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## **REPORT ON THE STATUS OF CURRENT AND FUTURE RUSSIAN SATELLITE SYSTEMS**

This document addresses the current status of Meteor-M №1 polar-orbiting meteorological satellite (launched in 2009) and Electro-L №1 geostationary meteorological satellite (launched in 2011).

Working paper provides an overview of future Meteor-M polar-orbiting satellite system, which will include three meteorological and one oceanographic satellite. The technical characteristics of forthcoming Meteor-MP series of satellites are presented.

Future Russian geostationary constellation will consist of three Electro-L satellites. The location of Electro-L satellites in orbit will be 14,5W, 76E and 166E. The mission objectives, payload and ground segment matters are provided.

Arctica-M constellation of highly elliptical orbit satellites is now under development. The system will include two spacecraft. These satellites will provide continuous observations over the Arctic region. The launch is scheduled for 2015–2016. An overview of the mission objectives, payload and ground segment matters are presented.

## STATUS OF CURRENT AND FUTURE RUSSIAN SATELLITE SYSTEMS

### 1 INTRODUCTION

According to the Russian Federal Space Program (2006-2015) the space system for hydrometeorological and environmental monitoring will consist of three polar-orbiting meteorological and one oceanographic satellite, and three geostationary satellites by the end of 2015. Currently, one spacecraft of each satellite series is already launched – Meteor-M №1 (2009) and Electro-L №1 (2011).

Meteor-M №1 and Electro-L №1 are now considered as experimental due to some limitations. Ground segment matters as well as data transmission details, projects and services are also presented.

Future Meteor-M series of polar-orbiting satellites and their payload, including oceanographic satellite Meteor-M №3, and forthcoming Meteor-MP series satellites are provided.

A constellation of Electro-L geostationary satellites to be located at 14,5W, 76E and 166E is presented.

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

### 2 CURRENT SATELLITE SYSTEMS

There are two meteorological satellites currently in orbit: one polar-orbiting and one geostationary. The satellite status in the WMO tables is updated below.

Current geostationary satellites contributing to the GOS

Sector	Satellite in orbit	Operator	Location	Launch date	Details on near real time access	Instrument payload and status
Indian Ocean (36°E-108°E)	Electro-L N1	Russian Federation /Roshydromet	76°E	20/01/2011	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 Altitude	Launch date	Details on near real time access	Instrument payload and status
Sun-synchronous "Morning"	METEOR -M N1	Russian Federation /Roshydro	09:30	830 km	17/09/2009	Signal structure	MSU-MR, MTVZA, KMSS,

orbit ECT between 19:00-24:00 and between 07:00-12:00		met					Severjanin, GGAK-M. Dissemination: HRPT, LRPT
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## 2.1 Status of current GEO satellite systems

According to the Russian Federal Space Program 2006-2015 the geostationary meteorological satellite Electro-L №1 has been located at 76E. Now it is regarded as experimental due to some payload failure.

The satellite was designed and built by Lavochkin Association and has a three-axis stabilized platform.

### 2.1.1 Mission objectives, payload/instruments, products

Primary objectives of Electro-L №1 mission:

- Continuous observation of the Earth within a radius of 55-60 degrees centred 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 hydrometeorological data from national and international platforms (DCPs);
- Retransmission of the data from ROSHYROMET 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 and in the more frequent mode is 15 min. 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 transmitting raw MSU-GS data.

GGAK Heliogeophysical Measurements Complex provides monitoring of the electromagnetic solar radiation, corpuscular radiation and terrestrial magnetic fields. The 1.7 GHz channel (1.2 Kbps data rate) is used for GGAK data transmitting.

Subsystem for data retransmission consists of:

- The channel for collecting and transmitting data from DCP network to the ROSHYROMET centers;
- The channel for hydrometeorological data exchange between ROSHYROMET centers;
- The channels for MSU-GS data dissemination in HRIT and LRIT formats;
- The transponder for the geostationary COSPAS-SARSAT Search & Rescue system.

SRC PLANETA produces various products such as cloud cover, etc., and provides these products to the number of users.

### **2.1.2 Status of spacecraft**

The current status of Electro-L №1:

- The three-axis stabilized space platform “Navigator” and ground segment flight tests are completed;
- The MSU-GS instrument is characterized by calibration failure and excessive noise level in some IR channels. The WV channel is not functional because of excessive noise. All visible channels are fully functional;
- The DCS is fully functional (300 national channels and 33 international channels);
- The data exchange between ROSHYDROMET centers is now established;
- The COSPAS-SARSAT system is functional;
- The GGAK instrument operates with significant limitations;
- The HRIT/LRIT channels are now used for the regular data transmission;
- The data in HRIT format is distributed on demand via SRC Planeta FTP server.

### **2.1.3 Impact on spacecraft due to space weather**

### **2.1.4 Ground segment matters**

Roshydromet ground segment consists of three regional SRC Planeta centers, responsible for receiving, processing, disseminating and archiving satellite data: European (Moscow-Obninsk-Dolgoprudny), Siberian (Novosibirsk) and Far-Eastern (Khabarovsk). These centers together give full coverage of the Russia and neighbouring territories.

Roshydromet ground segment for Electro-L satellite is based on SRC Planeta facility. The receiving and transmitting systems are located in European center (Moscow-Dolgoprudny), with the backup facility in Siberian center (Novosibirsk). The deployment of the receiving system in the Far-Eastern center (Khabarovsk) is underway. Satellite data is also received by Roscosmos facility in Moscow for the quality control purposes.

The ground segment of Roshydromet also includes the network of DCP, LRIT and HRIT stations.

### **2.1.5 Data transmission**

Electro-L N1 HRIT/LRIT channels are now used for the data distribution at 1.7 GHz. The data is currently transmitted every 3 hours. Additionally, the satellite is used for signal retransmission from COSPAS-SARSAT Search & Rescue system at 0.4/1.54 GHz.

The meteorological data in HRIT format is distributed to some users via SRC Planeta FTP server every 3 hours (standard synoptic hours).

### **2.1.6 Projects, services**

The list of services currently provided by Electro-L N1 satellite:

- Visible and IR imagery;
- DCS;
- The data exchange between ROSHYDROMET centers;
- COSPAS-SARSAT system.

### **2.1.7 User statistics**

Electro-L N1 satellite data is used by Russian Hydrometeorological and Environmental Monitoring Service.

## **2.2 Status of current LEO satellite systems**

The first spacecraft of Meteor-M series of new Russian polar-orbiting meteorological satellites, Meteor-M №1 was launched in 2009. It is located in a sun-synchronous orbit (820 km, ascending, equator crossing time ~ 9h:30min, inclination 98,79°). The satellite was designed and built by JSC “VNIEM Corporation”.

The satellite is considered as experimental due to limited functionality of the main payload.

### **2.2.1 Mission objectives, payload/instruments, products**

The main objective of Meteor-M-1 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, including global change climate monitoring;
- Sea water monitoring and forecasting;
- Space weather analysis and prediction (solar wind, ionospheric research, Earth's magnetic field, etc.).

Payload of Meteor-M №1 consists of:

- 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 Side-Looking Radar (500 m and 1000 m resolution);
- MTVZA-GY Imaging/Sounding Microwave Radiometer (module for temperature and humidity sounding of the atmosphere, 26 channels, 10.6-183 GHz)
- GGAK-M Heliogeophysical Measurements Complex;

- Data collection system.
- Meteor-M №1 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;
  - 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 №1 data is used by Roshydromet with limitations due to some instruments failures.

The current status of the basic instruments:

- MSU-MR instrument is functional with limitations (calibration issues and excessive noise level in the IR channels);
- MTVZA-GY instrument is non-operational due to failures of on-board memory and atmospheric sounding channels;
- KMSS instrument is fully functional;
- Severjanin instrument is non-operational;
- DCS is non-operational;
- LRPT transmission is non-operational;
- GGAK-M is operational with significant limitations.

### **2.2.3 Impact on spacecraft due to space weather**

### **2.2.4 Ground segment matters**

Roshydromet ground segment consists of three regional SRC Planeta centers, responsible for receiving, processing, disseminating and archiving satellite data: European (Moscow-Obninsk-Dolgoprudny), Siberian (Novosibirsk) and Far-Eastern (Khabarovsk). These centers together give full coverage of the Russia and neighbouring territories.

Roshydromet ground segment for Meteor-M №1 satellite is based on SRC Planeta facility. It also includes the network of DCP, LRPT and HRPT stations. Data acquisition and processing are also performed by Roscosmos operational facility in Moscow.

Meteor-M №1 ground segment has been developed by Roshydromet and Roscosmos.

### **2.2.5 Data transmission**

Global data downlink in X-band is used for Roshydromet purposes only.

The direct broadcast is operational in L-band in HRPT format. The detailed format description is published at SRC Planeta and WMO websites.

### 2.2.6 Projects, services

The list of services currently provided by the Meteor-M N1 satellite:

- Visible and IR imagery (MSU-MR instrument);
- Moderate resolution visible imagery (KMSS instrument).

Meteor-M N1 data is used for disaster monitoring such as floods and forest fires, as well as sea ice and water pollution monitoring, etc.

### 2.2.7 User statistics

Meteor-M N1 satellite data is currently used with limitations by Russian Hydrometeorological and Environmental Monitoring Service, and also provided to EMERCOM – Ministry of Civil Defence, 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 and status
Indian Ocean (37°E -109°E)	Electro-L N2	Russian Federation/ Roshydromet	77.8°E	2014	MSU-GS, HMS (GGAK), DCS, GeoSAR. Direct broadcast HRIT, LRIT
TBD	Electro-L N3	Russian Federation /Roshydromet	TBD	2016	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	2015	MSU-GS, DCS, HMS(GGAK)
	Arctica-M N2	Russian Federation /Roshydromet	Molnya Orbit	2016	MSU-GS, DCS, HMS(GGAK)

Sun-synchronous "Morning" orbit ECT between 19:00-24:00 and between 07:00-12:00	METEOR-M N2	Russian Federation /Roshydromet	9:30	836 km	September 2013	MSU-MR, MTVZA, IRFS-2, KMSS, Severjanin, GGAK-M, DCS. Dissemination: HRPT, LRPT
	METEOR-M N2-1	Russian Federation /Roshydromet	TBD	820 km	2014	MSU-MR, MTVZA, IRFS-2, KMSS, Severjanin, GGAK-M, DCS. Dissemination: HRPT, LRPT
	METEOR-M N2-2	Russian Federation /Roshydromet	Afternoon (Time TBD)	820 km	2015	MSU-MR, MTVZA, KMSS, Severjanin, GGAK-M, IRFS-2, DCS. Dissemination: HRPT, LRPT
	METEOR-M N3	Russian Federation /Roshydromet	TBD	835 km	2017	CZS, SCAT, OCS, Radiomet, SAR-X, Dissemination: HRPT, LRPT

### 3.1 Status of future GEO satellite systems

According to the Russian Federal Space Program 2006-2015 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.

Electro-L №2 is now under development and is scheduled to be placed at 77,8E in 2014. The launch of Electro-L №3 is scheduled in 2016.

The payload of Electro-L constellation is similar to Electro-L №1 spacecraft but with improved instrument performance. The payload will consist of MSU-GS Imager, standard meteorological communication package (DCS and re-transmitters), data retransmission



channel for hydrometeorological data exchange between ROSHYDROMET centers, and GGAK Heliogeophysical Measurements Complex.

### **3.1.1 Mission objectives, spacecraft, payload/instruments, products**

Primary objectives of Electro-L №2 & N3 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 ROSHYROMET 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 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 period between scanning sessions for all channels is 30 min and in more frequent mode is every 15 min. 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 transmitting raw MSU-GS data.

GGAK Heliogeophysical Measurements Complex provides monitoring of the electromagnetic solar radiation, corpuscular radiation and terrestrial magnetic fields. The 1.7 GHz channel (1.2 Kbps data rate) is used for GGAK data transmitting.

Subsystem for data retransmission consists of:

- The channel for collecting and transmitting data from DCP network to the ROSHYDROMET centers;
- The channel for hydrometeorological data exchange between ROSHYDROMET centers;
- The channels for MSU-GS data dissemination in HRIT and LRIT formats;
- The transponder for the geostationary COSPAS-SARSAT Search & Rescue system.

### **3.1.2 Ground segment matters**

Electro-L N2 & N3 ground segment will be developed by Roshydromet and Roscosmos. Roshydromet main ground segment for Electro-L N2 & N3 satellites will be based on SRC Planeta facility. The ground segment will also include the network of DCP, LRIT and HRIT stations.

### 3.1.3 Data transmission

The Electro-L N2 & N3 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 2006-2015 the polar-orbiting satellites system should consist of three hydrometeorological and one oceanographic satellite.

Meteor-M №2 spacecraft is about to be launched in 2013. Meteor-M №3 oceanographic satellite is scheduled to be launched in 2016.

These satellites will be designed by JSC “VNIEM Corporation”.

Payload of Meteor-M №2 consists of:

- 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 and 100m spatial resolution);
- Severjanin X-band Side-Looking Radar (500 m and 1000 m resolution);
- MTVZA-GY Imaging/Sounding Microwave Radiometer (module for temperature and humidity sounding of the atmosphere, 26 channels, 10.6-183 GHz);
- IKFS-2 Infra-red Fourier-transform spectrometer (IR atmospheric sounder, spectral range 5-15  $\mu\text{m}$ , spectral resolution  $\sim 0.5 \text{ cm}^{-1}$ );
- GGAK-M Heliogeophysical Measurements Complex;
- Data collection system.

Meteor-M №2 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;
- L-band radio link (1.7 GHz) with 665.4 Kbps data transmission rate;
- VHF-band radio link (137 MHz) with 80 Kbps data transmission rate (LRPT data transmission).

All instruments for Meteor-M №2 mission are now built and installed on-board the spacecraft. The satellite is scheduled to be launched in a sun-synchronous orbit (820 km, equator crossing time  $\sim 9\text{h}:30\text{min}$ , inclination 98,79) in 2013.

It is planned to launch two similar satellites with the same payload as Meteor-M №2, i.e. Meteor-M №2-1 (launch due 2014) and Meteor-M №2-2 (launch due 2015). The goal is to create a system of identical operational meteorological satellites in morning and afternoon orbits.

Meteor-M №3 oceanographic satellite is currently under development. Its payload will consist of:

- Multimode radar based on Active Phased Array Antenna (APAA) technology (X-band, spatial resolution from 1 to 500 m, swath 10 - 750 km);
- Scatterometer (Ku-band; 25x25 km spatial resolution, swath 1800 km);

- Coastal Zone Scanner (4 channels, visible range, 80 m spatial resolution, swath 800 km);
- Ocean Color Scanner (8 channels, visible range, 1 km spatial resolution, swath 3000 km);
- Radio-occultation instrument (Radiomet).

Meteor-M №3 is scheduled for launch in 2017.

According to the Federal Space Program the development of Meteor-MP constellation of the New Generation Satellites has been started in 2011.

Meteor-MP constellation will consist of 3 satellites: two meteorological and one oceanographic satellite. Meteor-MP payload will be basically similar to Meteor-M series payload, but with improved instrument performance.

Meteor-MP payload will consist of:

	Meteor-MP №1	Meteor-MP №2	Meteor-MP №3
Scanning radiometer (low-resolution multichannel scanning unit)	+	+	-
Ocean color scanner	-	-	+
Visible spectrum scanning imager (Moderate resolution multispectral imaging system)	+	+	-
Coastal zone scanner	-	-	+
Infra-red Fourier-transform spectrometer	+	+	-
Moderate resolution multispectral infra-red scanner	-	-	+
Atmospheric composition spectrometer	+	+	-
Microwave imager-sounder (module for temperature and humidity sounding of the atmosphere )	+	+	-
Scatterometer	-	-	+
Side-looking radar system	+	+	-
Multimode radar system based on Active Phased Array Antenna (APAA)	-	-	+
Radio-occultation instrument	+	+	-
Data collection system	+	+	+
Heliogeophysical Measurements Complex	+	+	-
1.7GHz data downlink system	+	+	-
X- and Ku- 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 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, including global change climate monitoring;
- Sea water monitoring and forecasting;
- Space weather analysis and prediction (solar wind, ionospheric research, Earth's magnetic field, etc.).

### **3.2.2 Ground segment matters**

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

Roshydromet ground segment consists of three regional SRC Planeta centers, responsible for receiving, processing, disseminating and archiving satellite data: European (Moscow-Obninsk-Dolgoprudny), Siberian (Novosibirsk) and Far-Eastern (Khabarovsk). These centers together give full coverage of the Russian territory and neighbouring states.

The ground segment also includes the network of DCP, LRPT, and HRPT stations.

### **3.2.3 Data transmission**

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

The direct broadcast will operate in L-band in HRPT 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 it was reported on the Russian project of Arctic region monitoring from the “Molnya” highly elliptical orbit for the first time. Now this project evolved into mission of two HEO satellites called Arctica. The work has been started in 2011 and the first satellite is now being produced by Lavochkin Association.

### **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 cycle time for each satellite is exactly 12 hours. The payload and design of the satellites are similar to Electro-L series.

The essential feature of Arctica system spacecraft is their mass and power reserves allowing to add different types of complementary instruments, including international ones if it is considered necessary. The launch of the first Arctica satellite is scheduled for 2015.

### **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. Also it is planned to deploy the network of small data acquisition centers in the coastal zone along the Northern Sea Route.

### **3.3.3 Data transmission**

Data transmission system of Arctica satellites will consist of:

- Downlink in X-band with data transmission rate of 30.72 Mbit/s;
- Downlink in L-band for the GGAK 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 ACTIONS AND/OR RECOMMENDATIONS FOR CONSIDERATION BY CGMS PLENARY SESSION**

The geostationary Electro-L satellite located over the Indian Ocean at 76°E has international DCP channels which may be used to gain information from remote meteorological sites or sensors located within its footprint. Thus, CGMS could recommend its members to use this opportunity.

As the second recommendation, it is suggested to make an additional effort into channels inter-calibration of the geostationary and polar-orbiting satellites, especially in the infrared and microwave channels.

## **5 CONCLUSION**

Russia is currently developing national constellation of meteorological satellites. It will be complemented by the satellites in highly elliptical “Molnya” type orbits. Two satellites in HEO, the first spacecraft is scheduled for launch in 2015, will provide the continuous monitoring of the atmosphere, ocean and land in the northern Polar Regions.