Space Apps is a NASA

incubator innovation program.

Dushanbe

TAJIKISTAN

«Eclipse»

Hackathon Project Report

"THE SECRETS OF THE SUN"

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Tajikistan-2021

Introduction

A satellite is a celestial body orbiting along a certain trajectory (orbit) around another object in outer space under the influence of gravity.

Small satellites are a type of artificial Earth satellites with low weight and size. Satellites with a mass of less than 0.5– 1 ton are usually considered small. There is a more detailed classification of types depending on the mass. The launch of small satellites into orbit can be carried out by simpler rockets or as an additional load to conventional satellites.

Cubesat— "CubeSat" is a format of small (ultra-small) artificial Earth satellites for space exploration, having a volume of 1 liter and a mass of no more than 1.33 kg or several (multiples) more. The creation of cubesats became possible thanks to the development of microminiaturization and nanotechnology and became a mass phenomenon in the XXI century. After the appearance of the cubesat format, an even smaller poketsat format (literally pocket) appeared in several hundred or tens of grams and a few centimeters.

The specifics of "CubeSat"-s

Modern nanosatellites are characterized by relatively high functionality, despite their small size. Their scope of application is wide - from attempts at remote sensing of the Earth to space observations: development of the latest technologies, methods, software and hardware solutions; solar activity research; space weather; educational programs; environmental monitoring; astronomical observations etc.

The CubeSat standard makes it possible to create miniature satellites weighing 1-10 kg in a short period of time (1-5 years) and relatively small funds. Work on the creation of "CubeSats" is underway in dozens of training centers and creative teams around the world. The rapid development of the element base gives hope for a possible commercial application of these satellites in the coming years. The creation of such satellites is very relevant in the conditions of Russia, Europe and the USA, which have great potential in the field of launching spacecraft. This would allow Tajikistan, in the intervals between the implementation of major projects, to carry out space research at relatively low financial costs.

Task

To develop a method of increased public awareness of cubesats with a goal of attracting young people to the space industry.

The Eclipse project is aimed at researching and promoting the technology of developing nanoclass spacecraft among schoolchildren and students, as well as how the valuable data they provide affects how we live and work.

Technologies and techniques have finally combined to make possible missions such as the Parker Solar Probe and Solar Orbiter, which are designed to study the Sun closer than ever before, with a robust spacecraft fortified to conduct research in dangerous regions with an intense heat and solar radiation. The Parker Solar Probe, for example, will fly close enough to the Sun to observe and record solar wind accelerations within its zone, and will fly through the birthplace of solar particles with the highest energy. The thrill of developing such a complex mission as the Parker Solar Probe has inspired the scientific community and raised its aspirations. NASA has launched the «Heliophysics 2050» program to expand the vision and goals for missions and science by 2050.

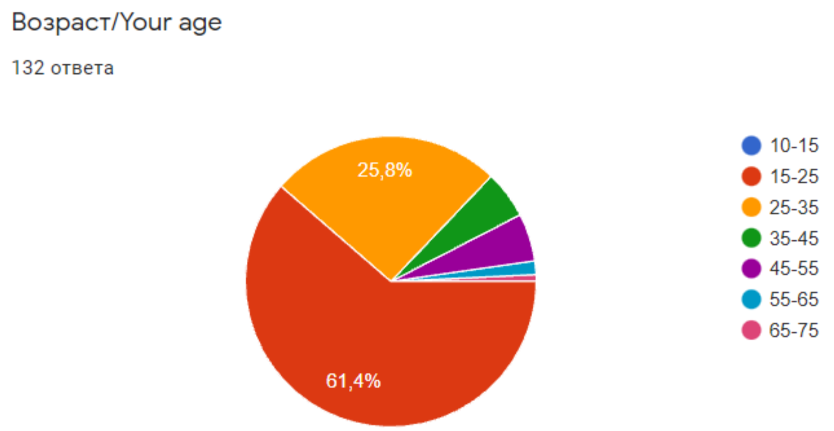
The project pays special attention to current heliophysical missions, such as Parker Solar Probe and Solar Orbiter, while encouraging users to think about the future of solar exploration; for example, "What will the future mission look like and what aspects of the Sun will it explore?"

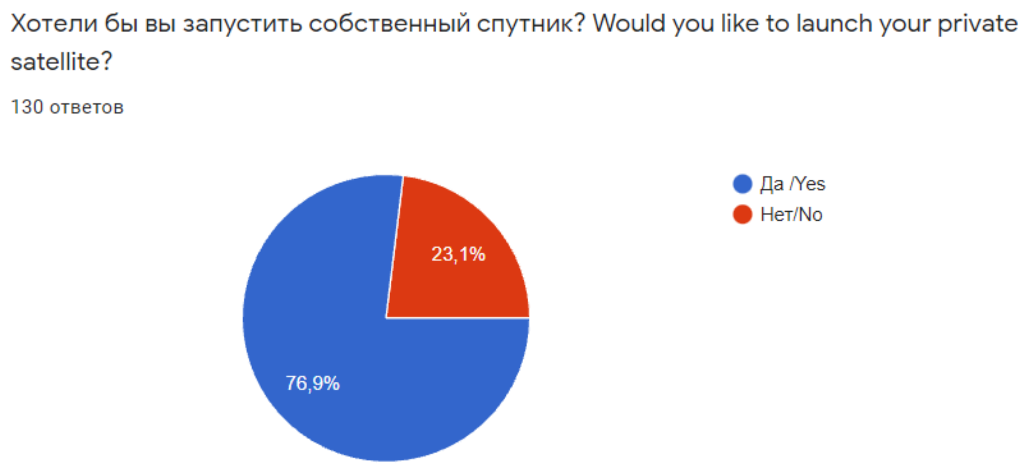
According to NASA's Heliophysics 2050 program, we want to launch an orbital solar nanotelescope that researches the Sun.

Social survey

People who have completed a social survey through a Google form. Citizens of the following countries took part in the survey:

Tajikistan – 53; Russia -39; Brazil-3; Peru-2; USA-2; Nigeria -3; Burkina Faso -1; UK-1; Japan -1; Mexico -1; Bulgaria -1; Kazakhstan -4; India-3; Ethiopia -2; Iraq -1; Canada-1; Bangladesh-2; Indonesia -1; Uzbekistan -1; Palestine -1; Cameroon -1; Belarus -1; Egypt -1; DNR -1

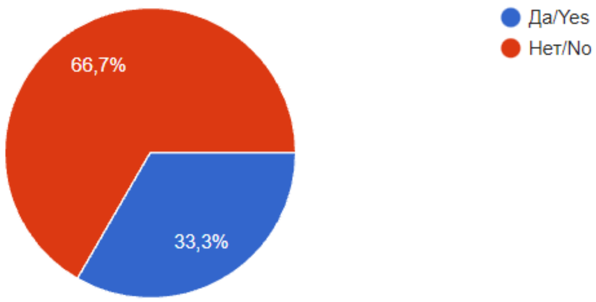




An analysis of interests by age was carried out. The results showed that many are not familiar with the Parker Solar Probe and Solar Orbiter space mission.

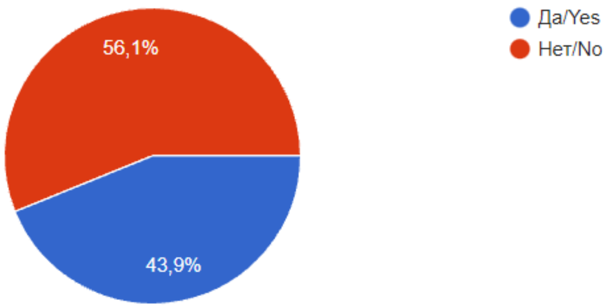
Вы знаете о космической миссии Parker Solar Probe? Do you know about the space mission of the Parker Solar Probe?

57 ответов



Вы знаете о космической миссии Solar Orbiter? Do you know about the space mission of the Solar Orbiter?

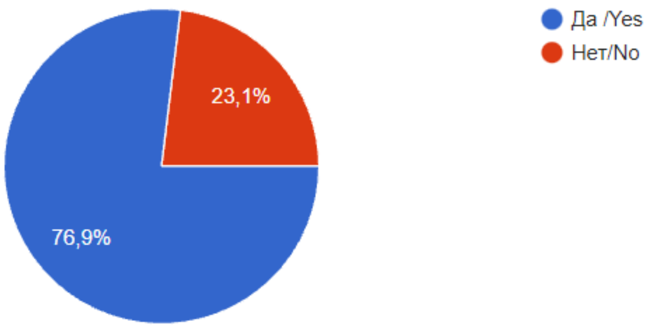
57 ответов



More than 75% want to launch their own satellite and take part in our project.

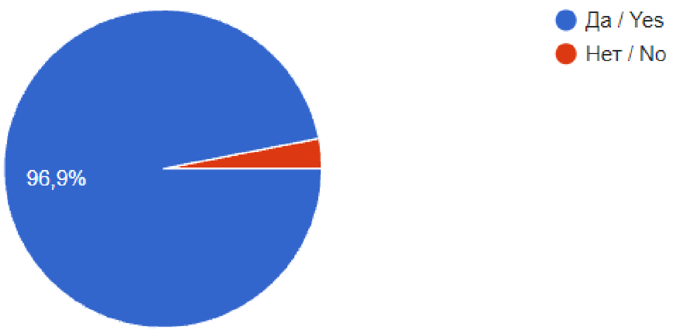
Хотели бы вы запустить собственный спутник? Would you like to launch your private satellite?

130 ответов



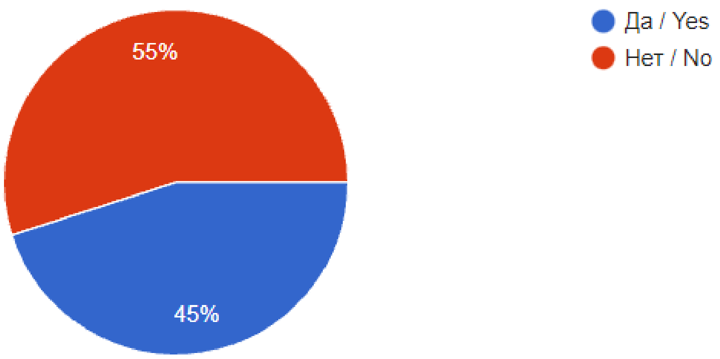
Хотели бы вы, чтобы в вашем регионе появились развивающиеся программы по направлению аэрокосмической отрасли? Would you like to have a developing program to the direction of the aerospace industry in your region?

131 ответ

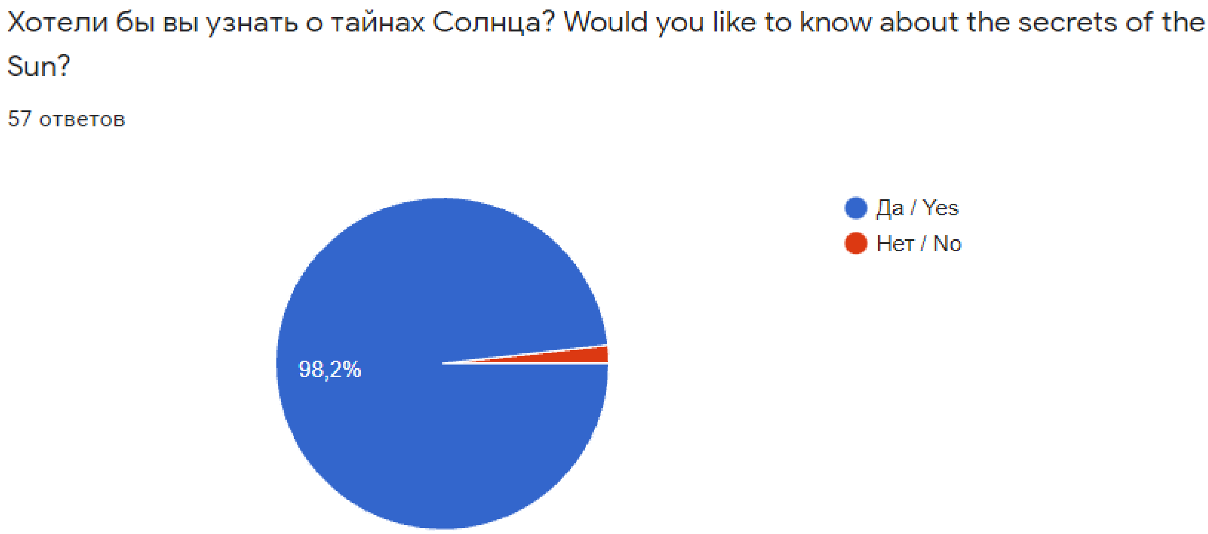


Знаете ли вы, что такое "cubsat"? Do you know what "cubsat" is?

131 ответ



Solar activity



Solar Cycle 25 has begun. The Solar Cycle 25 Prediction Panel, an international group of experts co-sponsored by NASA and NOAA, announced that solar minimum occurred in December 2019, marking the start of a new solar cycle. Scientists use sunspots to track solar cycle progress. The dark blotches on the Sun are associated with solar activity, which often indicate as the origins for giant explosions – such as solar flares or coronal mass ejections – as a result can spew light, energy, and solar material into space.

Space weather predictions are also critical for supporting Artemis program spacecraft and astronauts. Surveying this space environment is the first step to understanding and mitigating astronaut exposure to space radiation. The first two science investigations to be conducted from the Gateway, will study space weather and monitor the radiation environment in lunar orbit. Scientists are working on predictive models so they can one day forecast space weather much like meteorologists forecast weather on Earth.

Some aspects of the Sun structure, nature of its activity, relations of solar activity with its large-scale structures and with its internal parts are waiting to be solved. Starting investigators are able to contribute to research of these issues providing high quality observations for astronomers. It is not suggested only individual pictures and spectra. To comprehend theoretically, obvious and complete data on real processes on the Sun are required. In my opinion my mind, starting investigators can provide research on evolution of active areas of the Sun. It is a very wide field of action both for personal researches observing and sketching sunspots, and for teams of researches carrying out various investigations. Another focus is everyday observation of the Sun according to some permanent programs. These programs can include determination of Wolf numbers, coordinates, square of all groups, and the main sunspots. Squares of follicles, solar bursts, and solar prominences are also, need to be researched. If there is a wide range of such data, it is possible to investigate various aspects of physics of the Sun, and the influence of the Sun on Earth. [1]

Wolf numbers are used as a measure of solar activity. Wolf number is proportion to a total sum of sunspots f and increased tenfold number of their groups g:

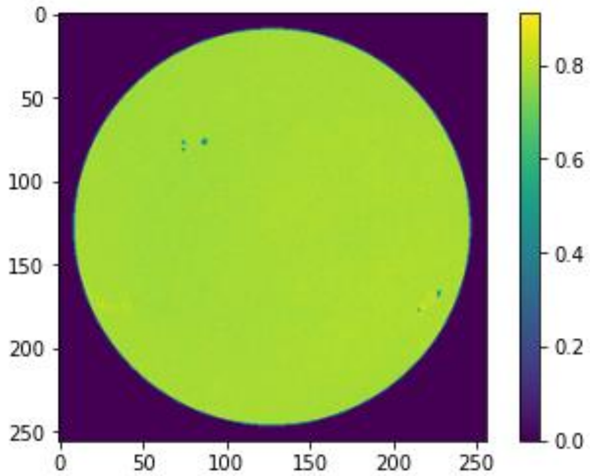
$$W = k\,(f + 10g).$$

Coefficient of proportionality k depends on the power of the instrument used. Wolf numbers are usually averaged on months or years. Starting the investigation of solar-terrestrial physics it is necessary to realize that we deal with, at least, three objects – the Sun, the Earth, and the interplanetary medium. This fact essentially complicates the task and requires some more knowledge. In other words, solving tasks dealing with Sun - Earth relations, requires a good grounding understanding in some spheres beyond purely observations of the Sun. Far from all research teams to solve scientific tasks. Some of them are acquaint people with modern science; demonstrate the Sun, stars, foster interest in learning the world. Each item involved is to be considered fully, including internal and external aspects, relations, their interactions and trends. Social world is an endless web of relations and interactions – nothing remains motionless and invariable submitting to objective laws in their development. Unfavorable in physiological relations solar factors worsen all negative moments of peoples' vital activity – intensifies depression, increases expression of objectionable emotions, intensifies unhealthy irritability and negative reactions. [1]

Prepearing training DataSet

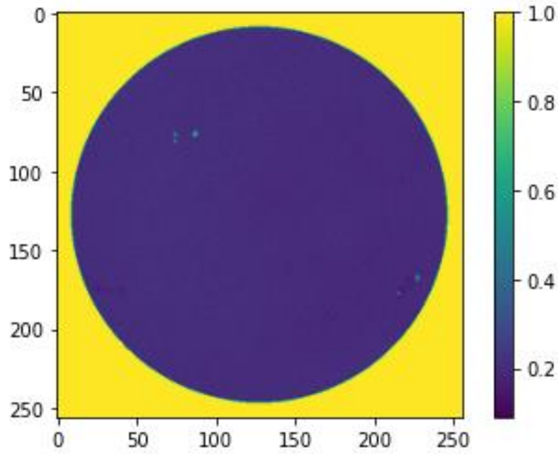
We used data from NASA and ESA spacecraft to predict space weather and train convolutional neural network to find a Wolf number.

1) First of all, we load an image from BMP file as bitmap and normalize it:



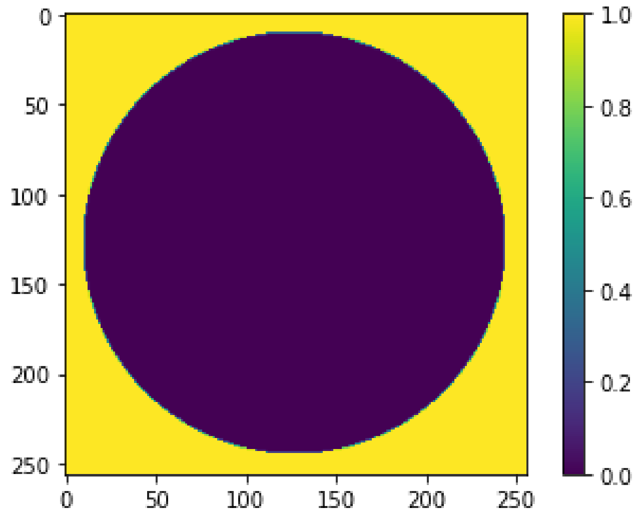
2) Inverting image:

$$Image_{i,j} = 1 - Image_{i,j}$$



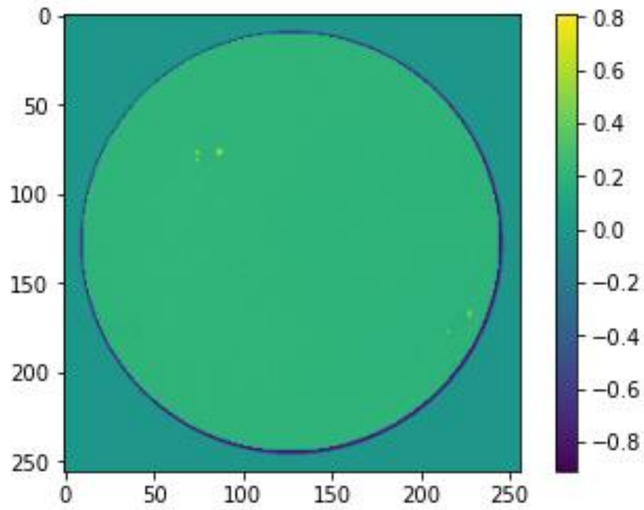
3) Creating a Sun mask:

$$Mask_{i,j} = \{0, \quad (i-127)+(j-127) < 120^2 \; 1, \quad (i-127)+(j-127) \geq 120^2$$



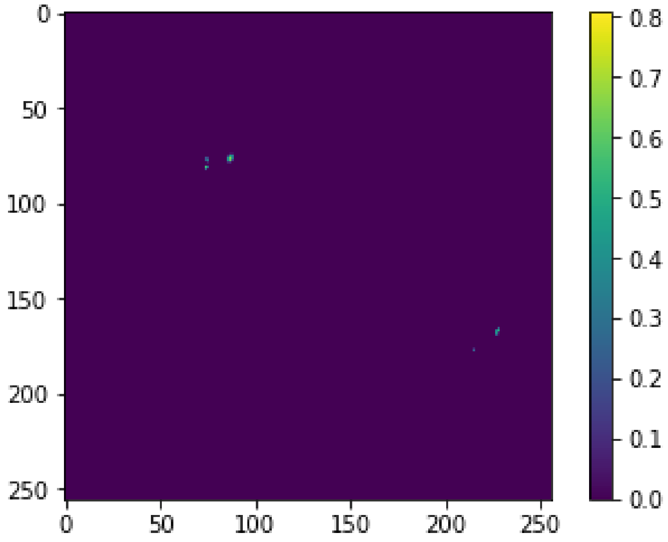
4) Applying mask to the image

$$Image_{i,j} = Image_{i,j} - Mask_{i,j}$$

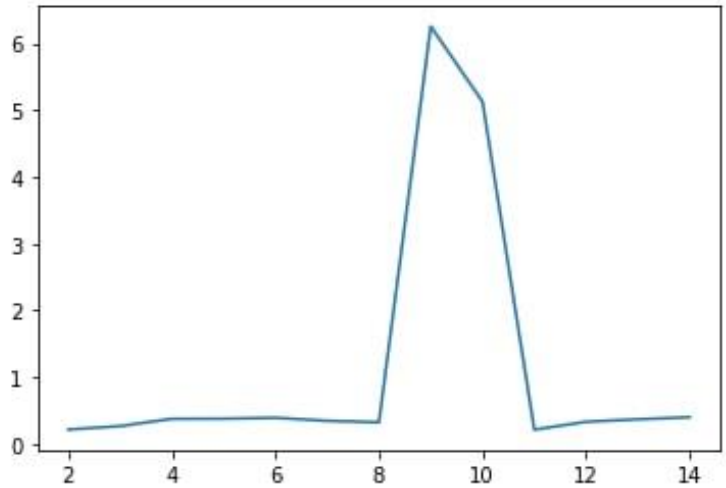


5) “Brightness Filter”

$$Image_{i,j} = \{0, \quad Image_{i,j} < 0.4 \; Image_{i,j}, \quad Image_{i,j} \geq 0.4$$

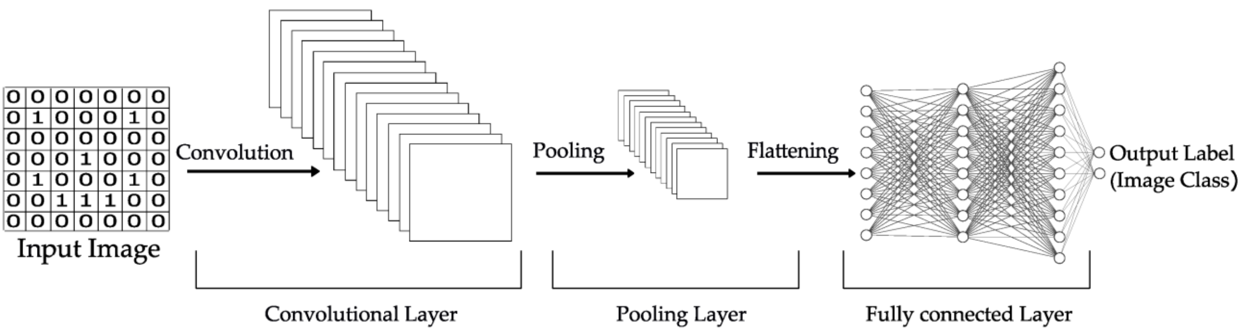


The right-side column is “Brightness”



Horizontal axis is testing images and vertical axis is relative error (%)

The last plot shows accuracy.

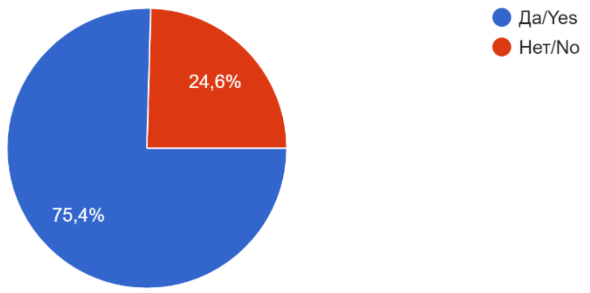


We’ve used Python and Tensorflow with Keras to learn CNN and calculate Wolf number. Code and DataSet will available on GitHub [2]

Project analysis and progress of work.

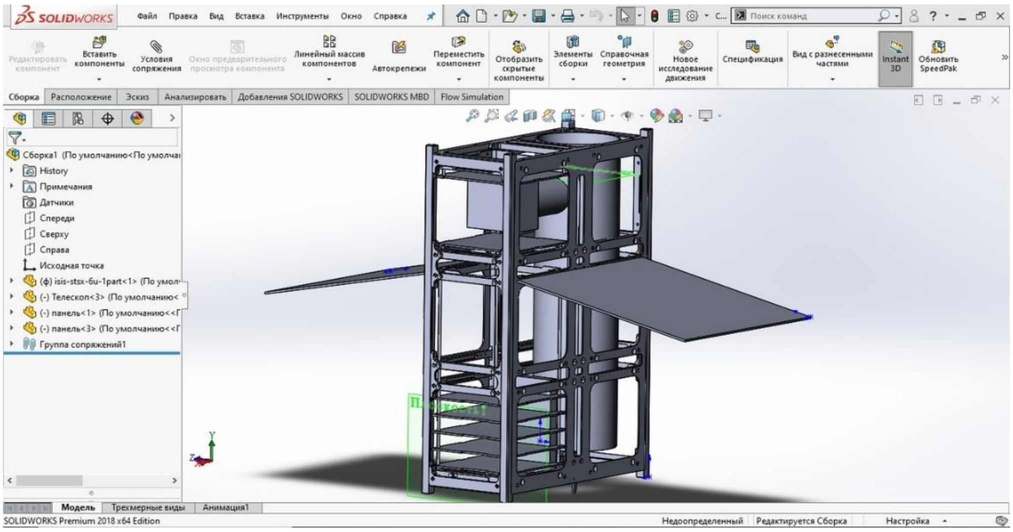
Хотели бы вы участвовать в нашем проекте ? Would you like to participate in our project ?

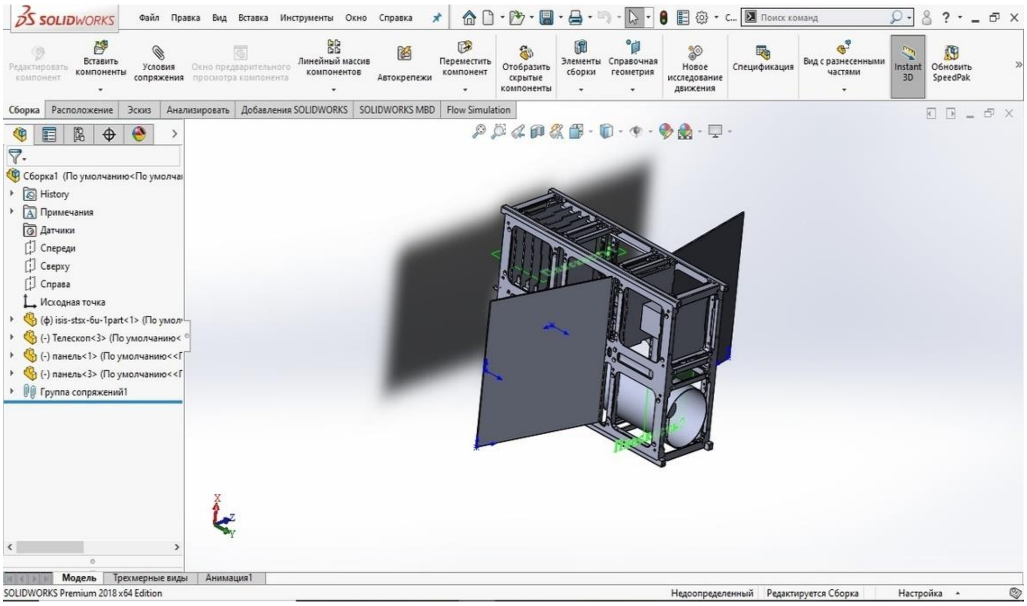
57 ответов

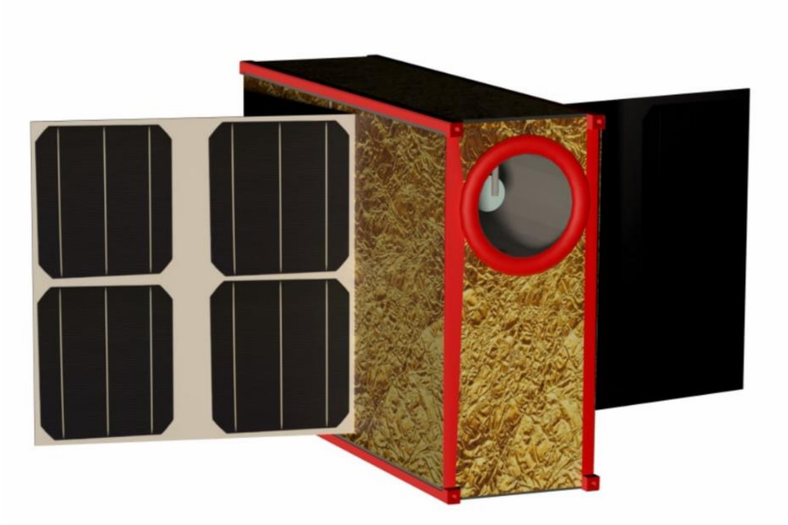


People from other countries are showing great interest in the Eclipse project.

Designing EclipseSat 6U in SOLIDWORKS







Pic. EclipseSat 6U

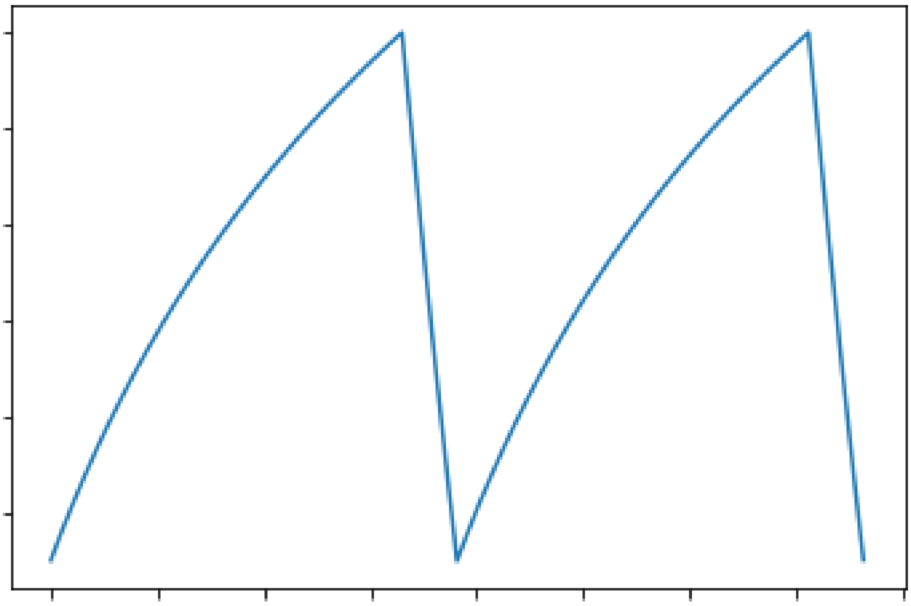
Equation of charging the battery

$$\frac{dC}{dt} = \frac{\varepsilon_p - \varepsilon_B(1 - exp\,(-C))}{r}$$

C-battery capacity, $\mathcal{E}_p$-solar panel voltage, $\mathcal{E}_B$-max.battery voltage, r-resistance

We have used the Runge-Kutta method in Python

Plot -Charging and discharging cycles



Horizontal axis – time in seconds, vertical axis – capacity in $mA \cdot h$

Mathematical modeling of satellites motion

The motion of the center of mass of the NS at an altitude of 700 km is simulated. And the route of the

Eclipse satellite.

Initial data:

m, kilo	Unit, pc	S_0, deg	$H_{\pi 0}$, km	$H_{\alpha 0}$, km	i_0, deg	Ω_0, deg	ω_0, deg	ϑ_0, deg
6	6	0.53	700	700	90	2.1	0	0

Here:

γmin – minimum seat tilt angle;

m – mass of spacecraft;

$S0$ – sidereal time on the Greenwich Meridian at midnight GMT;

i_0 – the inclination of the orbit;

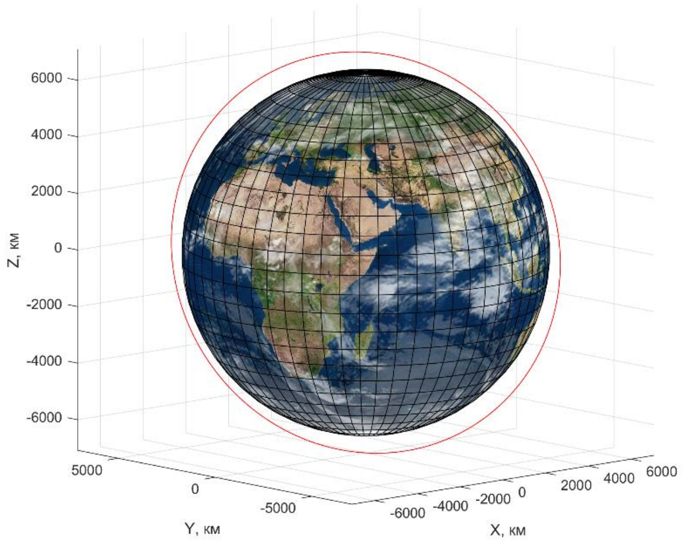
Ω_0 – longitude of the ascending node;

ω_0 – the perigee argument;

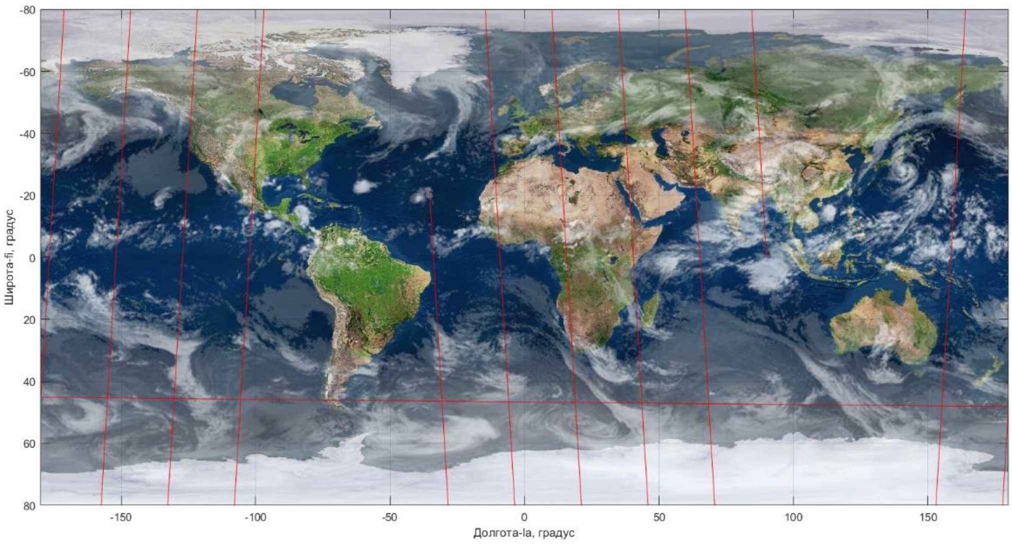
$u_0 = \omega_0 + \vartheta_0$ – latitude argument;

ϑ_0 – the angle of the true anomaly;

Simulation results in the MATLAB environment [2]:



Pic. EclipseSat orbit



Pic. Ground track of EclipseSat

Pontryagin's Maximum Principle for the Optimal Control Problems with Multipoint Boundary Conditions

Let the controlled process on a fixed time interval $[0, T]$ be described by a system of differential equations:

$$\frac{dx}{dt} = f(t, x, u)$$

with multipoint boundary conditions:

$$\sum_{j=0}^{N} B_j x\left(t_j\right) = C,$$

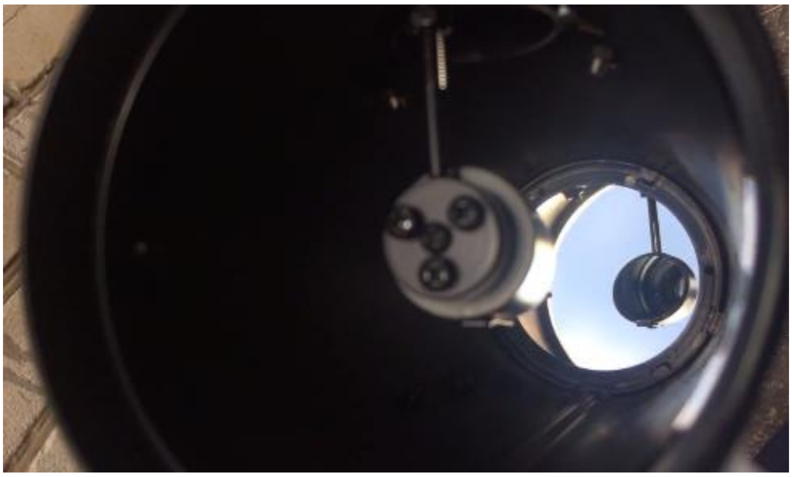
where $x(t) \in R^n$; $f(t, x, u)$ is the given u dimensional vector-function; $C \in R^n$ is the given constant vector; $0 = t_0 < t_1 < \cdots < t_N = T$ are fixed points; $u(t)$ is the r dimensional and bounded vector of control actions with the values from the nonempty, bounded set U; that is

$$u(t) \in U \subset R^r, \quad t \in [0, T].$$

It is required to minimize the functional [3]

$$J(u) = \varphi(x(0), x(T)) + \int_0^T F(t, x, u)\, dt$$

Optic system



Pic. Optic of EclipseSat 6U

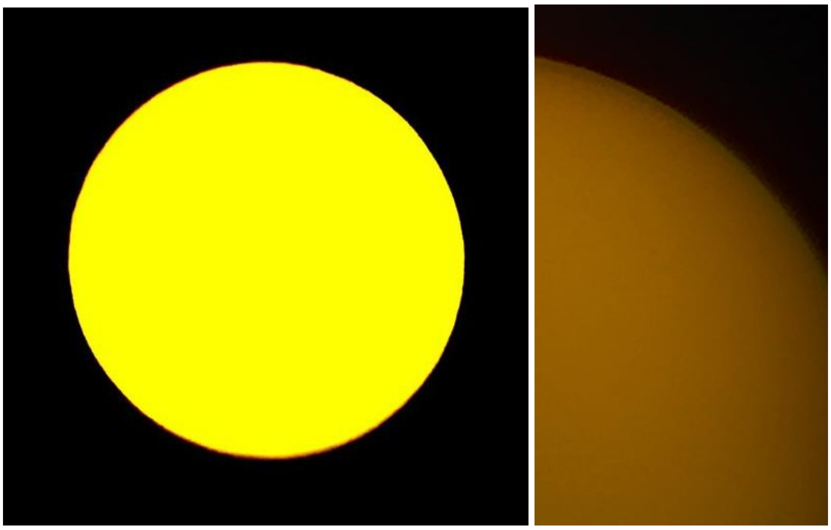
The optical system of the nanosatellite was selected due to the peculiarities of the size of the cubesats.

Telescope Characteristics.

Optical design	reflector
Objective lens	Newtonian
Optics coating	fully multi-coated
Primary mirror diameter (aperture), mm	76
Focal length, mm	300
Highest practical power, x	152
Focal ratio	f/3.95

Pic. EclipseSat 6U

Result



Pic. Images of the Sun in a telescope of EclipseSat 6U

Economic calculation

Approximate budget for the implementation of the Eclipse project.

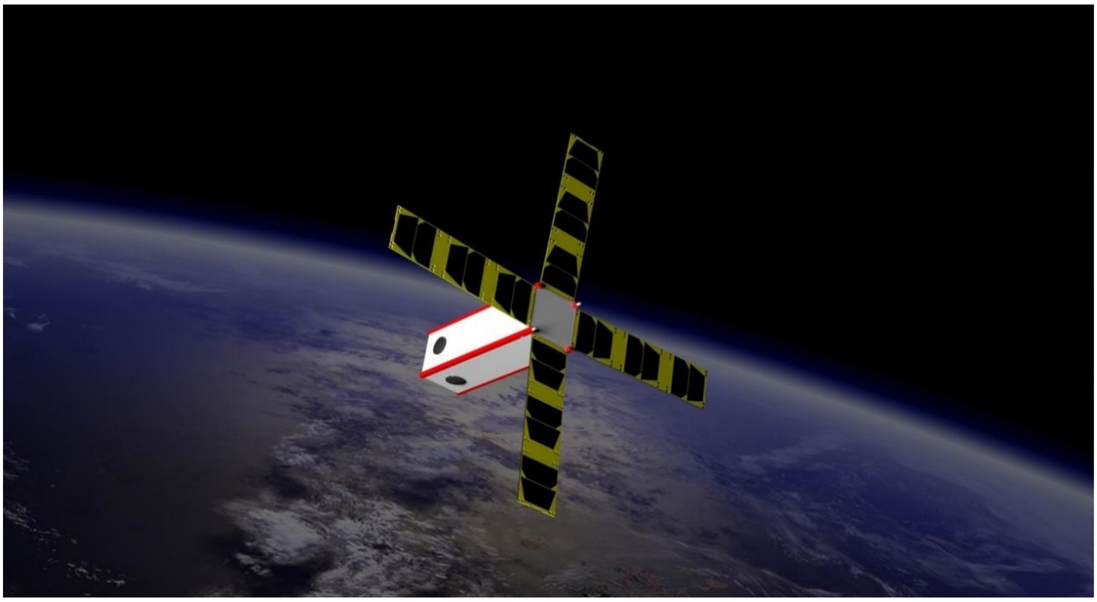
	A	B	C	D	E
1	Датчики связи и ананлиза БК (EyeStar-S3 Satellite Simplex Communications System)	2500		Солнечный фильтр (Solar filter)	500
2	Оптика телескопа (Telescope)	6000		Контролер заряда (Charge controller) TP 4056	5
3	Корпус наноспутника (Nanosatellite body)	2000		Коронадо солнечный фильтр (Coronado solar filter)	1800
4	Солнечные панели (Solar panels)	1500		Провода (Wires)	300
5	Маховики (CubeWheel Small)	4700		Радиаторы (Radiators)	7
6	Аккумуляторы (Batteries)	2250			
7	StereoPi Standart	5745			
8	Майларовая пленка (Mylar Film)	10			
9	ISIS Modular Electrical Power System	1000			
10	Солнечный датчик (NSS Fine Sun Sensor)	12000			
11	USB Adapter WI-FI for Rpi	20			
12	Raspberry Pi Compute Module 16 GB eMMC Memory	54			
13	Li 500-2 - зарядное устройство (Charger)	18			
14	Бортовой компьютер (ISIS On board computer)	10000			
15	Батарейный отсек (Holder)	50			
16	LM2596 DC-DC MODULE стабилизатор напряжения (Voltage regulator)	15			
17	Камеры (Camera)	100			
18	Сумма расходов (Cost amount)	50074	$		

ToySat

We offer to popularize space to all children, schoolchildren, and students to assemble their own cubsat. We have developed a methodology for increased public awareness of cubesats with a goal of attracting young people to the space industry.

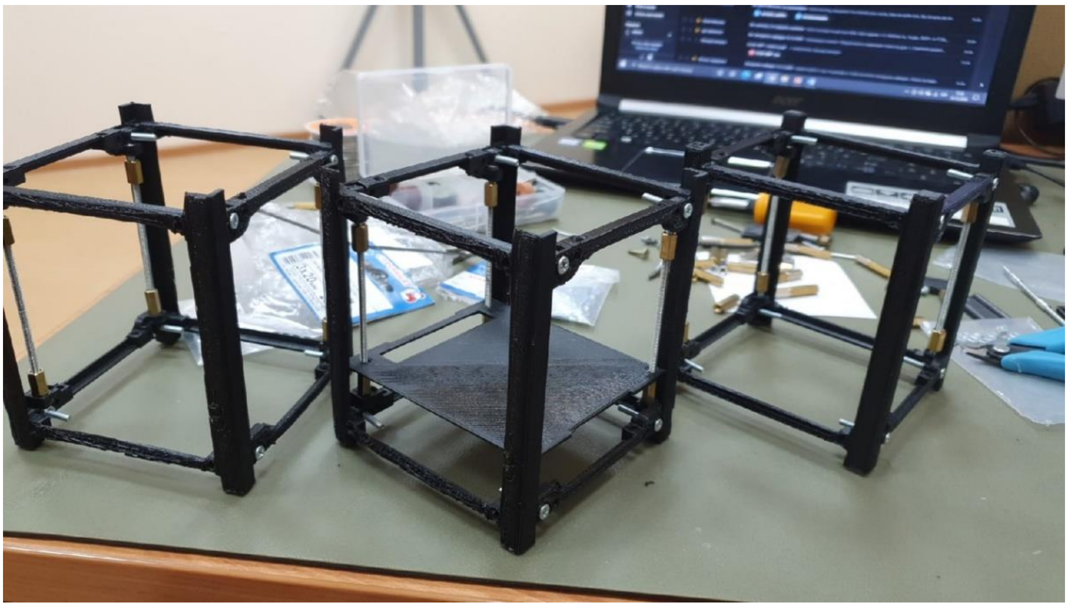
The Eclipse project aims to research and promote the technology of developing nano-class spacecraft among schoolchildren and students and inspire young people to conduct scientific research.

The idea of developing a nanosatellite with a VR camera and the possibility of a remote connection to it, thereby anyone will be able to observe the planet Earth from a height of 550 km and fully immerse themselves in space. And also the thermal imager is able to detect foci of forest fires.

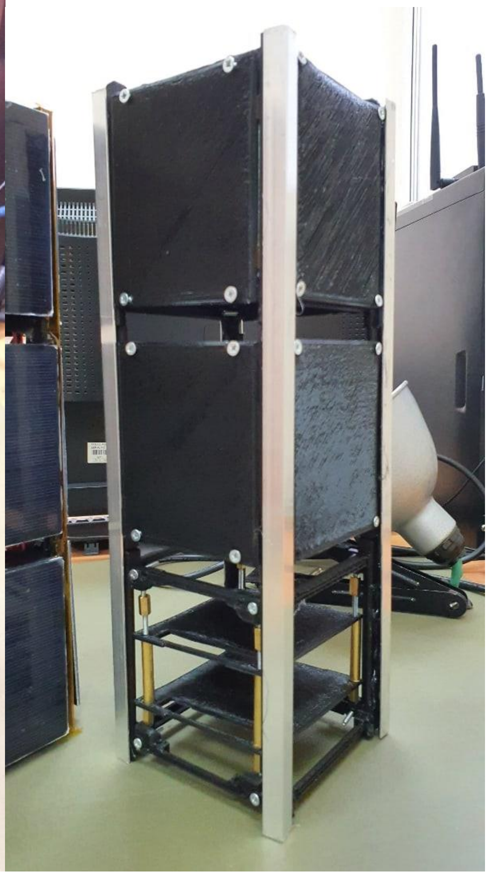


The initial appearance of the satellite was complex in design and it was decided to optimize the design. The classical scheme of cubesats for 3U was chosen.

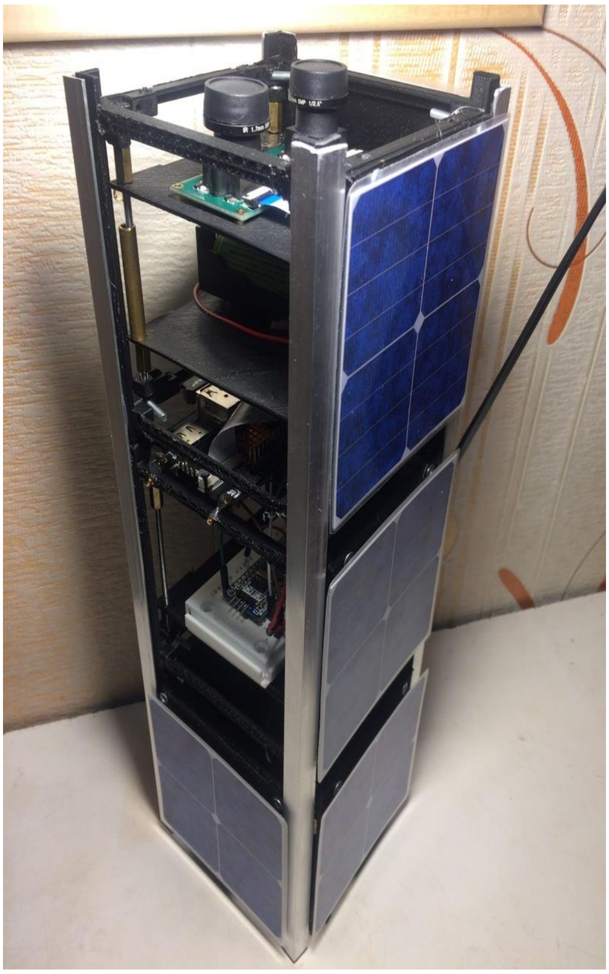
In the first stage, "ToySat" is made of PLA material and printed on a 3d printer.



Then these units were assembled

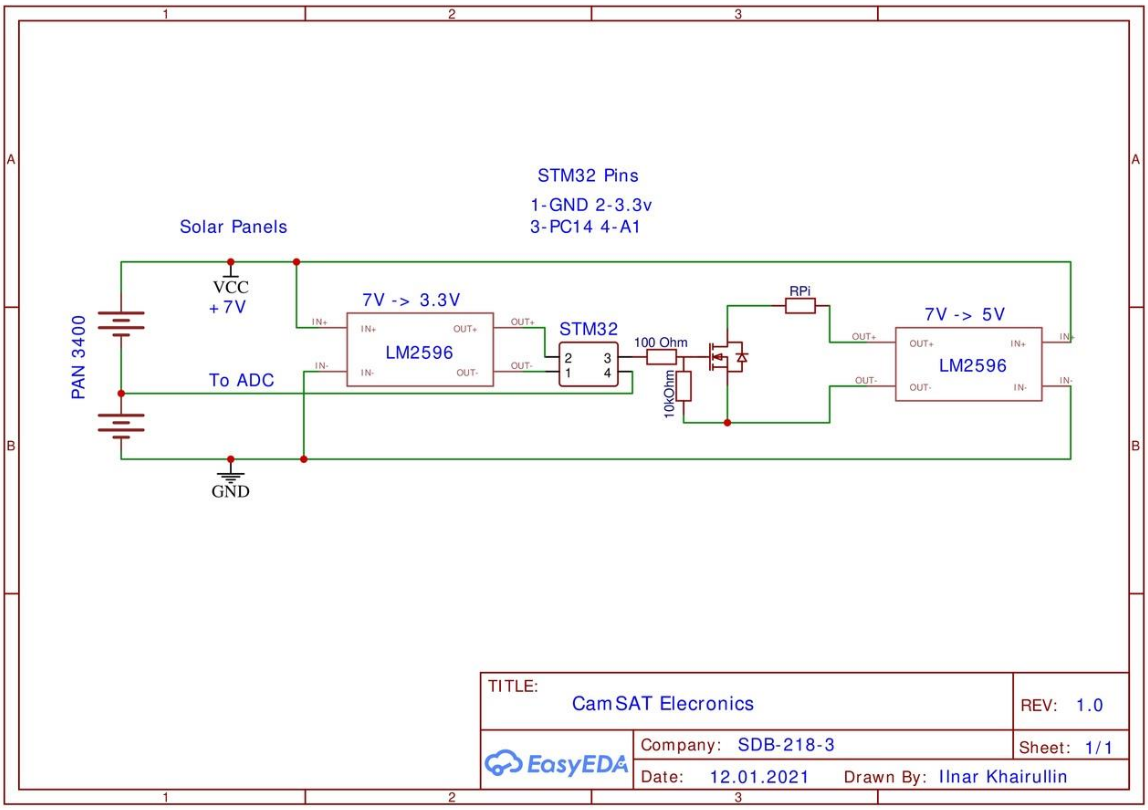


Imitation solar panels are attached to the case.



ToySat-3U

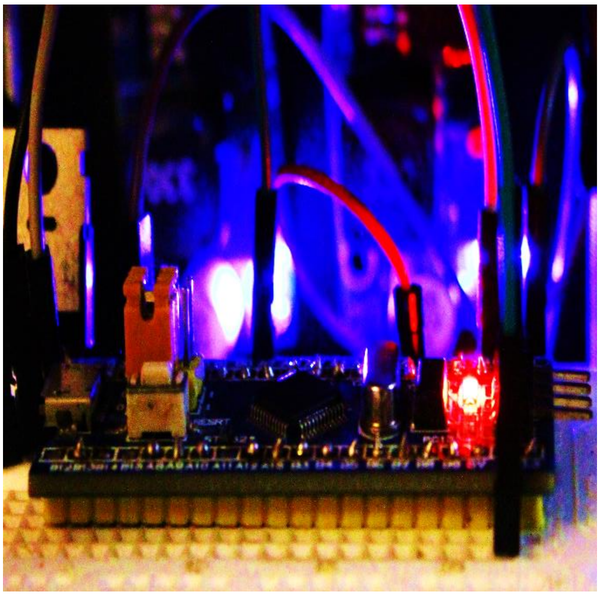
Simulation of spacecraft power supply.



The STM32 microcontroller controls the power supply of the system and does not allow the Raspberry Pi to discharge the batteries. Also in the future, it is planned to set active stabilization using coils and inertial flywheels.

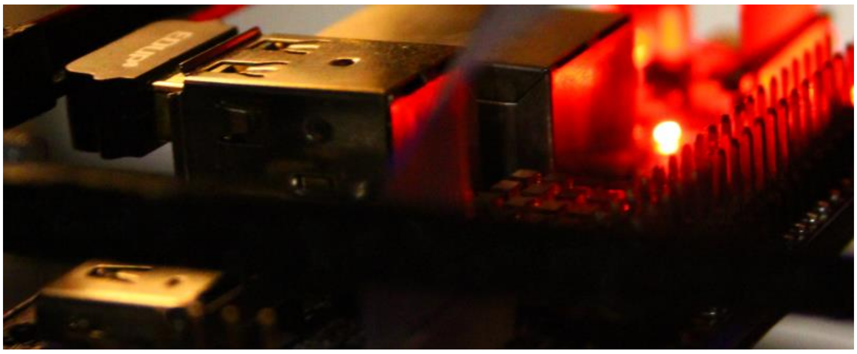
```
HAL_ADCEx_Calibration_Start(&hadc1);

while (1)
{

    HAL_ADC_Start(&hadc1);
            HAL_ADCEx_InjectedPollForConversion(&hadc1, 100);
            adc_val = HAL_ADC_GetValue(&hadc1);
            HAL_ADC_Stop(&hadc1);
           // HAL_Delay(100);
            voltage = adc_val * (3.3/4095);
            if (voltage >= 3.2 )
                HAL_GPIO_WritePin(KEY_GPIO_Port, KEY_Pin, 1);
          if (voltage <= 2.7 )
              HAL_GPIO_WritePin(KEY_GPIO_Port, KEY_Pin, 0);

}
```

Part of the program for the STM32 microcontroller(C++).

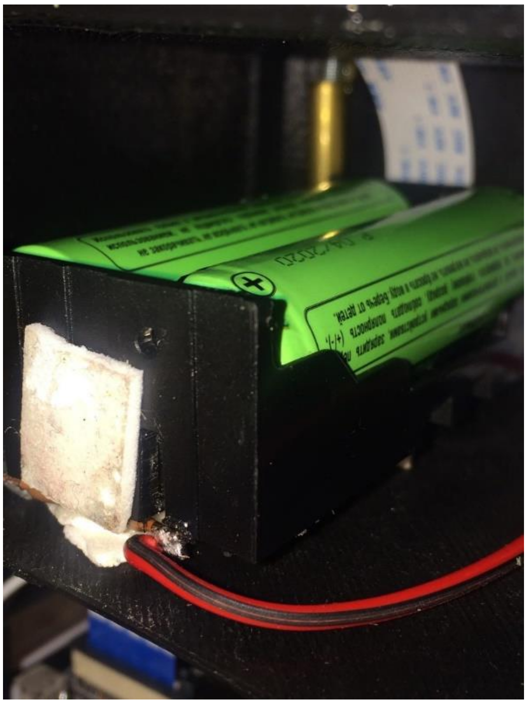


STM32 Microcontroller

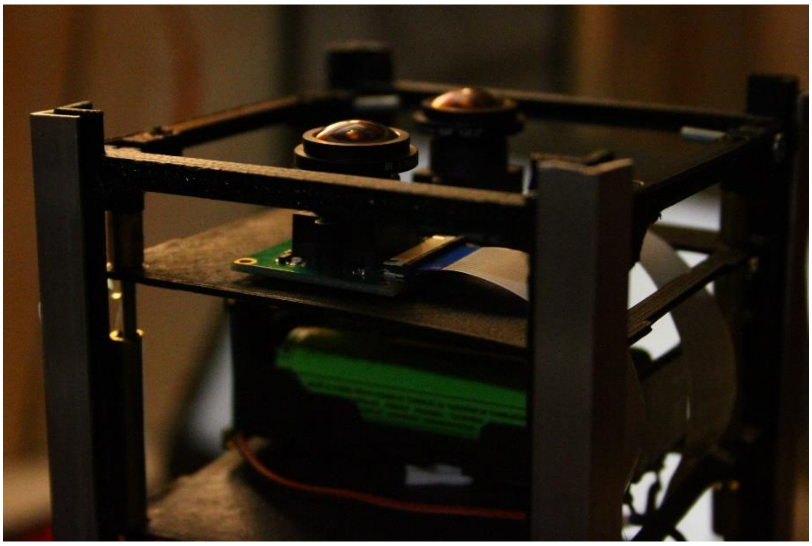
Stereo Pi Hat and Raspberry Pi compute module 3



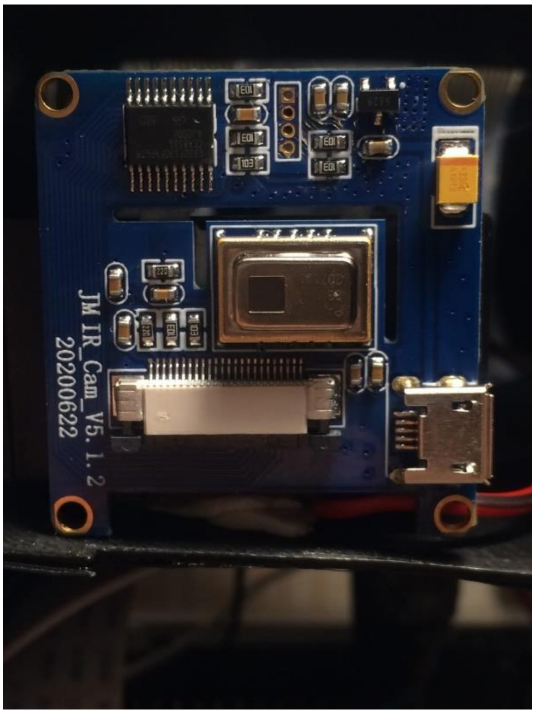
USB WI-FI Adapter for Raspberry Pi



Li-Ion Batteries

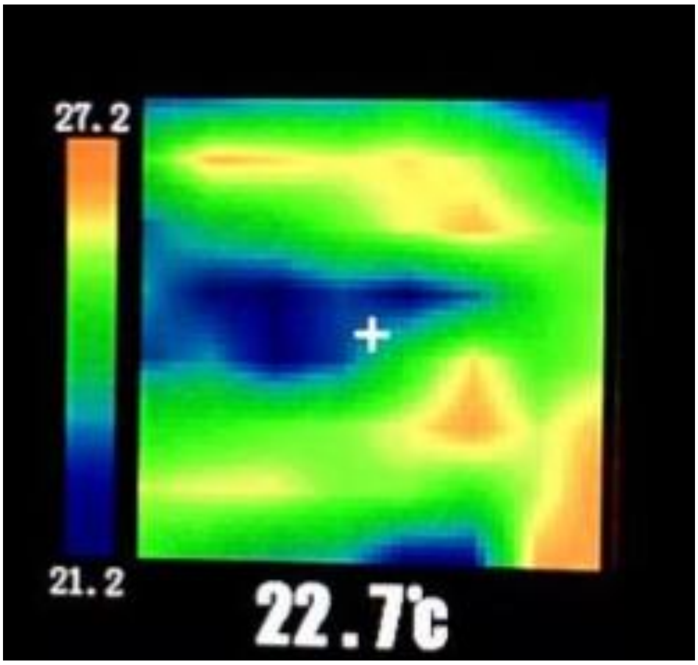


Cameras with a viewing angle of 175 degrees for VR.



Thermal imager

Photos taken from the satellite "ToySat"



Photos taken from the thermal imager "ToySat"

Economic calculation

We have spent 42899.92 rubles ($585.78) to implement the project

	A	B	C	D	E	F
1	Хостинг и сайт (Hosting and website)	600	8,19			
2	Тепловизор (Thermal imager)	3790,76	51,76	Контролер заряда (Charge controller) TP 4	200	2,73
3	Корпус наноспутника (Nanosatellite body)	9886	134,99	Двухсторонний скотч (Double-sided tape)	100	1,37
4	Солнечные панели (Solar panels)	2653,09	36,23	Провода (Wires)	640	8,74
5	Расходные материалы и транспортные расходы (Consumables and transportation costs)	452	6,17	Радиаторы (Radiators)	484,34	6,61
6	Аккумуляторы (Batteries)	2250	30,72		rubles	dollars
7	StereoPi Standart	5745	78,44			
8	ST-LINK MINI	920	12,56	Dollar rate 1$=73,24 Rub		
9	Резистор x 4 (Resistor x 4)	24	0,33			
10	MOSFET x 2 IRLB 3813	197	2,69			
11	USB Adapter WI-FI for Rpi	1310	17,89			
12	Raspberry Pi Compute Module 16 GB eMMC Memory	4040	55,16			
13	Li 500-2 - зарядное устройство (Charger)	1240	16,93			
14	Copper Heat Sink & SD card	560	7,65			
15	Батарейный отсек (Holder)	130	1,78			
16	LM2596 DC-DC MODULE стабилизатор напряжения (Voltage regulator)	960	13,11			
17	Камеры (Camera)	1702,7	23,25			
18	Сумма расходов (Cost amount)	37884,89	517,3			
19	Остаток (balance)	5015,03	68,48			
20	Сумма всех денег с расходами и остатком (Sum of all money with expenses and balance)	42899,92	585,78			
21	Деньги гранта (Amount) 6500 tjs=42900 rubles (1 $ = 10 tjs)	42900	650$			

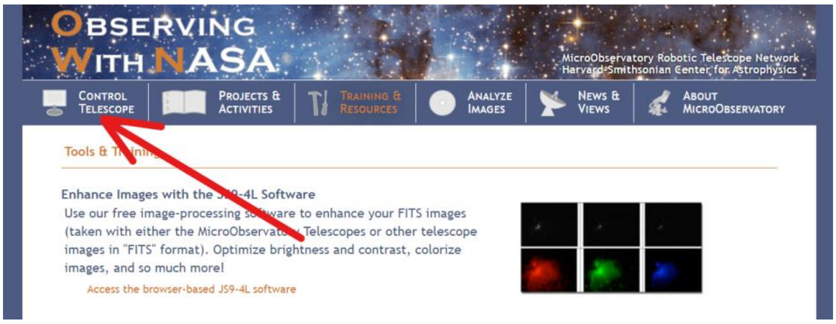
We assume that $500 is needed for each toy during implementation. This is the best solution for students' practice

What do you do, if you want look through a telescope, but you don't have free time or money?

The Observing with NASA website of the Harvard-Smithsonian Center for Astrophysics provides an opportunity to conduct free observations and photographing of spacecraft using a network of micro-observational robotic telescopes. In order to organize the observation process, it is necessary to send an e-mail request to receive an image of the space object of interest from the list posted on the website. [4]

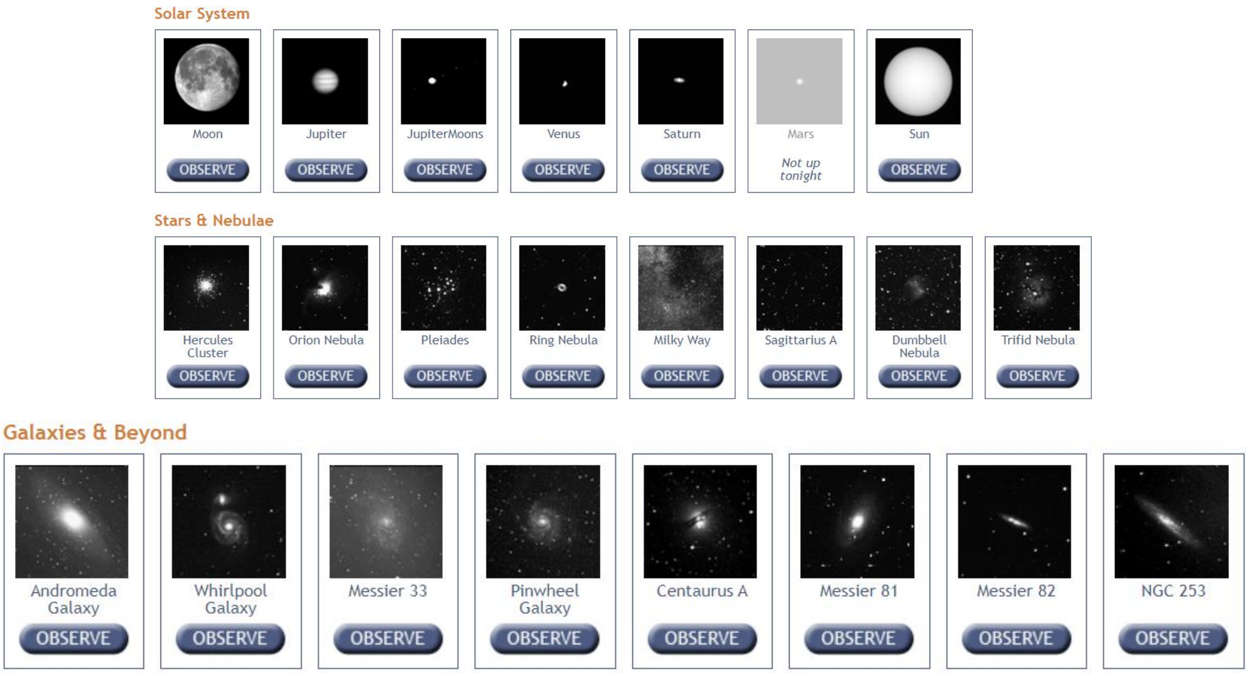
Algorithm for using NASAs telescope:

1. 1. Click on the hyperlink (mo-www.cfa.harvard.edu/MicroObservatory/), click on the upper left window.



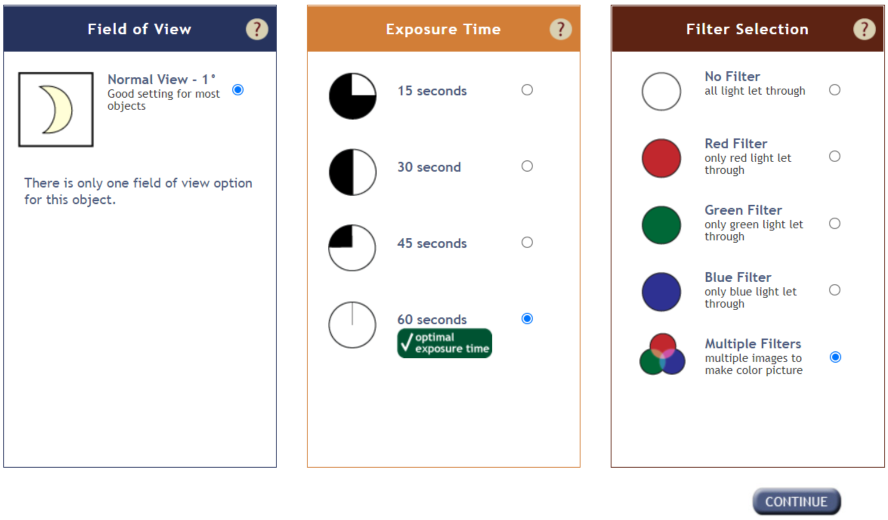
Observing with NASA

1. Space objects are divided on the site into three groups: the Solar system, stars and nebulae, galaxies and others. Select the space objects, of your interest. Click on the word "OBSERVE



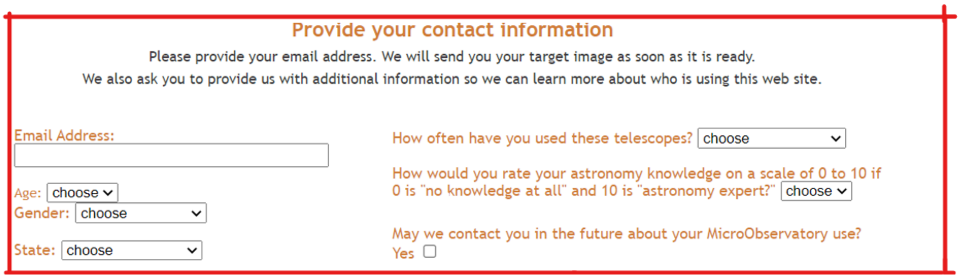
Choose the space object

2. Next, adjust the field of view, exposure time and select filters for further research.



Monitoring parameters

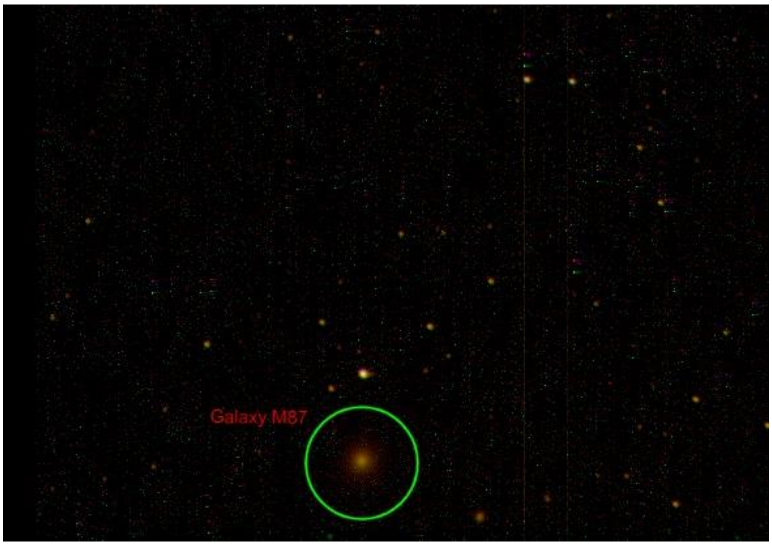
3. We enter data and information to collect statistics of robotic telescope requests.



Collecting statistics

Within 24-48 hours after sending the request, images taken by micro-observer telescopes or images from other telescopes in the FITS format are sent to the specified email address.

4. The next step is image processing. Follow the link provided in the mail and click on JS 9/4L. We turn to the training instructions for photo processing. To learn more about working with this system, go to www.youtube.com/watch?v=hxioUmssb1o&list=PL2TJ0Y_PLXCyc9dIJNKSxaubOwxoboFvq



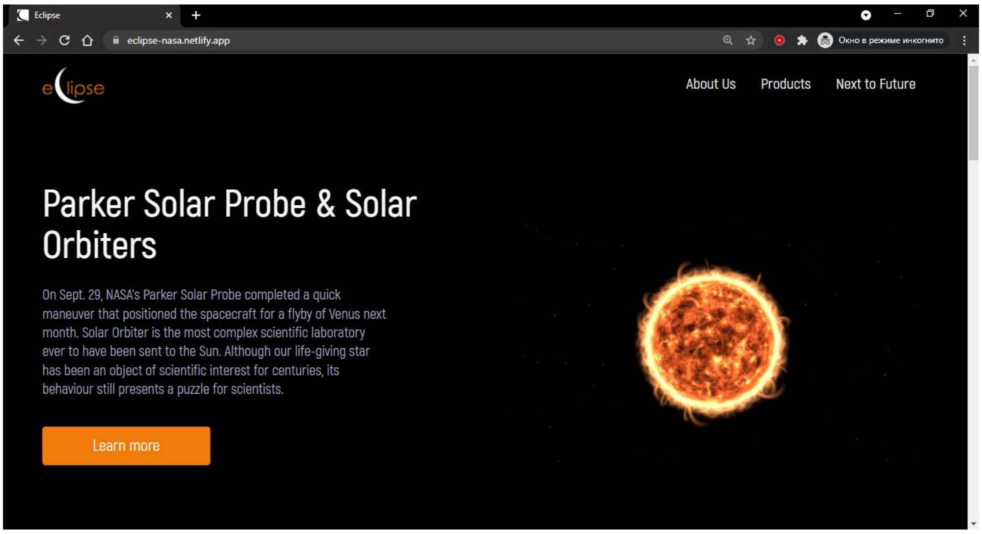
M 87 with red filter

M 87 without filter

The quality of the resulting image depends on the shooting location and weather conditions

Creating a website «Eclipse»

On the website you can get acquainted with orbiting spacecraft, receive daily space forecasts and photos from orbit. The site will tell you more details about space flights and the secrets of the Sun. [5]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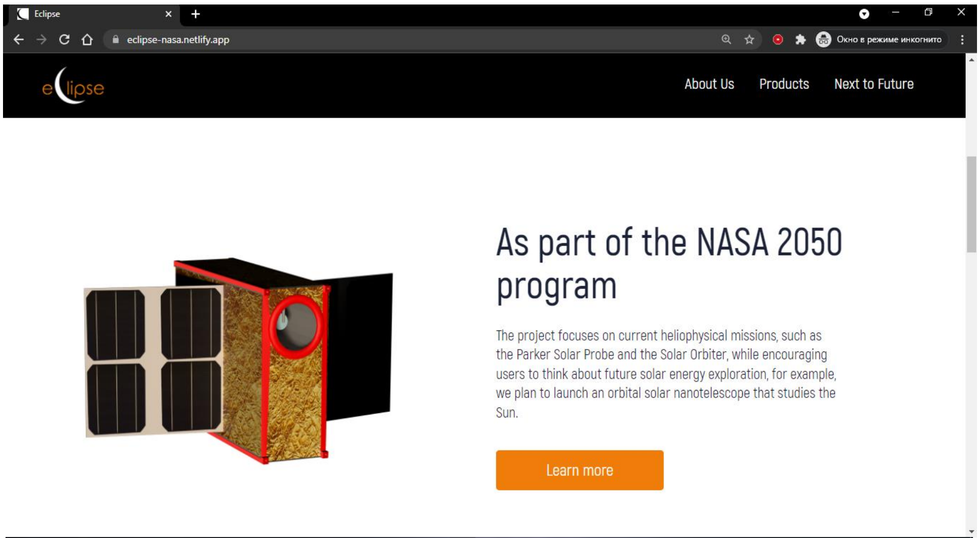
Parker Solar Probe & Solar Orbiters
On Sept. 29, NASA's Parker Solar Probe completed a quick maneuver that positioned the spacecraft for a flyby of Venus next month. Solar Orbiter is the most complex scientific laboratory ever to have been sent to the Sun. Although our life-giving star has been an object of scientific interest for centuries, its behaviour still presents a puzzle for scientists.
Learn more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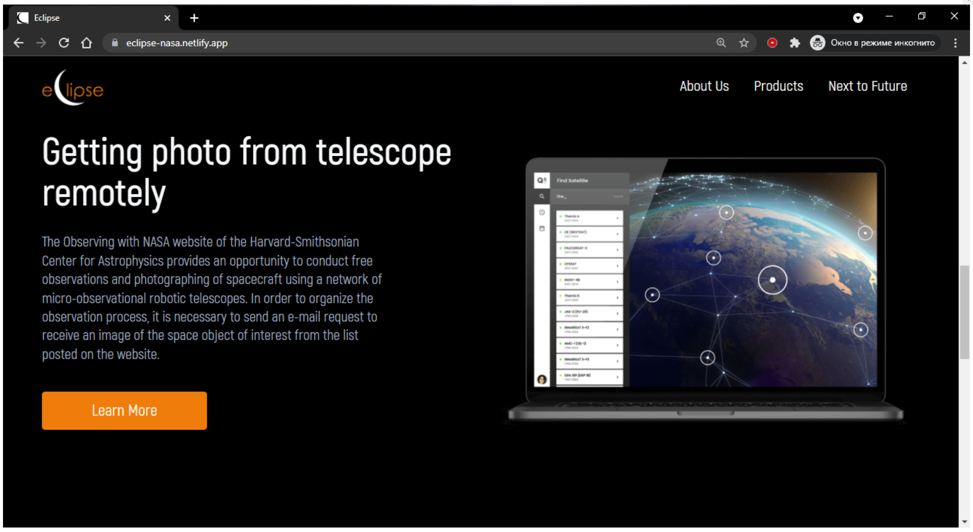
As part of the NASA 2050 program
The project focuses on current heliophysical missions, such as the Parker Solar Probe and the Solar Orbiter, while encouraging users to think about future solar energy exploration, for example, we plan to launch an orbital solar nanotelescope that studies the Sun.
Learn more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Getting photo from telescope remotely
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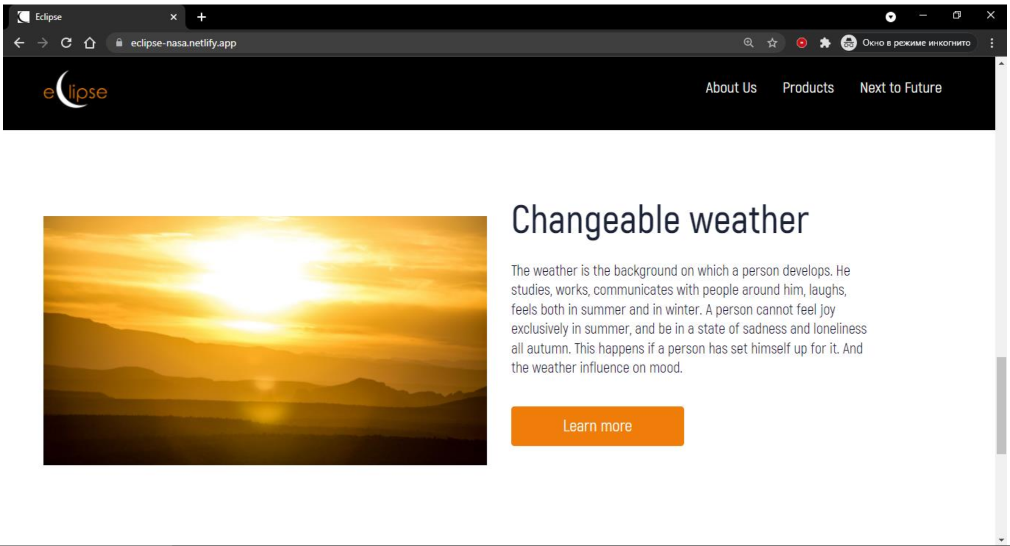
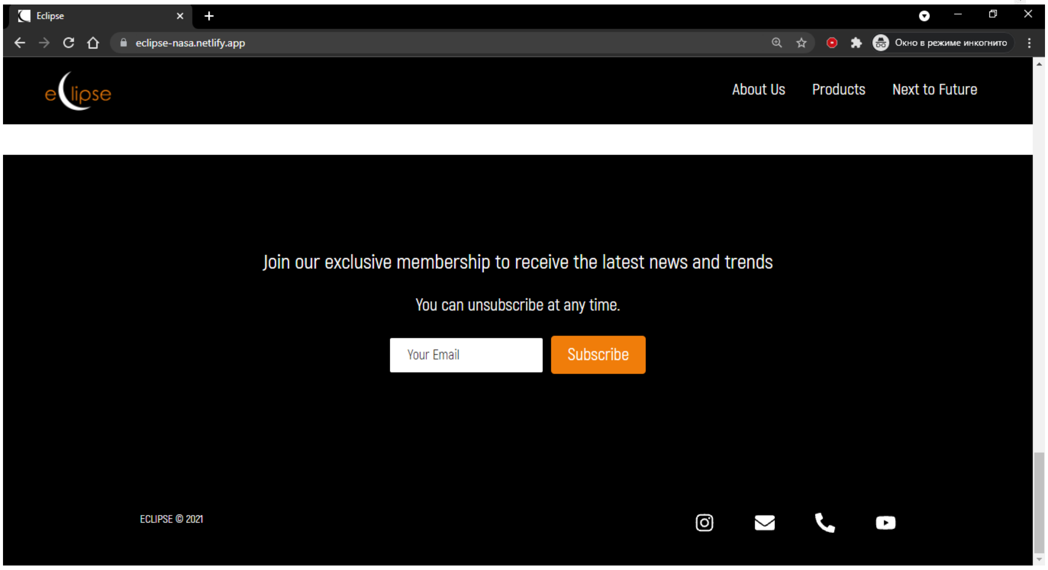
Learn More





Conclusion

The calculated work of the satellite's orbit was carried out and the financial costs were calculated. The neural network has learned to determine solar activity by sunspots from NASA and ESA databases. The site is under development. Images of the Sun were obtained using the Eclipse jet telescope. Two nanosatellites were assembled, images and videos were transmitted from the satellite via Wi-Fi. The algorithm of work with the robotic telescope of the site is shown.

In the future, it is planned to train students to assemble any nanosatellite using the Eclipse project and allow them to enter scientific research. It is planned to change the satellite body to an aluminum body. Also, add a Coronado solar filter and flywheels to stabilize the satellite in space.

Sources

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