# HISTORICAL REASONS FOR HYDROAVIATION REVIVAL

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The history of aviation reveals a period of high activity in creation and implementation of seaplanes between the ‘20s and ‘40s of the past century.

The principal reason for such activity was a demand for special planes for overwater flights which could serve the reconnaissance purposes of naval forces that were developing intensively after World War I. Besides, such planes could be used for specific military, search-and-rescue, and transportation missions at sea and in hard-to-reach coastal areas. Seaplanes were fitted for water operations, and therefore they were safer than land-based aircraft in case of emergency landing on water which was unfortunately not an infrequent event in those days [1].

The second reason lay in the fact that speeds and flight ranges of seaplanes were higher and greater than those of land-based aircraft (landplanes) with non-retractable landing gear, due to the lower aerodynamic drag of streamlined seaplane hull.

Ability of seaplanes to perform landing on water and take-off from water area without any need for arrangement and operation of aerodromes was the third reason why those planes could fill the niche of aviation demands.

However, speeds and flight ranges of landplanes grew incessantly due to improvements in aerodynamics and engine-building; civil and military flights were carried out primarily over continents; the number of aerodromes was increasing at a fabulous rate. Thus, seaplanes eventually lost their advantageous positions. Their field of activity gradually drifted to coasts and seas, rivers and lakes; their functions became associated only with water operation abilities.

Still, the impending World War II made the greatest powers of the world consider protection of military navies and merchant fleets, ports, and coastal military bases against attacks of surface and subsurface ships of the enemy [2]. Landing operations and recovery of besieged strong points required performance of painstaking tasks. All this made many nations create numerous air forces and keep them in battle readiness [3]. For example [4], the USA possessed about 6100 seaplanes and amphibious aircraft, Great Britain had 2100 of the kind, Italy – 1259, Germany – 700, Japan – 600, and the USSR – 2173 aircraft of this type. Analysis of take-off mass of these seaplanes reveals a peculiar fact: all countries which were making preparations for war at sea areas had seaplanes with take-off mass exceeding 10 ton, whereas among Soviet seaplanes there were none with take-off mass over 3.3 ton, which indicated defensive doctrine of Soviet naval forces and aviation.

During postwar years, hydroaviation was on the decline, as regards both operation and development. However paradoxically it might seem, development of sea aviation was most of all impaired by implementation of jet engines on aircraft.

Still, the "jet age" came for hydroaviation, too. The world's first jet-fighter SR/A1 designed in Great Britain (flight in 1947) was a failure because of engine flooding, which made British seaplane designers and customers more cautious. Therefore, the second English aircraft type, SR/45 "Princess", was a large aircraft (see Fig. 1; take-off mass of 150 t, 10 turboprop engines with 4 out of them coupled; flight in 1952). But it was a disappointment to everyone in England. Its cruising speed proved to be only 480 km/h, which seemed "slow operation" as compared to the speed of fighter aircraft and passenger-carrying "Comet" planes. This aircraft was not placed in service either, though from today's point of view it had rather good seaworthiness qualities which made it quite fit for ocean operations.

The USA designers also had some trouble with Sea Dart jet fighter which never went into serial production. However, Martin company specialists found a way to study hydrodynamics of the would-be large aircraft hull with regard to high-speed skimming and stability on water. For this purpose, they used special modifications of full-scale seaplanes with composite engines. The company specialists managed to obtain acceptable hydrodynamics, and finally designed XP6M "Seamaster", an 86-ton jet seaplane which demonstrated excellent performance (see Fig. 2; four turbojet engines, maiden flight in 1955, maximum speed during tests was 1,020 km/h). Characteristics of this aircraft [5] were ahead of the time, but at the end of 1959, several production aircraft were scrapped for some reasons, which still seem obscure to Russian specialists. Since then, the USA companies have never dealt with large seaplanes.

Fig. 1. SR/45 "Princess" seaplane (Great Britain, 1952)

Fig. 2. XP6M-1 "Seamaster" seaplane (USA, 1955)

Fig. 3. Be-10 seaplane (USSR, 1956)

In the USSR [6], specialists of Beriev Aircraft Company headed by Chief Designer G. Beriev designed R-1, the first Soviet jet seaplane. This was accomplished with active participation on the part of TsAGI experts. The seaplane revealed a number of troubles which accompanied high (as compared to those of piston-engined seaplanes) take-off speeds. After a series of upgrades, this 20-ton seaplane flew in 1952. It proved to be the first in the world in this weight category, and demonstrated a record cruising flight speed of 830 km/h for this class of seaplanes. Unfortunately, this aircraft was not put into full production; nevertheless, its operational experience gave basis for development, construction and tests of Be-10 jet seaplane (see Fig. 3; two turbojet engines; maiden flight in 1956, i.e. a year after the American “Seamaster” jet). This aircraft went into series production, and was used by naval air forces. It was followed by Be-12 turboprop seaplane (see Fig. 4; two turboprop engines, maiden flight in 1960) which was put into service, set up 42 world records, and is still in operation. A-40 “Albatross” jet amphibian (see Fig. 5; take-off mass of 92.5 t, two turbojet engines, cruising speed of 700 km/h) created by Soviet engineers, workers, and scientists took wing in 1986. About 150 world records were achieved in the course of its tests; still, economic status of its customer, i.e. the Ministry of Defense, prevented it from being put in service. Finally, Beriev Aircraft Company engaged in civil aircraft production, and Be-200 amphibian (see Fig. 6, two two-shaft turbojet engines, cruising speed = 610 km/h) made its first flight in 1998. This aircraft can be considered as a “younger brother” of the “Albatross”.

Fig. 4. Be-12 amphibian (USSR, 1960)

Its main purpose is forest and tundra firefighting with taking water to fire areas from the nearest water source. This aircraft is in series production and finds demand on the market.

Fig. 5. A-40 “Albatross” amphibian (USSR, 1986)

Fig. 6. Be-200 amphibian (Russia, 1998)

High performance level of the mentioned aircraft designed by Beriev Aircraft Company specialists is evidenced not only by science-based evaluation criteria [7], but also by about 200 world records registered by International Aeronautical Federation.

Another aircraft which is worth mentioning is VVA-14 experimental vertical take-off amphibian (see Fig. 7) designed, manufactured and flight-tested at Beriev Aircraft Company within time period from 1968 till 1976 under the direction of Chief Designer R. Bartini. This aircraft had 12 lift turbojet engines and 2 cruise turbojet engines [8,9], and was provided with two extendable floats which served as landing gear and allowed operation from any type of soil as well as from water surface (each float had 2.5 m in diameter, and about 14 m in length). The aircraft with take-off mass of 52 t and cruising speed of

640 km/h was equipped with a high-powered jet control system for take-off and landing conditions. This control system was supposed to allow landing on water and take-off from it in conditions of wave height exceeding 10 m. A lot of flight and on-water tests were performed on this unordinary amphibian. Still, it never experienced vertical take-off and landing, due to inability of the Soviet aircraft engines manufacturing industry of that time to fabricate lift turbojet engines with special fans.


Fig. 7. VVA-14 vertical take-off and landing amphibian (USSR, 1972)

Fig. 8. SH-5 “Harbin” seaplane (China, 1976)

Fig. 9. CL-415 Canadair amphibian (Canada, 1994)

1976 was the year of maiden flight for SH-5 “Harbin” aircraft (see Fig. 8), the Chinese analogue of the Be-12 amphibian. This aircraft has take-off mass of up to 55 t, and cruising speed of 450 km/h. It is provided with mobile beaching landing gear which enables the aircraft to leave water using a ramp, and to move along taxiways of a land aerodrome. And what is still left to be mentioned is the modern CL-415 amphibian (see Fig. 9, maiden flight in 1994) designed in Canada (following the piston-engined CL-215 and the originally designed turboprop CL-215T). It is a fire-fighting aircraft with small take-off mass of 17 to 19 ton, and cruising speed of 300 km/h [10].

So what progress have jet seaplane designers made? The primary achievement is the same as for landplanes, i.e. a considerable increase in speed, size, and weight, as compared to those of piston-engine seaplanes. But the steep increase in cruising speeds was insufficiently balanced out by a very small advance in wing lift achieved by implementation of high-lift devices. That led to significant growth of aircraft take-off and landing speeds, squares of which are inversely proportional to seaworthiness defined in terms of allowable wind-induced sea wave height. And this considerable decrease in seaworthiness resulted, in its turn, in reduction of seaplane application feasibility [11]. Though, the increase in size and mass of seaplanes could, in spite of high take-off and landing speeds, add to the application feasibility [12]. However, none of potential customers offered such a price for the designing of new seaplanes in view of rapid development of land aviation.

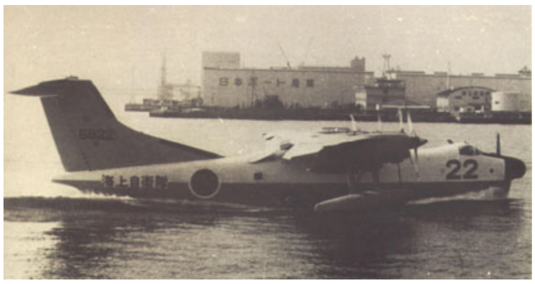


Fig. 10.PS-1 Shin Meiwa high-seaworthiness amphibian (Japan, 1967)

Against the background of total decrease in jet seaplanes seaworthiness, the Japanese Shin Meiwa company introduced, in 1967 [13], energy-based wing high-lift devices by installing a gas generator as an additional (fifth) engine on PS-1 four-engine turboprop seaplane (see Fig. 10, first flight in 1967). This, with the flaps extended at nearly 90° and blown by air from the gas generator, resulted in a striking reduction of take-off and landing speed which, in turn, provided excellent seaworthiness in wind-induced waves of 2 to 3.5 m for the aircraft of small mass (43 ton) and cruising speed (440 km/h). In case of gas generator failure, however, the PS-1 becomes an ordinary seaplane with seaworthiness not exceeding 1.2 m. Still, the solution implemented on the PS-1 can be considered as rather bold and innovative.

That is probably the whole range of jet airplanes and amphibians with take-off mass of more than 10 ton which were designed in the world throughout the postwar (from 1945 to 1998) years.

Today it can be stated that military customers scarcely find even modest funds to keep some "smoldering" new amphibian projects going.

For civil customers, only firefighting amphibians are of interest due to severe fires in green areas of our planet. These fires come as a result of the obvious climate warming, and do the most harm not by burning timber in forests, but by destruction of oxygen in the atmosphere during fire, and by depriving the burned areas of oxygen replenishment source for a long time. As for reconnaissance missions of seaplanes for the purposes of navigation and timely preparation of ships for battles during armed conflicts, such missions ceased to be vital as satellite surveillance system came into existence.

But has nothing changed in the world to make us have a closer look at the World ocean which occupies 71% of the Earth's surface, at its seas, coasts, and finally and unavoidably at hydroaviation? A lot of things have changed, but of primary importance with respect to the future of the mankind is a tangible reduction in the stock of natural resources of the land.

In fact, each successive year of the 21st century brings us multifarious negative information concerning the dwindling of terrestrial mineral, energy, and biological resources, while the population of the Earth keeps growing [14, 15]; more and more emphatic become the ideas about the urgency of finding a way out of the impending deadlock, glimpses of which the mankind got during the Iraqi events.

One of the most feasible ways out of the said situation can lie in exploration of the World Ocean treasures. Preservation of ecologically sustainable state of the World Ocean has already become a vital task. According to experts, ocean resources contain almost 4 times as much hydrocarbon materials, and 9 times as many methane-containing concretions, as terrestrial resources do. As for methane-containing concretions, some leading experts of the power industry consider them as a probable base for power systems of the future. The ocean bed holds 2.5 times as many metallic ore concretions as the land does, and concentration of rare-earth elements in the ocean water is 19 times greater than that in the terrestrial portion of the world. Biological resources of the ocean water can, in case of proper exploration, provide 50 times as much high-quality products, as the land can. And with regard to power generated by ocean currents, high and low tides, temperature differences, eruptions of undersea volcanoes etc., it can be stated that it is actually beyond any comparison to terrestrial resources.

**Hence follows a well-founded conclusion that civilized exploration of the World Ocean is one of the grandest and most honorable tasks of the human civilization.**

Solution of this task requires, undoubtedly, tremendous activities within a vast scope, from the first modest steps in the form of platforms for oil and gas extraction from the ocean bed, and to underwater settlements and maybe even cities within the depths of the ocean. Integrated solutions should be found for problems relative to transportation communications with continents, and between the settlements. The principal transportation load will be apparently taken by maritime fleet which is considered to be the most cost-effective means. In certain areas, pipeline transport will be used for these purposes. An adequate method may consist in the over-water or underwater towing of cargoes in special large containers, in which case the cargoes will not be affected by sea disturbance.

Still, there will be a necessity of high-speed communication for purposes of crew rotation, delivery of the required rare equipment, rendering emergency highly skilled medical aid, dealing with consequences of man-made and natural disasters, and evacuation of personnel. These, an a number of other similar missions, require application of high-speed and maneuverable vehicles; therefore, this type of transportation communication will be allocated to hydroaviation, vehicles of which will include not only seaplanes and amphibians, but also ekranolyots, wing-in-ground effect vehicles, and airships.

Thus, we inevitable arrive at a most natural conclusion that **the revival of sea aviation is a logical result of development of the human civilization.**

In view of the prospects outlined above, the vital task of sea aviation is considered to consist in the monitoring of oceanic ecology, and probable abatement and control of contamination, as well as participation in exploration of coastal and over-flooded areas.

Out of the modern amphibian aircraft mentioned herein, the A-40 “Albatross” amphibian designed at Beriev Aircraft Company is actually capable, while being based at sea shores, of performing transoceanic flights with en-route landings, and informing ocean services via satellites about state of surface, moderate depths, and atmosphere at water landing points on a real-time basis. Calculations demonstrate [16] that costs of such monitoring are several times lower than those required for using marine guard vessels which are supposed to be of considerable size and tonnage due to inability to leave the area quickly under the threat of storm.

Vertical take-off amphibian (type VVA-14) can take rescue teams and survival aids to disaster zones located at any area on ocean or sea surface, in practically any weather (except cases of frosting on water).

The Be-200 firefighting amphibian seems promising as an advanced aircraft for the fighting of fires in terrestrial green areas of the Earth. It can also be used as a basic aircraft for the designing of still more efficient amphibians. Some other contemporary amphibians, among which the PS-1 stands out, can also perform transport and search-and-rescue missions at sea, and can be used as firefighters in Earth’s green areas.

The above examples prove that the world still has unique teams capable of designing hydroaviation airborne vehicles which can provide basis for the future exploration of the World Ocean. The international community should be concerned with maintaining these companies and giving them proper opportunity for advanced ahead-of-the-time explorations which have long-term cycles, and are better kept going today lest any hindrances should be encountered in future.

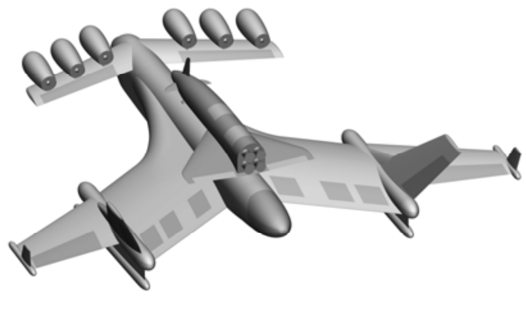

Fig. 11. Be-2500 amphibian (Russia, project design)

Be-2500 type super-heavy amphibians and seaplanes (see Fig. 11) should be mentioned among advanced hydroaviation vehicles. Preliminary activities for designing this aircraft are being carried out now at the facilities of Beriev Aircraft Company. At present, this is a conceptual project for military and police purposes. But near at hand is the time when such huge aircraft will find peaceful application.

The acuteness of problems relative to protection and exploration of the World Ocean is understood by Russian scientists and authorities. That accounts for calling special attention of Russian scientists and engineers to the above problems in such presidential documents as "List of Critical Technologies of the Russian Federation" (Пр-578) and "Priorities for Scientific, Technological, and Engineering Development in the Russian Federation" (Пр-577). In the latter document, in particular, among the priorities for scientific, technological, and engineering development we find **new transportation practices** which will include transportation systems for communication within the World Ocean during its exploration. And document Пр-578 defines **"Transportation and shipbuilding technologies for exploration of areas and resources of the World Ocean"** as critical technologies of the Russian Federation, and they are directly related to the future of hydroaviation. Besides the mentioned issues, the Lists contain 20 problems pertaining, to a certain extent, to development of hydroaviation with the aim of exploration of the World Ocean, and firefighting in green areas of the Russian Federation and the Earth.

A clear understanding of objectives and problems faced by seaplane designers resulted in a series of International "Hydroaviasalon" forums organized by the Government of the Russian Federation on the initiative of Beriev Aircraft Company, and held in 1996, 1998, 2000, 2002, and 2004. Approximately 300 scientific papers were presented, discussed, and published in the course of scientific and technical conferences which took place at those forums. The number of papers grows from year to year, and we believe that the conferences should not only become traditional for the "Hydroaviasalon" forums, but should also cross the national territorial boundaries. This initiative is based on realizing the fact that construction of transportation systems for exploration of the World Ocean is a costly, painstaking, and long-term task which can only be duly handled by interstate communities. Issues of application and designing, control of seaworthiness, corrosion resistance, service life, safety and maintainability of hydroaviation flying vehicles require a well-organized and well-planned approach. The same can be attributed to matters which concern the designing of equipment for these vehicles, their testing and certification, problems of loading and unloading afloat at heavy sea, development of infrastructure for operation. Without such an approach, it is impossible to solve the task of ranking the hydroaviation vehicles design activities, and to plan the expenses. Scattered developments of some individual aircraft on a national basis may finally result in the overlapping of activities, retardation in exploration of the World Ocean, and depletion of natural resources. Therefore, specialists of Beriev Aircraft Company are carrying out research into synthesis of image of hydroaviation flying vehicle at preliminary design stages. This research is based on a system concept approach [17]. Also, Beriev Aircraft Company experts are engaged in working out international cooperation patterns, an example of which is shown in Fig. 12 [18].

In general, this pattern can be applied to all aspects of advanced activities aimed at protection and exploration of the World Ocean. The pattern includes creation of national and international Centers which will comprise Committees dealing with the following: the development and monitoring of technologies and means employed for the mining of minerals and for production and reproduction of raw biological materials; control of operational safety of the World Ocean objects and expeditions, etc. The Committees should include those for supervision of high-speed marine transportation system, with appropriate agencies dealing with transport vehicles among which are hydroaviation flying vehicles, i.e. amphibians, seaplanes, ekranolyots, wing-in-ground effect machines. Organizational integrity and proper arrangement of responsibilities within the system will provide its comprehensiveness and versatility, as well as proper feedback during exploration activities.

The presented pattern is by no means positioned as an absolutely impeccable system, but is shown to demonstrate the international community's time– and cost-saving opportunities in the way of achieving the grand goal of the World Ocean exploration.

In conclusion, it should be worthwhile to mention some risky and ecologically hazard-

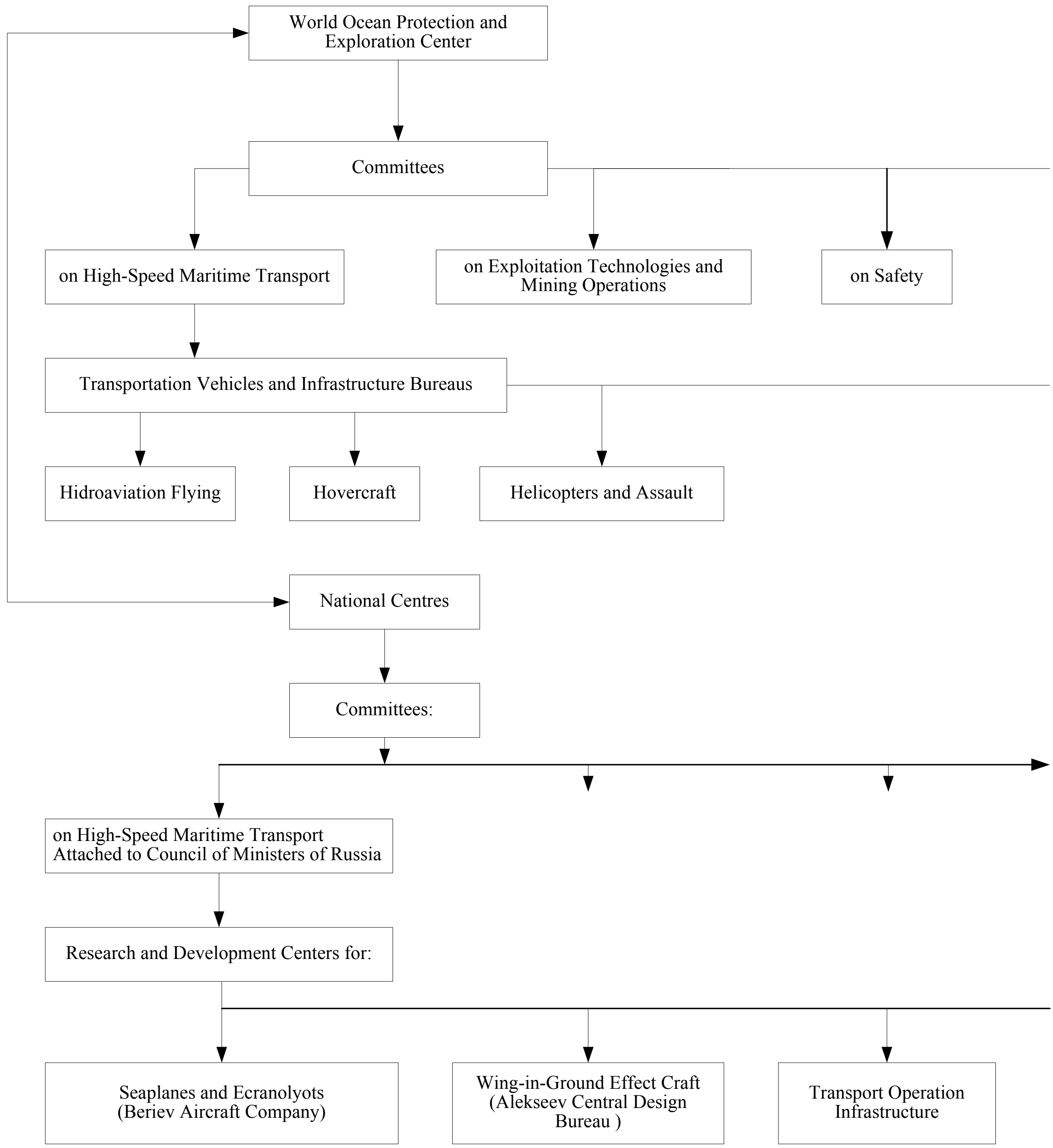


Fig. 12. Suggested organizational pattern for exploration of the World Ocean resources

ous, in our opinion, national and international projects.

An example of such a project is the maritime launching of space vehicles from ships located in equatorial zones of the World Ocean. Economic benefits from utilization of the maximum speed of Earth's rotation for space vehicles launching are undoubtedly obvious. But the history of space technology bears record to accidents which occurred during rocket launches, and at the initial stages of their flight. Such accidents can do colossal harm to the ocean ecology. The degree of harm sometimes exceeds losses caused by alienation of land contaminated as a result of failures and accidents occurring during rocket launches from continental launch areas. This is accounted for by the fact that aquatic environment cannot block the propagation of detrimental fuel components and soluble structural units of rockets and launch complexes. We do not doubt that maritime launch complex designers are to a certain extent aware of environmental hazards caused by their projects, but still there is no absolute surety of complete international control of these projects.

At the same time, the project of Be-2500 superheavy seaplane (with take-off mass of 2500 ton) now being developed by Beriev Aircraft Company specialists is intended for the launching of space vehicles, and preserves the advantages of equatorial launching. Extra advantages are featured, in the first place, by possibility of performing launches over desert land areas, and thus avoiding ocean contamination in emergency cases. Further, aircraft speeds and flight altitudes render the launches possible irrespective of ocean weather, and allow performance of preflight activities in sea ports with acceptable meteorological conditions. With launch time strictly controlled, operation becomes more cost-effective and reliable. And, finally, a seaplane of the Be-2500 type has an ability to search and lift de-orbited space vehicles and cosmonauts quickly and safely after their return, even if the landing takes place in unplanned ocean areas away from search vessels.

To dwell further upon the subject of protection of the World Ocean ecology, it should be noted that instances of its environmental pollution are presented by long-term and multifarious activities taking place during exercises of naval forces of different countries, because these activities may include above-water and underwater firing using rockets and underwater service projectiles equipped with propulsion units operating on environmentally harmful fuel.

Examples of using oceanic atolls and islands for nuclear tests should cause serious concern as to the future of the World Ocean's flora and fauna, and these practices that used to exist in the recent past should remain prohibited for the sake of the future of the civilization.

In general, there is an impression that the legal sphere of the modern civilization is void of regulatory requirements for the considering of various projects from the point of view of their comprehensive interaction with nature – up to termination of life cycle of a project's material components, and their disposal. Here, apart from environmental effects of heavy industry operation, it is enough to imagine the degree of contamination of the planet with various synthetic wrappings, films, detergents, etc whose ecological properties are analyzed only for consumption stage, and it will become clear that our civilization is rapidly becoming compliant with the attribute of a "**self-littering**" one given by the Soviet academician Shklovsky in the '60s of the past century. Litter discarded on land can be collected and recycled, but no global approaches exist as to collecting waste and rubbish in the ocean. Back in the '50s of the past century, A. Bombar who was sailing across the Atlantic alone in a boat, found derelict floating rubbish consisting of packages and waste thrown away by someone from passing-by vessels. The task that also awaits solution is quick determination of extent of technogenic and natural cataclysm consequences, and finding required means for their isolation. Hydroaviation should actively assist in solving all such problems. But there has hardly been any drastic change in this region within the latest decades.

The problem of reproduction of the World Ocean's biological treasures is also apparent and global. Here, hydroaviation vehicles can perform a number of actually important duties, from long-range patrolling for seafood fishery control, and to the fertilizing of productive biological areas.

Therefore, speaking about exploration of the World Ocean, and about the inevitable revival of hydroaviation in view of this purpose, we believe the following to be true:

1) Time has come to raise the question of an integrated organizational and environmental approach to the forthcoming process. This question should be considered internationally at the United Nations level with the aim of identification and planned development of hydroaviation airborne vehicles.

2) Absolutely all projects which regard objects constructed and operated in the ocean should be reviewed by interstate agencies of the UN. Measures taken as part of such projects for prevention of ocean pollution should become stricter and more controllable, because the ocean is much more vulnerable than the land.

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