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Title: Nuclear Security for Floating Nuclear Power Plants

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Nuclear Security for Floating Nuclear Power Plants

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Recently there has been a lot of interest in small modular reactors. A specific type of these small modular reactors (SMR,) are marine based power plants called floating nuclear power plants (FNPP). These FNPPs are typically built by countries with extensive knowledge of nuclear energy, such as Russia, France, China and the US. These FNPPs are built in one country and then sent to countries in need of power and/or seawater desalination. Some "fifteen countries, including China, Indonesia, Malaysia, Algeria, Namibia, Cape Verde and Argentina, have previously expressed interest in acquiring such power stations.[1]"

One concept is a floating barge, which Russia is aggressively pursuing. Russia began testing the floating nuclear power plant this summer (2015).[2] The expected delivery of the first floating nuclear power plant is October 2016.[3] Russia plans to deploy these floating nuclear power plants in Russia and worldwide. These plants are placed on floating barges that are not self-propelled, and therefore would need to be towed to the working site. Once they are located offshore at the place of interest, the power plants would need to be connected to the local power grid(Figure 1).

"Afrikantov OKBM" is listed as a future cooperating facility under the R&D agreement; they are the designer, manufacturer and complete supplier of FNPPs in Russia. The Afrikantov OKBM design is based on Russia's KLT-40S, used in icebreakers, but used a smaller version, the KLT-20, for FNPPs. The reactor was redesigned to use low-enriched uranium aluminum silicide fuel (<20% enriched with uranium-235); and its use is now expanded to include both power and desalination. The reactor is designed for 150 MWt (megawatts thermal), which will produce 35 MWe (electric) as well as 35 MW of heat for desalination or district heating. These reactors are designed to run for 3-4 years between refueling, with an onboard refueling capability, and include storage for used fuel. At the end of 12-years of operation, the entire FNPP is taken to a central facility for overhaul and storage of the used fuel. The plan is to place two reactor units on a barge.

China is a nuclear weapon state and has a strong interest in FNPP.[4] China Atomic Energy Authority signed an agreement with Rosatom, to cooperate in construction of nuclear

1 "World's first floating nuclear power plant to begin operating in Russia in 2016," https://www.rt.com/news/floating-nuclear-plant-russia-759/, July 9 2013 (accessed Oct 5, 2015)
2 Trude Pettersen, "Dock Trials of Floating Nuclear Power Plant to Start this Summer," in Barents Observer, available at: http://barentsobserver.com/en/energy/2015/06/dock-trials-floating-nuclear-power-plant-start-summer-09-06, July 9, 2015 (accessed 5 Oct 2015).
3 Nick Cunningham, "Russia to Power Artic Drilling with Floating Nuclear Reactors," Christian Science Monitor, 28 April 2015, available at: http://www.csmonitor.com/Environment/Energy-Voices/2015/0428/Russia-to-power-Arctic-drilling-with-floating-nuclear-reactors (accessed 5 October 2015).
4 "Rosenergoatom: China's participation in the project of floating nuclear power plants will soon decide", February 6, 2015, http://ria.ru/atomtec/20150602/1067724562.html (accessed 5 Oct 2015).

cogeneration plants for China's offshore islands. These FNPPs would be build in China, but based on Russian technology, possibly using Russian KLT-40S reactors.[5]

Many of these countries, such as Algeria, Namibia, Cape Verde, Indonesia, may not have extensive infrastructure for nuclear security.

In August 2015, Russia's Rosatom signed a cooperation agreement with Indonesia's BATAN on construction of floating nuclear power plants.[6,7]

We propose several different avenues for cooperation in FNPPs technologies:

1. IAEA Nuclear Security (i.e., safeguards) – work with the IAEA in analyzing designs for IAEA nuclear security (both PPS and nuclear material accounting & control) requirements and making recommendations when needed for meeting all requirements
2. Multi-lateral or bi-lateral agreements: work with individual countries that want to employ FNPP technology, but have limited nuclear security infrastructure, to improve nuclear security before delivery of FNPPs; i.e., best practices
3. Work with Russian design that incorporates nuclear safeguards for IAEA inspections in non-nuclear weapons states

5 "Nuclear Power in Russia," World Nuclear Association, updated October 2015, available at: http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Russia--Nuclear-Power/#FNPP (accessed 7 October 2015).

6 "Moscow and Jakarta signed a memorandum on the draft NPP for Indonesia," in RIA.ru, 17 September 2015, available at: http://ria.ru/economy/20150917/1257182521.html#ixzz3mmU4oimN (accessed 5 October 2015).

7 "Nuclear Power in Russia," ibid.

Appendix A

FNPPs Under Construction or in Design

Russian FNPPs under construction and testing of the reactors, see Figure below.

Figure 1. The Akademik Lomonosov under construction (from: http://revolutionizingawareness.com/tag/akademik-lomonosov/).

Figure 2. Installation of the Akademik Lomonosov's nuclear reactors in the Baltic Shipyard (available at: http://bellona.org/news/nuclear-issues/nuclear-russia/2015-04-arctic-hopping-russian-deputy-minister-promises-russias-floating-nuclear-plant-next-year).

Design of Russia's first FNPP, see Figures below.

Figure 3. Russia's floating nuclear power plant (FNPP). [8]

Figure 4. FNPP design.[9]

Russia's plans for deployment of FNPPs, see Figure 8.

8 See Ref 1.
9 Available at: www.okbm.nnov.ru

Figure 5. Russian plans for deployment and potential deployment of FNPPs (from http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/Russia--Nuclear-Power/).

The US is pursuing a design that would be located further from shore using oil platform technology. In the case of loss of coolant, this design uses the ocean for natural cooling of the nuclear reactor. These are designed to withstand Tsunamis and earthquakes provided they are located far enough away from shore. These are located well away from coastal populations, and are linked by underwater transmission lines.[10]

Figure 6. Design of offshore floating nuclear power plant designed by MIT. (from http://phys.org/news/2015-06-nuclear-power-miles-sea.html)

10 "Floating Nuclear Power Plant that is Safer and Cheaper," in TechDaily, June 25, 2015, available at: http://scitechdaily.com/floating-nuclear-power-plant-safer-cheaper/ (accessed 5 October 2015).

The US design for a proposed offshore floating nuclear plant structure is shown below. This structure is 45 meters in diameter, and the plant will generate 300 megawatts of electricity. An alternate design for a 1,100 MW plant would need a structure 75 meters in diameter. Both structures include living quarters and a helipad for transporting personnel. This is similar to an offshore oil drilling platform. See next two figures. Design by MIT.

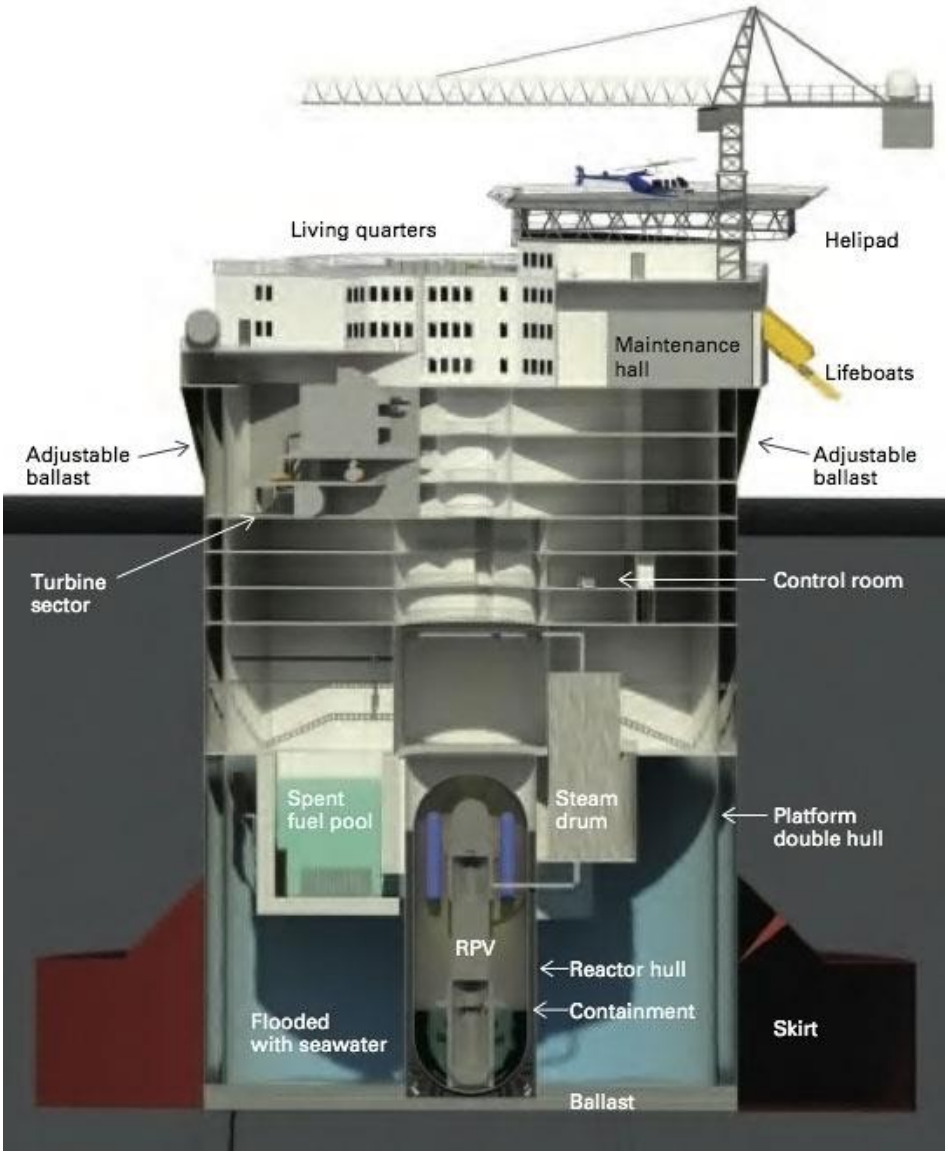

Figure 7. Proposed offshore floating nuclear plant, similar to offshore drilling platform.[11] RPV is the reactor plant vessel.

Direction of Construction of Naval and Submarines (DCNS) in France (part of the Naval Defense Industry) is pursuing development of the Flexblue, a small marine based modular designed reactor that

11 "Floating Nuclear Power Plant that is Safer and Cheaper," ibid.

is 160 MWe operated on the seafloor. This is a water cooled reactor that uses naval offshore and passive nuclear technologies to take advantage of the sea's infinite and permanently available heat sink for cooling. [12]

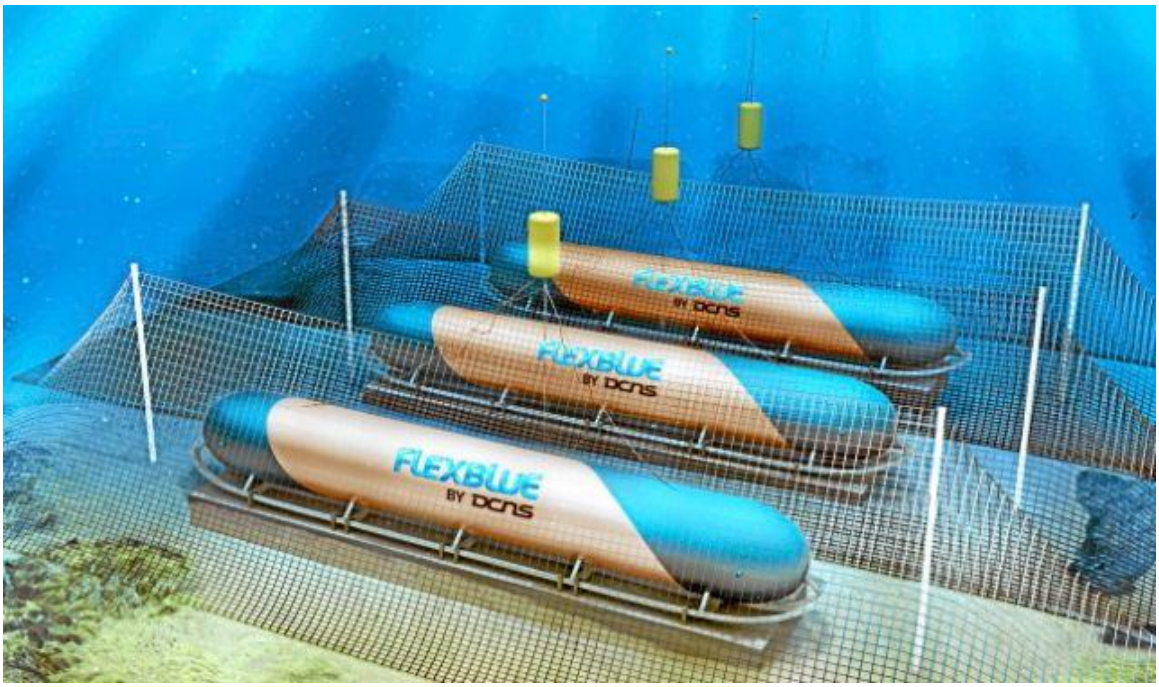

Figure 8. The Flexblue marine based nuclear power plant.[13]

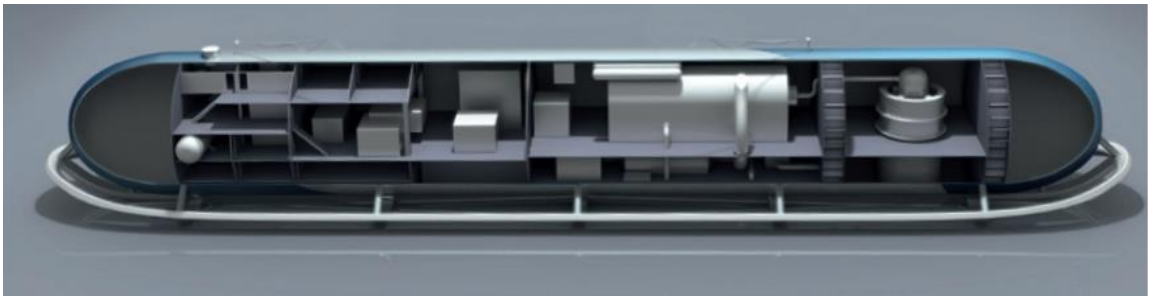

Figure 9. Inside of the Flexblue.[14]

12 "Nuclear Technology Review," Fifty-eighth regular session of the General Conference, International Atomic Energy Agency (IAEA), GC(58)/INF/4, 17 July 2014, Paragraph 150.

13 "France's DCNS, AREVA, EDF, CEAR Plan Underwater Nuclear Plant (US)," France-Metallurgie, 24 January 2011, available at: http://www.france-metallurgie.com/index.php/category/recherche-developpement/page/10/#sthash.qFg0nvax.dpbs (accessed 7 October 2015).

14 "France's Underwater Nuclear Reactor," available at: http://large.stanford.edu/courses/2011/ph241/nazir1/ (accessed 7 October 2015).