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THE BUSHEHR NPP: WHY DID IT TAKE SO LONG?*

By Anton Khlopkov and Anna Lutkova**

After years of delays, Iran's first nuclear power plant at Bushehr was finally launched on August 21, 2010. Commercial power generation is now expected to begin by the end of 2010.

The agreement between the Iranian and Russian governments on building a nuclear power plant in Iran was signed in Moscow on August 25, 1992. The deal covered the construction and actual operation of the plant.[1] The Bushehr NPP was supposed to have two reactor units, with the possibility of adding another two at a later time. On January 8, 1995, the two sides signed a contract in Tehran to finish the first reactor unit based on the VVER-1000 reactor design (on the Russian side it was signed by Zarubezhatomenergostroy, ZAES). In August 1995, they signed a nuclear fuel supply deal for the first 10 years of the plant's operation.[2]

The V-320 reactor unit (VVER-1000) of the Balakosvkaya NPP in Russia's Saratov region was chosen as the reference design. It was expected that the construction and start-up would take 55 months, with the commissioning date some time in 2001.[3] So why did the Bushehr NPP take almost 15 years to complete?

Work on the project was launched by German specialists back in July 1975.[4] The original plan was to build two 1,240 MW power reactors based on the Convoy design. The site was located in the southwest of the country, 18 km from Bushehr. The reference design for the two reactors was the second reactor unit of the Biblis NPP (Hesse state)[5], which was the most advanced reactor in Germany at the time. Kraftwerk Union A.G. (KWU, a joint venture between Siemens AG and AEG Telefunken) was chosen as the general contractor for the project. The first reactor was to be launched in 1980, the second a year later.[6]

However, in July 1979 KWU suspended all operations at the Bushehr site after Iran ran up big debts for the work already completed.[7] The first reactor unit was 80-85 per cent finished at the time, the second 50-70 per cent finished.[8] Some 80,000 pieces of equipment had already been delivered. During the Iran-Iraq war (1980-1988) the half-finished NPP sustained serious damage to the reactor containment dome and other structures.

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* - The article is based on the report prepared by the authors for the Nuclear Club journal.

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In the early 1990s, the Russian specialists tasked with completing the plant faced some difficult choices as to what to do with the structures and equipment already installed by the Germans.

Experts of the Russian Ministry of Atomic Energy (Minatom) offered the Atomic Energy Organization of Iran, the AEOI, three options:

- Build two reactors based on Russian technology but using the existing German-built structures;
- Dismantle the existing structures and start the NPP from scratch at the same site;
- Begin construction at a new site.

The Russian engineers themselves preferred the third option. But Iran had already invested 5.3bn Deutschmarks (1.4bn dollars) into the existing site in the 1970s.[9] The AEOI therefore insisted on making the full use of the existing structures and the equipment the Germans had delivered before abandoning the project. The situation was compounded by the absence of any manuals and other paperwork for much of that equipment. The Russian specialists were faced with the task of not only certifying all that unfamiliar machinery but also developing repair and maintenance procedures for it. Moscow therefore offered Germany partnership in completing the NPP. A letter to that effect was sent by Russian Minister of Atomic Energy Victor Mikhaylov to the German economics minister. But the Germans rejected the offer.[10]

Under the contract signed with the Iranians, Russia undertook to finish the construction of the first reactor unit at the Bushehr NPP using the V-446 design (1,000 MW), a version of the V-320 reactor adapted to the existing Bushehr site. The design also took into account seismic activity in the region: the plant can withstand a Magnitude 8 earthquake (MSK-64 scale) without any serious damage, and survive up to Magnitude 9.[11]

Given the specifics of the Bushehr project, it was divided into three separate stages. During the first stage, experts examined the existing structure and equipment, assessed the damage done to the containment dome and developed designs and blueprints for the repairs. The second stage included the actual repairs to the containment dome; and the third delivery and installation of the rest of the equipment.[12]

There were substantial differences between the Russian and German designs in the layout of the reactor unit (some of them resulted from using different types of steam generators). That necessitated serious changes to the existing structure of the reactor floor, and the removal of large quantities of reinforced concrete. Similar work was required at other buildings to accommodate the different size and shape of the Russian equipment.

Therefore, the main problem at the first stage of the project was the complexity of integrating the Russian reactor design into the existing German-built frame. Russian specialists also needed to ascertain whether the German equipment mothballed and left in storage at the site was still in good working order. That work took several years

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to complete. Some 47,000 pieces of equipment passed the vetting; another 11,000 seemed to be in working order but the specifications and manuals to them were missing and needed to be restored. Meanwhile, over the years since the Germans made a start on the NPP, the nuclear safety requirements in Russia and internationally have become more stringent. Some of the German machinery being integrated into the Russian design therefore required upgrades to comply with the modern safety standards.

It took the Iranians until December 1999 to approve the final set of requirements and specifications for the first reactor unit of the Bushehr plant[13], incorporating all the technological changes. Overall, the Russian design made use of some 12,000 metric tons of German equipment.

Table 1 contains the key specifications of the German reactor design chosen for the Bushehr project in the 1970s and of the Russian design that eventually replaced it.

Table 1. Specifications of the reference reactors chosen by KWU and by Minatom for the Bushehr NPP project.

Specification	Biblis NPP, Reactor B	Balakovskaya NPP, Reactor 4
Type	PWR-1240 (Convoy)	VVER-1000 (V-320)
Electrical output, MW	1,240	1,000
Heat output, MW	3,752	3,000
Efficiency, %	33.2	33
Reactor vessel height, mm	13,250	10,880
Reactor vessel internal diameter, mm	5,000	4,155
Reactor vessel weight, metric tons	550	304.3
Uranium load	102.7	66
Steam generator layout	Vertical	Horizontal

Sources: Biblis power plant. A brief portrait. RWE Power. P. 14.
http://www.rwe-kundenservice.com/web/cms/contentblob/77496/data/2858/B-KKW-Biblis-e-pdf.pdf.

Another major difference between the German and Russian designs was that the former doubled as a desalination plant. Two desalination facilities were supposed to be built at Bushehr, each capable of producing 100,000 cu.m. of fresh water per day.[14] The protocol of negotiations between Russian Nuclear Energy Minister Mikhaylov and his Iranian counterpart Reza Amrollahi held on January 8, 1995 mentions the possibility of cooperation in building desalination plants.[15] But these plans were dropped in the final Russian designs for the Bushehr NPP.

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Crisis in the industry and economy

The engineering complexity of integrating a Russian reactor design with the existing structures and equipment at Bushehr was further compounded by the crisis in the nuclear energy industry and the Russian economy. In addition, Bushehr was the first foreign contract for building a nuclear power plant that Russia had secured since the collapse of the former Soviet Union.

The dissolution of the Council for Economic Mutual Assistance (CEMA) and then the fall of the Soviet Union spelt the end of close cooperation between the former Soviet countries in many areas, including nuclear engineering. Russia faced the task of assembling a new and very complex supply chain required for building a nuclear plant based on the VVER design. It had to overcome differences at every single step, such as securing credit financing, hiring skilled personnel, finding the subcontractors, etc.

Under the established international practice, the foreign customer pays upfront 5 per cent of the value of the contract. Another 85 per cent is paid once the equipment has been delivered, and the remaining 10 per cent after the reactor has been launched.[16] In March 1997, the AEOI paid the first 60m dollars to the Russian contractor[17] - but that money was not enough to make the downpayments for the equipment to the Russian subcontractors. The government had already stopped subsidizing the industry, so ZAES had to seek credit financing. The state-owned banks turned it down; luckily, the company managed to secure credit from several commercial banks. The loans were relatively small; the interest rates in the area of 13-15 per cent. *Alfa Bank* accounted for the bulk of that financing; it was supplemented by *Konversbank* and *MDM Bank* loans. Later on, *Gazprombank* became the company's main creditor.

There was also a shortage of skilled Russian engineering and construction specialists with suitable experience. Back at the time, the last nuclear energy reactor built in the former Soviet Union itself was the No 6 reactor at the Zaporizhzhya NPP, Ukraine. That is why Ukrainian specialists were invited to work in Iran after they had completed their stints at Zaporizhzhya. At some point Ukrainians made up 80 per cent of all non-Iranian personnel working at Bushehr. During the frequent pauses in construction at the site, when engineers should have been sent back home, the Russian contractor had to keep them at Bushehr on full pay, fearing that "once they leave and move on, they'll be lost to us". At some points during the project, the number of people on the Bushehr payroll was over 2,500. For example, in February 2009 there were 2,751 people working for the Russian contractor at the Iranian site[18]; in September 2008 there were 2,111.

Meanwhile, the equipment subcontractors back home in Russia were facing similar problems. The Izhorskie Works, which lost most of its government contracts in the 1990s and slashed its workforce, had to bring in qualified welders from all over Russia.[19] The reactor vessel it shipped to Bushehr via the St Petersburg sea port in November 2001 was its first in 14 years.

Finding suitable subcontractors in Russia was also a challenge. Orders were scarce, so every subcontractor tried to milk the Bushehr project for all its worth. That meant

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additional delays for the general contractor trying to drive the prices down to an acceptable level in each individual case. There were frequent problems with quality and deadlines, and some of the required services could not be obtained from Russian companies at any price.

To illustrate, in November 2001 ZAES needed a ship to deliver the reactor vessel to Iran from the St Petersburg sea port. The ship had to meet a set of special requirements, including an onboard crane capable of lifting 400 tons. Russia did not have a single one of such ships left at the time, so the ZAES had to turn to foreign shipping companies. To make things even more difficult, Iran insisted that the choice of the ship, its flag and the route it would take should be agreed with the government in Tehran.

Another incident happened in November 2003, when the body of the steam separator for the Bushehr NPP was being brought by platform truck from a factory in Podolsk, Moscow Region, to St Petersburg. To circumvent the weight restrictions (45 tons) on road haulage and speed up the delivery, the haulage company massively understated the weight of the cargo, putting the figure of 44.8 tons in the paperwork.[20] The truck, along with its cargo, was impounded by traffic police in Pskov Region; it was released only after the government roads agency had examined all the bridges and overpasses the overweight truck had passed, presented the bill of damages to the hauler and received the compensation.[21] The whole process took over three months.[22]

Unrealistic deadlines

Even disregarding the difficult situation at the time in Russia's nuclear industry and its economy as a whole, the schedule of the project's delivery dates was entirely unrealistic.

In January 1995, when the Bushehr contract was signed, there were a total of 14 VVER-1000 (V-320) reactors in operation in Bulgaria, Russia and Ukraine. On average, each one took 71 months to build. Only three of the still operational V-320 type reactors had taken 55 months or less. And not a single one of the reactor units built after the Chernobyl disaster had taken less than 112 months to complete.

It is therefore safe to say that the task of completing the first reactor unit of the Bushehr NPP in less than five years was not simply ambitions but next to impossible. The explanation offered by the Russian side for accepting such a tight schedule is that they were facing serious pressure from the AEOI, which was eager to minimize the time frames written in the contract.

Iranian subcontractors

The protocol signed by Russian Nuclear Energy Minister Victor Mikhaylov and the president of the AEOI, Reza Amrollahi, on January 8, 1995 contained a commitment by the Russian side to maximize the involvement of Iranian subcontractors in completing the first reactor unit of the Bushehr NPP.

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In the actual contract, the share of the project the Iranians had secured for themselves included the completion of all building works, repairing the damaged steel containment dome and the polar crane of the reactor unit, as well as installation and start-up of equipment at the auxiliary facilities of the power plant. The Iranian side assumed full responsibility for the quality and timely completion of its share of the project. The Iranian companies were supposed to work under the technical supervision of Russian specialists. The Iranians also undertook to supply some of the equipment, including cabling, pipelines, etc. In practice, they simply lacked the experience required for such a complex project. Once the actual work had begun, it soon became clear that the Iranian subcontractors were not up to the tasks they had secured for themselves in the contract.

During the first attempt to build the NPP 20 years previously, the German general contractor was commissioned to deliver not only a fully operational power plant but also to build all the required infrastructure, including housing, schools and hospitals for the builders involved in the project and their families. Even the roads and port facilities needed to bring in the equipment for the plant were the Germans' responsibility. The Iranian Shah, Reza Pahlavi, wanted his nuclear energy program to deliver quick results, so he preferred to commission foreign specialists to do all the work on the first nuclear power plants rather than rely on the skills and efficiency of Iranian subcontractors. And even those few Iranians who were involved in the "German" phase of the Bushehr NPP project in the late 1970s had either retired or left the country by the mid-1990s.

Each one of the tenders announced as part of the Russian project normally attracted several Iranian bidders. The contract was awarded to those who had the recommendations from the AEOI and offered the best commercial terms. But during the first few years of the project, it often turned out that those subcontractors were unable to deliver their part of the work on time and to the required quality standards. The existing contracts had to be cancelled, and new bids were invited. As a result, it took the Iranian subcontractors three years (from 1995 to 1997) to do the work that should have been done in 12 months.[23]

In order to keep the project on track, a Minatom delegation sent to Tehran in January 1998 pushed through the decision that the Russian general contractor would finish the first reactor unit on its own. An agreement to that effect was signed on August 29, 1998 as Addendum 1 to the main contract by Atomstroyexport (the successor to ZAES) and the AEOI. The Russian general contractor undertook to complete the project within 52 months, although even the optimists among the Russian experts thought it would take at least 70 to 90 months of hard work.

Former Russian atomic energy minister Evgeniy Adamov later recalled in his memoirs that he was approached by AEOI president Gholam Reza Aghazadeh, who had replaced Reza Amrollahi a few months earlier. Aghazadeh asked Adamov to keep the unrealistic delivery dates when Addendum 1 was being negotiated, saying that the deadlines could then be pushed back once clear progress has been achieved on the construction of the first reactor unit. He assured Adamov that Russia would not be held responsible financially for the delay. The AEOI was eager to avoid a new wave

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of criticism from the opponents of the Bushehr project in the Iranian parliament and other centers of power.[24] Be that as it may, under the addendum to the contract the Russian general contractor undertook responsibility for all the work initially allocated to the Iranian subcontractors.

US policy on Bushehr

The US stance on Bushehr had a serious impact on the project's implementation. In the early 1980s Washington imposed an embargo on exports of nuclear technologies, including those related to peaceful use, to Iran. The US government argued that there was a danger of those technologies being diverted to illicit purposes. It also maintained pressure on other nuclear exporters to join the embargo. It succeeded in persuading Germany not to take part in the completion of the Bushehr plant and to ban exports of any required components. Iran asked Germany to resume the project in the mid-1980s, and Russia offered Berlin to take part in the completion of the first reactor unit in the mid 1990s. Both offers were turned down.

Over the years, US officials voiced four main reasons for their concern over the Bushehr project:

- The NPP could help the Iranian scientists to obtain weapons-grade nuclear material (that argument was the first to be withdrawn, groundless as it was);
- The construction and operation of the NPP will give Iran valuable skills and experience and help it train nuclear scientists;
- The NPP can be used by Tehran as a pretext for developing nuclear fuel cycle technology, including nuclear fuel manufacturing and uranium enrichment.
- The Bushehr project can be used as a cover for unauthorized transfer of sensitive information and technology to Iranian scientists, as well as illicit acquisition of nuclear technology and materials by in third countries.

Washington used a wide range of instruments to put pressure on Russia on the Bushehr issue. In the late 1990s and the beginning of this decade, the United States made the development of US-Russian relations in a number of areas, including cooperation in the peaceful use of nuclear energy (covered by 123 Agreement), conditional on Moscow's agreement to abandon all nuclear dealings with Iran, including the Bushehr project. When Russia was in the throes of a deep economic crisis in the mid to late 1990s Washington often raised the issue of Russian-Iranian cooperation in the context of international financial assistance to Moscow, as well as US assistance programs (such as the Nunn-Lugar program).

But all Washington has managed to achieve is a commitment by Moscow to limit its cooperation with Iran to completing the first reactor unit of the Bushehr NPP, supplying fuel for it and training Iranian specialists to operate the plant. That commitment, termed "Bushehr Only" in the media, was formulated in a confidential letter from Russian Prime Minister Viktor Chernomyrdin to US Vice President Al Gore in December 1995. Many in the United States believed that following Russia's refusal to cooperate with Iran on nuclear fuel cycle technology,

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Tehran would lose interest in the Bushehr project, and that the nuclear power plant would never be completed.[25]

Washington spared no diplomatic effort to persuade foreign subcontractors to walk away from the Bushehr project. Those efforts eventually brought some significant results.

Ukrainian and Czech companies were supposed to manufacture some of the equipment for the Bushehr NPP. Ukraine's Turboatom was due to supply a set of two turbines. But those plans were cancelled shortly before US Secretary of State Madeleine Albright's visit to Kiev on March 6, 1998. The government in Kiev ordered Turboatom to pull out of the Iranian project. In return, Washington pledged to support Ukrainian membership of the Missile Technology Control Regime (MTCR) and sign a nuclear cooperation agreement (123 Agreement). It also promised to facilitate private US investment into the Ukrainian economy, especially the economy of the Kharkiv Region (the so called Kharkiv Initiative). That latter promise was never fulfilled. Meanwhile, the Ukrainian government set about fulfilling its own side of the bargain in a fairly brutal way: according to some reports, President Leonid Kuchma simply telephoned the Turboatom director and told him about the decision made regarding Bushehr. However, Ukraine managed to avoid any commitments regarding the participation of its specialists in the construction and installation works at Bushehr. At some point, Ukrainians made up about 80 per cent of all expat personnel at the Bushehr site.

The Czech Republic's ZVVZ Milevsko was due to supply ventilation equipment. But in March 2000, shortly before Madeleine Albright's visit to Prague, the Czech government passed a law through parliament which effectively vetoed the deal. Russia's Atomstroyexport therefore suddenly faced the problem of looking for alternative suppliers. That caused additional delays, but the problem was resolved in the end.

There were several other cases of politically motivated decisions by subcontractors to walk away from the Bushehr project, despite their earlier commitments. For some of the equipment, Atomstroyexsport had to place orders three times with three different supplies before the delivery was actually made.

Not before 2005 did George W Bush recognize that the Bushehr nuclear plant poses no threat to the nuclear nonproliferation regime. And in December 2007 he welcomed the Russian decision to supply nuclear fuel to Bushehr, arguing that this would remove the need for Iran to build its own uranium enrichment facility or develop independent nuclear fuel cycle capability. Part of the reason for US support was the deal signed by Moscow and Tehran on February 28, 2005, under which spent nuclear fuel from the Bushehr plant would be shipped back to Russia. But in November 2000, Russia‘s then president, Vladimir Putin, announced that Russia was no longer bound by the Gore-Chernomyrdin agreement.

Financial difficulties

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During the negotiations on the Bushehr contract, Tehran agreed to pay 80 per cent of the value of the contract in cash, and only 20 per cent in kind[26]. That was one of the major incentives for Minatom to undertake the whole complicated project of finishing a nuclear power plant started by the Germans[27]. The total value of the contract, as agreed in the contract and the 1998 Addendum 1, was set at just over 1bn dollars.

Ever since the signing of the addendum, that figure has not been adjusted for inflation. A serious strengthening of the euro against the dollar posed a further problem, since some of equipment and material suppliers come from the Euro area. In addition, equipment and material costs have also increased very substantially even without the exchange rate fluctuations. One of the contributing factors is the growing metal prices. Another is the rising global interest in nuclear energy, which has driven up the prices of hardware and services in this sector. To illustrate, Russia is now negotiating a Turkish contract to build a nuclear power plant. The Russian price offer is about 4bn dollars for one VVER-1200 reactor, which is more than triple the worth of the Bushehr contract.

In February 2007, work at the Bushehr site started to grind to a halt due to funding shortages. By the summer of that year, the Russian contractor had reduced the number of staff there from 3,000 to just 800 people[28]. After some hard bargaining, during which the Russian general contractor even contemplated pulling out of the project, an agreement was reached with the Iranians that the growing cost of equipment and engineering works would be compensated once the reactor goes live. The size of that compensation will also be finalized once Bushehr becomes operational. This resolution of the financial problems enabled Russia to make first deliveries of nuclear fuel to Bushehr in December 2007, thus ruling out the possibility that the project would once again be abandoned.

Over the course of the project, Iranian payments were often behind schedule for a variety of reasons - sometimes by as much as six months. That too caused additional delays at the Bushehr site.

UN Security Council sanctions

In 2002 it was discovered that Iran had a large undeclared nuclear program which included the construction of a uranium enrichment facility based on centrifuge technology and a heavy water research reactor. In September 2005, the IAEA Board of Governors passed a resolution declaring that Iran was in breach of its commitments under the safeguards agreement signed on May 15, 1975.[29] In July 2006 the UN Security Council passed Resolution 1696 (2006) which warned of measures under Article 41 Chapter VII of the UN Charter if Iran fails to comply with the Security Council and IAEA demand to halt uranium enrichment activities.[30] In 2006-2010 the Security Council passed four rounds of sanctions (Resolutions 1737, 1747, 1803, 1929) in response to Iran's non-compliance.

Resolution 1737 (2006) banned exports to Iran of any equipment or technology that can be used for uranium enrichment and reprocessing of spent nuclear fuel.

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But neither that resolution nor the subsequent ones impose any restrictions on Russia's cooperation with Iran on the Bushehr NPP project. However, Resolution 1737 contains the requirement to notify the Security Council Committee established pursuant to the same resolution of any deliveries to Iran of equipment or materials, which can be used to build a nuclear power plant. Notifications about such deliveries must be submitted "within ten days of the supply, sale or transfer" of such technology.[31]

Although the sanctions do not impinge on the Bushehr plant directly, they do create additional difficulties in its implementation. In particular, they have made the procedure of signing contracts with third country suppliers much more complex. There have also been problems with the transit of shipments to Iran. On March 29, 2008 a cargo of heat insulation equipment for the Bushehr NPP en route from Russia to Iran was seized on the Azeri-Iranian border (Astara border terminal).[32] In view of the recent sanctions imposed on Iran, Azeri customs officials requested additional information about the cargo's technical specifications and intended use, which caused a delay of more than a month.

Finally, it must be noted that ever since the IAEA began investigating Iran's undeclared nuclear program in August-September 2002, and until the nature and scale of that program had been clarified, Russia was in no hurry to speed up the work at the Bushehr site, although the project was significantly behind schedule.

Conclusion

Russian specialists working on the project to complete the first reactor unit of the Bushehr NPP faced a whole host of technical, engineering, political and financial challenges. They were compounded by the fact that the Bushehr contract was the Russian nuclear engineering industry's first foreign contract to build a nuclear plant since the collapse of the Soviet Union and the dissolution of the CEMA. The fact that the project was the first of its kind for Iran as well did not help things, either. Another factor was the unrealistic schedule of the project, which the Russian general contractor agreed to under pressure from the Iranians.

But the project has given both Russia and Iran some valuable experience of cooperation in the construction of a nuclear power plant. That experience (some of it positive, and some negative) can now be used to build more nuclear power plants in Iran, especially the second reactor unit at Bushehr (provided that there is political will in Russia). Most of the technical and technology problems in Russian-Iranian nuclear cooperation mentioned in this article have already been resolved. For example, Russia has now identified the subcontractors that can be relied upon to deliver. Mutual understanding has been reached with the Iranians that the proposed second reactor unit should be built from scratch instead of trying to integrate it into the existing German-built frame. There is also greater willingness in Russia to provide government support to joint NPP projects.

The only obvious factor that is working against further Russian-Iranian cooperation in this area is the questions which the IAEA still has about Iran's undeclared

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nuclear activities. Any decisions on the proposed second Bushehr reactor would have to wait until Iran answers the key remaining questions on its past undeclared nuclear activities, and until the most sensitive issues of the Iranian nuclear dossier are resolved. Meanwhile, the very first step towards a second Bushehr reactor has already been made now that the first reactor has finally been launched.

Notes

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