Abstract
MIRNOVA Academy has developed and begun to introduce a unique program that successfully combines education and research in novel ways. This program is designed to cultivate academic and technical learning, social interaction skills including teamwork and collaboration, project management, time management, and business entrepreneurship. Broadly, this program centers upon “S.T.E.A.M.” - science, technology, engineering, art, and mathematics. More specifically, it is focused upon robotics and cybernetics – command, control, communications and computing (“C4”) for robots, sensors, and systems involving multiple devices – operating in environments that assist in project learning and experimenting while at the same time offering opportunities to accomplish useful tasks beyond the educational experience.

The projects in which student apprentices, interns and experts work together are linked with research projects in academic, business and public institutions. The projects involve common-core problems, methods, tools and solutions in computation, software, and electro-mechanical hardware, which are applied to different themes in three basic areas, chosen for their critical importance (for present and future society) and the ease of transition and re-application to other areas of use. Thus, this new program brings together the education, research and social experiences, all valuable and important for present and future generations and for all forms of employment and personal development.

Introduction
The MIRNOVA S.T.E.A.M. Program (MSP) is conducted and managed by MIRNOVA Academy, a private non-profit organization, in close cooperation with university-level and corporate research scientists and centers. The MSP
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is oriented to both students and the general public and it incorporates both online and onsite components. All activities are designed to be integrated with other academic and professional activities and to support internships, technical competitions, and future employment and/or startup business opportunities. The MSP has a strong focus upon robotics and interactive human-robot systems, including unmanned vehicles (“drones” - UAV (air), UGV (land), AUV (water) types), and also a strong emphasis on the communications and computing software for controlling, automating, and creating practical and economical uses for such technologies. Projects are not exclusively involving mechanical robots but also involve virtual machines and robots such as software agents. All projects have clearly defined linkages to research programs in progress by individuals and teams in different institutions, and in many cases the scientists and engineers involved in such research are also participants as mentors and expert advisors (“masters”) to the students and senior-level trainers who assist in the specific MIRNOVA-based projects.

All of the MSP projects are designed to cultivate and encourage skills beyond the scientific and technical, for the benefit of participants in their careers and lives. These skills are developed in the course of the project activities including competitions and conferences in which the project team members may participate.

The MSP is expressly designed for three types of participants:

- students who are in college, high school and middle school levels of education, engaging in creative learning projects with the assistance of more experienced mentor-experts (“learners”);
- community members of any professional experience and any level of academic skills, engaging as junior-level developers (e.g., students already enrolled in university or post-graduate studies) and/or desiring to learn techniques for educating and guiding young people in STEM – “training the trainers”;
- experts from academia and industry who are drawn to be mentors, advisors, and guides to both the “learners” and the “trainers,” bringing their knowledge and skills in STEAM topics and in business and finance as well (“mentors”).

MIRNOVA is the “brain-child” of a pre-eminent educator and teacher in the arts, humanities, and basic sciences, Marianna Valerievna Tsepeleva. Along with MIRNOVA co-founder Martin Joseph Dudziak (physics, mathematics, space research, complex systems), she has developed the foundations for the Academy, beginning with an initial focus upon creative projects that involve student participants in high school and middle school.

Participating students in these pre-teen and teen age groups interact directly with college-level students, teachers, instructors, professors and experts in several STEM disciplines. Their education and learning is not limited to brief one-time projects or competitions but may extend beyond one or more academic school years, and their activities include working with sophisticated instruments, equipment, computers, and software. Indeed, they gain preparations for both university education and for employment in the STEM fields. All participants have the opportunity to join as co-authors on articles and papers for publication and for presentation in technical conferences.

In conjunction with other international and multi-national organizations, scientists and engineers, MIRNOVA is concentrating now upon projects that have the following valuable characteristics:

- learning project and team skills as well as scientific and technical ones
- practicing innovation and inventiveness with practical, marketable technologies
- “doing more with smaller and simpler” - economy and simplicity of technologies that can serve multiple future applications
adaptability, modularity and re-usability, precisely the models that paved the way for growth and success in the software and IT worlds
addressing in simpler, beginner-level and then more advanced and complex ways the challenging problems that are the “big challenges” for human society in coming years and decades

What this translates into concretely, in the initial activities of MIRNOVA are projects in robotics, informatics, cybernetics, and with contest tasks replaced with well-planned experiments, simulations and tests. Projects are generated and managed by the participants, students and mentors working together.

The MIRNOVA philosophy and its planning by its team have resulted in a Strategic Landscape for STEM education that links education with current and future research, jobs growth, and social needs. Adding in the “A” for Art is an integral ingredient for this because it builds individual and public awareness, communication, enthusiasm, and cultivates aesthetic qualities which also fuel future technical creativity. Projects bring together students and other participants from different schools, universities, institutes and countries. All of this becomes a learning experience for all in teamwork, distance-based and remote-experiment activities, interacting with people from other regions, nations and social structures, and practicing the skills of project management, time management and personal/team responsibility.

MIRNOVA’s Strategic Landscape of STEM and STEAM Education and Research
This Strategic Landscape now offers students the opportunities to work – at their own level and pace, in combination with formal school programs and also during after-school periods and vacation times - on serious projects using robots, sensors, cameras, and extensive software, and to combine their learning experience and growth with being involved – as interns and apprentices - with larger and more sophisticated research teams connected with universities, corporations and other institutes involving expert researchers.

This generates excitement, enthusiasm, energy, and sustainability for All.

The focus of MIRNOVA’s STEAM Program, most broadly stated, is on Cooperative Robotics. Robots, sensors, computers and other devices that work together to solve some problems. “Real-world” problem-solving and also doing “everyday tasks” with better quality results, more efficiently and economically.

The primary reason for this choice and emphasis is to optimize everything possible for Success in the projects and the outcomes for both participants and sponsors:
- interest and enthusiasm by participants
- research and development relevance
- future employment relevance and strength
- sponsor interest, support and sense of relevance
- economics of doing the projects
- ease of access for equipment, software and other technical resources
- general popularity
- interest by mass media and news channels
- reduction of the learning thresholds to allow for more to be gained and retained by more types of students, ease in obtaining trainers and mentors
- opportunities for practical innovations that can be made by all levels of participants
opportunities for meaningful, profitable technology transfer and entrepreneurial start-up businesses
• solid scientific models and tools that can be applied to more challenging research such as in deep space, deep seas, or micro-nano environments.

The MIRNOVA founding team spent many man-months studying and researching a world of STEM programs and projects as well as reflecting upon past and current direct experience in STEM and STEM programs in several countries in North America, Europe and Asia. The result is a Landscape of activities, resources, knowledge, people, and Directions in which things can be done optimally and with powerful results as outcomes.

Diagram 1 below illustrates the expanse of the MIRNOVA Strategic Landscape. There are four very important points about this Landscape.
These are the most critical, severe, demanding problems and challenges facing our society today and into our open-ended future of tomorrows.

These are also the greatest opportunities for development of new technologies and products that really address people's needs, not only their momentary likes, wants and passing interests.

All of these involve increasingly extreme complex systems (XCS) – biological, chemical, environmental, mechanical, physical, and also financial psychological, and social systems that do not lend themselves easily or well at all to conventional linear thinking or conventional/traditional analysis, modeling and computing.

All are linked together in both formal and informational ways and are at the center of attention for a group of research teams and persons who are also interested in and committed to the education and cultivation of today's Youth and tomorrow's scientists, engineers, thinkers, and leaders.

Focusing the Beam on Earth, Sky and the Heavens

Naturally, there must be both a beginning point and a cohesive connectivity to everything and this is how MIRNOVA, in cooperation and collaboration with several other institutions and people, has further refined its S.T.E.A.M. Program.

The foundations include work by some founders and partners in areas of research that concern complex systems, supercomputing, quantum computers, and space sciences and technologies. This work includes the ASTRIC Project, a long-term and challenging project to develop an engineering system and space-based platform for Astrophysical Object Reconnaissance Intervention and Construction (“ASTRIC”), including for asteroid redirection and other countermeasures to prevent catastrophic collisions of asteroids and similar space objects with Planet Earth.

Bold, daring, and borderline impossible, according to some. Absolutely necessary and therefore a “must be achievable” project in the minds of increasingly many.

But how can such a complex and difficult project – or anything else like that – fit in with MIRNOVA's Program in a meaningful way? This is wherein lies some of the special beauty of the MIRNOVA Program.

Cooperative robots, sensors, and operations with images and signals of many types is the general focus for MIRNOVA Projects, and this encompasses human-robotic interactions, command, control, and the full gamut of issues and tasks for a complicated multi-component system – in this case, different robots and machines they use or that use them.

This is at the heart of the ASTRIC Challenge. But that is for Deep Space, either in earth-orbit or farther beyond. And that is going to take time, and resources, and it is not something that can be easily modeled or be “hands-on” for teams of students who may be in college, high school or middle school.

However, all of these types of tasks can be found in some definitely “down to earth” projects and it turns out that some of these “down to earthers” are precisely what will help the researchers who are tackling the challenges of ASTRIC.
This brings us to the world of cooperative robots, sensors, actuators and analytical systems that include UAVs, UGVs, even AUVs (“drones”) working in everyday locations and environments.

Going back to the “map” of MIRNOVA’s Strategic Landscape (the diagram above - Figure 1), there are many excellent avenues for education-rich, research-supportive, experiment-building, innovation-creating projects that can attract, enthuse, enable and empower youth of all ages, minds and dispositions.

In working out the “Optimization Equation” for what to have as the initial, “#1” focus of attention, MIRNOVA directors examined all of these eight “physical-centric” and four “information-centric” areas – the problems and challenges, the opportunities, the relevances, the support mechanisms.

This is how AgriBrains evolved as the primary and first-cut focus for MIRNOVA. Agricultural applications of multiple robots, from 1 to many, with cameras, sensors, and actuator devices, solving problems that will make many jobs and tasks easier, more economical, and with better quality results, for farmers around the world.

AgriBrains is about doing things with STEM that will improve agriculture and food production (processing), using multiple types of robot devices.

ASTRIC is about doing something similar, in terms of functions and operations, but in Space.

From Earth to Space. From the farm fields to the star fields. Not just an appealing metaphor but a strong engine for people to use – on Earth and in Space.

About AgriBrains
The Project is a suite of different avenues for developing practical expertise, technical and operational skills, and doing innovative exploratory studies and experiments in Agricultural Productivity Optimization using cooperative robots for sensing, analytics and control. (Thus the name, “AgriBrains.”) It encompasses a variety of directions in which student-mentor projects can be conducted over periods of several months to even a few years:

- Use of robot networks (UAV, ULV, AUV) with both human-assisted and autonomous functionality, employing a diverse array of CBR (chem-bio-rad) and EM (electromagnetic) multi-spectral sensors as well as electro-mechanical actuators.
- Onboard and mobile, as well as manually-delivered
- Dynamic mobile operation, and static-placed stationary operation
- “Plug-n-play” device independence for all platforms including applicability to other systems (e.g., aircraft, helicopters, etc.)
- Data acquisition and integration with satellite-based and other telemetry and knowledge sources
- Analytics employing human expertise and synthetic (AI, machine-learning) intelligence
- BOINC-based distributed processing for massive computational tasks
- Data management and knowledge representation and distribution

Projects undertaken within AgriBrains will enable participating students, teachers, mentors and teams to implement practical technologies, products and services serving the global agricultural industry in the following 12 manners, gradually over a period of months and years:
- CB (chem-bio) sensing and monitoring – focus upon toxins, bacteria and viruses
- Frost control – this is an emerging problem given the trend in non-linear climate change
- Seed planting – focus upon actual planting and follow-up for germination/replanting
- Fertilizer optimization – focus upon reduction of excess use and cost
- Irrigation optimization – focus upon balance in hydration
- Pest control – focus upon emerging insect and micro-fauna due to climate change
- Sugar content – a critical area for fruits and for crops used in beverage production
- Ripeness and harvest readiness – focus upon increasing yield and turn-around
- Tree and bush pruning (management and planning)
- Differentiation and specialization for crop type variants
- Predator control (e.g., birds, foxes, wolves) – focus upon deterrence
- Planting and harvest planning (info, maps, AI-recommendations)

Figures 1, 2 and 3 below illustrates the basic UAV types and functions used within AgriBrains. Activities will initially commence with existing, standardized, pre-manufactured UAVs, which can then be customized by add-on devices and application-specific software, to perform increasingly complex and useful tasks for agriculture. There is an emphasis upon certain types of tasks, which serve both the educational and innovative motives of the Program, and which specifically – emphatically so – will serve the needs of applications in more complex domains such as space operations, mining, manufacturing and other engineering.

Figure 1: eBee SQ drone for spectroscopic surveys  Figure 2: DJI eight-rotor drone with 10-liter capacity

Figure 3: Sentroid UAV illustrating air sampler, analytical results and control unit
AgriBrains enables the development and training, by teams of different capabilities, skills, experiences and backgrounds, within the uses of cooperative robots for functions that are similar, functionally and computationally and mechanically, to the operations required in other applications such as ASTRIC which concerns cooperative robots engaging in sensing, measuring, and manipulative tasks with objects such as asteroids in space. Those manipulative tasks will differ, of course, from those performed with farms and orchards on Earth, but there are significant parallels which include, for instance, feature search and location, operations with contact devices, non-contact interactions requiring precise positioning, aiming and device control, and the cooperation among multiple robots (agents) operating within a relatively confined 3D space and with risks of collision.

About I-Bank

The I-Bank Project is the “Sky” or “Cloud” level of MIRNOVA’s world-space of activity. It is also about “cooperative robots” but these are more typically considered as agents or cybots, not as mechanical systems. This is the realm of applying tools that are software-based for tasks such as analysis of trends, moods, dispositions, and attitudes within the broad domain of social networks and mass-media activity on the internet. Thus, metaphorically, the “Cloud” realm.

I-Bank as an MSP Project is in its early stages of definition. However, it has received an influx of interest and support because of many active “hot buttons” in our present social and business world which concern cybersecurity, cryptocurrency, information privacy,

Figure 4 illustrates the overall functional component map of I-Bank. There are many directions in which the educational projects within the MIRNOVA Program may develop. The main emphasis will be upon analysis of patterns and especially anomalies and non-linear trends from massive social network and mass-media data streams, in order to identify control parameters of use within applications that depend upon such predictive information. Note that the same logics and the same algorithms are what will serve different application needs in systems that operate in radically different physical environments – such as in robotic-based space construction, mining, manufacturing - and the handling of objects such as asteroids.
About ASTRIC

The ASTRIC Project is a multidisciplinary, multinational program of scientific research and engineering development that will produce an integrated system for space-based robotic missions. These missions will have a primary objective of providing measures of security and protection to Earth from potential collisions by hazardous extraterrestrial objects such as asteroids. These defensive functions will be accomplished by means of multiple reconfigurable operations to alter trajectory or otherwise mitigate a collision threat. The technologies include modular components that can provide reconnaissance and interventions that result in alterations to object trajectories. These tasks are accomplished by means of mechanical leverage as well as coordinated ballistics. Certain tasks involve direct contact with the target object and other tasks are managed without physical contact.

Of central importance within ASTRIC is the development of intelligent semi-autonomous cooperativity among modular and reconfigurable robots that can operate in a fault-tolerant architecture, in deep space environments. In the context of an asteroid or similar space object, ASTRIC will enable a multi-tasking solution to trajectory modification and collision-threat mitigation, and it will support diverse alternatives such as those explored by NEOShield and other programs. In other contexts, ASTRIC provides an engineering platform for exploration, mining and industrial uses of asteroids and space objects.

ASTRIC research places strong emphasis upon cybernetics and automatic control of extreme complex systems and applies proven mathematics and well-demonstrated computational results to the challenges of operating multiple devices including robots in an environment with unknown parameters concerning the target asteroid or other object. This emphasis upon command, control and computing is a major-needs area for the tasks and an area in which the core team and projected partners have excellent foundations and capabilities.

ASTRIC will be conducted as a research and development project involving a consortium of institutions and experts, in close cooperation with the NEOShield program for asteroid defense and countermeasures (EU), NASA (USA), Roskosmos (RU), and others in Russia, Europe, North America and Asia. Support will be obtained from both private and public sources already engaged in the problems and challenges of near-earth-object threat mitigation and in the cybernetics and control of extreme complex systems. There will be a strong educational component to ASTRIC through special courses, seminars, conferences and workshops which will be offered both onsite and online for students, scientists, engineers and other professional interest groups.

ASTRIC systems will be deployable in a variety of mission types and orbital configurations relative to Earth. Mission components will employ technologies including ion propulsion, solar power and high-strength carbon fibres and composites. Mission planning and operations include intervention techniques for object trajectory modification or target break-up. Such control methods employ synthetic intelligence technologies specialized for extremely complex, non-linear, stochastic systems comprising multiple components. ASTRIC incorporates a strong emphasis upon the cybernetics of multiple non-linear dynamical systems and cooperative, semi-autonomous, multi-axial robotic operations.

The ASTRIC Project is conducted as an international consortium. That will be managed and coordinated by the ASTRIC Global Laboratory for Space-Based Intelligent Engineering Systems affiliated within the Aerospace Technologies Research Center at South Urals State University in Chelyabinsk, Russia, and working in close cooperation with other established programs in USA (Michigan) and UK (Scotland) and EU (Germany, Luxembourg, Spain).
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Mentors and Experts for MIRNOVA Projects
From where do they come? Why do they join into MIRNOVA?

Here are the places where there are people expressing interest and commitment to MIRNOVA, its Mission and Strategic Landscape, its S.T.E.A.M. Program. They come and join-up because they are also enthusiastic about the future, about youth being creative, adventurous and productive in teams with themselves and other experts, and because they care about Our Collective Future and see MIRNOVA's work as a valuable ingredient in the Equation for a Better World.

♦ Institute for Innovative Study (EU, US) and the LEAPS Laboratory for Emergent Adaptive Processes and Systems
♦ Aerospace Tech Research Center at South Urals State University, Chelyabinsk (RU)
♦ Saint Petersburg State University (RU)
♦ Smart Solutions (RU)
♦ Russian Center for Robotics and Technical Cybernetics
♦ Norwegian University of Science and Technology

MIRNOVA is grateful and excited about the engagement and interests expressed by individuals and teams in other organizations, including:
- Airbus
- DLR - German Aerospace Research Center
- Max Planck Institutes (several)
- Centre National de la Recherche Scientifique
- Reaction Engines Ltd (UK)
- Clyde Space
- Technical University Berlin
- Technical University Dresden
- Fraunhofer Ernst-Mach-Institut
- ETHZ (Switzerland)
- Technical University, Eindhoven (NL)
- Cambridge University (UK)
- Edinburgh University (UK)
- Novosibirsk State University
- Krasnoyarsk State University
- KAIST (Korean Institute for Advanced Science and Technology)
- KARI (Korean Aerospace Research Institute)
- AIRI (Artificial Intelligence Research Institute)
- Michigan Technological University
- NASA
- Universities Space Research Association
- University of Michigan, College of Engineering
- Georgia Inst. of Technology, College of Engineering
- Massachusetts Institute of Technology
- Johns Hopkins University
- University of Maryland
• China Academy of Space Technology (CAST)
• Shanghai Jiaotong University
• Zhejiang University
• Tsinghua University
• Tokyo University
• Mitsubishi
• Kawasaki