COMMONWEALTH OF INDEPENDENT STATES

COUNCIL OF HEADS OF GOVERNMENTS

DECISION

October 25, 2019 **Moscow city**

About the main directions (plan) of the development of radio navigation CIS member states for 2019–2024

Council of Heads of Government of the Commonwealth of Independent States

I decided:

1. To approve the Main directions (plan) of the development of radio navigation CIS member states for 2019–2024 (attached).

2. Recommend to interested ministries and departments CIS member states in the development and improvement radio navigation support in their states The main directions (plan) for the development of radio navigation of states - CIS participants for 2019–2024.

3. Interstate Council "Radio Navigation" with the participation of CIS Executive Committee to monitor the Principal directions (plan) for the development of radio navigation of the CIS member states for 2019–2024 and inform the Economic Council if necessary CIS on the progress of their implementation.

From the Republic of Azerbaijan	**From the Russian Federation**
--------	**D.Medvedev**
From the Republic of Armenia Vice Prime Minister **M. Grigoryan**	**From the Republic of Tajikistan** **K.Rasulzoda**
From the Republic of Belarus	**From Turkmenistan**
S. Rumas	**--------**

From the Republic of Kazakhstan

A. Mom

From the Republic of Uzbekistan

A. Aripov

From the Kyrgyz Republic

M.Abylgaziev

From Ukraine

From the Republic of Moldova

APPROVED

By decision of the Council of Chapters
CIS Governments on Basic

directions (plan) of development
state radio navigation -
CIS participants
for 2019–2024

October 25, 2019

MAIN DIRECTIONS (PLAN) RADIO NAVIGATION DEVELOPMENT STATES - PARTICIPANTS OF THE CIS FOR 2019–2024

LIST OF DESIGNATIONS AND ABBREVIATIONS

Runway	- runway;
GIS	- geographic information system;
GLONASS	- Global navigation satellite system of the Russian Federation
GNSS	- global navigation satellite system;
ICAO	- ICAO; International Civil Aviation Organization;
IMO	- IMO; International Maritime Organization;
KA	- spacecraft;
KVNO	- time-coordinate and navigation support;
KPM	- marine circular beacon;
IAMS	- IALA; International Association of Lighthouse Services;
ICG	- International Committee for Global Navigation

satellite systems;

ITU - International Telecommunication Union;
IEC - International Electrotechnical Commission;
RMA - azimuthal beacon (type BOP);
RMD - rangefinder radio beacon (type DME);
RNS - radio navigation system;
RSBN - radio navigation system;
RSDN - radio system of long-range navigation;
SDKM - system of differential correction and monitoring;
UPC - standard error;
VHF - ultrashort waves;
APV - Approach with Precise Vertical; controlled approach vertically;
BEIDOU - GNSS of the People's Republic of China;
Dgnss - differential GNSS; functional complement system GNSS;
DGPS - differential global positioning system; differential GPS system GPS accuracy enhancement system;
Dme - Distance Measuring Equipment; measuring equipment range;
DVOR - Doppler High Frequency Omnidirectional Range; Doppler omnidirectional VHF radio system;
Egnos - European Geostationary Navigation Overlay Service; European wide-area differential satellite subsystem;
FERNS - Fast Eastern Radio Navigation Service; FERNS, Far Eastern Radio Navigation Service;
Gagan - geostationary navigation supplement GPS (India);
Galileo - GNSS of the countries of the European Union;

GBAS - Ground-Based Augmentation System; ground system functional complement (ICAO standard);
Gprs - General Packet Radio Service; general packet radio use;
GPS - Global Positioning System; Global system location (USA);
GRAS - Ground-Based Regional Augmentation System; ground regional functional complement (ICAO standard);
Iers - International Earth Rotation Service; International service Earth rotation;
ILS - Instrumental landing system; tool system landing;
ITRF - International Terrestrial Reference Frame; International Earth reference system
ITRS - International Terrestrial Reference System; International Earth coordinate system
LAAS - Local Area Augmentation System; local DPS ground basing for landing aircraft (USA);
Msas - Multifunctional Transport Satellite Augmentation System; Japanese wide-area differential satellite subsystem;

Msc - Maritime Safety Committee (MSC), Safety Committee at sea - a special department within IMO;
NPA - Non Precision Approach; inaccurate entry;
PBN - Performance Based Navigation; based navigation characteristics (ICAO concept);
PPP - Precise Point Positioning; high positioning accuracy; method for obtaining high-precision coordinates
RAIM - Receiver Autonomous Integrity Monitoring; autonomous integrity control in the receiver;
Rnav - Area Navigation; area navigation;
Rnp - Required Navigation Performance; required navigation characteristics (ICAO concept);
Rtca - Radio Technical Commission for Aeronautics; Commission for aviation radio equipment
Rtcm - Radio Technical Commission for Maritime Services; Radio technical commission of marine services;
RTK - Real Time Kinematic; set of techniques and methods obtaining the planned coordinates of the centimeter and decimeter accuracy;
SARPs - Standards and Recommended Practices; standards and ICAO Recommended Practices;

SBAS - Space-Based Augmentation System; satellite system functional complement;
TRS - Terrestrial Reference System; Earth coordinate system
UTC - Universal Coordinated Time; worldwide coordinated time;
V2x - data exchange systems between the car and others objects of road infrastructure like "Vehicle-to-Everything ";
Vor - Very High Frequency Omnidirectional Range; omnidirectional goniometric ground beacon of the VHF range;
Wgs - World Geodetic System; World geodetic system;
WAAS - Wide Area Augmentation System; wide area system functional supplement (USA).

1. GENERAL PROVISIONS

1.1. Grounds for the development of the Guidelines (plan) development of radio navigation of the CIS member states for 2019–2024

The development of the economy of the modern state and its welfare citizens, the country's international authority and defense are not in the last turn depends on the level of development of coordinate-time and navigation technology.

The unique geographical position of the CIS member states predetermines their high potential in the implementation of transit operations between the countries of Europe and the North Atlantic region, on the one hand, and countries of Central and Southeast Asia and the Pacific, on the other hand.

Transport capabilities of CIS member states include to competitive advantages along with their natural resources and geographic location. Export of transport services becomes important component of gross national product.

Without reliable navigation support the required level of safety when using all types of transport: air, water and land. Multimodal implementation interstate traffic determines the need for guaranteed providing customers and reliable navigation services providers information in accordance with international requirements.

Radio navigation systems (RNS) of the CIS member states must line up and develop as harmonized parts of a single structures united both at the CIS level and at the global level.

The complexity of satellite and terrestrial RNS, the diversity of customers, performers and consumers of navigation services, as well as resource restrictions necessitate the use of a coordinated approach to solving problems of maintenance, development and use radio navigation fields.

Thus, the task of developing coordinate-time systems and navigation support for CIS member states far beyond interdepartmental and interregional relations and requires an integrated approach at the interstate level.

The main directions (plan) for the development of radio navigation of states -

CIS participants for 2019-2024 (hereinafter - the Main Areas) are called upon
to provide coordination of efforts and interaction in the field of radio navigation.

By a decision of the Council of Heads of Government of the CIS of May 26, 2017, it was approved Interstate Radio Navigation Program of States Parties Commonwealth of Independent States until 2020. Paragraph 1

The list of activities of the specified Interstate program development of updated development directions is provided navigation area in the CIS member states for the period up to 2025, which was the basis for the development of the Guidelines.

1.2. Legal Status of the Guidelines

The main areas are official current status and development prospects of the RNS and the means that determine ways to implement the policies of the CIS member states in this area.

Key areas recommended for practical guidance executive authorities, industrial enterprises, scientific organizations and institutions of the CIS member states implementing development, production of RNS and facilities, their operation and provision of services radio navigation.

The development of the guidelines was carried out on the basis of analysis national, interstate and international regulatory and regulatory and technical documents in the field of radio navigation.

The main directions take into account the relevant requirements international organizations (ICAO, IMO, IALA, ITU), recommendations ICG, the provisions of the radio navigation plans of the CIS member states, and also the obligations of the CIS member states on international to contracts.

1.3. Objectives of the Guidelines

The main directions are developed in the interests of development, building up and improvement in the territories of the CIS member states radio navigation fields through the use of modern technologies and implementation of the agreed technical policy of the participating States CIS.

The objectives of the main areas are:

coordination of the technical policies of the CIS member states in areas of radio navigation;

improving individual national plans and defining RNS, which will be key to ensuring safe and effective traffic of the CIS member states;

identification of developments to identify areas of activity, requiring resource allocation and research works;

information interaction between developers and consumers of navigation services in the CIS member states;

orientation of foreign consumers to the opportunity the use of existing and promising RNS and state funds - CIS participants;

integrated use of space and ground RNS fields within the framework of the CIS member states and European states for meet the requirements of consumers in navigation support.

The implementation of the Guidelines will ensure:

planning the most promising areas of state policies of CIS member states in the field of industry development radio navigation services, taking into account the interests and requirements of various consumer groups, as well as the conditions for determining the most effective methods of using resources in this area;

improvement and harmonization of navigational aids CIS member states;

increasing the economic efficiency of use by all consumer groups of existing and promising RNS and ground and space based CIS member states, as well as united interstate systems;

conditions for interstate coordination of activities the creation and maintenance of the operation of the RNC and the means and provision high-quality radio navigation services to consumers;

compatibility and integration of the RNS of the CIS member states during their development, operation and modernization;

development and implementation of agreed requirements for radio navigation support for air, sea and land consumers of the CIS member states through the development of appropriate interstate regulatory documents (technical regulations, standards, etc.) and certification of RNS and facilities;

improving the professional level and quality of training in CIS member states navigation specialists providing.

Financial support for the objectives of the Guidelines will be implemented by CIS member states within budget appropriations allocated to interested ministries and departments for fulfillment of the functions assigned to them, as well as due to attracted or extrabudgetary sources of funding.

1.4. Scope of the Main Areas

The scope of the Guidelines covers the available RNS and civil and dual-use facilities used in CIS member states.

In the main areas are not considered inertial navigation systems as well as radio systems that perform radar survey or communications functions. In particular, the document does not include automatic identification systems and automatic dependent surveillance systems but included navigation aids on which these systems rely.

RNS considered in the Main Areas are divided into following main groups:

1) global navigation satellite systems and their functional additions;

2) ground-based RNS:

long distance navigation radio systems;

short-range radio engineering systems;

landing systems and beacons.

When considering RNS, the following were taken into account:

technical specifications;

operational characteristics;

economic characteristics;

organizational characteristics and legal issues;

state of development and production;

the use of RNS and consumer navigation equipment.

The main technical parameters are accuracy, integrity, working area, availability and continuity of the system. Attention is paid to the use of the frequency spectrum and some specific parameters, such as anti-interference characteristics, which apply not only to military systems, but also affect accessibility and continuity of the functioning of civil systems.

2. REQUIREMENTS OF CONSUMERS TO RADIO NAVIGATION SYSTEMS

2.1. Tasks solved using radio navigation systems CIS member states

RNS requirements are determined by consumers in accordance with tasks and conditions of use.

Navigation is a branch of science on how to conduct aircraft and spacecraft, sea and river ships, as well as land vehicles from one point in space to another one. The navigation problem is solved by methods and navigation devices, which allow you to determine the location and orientation of a moving object relative to the adopted coordinate system, size and direction driving speeds, direction and distance to destination, etc.

The use of RNS and means will increase the accuracy of passage routes by moving objects and their withdrawal to a given area, as well as significantly improve vehicle safety in difficult weather conditions.

Combining various radio navigation devices into specific system in principle allows you to ensure that all basic tasks navigation. However, in order to increase the reliability and safety of driving objects in the most difficult conditions, such systems in practice use together with non-radio equipment, for example, with inertial navigation system with which they form integrated (combined) navigation systems.

Existing and under development RNS are designed to solve tasks of navigation of moving objects and personal navigation, geodetic reference of motionless objects, time synchronization, and also special tasks.

Navigation of moving objects is divided into specific areas:

spacecraft navigation and guidance;

air navigation;

navigation at sea and inland waterways;

ground vehicle navigation.

The task of space navigation in relation to the spacecraft is to determining the location of the spacecraft relative to other spacecraft or space bodies and in predicting the motion of the spacecraft as a material point.

The main task of air (aviation) navigation is the conclusion moving object at the optimal (most favorable for these conditions) trajectories to a given point or region of space at a given moment time. The solution to this general problem is divided into a number of particular tasks, diverse in nature and solution methods.

Significant stages of aircraft navigation are:

flight en route;

flight in the area of the aerodrome;

categorized or non-categorized approach.

Navigation on the sea and inland waterways aims to ensure safe driving of ships in the most advantageous ways at any time of the day and under various hydrometeorological conditions and suggests the following private tasks:

swimming on the high seas;

swimming in coastal areas and narrownesses;

maneuvering in ports and harbors;

swimming on inland waterways;

maneuvering in the interests of fishing, carrying out work on the sea shelf and dredging.

Ground-based navigation with all the diversity interests and tasks of consumers can be carried out in three main options for moving wheeled vehicles:

movement on established routes;

movement in a given area;

movement on arbitrary routes.

Geodetic reference of stationary objects can be carried out in

interests;
geodesy, cartography, hydrography and GIS support;
exploration, mining, control
product pipelines;
navigation preparation of transport infrastructure facilities;
binding lighthouses, navigation buoys, platforms, reference
navigation stations;
capital construction, control of structures, cadastre,
land management and precision farming.

Special tasks performed subject to navigational
collateral include:
search and rescue work;
research work, fundamental and applied
research of coordinate-time and navigation support;
studies of the earth's surface and tectonic displacement of the earth
bark;
providing cellular communication systems;
observation of the situation;
military tasks and special operations.

The use of the RNS of the CIS member states in the interests of bodies
authorities, departments and other consumers allows achieving
the following goals:

security of the CIS member states in economic, scientific and
technological, social, informational and environmental spheres;
traffic safety, especially passenger transport
funds, as well as the transportation of special and dangerous goods, cargo under
customs control;
flight safety of aircraft and spacecraft for various purposes;
navigational safety of sea and river transport;
consistency of international transit traffic
transport corridors;
guaranteed access for users to information produced
RNS and necessary for their functional tasks, except especially
agreed conditions.

The structure of the tasks to be solved using RNS is shown in Fig. 1.

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Fig. 1. The structure of problems solved using RNS

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2.2. System-wide requirements for radio navigation systems

The main system-wide parameters of the RNS, to which requirements from consumers are:

the size of the working area of the RNS;

location accuracy and timeline synchronization objects;

availability of RNS;

RNS integrity;

continuity of service (functioning) of the RNS;

discreteness of location;

RNS bandwidth.

Requirements for the size of the working area

Working area (action area) - area of space (closed surface) within which the navigation system allows the consumer to determine the location, speed and time with the given characteristics.

Increasing traffic intensity, expansion of the boundaries of movement, increase in speeds, heights and lengths of modern routes (routes) vehicles are subject to ever-increasing demands on navigation support. This predetermined the need meet consumer requirements to create the conditions for accurate location at any point on the Earth and near-Earth space, i.e. Global work area requirements.

Location accuracy requirements

Location accuracy is the degree to which the location matches. the consumer currently identified using the navigation system, its true position.

Location accuracy is characterized by the magnitude of the deviation measured coordinates from true. A quantitative measure of accuracy can the absolute value of the difference between the definite and the true coordinate values, as well as the standard error.

Requirements for the accuracy of positioning of objects depend on the nature tasks solved by consumers. Numerical values of accuracy locations vary widely - from fractions of a meter to several kilometers.

Requirements for the accuracy of determining the time (synchronization)

The accuracy of determining (synchronizing) time is characterized by the deviation of the time scale adjusted according to the RNS object from the scale adopted as a reference. Accuracy requirements synchronization depends on the nature of the tasks performed by consumers. Accuracy values vary widely - from seconds to nanoseconds.

RNS Availability Requirements

Availability (availability) is the ability of the RNS provide navigational definitions at a given moment time in a certain range.

RNC availability is characterized by the likelihood of receiving consumer in the working area reliable navigation and time information in a certain period of time and with the required accuracy.

Availability requirements vary based on vehicles and consumer tasks.

Highest requirements for availability

almost equal to one, presented on the basis of collateral
flight safety and navigation of sea and river vessels, and
it is during the approach and landing by ICAO categories, as well as when maneuvering in ports and moving along inland waterways.

RNS Integrity Requirements

RNS integrity is the ability of RNS to deliver to the consumer timely and reliable warning in cases where any navigation signals cannot be used for their intended purpose in full volume. Integrity is characterized by corresponding probability and time.

Requirements for the integrity of the RNS marine, river and land consumers lower than for air consumers due to lower speeds and longer valid update intervals information.

Requirements for the continuity of service (functioning) RNS

Continuity of service (functioning) is the ability navigation system provide navigation service consumers for a given time interval without failures and breaks. It is characterized by the likelihood of service.

Location Discreteness Requirements

Position resolution is temporary interval at which a new positioning is possible with using the same type of RNS.

RNS bandwidth requirements

Bandwidth is characterized by the number of users RNS that can be served simultaneously.

Given the importance of timely navigation information to ensure safe navigation and flights, bandwidth the ability of the RNS should be unlimited, and continuity, i.e. reliability of service should correspond to a given value.

2.3. Aviation Consumer Requirements

The following main phases (stages) are defined for aircraft movement:

taxiing from the aircraft parking to the take-off point;
take-off and exit to the starting point of the route (route);
flight on a route (route flight);
flight in the area of the aerodrome (terminal flight);
uncategorized (inaccurate) approach;
approach and landing by categories of ICAO;
landing and taxiing to the aircraft parking lot.

The requirements for navigation support at each stage are different. For the route phase of an aircraft flight, categories are established areas (zones):

oceanic (referenceless terrain);
internal continental (local) line;
areas for performing special tasks.

One of the most important and most critical phases of a flight is approach and landing of the aircraft. Air requirements consumers to the accuracy of determining the location during approach and landing

ICAO categories based on experience with use
instrumental landing systems are given in table. 1.

Table 1

Air Consumer Requirements for Approach and landing by ICAO categories

Category landing	Height above take-off landing strip for verification, m	Requirements for accuracy (SKP), m	
		in the horizontal plane	in the vertical plane
I	thirty	4,5-8,5	1,5–2
II	fifteen	2.3–2.6	0.7–0.85
III	2,4	2	0.2–0.3

Currently in civil aviation for scheduled flights and operations in the aerodrome area there is a transition from requirements based on RNP to the requirements formulated using the concept of PBN - navigation on based on characteristics. At the same time, PBN involves sharing area navigation RNAV and RNP.

Not only are air navigation accuracy requirements on the routes indicated by navigation beacons, but also on routes without beacons. In particular, when using zone navigation RNAV different categories apply the following precision characteristics that, in neglecting pilot errors, can be considered as double UPC determination of aircraft position:

RNAV 10 - assumes aircraft deviation (95% of the time) flight, P = 95%) within the corridor 10 nautical miles, or 18.5 km, without ground control (SKP = 9.25 km);

RNAV 5 - 5 nautical miles, or 9.25 km, with radar control (SKP = 4.62 km);

RNAV 2 - 2 nautical miles, or 3.7 km, with radar control (SKP = 1.85 km);

RNAV 1 - 1 nautical mile, or 1.85 km, with radar control (SKP = 0.92 km).

ICAO Basic Requirements for Navigation Support through satellite navigation systems and their functional additions in accordance with the Amendment to the standards and recommended ICAO Practice (SARPs) for DGNSS, Volume 1, Appendix 10, Getting Started from November 18, 2010 to the characteristics provided by navigation systems at different stages of flight are given in table. 2 and 3.

Moreover, under the characteristics of systems are understood:

accuracy - the ability of a system with a 95% probability to hold aircraft within the total system error at each point established flight pattern;

integrity - a measure of trust that can be attributed to the correctness of the information issued by the system as a whole; integrity includes the ability of the system to provide the user with timely and reasonable warnings (alarm triggering);

alarm activation - indication for any air systems vessel or warning the pilot that this navigation parameter the system is out of tolerance;

alarm threshold - level above which for

this measured parameter causes an alarm;

alarm delay (time before warning) - the maximum allowable time elapsed since the system exited allowable thresholds before the alarm is triggered;

service continuity - the ability of the entire system function without interruption during the execution of the intended operation;

readiness - the ability of the entire system to perform its function in the moment of the beginning of the intended operation.

table 2

Space signal performance requirements

Typical operation	Accuracy horizontally, m P = 95% / SKP [1-3]	Accuracy by vertical m P = 95% / SKP [1-3]	Integrity note [2]	Time to warning rebuke from [3]	Continuous nost [4]	Operation mysterious readiness [5]
On the route	3 700/1 850	Not assigned	$(1–10^{-7})$ in an hour	300	From $(1–10^{-4})$ to $(1–10^{-8})$ per hour	From 0,99 before 0,99999
On the route and in aerodrome area	740/370	Not assigned	$(1–10^{-7})$ in an hour	fifteen	From $(1–10^{-4})$ to $(1–10^{-8})$ per hour	From 0,99 before 0,99999
Initial approach intermediate approach, NPA, departure	220/110	Not assigned	$(1–10^{-7})$ in an hour	10	From $(1–10^{-4})$ to $(1–10^{-8})$ per hour	From 0,99 before 0,99999
Inaccurate entry for landing with management by vertical (APV-I)	16/8	20/10	$1–2 * 10^{-7}$ per call	10	$1–8 * 10^{-6}$ in any 15 s	From 0,99 before 0,99999
Inaccurate entry for landing with management by vertical (APV-II)	16/8	8/4	$1–2 * 10^{-7}$ per call	6	$1–8 * 10^{-6}$ in any 15 s	From 0,99 before 0,99999
Precise approach to landing on category I	16/8	6–4 / 3–2	$1–2 * 10^{-7}$ per call	6	$1–8 * 10^{-6}$ in any 15 s	From 0,99 before 0,99999

[1] To carry out the planned operation at the lowest altitude above the take-off threshold landing strip requires 95% position error with GNSS, interpreted here as 2 UPC. Detailed requirements are defined in Appendix B SARPs, and guidance material is provided in Section 3.2 of Appendix D SARPs.

[2] The definition of integrity requirements includes an alarm threshold, in depending on which it can be evaluated. Vertical Limit Range for an accurate Category I approach, it relates to the range of limits errors in the vertical plane depending on the characteristics of the control system devices. The alarm thresholds are given in table. 3.

[3] Requirements for accuracy and alarm delay include nominal operational performance of a failsafe receiver.

4 Due to the fact that the requirement of continuity during flight en route and in the area of the aerodrome
when performing the initial approach stages, NPA and departure operations depends on
several factors, including the intended operation, air density
traffic, airspace complexity and availability
alternative navigation aids, then this requirement appears at intervals
values. A lower value represents minimum requirements for areas with
low air traffic density and simple airspace structure.
A higher value corresponds to areas with heavy traffic and complex
airspace structure (clause 3.4 in appendix D SARPs).

5 A range of values is given for availability requirements as these
requirements are dependent on operational need, which is based on several
factors including frequency of operations, weather conditions, scale and
failure duration, availability of alternative means
navigation, radar coverage, air traffic and
reversibility of operational procedures. Lower requirements
correspond to the minimum availability at which the DGNSS system
used in practice, but cannot adequately replace other navigation aids.
Higher values for route navigation correspond
using GNSS as the only means of navigation in some area.
Higher quoted values for approach and departure operations respond
availability requirements at high-intensity airports
air traffic assuming landing and takeoff operations on several
Runways interconnected but separate operating procedures used
guarantee the safety of the operation (clause 3.5 in appendix D SARPs).

Table 3

Trigger thresholds for integrity monitoring

Typical operation	Response threshold horizontally, m	Response threshold vertical m
On the route (oceanic / continental airspace low traffic density)	7,400	Not assigned
On the route (continental space)	3,700	Not assigned
On the route, at the airport	1 850	Not assigned
NPA	556	Not assigned
APV-I	140	fifty
APV-II	40	20
Category I precision approach	40	15 to 10

Range I defined for an accurate approach
values. The value of 4 m is determined by the technical requirements of the ILS system and represents a conservative version of these requirements (paragraph 3.2.7 Supplement D SARPs). The designations APV-I and APV-II refer to two various levels of approach and landing with vertical control and do not imply mandatory operational use.
DGNSS Performance Requirements for Precise Entry Category II and III landing pending and will be submitted later.

2.4. Marine Consumer Requirements

In maritime transport, the following stages of navigation are defined:
ocean swimming;
coastal navigation in areas with low traffic;

sailing in ports, on approaches to them and in the coastal zone with high traffic intensity.

International Marine Consumer Accuracy Requirements determining the location, accessibility, integrity of the RNS depending on the areas sailing determined by resolution IMO - A. 953 (23) dated 12/05/2003, and resolutions of the Maritime Safety Committee - MSC.112 (73), 2000; MSC.113 (73), 2000; MSC.114 (73), 2000; MSC.115 (73), 2000.
The requirements are defined for ships whose speed does not exceed 70 knots.

Requirements of marine consumers for RNS depend on navigation areas and make up:

in the area of ocean navigation:

coordinate determination error with probability P = 0.95 no more 100 m (SKP = 50 m);

availability of at least 99.8% for a 30-day period;

in the area of coastal navigation at low intensity ship traffic:

the error in determining the place with a probability of P = 0.95 is not more than 10 m (SKP = 5 m);

the frequency of determining a place must be at least once every 1 s.
The differential correction value must be updated at least one every 30 s;

availability of at least 99.5% over a two-year period;

system operation continuity of at least 99.85% for 3 hours

when sailing in ports, on approaches to them and in the coastal zone with high vessel traffic intensity:

the error in determining the place with a probability of P = 0.95 is not more than 10 m (SKP = 5 m);

availability of at least 99.8% over a two-year period;

system operation continuity of at least 99.97% for 3 hours.

In accordance with IMO resolutions MSC.112 (73) - MSC.115 (73) in areas of ocean and coastal navigation, as well as when sailing in ports and on approaches to them, the rate of updating the data on the coordinates of the place should be at least 1 time in 1 s, and for high-speed vessels the recommended the resolution is 0.5 s.

The system integrity index cannot be more than 10 s.
It characterizes the period of time during which consumers there should be a warning that the characteristics of the signal distorted and this data cannot be used to provide navigation swimming safety.

An analysis of the stated requirements of marine consumers indicates the ability to satisfy them to the greatest extent using existing GNSS GLONASS and GPS, functionally complemented

differential subsystems, as well as promising GNSS. Based of this, in November 2001, the 22nd IMO Assembly approved the requirements for future GNSS system as set out in Resolution A.915 (22) "Revised Maritime Policies and Requirements promising world satellite navigation systems. "

The annexes to this resolution indicate promising for the period after 2010, requirements for accuracy and reliability indicators navigation information.

In accordance with this document, accuracy requirements must be increased to 10 m (P = 0.95) throughout the oceans (SKP = 5 m), and in port water area - up to 1 m (SKP = 0.5 m). For some activities on sea (hydrographic work, underwater laying pipelines, etc.) it is considered necessary to increase accuracy to 1 m (SKP = 0.5 m) and even up to its tenths when automatically set to dock (SKP = 0.05 m). As accuracy requirements become more stringent, requirements for reliability indicators for obtaining information:

integrity (less than 10 s);

sign of a warning system integrity (0.25–25 m);

availability (99.8–99.97%).

GNSS GLONASS and GPS in operation in 1996 approved by IMO as components of the World Radionavigation system. In accordance with IMO Resolutions A.953 (23) and A.815 (19) on recognition and acceptance of RNS for international satellite use GALILEO system is also recognized as an integral part of the World radio navigation system.

In the new edition of chapter 5 of the Convention for the Protection of Human Life on the sea (SOLAS), which entered into force on July 1, 2002, laid down the requirement for mandatory equipment of sea vessels, regardless of displacement, GNSS receiving equipment or ground-based RNS, or other automatic suitable for use at any time during the intended flight to determine the current coordinates.

The type of this ship equipment is approved based on the requirements developed and approved by IMO, IEC standards, as well as national standards.

2.5. Demands of River Consumers

For ships using inland waterways (rivers, lakes, etc.), initial in determining the requirements for the RNS are: dimensions of the ship the course, its depth and the ratio of the main dimensions of the vessels (length, width, draft).

River consumer requirements for RNS availability vary by region swimming and make up:

in the Unified Deepwater System of the European part of Russia - no less than 99.8% for a biennium;

the main rivers of Siberia - at least 99.5% for a two-year period.

The requirements of river consumers for integrity amount to waterway traffic no more than 5 s.

The frequency of determining a place must be at least once every 2 seconds. The value of the differential correction must be updated at least 30 sec

River Consumer Requirements for Location Accuracy

oversized vessel depending on navigation areas when assessing
the probability of the absence of a navigational accident is more than 0.997, and requirements of river consumers to the accuracy of determining the place when solving other tasks are given in table. 4.

Table 4

Requirements of river consumers for various tasks

Tasks to be Solved	Sailing areas and work	Measurement accuracy coordinates (SKP), m
Ensuring the movement of the vessel by inland waterways	Lakes, reservoirs	10-17
	Free rivers:	
	European part of Russia;	2.5–5
	Siberia	2.5-7.5
	(other states - CIS participants)	-
	Channels	1–2.5
Hydrographic work, shipping marks furnishings; maintaining given dimensions of water the way	Lakes and reservoirs	2–3.5
	Free rivers:	
	European part of Russia;	0.5–1
	Siberia	0.5–1.5
	(other states - CIS participants)	-
	Channels	0.2–0.5
Excavating and dredging	Free rivers and canals	0.1–0.2
Cabling and pipelines	Free rivers and canals	0.5
Dispatch tasks for monitoring	Inland waterways Of Russia	fifty

The analysis of the stated requirements of river transport shows that their Satisfaction is most possible using GNSS and their functional additions.

2.6. Ground Consumer Requirements

Motor transport

Generalized tasks when using vehicles and relevant requirements for RNS can be grouped as follows way:

urban transportation requires accuracy (UPC) of 5 m, availability of RNS and their functional additions 0.98–0.99, including in conditions of high-rise urban development. Special Requirements for continuity of navigation services in such systems is not are presented;

intercity transportation and off-road transportation operations, which require accuracy of coordinate determination (SKP) 10 m, accessibility RNS and their functional additions 0.98–0.99;

transport of special and dangerous goods require accurate determination coordinates (SKP) 5 m, the availability of RNS and their functional additions more than 0.99 and high continuity of service. Also required ensuring stable control of the situation under conditions of possible interference;

transport operations of special equipment of road services require coordinate accuracy (UPC) of 5 m in cities and 10 m on highways;

providing construction, planning and road works in cities and on roads requires geodetic accuracy (SKP) of 0.02–0.05 m and should implemented using special navigation equipment, working with both GNSS signals and their functional signals additions, the same level of accuracy requires location agricultural machines in the interests of solving the tasks of precision farming.

Navigation information is essential for effective management. vehicles both in personal navigation mode and in external control mode. Personal navigation is carried out with using special GNSS user equipment - so called navigators. Similarly carried out and personal navigation of pedestrians, tourists, etc.

Typical requirements for the accuracy of navigation transport support are given in table. 5, the main operating technical requirements for vehicle management systems - in table. 6.

New requirements arise in the provision of navigation the needs of highly automated vehicles with unconditional compliance with road safety requirements. IN the concept of highly automated vehicles are also included autonomous or unmanned vehicles. It is necessary take into account the likely occurrence of self-governing in the near future cars interacting with each other, with intelligent transport systems and road infrastructure using V2X technology. In all cases, in automated transport control systems means navigation data should be used.

Table 5

Typical Precision Performance Requirements (UPC) navigation support of transport (m)

Ground traffic conditions of transport	Requirements for the accuracy of positioning (m), in modes	
	Offline Location	Dispatch control
Citywide and suburban transportation	15–65	7-50
Vehicle wiring city center	15–65	1,5-15
Transit between cities	50–250	12–150

Thus, a substantial increase is currently required. accuracy of determination of coordinates and high continuity of service. It is necessary to focus on positioning accuracy (UPC) within lanes of highly automated vehicles from 0.33 m up to 3.3 cm when driving at permissible road speeds.

These requirements must be submitted for ensure sustainable positioning of highly automated vehicles in conditions of probable interference, especially in the dense area urban development. It should be noted that the original scope introducing new technologies focused on highways with gradual transition to the urban environment.

Such an increase in accuracy can be realized using

GNSS RTK methods through differential
corrections received by the user equipment from the base station.

A promising way to solve the problem also seems using high precision PPP positioning methods, but in this In this case, consumers need relatively expensive (at this moment) multi-frequency receivers.

However, it is advisable to ensure compatibility of funds positioning with technical solutions adopted by manufacturers highly automated vehicles in states - CIS participants.

Special requirements for navigation continuity services in terrestrial consumer systems are currently not are presented.

Table 6

Key operational and technical requirements for promising vehicle management systems

Characteristic	Systems management urban by road	Systems management regional transportation	Systems management international transportation	Systems management for individual motor transport
Instrumental system capacity (quantity at the same time served by cars)	500–1,000	500	1,000 [1]	-
Average pace data exchange with	thirty 10 - for special vehicles	60–90	900–7,200	-
Accuracy (UPC) navigation, m	In the center - 2.5; on the highway - 15	10	fifteen	20
Availability navigational providing	0.99 [1]	0.95	0.95	0.9
Integrity (reliability) providing navigational data and communication	0.98; 0.99 - for special systems	0.97	0.97	-
Compatibility of systems	Unified standards for interfaces, used to access the radio lines			-

[1] Based on local navigation.

Railway transport

Accuracy requirements for satellite RNS determining the location (positioning) of objects Railway transport can be combined into three groups:

1) those systems and transport operations in which it is necessary control the deployment of rolling stock, including those with dangerous by cargo and guarded persons, location of vehicles diagnostics and track machines in order to monitor the implementation of planned

tasks, approach to the place of work, etc. For such functional
applications sufficient positioning accuracy (UPC) of 10 m, which, in
in principle, achieved with direct satellite determinations at
the condition of working with GLONASS / GPS orbital groups in regular
24 satellite configurations in each system;

2) those systems and production operations in which satellite
navigation information is used directly in systems
management and safety of objects
railway transport. For such functional applications

navigation is required with the accuracy of determining the position of the object
composition to a specific rail track, which corresponds to accuracy
positioning (SKP) 0.33 m;

3) systems for ensuring control of track facilities and track
construction that require "centimeter / millimeter" accuracy
location determination. Technically, this is possible only in the case of
sharing signals of GLONASS / GPS / GALILEO systems with
amendments of differential correction systems (differential
amended) using satellite wide-area or terrestrial
local (regional) differential complement.

Summary of required positioning accuracy
directions of activities of farms and railway services, determined
current regulatory and technical documents are given in table. 7.

Table 7

Consumer Specifications to location accuracy

Area (types) application coordinate of information	Objects requiring coordinate definitions	Requirements by accuracy definitions location	Requirements to reliability definitions location	The main regulatory technical sources

1	2	3	4	5
1. Engineering geodesic research for building new and capital repair acting iron dear	Items satellite geodesic the network	UPC mutual clauses satellite geodetic network should not exceed 2-3 cm in plan	Marginal errors equal 5 cm, not should exceeded by 10 %	1. Instructions for topographic shooting in scale 1: 5000–1: 500. GKINP-02-033-82. 2. The code of rules of the joint venture 11-104-97. Engineering geodesic research for construction. 3. Richtlinie DB 883.0031. Fahrbahnen abstecken (Guide field tracing)
	Clear objects (elements) terrain	UPC definitions clear objects terrain regarding points satellite geodetic network should not exceed 0.4-0.5 mm per topographic plan	Marginal errors equal to 0.8 mm in scale plan should not exceeded by 10 %	
	Relief terrain	UPC images relief horizontals not more than ¼ accepted relief sections	Marginal errors equal ½ adopted relief sections should not exceeded by 10 %	
2. Field tracing (transfer project in nature)	The main the elements rail ruts switch transfers, etc.	UPC Transfer elements rail track not must exceed 1.5 cm in longitudinal direction 0.25 cm in transverse direction regarding points satellite geodetic network	Double UPC should not exceeded by 5 %	
3. Control geometric parameters rail gauge with help track-real funds for computation installation data for straightening the way	Wireframe points special reference network	UPC provisions point - 25 mm; UPC mutual position - 5 mm in terms of	Double UPC should not exceeded by 5 %	Special reference system control state railway way in profile and plan. Technical requirements approved Ministry of Railways of Russia 26 March 1998 year
	The main and intermediate (ordinary) points special reference network	UPC mutual clauses after 10 km - 15 mm in terms of; after 500 m - 4 mm in terms of; after 500 m - 2.5 mm in height		
	UPC Mutual Working Points			

1	2	3	4	5
	special reference network	provisions - 2.5 mm in plan and 1.5 mm in height		
	Geometric specifications rail gauge	Relative UPC definitions axis deviations paths from a given no provisions must exceed	At using track gauge wagon and trolleys for increase	Materials justification investment in construction high speed railway

		0.04 mm / m in plan and 0.03 mm / m height	reliability and accuracy with application satellite receivers and satellite inertial systems on practice produce excess measurements with in such a way to eat of information was carried out every 20–25 cm the way	highways Moscow - St. Petersburg Engineering geodesic research. RZHD-077 / 03-008
4. Content earthen canvases	Items earthen canvases drainage, fortifying protective facilities	Species requirements periodicity terms and order the implementation oversight of subgrade installed Instruction on content subgrade. Directory defined earth defects canvases. Digital earth model canvases compiled on performance basis special periodic filming with using satellite aerospace airborne and ground methods shooting, including using radars. By precision digital	To strengthen sustainability earthen canvases on each track distances approved list of species activities for content earthen canvases designed for complete elimination deformations	Instructions for content subgrade the railway the way. Approved by Ministry of Railways of Russia March 30, 1998 CPU-544

1	2	3	4	5
		earth model canvases corresponds to precision scale 1: 1,000		
5. Content artificial facilities	Items artificial facilities (bridges, overpasses flyovers viaducts tunnels water starting pipes trays, galleries, mudflows and etc.)	Requirements to species periodicity terms and order the implementation oversight of artificial facilities installed Instruction on content artificial facilities. Digital model artificial facilities	Reliability oversight of artificial facilities provided by automated system created for permanent observation of artificial facilities	Instructions for content artificial facilities. IPU approved Russia December 28 1998 CPU-628

		compiled on basis instrumental periodic filming with using satellite receivers laser scanning systems high precision electronic total stations automatic machines geotechnical sensors. For operational observations dynamic properties of the most important and responsible objects should to be provided high accuracy measuring spatial data in mm and cm range in real time		

1	2	3	4	5
6. Land surveying right of way iron the roads	Land marks allotment bands iron the roads	UPC provisions boundary marks regarding points satellite geodetic network should not be more than 10 cm (0.1 mm on the plan scale 1: 1,000)	Reliability received results controlled by based established the procedures land surveying	Instructions for land surveying. Approved by Roskomzem April 18th 1996 year. The main provisions on reference boundary network. Approved by Roszemkadastrom April 15th 2002 year
7. Security safety iron road movements	Movable facilities, special movable facilities	In accordance with requirements security UPC definitions location train should be 0.5 m (for recognition the way in which there is a train) operational readiness - 99.98% and duration disturbing state - 1 s	To provide reliability definitions location trains in the system differential correction and monitoring GLONASS and Galileo are being created services for increase reliability satellite navigation on iron the roads	Project "GALILEO for iron dear

Regarding the characteristics of the availability of satellite navigation data definitions for railway systems required value corresponds to 0.98–0.99 in all conditions, including railway operations on the territory of enterprises and in cities with high-rise buildings, operations in deep quarries and on stages in deep ditches.

To ensure sustainability and increase accuracy of positioning on moving objects of railway transport it is necessary to implement a multisystem GLONASS / GPS, and in perspective - GLONASS / GPS / GALILEO navigation equipment with satellite corrections wide-zone differential correction and monitoring system. Centimeter and higher levels of accuracy can be achieved with using local differential subsystems.

2.7. Requirements for Surveying

The advantage of satellite technology over conventional methods Surveying is so impressive that they find in topographic the geodetic production of the CIS member states is increasingly application, despite the high cost of equipment.

The high accuracy required in surveying can be obtained with simultaneous observations of GNSS satellites by several receivers phase measurements. With this observation technique, one of the receivers usually located at a point with known coordinates, and position other receivers can be determined relative to the first receiver with accuracy of a few millimeters. This method is called relative method. In this case, measurements are possible at distances from several meters to thousands of kilometers.

It should be noted that in the territories of the CIS member states various coordinate systems are used, including GSK-2011, PZ-90.11, SK-95, SK-42, WGS-84. National Government Reference Systems coordinates are implemented by points of the state geodetic network, including points of the fundamental astronomical and geodetic network, high-precision geodetic network, satellite geodetic network of the 1st class and geodetic thickening networks.

Requirements of various consumers for the initial astronomical geodetic and gravimetric data differ significantly in accuracy and efficiency.

Consumer requirements for the accuracy of the original astronomical and geodetic and gravimetric data for solving special problems are given in tab. 8.

Table 8

Consumer requirements for accuracy astronomical and geodetic and gravimetric data

Tasks of geodetic support	Consumers	Accuracy (UPC)
Creating a geocentric system coordinates (accuracy of reference to Earth's center of mass), m	Space exploration fundamental science navigation, oceanography,	0.05

	space geodesy	
Parameter Definition Earth's gravitational field:		
geoid heights globally, m		0.1
		0.02-0.03 (territory of Russia)
steep line deviation, ang. sec		0.5–1
Defining System Connections coordinates:		
linear elements, m		0.05–0.1
corner elements sec		0.01

Tasks of geodetic support	Consumers	Accuracy (UPC)
Defining orientation parameters Earth, ang. sec		0.001

GNSS-based precision positioning technology GLONASS in post-processing mode allows you to determine the coordinates points of the state geodetic network with an error of the order of units millimeters, which guarantees customer satisfaction in interests of geodetic support.

2.8. Requirements for Space Consumers

For promising spacecraft for various purposes a significant increase in the effectiveness of target solutions is envisaged tasks while increasing the autonomy of their functioning. it causes a sharp increase in the requirements for navigation support of the spacecraft, which cannot be provided with traditional ground facilities and require the use of on-board navigation aids.

At the same time, GNSS GLONASS navigation receivers become an integral part of the onboard spacecraft control complex, information from which is used both to refine the orbital motion parameters spacecraft mass center, and for planning targets in the airborne complex spacecraft control.

Basic requirements for the accuracy of determining motion parameters of the center of mass and orientation of promising spacecraft by airborne means navigation support are presented in table. 9 and 10.

Table 9

Accuracy requirements for airborne navigation aids providing promising spacecraft

KA classes	Determination error motion parameters of the center of mass (UPC)	Note
Communication and relay spacecraft	Not worse than 200 m in all coordinates	
Spacecraft navigation support	0.7 m - equivalent ephemeris error (in the direction from the spacecraft to consumer)	The error is given for 2014 onwards declining in According to provisions federal target programs "Maintenance, development and use of system GLONASS 2012–2020 years
Geodesic support satellite	0.03 m - along the orbit and in lateral direction 0.03 m - in height	
Spacecraft detection system distressed objects	33 m in all coordinates	
Spacecraft of geophysical support	17–50 m in all coordinates	

Table 10

Requirements for the accuracy of orientation systems of perspective spacecraft

KA classes	Orientation accuracy requirements KA (SKP), ang. min
Communication and relay spacecraft	1 - 1.3 across all channels
Spacecraft navigation support	10 on all channels
KA of geodetic support	2 - 3.3 on all channels
Spacecraft of geophysical support	2 on all channels

The required accuracy of the navigation support of other spacecraft, missiles carriers, booster blocks, orbital stations is 20-30 m. For performing a number of critical dynamic spacecraft operations (spacecraft approach, spacecraft descent and landing on Earth, etc.), as well as solutions of a number of high-precision tasks of navigation, geodesy, geodynamics, cartography and other using special spacecraft (navigation, geodetic, Earth remote sensing, etc.) required accuracy the location of these spacecraft should be no worse than 1 m.

The highest requirements for accuracy are presented to onboard spacecraft navigation and geodetic support, and accuracy orientation - to the onboard means of the spacecraft communications and navigation. For promising space assets, it is advisable to submit requirements for accuracy (UPC) for speed and orientation angles at the level of 0.01 m / s and 0.6 ang. min respectively.

2.9. Unified Rescue Services Requirements

Currently in the interest of finding those in distress facilities operated by international satellite search and rescue Cospas-Sarsat system (Cospas-Sarsat system). As part of the system geostationary and low-orbit spacecraft are involved. 35 years of experience system operation has proven its high efficiency compared with other means of rescue.

However, the current needs of rescue services cannot be fully ensured that satellite systems are inherent disadvantages such as poor accuracy in positioning objects and insufficient efficiency of information transfer (in low-orbit systems), as well as non-provision of a global overview of the earth's surface (in geostationary systems).

Requirements for Advanced Satellite Detection Systems distressed objects are in the process of formation.

Updated Cospas-Sarsat system requirements were identified when deciding on the use of the medium-orbit spacecraft GNSS (including the GLONASS spacecraft) in order to ensure search and rescue in addition to existing space systems in view of the completed development of emergency beacons and beacons of the second generation.

The requirements take into account the variety of possible objects: from large ships and aircraft to small boats and light aircraft, as well as people in emergency situations.

Requirements have the following indicators:

service area is global;

object detection efficiency - units of minutes;

the probability of detecting an object is not worse than 0.99;

Efficiency of information delivery to reception centers - units of minutes;

Accuracy of determining the coordinates of the accident site (UPC) - 33 m;

the number of simultaneously detected emergency facilities - 150–250;

ensuring the functioning of the feedback line to emergency beacons to acknowledge distress reception and control emergency beacon transmissions;

generating additional encoded data for search services.

These requirements are put forward to ensure rescue operations not only in open but also in rugged terrain.

2.10. Time-Frequency Support Requirements

Existing practice shows an urgent need for continuous consumer information on the exact time and reference frequencies.

Generalized requirements for timeline synchronization and frequency synchronization of the master oscillators are given in table. eleven.

Table 11

Requirements for synchronizing timelines of objects and to frequency instability

Objects and Tasks	Parameters					
	Universal Snap Accuracy coordinated time (UTC)			Coating	Access-%	Discretion nost
	Level	Stable nost	Relative nost			
Communication systems including subsystems management and others support systems	Dozens ns	10^{-12} (frequency)	Up to 100 ns 1 day averag	National flaxseed	99.7	Continuous jerkily
Science community	Ns	10^{-16} (frequency, 30 days Avg.)	50 ns 1 day averag	Global new	99.7	Continuous jerkily
Banks and Finance	FROM	-	-	-	Utoch-huddles	Utoch-huddles
Synchronization electric power industry	ISS	-	-	Continent	99.7	1 s

The main consumers in the system of time-frequency support are telecommunication network operators. Consumers of signals a single exact times are also: computing systems and computer servers (network management and monitoring systems equipment), equipment of transport networks and switching networks, billing and database servers; data transmission and packet equipment switching (routers, switches), etc.

Information about the exact time can be used by energy companies for measuring the phase difference in power plants, registration events, subsequent analysis of situations, phase and current frequency measurements power plants etc.

Another application of accurate time is clock synchronization. when conducting astronomical observations such as observations on ultra-long base interferometers using pulsars.
The relevant requirements here are still in the process of formation.

The development of digital networks of telecommunication operators determines the need to create and improve a network clock system synchronization, which is called a set of technical means, providing the formation of reference synchronization signals and their network transmission to all master oscillators in digital equipment transmission and switching systems. Highest requirements synchronization are presented when digital switching systems interact with transmission systems of a synchronous digital hierarchy.

In the CIS member states, the task of the time-frequency software is solved by emitting reference frequency signals and specialized radio facilities, as well as methods and means of network clock synchronization.

Reference signals of frequency and time are intended for transmission units of time, frequency, and UTC from state primary standard to reference and working means measurements in order to ensure the uniformity of measurements in the country.

Radio navigation aids, including GNSS GLONASS and radio navigation systems of ranges of long and extra-long waves, are means of broadcasting reference signals of frequency and time.

2.11. Requirements of special consumers of navigation services

Radio navigation support for consumers of law enforcement agencies and law enforcement agencies of the CIS member states is required when solving the following tasks:

management of mobile forces and assets;

remote determination of coordinates of remote objects and output navigation designations;

geodetic and cartographic support of special tasks;

synchronization of time scales in communication systems, local computer networks and control points of law enforcement agencies;

official transport control;

equipping transport, technical means and systems subject use in the announcement of mobilization readiness and intended for work in special periods of the military-political the setting.

In the activities of law enforcement agencies can be allocated special tasks requiring special navigation support:

creation of safety auto corridors, implementation of trunk passenger and cargo transportation, intercity transportation special contingent monitoring large groupings of official vehicles law enforcement;

security during the protection of important state facilities (critical and potentially dangerous objects), including control for the displacement of elements of stationary structures and structures;

crime detection (covert surveillance of arms transfers, narcotic drugs, etc.);

actions of special forces in solving security tasks public order, special operations in limited spacecraft visibility (including in “enclosed” rooms, wooded and mountainous terrain);

search for stolen or stolen vehicles equipped navigation equipment of satellite anti-theft systems;

monitoring of supervised persons using small-sized bracelets;

control of unmanned aerial vehicles, balloons and air probes for special tasks;

Earth remote sensing in order to detect illegal activities (illegal logging, sowing of drug-containing plants, deliberate arson, etc.).

Special consumer requirements for radio navigation software are formulated by groups of tasks and are presented in table. 12.

Table 12

Special customer requirements for location accuracy

Tasks to be Solved	Error location (UPC), not more than, m

Dispatch tasks	fifteen
Prevention and disclosure of crimes. Problem solving in urban conditions (street patrolling, harassment and detention criminals, search for stolen cars, covert surveillance single moving objects, etc.)	5-7.5
Conducting anti-terrorist operations, release hostages, warfare, monitoring of individual fighters and military personnel, monitoring of special trains and rail compositions	1.5–2.5
The work of special forces in special conditions (closed, smoky premises, underground premises (cellars, tunnels), mountainous terrain, difficult interference environment, etc.), monitoring unmanned aerial vehicles in the area of special operations	0.5–1.5 (using means functional additions)

An important element of a future perspective coordinate system temporary and navigation support for special consumers based on GNSS GLONASS should become a radio navigation interference monitoring system GNSS. The expediency of creating this system is due to the deterioration electromagnetic environment due to an increase in the number navigation-related systems, increasing the level of industrial interference

due to industrial production, as well as increased risks of creation intentional interference.

2.12. Generalized requirements of the main consumer groups

The generalized requirements for RNS are determined based on the requirements air, sea, river land and space consumers taking into account international requirements to ensure the most mass consumers radio navigation information - air and sea.

International Navigation Support Requirements aviation facilities and ships are defined in international documents ICAO and IMO organizations.

Basic general requirements for radio navigation support when positioning are given in table. thirteen.

Table 13

The main generalized requirements of consumers to navigation support

Potre-beaters	Tasks to be Solved	Work zone	Error a place-definitions (UPC), m	Availability (operation national willingness)	Integrity (probability or time)

1	2	3	4	5	6
	Route Flights (track)	Global regional	370–1850	0.99–0,99999	$1 \cdot 10^{-7}$ / h
	Flights at the airport	Area airdrome	370	0.99–0,99999	$1 \cdot 10^{-7}$ / h
E S N W At	Uncategorized call for landing	Area airdrome	8–110 - in plan; 4-10 - by height	0.99–0,99999	$1 \cdot 10^{-7}$ / h
ZD ABOUT IN	Sunset and landing on ICAO categories	Facility area landing	2–8.5 - in plan; 0.3–2 - each height	0.99–0,99999	$1–2 \cdot 10^{-7}$
	Special tasks, geodetic and geophysical observations	Local	1-10	0,999	0,999
	In areas of the ocean swimming	Global	fifty	0,998 for 30 days	10 s
	In coastal areas swimming at low traffic intensity ships	Regional	5	0,995 for 2 years	10 s
E AND TO FROM R ABOUT M	When sailing in ports, on approaches to them and in high coastal area traffic intensity ships	Local	5	0,998 for 2 years	10 s
	Across the oceans (prospective requirements)	Global	5	0,998–0,9997	10 s
	When swimming in water areas ports and execution special works (promising requirements)	Local	0.05–0.5	0,998–0,9997	10 s
E S N H E R	Vessel traffic on inland waterways:				
	lakes, free rivers	Lakes Areas, rivers	2,5-17	0,995–0,998	5 s
	channels	Areas channels	1–2.5	0,995–0,998	5 s
	character placement cartography, etc.	River areas channels	0.1-3.5	0.99	5 s
	Ship monitoring	Domestic waterways Of Russia	fifty	-	-
E S N M ZE A	Ground movement transport in cities and	Local	2,5-10	0.98-0.99	0.98-0.99

N suburbs. Monitoring
Calling cars in an accident,

1	2	3	4	5	6
	ambulances				
	Movement at long distance regional and international transportation. Monitoring Calling cars in an accident, ambulances	Regional local	10-15	0.95	0.97
	Special solution tasks (providing special consumers of the Ministry of Internal Affairs and other)	Local	2.55–15	0.99	0.99
	Motion control Russian Railways facilities construction and agricultural cars	Regional local	0.05–0.5	0,9998	1 s
	Cartography and geodesy, land management Russian Railways	Global regional local	0.1 0.02–0.05 0.003–0.006	-	-
	Communication and relay spacecraft		200		
E AND TO FROM E H AND M FROM ABOUT TO	Spacecraft navigation providing		0.5 (can decline)		
	Geodesic spacecraft remote sensing software		0.02-0.3		
	Spacecraft detection system distressed objects		33		
	Spacecraft geophysical providing rockets-carriers, booster blocks, orbital stations		17-50		

3. GENERAL CHARACTERISTICS OF EXISTING AND DEVELOPED RADIO NAVIGATION SYSTEMS

3.1. Classification of radio navigation systems

Existing and under development RNS are divided into two main groups depending on the location of the regular transmitting means:

1) space-based (satellite RNS);

2) ground-based (stationary and mobile).

The classification of RNS is presented in Fig. 2.

The allocation of radio frequency bands for electronic equipment RNS carried out in accordance with Article 5 of the ITU Radio Regulations for Region 1. Radio frequency bands used by existing radio-electronic means of radio navigation systems are indicated in application.

Fig. 2. Classification of existing radio navigation systems

3.2. Satellite navigation systems

3.2.1. Global Navigation Satellite Systems

Currently and in the short term, by consumers
The following GNSSs may be used by CIS member states:

GLONASS (Russia);

GPS (USA);
GALILEO (EU);
BEIDOU (PRC).
GNSS GLONASS and GPS are fully operational.
GNSS GALILEO and BEIDOU are under deployment.
The main characteristics of these GNSS are given in table. 14.

Table 14

Key GNSS Features

Characteristic	GNSS Type			
	GLONASS	GPS	Galileo	BEIDOU
Type of orbit	Medium high pericircular	Medium high pericircular	Medium high pericircular	Medium high pericircular, geosynchronous inclined pericircular, geostationary
Orbit height no more, km	19 100	20 181.6	23,222	21,527
number planes	3	6	3	3
Mood, hail.	64	55	56	55
The number of spacecraft in the plane	8	5-6	10	9
Regular / current squad KA	24/26	32/31	27/17	31 / (15 + 16) 3/6 5/6
Period treatment	11 h 15 min	11 h 58 min	14 h 4 min	12 h 53 min
Used ranges frequencies	L1, L2, L3	L1, L2, L5	E1, E5, E6	B1, B2, B3
Carrier frequency, MHz	L1: 1,600.995 L2: 1,248.060 L3: 1 202.025	L1: 1,575.42 L2: 1,227.60 L5: 1,176.45	E1: 1,575.42 E5: 1,191.79 E6: 1,278.75	B1: 1,575.42 B2: 1,191.79 B3: 1,268.52

Characteristic	GNSS Type			
	GLONASS	GPS	Galileo	BEIDOU
Signal	L1OCd L1OCp L2 CSI L2OCp L3OCd L3OCp	C / a P M $L1C_D$ $L1C_P$ L2c L5I L5Q	E1a E2b E1C (pilot) E5a-i E5a-Q (pilot) E5b-i E5b-Q (pilot) E6a E6b E6C (pilot)	B1-CD B1-CP B1d B1p B2aD B2aP B2bD B2bP B3 B3-ad B3-AP
Type of modulation	BPSK (1) BOC (1, 1) BPSK (10)	Bpsk BOC (10, 5) BOC (1, 1)	BOC (15, 2.5) MBOC (6,1,1 / 11) AltBOC (15, 10)	MBOC (6,1,1 / 11) BOC (14, 2) AltBOC (15, 10)

TMBOC (6, 1, 1/11)	BOC (10, 5) Bpsk	QPSK (10) BOC (15, 2.5)

3.2.2. GNSS GLONASS

GLONASS is designed to determine location, speed movement, exact time of sea, air, land and space consumers, as well as to perform additional information functions.

GLONASS provides the solution of tasks of coordinate-time and absolute navigation support for unlimited the number of stationary and mobile consumers continuously throughout the Earth's surface and to heights of 2,000 km, and discrete to heights of 40,000 km.

GLONASS in advanced configuration includes the following components:

space complex, consisting of an orbital constellation, means withdrawal, ground control complex;

functional add-ons including wide-area system functional complement - differential correction system and monitoring, as well as regional and local monitoring systems and differential navigation;

high precision ephemeris time detection system information;

fundamental support tools - operational systems determining the parameters of rotation and orientation of the Earth, system the formation of a global coordinated state scale time, geodetic basis of the Russian Federation;

navigation equipment of consumers.

The radio navigation field of the GLONASS system is created by the spacecraft, located in medium orbits. Orbital grouping system GLONASS includes 26 spacecraft: 2 spacecraft Glonass-K and 24 spacecraft Glonass-M. Mid-orbit navigation spacecraft move in circular orbits with with a nominal altitude of 19,100 km, an inclination of 64.8 and a circulation period of 11 hours 15 minutes. 44 sec Orbital planes of navigation spacecraft and their consistent orbit movement selected in such a way as to ensure continuous and global coverage of the earth's navigation field and near-Earth space to an altitude of 2,000 km.

Number of reserved rangefinding code signals provides the ability to expand the orbital constellation to 64 navigation spacecraft. Expansion of the orbital constellation may performed as adding navigation satellites inside or between orbital planes, and the construction of orbital additions on mid-altitude, geosynchronous and highly elliptical orbits.

At the design stage for the GLONASS system, a frequency the method of separation of signals of different spacecraft: each of them uses its own a pair of carrier frequencies, one of which belongs to the range L1, the other - range L2. Until the end of the use of signals L1, L2 s frequency division will support basic orbital grouping. Navigation spacecraft extensions of the orbital constellation may emit only code signals or code and frequency signals together (when the presence of free carrier frequencies).

At this stage in the development of the GLONASS system, development is underway

frequency range L3 and code division.
For the radio signals of the navigation satellites of the GLONASS system the following limits of emission bands:
L1 (1 592.9–1 610) MHz;
L2 (1 237.8–1 256.8) MHz;
L3 (1,190.35–1,212.23) MHz.
The parameters of the signals of the navigation spacecraft are reflected in the following docs:
“GLONASS Global Navigation Satellite System. Interface control document. Radio navigation signal in ranges L1, L2 (version 5.1) ";
“GLONASS Global Navigation Satellite System. Interface control document. Radio navigation signal open access with code division in the range of L1. Edition 1.0 ";
“GLONASS Global Navigation Satellite System. Interface control document. Radio navigation signal open access with code division in the L2 range. Edition 1.0 ";
“GLONASS Global Navigation Satellite System. Interface control document. Radio navigation signal open access with code division in the range of L3. Edition 1.0 ";

“GLONASS Global Navigation Satellite System. Interface control document. General Description of the Code System signal separation. Revision 1.0. "

3.2.3. GNSS GLONASS Functional Additions

GNSS functional supplement is a complex hardware and software designed to provide GNSS consumer with additional information to enhance accuracy and reliability of determining its spatial coordinates, components of the velocity vector and corrections of the clock and guarantee GNSS integrity.

In general, functional additions are not understood to mean hardware and software included in GNSS designed to improve the accuracy of navigation definitions consumers based on GNSS navigation signal. General principle the construction of functional additions GNSS is to implement differential mode of navigation definitions, in which consumers receive corrective information, which is a guarantee differential corrections in the "classical" differential mode navigation using ground control stations. This corrective information is an error estimate. measurements and data on the integrity of the GNSS navigation field, which taken into account by consumers in their navigation definitions and allow eliminate the corresponding components of the total determination error location.

In the CIS member states, the following are deployed and operate: a set of functional add-ons GLONASS; satellite system accurate positioning of the Republic of Belarus; precision system satellite navigation of the Republic of Kazakhstan.

The complex of GLONASS functional additions includes: wide-field SDKM; regional and local differential system. SDKM is designed to improve accuracy and ensure

the integrity of the location of marine, air, land and
space consumers.

The principle of work of SDKM is to obtain on the basis of measurements current navigation parameters and navigation information open GLONASS and GPS signals in the ranges L1 and L2, operational and a posteriori estimates of ephemeris-time information and a value map vertical ionospheric delays. The obtained data are used for the formation of corrective information and integrity information. This information is delivered to the consumer via spacecraft and over the Internet.

SDKM provides consumers:

information about the integrity of the navigation field;

updated ephemeris-temporal information;

corrective information on measurements;

information on the quality of GNSS GLONASS, GPS and perspective - GALILEO.

SDKM provides accuracy at the level of units of meters, compliant with ICAO SBAS standards. Main The consumer of the system is civil aviation.

SDKM provides a high-precision positioning service, designed to determine the absolute coordinates of fixed consumers (with an error of up to 1 m) using a large-base system GNSS GLONASS measurements using ephemeris-time SDKM information located from the nearest base station no more than 3,000 km. The accuracy of estimating the coordinates of consumers depends on the duration of the navigation session.

SDCM coverage area is the territory of the Russian Federation and adjacent geographic areas. More than 20 SDKM observation points located in Russia, South America and the Antarctic stations. The development of SDKM involves the deployment of additional stations in Russia and about 50 measurement collection stations more than in 30 countries of the world.

GNSS differential satellite subsystems providing navigation activities are represented by local marine and aviation subsystems.

The marine differential satellite subsystem is complex of technical means, including control and corrective station and marine beacon with appropriate infrastructures, GNSS differential corrections GLONASS / GPS and the transmission of corrective information, which provides improving the accuracy and reliability of navigation definitions.

Marine differential satellite subsystem designed to solving the following tasks:

increased navigational safety of navigation while sailing along fairways, recommended routes, traffic separation systems, and in areas with limited maneuvering capabilities;

providing ship traffic control systems with information on ship location coordinates;

implementation of an automatic identification system for control movements of vessels with dangerous goods, as well as for vessels whose place should precisely and automatically controlled;

improving the conditions for the protection of marine resources;

creation of landfills for determining the maneuverability characteristics of ships;

provision of special works, which include:

survey of waters during the construction of new port facilities;
dredging and monitoring;
hydrographic trawling;

precise setting of navigational aids;
high-precision geodetic reference points and signs on approaches to new port facilities.

On inland waterways, in the seaports of the Russian Federation and on the approaches to them, as well as in the waters of the Northern Sea Route and 63 local control and correction are in operation GLONASS differential subsystem stations and local control correction stations of base stations automatic identification system. Range of control correction stations is 200 km.

GNSS marine differential satellite subsystem contributes to emergency assistance and other emergency situations due to high-precision location disasters, oil spills, etc. For the organization of operational support search and rescue operations and other special operations performed out of range of stationary stations marine differential satellite subsystem, mobile differential stations are being created GNSS with a range of customer service up to 100 km and preserving all established for the marine differential satellite subsystem characteristics.

The port of Aktau (Republic of Kazakhstan) has a sea differential satellite subsystem that operates as part of high-precision satellite navigation systems of the Republic of Kazakhstan.

Aircraft local differential satellite subsystems (ALDPS) are a satellite airborne landing system ships. The composition of the equipment and the main characteristics of ALPS are determined ICAO SARPs for GNSS functional complement system with ground GBAS stations designed to land aircraft in category I. The VHF radio channel was adopted as the GBAS data transmission line frequency range 108–118 MHz.

Currently, at 106 airfields of the Russian Federation GNSS functional aids deployed ground-based ALDPS GBAS based on domestic local control and correction stations LKS-A-2000.

Appointment LKS-A-2000:
ensuring meter accuracy of navigation;
providing uncategorized and categorized visits to landing from both courses of all runways of the aerodrome and implementation of standard schemes Arrival and Departure (P-RNAV; RNP AR; RNP 0.01);
GLONASS / GPS signal integrity control and transmission to aircraft landing data blocks, curved data blocks approaches and differential corrections;

registration and storage of data on the state of GNSS GLONASS / GPS in service area in accordance with the requirements for the organization of air movement

issuing GNSS status information to interacting services.

Satellite positioning system of the Republic of Belarus provides coordinates and heights of points of geodetic and survey substantiation of topographic surveys, determination on the ground land boundaries, boundary marks and turning points of borders urban features as well as aerial photography centers in given coordinate system.

Satellite positioning system of the Republic of Belarus totals 98 permanently operating points (base stations) and provides coverage with an RTK signal throughout the Republic Belarus, providing GNSS signal reception and GPRS communication.

The time for obtaining coordinates for the first point is no more than 1–1.5 min., for subsequent measurements - in real time. Accuracy determining the coordinates of objects in ITRF by phase measurements is 1–2 cm in plan, 2-3 cm in height.

Coordinate accuracy for DGPS applications using code measurements is 0.25–1 m. The resolution of the RTK mode is 1 s. Reception corrections are carried out via GPRS communication from satellite system servers accurate positioning of the Republic of Belarus.

System of high-precision satellite navigation of the Republic of Kazakhstan provides high accuracy, quality and integrity of navigation data throughout the Republic of Kazakhstan.

On the territory of the Republic of Kazakhstan 60 differential stations located in all regional and part district centers. Each station provides high precision coverage data within a radius of 35 km from the center of the antenna.

The resulting coordinate accuracy:

in DGNSS service mode - 1 m in real time by 94% territory;

in RTK service mode - 2 cm in real time by 18% territory;

in the PPP service mode - does not exceed 1 cm in the post-processing mode.

3.2.4. Cospas-Sarsat System

Cospas International Satellite Search and Rescue System Sarsat is designed to determine the coordinates of distressed ships, planes and people.

The system uses geostationary and low orbit KA.

Parameters of geostationary spacecraft:

the height of the orbit is 36,000 km;

angle of inclination of the orbit - 0 ° ;

geostationary spacecraft survey area - 90% of the earth surfaces excluding polar latitudes above 75 ° .

Parameters of low-orbit spacecraft:

the height of the orbit is 850–1,000 km;

circulation period - 100-102 min;
angle of inclination of the orbit - 98–99 ° ;
the radius of the instantaneous visibility zone is up to 2,500 km.

Complementary spacecraft groupings of the Cospas-Sarsat system provide:

global survey of the earth's surface;

instant alarm relay from all over the earth surface;

receiving a re-reflected alarm in the conditions of its blocking obstacles.

As sources of distress signals and definitions Cospas-Sarsat locations use transmitters emergency beacons operating at frequencies in the range 406.0–406.1 MHz. An additional emergency beacon emergency frequency is the frequency search and rescue services 121.5 MHz.

The accuracy of the location of the emergency beacons is not worse than 5 km for the low-orbit spacecraft constellation and 100 m for geostationary spacecraft (in the presence of a navigation receiver as part of emergency beacons). The delay time in the system does not exceed 1.5 hours in middle latitudes when working through low-orbit spacecraft and 10 min. - at work through geostationary spacecraft. The probability of determining the coordinates emergency beacons - not worse than 0.9.

System throughput is for low-orbit spacecraft groupings of at least 90 signal sources, and for geostationary spacecraft - at least 14 signal sources in a narrow band and at least 50 in a wide band strip.

In the future, to ensure the globality and accuracy of the system, as well as the efficiency of receiving signals, it is expected to use second generation emergency beacons, as well as groupings medium-orbit spacecraft from the GNSS GLONASS, GPS and GALILEO with special onboard equipment installed on them.

3.3. Terrestrial Radio Navigation Systems

3.3.1. Classification of ground-based radio navigation systems

Depending on the purpose and range of action, ground-based RNSs may be divided into the following groups: distant radio system navigation (RSDN); short-range radio engineering system (RSBN); landing systems.

3.3.2. Long Range Navigation Radio Systems

Radio systems are currently in operation long-range navigation "The Seagull" and "Mars-75."

Seagull system

Difference-range measuring pulse-phase radio engineering system long-range navigation "The Seagull" ("Tropic-2") is intended for positioning moving objects of all consumer groups in the regions of their intense movements with accuracy sufficient to solve transport problems, including en-route aircraft, ships sailing in coastal waters and land traffic control.

There are three system circuits in operation:

European (RSDN-3/10) consisting of five stations located in Russian Federation in the areas of the cities of Karachev (leading), Petrozavodsk, Syzran, as well as in the region of Slonim (Republic of Belarus);

Vostochnaya (RSDN-4) as a part of four stations located in
Of the Russian Federation in the areas of cities of Alexandrovsk-Sakhalinsky (presenter), Petropavlovsk-Kamchatsky, Ussuriysk and Okhotsk;

Severnaya (RSDN-5) as a part of four stations located in the Russian Federation in the areas of the cities of Inta (leading), Dudinka, pos. Foggy, Novaya Zemlya archipelago.

The system provides the determination of plan coordinates with accuracy (SKP) 60–1 500 m. The total area of the working zones of all chains is about 20 million square meters km

To work on the system, consumer equipment is used:

air means - A-711, A-720, A-723;

marine assets - KPI-5f (-6f - -9f), RC;

land means - "Neva".

Radio transmitting stations of the system work in accordance with an established schedule drawn up annually.

The analogue of the Chaika system (Tropic-2) is the RNS Laurent-S (USA).

Main characteristics of a pulse-phase radio engineering long-range navigation systems "Seagull" are given in table. fifteen.

Table 15

Main characteristics of a pulse-phase radio engineering long-range navigation systems "Seagull"

Name of characteristic	Chains of a pulse-phase RSDN "Seagull"		
	European	East	North
Type of basing	Stationary		
The principle of the system	Differential-range pulse-phase		
Working frequency, kHz	100		
Range, km	1 500–1 900	1,600–2,200	1,200
Determination accuracy coordinates, km	0.5–2	0.5–1.5 [1]	0.5–1.5
The area of the working area, million square meters Km	6.5	5.5	1.7
Throughput	Unlimited		
Number of stations	5	4	4
Availability	0,9995	0,9995	0,9995
Transmitter power supplied to the antenna, kW	650	650; 3000 [2]	500; 2500 [2]
Measurement Resolution	Continuous		
Signal transmission capability	Is available	Is available	Is available

single time			
Transmission capability service information for radio navigation channel	Is available	Is available	Is available
Number of masts	5-6	1	1
Mast height, m	250	350	460

1 Amendments to the propagation of radio waves in most areas of the work area significantly increase the accuracy of the system by approximately 2-3 times.

2 Depending on the type of ground station (mobile or fixed).

System "Mars-75" ("Neman-M")

Differential rangefinder multi-frequency pulse-phase Mars-75 long-range radio navigation system developed by order The Russian Ministry of Defense is designed to provide navigation, performing hydrographic and special works. Working area one chain is 0.8–1 million square meters. km; range of up to 1,000 km.

To work on the system, KPI-5f consumer equipment is used, RC and others

Operation of existing circuits of the radio system of the far navigation "Mars-75" will continue until the development of a technical resource and replacements with a new similar Neman-M system.

3.3.3. Short-range radio engineering systems

Short-range radio systems are operated in currently in the interests of air and sea consumers:

air consumers: RSBN-4N (-4NM, -8N), Trail-SMD; RMA-90; RMD-90; DVOR-2000; DME-2000; DME-2700; VOR-2700;

marine consumers: BRAS-3; RS-10; GRAS (GRAS-2); Octopus-H1; Krabik-B, Krabik-BM; marine circular beacon (CRM); DIAMOND.

The main characteristics of short-range radio systems are presented in table. 16.

Systems RSBN-4N (-4NM, -8N), Trail-SMD

Goniometer-rangefinding radio systems of the near navigation RSBN-4N (-4NM, -8N), Path-SMD are designed to provide air navigation, exit to the airport area and uncategorized approach.

The system operates on a “request-response” basis, throughput no more than 100 aircraft at a time, navigation information is issued in polar coordinates (range - azimuth).

The RSBN-4N system (-4NM, -8N) is used in military aviation and limited in civil aviation, for example, to drive to the military airfield designated as a reserve.

In the near future, it is planned to transfer electronic means of radio systems of short-range navigation in the radio frequency bands, Recommended by the International Radio Regulations for Air radio navigation service. This procedure can be provided. the use of the Tropa-SMD azimuth-rangefinder radio beacon.

The main characteristics of short-range radio systems

Name the system	Type of system	Operating frequency range MHz	Range actions, km	Determination accuracy places (UPC)	Discreteness measurements	Bandwidth the ability	A
Existing systems							
RSBN-4N (-4HM, -8H)	Rangefinder	770-812.8; 873.6-935.2; 939.6–1 000.5	50-550	200 m ± 0.03% m; 0.25 °	Continuously	100	
Path-SMD	Azimuthal Rangefinder	962.0–1 000.5	50-380	35 m; 0.35 °	Continuously	30/50	
PRS-ARK	Goniometer	150-1 750 kHz	50-200	1–2.5 °	Continuously	Unlimited - numb	
BRAS-3	Differential rangefinder pulse phase	1.6–2.2	200	12-60 m	Continuously	Unlimited - numb	
RS-10	Differential rangefinder pulse phase	1.6–2.2	250	3.6-12 m	Continuously	Unlimited - numb	
GRAS / (GRAS-2)	Rangefinder	4 100-4 300 / 3 902-4 198	60	0.5–1.5 m	0.03 minutes	5	
Krabik-B	Rangefinder phase	321–331	100	1m	0.03 minutes	3	
RMA-90	Goniometer	108–118	200-260	0.5–1 °	Continuously	100	I
DVOR-2000	Goniometer	108–118	240-340	0.5–1 °	Continuously	200	I
RMD-90	Rangefinder	950–1,215	200-260	± 150 m and ± 75 m during operation with ILS	Continuously	100	I

Name the system	Type of system	Operating frequency range MHz	Range actions, km	Determination accuracy places (UPC)	Discreteness measurements	Bandwidth the ability	A
DME-2000,	Rangefinder	962–1 213	240-340	± 150 m	Continuously	200	I

DME-2700				and ± 75 with ILS during operation		
Systems under development						
Octopus-H1	Differential rangefinder	1.6–2.2	600	15–20 m	Continuously	Unlimited - numb
Krabik-BM	Differential rangefinder rangefinder combined; active mode	230-332	150	0.5–3 m	Continuously 0.03 min	Neograny- numb

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The Tropa-SMD azimuthal rangefinder radio beacon is intended for formation and transfer aboard aircraft equipped equipment of radio systems of short-range navigation of the third and subsequent generations, the signals needed to measure azimuth and inclined range from the aircraft to the installation site of the beacon, and also providing aerial location information display vessels on remote indicators.

Range at a flight height of 250 m is at least 50 km, 3,000 m - at least 195 km, 12,000 m - at least 380 km.

Complexes like VOR / DME

Complexes of type VOR / DME by purpose and principles of operation similar to the goniometric rangefinder radio system of the near navigation. They are used to ensure the flight of aircraft area navigation routes with navigation characteristics such as RNAV 5, standard instrument arrival / departure routes based on equipment-based navigation.

They operate in the permitted international frequency range.

Equipment used: azimuthal - PMA-90, 5850 VOR, CVOR 431, DVOR-2000; rangefinder - RMD-90, DME-2000, 5960 DME, DME 435.

Complexes type DME / DME

DME / DME rangefinder systems are used for support for aircraft flights along zonal navigation routes with navigation characteristics of types RNAV 5, RNAV 2, standard arrival / departure routes for instruments, as well as for entry routes instrument landing at the initial, intermediate stages and interrupted approach (approach to the second round) based on navigation based on application of equipment.

They operate in the permitted international frequency range.

Equipment used: RMD-90, DME-2000, 5960 DME, DME 435.

Complex PRS-ARK

The radio navigation complex PRS-ARK is designed to provide flight along the route, bringing the aircraft to the landing aerodrome, providing pre-landing maneuver and inaccurate landing approach (approach to land on instruments without navigational guidance along the glide path, formed by electronic means).

The complex consists of a ground-based drive radio station and an onboard automatic radio compass, is a goniometric navigation means (gives the direction of flight of the aircraft to the accepted radio station).

Driving radios are equipped with all airfields and air tracks. A number of types of automatic radio compasses are serially produced, which equipped the entire aircraft and helicopter fleet of Russia and others CIS member states.

BRAS-3 system

The differential-ranging RNS BRAS-3 is designed to provide navigation in the coastal area of navigation and when approaching ports.

The system circuit includes three stations.

To operate the system, an on-board receiver-indicator is used GALS, KPF-3K, RS-1 and RKS equipment.

The serial production of the BRAS-3 system is discontinued, the system is removed from operation and is replaced by the PC-10 system.

RS-10 system

RNS RS-10 in purpose and principle of operation is similar to the system BRAS-3, but has higher tactical, technical and operational specifications.

The chain includes 3–6 stations.

To obtain navigation information on board the vessel, the same types of receiving indicator equipment as for the BRAS-3 RNS: GALS, KPF-3K, RS-1 and RKS.

BRAS-3 and RS-10 systems for general navigation The Ministry of Transport of the Russian Federation are not used.

Operation of the existing RNS circuits is planned before development technical resource, and then will be replaced by a new system "Octopus-N1."

Analogs of the BRAS-3 and RS-10 systems are the Zheolok RNS (France) and Hyperfix (England).

GRAS system (GRAS-2)

The rangefinding RNS GRAS (and its modification GRAS-2) is intended for solving hydrographic problems and other special tasks requiring high location accuracy.

According to the principle of operation, the system is two-channel radio range finder.

To work on the GRAS system, consumer equipment is used RNA-2, according to the GRAS-2 system - RD-1 equipment.

The serial production of the GRAS system (GRAS-2) is discontinued, as development of the technical resource of the stations, the system will be derived from operation and replaced by the radio-geodetic complex Krabik-BM.

The analogue of the GRAS system (GRAS-2) is the Siledis system (France).

Krabik-B system

Rangefinder phase radio geodetic system Krabik-B designed for high-precision geodetic reference of moving and stationary surface objects in the coastal zone.

The system implements four operating modes: differential rangefinder, rangefinder, combined and active remote (using buoy radio beacon transponders).

The system will be used before the implementation of the radio geodetic complex Krabik-BM.

Marine beacons

Marine beacons are radio stations with a circular radiation signals in the frequency range 300 kHz, providing determination of the direction for them when used on ships direction finders with an error of not more than 3 ° (with a probability of 95%). On the several dozen types of radio beacons have been installed on the Russian seaside KPM and DIAMOND.

In connection with IMO approval of the application of global navigation satellite systems and exclusion from mandatory ship of direction finding equipment some marine beacons are supposed use as radio stations for transmitting differential amendments when creating GNSS functional additions.

3.3.4. Landing systems

Landing systems are designed to be received on board an aircraft, issuing information to the crew and to the automatic control system about value and sign of deviation from the established descent path, as well as to determine the moments of flight of characteristic points defined installation of marker radio beacons (MRM-V, MRM-70, RMM-95, MRM-97, MRM-E612, MRM "Quartz", MRM-734), when approaching and performing landing.

Key Features of Existing and Developed beacon landing systems are given in table. 17.

Are in operation and used by air consumers beacon landing systems: SP-75 (-80, -90, -200); ILS-2700, ILS-734, PRMG-5 (-76U, -76UM).

Landing systems SP-75 (-80, -90, -200)

SP-75 systems (-80, -90, -200) form the aircraft landing path and provide its landing in adverse weather conditions. Data systems widely used in civil aviation and meet ICAO requirements in parts of landing support for categories I, II and III, depending on modifications. The systems are analogous to the international ILS system.

The systems are stationary and operate in meter range of radio waves.

For work on landing systems SP-75 (-80, -90, -200) is used on-board equipment "Course-MP" (-2, -70), ILS-85, "Axis-1", VIM-95.

PRMG-5 system (-76U, -76UM)

The purpose of the landing system PRMG-5 (-76U, -76UM) is similar purpose of the SP-75 systems (-80, -90, -200). The system operates in decimeter range of radio waves and has two placement options: landline and mobile.

PRMG-5 (-76U, -76UM) provide a military landing approach air consumers in the conditions of category I (PRMG-5) and categories I – II (PRMG-76U, -76UM).

To work on the PRMG-5 (-76U, -76UM) system, the on-board is used RSBN equipment.

Due to the fact that part of the range used is allocated to mobile communication systems, the work of the landing beacon group provided only in the permitted part of the range in accordance with frequency-spatial planning.

On civil aircraft, RSBN equipment may be involved in the operation mode according to the signals of the landing beacon group to provide instrumental landing at aerodromes joint basing and, if necessary, to military airfields.

However, civil aviation in the future use of this regime not planning.

System "Bridgehead-1N"

The landing site "Bridgehead-1N" ensures the implementation of curved approach patterns. Operating frequency range - 5 GHz, instrumental error of the system (SKP) - 0.02. Characteristics for availability and integrity are consistent with ICAO standards. The number of channels - 200. In accordance with the international classification the analogue of the "Bridgehead-1H" system is a microwave landing system MLS

The "Bridgehead-1N" system is not planned for civil use aviation in the territories of the CIS member states.

In connection with the decision adopted by ICAO to extend the life of ILS landing systems and the development of satellite landing technologies, in civil aviation of the CIS member states MMR multi-mode airborne receivers (ILS / MLS / GNSS), including to ensure international flights.

Aircraft local differential satellite subsystems type GBAS

Currently certified and accepted to equip Russian civil aviation aerodromes local GNSS differential subsystem - ground control station LKS-A-2000. This system meets the requirements for perform landing according to ICAO category I. Work is underway to evaluate it Opportunities for landing in categories II and III.

A prototype LKS-- was created and tested with the assignment of the letter “O $_1$ ” A-2014, working on promising GNSS signals GLONASS / GPS / GALILEO.

Key features of landing systems

Name the system	general characteristics	Working range frequencies, MHz	Range of action not less than km	Category landing	Discreteness measurements	Bandwidth the ability	Access-nost
SP-75 (-80, -90; -200) ILS-2700 (-734)	Stationary	108-112; 329–335; 75 (marker)	46 (course channel), 18.5 (channel glide paths)	I – III	Continuously	Neograny-numb	0.986
PRMG-5 (-76U, -76UM)	Mobile / stationary	772–1,000.5 (abbreviated) [1]	45 (course channel), 29 (channel glide paths)	I – II	Continuously	Neograny-numb	0.95
Bridgehead-1N	Stationary	5 030–5 090	Height up to 6,200 m	III	Continuously	200 channels	0.95
LKS-A-2000	Stationary	108–118	37	III	Continuously	Neograny-numb	0.99

[1] Clarified as the range for mobile communication systems becomes free.

3.4. Coordinate systems and time scales used in radio navigation systems

3.4.1. Coordinate systems

To ensure the functioning of the RNS in the territories of states - CIS participants apply the Earth coordinate system (TRS), as well as its practical implementations.

TRS participates with the Earth in its daily rotation around the axis and designed to quantify position and movement objects located on the surface of the Earth and in near-Earth space.

Practical implementation of TRS by the International Earth Rotation Service (IERS), received the name International Earth reference system (ITRF) and consists in determining the coordinates points (and their rates of change over time) securing ITRF to the surface of the earth. The accuracy of the latest practical TRS implementations is at the sub-centimeter level of accuracy of determining coordinates points.

Currently, the International Earth Rotation Service has received practical implementation of TRS, designated as ITRF-2014 for the 2010 era.

Practical implementations of the Earth coordinate system used in GNSS GLONASS (PZ-90) and GPS (WGS-84), as well as reference systems coordinates of the Russian Federation (SK-42, SK-95, GSK-2011) are given in interstate standard GOST 32453-2017 "Global navigation satellite system. Coordinate systems. Coordinate Transformation Methods defined points. "

Currently, in accordance with the decree of the Government Of the Russian Federation of November 26, 2016 No. 1240 "On the establishment of state coordinate systems, state altitude system and state gravimetric system "established state geocentric coordinate system "1990 Earth Parameters" (PZ-90), attributed to the era of 2010.0 and designated as PZ-90.11.

By this decision of the Government of the Russian Federation It was also established that:

Baltic is used as a state system of heights 1977 altitude system, the reference to which normal heights is taken from zero Kronstadt footstock, which is a horizontal bar on copper a plate fixed in the mouth of the bridge over the bypass channel in the city of Kronstadt;

used as a state gravimetric system gravimetric system, determined by the results of gravimetric measurements at points of the state gravimetric network performed in the 1971 gravimetric system.

PZ-90.11 is used for geodetic support of orbital flights, solving navigation problems and performing geodetic and cartographic work in the interests of defense, is established and

distributed using a space geodetic network and State Geodetic Network of the Russian Federation.

1995 Geodetic Coordinate System (SK-95), established Decree of the Government of the Russian Federation of July 28, 2000 No. 568 “On the Establishment of Unified State Coordinate Systems” in as a single state coordinate system, and a single system geodetic coordinates of 1942 (SK-42), introduced by the Council Of Ministers of the USSR of April 7, 1946 No. 760 "On the introduction of a unified system geodetic coordinates and heights on the territory of the USSR ", apply until January 1, 2021 when performing geodetic and cartographic works in relation to materials (documents) created with their use.

In the implementation of geodetic and cartographic work in the interests of civilian consumers use a geodetic system coordinates of 2011 (GSK-2011), established and distributed with using the State Geodetic Network of the Russian Federation and harmonized with the international earth support system ITRS.

Most CIS Member States formation of a highly efficient state geodetic system ensuring the territory of the country providing for integration with the international earth support system ITRS, for implementation geodetic and cartographic work, orbital flights and solving navigation problems.

WGS-84 World Earth Surveying System May used as an auxiliary when using foreign RNS and ensuring the movement of foreign vehicles in the territories CIS member states.

3.4.2. Time scales

Temporary provision of radio navigation activities on the territory of the CIS member states is based on a scale coordinated time of the Russian Federation UTC (SU) specified by existing reference base of the Russian Federation.

In order to broadcast accurate time signals, the State Service time, frequency and determination of rotation parameters of the Russian Earth Federation uses an extensive network of means of transmission, which includes:

two specialized long-wave radio stations - RBU and RTZ;

shortwave specialized radio station;

ultra-long and long-wave navigation radios State system of common time and reference frequencies;

GNSS GLONASS;

transmission media in conjunction with television signals;

means of transmitting accurate time over the Internet.

GNSS GLONASS transmits to consumers signals with information about UTC (SU) timeline and GLONASS system timeline.

As an auxiliary timeline when using signals GNSS GPS U.S. Coordinated Timeline - UTC (USNO) supported by the US Naval Observatory, as well as GPS timeline - GPST.

GNSS GALILEO Timeline (GST, Galileo System Time) synchronizes relative to TAI international atomic time and UTC. Value Information GST timeline discrepancies with respect to the TAI and UTC scales are included in navigation message for transmission to consumers.

GNSS BEIDOU (BDT) time associated and synchronized with Coordinated UTC According to the creators systems, BDT compatible with GNSS GPS / GALILEO. Discrepancy between BDT and GPST / GST timelines measured and transmitted to consumers.

4. DIRECTIONS OF RADIO NAVIGATION DEVELOPMENT STATES - PARTICIPANTS OF THE CIS

4.1. Basic approaches to the development of radio navigation aids

The current stage of development of science and technology involves the expansion a range of practical tasks in which technologies are used navigation on the artificial radio navigation field of the Earth.

Currently, satellite navigation aids have become highly accurate and highly reliable and play a significant role in the process the formation of the digital economy.

Means of coordinate-temporal and navigation support, opening to a wide range of existing and potential consumers opportunities for high-precision navigation and building on its basis highly efficient systems and complexes in various scopes. Traditional consumer tasks in the areas of transport, energy, communications, geodesy and cartography, agriculture and special customer navigation added new tasks management of the spatio-temporal state of consumer complexes carried out with a decrease in human participation.

At the present stage, the basis of radio navigation support consumers of CIS member states may be GNSS GLONASS, GPS, GALILEO and BEIDOU.

GNSS GLONASS and GPS will be used by almost everyone by consumers, since both systems are fully deployed, and each provides global coverage of the globe. Integration of both systems at the level of navigation equipment of consumers guarantees users a high level of reliability and integrity of navigation maintenance in difficult operating conditions.

Opportunities for receiving and processing signals in GNSS consumer navigation equipment GALILEO and BEIDOU will increase stability of integrated systems for all categories users.

Priority areas for the development of national systems coordinate-time and navigation support of states - CIS participants should be:

the formation of regional, local (industry) differential RNS satellite subsystems for various purposes;

modernization and development of pulse-phase RNS to the level of full-fledged duplicating (complementary) RNS;

improving the network of short-range navigation aids and beacon systems;

development of means for the formation of radio navigation fields, including alternative;

the development of systems and means of frequency-time support;

definition and refinement of fundamental astronomical and geodetic Earth parameters, as well as monitoring the accuracy characteristics of systems coordinates of the CIS member states.

GNSS standard regimes should continue to provide aircraft requirements for flights en route, in the terminal area and with an inaccurate approach; navigation of ships on the high seas; road transport needs.

Russian system of differential correction and monitoring will provide accuracy of location at the level of units of meters. Expected also that when using the mixed constellations GLONASS / GPS (in perspective - GLONASS / GPS / GALILEO) wide-range correction will allow increase the accuracy of positioning by 2–3 times and bring it to the level of 0.5–0.8 m in the plane and 0.7–1 m in height. Location accuracy can reach 0.3-0.7 m with an increase in the number of spacecraft grouping and further improving GLONASS and SDKM.

The implementation of local aviation should continue. differential satellite subsystems for uncategorized landing and category I landings as well as opportunity assessments use of SDKM and regional differential satellite subsystems.

Navigation support of sea and river vessels in coastal and torrential zones, narrownesses, harbors and ports, inland waterways will be carried out using marine differential satellite subsystems.

In the coming period, vehicles will use information from GNSS GLONASS and GPS in standard and differential modes via reference stations that will be part of the respective centers management and strong points.

The widespread use of information remains an important area. GLONASS in emergency response systems for ERA-RB, EVAK and ERA-GLONASS harmonized with the European emergency system e-call alerts.

Increased intensity of the use of unmanned vehicles and creation of commercial products based on them determine the need lower thresholds for the formation of warning signals about violation of the integrity of navigation and temporary support from 45 to 0.5 m and their delivery to consumers in less than 6 s in the service area. At safety critical operations human activity, delivery time should be no more than 2 s.

A wide range is used in the CIS member states ground navigation aids.

RNS development plans in the CIS member states for the period up to 2025 are given in table. 18.

Most air traffic management routes and Departure, arrival and approach routes are based on coverage ground navigation aids: VOR, DME, ILS, etc. by users airspace also operates zonal navigation using GNSS consumer navigation equipment as the main navigation aid.

To ensure aircraft landing by categories will be use precision approach systems like SP-75 (-80, -90, -200) and landing beacon groups, as well as local aviation differential satellite subsystems (ALPS) of the GBAS type.

Table 18

RNS Development Plans

System (consumers)	Years: 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025
Orbital GNSS group GLONASS (all consumers)	Glonass-K, Glonass-K2 launch; 24 spacecraft for the intended purpose
SDKM	Development; OKR "KFD-V" certification, operation
Cicada m (navy, Naval fleet)	Decommissioning and transition to GLONASS
Marine differential satellite subsystem (sea and river navy, military navy)	Number of stations: 63; 72; Operation and Development
Aviation local differential satellite subsystems (Civil aviation, Ministry defense)	Number of stations: 106; Operation and Development
Regional differential satellite subsystems on pulse-based phase RNS (Ministry defense marine fleet)	No work planned

System (consumers)	Years: 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025
Control centers and dispatching ground points of transport	Number of stations: 110; Operation and Development
Geodesic differential satellite subsystems	Number of stations: more than 530; Operation and Development
Park nautical instrumentation GNSS consumers	Number of users: more than 500,000 operation and development
Alpha Route (Ministry defense)	Number of stations: 4; Solution for future use
Seagull, Tropic-2P (Ministry	Modernization according to the Scorpion R&D; Continuation of operation

defense)	
Mars-75, Neman-M (Naval fleet)	Operation and replacement as the resource is developed RNS "Neman-M"
Radio engineering dipped system navigation (Ministry defense)	Transfer to the permitted part frequency range. Operation as a fixed asset middle navigation
Equipment type VOR / DME (Civil aviation)	The main tool for providing route flights and inaccurate calls; development, will be used as long as it is economically appropriate
Complex PRS-ARK (Civil aviation, Ministry defense)	The main means to equip the aircraft with promising navigational aids. Reserve and emergency means. Gradual decrease in the number of systems
RNS BRAS-3, and RS-10 (Naval fleet)	Operation of the RNS until the resource is exhausted - replaced with Octopus-N1 and marine differential satellite subsystems
GRAS (GRAS-2), Krabik-B (BM) (Naval fleet)	GRAS (GRAS-2), Krabik-B as resources are developed, are replaced by Krabik-BM
SP-75 (-80, -90, -200) (Civil aviation, Ministry defense)	Operation, while it is economically feasible. Is possible replacement of category I systems with local aviation differential satellite subsystems

System (consumers)	Years 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025
PRMG-5 systems (76U, 76UM) (Ministry defense)	Refinement and modernization systems for work in permitted parts of the frequency range. Replacing part of systems with local aviation differential satellite subsystems Continued operation until 2021 onwards

In the short term, it is planned to use jointly with GNSS of traditional ground-based radionavigation systems RMA-90, RMD-90, DVOR 2000, DME-2000 and similar, which provide the required level of integrity and continuity aircraft flight services.

In order to reserve satellite navigation systems in mid-term development of alternative positioning, navigation and time systems (APNT) and their subsequent long term operation. As ground support APNT capabilities while maintaining area navigation specifications for flight en route, multi-position systems are provided observations operating in conjunction with a digital transmission line data aboard the aircraft.

To provide precision measurements for hydrography and special tasks will be used RNS type GRAS (GRAS-2), Krabik-B, Krabik-BM, Octopus-N1. RSBN of the Chaika type remain redundant tasks and / or functional additions.

High-precision satellite coordinate systems for the basis of networks of satellite reference stations provide the calculation amendments to bring the accuracy of positioning to 2–3 cm in real time and 2–4 mm in post-processing.

Providing a centimeter level of accuracy in determining coordinates in real-time allows you to solve geodetic problems on railway transport in the field of construction and operation track economy. The range of the system is up to 200 km relative to reference stations and is determined by the capabilities of the channels delivery of corrective information.

The characteristics of the provided navigation services should subject to continuous monitoring. Direct control efficiency affects the safety factor. Quality control of navigation services should be carried out stationary, mobile and mobile means. The functions of monitoring the radio navigation field should lay in the developed navigation equipment of consumers.

Formulated approaches form the basis for development organizational and technical measures to create a single navigation and information space in the territories of states - CIS participants.

4.2. GNSS GLONASS

4.2.1. Directions of development of GNSS GLONASS

Over the past 10 years, the degree of use of the GLONASS system increased significantly and now navigation technology on her basis are actively used in all sectors of the economy, which makes the system GLONASS is a critical element of national infrastructure.

One of the main objectives of GLONASS development is to satisfy the needs of all categories of navigation data consumers through achieving parity with overseas GNSS.

Currently, the GLONASS system together with functional Add-ons provides the following types of navigation services:

basic service for navigational-temporary providing all categories of consumers in absolute mode. It is provided by navigation satellites in medium orbits;

elevated life safety service reliability and accuracy of navigation support. KA is provided on medium orbits and functional complements of the space and ground-based (local, regional and wide-area) in differential mode;

Relative navigation service with high accuracy at the use of networks of ground stations functional additions to ranges up to 50 km;

high accuracy service provided over terrestrial communication channels and Internet channels. In the future it is supposed to provide a service also through space channels of spacecraft information delivery to geostationary and high orbits.

GLONASS development work will be carried out in accordance with
federal target program “Maintenance, development and use
GLONASS system for 2012–2020 ”and its continuation until
2030 year.

Key target indicators and performance indicators
federal target program “Maintenance, development and use
GLONASS systems for 2012–2020 ”are presented in table. 19.

The operation and improvement of GLONASS will be aimed at
enhancing economic and consumer effects based
balanced development of all GLONASS elements using
mechanism of public-private partnership.

It is planned to maintain channels of high and standard accuracy
GLONASS, which will allow to resolve the contradiction inherent in systems
dual purpose, namely, to provide a solution to military problems and
Fulfillment of international obligations to provide navigation
services to civilian consumers.

Table 19

Key target indicators and performance indicators federal target program “Maintenance, development and use of the GLONASS system for 2012–2020 ”

Targets and indicators	2018	2019	2020
Real-time location accuracy in state coordinate system due to the space segment systems without the use of systems of functional additions, m	0.9	0.75	0.6
The average value of the spatial geometric factor	1.85	1.85	1.85
Component of the equivalent measurement error pseudorange due to onboard ephemeris error time information, m	0.5	0.4	0.3
Real-time location accuracy in state coordinate system due to the space segment systems using functional complement systems:			
online, m	0.3	0.3	0.1
operational mode with initial initialization, m	0.1	0.1	0.05
a posteriori mode, m	0.05	0.05	0,03
Consumer integrity warning time navigation support, with	6	6	6
The error in determining the consumer time in the system time scale due to space segment, ns	1,5	1,5	1
Accuracy of matching the system timeline with national time scale UTC (SU), ns	10	7	4

The GLONASS system should be improved in the following
directions in accordance with the prospective requirements of consumers:

improving the accuracy and reliability of navigation support;

expanding the range of tasks;

lower operating costs and maintaining orbital
groupings, etc.

In accordance with the federal target program “Maintenance,
development and use of the GLONASS system for 2012–2020 ”

planned to provide:

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maintenance of at least 24 KA and a consistent increase
full-time orbital grouping by launching the GLONASS-K, GLONASS-K2 spacecraft and Glonass-M;

ensuring GLONASS competitiveness comparable to foreign counterparts;

increase in accuracy of navigation definitions by 2–2.5 times;

use of code division signals in the ranges L1 – L3 GLONASS;

improvement of the main tactical and technical characteristics of GLONASS for account for the use of inter-satellite measurements;

expansion of the range of GLONASS tasks to be solved, including detection of distressed objects;

increased use of the inter-satellite radio link for ensuring integrity, operational management and control of the spacecraft, etc .;

deployment of new global integrity monitoring tools;
further modernization of ground control complex facilities and fundamental means of providing GLONASS;

transfer of consumers of ground navigation systems to interaction with GLONASS; completion of the integration of RSDN with GLONASS;

creation of favorable conditions for the introduction of navigation services with using GLONASS;

ensuring serial production of competitive designs consumer navigation equipment GLONASS, GPS and GALILEO;

creation of open digital navigation charts;

development of the regulatory framework in the field of coordinate-time and navigation support and radio navigation;

ensuring the use of GLONASS on a global scale in compliance with international standards GNSS application.

4.2.2. GNSS GLONASS space segment

The newly launched navigation satellites Glonass-M and Glonass-K Compared with the GLONASS spacecraft of the first modification, the following main advantages (tab. 20):

extended guaranteed period of active existence;

upgraded spacecraft service systems;

increased stability of the on-board synchronization device;

application of new management technologies and ephemeris-time security;

payload expansion for solving search problems and rescue;

use of new navigation signals.

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The level of unaccounted disturbances is reduced in the control system NCA orbits, which improves the accuracy of determination and forecast ephemeris measurements.

Glonass-K2 more stable onboard nuclear frequency standard provides maximum error of the time-frequency correction of 2.5 ns with a forecast of 12 hours and 3.5 ns - with a forecast of 24 hours.

Table 20

Comparative characteristics of the GLONASS spacecraft

Specifications	Spacecraft type		
	Glonass-M	GLONASS-K	Glonass-K2
Years of deployment	2003–2016	2011–2018	After 2017
condition	In operation	Flight held trials	In developing
Guaranteed active term existence, years	7	10	10
Mass of spacecraft, kg	1,415	935	1,600
Spacecraft dimensions, m	2.71x3.05x2.71	2.53x3.01x1.43	2.53x6.01x1.43
Power usage, Tue	1,400	1,270	4,370
Type of execution KA	Sealed th	Unsealed unsealed	
Daily allowance instability airborne synchronizing devices in According to technical task / actual cheskaya	$1x10^{-13}$ / $5x10^{-14}$	$1x10^{-13}$ / $5x10^{-14}$	$1x10^{-14}$ / $5x10^{-15}$
Signal type	Mostly FDMA (CDMA on KA No. 755–761)	FDMA and CDMA	FDMA and CDMA
Signals from open access (value central frequency)	L1OF (1 602 MHz) L2OF (1,246 MHz) starting from number 755: L3OC (1 202 MHz)	L1OF (1 602 MHz) L2OF (1,246 MHz) L3OC (1 202 MHz) starting from No. 17L: L2OC (1,248 MHz)	L1OF (1 602 MHz) L2OF (1,246 MHz) L1OC (1,600 MHz) L2OC (1,248 MHz) L3OC (1 202 MHz)
Signals from authorized access	L1SF (1,592 MHz) L2SF (1,237 MHz)	L1SF (1,592 MHz) L2SF (1,237 MHz) starting from No. 17L: L2SC (1,248 MHz)	L1SF (1,592 MHz) L2SF (1,237 MHz) L1SC (1,600 MHz) L2SC (1,248 MHz)

Availability inter-satellite communication lines:			
radio;	+	+	+
optical	-	-	+
Availability equipment search systems and rescue	-	+	+

Launched in orbit in 2011 for spacecraft tests Glonass-K modifications of the 1st stage along with the radio signals L1 and L2 with frequency division, completely analogous to Glonass-M signals, additionally radiates in the L3 band open access radio signals with code division.

Glonass-M satellites manufactured since 2014 (No. 755–761) equipped with L3OC signal transmitters.

In connection with the transmission of the ranging code in the range L2 (L3) in an additional parameter will be transmitted to the navigation message, characterizing the difference in hardware delays of the ranging codes in ranges L1 and L2 (L3). In addition, a sign of modification will be introduced. NKA and the sign of the expected second correction of the UTC (SU) timeline.

Currently, work is underway on the manufacture of 9 Glonass-K spacecraft three versions and 4 Glonass-K2 in two versions, which involve the various implementation of airborne assets the formation and emission of navigation radio signals L1OF, L1SF, L20F, L2SF frequency division and L1OC, L1SC, L2OC, L2SC, L3OC with code separation.

Glonass-KM satellites, the development of which began in 2017, replenish the orbital group in 2025.

Glonass-KM spacecraft will emit navigation signals: FDMA - L1OF, L1SF, L2OF, L2SF; CDMA - L1OC, L1SC, L2OC, L2SC, L3OC, L3SC.

We are exploring the possibility of broadcasting compatible CDMA signals: L1OCM, L3OCM, L5OCM, at the frequencies L1 (1 575.42 MHz), L3 (1 207.14 MHz), L5 (1,176.45 MHz). Presumably, up to 6 will be used in new spacecraft open and up to 3 encrypted signals with code division, frequency and whose modulation will coincide with the signals of the upgraded GPS third generation and GALILEO / BEIDOU.

Examples of possible intersection of modulations:

L1OCM signal - BOC (1,1) modulation at a frequency of 1,575.42 MHz, matches the upgraded GPS signal L1C, the system signal E1 GALILEO and signal B1C of the BEIDOU system;

L3OCM signal - BPSK modulation (10) at a frequency of 1 207.14 MHz, matches the E5b signal of the GALILEO system and the signal E2b of the system BEIDOU;

L5OCM signal - BPSK modulation (10) at a frequency of 1 176.45 MHz, matches the Safety of Life (L5) signal of the upgraded GPS signal GALILEO system E5a and BEIDOU system E2a signal.

This configuration will help ensure broad compatibility. receiving equipment and increase the accuracy and speed of determination coordinates for critical applications, primarily in aviation and maritime security.

4.2.3. GNSS fundamental support system

GNSS fundamental support system continues to evolve in accordance with the implementation of measures adopted by the Government Of the Russian Federation of November 24, 2016 No. 1240 "On the establishment of state coordinate systems, state altitude system and state gravimetric system ”and the federal target program “Maintenance, development and use of the GLONASS system on 2012–2020. ”

The main tasks of the development of the fundamental support system within the framework of the coordinate-time support of GLONASS are:

regular high-precision determination of world time with means providing the technology of radio interferometry with extra-long bases at the disposal of the CIS member states regardless of international services;

development of colocation nodes based on observatories radio interferometric complex Quasar-KVO connected high speed fiber optic communication lines with speeds data transmission up to 10 Gb / s, with the inclusion of funds ultra-long-range radio interferometry, GPS / GLONASS-observations and laser location of satellites;

creation and implementation of universal software packages, allowing the joint processing of various types of precision coordinate-time and navigation measurements;

coordination of state coordinate systems PZ-90.11 and GSK-2011 with the international terrestrial reference system;

ensuring alignment of coordinate axes and angular speeds of unified state coordinate systems as part of numerical geodetic parameters of unified state coordinate systems recommendations of the International Earth Rotation Service and the International bureau of time;

creation of reference bases of long lengths by means ultra-long-range radio interferometry and GPS / GLONASS-observations.

4.3. GNSS functional complement systems

4.3.1. Differential correction and monitoring system

It is planned to expand the composition and coverage of the Russian SDKM. The full network of the system will include 40 stations on the territory of the Russian Federation and 15 stations beyond, taking into account 4 stations in Antarctica.

The development of an air navigation support system requires further SDKM development for instrumental approaches with vertical guidance (RNAV GNSS) corresponding to level APV-II ICAO and later LPV-200 level.

In this regard, the creation of a wide-field SDKM is envisaged. GNSS navigation fields and certification of services provided on compliance with civil aviation requirements (Standards and Recommended ICAO practice and MOPS RTCA DO-229D).

4.3.2. National network of high-precision positioning of the Russian Federation

As part of the provision of relative navigation services, including in real time, JSC "Russian Space Systems" implements project “Creation of the National High-Precision Positioning Network” for providing services in the field of high-precision satellite measurements corporate customers based on integrated integrated network base (reference) stations of various manufacturers, owners and operators. National high-precision positioning network will provide translation of corrective information in a single information field. To control and confirm the quality of this service is required use of mobile measuring systems.

4.3.3. High accuracy ephemeris time detection system of information

As part of the implementation of high accuracy services in the federal target the program "Maintenance, development and use of the GLONASS system at 2012–2020 ”envisages work on the creation of a high-precision system determining ephemeris time information.

The scope of this system is a wide range of tasks, requiring high accuracy of the GNSS ephemeris-time information:

high-precision navigation support of motionless and mobile consumers;

geodetic and cartographic work;

fundamental scientific research in various fields;

social and economic research.

High accuracy detection assisting information ephemeris-time information is transmitted over terrestrial publicly available communication channels (Internet) and is processed together with GNSS signals in specialized navigation equipment of consumers that provides improved navigation accuracy by more than an order of magnitude, up to centimeter level. Real-time data available only to registered consumers. Posterior information is available to consumers without restrictions.

High accuracy ephemeris time detection system Information includes: system control center; global network GNSS measuring stations; consumer navigation equipment; information delivery subsystem.

The system control center calculates the navigation information and high-precision ephemeris-time information GNSS navigation spacecraft in real time with a delay of not more than 10 s from the moment of receipt of the measurement for processing and a posteriori with a delay of not more than 1 day from the moment of the last measurement, as well as performs short-term ephemeris-time prediction information for generating highly accurate assisting information real time.

The network of GNSS measuring stations is located in Russian and foreign territories based on intergovernmental agreements. She provides a high-precision detection system to the control center ephemeris time information source measurement information for highly accurate navigation and ephemeris-time information.

The developed navigation equipment for consumers has the ability to conduct code and phase measurements of current GNSS spacecraft navigation parameters in two frequency ranges and allows calculate the coordinates of consumers using modern algorithms, including in real time, as a result of signal processing

GNSS navigation satellite and assisting information.
Information Delivery Subsystem Uses Terrestrial Public communication channels (Internet). In the future, additionally planned use of space data channels. For data transfer composite space channels will be used for consumers parts of airborne radio complexes of communication satellites and relay, as well as earth stations transmitting information to satellites, which will allow the broadcasting of assisting information to consumers on the entire surface of the Earth and in the near space.

Creation of a system for high-precision determination of ephemeris-time information is carried out in stages with a gradual increase accuracy and operational characteristics.

In the conditions of functioning of measuring stations of the global network the first stage of the error in determining the location in the state

geocentric coordinate system of the Russian Federation due to space segment using high-precision system data determination of ephemeris-time information does not exceed 0.3 m in operational mode and 0.05 m in a posterior mode.

When creating at the second stage a global network of measuring stations GNSS in full (according to plan in 2020) indicated error in operational mode will not exceed 0.1 m, in a posterior mode - 0.03 m.

The area of the provision of high-precision navigation services will be expanded by transmitting information as part of the navigation radio signal L3 from SC of a high-orbit space complex.

Quality control of high accuracy services can be carried out stationary means, however, requires the establishment of operational specialized means, including fast-release drugs or mobile.

4.3.4. Performance Monitoring and Verification System

In accordance with the federal target program "Maintenance, development and use of the GLONASS system for 2012–2020 " creation of a system for monitoring and confirming characteristics is provided GLONASS and other GNSS radionavigation fields in the interests of civil consumers, including in real time.

The main purpose of the control and confirmation system characteristics is to ensure independent monitoring of key characteristics specified in the tactical and technical requirements for the system GLONASS and the creation of its components in the interests of civil consumer monitoring and forecasting functional GNSS characteristics (accuracy, availability, integrity, reliability), formation of initial data for the assessment of target indicators and program indicators, determining consumer characteristics of the system GLONASS, as well as to calculate the source data for its certification.

The system of control and confirmation of performance is a a single set of methodological and hardware-software controls and prediction of the functional characteristics of GNSS and consists of the following parts:

GNSS monitoring and verification center;

stations of the system of control and confirmation of characteristics, including stations for collecting measurements and quantum optical means;

equipment for assessing the energy characteristics of GNSS signals.

GNSS monitoring and verification center facilities

should be deployed on the federal state
unitary enterprise "Central Research Institute
mechanical engineering. "

Measurement collection stations, including stations in foreign territories, designed to collect measurements of current navigation parameters - pseudorange by phase of code and phase of carrier oscillations of navigation signals, slant ranges, as well as information transmitted as part of navigation messages open navigation signals with frequency and code division for all existing GNSS. Full deployment the composition of measurement collection stations and the involvement of measurement information from measuring instruments of the State Space Corporation the activities of Roscosmos allows you to solve all the tasks with a given accuracy, set before the system of control and confirmation of performance, for excluding evaluation of energy and spectral characteristics navigation signals.

Quantum-optical means are used to solve the problem monitoring ephemeris and time-frequency parameters of the GLONASS system.

Equipment for assessing the energy characteristics of GNSS signals provides:

assessment of energy characteristics of open navigation signals of all existing GNSS, as well as functional additions, developed as part of the federal target program “Maintenance, development and use of the GLONASS system for 2012–2020 ”, with error not more than 1 dB;

assessment of the quality of work of airborne formers navigational spacecraft radio signals, determining the parameters of the spacecraft transmitting antenna.

The stage of creating a system of control and confirmation of characteristics in It is generally planned to be completed by the end of 2025.

To monitor the parameters of the radio navigation field GNSS created metrological complex in the federal state unitary All-Russian Research Institute of Physics technical and radio engineering measurements. "

As part of the deployment of new global monitoring tools GLONASS integrity as part of the space chief designer complex requires the creation of a ground station for precision control parameters of GLONASS spacecraft navigation radio signals based on antennas with large aperture, allowing to obtain a gain of up to 90 dB.

4.4. Marine differential satellite subsystems and differential satellite subsystems for inland waterways

Marine differential satellite subsystems are considered as the most promising means of navigation support navigation in coastal and straining zones, ports and narrownesses, water transport on inland waterways.

Marine differential satellite subsystems have the possibility of increasing the accuracy of positioning to solve such problems, how to perform hydrographic work, laying submarine pipelines and automatic docking using phase methods definition of navigation parameters.

To the currently available 63 control and corrective 9 stations will be added in 2019 at the facilities of the Navy Russian Federation (see table. 18).

In order to prevent mutual interference of adjacent stations of the marine differential satellite subsystems and beacons belonging Russian Federation and neighboring states, under the auspices of IALA coordination of frequency assignments in the radio navigation band 283.5–325 kHz for the European maritime zone.

In accordance with the project “Creation of ground infrastructure high-precision satellite navigation systems of the Republic of Kazakhstan "created and the marine local differential station in the port of Aktau is used. Further deployment of similar systems in the water area is expected. The Caspian Sea.

4.5. Aviation local differential satellite subsystems such as GBAS and regional differential satellite subsystems of type GRAS

In order to equip the Russian civil aviation aerodromes Federation adopted ground control and correction station LKS-A-2000. The system is located at 106 airports and corresponds to landing requirements for ICAO Category I.

Subsequently, after the development and adoption of appropriate SARPs, revision of LKS-A-2000 to requirements of categories II and III is expected ICAO and their installation in aerodrome zones and airfields.

A prototype of the LKS-A-2014 system has been created, working on promising GNSS GLOHACC / GPS / GALILEO signals.

In the Russian Federation, an onboard GBAS equipment for various types of aircraft. Are being developed regulatory framework and design documentation necessary for installation and use of this equipment.

Preliminary work is underway to create aviation regional differential satellite subsystems of the GRAS type at using ultra-shortwave stations to transmit differential corrections and integrity control information.

4.6. Regional differential satellite subsystems based on pulse-phase RNS

In the Russian Federation and the Republic of Belarus there is a ground navigation base that supports control technology transmission corrective information from regional differential GNSS satellite subsystems using Eurofix technology. In Russian

Federation, this base is presented in the form of pulse-phase RNS types "The Seagull", "Tropic-2V" and "Tropic-2C". Modernization in progress a similar station located in the city of Slonim of the Republic of Belarus.

An experimental batch of consumer navigation equipment was produced, providing reception and processing of signals from GNSS

GLONASS / GPS / GALILEO and RSDN "Chaika / Loran-C" ("NAP" Integration ").

For the implementation of regional differential satellite subsystems in the territories of the CIS member states is necessary expand the range of navigation equipment for consumers and prepare regulatory legal acts and regulatory technical documents, governing commissioning, application and further improvement of these systems.

4.7. Long Range Navigation Radio Systems

Radio-technical systems of distant navigation "Tropic-2" ("The Seagull"), Tropic-2P, Mars-75 (Neman-M) remain an important tool correction of autonomous reckoning (see tab. 18), performing the function autonomous backup navigation system.

In the period until 2020, a planned replacement of mobile long-range radio navigation systems "Tropic-2P" to the information system coordinate-temporal support "Scorpio". As part of the complex equipment there are local control and correction stations, which can significantly improve the accuracy of determining coordinates consumers.

Operation of the operating circuits of the RNS "Mars-75" is planned until development of a technical resource.

To cover the Northern water area with a radio navigation field the sea route worked out the issue of building new promising stations RNS of the long-wave range "Neman-M" integrated with GLONASS and control and correction stations. Deployment of the Neman-M RNS on The coast of the Barents Sea is planned to be implemented until 2021.

4.8. Short-range radio engineering systems

RSBN-4N, RSBN-4NM short-range radio navigation systems, RSBN-8N will operate in the allocated frequency bands as main means of short-range navigation of military aircraft at at least until 2021 (see tab. 18). Then it is supposed to use short-range radio engineering systems as a backup tool.

The azimuthal beacon / rangefinder type beacon complex will be remain the main radio navigation facility in civil aviation as long as it is economically feasible. The complex provides air navigation and in aerodrome areas and compatible with foreign equipment like VOR / DME.

Complex drive radio station - the automatic radio compass will be used as a radio navigation aid aircraft before they are equipped with advanced navigation means, and then - as a backup and emergency navigation funds with a gradual decrease in the number of systems.

Operation of the existing circuits of differential-range RNS BRAS-3 and RS-10 is planned before the development of a technical resource. Subsequently they will be replaced by the Sprut-H1 system created so far and marine differential satellite subsystem.

GRAS (GRAS-2) and Krabik-B rangefinding radio navigation systems will continue to provide a solution to the tasks of high-precision geodetic binding of mobile and stationary surface objects in the coastal zone, special and hydrographic tasks requiring ultra-high accuracy

location determination. As they develop a technical resource, they
will be decommissioned and replaced by a radio geodetic complex
Krabik-BM.

4.9. Landing systems

As a standard means of providing aircraft landing
international civil aviation and an analogue of ILS, the SP-75 system (-80, -90,
-200) will be operated in accordance with the ICAO decision, while this
remains economically viable.

Possible replacement of landing systems of category I by aviation
local differential satellite subsystem.

PRMG-5 systems (-76U, -76UM), being the main
military aircraft landing tools will
operated after 2021. Starting in 2017,
modernization.

4.10. Geodetic differential satellite subsystems

One of the conditions for successful geodetic measurements,
topographic and cadastral works, engineering surveys is
effective system of geodetic support. Source geodetic and
map data serve as the basis for obtaining geodetic
coordinates of characteristic points describing the boundaries of spatial
the position of the property.

However, the use of points of the State Geodetic Network
as a supporting rationale, it is often accompanied by a number of difficulties. Them
can be avoided by using accurate positioning systems based
on a network of GNSS base stations - permanent differential
stations located at specially equipped points with well-known
spatial coordinates.

One of the promising areas is the technology of precise
measuring spatial coordinates on permanent networks

differential geodetic stations
positioning.

In the framework of the federal project "Information Infrastructure",
part of the national program “Digital Economy
Of the Russian Federation ”, in 2021 a federal network should be created
differential geodetic stations providing an increase
accuracy of determination of coordinates, and also the center of integration of networks
differential geodetic stations and processing obtained
information. It is planned that in 2019 there will be 600 stations in this network, in
2021 - 1 800. Creation of a federal differential network
geodetic stations will ensure the implementation of uniform requirements for
geodetic measurements.

Metrological certification completed in the Republic of Belarus
satellite accurate positioning system that provides
guaranteed obtaining by users of coordinates and heights throughout
territory of the republic.

Geodetic subsystems of the Republic of Kazakhstan are created on the basis of
local differential stations put into operation in
in accordance with the project “Creating a ground-based infrastructure of the system
high-precision satellite navigation of the Republic of Kazakhstan. "

Development Activities Held in the Kyrgyz Republic
systems of geodetic services based on GPS / GNSS network of Kyrgyzstan - network

permanent geodetic receivers (base stations), data
with which they are used to generate RTK corrections for work
GPS / GNSS field receivers and real-time positioning
time.

The Republic of Moldova has a national system
MOLDPOS positioning, compatible with GNSS GLONASS and GPS.
It is planned to integrate it into the European system.
positioning according to EUPOS standards.

In the structures of the State Committee on Land Management and
surveys of the Republic of Tajikistan are functioning and developing
automatic position monitoring stations.

Global positioning systems are also used to
warning and monitoring of emergency situations in the territories
high seismicity. GNSS GLONASS and GPS allow you to conduct
continuous monitoring of crustal deformations in the territories of any
area and thereby create a reliable basis for earthquake prediction.

4.11. Prospects for the development of consumer equipment

Further development of consumer navigation equipment
associated with the expansion of its fields of application. Initial tasks
solved using GNSS and ground-based RNS, related to
traditional area of navigation of moving objects. Level reached

technical and operational characteristics greatly expanded
the boundaries of the use of consumer equipment and allowed to cover:

vehicles of both military and civilian use;

military and civilian management and identification systems
destination;

conducting geodetic and cartographic work;

synchronization of clock systems, communication, automatic
identification system, etc .;

land management and cadastral works, condition monitoring
Earth's crust;

exploration and operation of fuel
energy complex;

construction and control of long and high-rise structures;

work in long and deep careers and in other
mining enterprises;

frequency stabilization systems of electric power systems;

providing accurate agricultural technology, for example, in cultivation and
cultivation of land, as well as in the processing of crops by pesticides;

interfacing with the equipment of the global marine communications system
disaster and security;

information and navigation systems and complexes;

GIS technology.

Retrospective analysis of changes in the characteristics of navigation
GNSS and ground-based RNS consumer equipment and research
the dynamics of the requirements for it allow us to designate the following
development trends:

1) improving the characteristics of the equipment:

improving accuracy characteristics;

increased reliability, noise immunity and electromagnetic
compatibility;

providing autonomous methods for monitoring the integrity of the system;
expanding the list of service tasks;
decrease in weight and size characteristics;
reducing the cost of equipment for the mass consumer and increase its availability;

2) expansion of functionality:

determination of spatial orientation angles, system corrections heading, time stamps;

providing the ability to integrate equipment with autonomous object navigation systems;

enabling equipment to interact with automated information systems and control systems movement;

3) the creation of a unified series of functional elements, nodes, blocks. It should be noted the creation of navigation and information modules based on integrated chips "VLSI - extra large integrated scheme "intended for use by the most massive by consumers.

The main trends in the development of consumer navigation equipment GNSS are displayed in tab. 21.

Table 21

The main directions of development of navigation equipment GNSS consumers

Existing equipment	Promising equipment
Work on GNSS GLONASS and GPS	GNSS work GLONASS / GPS / GALILEO / BEIDOU
Tracking code and frequency	Tracking code, frequency and phase (with a resolution of significance and elimination of phase jumps)
Determination of coordinates and speed antenna phase center	Determining the coordinates and speed of a given points and angles of orientation of the ship
Work in the frequency ranges L1 GLONASS and GPS	Work in the frequency ranges: L1, L2 and L3 GLONASS; L1, L2 and L5 GPS; E1, E5 and E6 GALILEO; B1 B2 and B3 BEIDOU
Work on a standard code signal GLONASS accuracy	Work on standard and high precision GLONASS
Ability to work in differential mode	Differential operation in the zone actions of marine, aviation local, regional and wide-area differential satellite subsystems, including in PPP mode
Work on all visible GNSS spacecraft	Work on all visible GNSS spacecraft
	Interference Detection and Management radiation pattern to exclude their influence
	Autonomous integrity control navigation definitions

Existing equipment	Promising equipment
Used coordinate systems: SK-42; WGS-84, PZ-90.02, Gauss - Kruger	Used coordinate systems: SK-42, WGS-84, SK-95, GSK-2011, systems PZ-90.11, Gauss - Kruger, quasi-coordinates
	Receiving and accounting in navigation solutions auxiliary (assisting) data from external information systems (GNSS, single global information geospatial basis, etc.)

Technical requirements for consumer navigation equipment should be established national, interstate or international standards, as well as technical regulations.

5. WAYS OF TECHNICAL DEVELOPMENT AND IMPROVEMENT RADIO NAVIGATION SYSTEMS

5.1. General tasks and ways of technical development radio navigation systems

The increasing demands of various consumer groups navigation services define tasks to improve performance existing technical means of radio navigation support:

accuracy of determining the location of the object;

availability of RNS;

RNS integrity;

continuity of service (functioning);

stability of work, especially in conditions of interference.

Ways to solve these problems are:

modernization of existing and creation of new GNSS;

improving the functional complement of GNSS;

improving the technical characteristics of ground-based RNS;

creation of alternative positioning, navigation and time based on multi-position surveillance systems and digital lines data transmission;

application of integration methods of various RNS;

reducing the vulnerability of the RNS from the effects of interference;

Creation of a developed infocommunication infrastructure, designed to provide navigation services based on navigation resources;

development of navigation equipment for consumers.

5.2. Satellite Radio Navigation Systems

General directions for upgrading satellite RNS are aimed at improving the quality of services and identified in the form of the following measures:

improving the availability and accuracy of navigation definitions;

increase reliability and service life of equipment and improvement system integrity;

improved compatibility with other radio systems;

Improving the service provided to users.

Satellite RNS can meet the needs of navigation support for a wide range of consumers. Exist tasks requiring high accuracy of navigation, such as take-off, approach landing and landing of aircraft, navigation in coastal waters, road transport navigation, etc.

On the accuracy of solving the navigation problem by definition The location of an object is affected by the following factors:

geometric arrangement of navigation spacecraft used in decision;

errors in the formation of the onboard time scales of navigation spacecraft;

ephemeris errors of navigation spacecraft;

errors due to the propagation of navigation radio signals in atmosphere (ionospheric and tropospheric errors);

hardware errors of navigation spacecraft.

The radical direction of increasing the accuracy of navigation Definitions is a *differential* navigation *mode* . His essence consists in eliminating some errors in the navigation field systems strongly correlated in local areas (up to 2,000 km).

The highly correlated include navigation errors definitions due to the following factors:

desynchronization of the onboard time scales of navigation spacecraft;

the influence of errors in the ephemeris of navigation spacecraft;

propagation of navigation signals in the ionosphere and troposphere.

Having obtained the values of these systematic errors (the so-called differential amendments), it is possible to implement compensation in consumer equipment basic systematic errors of navigation definitions by their accounting in navigation data processing algorithms.

A collection of hardware and software designed to improving the accuracy of navigation definitions based on the standard signal satellite RNS, called functional additions.

5.3. Satellite Augmentation Systems radio navigation systems

5.3.1. Tasks of functional additions and ways of their implementation

The main tasks of functional additions are:

ensuring the required integrity and availability of satellite RNS;

ensuring the necessary continuity of navigation definitions;

increasing the accuracy of navigation to the required.

These tasks are solved by applying the following measures:

use differential mode to increase accuracy of navigation definitions;

introduction of additional satellites (geostationary) to increase accessibility;

introduction of ground integrity monitoring stations and a special channel Integrity Channel (GIC - GPS Integrity Channel) to enhance integrity.

Integrity Enhancement Provides Network Stations integrity monitoring to ensure continuous monitoring real-time and regional system health a computer center for processing data received from a network of stations and generating integrity data for transmission to consumers.

As channels for transmitting GNSS integrity information terrestrial and geostationary communication channels are offered satellites. The channel can transmit both integrity information and additional radio navigation signals. As a result increase system integrity and availability.

Functional additions should be specifically highlighted, different from traditionally used by consumers, - pseudosatellite and assistive functional additions.

Pseudosatellite functional additions are one or more pseudo-satellites forming navigation signals in GNSS format. A pseudo-satellite is a control and correction station, emitting signal similar to the signal of the navigation satellite, and geodesically

precisely tied to the adopted coordinate system. In addition to transmission
differential corrections and warning signals are provided
additional channel for measuring the distance of the navigation object relative to ground item. Pseudo-satellites complement the radio navigation field satellite RNS (GNSS) in a given area and usually have a local work area. The size of the latter is determined by the transmitter power pseudosatellites and line of sight.

Assistive functional additions - systems that implement Auxiliary GNSS mode and forming non-correcting amendments, and additional supporting information to speed up entry into communication with navigation spacecraft and improving the reliability of positioning consumers.

The classic method of increasing the accuracy of navigation definitions is the use of differential mode definitions.

Differential mode involves the use of one or more basic receivers located at points with known coordinates that are simultaneously with the consumer receiver (fixed or mobile) receive signals from the same satellites.

Improving the accuracy of navigation definitions is achieved through the fact that errors in measuring navigation parameters of consumer and base receivers are correlated. When forming differences of the measured parameters most of these errors compensated.

The differential method is based on the knowledge of the coordinates of the reference points - control and correction station or reference station system, regarding which amendments to the definition can be calculated pseudo-range to navigation satellites. If these amendments are taken into account in consumer equipment, the accuracy of the calculation, in particular the coordinates, can be raised tenfold.

A special case of differential mode is the *method relative navigation* that improves accuracy characteristics of the standard modes of the RNS ground or space basing. This method is best used in solving problems. mutual coordination of objects working on the signals of one RNS, when knowledge of exact absolute coordinates is not required. With mutual coordinating a group of objects (ships, planes, etc.) one of them defined as a reference, the current absolute coordinates of which taken as the beginning of the system of relative coordinates and transmitted by a connected channel to other objects where their own coordinates relative to the reference object.

When using this method, the proportion of systematic error will be significantly reduced with decreasing distance to the reference object and time between observations. In the extreme case of error relative positioning is limited to instrumental errors of consumer receiving equipment.

A separate place in the number of global differential systems correction takes service PPP. PPP technology can provide positioning accuracy from decimeter to centimeter and better (for static processing mode) when combining accurate data about satellite orbits and time received by a dual frequency receiver

GNSS signals to take into account the effect of the influence of the first-order ionosphere.

The main advantages of PPP technology over others differential positioning methods should include the fact that for PPP implementation requires only one receiver and no special base stations in the immediate vicinity of the user.

The creation of a two-level differential a system including wide-area and specialized local differential satellite subsystems.

Isolation in the structure of a single differential system of two hierarchical levels associated with the need to meet the requirements different types of consumers and with organization features corresponding means of functional additions functional additions. The structure and composition of the differential satellite subsystems of different levels differ significantly, as well as methods, means of receipt and delivery to consumers used therein corrective information.

5.3.2. Classification of functional satellite add-ons radio navigation systems

Depending on the size of the functional area of the system additions are divided into four types (table. 22):

1) global differential correction systems;
2) wide-gap differential correction subsystems;

3) regional differential subsystems;
4) local differential subsystems.

The range of functional additions is determined by the zone actions of channels for transmitting information to consumers. Within the zone actions of functional additions are established service areas, which, in turn, are determined by the placed reference / control stations providing execution operations approved for use in the field.

Depending on the methods for solving the tasks and place placement of elements functional additions distinguish:

space - SBAS, for example, SDKM, WAAS, EGNOS, GAGAN, MSAS

ground - GBAS, for example, DGPS, LAAS, GRAS;

autonomous, implemented on board surface ships or on board aircraft, for example, ABAS according to ICAO classification, using standalone integrity monitoring methods RAIM & AAIM.

Table 22

Functional Addition Systems

Parameters	Functional Addition Systems			
	Local differential satellite subsystems	Regional differential satellite subsystems	Wide-gap differential satellite subsystems	Global differential satellite subsystems
Composition	One or some collection stations measurements [1]; transmission channel data	Station network measurements; channels transmission data; computational	Regional network of stations measurements; channels transmission data;	Global network stations measurements; transmission channels data; computational

		center	computational center; ground complex management	center; ground complex management
Action area Km	50-200	400–2,000	2,000–5,000	Global coating
Achievable error definitions location consumer	1 to 5 cm	5 to 50 cm	5 dm to 2 m	5 cm to 2 m

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Functional Addition Systems

Parameters	Local differential satellite subsystems	Regional differential satellite subsystems	Wide-gap differential satellite subsystems	Global differential satellite subsystems
Terrestrial Transmission	Channels the lines transmission data [4]	Land lines transmission data	Space communication devices and relay	Space communication devices and relay
Corrective information	Amendments to navigational m parameters measurable consumer; information on integrity system [2]	Amendments to navigational parameters measurable consumer; information on integrity the system	Amendments to ephemeris temporal information [3] ; amendments to navigational parameters measurable consumer; information on integrity the system	Amendments to ephemeris temporal information; amendments for exceptions atmospheric signal distortion; amendments to navigational parameters measurable consumer; information on integrity the system

[1] Stations of collection of measurements - control and correction stations, which are complex of high-precision navigation equipment installed at points with known coordinates.

[2] System integrity information - GNSS malfunction information, not discovered or not corrected by her own means in the process operation. The transmission of system integrity information prevents Consumers use incorrect navigation data.

[3] Ephemeris-time information - data for calculating the orbit of the spacecraft and data onboard hours.

[4] Terrestrial data lines - VHF radios, mobile systems wireless or internet.

Ground and space functional additions are built with attraction of additional ground and space systems and facilities. On the The Earth has special control and correction stations, calculating corrective corrections to increase accuracy navigation, as well as integrity control and increased reliability navigation definitions (accessibility). Transfer aboard the consumer

the additional information received is either
directly by ground transmitting stations (for GBAS), or with using special communication satellites in geostationary orbits (for SBAS).

The fundamental difference between SBAS and GBAS is in the methods of obtaining and delivery of corrective information, as well as in the coverage area of the systems.

GBAS is a local system operating in a range of up to 50–100 km, and SBAS is a global system with a range of up to several thousand kilometers.

The GBAS ground supplement includes the following key elements:

control and correction station;

differential corrections monitoring station;

station for transmitting differential corrections and signals warnings.

Control and correction station monitors integrity of navigation signals and differential calculation corrective information to improve accuracy. In the interest of control integrity can be involved in special monitoring stations that control the quality emitted by navigation satellites radio navigation signals and navigation field and in the case of failures and malfunctions form a sign of failure corresponding satellite.

The differential corrections monitoring station controls them quality. The summarized information is then generated in a single format and It is transmitted onboard via one of the available communication channels (VHF communication or others).

Terrestrial functional additions include local and regional differential subsystems for various purposes - marine, aviation, geodetic, special.

Local differential satellite subsystems have maximum range from the control station or data line transmitter - 50-200 km. Local differential satellite subsystems usually include one control and correction station (there are options with several stations), control and monitoring equipment (including control integrity), as well as data transmission media.

To provide high-precision navigation in aircraft at the stages of approach for landing and direct landing are widely developed and implemented airborne LAAS installed at the aerodrome. As a means data transfers aboard aircraft in LAAS are commonly used pseudosatellites.

5.3.3. Global differential satellite subsystems

There are commercial global differential systems corrections providing high-precision location services, based on networks of private reference stations tracking signals GNSS GLONASS and GPS. Service information is transmitted through geostationary satellite networks and the Internet.

Geostationary spacecraft are also used as additional navigation points for additional rangefinding measurements. The main methods of integrity control in this case are methods analysis of differences between measured and predicted values pseudo-ranges, as well as methods using measurement redundancy.

Service is available almost globally, with the exception of polar areas.

These services are widely used to improve accuracy. location in the coastal areas and in the oil and gas industry.

OmniSTAR Service Differential Corrections transmitted in the L-frequency range close to GPS frequencies, which allows use single frequency antennas to receive information data.

The system automatically provides the best solution. positioning for all users using a technique known as virtual base station VBS (Virtual Base Station). This way differential correction is more accurate than shaping differential corrections from a single reference station or from fixed base virtual base station.

5.3.4. Wide-area differential satellite subsystems

Five broadband satellite systems are currently under development. differential correction (Fig. 3):

1) SDKM (Russian Federation);
2) WAAS (USA);
3) EGNOS (European Union);
4) GAGAN, geostationary navigation supplement GPS (India);
5) MSAS (Japan).

Egnos
SDKM
WAAS
Msas
Gagan

Fig. 3. Wide-area satellite differential correction systems

SBAS space add-ons include ground and space segments.

The basis of SBAS is a network of wide-area monitoring stations, information from which is transmitted to wide-area main stations for joint processing to produce common corrections and signals integrity. The radius of the working area of the wide-gap differential satellite subsystem is 5,000-6,000 km. Integrity signals and corrective amendments developed on wide-area main stations are transmitted through ground stations transmitting data to geostationary spacecraft of the Inmarsat, Artemis type for subsequent relay to consumers.

5.3.5. Regional differential satellite subsystems

Regional differential satellite subsystems designed for navigation support of certain regions continent, sea, ocean. The diameter of the working area may be 400–2,000 km or more. Regional differential satellite subsystems may include one or more control correction stations as well as appropriate transmission media corrective information and integrity signals. This information produced at the main station or control and correction station.

Preliminary work on the creation of regional differential satellite subsystems of two types:

aviation type GRAS when using VHF stations for transmission differential corrections and integrity control information;

Eurofix type using Chaika pulse-phase RNS stations for transmitting differential corrections and control information integrity for the benefit of all consumer groups.

Regional differential satellite subsystems of the GRAS type differ from wide-area differential satellite subsystem the fact that control and corrective information is transmitted through ground VHF stations instead of the geostationary spacecraft GBAS. By this the reduced dimensions of the subsystem working area are determined, in comparison with wideband differential satellite subsystem. For instance, The radius of the Australian GRAS zone is about 2,000 km.

Regional Aviation Differential Satellite GRAS subsystems must satisfy approach requirements Category I ICAO.

The project of regional differential satellite subsystems with stations pulse-phase RNS "The Seagull" involves the use of technical solutions of the Eurofix project aimed at creating GLONASS / GPS regional differential satellite subsystems on based on the use of transmitting stations pulse-phase RNS "Laurent-FROM". It is assumed that the GNSS control and correction station

located in the area of the ground-based transmitting station pulse-phase RNS.

A number of advantages of this solution over other options are noted. creation of regional differential satellite subsystems, namely:

use of an existing structure for the implementation of the project;

coverage of a large area at a relatively low cost;

providing improved channel uptime and availability data transmission in urban and mountainous areas;

mutual complementation and redundancy of the “Laurent-S / Seagull ”and GLONASS / GPS.

GNSS location determinations can be used to calibration of readings RSDN and compensation for errors due to features of the propagation of radio waves. In turn, the data "Laurent-C / Seagull "can be used to monitor the integrity of satellite RNS.

Stations of the pulse-phase RNS "The Seagull" operate in the long-wavelength range of radio waves at a frequency of 100 kHz. System radius in mode regional differential satellite subsystem from one station pulse-phase RNS is 600–2,200 km. When using chain stations pulse-phase RNS working area of the regional differential satellite subsystem will be the result superposition of the private zones of pulse-phase RNS stations.

Conducted research on the use of Eurofix technology in relation to the European network of pulse-phase RNS "Seagull" Confirmed Expected Errors inherent in Eurofix Technologies (table 23). It is shown that the accuracy of determining the coordinates of the regional differential satellite subsystem can be no worse than 5 m (95%). Data lines based on pulse-phase RNS stations can provide an effective data rate of 15 to 30 bit / s per asynchronous data transmission mode DGPS / DGLONASS.

Table 23

Characteristics of Regional Differential Satellite Eurofix based subsystems

Parameter	Value
Availability (availability) of the signal in space,%:	
1 station	99.8
2 stations	99,9996
3 stations	99,999999
Accuracy (95%), m:	
– horizontally	1,5
– vertically	3
Integrity (alarm delay), s	6
Continuity (probability of occurrence of an error)	$1 * 10^{-4}$ for 150 s

5.3.6. Local differential satellite subsystems

Classification of local differential satellite subsystems

Local differential satellite subsystems provide maximum range 50–300 km from the control and corrective station. Most often, they have one control and correction station, control and monitoring equipment, data transmission facilities.

To date, three main classes of local differential satellite subsystems:

marine - to ensure navigation in the strait zones, narrow places and water areas of ports and harbors in accordance with IMO requirements;

aviation - to ensure an approach and landing of air vessels by ICAO categories;

subsystems for geodetic, surveying and other special works.

Marine local differential satellite subsystems and differential satellite subsystems to provide internal *waterways*

Marine local differential satellite subsystems are based on omnidirectional medium-wave beacons and designed to transmit corrective information and information about integrity for the preferential provision of ships and located along the coast and along the banks of large inland reservoirs.

Marine local differential satellite subsystems have consisting of one control and correction station, remote equipment management and control, as well as means of data transmission. As channeling equipment data lines apply radio beacons operating in the range of 283.5–325 kHz. Is applied minimal phase shift manipulation. Marine local differential satellite subsystems have maximum ranges actions 250-300 km from the control and correction station.

Corrective Information from Marine Local Differential satellite subsystem is broadcast in accordance with generally accepted RTCM SC-104 standard originally developed for GPS Ad Hoc Committee of the 104th Radio Engineering Navigation Commission USA and supported by IALA. Version 2.2 of this standard is designed to to account for the use of the GLONASS differential mode.

Correction information transfer rate is set to depending on the amount of data required to update them and may

be from 25 to 200 bps. In case of transfer of amendments for GLONASS bit rate is 25 bit / s. When working with GPS without selective access and selective access transmission rates make up 50 and 100 bit / s respectively.

The main disadvantage of the selected data line is its exposure to interference, e.g. due to static discharges electricity in meteorological conditions. For noise immunity Reed-Solomon correction codes are used for coding.

IALA recommends the coastal countries of the European Sea Area in GPS operating conditions without selective access restrict range of transmitting stations of marine local differential satellite subsystems at 200 km and set correction bit rate 100 bps to exclude the possibility of mutual interference.

Amendment on ships and vessels is carried out using corrective information receivers having appropriate interface for interfacing with navigation equipment GNSS consumers.

Location accuracy using control-corrective information from the beacon depends on the specifics beacon equipment and can vary from 1 to 10 m.

The accuracy of determining the coordinates at the edge of the marine working area local differential satellite subsystem with joint using GLONASS and GPS can have a value of 2 to 4.5 m (with a probability of 0.68). Service reliability and availability make up more than 0.9997 and 0.998, respectively, with a failure warning time less than 10 s.

Aircraft local differential satellite subsystems

To date, several types of aviation local differential satellite subsystems designed for ensure aircraft landing. These systems are different advantages, among which are:

possibility of use in conditions of I and more complex categories landing;

the ability to use with advanced operations in complex weather conditions;

the flexibility of operating modes, allowing to implement the approach trajectory with variable geometry, minimizing flight time and ensuring the fight against interference;

a relatively small composition of the equipment allows to reduce economic costs and ensure widespread local application airlines.

Some local differential satellite subsystems use code and phase measurements of GLONASS / GPS signals and signals of pseudosatellites (or pseudoliths) placed in front of the end runway for each approach direction.
Code and phase measurements of the ground control station are transmitted to board in real time.

Use on board the aircraft of its own code and phase measurements of the navigation spacecraft and pseudo-satellites together with additional measurements of ground control station allows you to successfully solve the problem of ambiguity phase readings and realize higher accuracy.

ICAO Position on Message Format and Radio Channel for aviation local differential satellite subsystems found reflected in the 1999 GNSS SARPs, which take into account the standard RTCA / DO-217 for the minimum characteristics of aviation systems, prepared by the United States Radio Technical Commission. IN
In accordance with this standard, a number of specific and described above systems that have been tested. They are supposed to be used for provision of civil aviation flights. Corresponding transmission line
The data uses the VHF frequency range 112–118 MHz.

The location of GBAS in the aerodrome area creates the conditions for expansion its functions. The opportunity to exercise control and control of all moving objects located in the aerodrome zone.
For this, airfield vehicles are equipped with navigation consumer equipment and over the air transmit the coordinates of their locations of the dispatcher, where they are displayed on the electronic map.
Having a complete picture of the location and movement on the airfield of all vehicles and aircraft, the dispatcher can carry operational management of them and thereby increase security.

5.3.7. Standalone Functional Add-Ons

ABAS standalone add-ons on board surface ships or consumer aircraft to solve problems integrity control, improving the accuracy and reliability of navigation definitions and use the technical means located on board consumer.

ABAS airborne add-on is essentially an improvement

autonomous integrity monitoring systems in the navigation receiver,
commonly referred to as RAIM, by using information from other airborne consumer systems.

All navigation information available on board the consumer used to provide the required navigation performance providing using the following methods:

use of algorithms in navigation equipment of consumers RAIM, among which are failure detection algorithms and algorithms for eliminating failed navigation satellites;

use of AAIM integrity control methods;

integration with navigation sensors mounted on board, which may include: airborne navigation sensors and facilities; altimeters; inertial navigation system; gyroscopic Sensors precision watch; magnetic compass;

integration with data from other GNSS.

5.3.8. The complementarity of differential satellite subsystems

It should be noted that all types of functional additions are not opposed to each other, and mutually complement them to ensure meeting the requirements of all consumers for accuracy, integrity, the availability of navigation support.

Scopes of WAAS and LAAS, as well as Autonomous Methods RAIM integrity controls are shown in table. 24 and 25.

Table 24

Scopes of WAAS and LAAS by category of requirements

Requirements	Category I	Category II	Category III
Accuracy definitions heights, m	4	2,5	2,5
Integrity	(1–3.3) * 10^{-7}	(1–3.3) * 10^{-8}	(1–1.5) * 10^{-9}
Availability	0,9975	0,9985	0,999
Detection time and bringing the signal warnings less with	6	2	1
Continuity	1 * 10^{-5} within 15 s; 1 * 10^{-4} within 150 s	(1–1.4) * 10^{-6} within 15 s; (1–1.4) * 10^{-5} within 165 s	(1–4) * 10^{-6} within 30 s
	WAAS	LAAS	

Table 25

Compliance with WAAS, LAAS, and RAIM Flight Stage Requirements

Flight stages	Flight phases	Integrity	Availability	Accuracy
Route flight over the ocean			RAIM	
Approach and landing	Indoor tracks			
	Inaccurate approach to landing	WAAS		RAIM
	Precise landing on category I		WAAS and LAAS	
	Precise landing on category II / III		LAAS	
Ground Operations Taxiing				

5.4. Satellite fundamental systems navigation systems

The main tasks of the system of fundamental coordinate temporary security in the General case are:

establishment of a celestial coordinate system and its implementation in the form catalogs of coordinates of sources in different wavelength ranges;

establishment of the earth coordinate system and its implementation in the form of a catalog coordinates of reference stations;

determination of the orientation parameters of the celestial and terrestrial systems coordinates - Earth rotation parameters;

establishment of a dynamic coordinate system and its implementation in the form theories of motion of bodies of the solar system;

creation and maintenance of a unified system of time and reference frequencies;

the establishment of the parameters of the figure of the Earth and the bodies of the solar system;

establishing the parameters of the gravitational field of the Earth and the solar bodies systems;

the formation of databases on the physical fields of the Earth (gravitational, geomagnetic, etc.);

development of theories, models and methods for solving these problems.

GNSS fundamental support system way to establish and maintain fundamental (heavenly and Earth) coordinate systems and determining the parameters of their relative orientation with high precision. These data are used in any RNS space basing.

The basis of the system of fundamental coordinate-time security is the complex "Quasar-KVO", which are held observations extragalactic radio sources method ultra-long base radio interferometry. Method ultra-long base radio interferometry is the only space geodesy, which allows to determine the complete set parameters necessary to establish the mutual orientation of the earthly and celestial coordinate systems.

The Kvazar-KVO complex has three observatories, each of which is equipped with: 32-meter full-circle antenna with system management; systems of time-frequency synchronization, reception, conversion and registration of signals; Sazhen-TM laser range finder; GLONASS / GPS receivers of a geodetic class.

Thanks to the participation of the Kvazar-KVO complex in international ultra-long-range observation programs the observatory coordinates were determined with great accuracy in ITRF. World Time Daily Online Requirements are performed with an error of 20 µs. Observatories also held monitoring of local geodetic networks.

5.5. Integration of radio navigation systems

5.5.1. Navigation Integration Goals

The characteristics of individual ground-based RNS do not allow to satisfy the growing requirements of major consumer groups in accuracy, availability and integrity.

With the introduction of GNSS GLONASS and GPS, an opportunity has arisen meet consumer requirements for navigation accuracy providing. However, in this case, the requirements may not be satisfied. consumers in terms of availability and integrity in difficult conditions, especially in the presence of unintentional and intentional interference.

To improve navigational support features such as accessibility and integrity, it is advisable to integrate navigation systems.

5.5.2. Integration of satellite and inertial navigation of systems

GNSS GLONASS and GPS are almost the most accurate global action navigation tools, but they need support in the interests of increasing the noise immunity of the tracking channels of receivers and ensuring continuity of navigation definitions during breaks in the use of GNSS caused by various causes, such as interference, ship maneuvering, signal shading, etc.

The required support is provided by autonomous numbering methods coordinates:

based on the data of the course system and lag of sea vessels;

odometric (course system plus odometer);

inertial (inertial navigation system);

course-air (course system plus air signal system);

course-Doppler (course system plus Doppler meter speed and drift);

inertial-Doppler (inertial and Doppler systems).

During interruptions in the operation of GNSS equipment, navigation definitions carried out on the basis of data from autonomous number systems taking into account increasing their accuracy by evaluating the sources of autonomous errors systems implemented during the integrated processing of information at the stages operability of navigation equipment for GNSS consumers.

The most promising autonomous system is recognized as inertial a navigation system that, with potentially high accuracy, is devoid of known flaws in airspeed, lag and Doppler meter. There is no inertial dependence navigation system from wind, currents, maneuvering, underlying surface, etc.

Inertial navigation systems exist and are being developed on mechanical, electrostatic, ring laser, fiber optical, wave and micromechanical gyroscopes. Most massive inertial navigation systems (for land and sea transport, general aviation) should be recognized in the future inertial navigation systems based on micromechanical gyroscopes, whose accuracy can reach 2–10 km / h. In this embodiment, UPC inertial navigation system can make offline about 60 m after 5 min. after GNSS failure.

By the degree of use of inertial data in GNSS equipment The following main integration schemes are distinguished: open and loosely coupled, highly connected, and deeply integrated.

In open and loosely coupled circuits, which have received the greatest propagation, inertial data in an integrated RNS receiver are used to a minimum extent - at best to speed up the search GNSS signals.

In a tightly coupled integration scheme, data from inertial navigation systems are also used to improve the quality of work GNSS receiver tracking channels.

In a deeply integrated circuit, the operation of GNSS and inertial channels
The navigation system should be implemented almost jointly.

Primary integrated information processing in strongly related and deeply integrated inertial-satellite systems allows to increase the noise immunity of GNSS reception and measurement channels by 15–20 dB

Using inertial navigation system information also allows to significantly improve the characteristics of control algorithms GNSS signal integrity and improve the reliability of navigation definitions.

5.5.3. Integration of satellite radio navigation systems

Integration of satellite RNS is understood as creation joint radionavigation field provided by these systems, with independent management of each system.

One of the most promising areas of integration space RNS is to ensure compatibility and complementarity of GNSS GLONASS, GPS, GALILEO and BEIDOU.

GNSS integration involves the creation and use of receiver-indicator equipment capable of receiving signals two or more systems, thereby increasing the accuracy and reliability location characteristics.

To share navigation options (pseudorange and pseudo-speeds) it is necessary to provide

intrasystem coordination of used coordinate systems and scales time systems GLONASS, GPS, GALILEO and BEIDOU.

Integration of GNSS GLONASS, GPS, GALILEO and BEIDOU will allow create a basic global RNS that meets existing and perspective requirements of air, sea, land and space consumers.

5.5.4. Integration of terrestrial and satellite radio navigation of systems

Integration of terrestrial and space RNS will allow creating separate navigation areas superior in technical the characteristics of each of its constituent systems.

As with the integration of space RNS, the creation of integrated ground and space systems involves integration at the receiving level (or receiver-indicator) equipment of consumers and requires coordination existing discrepancies in the used coordinate systems, scales time and clarify the structure of the transmitted radio signals.

As a result, geographic accessibility and integrity will improve. areas defined by the chains of ground-based RNS stations.

One of the ways to integrate ground and space RNS is integration of systems like "Seagull" and GLONASS.

Integrated systems "Seagull" / GLONASS may in the future used as the main systems for route stages navigation.

5.6. Reducing the vulnerability of radionavigation systems

RNS are exposed during operation destabilizing factors that can reduce quality indicators

functioning of the system and in the worst case
its inoperative state.

Vulnerability of the RNS is determined by the following factors:

changing the propagation conditions of radio waves;

a change in the state of the ionosphere;

the influence of unintentional and intentional interference;

occurrence of system failures;

the possibility of physical damage to system elements (spacecraft, ground means, communication lines).

cyber threats;

other factors.

Modern RNS operate in various ranges of radio waves, which are characterized by variable propagation conditions.

In general, propagation conditions are subject to diurnal and seasonal changes, depend on heliogeophysical

disturbances, the state of the Earth's atmosphere and the latitudinal position of the route the passage of radio waves.

Propagation of radio waves in an environment entails a change in parameters electromagnetic waves:

wave field amplitudes (usually a decrease due to scattering and absorption);

speed and direction of propagation;

polarization plane (rotation of the plane - the Faraday effect);

delays in time and phase;

forms of transmitted signals (pulses).

In the atmosphere surrounding the Earth, there are three areas that render influence on the propagation of radio waves: troposphere, stratosphere and ionosphere.

The boundaries between these areas are not pronounced and depend on season and geographical location.

Application of a simplified theoretical model of the ionosphere with a small a set of coefficients transmitted by GNSS satellites to calculate ionospheric corrections on the receiver side approximately halves pseudorange errors caused by ionospheric delays.

The effect of fast and prolonged ionospheric delays on GNSS can be significantly reduced by using the method dual frequency measurements. However, in conditions of magnetic storms, the availability and positioning accuracy may not be practical applications even when using dual-frequency equipment. In conditions geomagnetic disturbances of the ionosphere disruption signal tracking navigation spacecraft in phase and code at the second (auxiliary) GNSS frequency observed much more often than the first.

Changes in the state of the ionosphere (especially in the auroral zone) under the action of heliogeophysical disturbances should be monitored, as these changes may lead to significant location and time errors in features with a tendency to increase accuracy and speed location determination; the results of such controls should used by providers and consumers of navigation services.

Intentional and unintentional interference represent the greatest threat to the navigation equipment of GNSS consumers,

since the power of the received signals is very low and at a level
160–161 dBW. Interference effects can be arranged in channels
GLONASS, GPS, GALILEO and BEIDOU, EGNOS, MSAS, SDKM and local
GBAS differential satellite subsystems. In this situation
it is advisable to use a combination of methods, methods and ways to reduce
vulnerabilities.

Along with this, legislative measures are required in relation to interference.
artificial origin.

For the fundamental support system of space RNS
the greatest threat is the increase in the level of radio interference from the equipment
mid-range and broadband cellular radio systems in the field
location of radio interferometry with extra-long bases.
Radio interference level monitoring at national facilities
ultra-long base radio interferometry is necessary
a measure ensuring the operability of the fundamental
providing space RNS. Every action should be taken.
to prevent an increase in the level of radio interference at locations
national means of radio interferometry with extra-long bases.

List of recorded and possible sources of interference
for GNSS GLONASS and GPS airborne equipment is given in
tab. 26.

Intermittent and irreversible system failures caused by
aging of the component base of electronic equipment are
objective and inevitable factors in the fight against which should
a program for ensuring the reliability of electronic equipment is applied.

For terrestrial RNSs, the greatest threat is physical
damage to ground equipment, primarily antenna systems,
having the largest dimensions, height or extent. For reception
significant radio waves of the long-wave and medium-wave ranges
atmospheric interference, interference caused by
electrification of the aircraft body, etc.

Persons with criminal intentions have many
ways to carry out cyber attacks in the field of civil aviation, including
by hacking aircraft navigation and control systems. Although still
since most of these attacks were carried out at a low level and their
negative impact was limited, cyberattack could potentially
have disastrous consequences.

Any automated and
robotic systems on land, sea, in the air and space
spaces resulting in an impact on
information space of a computing device (computer),
Storing information that directly or indirectly affects the navigation solution.

Table 26

Sources of interference for GLONASS and GPS

Sources of interfering signals	Interfering options radiation (frequency, MHz; channel number; harmonic)	GPS frequencies MHz: 1,227.6; 1,575.42; 1,176.45	GLONASS frequencies, MHz: 1,242.94–1,247.75; 1,598-1604.25; 1,200
66th and 67th TV channels	2nd harmonic	+	+
22nd and 23rd TV channels	3rd harmonic	+	+
157 VHF	10th harmonic	+	+
131 and 121 VHF	12th and 13th harmonics	+	+
Range Request Signals radio engineering systems middle navigation	2nd harmonic	+	+
525 crystal frequency DME	3rd harmonic	+	-
Personalized systems satellite communications Globalstar, Iridium	More than 1,610	-	+
Digital data transmission (packet radio); Digipeaters, Germany	1,240–1,243.25	-	+
Amateur radio relay stations	1 242–1 242.7	-	+
Amateur television transmitters	1 243–1 260	-	+
Sightseeing radar stations air control traffic and airfield radar stations	1 250–1 259	-	+
Interference from terrorists and radio hooligans in stripes GLONASS and GPS	1 176; 1 226–1 250; 1,575–1,604	+	+
Interference from radio hooligans and terrorists in workers transmission line bands differential data satellite subsystems	108–118	+	+

The following main approaches to solving the problems of vulnerability of the RNS are identified:

identification of areas of application of navigation technologies critical to the quality of coordinate temporary support, and the formulation of requirements for each category of consumers;

improvement of methods and means aimed at reducing the impact of vulnerabilities inherent in a particular type of RNS;

integration and integration of various types of RNS among themselves and other navigation systems based on differing physical principles;

creation of alternative navigation systems used both autonomously and based on integrated radio navigation field;

creation of differential subsystems for various purposes and levels (global, regional, local);

development of requirements for noise immunity of consumer navigation equipment for critical applications, the adoption of special measures to increase its noise immunity at the stage design and mandatory certification of this equipment for compliance with the requirements of noise immunity;

conducting systematic studies to assess the impact on navigation equipment consumers from potentially hazardous electronic devices;

organization of integrated monitoring of electromagnetic compatibility;

creation of a ground-based system for monitoring the electromagnetic environment in the frequency ranges of the RNS using special ground and mobile detectors of interference sources, standard RNS receivers, means of warning consumers, databases of interference and the results of their effects;

conducting organizational events, including: training employees in the rules detect failures in the operation of navigation equipment and the procedure for using backup (alternative) systems and operational procedures; timely informing interested Interference Detection Services; strict regulation of compliance with established standards radio emissions representing a potential interference hazard to GNSS signals.

As one of the most important methods of protection against system interference GLONASS should consider expanding the composition of signal frequencies. IN in accordance with the GLONASS Navigation Signal Development Concept planned and implemented, in addition to frequency division signals in the ranges L1, L2, the use of code division signals in ranges L1 - L3 GLONASS, etc.

In this case, it is advisable to integrate GLONASS, GPS, etc. systems, and also ground-based systems at the level of navigation equipment of consumers.

The second method also involves the implementation of anti-interference measures in on-board satellite equipment and means of functional additions. This is due to the fact that ground facilities may not be enough reliable and operational. The method involves a significant change views on satellite equipment as something absolutely reliable and "Motionless" and involves:

creation of an electromagnetic environment analysis unit and use internal interference detectors;

creation of special circuits and noise reduction algorithms (filters, interchanges, etc.);

the use of smoothing algorithms for code measurements with involving carrier phase measurements;

the use of controlled spatial selectivity synthesized antenna systems, including those with “zeros” in the direction of hindrance.

Important ways to stabilize the navigation provision are redundancy, integration and integration navigation systems of various operating principles and various basing. The main systemic method for reducing vulnerability is integration with onboard autonomous systems, involving:

use of information from autonomous and other systems on board movable means for narrowing the bandwidth of the tracking paths GNSS receivers;

determination of navigation parameters according to autonomous means and GNSS in the navigation complex and the use of this data in solving all problems.

When solving the issue of increasing the survivability of a pulse-phase RNS followed mainly by the use of mobile (mobile) pulse phase RNS and the use of multi-frequency systems.

To increase the accuracy of navigation measurements progressive modes of operation of the pulse-phase RNS are applied, such as the:

operating mode with functionally equivalent stations;

simultaneous operation with adjacent circuits;

differential mode.

A further increase in accuracy is associated with a decrease instrumental errors in measuring the navigation parameter, improving algorithms for recalculating the results obtained from hyperbolic into a rectangular coordinate system and creating models corrections to the phase velocity of propagation of radio waves depending on topography and condition of the underlying surface.

Potential to reduce the impact of errors caused by by changing the propagation conditions of the radio waves by the total error pulse-phase RNS, limited by the resource intensity of the conjugate events.

In general, increasing the stability and accuracy of the pulse phase RNS requires a large amount of work to calibrate them parameters taking into account specific propagation conditions of radio waves, conditions of the underlying surface, geographical areas use, etc.

Also a significant improvement in the performance of navigation GNSS consumer equipment can be achieved through integrated software information processing. Integration of devices and systems at the level of software information processing will allow:

reduce the search time for meter signals;

reduce or completely eliminate the possibility of false captures tracking meters and reduce the likelihood of disruption tracking appropriate radio signal parameters;

improve accuracy and noise immunity radio meters in tracking mode and eliminate or reduce methodological errors of meters;

provide quasi-coherent reception and processing modes radio engineering signals (which was not possible in

corresponding non-complex meters) and thereby significantly improve their accuracy characteristics;

compensate for highly dynamic moving objects movement of the object to the work of meters.

It should be noted that in conditions when the reception of signals of the main staff RNS is impossible or difficult, it is extremely important to have alternative methods navigation and positioning, as well as backup navigation systems, providing the necessary accuracy of coordinate-time definitions.

Based on this, along with space-based and ground-based RNS lighthouse and radio beacon navigation aids are used, as well as using natural fields and forces (inertial, magnetometric, astronomical, gravimetric, etc.).

As RNS, reserve in relation to GNSS, can be local ground-based RNSs with high reliability and noise immunity, scalable infrastructure, as well as low operating costs.

Existing and future local navigation systems able to solve the problem of determining the location of people, equipment and other physical objects within a specific territory or inside buildings, providing centimeter accuracy.

In recent years, becoming more widespread alternative navigation systems, as well as integrated, combining the advantages of RNS, inertial navigation and other alternative methods for determining coordinates.

The main of the used alternative technologies, used for local navigation and positioning are technology:

radio frequency;
infrared positioning;
ultrasonic positioning;
using magnetic and electromagnetic fields;
using inertial sensors;
using digital video cameras;
using tactile systems and theodolites;
hybrid or combined technologies.

5.7. Prospects for the development of consumer equipment

5.7.1. General trends in the development of consumer equipment

Consumer navigation equipment is an essential component part of navigation support.

In general, the navigation equipment of consumers is understood as finished product or a set of receiving module with

an antenna designed to receive and process RNS radio signals in to solve navigation problems and synchronize timelines consumers.

Receiving indicator equipment of navigation equipment consumers designed for air, sea, river and land consumers to work on different types of RNS taking into account the specifics tasks to be solved.

Almost all consumers are oriented in the long term to use of onboard integrated equipment with integrated Signal processing from several space and ground RNSs basing.

In recent years, there has been a rapid growth in the fleet of navigation consumer equipment. Thanks to the development of microprocessor technology and communications on the market there are new models of goods and types of services in navigation area. Composition of requirements for navigation equipment consumers and its characteristics is determined by the specifics of the tasks to be solved by consumer.

The most massive technical tool that finds its consumers in various fields of activity, becomes a navigation GNSS consumer equipment.

Along with solving exclusively navigation problems GNSS are widely used in systems of exact time, communication, geodesy, cartography, meteorology, transport, urban management economy, construction, agricultural activity, with conducting search and rescue operations, for tourism and travel.

Over the past decade, the global appliance and services sector positioning has become the fastest growing commercial industry.

5.7.2. GNSS consumer equipment

Classification of navigation equipment for GNSS consumers

In accordance with the purpose, the following main types are distinguished GNSS consumer navigation equipment:

aviation application;

sea and river use;

ground application;

geodetic application;

with functions of synchronization of time and frequency;

general purpose;

navigation receivers for mobile wireless devices;

GLONASS navigation OEM modules.

To navigation equipment for *aviation* users referred items installed on board an airplane or helicopter and interfacing with other airborne navigation systems and

communication. Range of applications for on-board navigation equipment of consumers quite wide - from a standalone navigator to an integral part of a single complex communications, navigation and surveillance. Specification (Characteristics) airborne navigation systems defined by international and national standards and must meet, first of all, safety requirements for aircraft.

To the apparatus *marine applications* assigned radionavigation receivers designed to be placed on board ships of the sea or river fleet. The characteristics of this class of equipment are defined international and national standards. Such systems allow integration with other navigation aids, for example, with radar stations or echo sounders, forming a single navigation complex, providing the specified parameters of shipping. Moreover, GNSS navigation sensors can interface with airborne beacons, which can significantly increase the effectiveness of search and rescue works.

The equipment for *ground use* includes automotive and domestic wearable receivers RNS. For household receivers basic requirements are: reasonable price, ease of use, compactness, convenient interface, the ability to connect a computer. Car navigation receiver is a wider class equipment - from a standalone navigator to a complex telematic module allowing real-time in non-request mode to control the movement of vehicles, including search for stolen vehicles. In some cases, the telematics module can carry out additional functions for monitoring sensors, state-monitoring devices of the car or cargo.

Radio navigation equipment *geodetic application* designed for high-precision geodetic assessment of baselines by the use of code and high-precision phase measurements followed by cameral processing or in real-time kinematics. Surveying class navigation receiver, depending on conditions applications, can support a wide range of options, the inclusion of which Depends on buyer's requirements. Among the most significant options you can note the reception of signals from several navigation systems, dual-frequency

measuring, receiving signals of local or wide-area systems
functional additions, support for the RTCM protocol, solution for real-time or pseudo-real-time baseline. To the same class reference equipment reference reference stations, which provide a standard set of functions for receiving, storing, processing and transmitting information, including differential correction data.

To consumer navigation equipment *with synchronization functions* referred devices providing frequency or time synchronization of systems and user tools. Keeper of the frequency reference and

time is a satellite system providing a global zone actions of your service. Similar consumer navigation equipment actively used to create systems of uniform time in locations, communications, management and monitoring of remote objects, including high dynamics of state. Accuracy of time synchronization, depending on conditions of use and hardware solutions, can reach 10-30 ns without use of additional stabilization devices.

By navigation equipment for users *of general purpose* assigned boards of navigation receivers on the basis of which it is possible to construct devices for subsequent use in accordance with the requirements the customer. Use of various navigation receiver platforms allows you to create a significant number of telematic modules for monitoring the movement of land vehicles, including anti-theft systems. Based on platform capabilities and requirements customer, the same product can be used in various systems and conditions of use.

Navigation Receivers for Mobile Wireless Devices (communicators, smartphones, Internet tablets, etc.) are one of the most promising and fastest growing segments of the hardware market global positioning. To break GNSS receivers on the cell The market created significant technological prerequisites, including miniature GNSS chips and multifunction processors with special software.

The class of navigation OEM modules includes elements navigation receivers as part of navigation boards or kits microcircuits. These elements perform the basic functions of navigation systems - solving a navigation problem and receiving information messages navigation spacecraft. Based on the specifics of the developer's activities, OEM modules are integrated with other technical means that implement interface, processing and data transfer depending on the specifics customer requirements. Given the wide range of applications navigation equipment, product range based on OEM modules finds application in telematics systems in transport, communications, security systems, etc.

The main characteristics of consumer navigation equipment GNSS

Satellite navigation is recognized by consumers as one of the most reliable and accurate positioning tools. Navigation requirements GNSS consumer equipment is formulated and regularly updated.

Requirements usually include errors determination of coordinates, velocity and time vector, time of first reference, continuity (stability) of navigation measurements navigation equipment of consumers (duration of breaks in navigation definitions) in the presence of external interference, time restore the issuance of navigation parameters after losing tracking navigation signals, etc.

When conducting an analysis of various navigation equipment GNSS consumers within the same class are accepted for comparison following characteristics:

number of monitored channels;
type of tracked signal;
maximum number of monitored satellites;
dimensions;
weight;
positioning accuracy (positioning);
data refresh rate;
cold start time;
warm start time;
capture time (synchronization);
number of ports;
types of interfaces;
data transfer rate;
range of operating temperatures and other conditions of use;
power consumption;
power supply requirements;
availability of integrity monitoring function;
the ability to receive information from additional external sources;
type of antenna used.

The main characteristics of consumer navigation equipment GNSS modern models lie in the following ranges:

the number of receiving channels is not less than 12. Various multisystem consumer navigation models are able to track from 20 to 216 and even 336 channels, using additional signals GLONASS, WAAS, EGNOS, MSAS and others;

positioning error depending on the operating mode from 1 to 20 m. There are models of navigation equipment consumers providing centimeter accuracy;

power consumption ranges from 0.03 W to several tens of watts;

capture time is from 1 to 1,000 ns;
“cold start” time - from 30 s to 10 min .;
hot start time - from 5 s to 4 min .;
working temperatures - from minus 50 to plus 85 ºC;
data transfer rate - from 300 bit / s to 100 Mb / s;

range of overall dimensions of consumer navigation equipment
GNSS - from values measured in millimeters to several tens
centimeters;

weight - from several grams to several kilograms.

5.7.3. The equipment of consumers of ground-based radio navigation systems

More than 30 types are operated in the CIS member states navigation equipment of ground-based RNS consumers, a significant number of which was developed on an outdated element base, has large weight and size characteristics, low reliability, outdated and already out of production.

Many samples of commercially available equipment do not meet international requirements and uncompetitive in the global market.

New designs are currently under development. receiving indicator devices.

Further development of consumer navigation equipment specialization is associated with the expansion of its fields of application.

5.8. Information Systems for Radio Navigation

Radio navigation information systems are designed to informing consumers about the condition and basic characteristics GNSS and their functional additions. This information is required. to consumers for planning navigation support on the route, in terminal zones (airport zones), when navigating in torrential zones and narrowness, etc.

These systems should receive status information. GLONASS from the system control center and GLONASS monitoring tools, as well as information on the status of foreign GNSS and their additions - from foreign information systems and own monitoring tools.

Detailed status information and real accuracy GNSS GLONASS and GPS characteristics can be obtained on the website analytical center of coordinate-time and information providing the federal state unitary enterprise "Central Research Institute of Mechanical Engineering" (http://www.glonass-center.ru).

Civil Aviation Consumer Awareness provide through the use of the Center for Air Navigation information and the creation of an aeronautical information system.

6. INTERNATIONAL COOPERATION IN THE AREA RADIO NAVIGATION

International cooperation of the CIS member states in the field of radio navigation support is determined by interstate treaties and agreements in the framework of their activities and international agreements with non-CIS countries.

The main objectives of international cooperation are:

coordination of the technical policies of the CIS member states in

areas of radio navigation taking into account national interests;
development of the international market for navigation services and the creation of territories of the CIS member states favorable conditions for consumption of navigation services;
mutually beneficial information exchange for improvement and development of navigation systems and tools.
Collaboration covers creation and use. international RNS, as well as pairing the RNS of the CIS member states with European and world systems.
Significance of joint work is determined by globalization of the world economy and stricter requirements for the safety of air traffic and marine consumers.
The objectives of international cooperation to achieve designated goals are:
improving individual national development plans radio navigation of the CIS member states;
integrated use of space and ground RNS fields;
creation of integrated RNS using stations of the "Chaika" system and “Laurent-S” or other means of radio navigation support in CIS member states, European and Asian countries, including in Far Eastern region;
identification of key RNS, providing traffic CIS member states;
creation and provision of conditions for combined use consumers of existing and promising GNSS: GLONASS, GPS, GALILEO and BEIDOU;
ensuring compatibility and complementarity of the GLONASS system with other global and regional navigation systems;
implementation of GLONASS functional aids and navigation equipment of consumers working on signals standard accuracy, assisting in their maintenance, repair and operation, implementation of civil objects in the information circuits industries;

creation of conditions for expanding the export of navigation equipment GLONASS consumers and equipment manufactured at enterprises of the CIS member states to foreign markets;
enforcement of international treaties and other international obligations of the CIS member states in the field of radio navigation;
coordination of research and development design work on the creation of international RNS and facilities;
harmonization of the legal and regulatory framework, providing effective navigation activity in the territories CIS member states, neighboring states and in countries far abroad.
International cooperation in the field of radio navigation provides for activities in the following areas:
implementation of activities under interstate agreements;
development and implementation of interstate radio navigation programs of the CIS member states;

participation in the work of the Interstate Council "Radio Navigation";

implementation of the guidelines (plan) for the development of radio navigation CIS member states for a designated period of time;

cooperation with navigation institutes of the CIS member states in joint research and development design work on the development and creation of individual elements national space navigation systems based on GLONASS and new navigation technologies;

participation in the work of international organizations of the UN system and others global and regional GNSS-related associations and international RNS;

participation in interstate cooperation programs in the field of fundamental and applied sciences, the establishment of international scientific centers, development of bilateral scientific and technical cooperation, enhancing the exchange of scientific and technical information in the field of GNSS;

participation in international radio interferometric sessions observations to solve the problems of coordinate-time and navigation providing.

International cooperation of the CIS member states with far-abroad countries in the field of radio navigation is carried out participation in international organizations: European Group institutes of navigation; International Committee on Global navigation satellite systems; ICAO; IMO; IAMS; International Association of Navigation Institutes; International service GNSS (IGS); Radio Engineering Commission for Aviation Radio Engineering means; Radio technical commission of marine services; Far Eastern radio navigation service.

7. EFFECTS EXPECTED FROM THE IMPLEMENTATION OF THE BASIC DIRECTIONS

The development of RNS in the CIS member states is aimed at achievement of the following effects:

socio-economic effect - reduction in transportation costs due to:

5% fuel savings due to reduced residence time vehicle on the way;

10% reduction in operating costs;

saving capital investment by eliminating the installation of new ground-based radio navigation aids, inventory reductions consumer navigation equipment;

saving energy by reducing the amount operated ground-based radio navigation aids;

social effect:

predicted decrease in the number of emergencies over by increasing the level of security on all modes of transport;

creation of more favorable conditions for effective fight against crime and terrorism;

improving the quality of passenger service by increasing regularity of traffic;

increase in labor productivity by increasing volumes traffic during rush hours and, as a result, a decrease in the “transport” factor fatigue ";

increase in the number of jobs due to expansion of production satellite navigation equipment of consumers;

raising public awareness by creating navigation and information modules based on integrated chips, introduced into the developed domestic means of individual use - cell phones and smartphones, medical sensors for telemedicines, personal safety equipment and social assistance (for pensioners, disabled people, children) with panic button, etc.

scientific and technical effect:

creation of high-precision continuous global navigation-time field;

improving the accuracy of location of transport and other objects 20–50 times;

increasing the reliability of obtaining navigation information;

creation of conditions for scientific research of the atmosphere and the earth surface, earthquake and other prediction capabilities adverse events and disasters;

mastering the most advanced microelectronic and information technology;

environmental effect:

the exclusion of radio emissions from ground-based RNS, decommissioned, environmental improvement due to decommissioning diesel installations at ground-based radio navigation facilities;

environmental improvement by reducing fuel consumption when flying aircraft and driving on the most profitable and straightened routes.

application

Radio frequency bands used by current radio electronic means RNS

Types of RNS (local deployment)	Region application of rns	Name of RNS	Frequency range
Satellite	General destination	GLONASS	1 592–1 621; 1 237–1 262; 1 197–1 213 MHz
	Geodesy	GEO-IR-2	267-273; 2,200 MHz
Ground	Aviation RNS	Route (Alpha)	10-17 kHz
		Tropic-2 (Seagull), Tropic-2P	83–117 kHz
		PRS-ARK	150-1 750 kHz
		PMA-90 (VOR); local aviation differential satellite subsystems	108-118 MHz
		SP-75; SP-80; SP-90; SP-200	108-112; 329–335; 75 (marker) MHz
		RMD-90 (DME)	962–1 213 MHz
		RSBN-4N (-4NM, -8N), Trail-SMD	770-812.3; 873.6-935.2; 939.6–1 000.5 MHz
		PRMG-5 (-76U, -76UM)	772–808; 905.1-932.4; 939.6-966.9 [1] MHz
	Marine RNS	Mars-75, Neman-M	64–92 kHz
		Marine beacons circular lighthouse marine and DIAMOND; marine differential satellite subsystems	285–325 kHz
		Octopus-H1	1.6–2.2 MHz
		Search	1–2.4 MHz
		BRAS-3	1.6–2.2 MHz
		RS-10	3.6-12 MHz
		GRAS / GRAS-2	4 100-4 300 / 3 902-4 198 MHz
		Krabik-B	321–331 MHz
		Krabik-BM	230-332 MHz

[1] Clarified as the range for mobile communication systems becomes free.