method.

The Project will be implemented mainly by the staff of scientists and engineering personnel of IGIC of NAS RA and YerPhI, having a great experience in the field of silicates technology, space materials science, semiconductor physics, radiation solid state physics.

The experts from other organizations will be involved as well in separate stages of the Project implementation.

The proposed project is prepared in accordance with ISTC Instructions and necessitated by the search of an alternative for the scientific and technical personnel earlier involved in development of weapons and military engineering.

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2. Expected Results and Their Application

The Project refers to the field of technology developments. Implementation of the proposed Project will provide obtaining of new scientific results, development of actual methods and high technologies, solution of important conversion problems, and its practical application will permit considerable reduction of production cost of the synthesized materials.

Nowadays unconventional methods of obtaining new materials with predetermined properties on the basis of solutions or their suspensions being high reactivity systems in ultrafine state are developed very extensively. From this point of view, actuality of the propose Project does not raise doubts. The proposed activity within the framework of the Project will permit to realize:

- Development of a new technology for obtaining from silica containing rocks and clearing of silicate solutions by hydrothermal-microwave method, which surpasses the known methods in technological effectiveness and economic feasibility;
- Development of the hydrothermal-microwave method for synthesis of high-purity nanopowders of silicates of zirconium, zinc**,** etc., with pre-determined characteristics modified by oxides of yttrium, cerium, etc. of controllable composition;
- Development of temperature regulating coatings of "solar reflectors" type meeting the Russian (ROSCOSMOS), European and International (NASA) requirements with an optimum set of all parameters necessary and sufficient for long-term operation of SV under the impact of space factors;
- Development of physical process model;
- Reorientation of scientific staff to the solution of peaceful problems and support of peaceful investigations and developments;
- Integration of scientists into international associations;
- Creation of high technologies;
- Long-term support of the research team activities.

The organizations taking part in the proposed Project have adequate experience to conduct above mentioned works.

The authors of the Project invite research teams, research establishments, as well as private experts and scientists from USA, countries of European Community, Japan, Canada and Korea to collaboration.

It is planned that intellectual property rights will be regulated by the laws of Republic of Armenia, international legislation and by procedures developed by ISTC.

Positive consequences of Project execution have the following aspects:

Scientific aspect

Achievement of the Project aims supposes in-depth investigation of physico-chemical regularities of the obtaining processes and characteristics study of nanocrystalline silicate materials and TRC on their base.

Use of doped nanopowders of silicates of zirconium, zinc, titanium, etc. for TRC and their obtaining on the basis of silica containing rocks are new directions in space materials science; besides, during the Project implementation it is supposed to obtain new materials applicable in other fields.

It is planned to develop a large laboratory-scale installation for hydrothermal-microwave processing of silica containing rocks. It will give an opportunity to enlarge the raw materials resources for obtaining and investigation of high-purity silicates within the framework of materials science.

International Collaboration

At present there is an agreement with the Air Force Office of Scientific Research **(AFOSR)** for collaboration and joint research. Besides, it is planned to get into contact with leading scientific centers involvied in investigations on obtaining of

TRC by nonconventional methods and interested in the experience exchange. It is supposed that some of them will be the Project collaborators after acquaintance with this Project. In addition, it is expected to enlarge the field of collaboration with some centers for materials science with the aim of introduction of the developed technology.

Industrial, economic and commercial aspects

Doped nanopowders of silicates and silicates on the basis of the products of hydrothermal-microwave processing of silica containing rocks will find a widespread occurence in chemical, ceramic, glass, etc. industry. In particular, doped nanopowders of silicates will be used for obtaining of TRC.

An appreciable advantage of the developed technology is the opportunity to obtain several silicates with predetermined properties.

It is reasonable to note that the proposed hydrothermal-microwave method of obtaining of the mentioned silicate products is economically sound in comparison with the known concurrent methods: preliminary calculations show that cost saving will make 60 % and more.

Thus, during the Project implementation it is planned to develop for the first time a typical technology for obtaining of doped nanopowders and silicates on the basis of silica containing rocks by hydrothermal-microwave synthesis method. It is expected that after the Project closure there will be organizations, companies or firms expressing interest in commercial application of the developed technology.

2.1. Sustainability Implementation Plan

2.1.1. Results to be promoted

It is planned to promote the technology of obtaining of pigments nanopowders for thermoregulating coatings at commercial marketplace.

2.1.2. Uniqueness of results

The developed technology will be unique as for the first time the nanopowders of modified silicates for thermoregulating coatings will be synthesized by the hydrothermal-microwave method. New compositions of thermoregulating coatings for SV with improved characteristics will be elaborated using the silicate modified pigments. Application of the silica containing rocks as raw materials for the obtaining of thermoregulating coatings for SV is uniqueness of the proposed technology as well.

2.1.3. Demand for results

Potential customers of the technology and composite structure for TRC to be developed are cosmonautics, organizations and enterprises involved in the space programs, nuclear power plants protection, reducing heating temperature of products and objects (gasoline and oil storages, gasholders, refrigerators, oil tankers, telescopes towers), ceramic and glass industry, etc.

2.1.4. Expected income

The proposed technology will provide 60 % cost saving of TRC.

2.1.5. IPR situation

The new composition and methods of obtaining thermoregulating coatings, as well as engineering solutions to be developed during the Project implementation, will be patented or secured by inventor's certificates.

2.1.6. Additional developments

Additional developments will be necessary for the purpose of developing of technological parameters in experimental and industrial conditions.

2.1.7. Plan of implementation

Organization of own production or a joint enterprise.

2.1.8. Additional licenses or permits

Licenses or additional permits for the output of stated products within the territory of the Republic of Armenia are not demanded.

2.1.9. Business network

Oral communications with collaborators, correspondence with interested establishments, production suppliers, bankers, owners, etc.

3. Meeting ISTC Goals and Objectives

The Project implementation will permit:

Reorientation of professional activity and rich experience of scientists and experts working before in the field of defense, for the solution of actual investigations in the field of applied chemistry, physics and materials science;

Further integration of scientists and engineers working before in military spheres into the international scientific society for the purpose of solution of actual technical problems and creation of mutually beneficial collaboration;

Prevention of outflow of highly skilled specialists;

Development of an effective technology having commercial value.

Realization of the Project will contribute to progress in the field of thermoregulating coatings promising for the use not only in SV, but also in various fields of science and engineering (safety systems of nuclear power plants, chemical plants, potteries, etc.)

ISTC support of investigations in the framework of the Project will promote fundamental and applied investigations, and technological elaborations for peaceful purposes as well.

4. Scope of Activities

General description of the activities within the project. Detailed description for each task follows.

Task 1

Task description and main milestones	Participating Institutions
Development of the hydrothermal-microwave method for obtaining and clearing of silicate solutions ($Na_2O{\cdot}nSiO_2$, $K_2O{\cdot}nSiO_2$, n=l-3,8) on the basis of silica containing rocks. Study of physical, chemical and radiation properties of silicate materials for TRC over a wide range of parameters.	
Stage A1. Study of conditions and investigation of chemical regularities of the hydrothermal-microwave method when obtaining sodium, potassium silicates solutions from silica containing rocks (perlite, diatomite, etc.). The hydrothermal microwave treatment will be conducted at the conditions that ensure obtaining of silicate solutions with predetermined characteristics.	IGIC of NAS RA
X-ray fluorescence analysis of chemical composition of sodium, potassium silicates and silica containing rocks	YerPhI
The impact of UV radiation on physical characteristics of silicate materials in extreme conditions (high vacuum and temperature interval from -110 to +200^oC).	YerPhI

Stage A2. Study of the impact of hydrothermal-microwave treatment parameters on the process kinetics when obtaining sodium, potassium silicates. Radiative stability of initial materials and end products irradiated by electrons and UV will be determined. Experimental samples of sodium, potassium silicates solutions will be obtained by hydrothermal-microwave method. **Stage A3**. Study of electromagnetic treatment jointly with microwave heating for clearing of silicate solutions. Study of the impact of the parameters of hydrothermal-microwave treatment on purification degree of silicate solutions. At this stage, optimum conditions of electromagnetic and hydrothermal-microwave treatment of solutions will be determined for the purpose of obtaining of high-purity silicate solutions. The samples of high-purity solutions of sodium, potassium silicates will be obtained, and their testing will be conducted.	IGIC of NAS RA YerPhI IGIC of NAS RA

Description of deliverables	
1	Quarterly, Annual and Final reports.
2	Literary Review.
3	Publication.
4	Seminars.
5	Experimental samples.

Task 2

Task description and main milestones	Participating Institutions
Development of hydrothermal-microwave method for obtaining of high-purity silicate pigments.	
Stage A4. Obtaining of $ZnO \cdot SiO_2 \cdot mH_2O$, $ZrO_2 \cdot SiO_2 \cdot mH_2O$ hydrosilicates by hydrothermal-microwave method. Synthesis will be conducted using purified silicate solutions and appropriate soluble salts on the basis of theoretical calculations and elemental analysis data.	IGIC of NAS RA
The effect of 18 MeV proton radiation on surface properties of silicate materials will be determined depending on the radiation intensity and temperature.	YerPhI
Modelling of physical processes related to the formation of radiation defects in silicate materials with different properties.	YerPhI
Stage A5. Study of $ZnO \cdot SiO_2 \cdot mH_2O$, $ZrO_2 \cdot SiO_2 \cdot mH_2O$, hydrosilicates doped with rare earth elements directly during the synthesis.	IGIC of NAS RA
Luminescent properties of rare earth elements doped silicate TRC materials in UV-VUV spectral region at different temperatures.	YerPhI
Determination of the optimum amount of doping elements, providing necessary structure and radiation characteristics of the synthesized pigments.	IGIC of NAS RA
Stage A 6. Study of structure and surface characteristics of the obtained products. Investigation of radiation-stimulated processes in irradiated pigments by absorption spectroscopy, diffusion reflection, luminescence spectroscopy in UV range, vacuum UV and by X-ray irradiation methods. The doped silicates obtained at this stage are of interest for the development of composite thermoregulating coatings of ‘‘solar reflectors" type.	IGIC of NAS RA YerPhI
The obtained results will permit to develop some general principles of the synthesis of doped crystalline silicate pigments with predetermined lighting characteristics.	

Description of deliverables	
1	Quarterly, Annual and Final reports.
2	Publications.
3	Seminars.
4	Testing Protocol.

Task 3

Task description and main milestones	Participating Institutions
Development of thermoregulating coatings.	
Stage A7. Elaboration of composites for thermoregulating coatings. Selection of binders from the series of sodium and potassium silicates for the purpose of increasing radiation stability and reduction of out-gassing under the impact of the space.	IGIC of NAS RA YerPhI
Stage A 8. Obtaining of thermoregulating coatings on the basis of the synthesized silicate pigments and their testing by absorption spectroscopy, diffusion reflection, luminescence spectroscopy in UV range, vacuum UV and X-ray irradiation methods.	IGIC of NAS RA YerPhI
Stage A9. Selection of optimum composition of radiation stable thermoregulating coatings with high reflectance and low absorption. Obtaining of laboratory samples and their testing.	IGIC of NAS RA YerPhI

Description of deliverables	
1	Quarterly, Annual and Final reports.
2	Publications.
3	Seminars.
4	Testing Protocol.

5. Role of Foreign Collaborators/Partners

- Information sharing during the Project implementation;
- Joint conducting of experiments and testing of the synthesized materials;
- Discussion of the obtained experimental results;
- Joint publications;
- Conclusions on Technical Reports (quarter, annual and final) submitted to ISTC by Project executives.

Air Force Office of Scientific Research **(AFOSR)**

6. Technical Approach and Methodology

The known data and publications as well as creative experience and achievements of the Project participants on the development of nonconventional methods for obtaining of new materials will be used at the Project implementation. The main innovations during the Project implementation will be the use of hydrothermal-microwave processing of rocks for the purpose of obtaining of silicate solutions; synthesis of silicates nanopowder pigments using microwave chemistry; and development of new composite structures for thermoregulating coatings on the basis of the synthesized pigments.

It is supposed to solve the problem of obtaining of silicate solutions and nanocrystalline silicates doped with various components on the basis of silica containing rocks after detailed fundamental and experimental investigations of the silicates formation processes. These investigations will permit to develop a new technology of thermoregulating coatings using hydrothermal-microwave synthesis. The main Project tasks as well as scientific and technological methodology of their solution are listed below.

The task of obtaining silicate solutions from silica containing rocks will be solved on the basis of detailed fundamental and experimental investigations of silicate formation processes during hydrothermal-microwave treatment of rocks at constant volume and 0.9-25 bar pressure within the temperature range of 90-220°C taking into account various factors (treatment time, initial concentration of solutions, grinding fineness, liquid and solid phases ratio). These investigations will permit to realize the formation of silicate solutions with predetermined characteristics by a single-stage method. Modern physico-chemical methods of analysis, i.e. IR-spectroscopy, X-ray analysis, as well as express methods of solutions analysis will be used to determine composition and structure of intermediate and end products during the experiments.

The task of clearing of silicate solutions from colored impurities will be solved by electromagnetic treatment jointly with microwave heating with subsequent precipitation of impurities as silicates. The structure and state of colored impurities in silicate solutions will be determined by IR-spectroscopy, X-ray analysis methods to reveal the formation mechanisms of colored impurity compounds. The influence of various factors on the purification degree will be taken into account, and optimum conditions of the formation of high-purity silicate solutions will be selected at the stage of purification of silicate solutions. The amount of colored impurities in the silicate solutions before and after purification will be determined by atomic absorptive spectroscopy, fluorometry and polarography methods.

The task of obtaining of $ZnO \cdot SiO_2 \cdot mH_2O$, $ZrO_2 \cdot SiO_2 \cdot mH_2O$ hydrosilicates will be solved by hydrothermal microwave synthesis. The synthesis will be conducted using purified silicate solutions and appropriate soluble salts on the basis of theoretical calculations and elemental analysis data. The state of $ZnO \cdot SiO_2 \cdot mH_2O$, $ZrO_2 \cdot SiO_2 \cdot mH_2O$ hydrosilicates doped with rare earth elements directly at the synthesis will be determined. The structure, properties, composition and surface characteristics of doped nanocrystalline silicates (pigments) will be studied by BET, electron microscopy, IR-spectroscopy, thermography, X-ray phase analysis and elemental analysis.

The task of obtaining of composites for thermoregulating coatings will be solved by a detailed study of radiative stability, reflectance, structural changes of pigments, binders and coatings using UV, vacuum UV spectroscopy and X-ray irradiation. The samples of various composition will be obtained and tested, and optimum compositions of thermoregulating coatings will be selected.

Simultaneously with the development of new compositions of thermoregulating coatings it is supposed to conduct testing of coatings with respect to the impact of space factors (separately and in the aggregate) on the coatings properties, using the existing installation (YerPhI).

On the basis of the obtained results, a new technology of production of thermoregulating coatings for SV from silica containing rocks using hydrothermal-microwave method will be developed.

A large laboratory-scale installation will be developed to specify more exactly the technology and improve the TRC parameters. Optimization of physico-chemical and technological characteristics of thermoregulating coatings will be based essentially on the results of own investigations of the synthesized materials and will be oriented on world experience in the field of space materials science. The obtained materials will be tested in various laboratories and enterprioses.

During the whole Project implementation it is planned to use widely Internet resources for the search of scientific and technological information, finding interested scientific and business corporations, and for interaction with collaborators.

7. Technical Schedule

	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 5	Quarter 6	Quarter 7	Quarter 8	Person*days
Task 1	Report. Seminar.	Report.	Report. Publication.	Report. Experimental Samples. Testing records					
Subtask 1	150	150	70						370
Subtask 2	161	146	55						362
Subtask 3			60	55					115
Person*days	**311**	**296**	**185**	**55**					**847**
Task 2			Report.	Report.	Report. Seminar.	Report. Testing records	Report. Publication.	Report. Experimental Samples. Testing records	
Subtask 4			80	55	60	40			235
Subtask 5			92	55	60	40	50		297
Subtask 6					60	40	45	40	185
Person*days			**172**	**110**	**180**	**120**	**95**	**40**	**717**
Task 3				Report.	Report	Report. Seminar. Testing records.	Report. Publication.	Report. Experimental Samples. Testing records	
Subtask 7				70	80	40	45	40	275

Subtask 8				70	77	40	45	50	282
Subtask 9						35	50	51	136
Person*days				**140**	**157**	**115**	**140**	**141**	**693**
TOTAL	**311**	**296**	**357**	**305**	**337**	**235**	**235**	**181**	**2257**

8. Personnel Commitments

8.1. Individual participants

Leading Institution: IGIC of NAS RA

Category I (weapon scientific and technical personnel)

Name	Birth Year	Scientific Title	Weapon Expertise Ref.	Function in project	Daily rate (US$)	Total days	Total grants (US$)
Baghramyan Volodya	1949	Ph.D. (Technical Sci.)	2	Project Manager	50	240	12,000
Sargsyan Anahit	1953	Ph.D. (Chemistry.)	2	Scientific Leader	35	280	9,800
Petrosyan Grigoriy	1949	Ph.D. (Chemistry)	2	Technological development	24	50	1,200
Knyazyan Nikolay	1951	Doctor (Technical Sci)	2	Theoretical researches	32	50	1,600
Gurgenyan Ninel	1949	Ph.D. (Technical. Sci.)	2	Physico-chemical researches	24	50	1,200
Sukhudyan Gohar	1939	M.S. (Chemistry)	2	Physico-chemical researches	25	48	1,200
					Total:	**718**	**27,000**

***Category II (other scientific and technical* personnel)**

Name	Birth Year	Scientific Title	Function in project	Daily rate (US$)	Total days	Total grants (US$)
Sargsyan Aleksandr	1995	Bakalavr	Computer data handling	25	140	3,500
Khostoyan Flora	1949	M.S. (Chemistry)	Experimental researches	20	50	1,000
Aslanyan Aida	1959	M.S. (Chemistry)	Experimental researches	20	50	1,000
Kirakosyan Anahit	1950	Technician (Technology)	Experimental researches	25	200	5,000
				Total:	**440**	**10,500**

Category III (participant personnel)

Name	Birth Year	Function in project	Daily rate (US$)	Total days	Total grants (US$)
Kocharyan Lida	1947	Laboratory Assistant	20	50	1,000
Aslikyan Andreas	1995	Mechanic-Technician	20	150	3,000
Navasardyan Lena	1959	Accountant	25	72	1,800
			Total:	**272**	**5,800**

Category IV (personnel, who will work less than 10% of project duration)

Number of persons	Function in project	Daily rate (US$)	Total days	Total grants (US$)
2	Technician (Analyst)	20	50	1,000
2	Technician (Technology)	20	50	1,000
2	Building Worker (for Laboratory Rooms Repair)	20	55	1,100
		Total:	**155**	**3,100**

Participant Institution 1: YerPhI

Category I (weapon scientific and technical personnel)

Name	Birth Year	Scientific Title	Weapon Expertise Ref.	Function in project	Daily rate (US$)	Total days	Total grants (US$)
Harutyunyan Vachagan	1954	Doctor (Phys. Mat. Sci.)	4	Project Sub- Manager	50	184	9,200
Hovhannisyan Agasi	1955	M.S. (Chemistry)	4	Research of the radiation resistance of materials	24	50	1,200
Grigoryan Norik	1946	PhD (Phys. Mat. Sci.)	4	Research of efficiency of a material	40	80	3,200
Sahakyan Aram	1946	Doctor (Phys. Mat. Sci.)	4	Research of physical properties	40	60	2,400
Baghdasaryan Valeri	1946	PhD (Technical Sci.)	4	Processing of results of an irradiation	30	60	1,800
Gavalyan Vasak	1946	PhD (Chem. Sci)	4	Development of calculation methods	24	50	1,200
					Total:	**484**	**19,000**

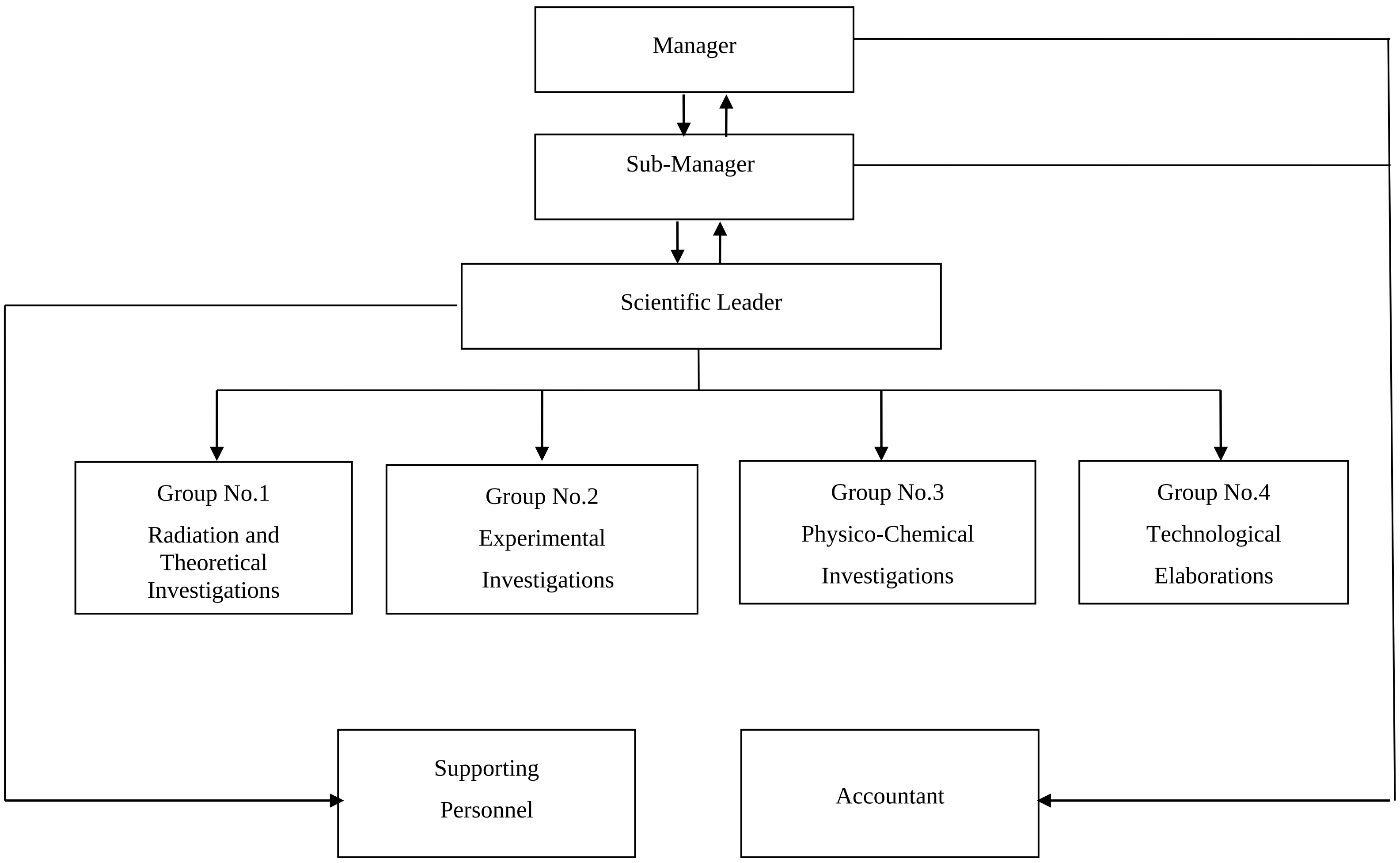
Category II (other scientific and technical personnel)

Name	Birth Year	Scientific Title	Function in project	Daily rate (US$)	Total days	Total grants (US$)
Harutyunyan Tigran	1981	PhD (Phys. Mat. Sci)	Research of physical properties	25	48	1,200
Aleksanyan Eduard	1983	PhD (Phys. Mat. Sci)	Modeling of physical processes	20	50	1,000
Sogomonyan Suren	1949	PhD (Phys. Mat. Sci)	X-ray fluorescence analysis	16	50	800
				Total:	**148**	**3,000**

Category IV (personnel, who will work less than 10% of project duration)

Number of persons	Function in project	Daily rate (US$)	Total days	Total grants (US$)
1	Technician (Analyst)	25	16	400
2	Technician (Technology)	25	10	250
1	Accountant	25	14	350
		Total:	**40**	**1,000**

8.2. Managerial responsibilities



9. Financial Information

TABLE 1

Estimated Aggregated Expenditures by Recipient

Category		Quarters 1 & 2		Year 1		Year 2		Total	
		(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
1	**Grant Payments:**								
1.1	Category I		12,360		25,200		20,800		46,000
1.2	Category II		3,550		8,060		5,440		13,500
1.3	Category III		650		2,500		3,300		5,800
1.4	Category IV		1,750		2,650		1,450		4,100
	Total Grant Payments		**18,310**		**38,410**		**30,990**		**69,400**
2	**Equipment:**								
2.1	Capital Equipment		12,000		12,000				12,000
2.2	Non-Capital Equipment		2,800		2,800				2,800
	Total Equipment		**14,800**		**14,800**				**14,800**
3	**Materials/Supplies**	**625**		**1,250**		**1,250**		**2,500**	
4	**Bank Fees**	**40**	**195**	**60**	**495**	**45**	**300**	**105**	**795**
5	**Other Direct Costs:**								
5.1	Technological Energy	250		500		500		1,000	
5.2	Communications	237.5		475		475		950	
5.3	Subcontracts/Seminars								
5.4	Logistics/Customs	300	1,200	300	1,200			300	1,200
5.5	Other	362.5		725		725		1,450	
	Total ODC	**1,150**	**1,200**	**2,000**	**1,200**	**1,700**		**3,700**	**1,200**
6	Travel:								
6.1	Internal ***								
6.2	Outside CIS				4,000				4,000
	Total Travel				**4,000**				**4,000**
	Overhead/Retainage	....	....	....	....	....	....	3,500	....
	Subtotals	**1,815**	**34,505**	**3,310**	**58,905**	**2,995**	**31,290**	**9,805**	**90,195**
	Totals	36,320		62,215		34,285		100,000	

Remarks: * (1) - Cash flow through Recipient Account
** (2) - Cash flow through ISTC
*** Include Local and inside CIS travel

TABLE 1-1

Estimated Aggregated Expenditures by Leading Institution: IGIC of NAS RA

Category	Quarters 1 & 2		Year 1		Year 2		Total	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
1 Grant Payments:								
1.1 Category I		6,900		14,280		12,720		27,000
1.2 Category II		2,650		6,300		4,200		10,500
1.3 Category III		650		2,500		3,300		5,800
1.4 Category IV		1,500		2,100		1,000		3,100
Total Grant Payments		**11,700**		**25,180**		**21,220**		**46,400**
2 Equipment:								
2.1 Capital Equipment		12,000		12,000				12,000
2.2 Non-Capital Equipment		800		800				800
Total Equipment		**12,800**		**12,800**				**12,800**
3 Materials/Supplies	**325**		**650**		**650**		**1,300**	
4 Bank Fees	**20**	**140**	**20**	**385**	**5**	**190**	**25**	**575**
5 Other Direct Costs:								
5.1 Technological Energy								
5.2 Communications	175		350		350		700	
5.3 Subcontracts/Seminars								
5.4 Logistics/Customs	300	1,200	300	1,200			300	1,200
5.5 Other	50		100		100		200	
Total ODC	**525**	**1,200**	**750**	**1,200**	**450**		**1,200**	**1,200**
6 Travel:								
6.1 Internal ***								
6.2 Outside CIS				4,000				4,000
Total Travel				**4,000**				**4,000**
Overhead/Retainage							2,000	
Subtotals	**870**	**25,840**	**1,420**	**43,565**	**1,105**	**21,410**	**4,525**	**64,975**
Totals	**26,710**		**44,985**		**22,515**		**69,500**	

Remarks: * (1) - Cash flow through Recipient Account
** (2) - Cash flow through ISTC
*** Include Local and inside CIS travel

TABLE 1-2

"1" Estimated Aggregated Expenditures by Participant Institution 1: YerPhI

Category	Quarters 1 & 2		Year 1		Year 2		Total	
	(1)	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
1 Grant Payments:								
1.1 Category I		5,460		10,920		8,080		19,000
1.2 Category II		900		1,760		1,240		3,000
1.3 Category III								
1.4 Category IV		250		550		450		1000
Total Grant Payments		**6,610**		**13,230**		**9,770**		**23,000**
2 Equipment:								
2.1 Capital Equipment								
2.2 Non-Capital Equipment		2,000		2,000				2,000
Total Equipment		**2,000**		**2,000**				**2,000**
3 Materials/Supplies	**300**		**600**		**600**		**1,200**	
4 Bank Fees	**20**	**55**	**40**	**110**	**40**	**110**	**80**	**220**
5 Other Direct Costs:								
5.1 Technological Energy	250		500		500		1,000	
5.2 Communications	62.5		125		125		250	
5.3 Subcontracts/Seminars								
5.4 Logistics/Customs								
5.5 Other	312.5		625		625		1,250	
Total ODC	**625**		**1,250**		**1,250**		**2,500**	
6 Travel:								
6.1 Internal ***								
6.2 Outside CIS								
Total Travel								
Overhead/Retainage	....	....	....	....	....	....	1,500	....
Subtotals	**945**	**8,665**	**1,890**	**15,340**	**1,890**	**9,880**	**5,280**	**25,220**
Totals	**9,610**		**17,230**		**11,770**		**30,500**	

Remarks: * (1) - Cash flow through Recipient Account
** (2) - Cash flow through ISTC
*** Include Local and inside CIS travel TABLE 1-3

10. Equipment and Materials Summary

10.1. Equipment Summary

TABLE 2

EQUIPMENT/MATERIAL SUMMARY

EQUIPMENT SUMMARY

for Project Agreement # 2133

To be provided in kind [X]

To be purchased by recipient [ ]

The ISTC will normally provide the most appropriate equipment that will perform the functions required; however, if very special reasons are given and explained in detail (Form PR-2E), the purchase of a particular make will be considered.

Please list items in the order of their priority and put an 'X' in the column next to "Item no." if ISTC form PR-2E, "Data for a Single Equipment Item', has been completed for a given item and is attached.

Item No.		DESCRIPTION OF ITEM	Date needed (quarter)	Qty	Unit cost (USD)	Amount (USD)
Leading Institution: IGIC of NAS RA						
1	X	Microwave samples digestion system MS-6, Russia, 190020, Saint Petersburg, Nab. Obvodnogo canala, 150, "Himanalyt, "NTF" Volta", phone +7 (812) 786-72-89, phone (fax) +7 (812) 786-65-89, www.volta.spb.ru	1	1	12,000	12,000
2		Notebook 15,6," HP PROBOOK G450, Intel core i5-4200, RAM 4GB DDR3, HDD 750GB, VGA 2 GB, Windows 7 Professional, Notebook Centre , Tumanyan 18/1, Yerevan, Armenia, www.notebookcentre.am	1	1	800	800
					Subtotal:	**12,800**
Participant Institution 1: YerPhI						
3		Notebook 15,6," HP PROBOOK G450, Intel core i5-4200, RAM 4GB DDR3, HDD 750GB, VGA 2 GB, Windows 7 Professional, Notebook Centre , Tumanyan18/1, Yerevan, Armenia, www.notebookcentre.am	1	1	800	800
4		Computer Intel Core i7 4770, (8M Cache, up to 3.90 GHz LGA 1150) / DDR3 4 GB 1600MHz/HDD 1TB SATA/DVD-RW/LAN onb/Sound onb/VGA onb free PCI Express slot /MB GIGABYTE GA-H87 HD3/Case Cooper Master / NO OS, Windows 7 Professional Lans Ltd, 49 Komitas Av., Yerevan, 0051, Armenia,	1	1	750	750
5		Monitor 21,5" Samsung S22B150 LED 1920X1080 / 75Hz/2ms/12000:1 Lans Ltd, 49 Komitas Av., Yerevan, 0051, Armenia	1	1	250	250
6		Printer –HP Laser P1505,A4,600x600dpi,23p/m,2IA,USB2.0 Lans Ltd, 49 Komitas Av., Yerevan, 0051, Armenia	1	1	200	200
					Subtotal:	**2,000**
					Estimated TOTAL COST:	**14,800**

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10.2. Materials Summary

TABLE 3-1

EQUIPMENT/MATERIAL SUMMARY						
MATERIAL SUMMARY for Project Agreement # 2133 To be provided in kind [ ] To be purchased by recipient [X]						
The ISTC will normally provide the most appropriate equipment that will perform the functions required; however, if very special reasons are given and explained in detail (Form PR-2E), the purchase of a particular make will be considered.						
Please list items in the order of their priority and put an 'X' in the column next to "Item no." if ISTC form PR-2E, "Data for a Single Equipment Item', has been completed for a given item and is attached.						
Item No.		**DESCRIPTION OF ITEM**	**Date needed (quarter)**	**Qty**	**Unit cost (USD)**	**Amount (USD)**
Leading Institution: IGIC of NAS RA						
1		Inorganic reagents (acids, alkalies, salt), Organic reagents(:immersion liquids, benzol, ethyl alcohol, aceton, etc), Laboratory glassware, etc. "Medisar" Ltd, Yerevan, Gorvetka str. 4, Tel: (374-10) 54-30-78 Fax: (374-10) 54-30-79	1-8	8	87.5	700
2		Stationery and office supplies, Work tools, Materials for repair of laboratory premises ,Others (cleaning materials, gloves, warehouse coats, etc.), "Apamart" Ltd, Yerevan, Azatutyan 16	1-8	8	75.0	600
					Subtotal:	**1,300**
Participant Institution 1: YerPhI						
3		Chemicals, chemical processing equipment, ovens, thermometers , filtering materials "Lantangim" LLC, Yerevan.	1-8	8	56.25	450
4		Forevacuum oils, vacuum seals " Shalvaryan "LLC"Yerevan.	1-8	8	25.0	200
5		Radio and electronic components ,"Techniken" LLCYerevan.	1-8	8	18.75	150
6		Rustless steel (3,5,8mm), rustless tube "Shinarar" LLC,Yerevan.	1-8	8	50.0	400
					Subtotal:	**1,200**
					Estimated TOTAL COST:	**2,500**

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10.4. Other Direct Costs Summary

TABLE 4

OTHER DIRECT COSTS SUMMARY						
OTHER DIRECT COSTS SUMMARY for Project Agreement # 2133 To be provided in kind [X] To be purchased by recipient [ ]						
Detailed breakdown of Other Directs Costs to include planned activities under items 5.1, 5.2, 5.3, 5.4, 5.5 from Table 1 of the Project Agreement						
Item No.		**DESCRIPTION OF ITEM**	**Date needed (quarter)**	**Qty**	**Unit cost (USD)**	**Amount (USD)**
Leading Institution: IGIC of NAS RA						
1	5.4	Logistics/Customs	1	1	1,200	1,200
					Subtotal:	**1,200**
					Estimated TOTAL COST:	**1,200**

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TABLE 4-1

OTHER DIRECT COSTS SUMMARY						
OTHER DIRECT COSTS SUMMARY for Project Agreement # 2133 To be provided in kind [ ] To be purchased by recipient [X]						
Detailed breakdown of Other Directs Costs to include planned activities under items 5.1, 5.2, 5.3, 5.4, 5.5 from Table 1 of the Project Agreement						
Item No.		**DESCRIPTION OF ITEM**	**Date needed (quarter)**	**Qty**	**Unit cost (USD)**	**Amount (USD)**
Leading Institution: IGIC of NAS RA						
1	5.2	Communications (Internet, mobile telephone)	1-8	8	87.5	700
2	5.4	Logistics/Customs	1	1	300	300
3	5.5	Other	1-8	8	25.0	200
					Subtotal:	**1,200**

Participant Institution 1: YerPhI						
5	5.1	Technological Energy	1-8	8	125.0	1,000
6	5.2	Communications (long-distance negotiations,the Internet)	1-8	8	31.25	250
7	5.5	Other(computer services, service of the equipment)	1-8	8	156.25	1,250
					Subtotal:	**2,500**
					Estimated TOTAL COST:	**3,700**

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