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Perspectives of using a drifting ice-resistant platform of the "North Pole" type, which is under construction, as a multifunctional research complex in the Arctic

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ABSTRACT

The ice-resistant self-propelled drifting platform (IRSPP) "North Pole" is intended for year-round complex scientific studies in high latitudes of the Arctic Ocean. In accordance with the model of use, the platform should make a long drift with duration of not less than one year together with the surrounding ice massif in the central Arctic Basin. It should replace drifting stations "North Pole", traditionally based on drifting ice floes. The platform is a self-propelled displacement steel ship with the ice class Arc5 and hull strengthening Arc8, which allows the ship to endure multiyear ice pressures. Onboard the platform, there are 15 scientific laboratories for conducting oceanographic, hydrological, synoptic, geological and other observations. The ice-resistant platform is equipped with a system of monitoring ice loads, which makes it possible to carry out studies of the mechanics of deformation and destruction of sea ice at interaction with engineering and natural objects and is an integral component of the general system of provision of safe operation and survivability of the platform. The system is produced at the base of fiber-optic technologies and is comprised of several subsystems. In order to carry out studies at the ice-resistant self-propelled platform it is envisaged to accommodate more than 30 scientists. Construction of the platform was started in 2018 in St. Petersburg at the "Admiralty shipyards". The first scientific voyage of the platform is planned in 2021.

KEY WORDS: Drifting ice-resistant platform, drifting stations "North Pole", Arctic research, research vessel, floating observatory

1. INTRODUCTION

In 2017, the Government of the Russian Federation has made a decision about construction of a new type of research vessel – an ice-resistant self-propelled drifting platform (IRSPP) "North Pole". It should replace the classic drifting research stations "North Pole", based on drifting ice floes of the central massifs of the Arctic Ocean. The main aim of creating the IRSPP is to increase the efficiency of scientific studies due to expansion of research programs, application of more advanced equipment, improvement of work and life conditions

of polar explorers and to a large extent due to reduced risks of emergency situations.

The idea of constructing an ice-resistant self-propelled platform (IRSPP) was considered by the AARI specialists as early as in the 1970s, when it was proposed to reequip for this purpose the legendary icebreaker “Krasin”. This variant was declined due to technical and economic considerations. Then a design was developed and the icebreaker “Otto Schmidt” was built which was also used as a drifting ice base. As a result of experience gained it was clear that a specially designed vessel is needed for long-term stationing of research laboratories.

For development of initial technical requirements to the design of IRSPP a unique experience of organization, conduct and results of studies and demobilization of all stations “North Pole” over the entire history of their existence (a total of 41 stations from 1937 to 2015) were analyzed at the AARI. In the opinion of the AARI specialists this analysis made it possible to find an optimal variant of the floating engineering structure for long-term basing of research observatories, which has the maximum efficiency at the minimum construction and operational costs.

The construction of the platform is being implemented as part of the State Program on the socio-economic development of the Arctic zone of Russia, including those aimed at consolidating the Russian presence in the Arctic and the position of Russia as the world leader in polar science. The construction of LSP will allow opening a new page in the studies of the Russian Arctic and in international cooperation on the study of northern latitudes. This floating observatory will allow covering the most part of the Arctic basin and timely receiving reliable scientific data on natural processes in the northern polar regions of the Earth.

In April 2018, the Roshydromet and the JSC “Admiralty Shipyards” signed a contract for design and construction of the ice-resistant self-propelled platform “North Pole”, project 00903. The construction of the platform began in December 2018, and the first scientific cruise of the platform is planned in 2021.

2. GENERAL DESCRIPTION OF THE IRSPP

The IRSPP is intended for year-round comprehensive scientific studies in high latitudes of the Arctic Ocean and should make prolonged drift with duration of not less than one year together with the surrounding it ice massif. The IRSPP presents a self-propelled displacement-type steel ship (Figure 1) with ice class Arc5 of Russian Maritime Register of Shipping (RS). Moreover, the hull strength at the sides and the bottom corresponds to class Arc 8 (RS), which allows the ship to withstand multiyear ice pressures. The main characteristics of the platform are given in Table 1.

Figure 1. General view of the IRSPP

Table 1. Main characteristics of the IRSPP

Length overall	83.1 m
Length by DWL	76.7 m
Breadth overall	22.5 m
Breadth by DWL	21.8 m
Side height at the middle-body	11.4 m
Draft by DWL	8.6 m
Deadweight	10 373 t
Total block coefficient	0.626
Block coefficient of the midship frame region	0.889
DWL block coefficient	0.927
Cruise speed in quiet deep water	10 knots
Power plant capacity	4200 kW
Crew	14 persons
Scientific personnel	34 persons
Endurance by food supplies	365 days
Endurance by fuel	730 days

The propulsion complex of the platform consists of a pod drive and hydraulic azimuthal jet in the bow, performing a role of a thruster. If necessary, the IRSPP will be able on its own to transit to the new point of the drift start in open water or in comparatively easy ice conditions.

In general, the IRSPP drift duration by fuel supply can comprise up to two years at replenishment of food supplies. It is supposed that personnel on the platform will work by the shift method. Comfortable accommodation onboard is envisaged for 54 people including 34 scientists, 14 crew members and 6 helicopter pilots. The IRSPP will have a helipad for receiving helicopters of the type of Mi-38.

The main principles of choosing the main parameters of the drifting structure were not only provision of the widest range of research studies, but also the requirements to their quality and processing of the results. They included arrangement of the maximum achievable comfortable conditions onboard the ship during the long-term polar drift for research work and living of the expedition members, leisure time activities and possibilities of sports and fitness exercises. Other requirements concerning possible accommodation of standard deck scientific equipment, cargo holds, receiving and temporary basing of helicopter, quick replenishment of supplies, expedition personnel rotation and receiving inspections and delegations.

3. MODEL TESTS IN THE ICE TANK

To test an optimal shape of the platform hull in the AARI ice tank, the ice and sea trials of the platform model were carried out in August-September 2018 under an extensive program (Figure 2). Their goal was to determine open water resistance at different motion speeds, determination of ice performance in solid ice, in channel and in broken ice. Based on the results of the trials the ice passage capability, i.e., the thickness of solid level ice, overcome at continuous motion with a speed of 2 knots at full propeller shaft power, will be 59 cm by ahead motion and 51 cm by astern motion.

Figure 2. Trials of the IRSPP model in level ice in the AARI ice tank

Additionally, a new type of trials was made – experimental determination of the parameters of stability of the IRSPP at compression in ice (Figure 3). An ice floe moved onto the model and forces acting on the hull and the pod drive from ice, accelerations of IRSPP, platform trim and heel angles occurring at interaction with ice were measured. Based on the results of the trials a conclusion was made that stability of the IRSPP under the conditions of compression is provided at all variants of loading.

Figure 3. Trials of the IRSPP model at compression in ice in the AARI ice tank

4. DESCRIPTION OF THE IRSPP SCIENTIFIC COMPLEX

The IRSPP presents a whole scientific complex for conducting different types of studies and observations. There are 15 research laboratories onboard the IRSPP:

- Meteorological laboratory,
- Atmospheric laboratory,
- Upper-air laboratory,
- Laboratory for receiving satellite hydrometeorological information,
- Geophysical laboratory,
- Ice loads monitoring laboratory,
- Laboratory of sample preparation,
- Geological laboratory,
- Hydrochemical laboratory,
- Ecological laboratory,
- Oceanographic “dry” laboratory,
- Oceanographic “wet” laboratory,
- Ice research laboratory,
- Ice research (cold) laboratory,
- Laboratory of special studies.

All laboratories have necessary inbuilt modern equipment. For performing work on the ice a mobile ice field camp and different transport vehicles are envisaged.

The scientific equipment installed at the IRSPP will allow us to perform different types of scientific work and observations, which can be divided into two groups:

- objectives fulfilled at transits of the IRSPP to the place of the drift and back and during the IRSPP drift in open water and in ice with low concentration;

- objectives fulfilled at the IRSPP drift in ice (using instruments and complexes installed onboard) and on the adjoining ice cover using an ice camp.

Along with the traditional complex of studies, creation of the ice-resistant self-propelled platform will permit us to expand the range of studies and observations in the following fields:

- ionospheric observations – based on the receiving station of oblique ionosphere sounding (modern digital ionosonde of new generation with a linear-frequency modulation), intended for operational diagnostics of conditions of propagation of short wave (SW) radio-waves. The definition of the range of operating frequencies for the SW radio-communication appears to be extremely necessary for provision of safety of air flights across the North Pole, and also for other users, which use radio-communication in the SW region of radio-waves;

- geological studies – on the basis of a sampling complex for the use of piston ground tubes and dredges, wet and analytical laboratories, core storage to carry out an extended complex of geological studies of the sedimentary layer of sparsely studied difficult for access regions of the Arctic Basin;

- chemical and ecological studies – on the basis of analytical complexes, allowing one to perform a highly precise analysis of the concentration of pollutants, suspended matter, gases, a-biotic pollutants contained in the water, air, ice and bottom sediment samples;

- studies of ice loads and mechanics of ice destruction – not earlier performed studies of the

mechanics of deformation and destruction of sea ice with the aim of improving the methods of calculation of local and global ice loads on ships and other engineering structures;

- acoustic tomography of the Arctic Basin – tracking (monitoring) of the state of the hydrographic fields of the Arctic Ocean;

- study of the boundary layer and the free atmosphere in the Central Arctic – on the basis of assimilation of data on the structure of the boundary layer and the free atmosphere, obtained by means of air balloons and aircraft (unmanned) measuring systems, improvement of the method of regional long-range and short-range weather forecasting;

- magnetic and gravity studies – conduct of observations for updating the magnetic and gravity fields (charts) in the high-latitudinal Arctic based on modern magnetic and gravity registering complexes, etc.

Equipment of the IRSPP with the ice load monitoring system (hereinafter, ILMS), which is contained in the ice research complex should be specially noted. The system of monitoring is an integral part of the system of provision of safe operation and survivability of the IRSPP by means of control of the hull state at action of ice loads at different modes of operation of the IRSPP. The system is made on the basis of fiber-optic technologies and consists of several subsystems:

- subsystem of control of parameters of ice loads and stress-strain hull state;
- subsystem of control of parameters of motions;
- subsystem of estimation of strain-stress behavior of ice cover around the IRSPP
- subsystem of control of meteorological and ice situation;
- subsystem of data collection and processing.

The subsystem of control of parameters of ice loads and stress-strain hull state includes fiber-optic sensors of strain measurements, both three-axial and uniaxial and temperature sensors for temperature compensation during measurements. For selection of the places of installation of sensors, a finite-element model of the IRSPP was developed and calculation of loads on the hull was performed.

The subsystem of control of motion parameters serves for measurement of ship heel, trim and vertical motion during pitch and roll and at different ice impacts. Data come to the system from the ship sensor of dynamic displacements, including three high precision accelerometers and three gyroscopes.

The subsystem of estimation of strain-stress behavior of ice cover around the IRSPP is a unique one and will make it possible to warn about possible dangerous situations in advance, for example, about the beginning of destruction of an ice floe.

The subsystem of control of meteorological and ice situation provides data from the ship weather station and the ice radar.

The subsystem of data collection and processing stores data of all measuring systems at the server and makes processing by means of algorithms devised by the AARI specialists. A possibility of data transfer from the server to onshore for performing remote operation of the system is also considered.

The ILMS will be used not only for provision of safe operation of the IRSPP, but also as a unique complex for investigation of the mechanics of sea ice deformation and destruction at interaction with engineering structures and natural objects.

New opportunities that will appear during the commissioning of long-term floating engineering structures will not only expand research programs, but also improve traditional

areas through the use of more modern technologies and tools for processing research results.

The list of possible new types of research in various fields is below.

A wide range of oceanology studies related to the possibility of using manned or unmanned arctic research submersibles.

The studies of the mechanics of deformations and the destruction of sea ice that were not carried out before when they were applied to an industrial facility in order to improve the methods for calculating local and global ice loads on ships and other engineering structures.

Development and testing of monitoring systems for ice loads on industrial facilities in order to increase the safety level of their operation.

Prospects for the use of new generation stations for the development of geological and geophysical work are determined by unique geological and geophysical materials that can be obtained during long-time continuous observations.

5. OPERATION OF THE IRSPP

The IRSPP presents a whole scientific complex for conducting different types of studies and observations. There are 15 research laboratories onboard the IRSPP:

The cycle of using the IRSPP will consist of several stages:

- transit from the basing point to the place of the drift carrying out complex studies en-route and during the drift of the IRSPP – about 20 days;

- drift in the ice with performance of a full complex of studies from the IRSPP and ice sites – about 730 days;

- transit from the place of the end of the drift to the basing point performing complex studies en-route and during the drift of the IRSPP – about 20 days;

Duration of the active cycle of the use of the IRSPP will be about 770 days. The dock repairs, repair of mechanisms and systems, repair or replacement of scientific equipment will be approximately 60 days at each of the first three cycles. Thus, one full cycle of the use and preparation of the IRSPP will comprise about 810 days or 2 years and 3 months.

The IRSPP will start its drift in the eastern sector of the Arctic, similar to the “North Pole” stations. The most favorable months for the IRSPP transit to the start of the drift are August-September, as at this time the minimal close sea ice extent is observed.

Figure 4 shows the proposed scheme of the motion and drift of the IRSPP in the first scientific cruise planned for 2021.

Several possible variants of the prolonged drift of the IRSPP are envisaged (Figure 5). Mooring to an ice floe (Figure 5a). At such variant to keep the IRSPP at the ice floe it will be necessary to freeze into the ice the mooring bitts for winding up the mooring lines, which should keep the IRSPP immobile taking into account the possible wind loads.

Mooring in a fracture or a natural crack between ice floes (Figure 5b).

Entrance into an ice floe independently or by means of icebreaker (Figure 5c). At this variant the channel made will rapidly freeze up with a great degree of probability and the IRSPP itself will freeze into the ice.

It is likely that during the planned two-year period of the drift of IRSPP the drift variants will change depending on the hydrometeorological conditions and ice situation formed and could require transfer of the ice camp.

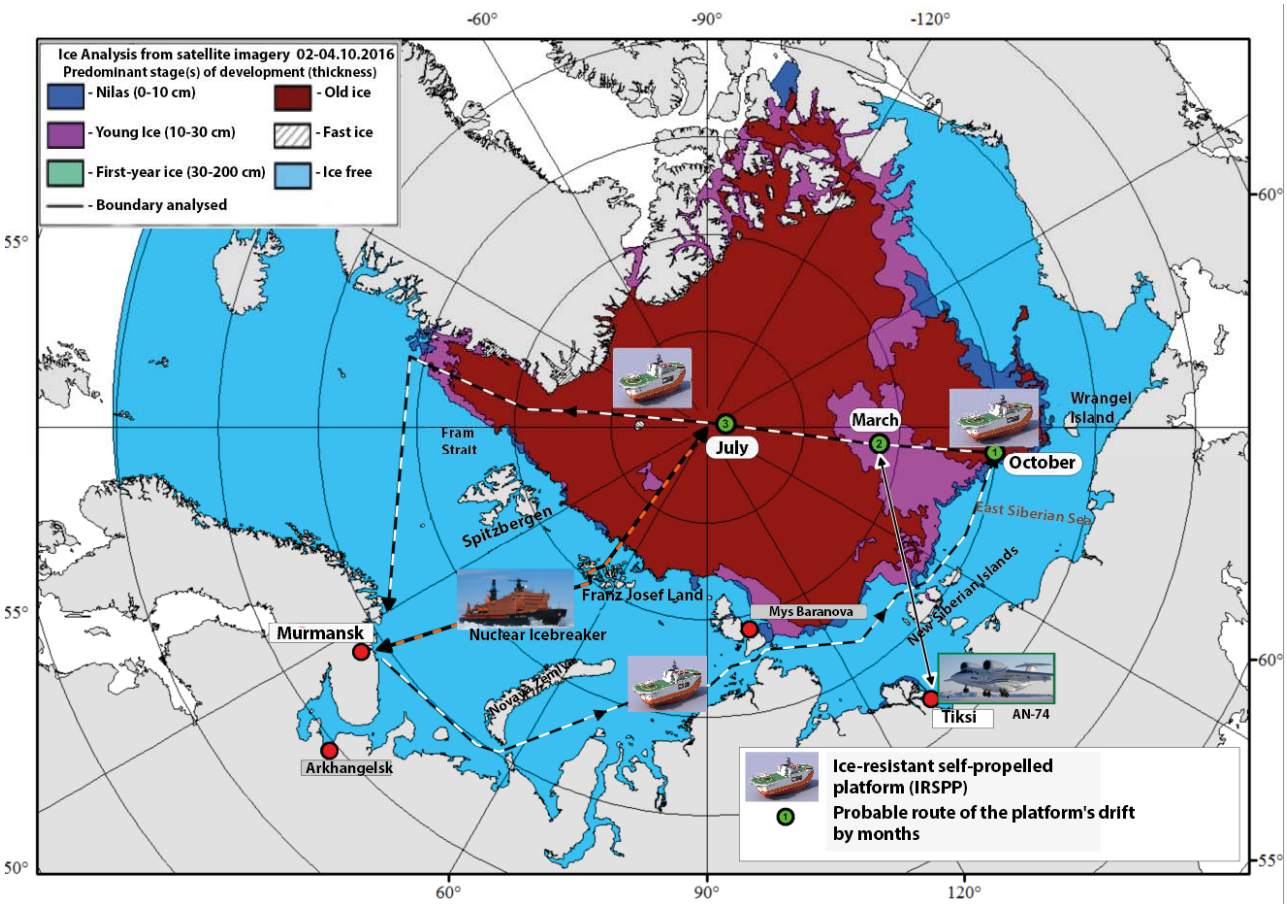

Figure 4. Scheme of motion and drift of the IRSPP in the first scientific cruise in 2021

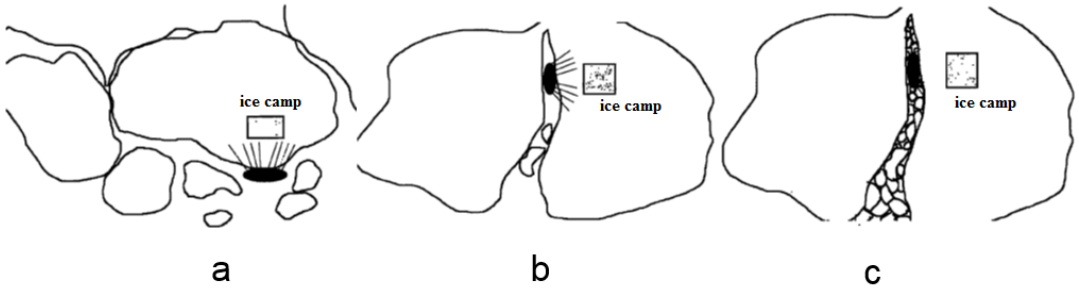

Figure 5. Possible variants of prolonged drift of the IRSPP

CONCLUSIONS

By all indicators the ice-resistant self-propelled platform does not have analogues in the world. Construction of the IRSPP will allow us to open a new page in the studies of the Russian Arctic and the international cooperation in investigation of the northern latitudes. Such floating observatory will make it possible to monitor most of the Arctic Basin and obtain reliable scientific data on the natural processes in the northern polar regions of the Earth on a timely basis.