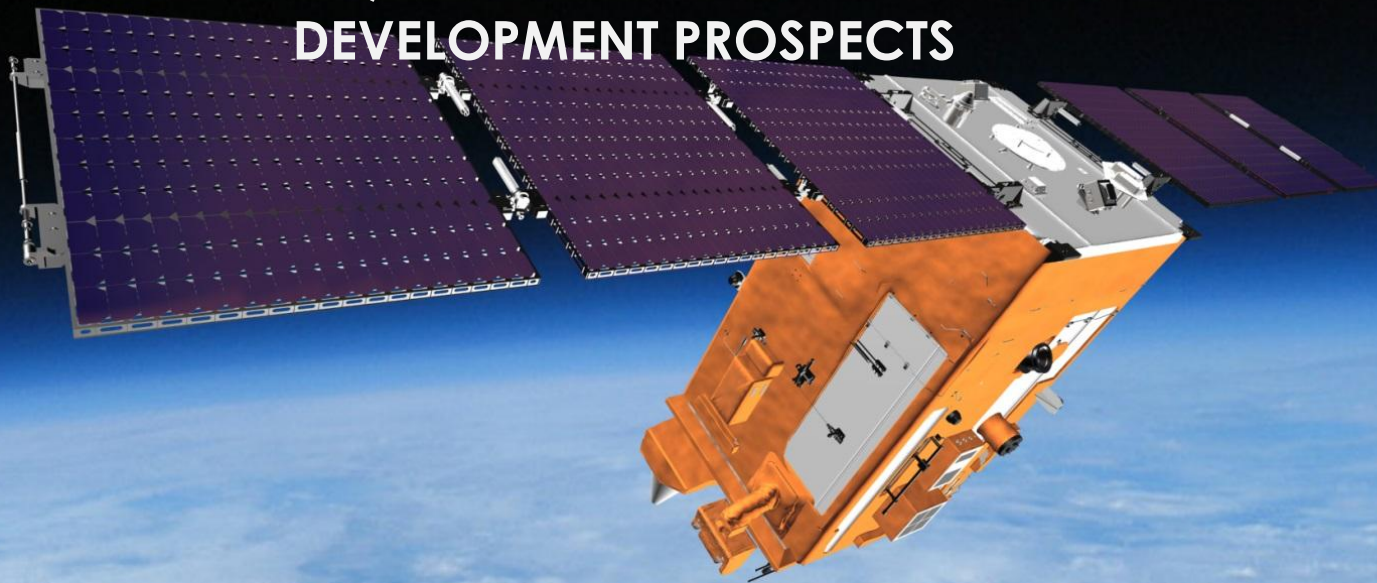




Space Rocket Centre 'Progress', JSC

SMALL SPACECRAFT AIST-2D: TECHNICAL FEATURES, RESULTS OF OPERATION AND DEVELOPMENT PROSPECTS



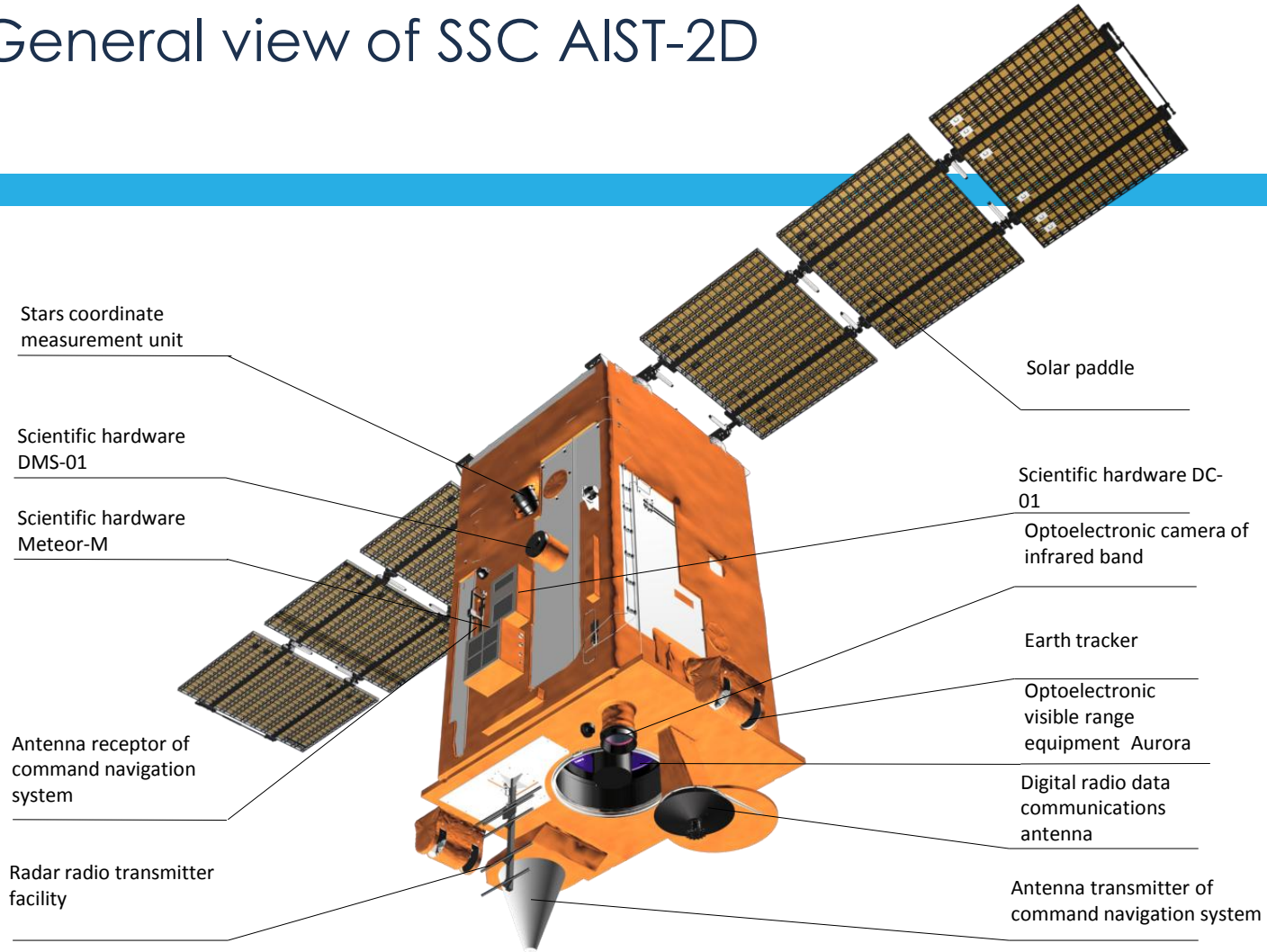
26 September, 2018
Crete, Greece

Head of Department, JSC SRC Progress
Anton Yudakov, Ph.D. in Engineering Science

AIST-2D small spacecraft had been produced by JSC SRC Progress in cooperation with leading companies of aerospace industry . On April 28, 2016 small spacecraft (SSC) Aist-2D together with Lomonosov spacecraft (designed by VNIIEM corporation) was launched from Vostochny cosmodrome by Soyuz-2-1a launch vehicle equipped by Volga Upper Stage.



General view of SSC AIST-2D





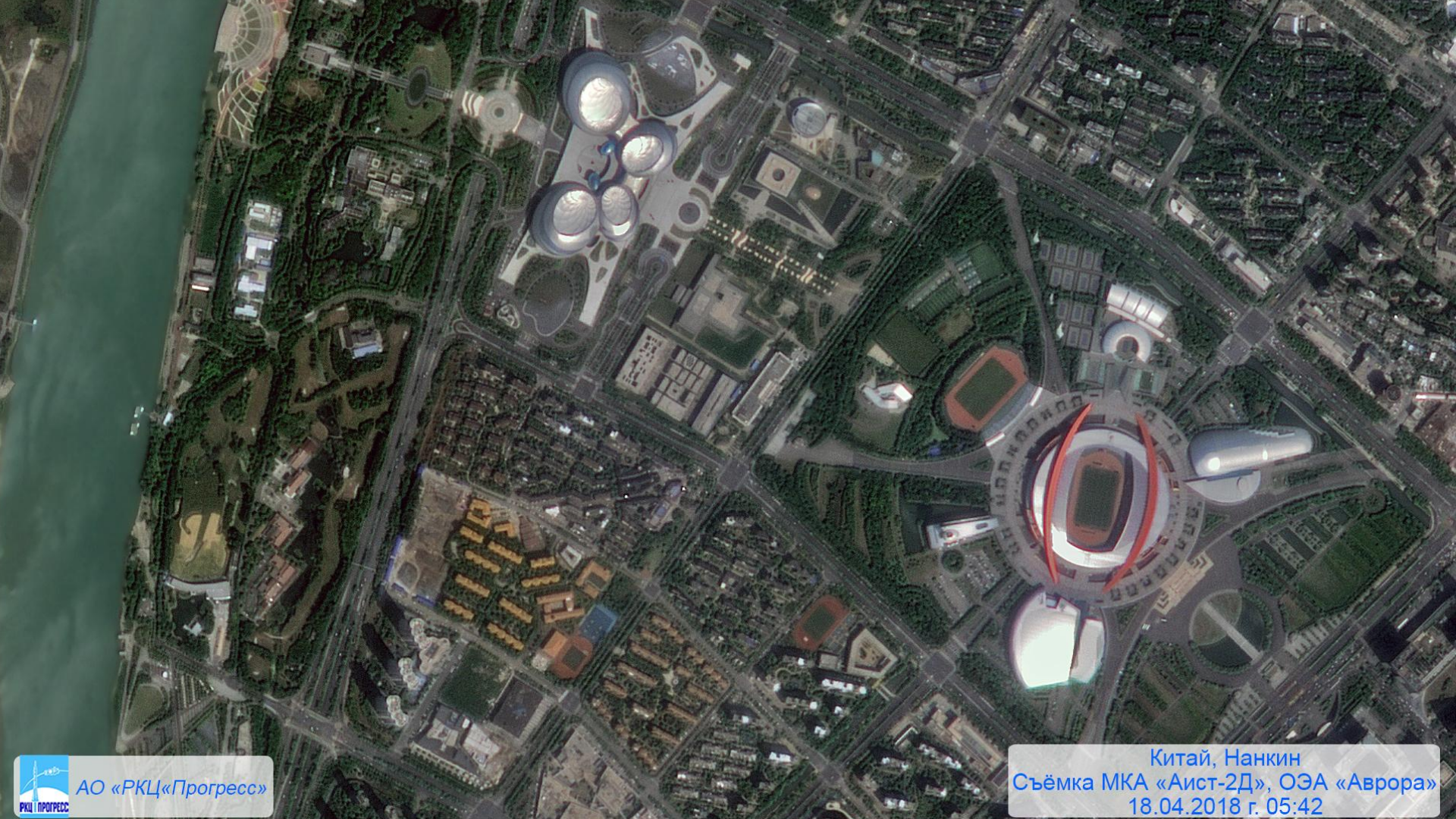
Key performance features of SSC Aist-2D based on flight test results

5

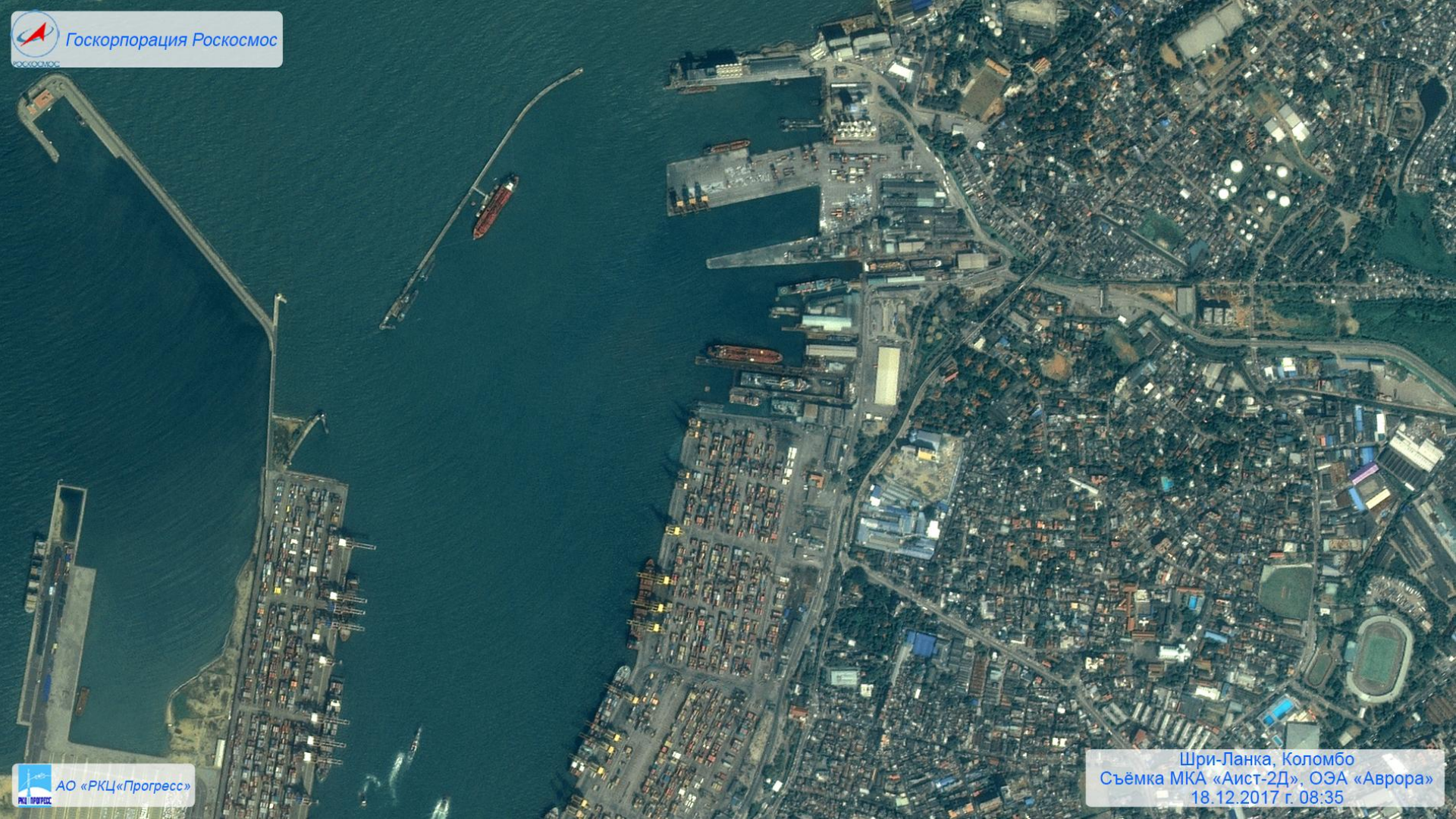
Item	Value
Linear ground resolution (pixel projection) at the altitude of 490 km, m - in panchromatic mode (0,58 - 0,80 μm) - in multispectral mode (RGB from 0,45 up to 0,52 μm ; 0,52 - 0,60; 0,63 - 0,69 μm)	1,48/2-2,5 4,44
Swath in visible range at H=490 km, km	39,6
Duration of survey route, sec	from 3 up to 300
Rate of imagery data transmission to the ground data reception station, Mbit/sec	150
Maximum daily output in panchromatic mode per one data reception station, km ²	80 000
Maximum possible number of imaging strips per orbit	5
Roll angle , degree	± 45
Time of retargeting	Up to 140 sec per 45° angle
Alignment accuracy during SSC software-based angular motion adjustment: - at yaw angle - at roll angle and pitch angle - at angular velocity	No worse 2` No worse 3` No worse 0,005°/sec
Navigational equipment accuracy: - orbital positioning error of small spacecraft, m - Velocity determination error of small spacecraft on orbit, sm/s	20 15
Gridding accuracy at root-mean-square error level without control points, m	12,3











Received data

Survey mode	Number of routs	Area (км ²)
Panchromatic	199	2 808 969,240
Multispectral	9	352 143,530
Panchromatic /Multispectral	4 741	18 209 538,510
Optic-electronic complex IR-band (OEC-IR)	121	1 237 538,060
Panchromatic /OEC-IR	241	1 583 218,990
TOTAL	5311	24 191 408,340 Among them: - at the territory of the RF: 7 854 185,552 - at the territory of Samara region: 1 476 617,55

Organization	Number of routs, pcs.
EMERCOM of Russia	248
International Civil Defense Organization	48
Ministry of Forestry, Environment protection and Natural Management of Samara Region	1362 fragments
State Space Corporation ROSCOSMOS	24
JSC Russian Space Systems	5
GIA Innoter	45
JSC Glavcosmos	44
Priroda State Research and Production Centre	156
Rosgidromet	4
JSC Gazprom Space Systems	16
JSC Rakurs	5
Ministry of Information Technologies and Communications of Kirov region	9
Saint-Petersburg Scientific - Research Ecological Safety Centre of the Russian Academy of Science	91
Samara Trans-regional Environmental Prosecutor's Office	11
JSC Gazprom Space Systems	16

The data was transmitted to Priroda State Research and Production Centre, EMERCOM of Russia, Ministry of Forestry, Environment protection and Natural Management of Samara Region and Ministry of Information Technologies and Communications of Kirov region for practical applications.

The data transmission to JSC Glavcosmos was performed at the stage of preparing and implementation of pilot projects for marine monitoring in the interests of foreign customers. Information was supplied to the rest organizations for the purpose of evaluation of its quality and customer properties, as well as the possibility of its practical usage.

No.	Organization	Conclusion
1.	EMERCOM of Russia (ref. No 3942-4-3 of 20.10.2017)	<p>Based on the statistical analysis of imagery properties of images obtained by SSC AIST-2D the following findings could be drawn:</p> <ul style="list-style-type: none">– original images have high informative and imagery quality that allows to use them efficiently for recognition of different object types within wide task range of monitoring natural and technogenic emergencies;– there is a possibility to extract information from images of different generalization degree while solving the tasks by the Ministry of Emergency at various levels and scales. <p>By its performance characteristics such satellites is not inferior to foreign satellites of similar class. Received data were actively used by territorial bodies of the Emergencies Ministry to provide the informational support for decision-making oriented to emergency prevention and control, as well as reducing of mortality and large-scale damage risks.</p> <p>The expansion of satellite constellations is appropriate for the spacecraft of similar class.</p>

No	Organization	Conclusion
2.	Priroda State Research and Production Centre (ref. No 6/16-67 of 17.11.2017)	<p>The values of linear ground resolution are ranged from 1,97 up to 2, 27m. Survey of 1A processing level provides planimetric part of topographic map with root-mean-square error no worth than 3,7m that matches the accuracy of maps in scale 1:25 000. Using the precise mathematical model of scanner image during its photogrammetric processing it is enable to create the transformed image in scale 1:15 000, and therefore, it is possible to create high-accuracy transformed image in scale 1:25 000. Survey of 2A processing level allows to get planimetric part of topographic map with root-mean square error no worth 11,5m provided the systematic errors and altitude of points while transforming are taken into account. Such accuracy meets the accuracy requirements of maps in scale 1:25 000. Assessment of panchromatic images found that they have high informative and imagery properties and can be effectively used to identify different objects of topographic types.</p>

No	Organization	Conclusion
3.	JSC Russian Space Systems (ref. No и-246/26-723 of 22.11.2016)	Submitted images from SSC AIST-2D could be characterized by good imagery properties and comfortable visual perception. Considering high linear ground resolution, absence of any apparent radiometrical defects and satisfactory geometry, submitted data could be used for solving different tasks, such as: mapping, indication of changes, generating of base landscape maps. Linear ground resolution of the images is ranged by: 2 - 2,5m in panchromatic channels; 5 – 6m in spectral channels. Geolocation accuracy of ortho-transformed images with ground control points is ranged by 10 – 15m, inner geometry accuracy 4 – 5m.

No	Organization	Conclusion
4.	GIA Innoter (ref. No 243/17 of 29.09.2017)	<p>Investigation findings revealed that RMS error of locating of contour positions based on images from SSC AIST-2D using one control point can reach 6m that meets the requirements to geometry accuracy of material intended for generating and updating of topographic maps in scale 1:25 000 and less. Increasing a number of control points, the data obtained from SSC AIST-2D allow to get RMS error of locating of contour positions 1,6m, that responds to accuracy for base material of ground maps in scale 1:5000. In the case of absence of control points, equaled on RPC-model image from AIST-2D allows to get the material with RMS error 17,2m, that is meets the map accuracy in the scale 1:50 000.</p> <p>Results of strip stereo survey processing show that AIST-2D can perform the stereoscopic survey by way of adjacent strips.</p>

No	Organization	Conclusion
5.	JSC Rakurs (ref. No2201/18-1 of 22.01.2018)	<p>Taking into account the spatial resolution of images, their orientation accuracy (especially panchromatic and integrated) based on RPC is sufficiently high. RMS error of the target positions of control points is expected to be 3-5m for panchromatic and integrated images (with spatial resolution 2m) and about 20 m for multispectral images (with spatial resolution 5m). Using the only control point per image and calculating the shift correction to initial RPC it is possible to achieve the accuracy 3-4.5m (RMS error based on control points) for panchromatic images and 6-8m for multispectral images. Usage of the only control point has a slightly effect to the orientation accuracy of panchromatic and integrated images, but allows to increase threefold the orientation accuracy of multispectral images. When using 4 control points, the shift correction allows to increase previously obtained orientation accuracy of panchromatic and integrated images only insignificantly – up to 3-4 m RMS error, and when using the affine correction, the accuracy could be increased up to 2.5-3m. The shift correction is more effective for multispectral images – it provides the control-point-based RMS error 5 m, and affine correction improves accuracy up to 3-5 m RMS error.</p>

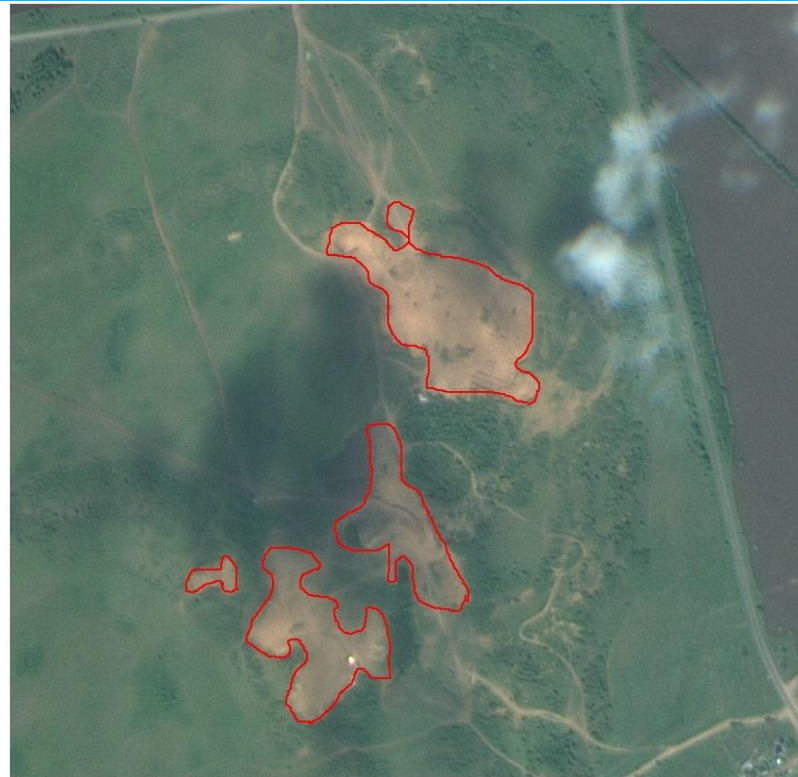
No	Organization	Conclusion
		<p>The further increasing of control points does not result in improvement of orientation accuracy with shift correction, however, when using a large amount of control points and affine correction to RPC it is possible to decrease RMS error to a level of spatial resolution for panchromatic and integrated images, and for multispectral images – if the measurements of points are performed by competent operator – RMS error may reach $\frac{1}{2}$ spatial resolution.</p> <p>The results of equating allow to use panchromatic and integrated images (with spatial resolution 2m) for creation of photographic plans corresponding to 1:25 000 scale without ground control points (according to <i>Instructions on photogrammetrical works for creation of digital topographic maps and plans</i>, Moscow, Central scientific Research Institute of Geodesy, Aircraft Survey and Cartography, 2002).</p>

No	Organization	Conclusion
6.	Ministry of Information Technologies and Communications of Kirov region (ref. No 419-71/06-01 of 20.11.2017)	<p>On the basis of remote sensing data obtained by SSC AIST-2D the following works had been fulfilled:</p> <ol style="list-style-type: none">1. 66% area of the Pizhemyky State Nature Preserve and 97,3% area of the Bylina State Nature Preserve had been monitored. It had been revealed 12 damaged forest plots of total area 31,124 ha. As a result of environmental monitoring it had been found 2 plots with mineral extraction signs of total area 1,086 ha and 2 plots with waste disposal sites of total area 0,363 ha.2. The forest management had been monitored at 50% territory of the Malmyzhsky forest of Kirov region. As a result of monitoring the diversion vector map had been created, and 101 plots of total area 580,50 ha with the signs of forest logging had been revealed.

Sphere	Issue
Agriculture	Delimitation of agriculture fields and agriculture seeding
	Agriculture seeding conditions definition based on color specification
Natural resource management and forestry	Control of illegal common minerals extraction places
	Control of illegal solid domestic waste dumping areas
	Control of unauthorized economical activity (such as nature conservation and water protection areas)
	Control of deforestation because of negative effects (windfalls, burnt, cutting trees)
	Density of canopy evaluation
Water resources	River network mapping
	Suspended sediments areas detection, coastal accumulation mode analysis
	Flood flows detection in high water period
Transport infrastructure	Roads network configuration definition, network change detection
	Evaluation of transport network load by vehicles
	Evaluation of traffic network sites construction progress
Mapping	Development and maintenance of topographical maps, scale 1:50000 и 1:25000
Regional infrastructure of spatial data	Maintenance of regional digital base material in order to provide effective operation of regional geographical information systems and services

Organization	Application of remote sensing data from SSC AIST-2D
Priroda State Research and Production Centre	Updating of digital topographic maps in terms of government order
EMERCOM of Russia	On-line situation assessment in the regions of emergencies and natural disasters especially in fire-hazardous period (detection and tracking of forest fires) and during flood events (detection and monitoring of waterflood and flooded areas).
Ministry of Forestry, Environment protection and Natural Management of Samara Region	Detection and monitoring the sites of illegal mineral extraction, as well as unauthorized dumps of solid domestic waste distributed all over Samara region. Illegal mineral extraction had been suppressed at several objects and responsible had been prosecuted.
Ministry of Information Technologies and Communications of Kirov region	Detection of damaged forest sites. While careful examination it had been found the sights with signs of mineral extraction and placing of solid domestic waste. Monitoring and weed control on the ground areas intended to agricultural crops.

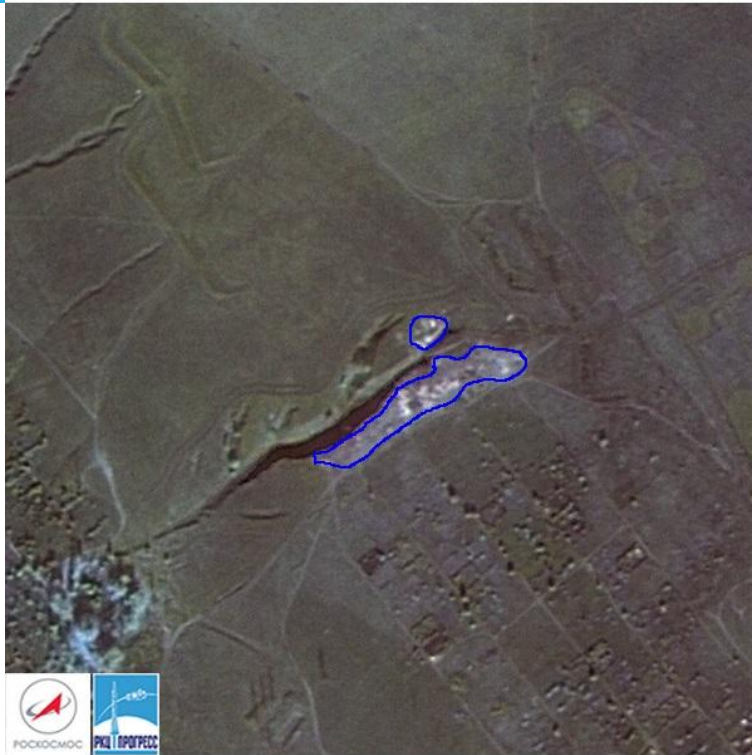
Examples of AIST-2D remotely sensed data thematic use



Illegal mineral resources mining detection (Samara region)
(Russia, Samara region, Kinel district, Mikhailovsky village)

Examples of AIST-2D remotely sensed data thematic use

23



Illegal storage of domestic solid objects in Samara region

Examples of AIST-2D remotely sensed data thematic use



Petropavlovsk-Kamchatsky_ Avacha Bay



Antarctica

Monitoring of hydrological and ice conditions



Examples of AIST-2D remotely sensed data thematic use

25



Forest fires detection

Потребители информации с МКА «Аист-2Д»

ФКУ НЦУКС
МЧС России (в т.ч. В интересах
МЦМК МОГО)

Министерство лесного
хозяйства, охраны
окружающей среды и
природопользования
Самарской области

Самарская межрайонная
Природоохранная прокуратура

Министерство
информационных технологий
и связи Кировской области

ООО «Лоретт»

ООО «Рисксат»

Росреестр
(АО «НИИП центр «Природа»)

Международная ассоциация
участников космической
деятельности

АО «Главкосмос»

Управление Государственной
охраны объектов культурного
наследия Самарской области

Коммерциализация информации с МКА «Аист-2Д»

Договор возмездного оказания
услуг по информационному
обеспечению данными ДЗЗ с АО
«Главкосмос»
(оформлен)

Договор возмездного оказания
услуг по информационному
обеспечению данными ДЗЗ с
ООО «САИНП»
(в стадии оформления)

Дистрибьюторский договор с
АО «Главкосмос»
(в стадии оформления)

Дистрибьюторский договор с
АО «Ракурс»
(оформлен)

Дистрибьюторский договор с
ООО «Иннотер»
(в стадии оформления)

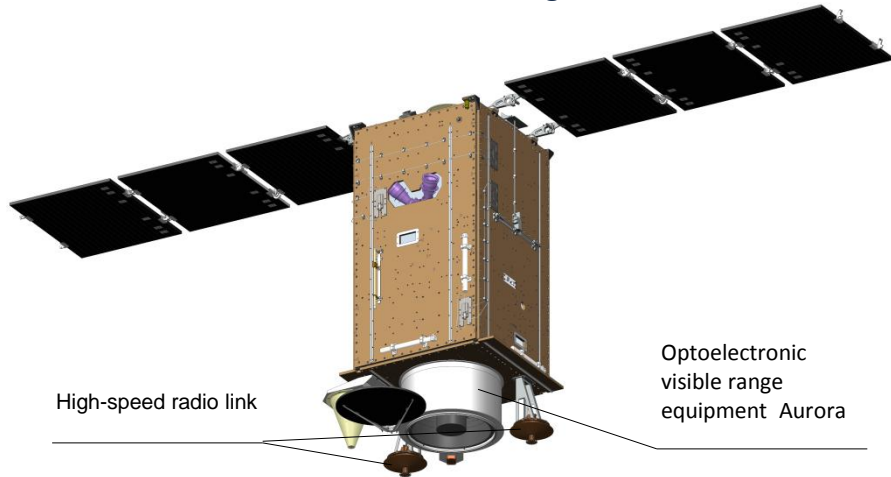
Реализация заявки Росреестра на получение информации с МКА «Аист-2Д» в 2018 году

Потребная площадь земной поверхности,
которую требуется покрыть снимками
с КА «Аист-2Д»
2 260 055,02 кв. км.

По состоянию на 05.07.2018
в 2018 году в АО «НИИП центр
«Природа» передано 56 маршрутов
съёмки, покрывающих земную
поверхность площадью
440291,2 кв. км., что составляет
19,5 % от потребной площади покрытия

По результатам реализации заявки в
Росреестра в 2017 году в АО «НИИП центр
«Природа» направлены предложения по
созданию двух КА типа «Аист-2Д» в
интересах Росреестра

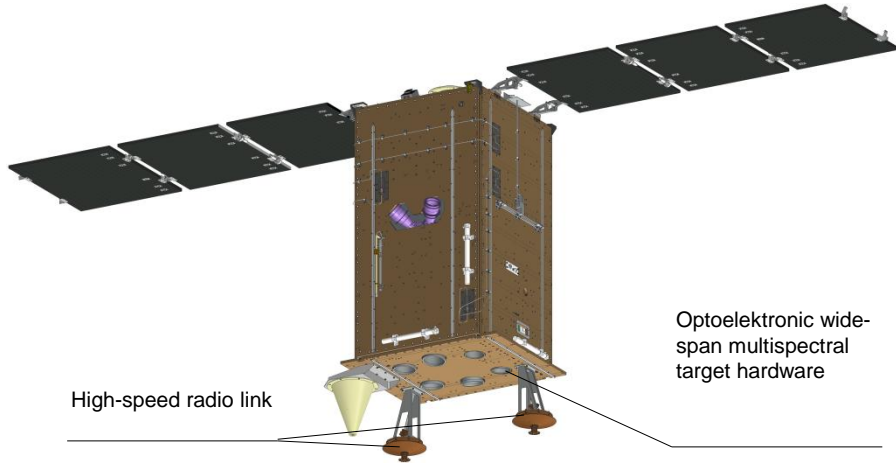
Detail observation Earth remote sensing SSC



SSC AIST-2D had been developed on the basis of platform approach – circuit and technical solutions in developing make possible to use different target hardware in new projects, and optoelectronic equipment AURORA has a great modification potential. Design view and characteristics of SSC with modified optoelectronic equipment AURORA are shown in the picture.
 In panchromatic range under success conditions such SSC can generate images with resolution better than 1,5 m.

Technical characteristics	
Target hardware	Modified optoelectronic equipment AURORA-M
Resolution (linear ground resolution) at the altitude H=500 km, - in panchromatic range - in multispectral range	no worth 1,5 m no worth 4,5 m
Swath in panchromatic and multispectral range	no worth 30 km
Rate of imagery data transmission to the ground data reception station	no worth 300 Mbit/sec
Mass	no more 600 kg
Active life time	no less 5 years

Area survey Earth remote sensing SSC

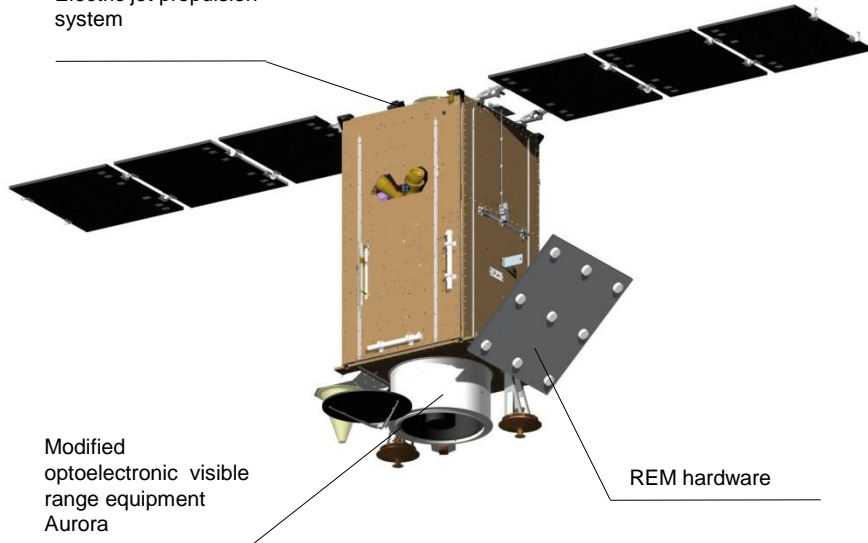


AIST-2D SSC operating experience had revealed availability and demand for images with average resolution and wide capture range by the customer. For the implementation of such a need it had been designed the project for prospective SSC equipped by the complex of optoelectronic wide-span multispectral target hardware. Images obtained by that hardware could facilitate to meet the challenges in ecology, agricultural development, environmental management, forestry, mapping and etc.

Technical characteristics	
Target hardware	Optoelektronic wide-span multispectral target hardware
Resolution (linear ground resolution) at the altitude H=500 km, - in panchromatic range - in multispectral range	no worth 4,6 m no worth 9,2 m
Swath in panchromatic and multispectral range	no less 180 km
Rate of imagery data transmission to the ground data reception station	no less 300 Mbit/sec
Mass	no more 600 kg
Active life time	no less 5 years

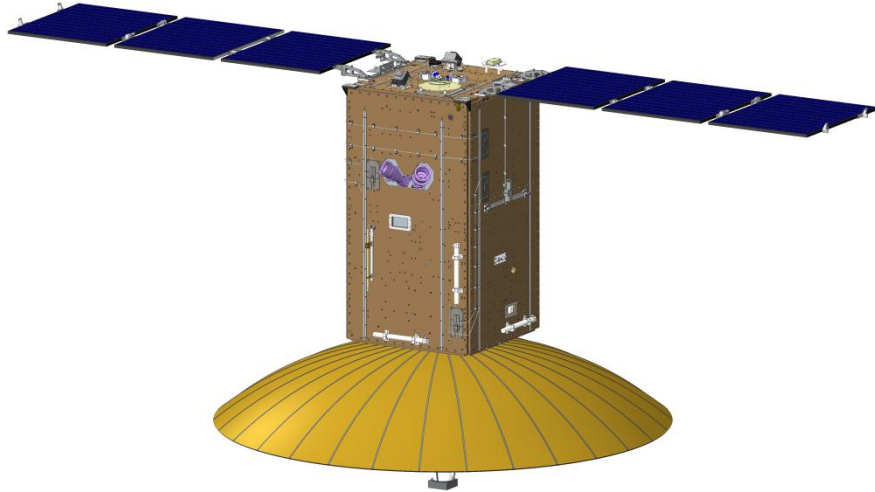
SSC equipped by integrated special onboard complex for radioelectronic monitoring (REM) and optoelectronic observation

Electric jet propulsion system



Characteristics	Value
Target hardware	Modified optoelectronic hardware Aurora equipped by the radio-electronic observation complex, REM (JSC Vektor Research Institute)
Resolution (linear ground resolution) at the altitude H=500 km, - in panchromatic range - in multispectral range	no worth 1,5 m no worth 4,5 m
REM characteristics	
Swath in panchromatic and multispectral range	no less 30 km
Rate of imagery data transmission to the ground data reception station	no less 300 Mbit/sec
Mass	no more 700 kg
Active life time	no less 3 years

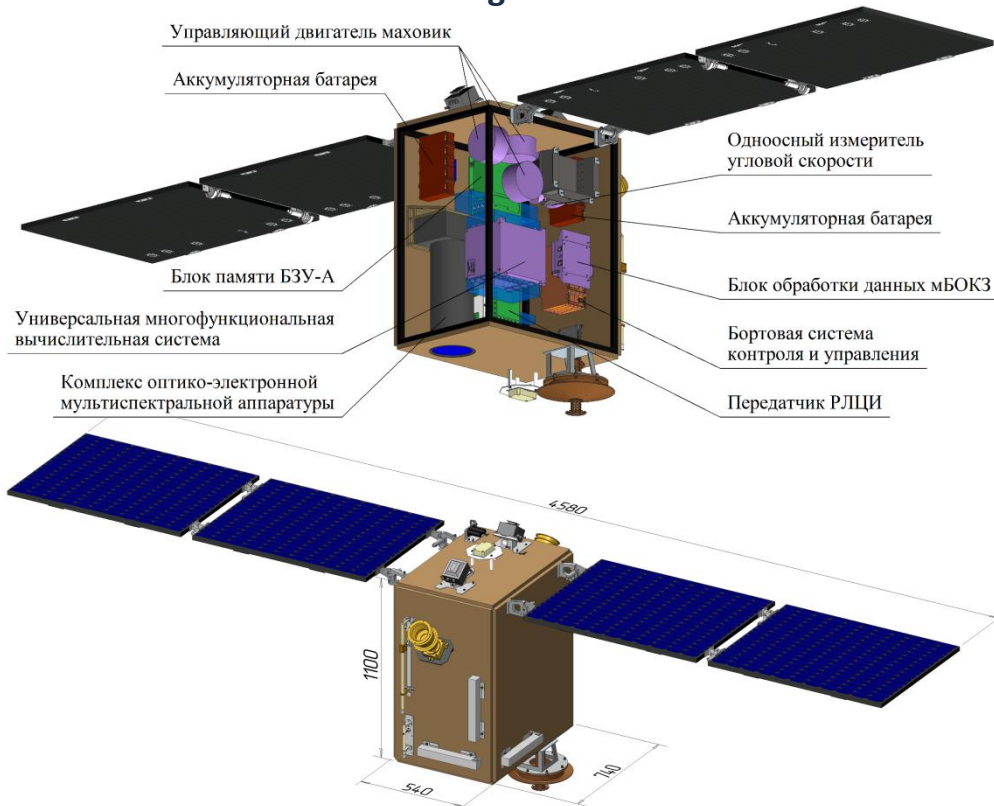
Earth remote sensing SSC equipped by radar observation hardware



One of the way of Earth surface survey under any weather conditions and at night time is using of radar observation hardware in combination with special onboard complex. The platform approach used in design of AIST-2D SSC allows to accommodate the radar complexes with large-diameter deployable reflectors to new SSC. The specialists of JSC SRC Progress consider that this activity area is quite prospective and information is meaningful for solving of wide task range.

Technical characteristics	
Target hardware	Radar observation hardware
Range	S
Resolution (linear ground resolution) at the altitude H=500 km, m	1
Rate of imagery data transmission to the ground data reception station	no less 300 Mbit/sec
Mass	no more 700 kg
Active life time	no less 5 years

Mini Earth remote sensing SSC



The most significant of AIST SSC design and operation result is the improvement of cooperation with scientific and educational organizations in Samara region. The work is under way on further cases, and the participation of institutes of higher education and scientific organizations in the new AIST SSC project should be more active. Korolev Samara State Aerospace University, St. Petersburg State Polytechnic University, RAS Institute of Medical and Biological Problems, Institute of Ecology of Volga basin participate in development of the SSC shown in the left figures .

In addition to scientific and educational tasks the prospective SSC should be intended to solve ecological problems in our country.

Technical characteristics	
Target hardware	Complex of optoelectronic multispectral hardware
Resolution (linear ground resolution) at the altitude H=500 km, - in panchromatic range - in multispectral range	1,5 – 2 m no worth 4,5 m
Swath in panchromatic and multispectral range	no less 11 km
Rate of imagery data transmission to the ground data reception station	no less 150 Mbit/sec
Mass	no more 150 kg
Life time	no less 3 years

SSC AIST-2D production cost and period

Title	Value
Production period of SSC up to readiness to a shipment, year	2,2
Estimated production cost of 1 SSC, million rubles	888,2*
JSC SRC PROGRESS availability to serial production of small spacecraft, pieces per year	3

*) without costs for:

- installation of special software to customer's data reception station, upgrading of ground control facilities, scheduling, data reception and processing, designed for AIST-2D SSC;
- development activity on SSC adaptation to launchers and launch service.



JSC Space Rocket Centre Progress

Thank you for your
attention!

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