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REPORT ON THE STATUS OF CURRENT AND FUTURE RUSSIAN SATELLITE SYSTEMS

This document addresses the current status of the Russian satellite systems: Meteor-M N2 polar-orbiting meteorological satellite (launched on July 8th, 2014), Electro-L N2 geostationary meteorological satellites (launched on December 11th, 2015).

Future Russian geostationary meteorological constellation will consist of three Electro-L series satellites. The satellites will be placed at 14,5W, 76E and 166E orbital positions. The mission objectives, payload and ground segment details are presented.

Working paper provides an overview of future Meteor-3M polar-orbiting satellite system, which will comprise of three meteorological and one oceanographic satellites; the next generation series of Meteor-MP satellites is briefly described.

Arctica-M constellation of highly elliptical orbit satellites is to be deployed in 2019-2025. The system will consist of four spacecrafts. These satellites will provide continuous observations over the Arctic region. An overview of the mission objectives, payload and ground segment details is presented.

STATUS OF CURRENT AND FUTURE RUSSIAN SATELLITE SYSTEMS

1 INTRODUCTION

According to the Russian Federal Space Program (2016–2025) the space system for hydrometeorological and environmental monitoring will consist of three polar-orbiting meteorological and one oceanographic satellites, three geostationary meteorological satellites and four highly elliptical orbit satellites. Currently, two meteorological satellites are considered operational: Meteor-M N2 (launched in 2014) and Electro-L N2 (launched in 2015).

Details on the next satellites of Meteor-M series and their payload, together with forthcoming next generation Meteor-MP series satellites are provided.

A prospective constellation of Electro-L geostationary satellites to be located at 14.5W, 76E and 166E is presented.

Arctica-M project of four highly elliptical orbit satellites is also presented. It will provide observations similar to geostationary satellites, but over the Arctic region. The payload of Arctica-M satellites should be similar to Electro-L series.

2 CURRENT SATELLITE SYSTEMS

Two Russian meteorological satellites are currently considered as operational: one polar-orbiting Meteor-M N2 and one geostationary Electro-L N2. The satellite status in the WMO tables is updated below.

Current GEO satellites contributing to the GOS

Sector	Satellite in orbit	Operator	Location	Launch date	Details on near real time access	Instrument payload
Indian Ocean (36°E-108°E)	Electro-L N2	Russian Federation /Roshydromet	76E	15/12/2015	HRIT/LRIT specification	MSU-GS, HMS (GGAK), DCS, GeoSAR. Direct broadcast HRIT, LRIT

Current LEO satellites contributing to the GOS

Orbit type	Satellite in orbit	Operator	Equator Crossing Time	Mean Alti-tude	Launch date	Details on near real time access	Instrument payload
Sun-synchronous "Morning" orbit ECT between 19:00-24:00	Meteor-M N2	Russian Federation /Roshydromet	09:30	820 km	08/07/2014	Signal structure <http://planet.iitp.ru/english/spacecraft/meteo	MSU-MR, MTVZA, IKFS-2, KMSS, Severjanin, GGAK-M.

and between 07:00-12:00						r_m_n2_structure_eng.htm>	Dissemination: HRPT, LRPT

2.1 Status of current GEO satellite systems

In order to provide the coverage of the Indian Ocean region Electro-L N2 geostationary meteorological satellite has been placed at 76 E orbital position.

2.1.1 Mission objectives, payload/instruments, products

Primary objectives of Electro-L mission:

- Continuous observation of the Earth within a radius of 55-60 degrees centered at the sub-satellite point;
- Simultaneous images of cloud cover and the Earth's surface in 10 visible and infrared channels;
- The development and maintaining the national data collection system (DCS), collection of the hydrometeorlogical data from national and international platforms (DCPs);
- Retransmission of the data from Roshydromet regional centers;
- Heliogeophysical measurements at geostationary orbit altitudes;
- Data dissemination in HRIT/LRIT formats to national and foreign users.

Besides standard meteorological communication package (DCS and re-transmitters) the key payload consists of MSU-GS imager that provides data in three visible and seven IR channels. The spatial resolution at sub-satellite point is 1 km for visible and 4 km for IR channels. The period between scanning sessions for all channels is 30 min (regular operation) or 15 min (frequent mode). The MSU-GS instrument is manufactured by JSC "Russian Space Systems". The 7.5 GHz channel with of 30.72 Mbps data rate is used for raw data downlink.

GGAK Heliogeophysical Measurements Suite provides monitoring of the electromagnetic solar radiation, corpuscular radiation and terrestrial magnetic fields. The 1.7 GHz channel (5 Kbps data rate) is used for GGAK data transmitting.

Besides general downlink for the raw hydrometeorological data, there are also following retransmission channels onboard:

- DCP network data collection and retransmission channel;
- Retransmission channel for hydrometeorological data exchange between regional Roshydromet centers;
- Channels for MSU-GS data dissemination in HRIT and LRIT formats;
- COSPAS-SARSAT Search & Rescue system.

2.1.2 Status of spacecraft

The current status of Electro-L N2 satellite:

- The MSU-GS instrument is functional with limitations (12 mkm channel is absent). Absolute calibration is ongoing.
- The DCS is functional;
- The COSPAS-SARSAT system is functional;

- The GGAK instrument is functional;
- The HRIT/LRIT data is being distributed via the land channels, including Internet channels.

2.1.3 Impact on spacecraft due to space weather

Impact on spacecraft due to space weather was not positively established.

2.1.4 Ground segment matters

Geographically Distributed System for Earth Monitoring from Space of Roshydromet as a part of Integrated Geographically Distributed Information System of Earth Remote Sensing (IGDIS ERS) is based on three SRC Planeta satellite centers, responsible for receiving, processing, disseminating and archiving of satellite data: European (Moscow-Obninsk-Dolgoprudny), Siberian (Novosibirsk) and Far-Eastern (Khabarovsk). These centers together provide Roshydromet and its users with full operational coverage of all the Russian Federation and neighboring territories.

Core ground segment for Electro-L series satellites is located at SRC Planeta facilities. The receiving stations together with retransmission systems are located in European center (Moscow-Dolgoprudny) and Siberian center (Novosibirsk). The deployment of the receiving system in the Far-Eastern center (Khabarovsk) is underway.

The ground segment for Electro-L series satellites also includes the network of DCP, LRIT and HRIT stations.

Satellite data is also received at Roscosmos facility in Moscow for the quality control purposes.

2.1.5 Data transmission

The Electro-L N2 HRIT/LRIT data is being distributed via the land channels, including Internet channels, and also provided to EUMETSAT in near real time.

Additionally, the satellite is used for COSPAS-SARSAT Search & Rescue signal retransmission at 0.4/1.54 GHz waveband.

Russian DCS relies on Electro-L N2 services and backed up by Luch-5B communication satellite. There are 609 DCPs currently deployed by Roshydromet. Those DCPs are being used at both manned and unmanned hydrometeorological stations all over Russian Federation, each usually operates 8 times a day, with an option for frequent mode (a message each 2 minutes, so called “storm” mode). Messages contain standard meteorological and hydrological measurements. Usage statistics for DCS is being accumulated and analysed at SRC Planeta, Moscow.

2.1.6 Projects, services

The list of services currently provided by Electro-L N2 satellite:

- Visible and IR imagery of MSU-GS instrument;
- DCS;
- GGAK Heliogeophysical Measurements Suite;
- COSPAS-SARSAT system.

2.2 Status of current LEO satellite systems

The second spacecraft of Meteor-M series of new Russian polar-orbiting meteorological satellites, Meteor-M N2 was launched on July 8th, 2014. It is located in a sun-synchronous orbit (820 km, ascending, equator crossing time ~ 9:30, inclination 98.79°). The satellite was designed and built by JSC "VNIIEM Corporation".

2.2.1 Mission objectives, payload/instruments, products

The main objective of Meteor-M N2 mission is to provide global observations of the Earth's surface and the atmosphere. The data acquired by the satellite is used for the following purposes:

- Weather analysis and forecasting on global and regional scales;
- Global climate change monitoring;
- Sea surface observations;
- Space weather analysis and prediction (solar wind, ionosphere research, Earth's magnetic field, etc.).

Meteor-M N2 payload includes:

- MSU-MR Scanning Radiometer (1 km spatial resolution multichannel scanning unit, 6 channels, VIS/IR);
- KMSS VIS Scanning Imager (6 channels implemented by 3 cameras, 50 m and 100 m spatial resolution);
- Severjanin X-band Synthetic Aperture Radar;
- MTVZA-GY Imaging/Sounding Microwave Radiometer (module for temperature and humidity sounding of the atmosphere, 26 channels, 10.6-183 GHz);
- IRFS-2 - IR Fourier-transform spectrometer (IR atmospheric sounder, spectral range 5-15 μm, spectral resolution ~ 0.5 cm^{-1});
- GGAK-M Heliogeophysical Measurements Suite;
- Data collection system (DCS).

Meteor-M N2 has three downlink radio lines:

- 2-channel X-band radio link (8.192 GHz and 8.320 GHz) with 122.88 Mbps data transmission rate in each channel;
- L-band radio link (1.7 GHz) with 665.4 Kbps data transmission rate (HRPT data transmission);
- VHF-band radio link (137 MHz) with 80 Kbps data transmission rate (LRPT data transmission).

2.2.2 Status of spacecraft

Meteor-M N2 is operational.
Instrument status:

- MSU-MR instrument is fully functional;
- MTVZA-GY instrument has failed in 2017;

- KMSS instrument is fully functional;
- IRFS-2 instrument is fully functional;
- Severjanin SAR instrument is functional;
- DCS is functional;
- LRPT transmission is functional;
- GGAK-M is functional.

2.2.3 Impact on spacecraft due to space weather

Impact on spacecraft due to space weather was not established.

2.2.4 Ground segment matters

Geographically Distributed System for Earth Monitoring from Space of Roshydromet as a part of IGDIS ERS is based on three SRC Planeta satellite centers, responsible for receiving, processing, disseminating and archiving of satellite data: European (Moscow-Obninsk-Dolgoprudny), Siberian (Novosibirsk) and Far-Eastern (Khabarovsk). These centers together provide Roshydromet and its users with full operational coverage of all the Russian Federation and neighboring territories with the lowest possible latency.

Core ground segment for Meteor-M series satellites is located at SRC Planeta facilities. It also includes the network of DCS, LRPT and HRPT stations. Data acquisition and processing are also performed by Roscosmos operational facility in Moscow.

Meteor-M N2 ground segment has been developed jointly by Roshydromet and Roscosmos.

2.2.5 Data transmission

Global data X-band downlink is used for Roshydromet purposes only (raw data dumps over the SRC Planeta centers).

The direct broadcast is operational in L-band in HRPT-like format. The detailed format description is published at SRC Planeta WEB-site.

The preprocessed data is also distributed to Roshydromet users via SRC Planeta FTP server.

The IRFS-2 data is available to EUMETSAT in near-real time via landline.

2.2.6 Projects, services

The list of services currently provided by the Meteor-M N2 satellite:

- Visible and IR imagery (MSU-MR instrument);
- Moderate resolution visible imagery (KMSS instrument);
- Temperature and humidity sounding (MTVZA-GY);
- Atmospheric sounding (IRFS-2).

Meteor-M N2 data is used for atmospheric sounding, disaster monitoring such as floods and forest fires, as well as sea ice and water pollution monitoring, and etc.

2.2.7 User statistics

Meteor-M N2 satellite data is currently used internally by Russian Hydrometeorological and Environmental Monitoring Service, and also provided to EMERCOM – Ministry of Civil Defense, Emergencies and Disaster Relief of the Russian Federation, Ministry of Natural Resources and Environment of the Russian Federation and other federal and regional institutions of Russia.

3 FUTURE SATELLITE SYSTEMS

Sector	Satellite in orbit	Operator	Location	Planned launch date	Instrument payload
TBD	Electro-L N3	Russian Federation /Roshydromet	TBD	2019	MSU-GS, HMS, DCS, GeoSAR. Direct broadcast HRIT, LRIT
TBD	Electro-L N4	Russian Federation /Roshydromet	TBD	2021	MSU-GS, HMS, DCS, GeoSAR. Direct broadcast HRIT, LRIT
TBD	Electro-L N5	Russian Federation /Roshydromet	TBD	2022	MSU-GS, HMS, DCS, GeoSAR. Direct broadcast HRIT, LRIT

Orbit type	Satellite in orbit	Operator	Orbit	Planned launch date	Instrument payload
Highly Elliptical Orbit (non-geo-stationary)	Arctica-M N1	Russian Federation /Roshydromet	Molnya Orbit	2019	MSU-GS, DCS, HMS(GGAK)
	Arctica-M N2	Russian Federation /Roshydromet	Molnya Orbit	2021	MSU-GS, DCS, HMS(GGAK)
	Arctica-M N3	Russian Federation /Roshydromet	Molnya Orbit	2023	MSU-GS, DCS, HMS(GGAK)
	Arctica-M N4	Russian Federation /Roshydromet	Molnya Orbit	2024	MSU-GS, DCS, HMS(GGAK)

	Arctica-M N5	Russian Federation /Roshydromet	Molnya Orbit	2025	MSU-GS, DCS, HMS(GGAK)

Orbit type	Satellite in orbit	Operator	Orbit	Planned launch date	Instrument payload
Sun-synchronous orbit ECT 09.00 (The descending unit)	Meteor-M N2-2	Russian Federation /Roshydromet	815,2 km	2018	MSU-MR, MTVZA, IRFS-2, KMSS, DCS, COSPAS-SARSAT Dissemination: HRPT, LRPT
Sun-synchronous orbit ECT 15.09 (The ascending unit)	Meteor-M N2-3	Russian Federation /Roshydromet	820,7 km	2020	MSU-MR, MTVZA, IRFS-2, KMSS, MeteoSAR, GGAK-M2, DCS, COSPAS-SARSAT Dissemination: HRPT, LRPT
Sun-synchronous orbit ECT 09.00 (The descending unit)	Meteor-M N2-4	Russian Federation /Roshydromet	820,7 km	2021	MSU-MR, MTVZA, IRFS-2, KMSS, MeteoSAR, GGAK-M2, DCS, COSPAS-SARSAT Dissemination: HRPT, LRPT

3.1 Status of future GEO satellite systems

According to the Russian Federal Space Program Electro-L constellation of the geostationary meteorological satellites should consist of three similar satellites.

The satellites are designed and built by Lavochkin Association and have a three-axis stabilized platform.

The payload of Electro-L constellation is similar to Electro-L N1, N2 spacecrafts but with improved instrument performance. The payload will consist of MSU-GS imager, standard meteorological communication package (DCS and retransmitters), data retransmission channel for hydrometeorological data exchange between Roshydromet centers, and GGAK Heliogeophysical Measurements Suite.

3.1.1 Mission objectives, spacecraft, payload/instruments, products

Primary objectives of Electro-L missions:

- Continuous observation of the Earth within a radius of 55-60 degrees centered at the sub-satellite point;

- Simultaneous images of cloud cover and the Earth's surface in 10 visible and infrared channels;
- The development and maintaining DCS, collection of the hydrometeorological data from national and international platforms;
- Retransmission of the data from Roshydromet regional centers;
- Heliogeophysical measurements at geostationary orbit altitudes;
- Data dissemination in HRIT/LRIT formats to national and foreign users.

Besides standard meteorological communication package (DCS and retransmitters) the key payload will consist of MSU-GS imager which provides data in three visible and seven IR channels. The spatial resolution at the sub-satellite point is 1 km for visible and 4 km for IR channels. The regular period between scanning sessions for all channels is 30 min or 15 min in frequent mode. JSC "Russian Space Systems" is a developer of this instrument. The 7.5 GHz channel with data rate of 30.72 Mbps is used for raw MSU-GS data downlink.

GGAK Heliogeophysical Measurements Suite provides monitoring of the electromagnetic solar radiation, corpuscular radiation and terrestrial magnetic fields. The separate 1.7 GHz channel (5 Kbps data rate) is used for GGAK data downlink.

Besides general downlink for the raw hydrometeorological data, there are also following retransmission channels onboard:

- DCP network data collection and retransmission channel;
- Retransmission channel for hydrometeorological data exchange between regional Roshydromet centers;
- Channels for MSU-GS data dissemination in HRIT and LRIT formats;
- COSPAS-SARSAT Search & Rescue system.

3.1.2 Ground segment matters

Electro-L N3, N4 & N5 ground segment will be jointly developed by Roshydromet and Roscosmos. Core ground segment for Electro-L satellites will be based on SRC Planeta facilities. The ground segment will also include the network of DCP, LRIT and HRIT stations.

3.1.3 Data transmission

Electro-L N3, N4 & N5 HRIT/LRIT channels will be used for the data transmission in L-band every 30 min. Additionally, the satellite will support COSPAS-SARSAT Search and Rescue system at 0.4/1.54 GHz.

3.2 Status of future LEO satellite systems

According to the Russian Federal Space Program (2016–2025) the polar-orbiting satellites system should consist of three hydrometeorological and one oceanographic satellites.

Meteor-M N2-2 hydrometeorological satellite is scheduled to be launched in 2018. It is planned to launch from three to five similar satellites with the same payload as Meteor-M N2, i.e. Meteor-M N2-2, Meteor-M N2-3, Meteor-M N2-4 (Meteor-M N2-5 and Meteor-M N2-6

are TBD). The goal is to create a constellation of identical operational meteorological satellites in morning and afternoon orbits. These satellites will be developed by JSC "VNIIEM Corporation". The payload of Meteor N2-2 will be modified to exclude Severjanin X-band Side-Looking Radar and Heliogeophysical Measurements Suite. From Meteor N2-2 to Meteor N2-4 will include COSPAS-SARSAT Search & Rescue system. For Meteor N2-3 and Meteor N2-4 there will be MeteoSAR and modified Heliogeophysical Measurements Suite GGAK-M2.

The Meteor-MP satellites constellation will consist of meteorological satellites. The Meteor-MP payload will be similar to payload of satellites of Meteor-M, but with improved characteristics of devices and additions.

Meteor-MP payload will consist of:

- Scanning radiometer (low-resolution multichannel scanning unit);
- Visible spectrum scanning imager (Moderate resolution multispectral imaging system);
- Infra-red Fourier-transform spectrometer;
- Atmospheric composition spectrometer;
- Microwave imager-sounder (module for temperature and humidity sounding of the atmosphere);
- Scatterometer;
- Radio-occultation instrument;
- Data collection system;
- Heliogeophysical Measurements Suite;
- 137 MHz data downlink system;
- 1.7 GHz data downlink system;
- X-band data downlink system.

3.2.1 Mission objectives, spacecraft, payload/instruments, products

The main objective of Meteor-MP mission is to provide global observations of the Earth's surface, the ocean and the atmosphere. The data acquired by the satellite can be used for the following purposes:

- Weather analysis and forecasting on global and regional scales;
- Global climate change monitoring;
- Sea water monitoring and forecasting;
- Space weather analysis and prediction (solar wind, ionosphere research, Earth's magnetic field, etc.).

3.2.2 Ground segment matters

The future Meteor-MP ground segment based on the existing facilities will be developed jointly by Roshydromet and Roscosmos.

Geographically Distributed System for Earth Monitoring from Space of Roshydromet as a part of IGDIS ERS is based on three SRC Planeta satellite centers, responsible for receiving, processing, disseminating and archiving of satellite data: European (Moscow-Obninsk-Dolgoprudny), Siberian (Novosibirsk) and Far-Eastern (Khabarovsk). These centers together

should provide Roshydromet and its users with full operational coverage of all the Russian Federation and neighboring territories with the lowest possible latency.

Core ground segment for Meteor-MP series satellites will be located at SRC Planeta facilities. It will also include the network of DCS, LRPT and HRPT stations.

3.2.3 Data transmission

Global data X-band downlink will be used for Roshydromet purposes only.

The direct broadcast will work in L-band in AHRPT and in a band of 137 MHz in LRPT format. The detailed format description will be updated and published at SRC Planeta website after the commissioning phase.

3.3 Status of future HEO [or other] satellite systems

At CGMS-34 the Russian project of Arctic region monitoring from the "Molnya" highly elliptical orbit was announced for the first time. Now this project evolved into mission of four HEO satellites called Arctica. The first satellite is planned to be launched in 2019.

3.3.1 Mission objectives, spacecraft, payload/instruments, products

The main purposes of the mission are meteorology, oceanography, including ice cover monitoring and disaster monitoring in the Arctic region. To perform operational monitoring of Polar Regions 24 hours a day each of two satellites will be covering the area for 6.4 hours and then step back for the next one. The repeat cycle time for each satellite is exactly 12 hours. The payload and general design of the satellites are similar to Electro-L series.

The essential feature of Arctica system spacecraft is their mass and power reserves, potentially allowing adding various types of complementary instruments, including international ones if agreed upon. The launch of the first Arctica satellite is scheduled in 2019.

3.3.2 Ground segment matters

The ground segment for Arctica constellation will be based on SRC Planeta/Roshydromet facilities in Moscow, Novosibirsk and Khabarovsk.

3.3.3 Data transmission

Data transmission system of Arctica satellites will consist of:

- X-band downlink with data transmission rate of 30.72 Mbit/s;
- L-band downlink especially for the GGAK instrument with data transmission rate of 5000 bit/s;
- DCS retransmission support at 401-403 MHz / 1.7 GHz;
- Meteorological data retransmission in L-band.

4 CONCLUSION

Russian Federation is currently developing a national constellation of both geostationary and polar orbiting meteorological satellites. It will be complemented by the satellites at highly elliptical “Molnya” type orbits. Four satellites in HEO, the first spacecraft is scheduled for launch in 2019, will provide the continuous monitoring of the atmosphere, ocean and land in the northern Polar Regions.