INTRODUCTION

The Supersonic Low Altitude Missile (SLAM), also dubbed “The Big Stick,” was conceived around 1964 as a third weapon system in addition to the Inter Continental Ballistic Missiles (ICBMs) and strategic bombers for delivering retaliatory strikes in the event of a nuclear conflict. The SLAM, a nuclear-powered cruise missile would have an unlimited range that could loiter following the terrain at low altitude, hence evading long-range radar, for weeks on end before dropping multiple payloads behind enemy lines.

The principle behind the nuclear ramjet or pipe-stove is that the forward motion of the vehicle pushed air in through the front of the vehicle or the ram effect. A compact nuclear reactor then heated the air, and the hot air expanded at high speed out through a nozzle at the back, providing thrust without the need for a chemical fuel. A rifle bullet going at 2,500 fps, is moving at a half mile a second, 30 miles a minute, 1800 miles an hour, or supersonic Mach 2.5.

Advances in metallurgy and materials science are needed for a successive implementation. Pneumatic motors necessary to control the reactor in flight had to operate while red-hot and in the presence of intense radiation. The need to maintain supersonic speed at low altitude and in all kinds of weather meant the reactor has to survive high temperatures and conditions that would melt the metals used in most jet and rocket engines. Beryllium oxide ceramic fuel elements would have to be used.

The USA efforts to build the nuclear-powered SLAM, was named project Pluto. From 1957-1964 the USA worked on a nuclear powered cruise missile, which would carry 16 nuclear munitions to targets in the USSR. The reactor would be unshielded and was colossal in size using a moderator in a thermal neutron spectrum. A fast neutron spectrum reactor would be more compact in size. For testing purposes, an electrical heating system can model the reactor heat input.

The large amount of radiation it generated in flight was considered a feature at the time. However, even though a full scale reactor and engine were built, the project was canceled because the system was considered both highly problematic from an engineering standpoint and also provocative. The SLAM was nixed in 1964. Some believed it would motivate the Soviet Union to build a similar device, and all in all ballistic missiles were far less problematic.
Figure 1. Conceptualization of a Triad of Supersonic Low Altitude Missiles (SLAM), Inter Continental Ballistic Missiles (ICBMs) and strategic bombers.

Figure 2. Operation range of Supersonic Combustion Ramjet.
Figure 3. Turbofan jet engine.

Figure 4. Nuclear-powered aircraft Project Convair B72, Weapon System WS 125.

Figure 5. General Electric GE Open cycle nuclear aircraft engine.
Figure 6. Pratt & Whitney closed cycle nuclear aircraft engine using liquid metal as a heat transfer medium.

Figure 7. GE open cycle engine.
Figure 8. Russian Tupolev T95 flew with a combination nuclear open cycle engine and conventional engines with shadow radiation shielding of the crew.

Figure 9. Supersonic Combustion Ramjet (SCRAMJET) engine.
Figure 10. Specific impulse versus Mach number. Air breathing engines are more fuel efficient than rocket engines, allowing sustained hypersonic flight. Space Shuttle Main Engine (SSME): Rocketdyne LOx/LH2 rocket engine; only high-pressure closed-cycle reusable cryogenic rocket engine ever flown. Source: Boeing.
Figure 11. NASA 43A used hydrogen fuel, and reached Mach 6.83 and 9.68 in 2004. Source: NASA.
Figure 12. X51-A Wave Rider hydrocarbon jet fuel scramjet test flight launched from B52, May 1st, 2013. Used a booster rocket to accelerate it from Mach 0.8 to Mach 4.8. Edwards Air Force Base. Source: USAF.

Figure 13. Tomahawk Block IV cruise missile.
Figure 14. X43-B hypersonic scramjet launch from a B-52 bomber aircraft and solid fuel rocket, Mach 7 speed, March 2004. Carbon/carbon light weight composite material can withstand 3,000 degrees Fahrenheit temperatures. Source: NASA. (Mach 10 = 7,000 mph = 12,000 kph).
Figure 15. Rocket-launched Waverider Boeing X51A scramjet, 2010.
A subsidiary of General Dynamics, Convair at San Diego, California envisioned it as an air-breathing, unshielded nuclear reactor-powered cruise missile that would penetrate enemy airspace at low altitude, drop nuclear payloads on enemy targets, and make a suicidal plunge into a final target.

Figure 17. Convair, General Dynamics Pluto 2 nuclear ramjet was conceived to reach a Mach 3.5 speed. Reactor is situated in the back, the payload in the middle and the control and guidance system in front.
Launched by single-stage booster rockets the nuclear-powered ramjet engine would kick in once the missile reached sufficient speed. The cruise missile could then loiter for days at an altitude of 1,000 feet or less at a Mach 3.5 speed. It could carry a single large yield thermonuclear warhead or up to 26 multiple smaller devices.

**HYPERSONIC STEALTH, RAMJET AND SCRAMJET**

Speed is the new stealth. A hypersonic weapon is a missile that travels at Mach 5 or higher, which is about 1 mile per second. Commercial airliners fly at subsonic speed below Mach 1, whereas modern supersonic fighter jets can travel at Mach 2 - 4.

A traditional turbo-jet engine could operate at up to Mach 3 – 4, but traveling faster would need a completely different design to unclutter the flow path and sustain combustion of the supersonic airflow inside the engine using a Supersonic Combustion Ramjet “SCRAMJET”, which can operate between Mach 5 - 15.

To maintain sustained hypersonic flight, a vehicle must endure the extreme temperatures of flying at such speeds. The faster a vehicle flies, the pressure and temperature rise exponentially needing materials that can withstand high temperatures over a long period of time.

Two types of approaches emerged: hypersonic cruise missiles and hypersonic glide vehicles:

1. Hypersonic cruise missiles are powered all the way to their targets using a SCRAMJET. It takes 6 minutes from the time they are launched until the time they reach their target. They can fly at altitudes up to 100,000 feet whereas hypersonic glide vehicles can fly above 100,000 feet.
2. Hypersonic glide vehicles are placed on top of rockets, launched, and then glide on top of the atmosphere like a plane with no engine on it. They use aerodynamic forces to maintain stability to
fly along and to maneuver. Because they are maneuverable they can keep their target as a secret up until the last few seconds of their flight.

**NUCLEAR REACTOR DESIGN FOR SLAM, SUPERSONIC LOW ALTITUDE MISSILE**

The reactor development work for nuclear propulsion systems was started by the NEPA Project and specific development for nuclear ramjet application at the Aircraft Nuclear Propulsion Department of the General Electric Company.

As the ramjet program gained in importance, it was moved to the Lawrence Radiation Laboratory (LRL) of the University of California in January 1957. The LRL’s worked with the Chance Vought Company in determining the reactor propulsion requirements.

![Diagram](image)

Figure 19. Nuclear reactor configuration for SLAM.

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<th>Table 1. Nuclear reactor characteristics for the SLAM reactor system.</th>
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<td><strong>Diameter</strong></td>
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<td><strong>Fissionable Core</strong></td>
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<td><strong>Length</strong></td>
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<td><strong>Core Length</strong></td>
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<td><strong>Critical Mass of Uranium</strong></td>
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<td><strong>Diameter</strong></td>
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<td><strong>Average fuel element Temperature</strong></td>
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The fuel elements for the test reactors were made of the high-temperature ceramic beryllium oxide (BeO). This was mixed with enriched uranium dioxide (UO₂) in a homogeneous mixture with a small amount of zirconium dioxide (ZrO₂) for stabilization. This mixture in a plastic mass was extruded by the Coors Porcelain Company under high pressure and then sintered to near theoretical minimum density.

Each fuel element was a hollow hexagonal tube approximately 4 inches long, 0.3 inches across flats, and had an inside diameter of 0.227 inches. These were stacked end to end to provide the 50.7 inch length of heated air passage. There were 27,000 of these heated airflow channels and 465,000 individual fuel elements. The design with these small unattached pieces was such that the problems of thermal stress in ceramics was minimized.

Two reactor tests were conducted to verify the feasibility of the project. The Tory II-A was a scaled-down test which was conducted in mid-1961 and operated at design conditions on October 5, 1961. The Tory II-C was a full-scale reactor test for a period of 292 seconds which was the limit of the air supply from the storage facility. That facility stored 1.2 million pounds of air which had to be preheated to 943 degrees Fahrenheit and supplied at a pressure of 316 psi to simulate ramjet inlet diffuser conditions. Tests were conducted at the Jackass Flats area in The Nevada Test Station by the Lawrence Radiation Laboratory. These tests demonstrated the feasibility of the nuclear power plant for the SLAM system.

RADIATION EFFECTS

The source of energy for SLAM propulsion was to be a nuclear fission reactor operating at a power level of 600 MWth. To minimize its weight, the reactor was not to have radiation shielding for the fission products of neutrons and gamma rays. As a result, the neutron flux was calculated to vary from $9 \times 10^{17}$ n / (cm²/sec) in the aft section to $7 \times 10^{14}$ n / (cm²/sec) in the nose section. Gamma ray energy was expected to be $4 \times 10^{11}$ MeV in the aft section and $1.2 \times 10^8$ MeV in the electronics compartment.

This requires careful selection of materials which could survive not only the high temperatures but also the high radiation levels. Some very sensitive components required a feasible amount of local shielding. The result of the investigations led to the conclusion that missile subsystems were available or could be made available for the SLAM application. Flight testing of the missile was planned to be conducted over the northwest Pacific Ocean with termination in deep ocean waters in the neighborhood where atmospheric testing of nuclear weapons had taken place at that time period.
Figure 20. Reactor configuration using a hexagonal BeO moderator configuration.

Figure 21. Tubular fuel elements connected with tie rods.
Figure 22. The generated pressures required the use of tie rods.

**SLAM AIRFRAME TESTING**

The airframe had been designed to operate in the environment of Mach 3 at sea level where skin temperatures reach 1,000 Fahrenheit and the sound pressure level is on the order of 162 db. The aerodynamics in this flight regime was little explored. Almost 1,600 hours of wind tunnel testing in the national laboratories resulted in a canard configuration design that could operate in the planned flight profile.

The classical spike inlet of a ramjet was replaced with a scoop-type inlet, which gave a pitch/yaw performance over a wider range and a pressure recovery of 86 percent that was much higher than the initial program objective.

An extensive materials investigative program resulted in the selection and fabrication of a section of fuselage using Rene 41 stainless steel with a skin thickness of 1/10 to 1/4 inch. This was strength-tested in a furnace to simulate aerodynamic heating. Forward sections of the missile were to be gold plated to dissipate heat by radiation. A 1/3-scale model of the missile nose, inlet and duct was constructed and wind tunnel tested.

Figure 23. Torre IIC air-cooled reactor core.
Figure 24. Torre IIC attached to exhaust nozzle.

Figure 25. Testing of nuclear ramjet engine.

Figure 26. Torre IIC on way to testing.
Figure 27. Tore IIC after testing.

Figure 28. Nuclear reactor and nozzle Torre IIA.
Figure 29. Reactor was tested at a power level of 500 MWth for 5 minutes.

Figure 30. SLAM missile technical components weights.
Figure 31. SLAM PLUTO diagram.
THE "BUREVESTNIK" NUCLEAR-POWERED CRUISE MISSILE

This is claimed to have a virtually unlimited range probably using a ramjet engine powered by a nuclear reactor. A possible 9M730 project, the device, once launched, heats up the inlet shocked-air, which is mostly nitrogen gas, and does not require any more fuel, hence claims an unlimited range: “Russia has completed the trials of miniaturized nuclear power units for cruise missiles of unlimited range and for autonomous submersibles of an oceanic multi-purpose system.” "Russia has created a small-size super-powerful power plant that can be placed inside the hull of a cruise missile and guarantee a range of flight ten times greater than that of other missiles." "A low-flying low-visibility cruise missile armed with a nuclear warhead and possessing a practically unlimited range, unpredictable flight path and the capability to impregnate practically all interception lines is invulnerable to all existing and future missile and air defenses". To date, those technologies have been designed and are in the testing phase by Russia.

Its main characteristics are:

i) Low-flying and steady,
ii) Nuclear powered,
iii) Unlimited flight range,
iv) Penetrates missile and air defense shields,
v) Unpredictable flight path.
Figure 33. Nuclear-powered earth-hugging, radar-evading cruise missile which is claimed to have a virtually unlimited range probably using a ramjet engine powered by a miniature nuclear reactor. This missile can take an arbitrary path to its target and circumvent enemy defenses. The advantage to being nuclear-powered is that it can loiter around for a long time, due to its almost practically limitless energy supply. The missile has special compartments where air is heated by a nuclear reactor to several thousand degrees, then thrust is created by ejecting the superheated air. The Russian photographs suggest that four rear nozzles are creating the thrust for the missile.

KINZHAL, “DAGGER” HYPERSOONIC CRUISE MISSILE

The Kinzhal “Dagger” air-launched, precision-guided cruise missile is designed to engage ground-based and seaborne targets. The air-to-ground missile code-named Kh-47M2 is launched from a modified MiG-31BM supersonic interceptor aircraft. It is based on the 9M723-1F variant
of the 9M723-1 missile as used by the 9K720 Iskander-M short-range road-mobile ballistic missile system. It uses a solid propellant motor with a non-separating warhead and a finned truncated tail-cone at the missile’s rear to decrease the aerodynamic effects of the missile when carried at high-speed on the aircraft and protects both its control components and motor nozzle from damage when in transit.

No extraneous external components are located on its surface other than its two cable ducts, which run from the control/motor nozzle section, over the motor and into to the guidance section, and the skin of the missile has been covered with a special heat-resistant and radar absorbing coating to minimize the heat effects on it and further lower its Radar Cross Section (RCS) [1].

Figure 34. High precision Kinzhal “Dagger,” hypersonic cruise missile launched from the belly of a Mikoyan Mig 31 Foxhound supersonic interceptor jet.
Figure 35. Kinzhal, “Dagger” cruise missile launch from Mig 31BM interceptor has a range of 1,000 kms.

Figure 36. Kinzhal Dagger hypersonic cruise missile in flight.
Figure 37. The Concord and the Boeing 2707 supersonic designs (Mach 3 and 300 passengers) in the 1960s were abandoned but are evolving into the Boom supersonic design for passenger jets. Source: Boom.

Figure 38. Boeing Mach 5 hypersonic jet model. On top, two vortices generate lift. At the bottom, the nacelle includes combined conventional and scramjet engines. Source: Boeing.
Figure 39. Boeing Mach 5, 95,000-feet hypersonic commercial aircraft concept. The speed of sound drops off with altitude, so Mach 5 at 70,000 or 95,000 feet is a much lower speed than a theoretical Mach 5 at sea level. Source: Boeing.

Figure 40. “Orient Express” Space plane concepts. Source: Boeing.

Figure 41. European scramjet propulsion wind tunnel testing model.
Figure 42. French conceptualization of supersonic aircraft.

Figure 43. TR3 B1 and TR3 B1 advanced alleged magneto hydrodynamic propulsion aircraft pictures in flight.
Figure 44. Matter/antimatter positron/electron futuristic space and jet propulsion conceptualization. Source: Positronics.

Figure 45. Antimatter from radioisotope source of positrons moderator to cold positrons patent. The annihilation gamma rays are converted to electrons that can be directed into a nozzle by electric and magnetic fields. Source: Positronics.
Boeing unveiled the initial concept of a hypersonic aircraft at the American Institute of Aeronautics and Astronautics (AIAA) Aviation 2018 conference in Atlanta, Georgia. The concept depicts a passenger capacity larger than long-range business jets, but much smaller than Boeing’s flagship 737, with indications the plane could enter service by the mid/late 2030s.

The hypersonic aircraft could fly at Mach 5 with an altitude ceiling of 95,000 feet. It would travel 2.5 times faster and 30,000 feet higher than the Aérospatiale / BAC Concorde, the British-French turbojet-powered supersonic passenger airliner, which operated from 1976 to 2003.

Boeing touts the ability to operate the aircraft with same-day return flights from the USA to Asia and Europe, which would significantly increase its asset utilization. Boeing determined that Mach 5 (3,836 mph) as the sweet spot between civil and non-transport military applications. The plane can get across the Atlantic in about 2 hours, and across the Pacific in about 3 hours. A fierce race for hypersonic technologies is underway among the global superpowers.

**DISCUSSION**

The USA Air Force in August 2018 has awarded a $480 million to Lockheed Martin Missiles & Fire Control to develop a hypersonic weapon prototype that would travel five times faster than the speed of sound to overcome Russian and Chinese missile defense systems. The contract covers the critical design review, test, and production readiness support for the Air-Launched Rapid Response Weapon (ARRW).

The AARW program now consists of two hypersonic weapon prototyping efforts administered by the Air Force to expedite hypersonic research and development. Lockheed was awarded the first $929 million contract on April 18, 2018, which was for the design and manufacture of the Hypersonic Conventional Strike Weapon (HCSW), a new air-launched weapon system.

Officials from the Defense Department, Missile Defense Agency, Air Force, Navy, and Army signed a memorandum June 28 to work jointly on the development of “hypersonic boost-glide” technology.

The ARRW effort is ‘pushing the art-of-the-possible’ by leveraging the technical base established by the Air Force/[Defense Advanced Research Projects Agency] partnership,” the release said. “The HCSW effort is using mature technologies that have not been integrated for an air-launched delivery system.”

In late 2017, China conducted several tests of a hypersonic-BGV glide vehicle that could be used to defeat U.S. missile defense systems. China has successfully tested its new aircraft, the Starry Sky-2, which can even be used to carry nuclear missiles at a speed never seen before.

The arms race in hypersonic weapons has ushered in the next Cold War between the USA, Russia, and China.

On March 28, 2018, USA General John Hyten addressed the 32nd Space Symposium. As head of the USA Strategic Command, he warned in an interview with CNN that China and Russia are working to produce new hypersonic weapons that the USA currently cannot defend against:

"China has tested hypersonic capabilities. Russia has tested. We have as well. Hypersonic capabilities are a significant challenge. We are going to need a
different set of sensors in order to see the hypersonic threats. Our adversaries know that."

There are currently no effective defenses against hypersonic weapons because of their speed and maneuverability. They can hug the ground at 500 feet below long range radars beams and hence escape detection. This is in contrast to ballistic missiles which possess predictable trajectories determined by momentum and gravity.

India's Brahmos II is a ramjet system developed with Russian design help. It might include a little chip imbedded in it that will cripple it when judged necessary like in most other weapons systems and computers reserved for export markets.

![Lockheed Martin scramjet](image1)

**Figure 46.** Lockheed Martin scramjet.

![Northrup-Grumman Global Hawk UAV](image2)

**Figure 47.** Northrup-Grumman Global Hawk Unmanned Aerial Vehicle UAV a candidate aircraft for nuclear propulsion as it does not need crew shielding. Instrumentation shielding will be required though.
Figure 48. DARPA Falcon HTV 2 vision of USA supersonic vehicles development.

Figure 49. Observe Orient Decide Act, OODA control loop.
Figure 50. Lasers on high flying aircraft as a defense against hypersonic vehicles are not affected by atmospheric conditions.

Deterrence with other systems such as the existing nuclear triad of land-based Intercontinental Ballistic Missiles (ICBMs), strategic bombers and submarine-launched ballistic missiles is an available counterweight. Laser defenses have limited capability in unfavorable weather conditions and electromagnetic guns have a limited line of sight capability.

Tracking is the real problem. Not shooting them down. If you can track them you can easily kill them. So instead of what you think of as a standard radar set that can track a missile, you instead need a net of radars that covers 100 percent instead of the area you are around or moving in. Or, if you have great point defense systems, such as lasers and rail guns, you can shoot the hypersonic vehicles down.

To defend against them, a space-based sensor system that would be able to track Hypersonic Glide Vehicles globally would be needed with some additional system to engage them. A one hundred percent coverage on radar requires space based systems. Their heat signature rather than their radar signature would be easily detectable from space sensors.

The USA, Russia, and China are developing hypersonic systems, as well as France, India, and Australia. Japan and various European countries are working on civilian uses of the technology, such as space launch vehicles and civilian airliners.

APPENDIX

NEW ARMS RACE. RUSSIAN STAR WARS WISH LIST [2]

In a bid for his reelection, President Vladimir Putin of Russia, in a repeat of President Ronald Reagan Star Wars initiative; gave a speech to the Russian Duma on March 1st 2018, outlying the development and deployment of six new weapon systems by the Russian military. It must be noted that Russia and China both have a history of exaggerating their weapon capabilities.

The aim of the six new directions of superweapons is to negate the effectiveness of the Anti-Ballistic Missile, ABM system that the USA surrounded Russia with. President George W. Bush in 2002 has withdrawn the USA from the treaty. The elimination of a retaliatory response by an ABM system makes the possibility of a decapitating first strike possible. The six high technologies comprise:

1. Sarmat RS-28 Super-heavy ICBM
An ICBM, Intercontinental Ballistic Missile System using nuclear Multiple Independently targeted Reentry Vehicles (MIRV) of large size of 200 tons: the RS-28 Sarmat with NATO designation SS-X-30 Satan-2. It replaces the RM-36M Voevoda with Nato designation is SS-18, Satan.

It uses a hypergol or hypergolic propellant with two components which spontaneously ignite when they come in touch with each other. Hypergolic propellants are difficult to handle because of their corrosiveness and toxicity. They can be stored as liquids at room temperature, Hypergolic rocket engines are easy to ignite reliably and repeatedly. The most common combinations are dinitrogen tetroxide plus hydrazine and its derivatives: monomethyl hydrazine and unsymmetrical dimethyl hydrazine.

It is difficult to detect in flight with a low orbit of 150 km, compared with classical ICBMs with an orbit height of 1,200 km. It has a long 11,000 km range capable of a South Pole trajectory avoiding detection by the ABM system installed for a North Pole trajectory.

![Figure 1. Ballistic missiles trajectories choices through North and South Poles.](image-url)
Figure 2. A north pole ICBM trajectory can be intercepted by the NATO/USA ABM system.

Figure 3. An ICBM South Pole trajectory avoids the installed ABM system.

Figure 4. The Sarmat mobile ICBM.
2. Burevestnik nuclear-powered Scramjet supersonic and “unlimited range and unlimited ability to maneuver” low altitude cruise missile

A Supersonic Low Altitude Missile (SLAM) powered by a miniature unshielded disposable nuclear reactor would hug the terrain, can loiter for a long time, and possess unlimited range since its heats the inlet and does not need a chemical propellant.

This is the Russian equivalent of the USA studied Pluto Project. Its speed would be between Mach 3 to 4.
Figure 7. Burevestnik nuclear-powered ramjet launch using a rocket and assembly line. Source: Russian Defense Ministry.
Figure 8. Zircon 3M22 scramjet cruise missile in flight testing.
Figure 9. Radar evading cruise missile.

3. Nuclear Unmanned Underwater Vehicle UUV, Kanyon Status-6

Since it can carry a large nuclear payload reaching a 50-100 MT device, it can target coastal cities and marine installations by an intense tsunami.

Its silent operation is possibly attributed to a magneto-hydrodynamic propulsion system powered by the nuclear reactor.

Figure 10. Two versions of autonomous nuclear torpedoes.

4. Kinzhal, Dagger Kh47M2 hypersonic transported system

This is claimed to be a hypersonic Mach 10 system that would be impossible to intercept with existing rockets. It would operate as a ramjet or scramjet. It launch vehicle would be a supersonic jet. It could carry nuclear or conventional payloads.

Its range would be 2,000 km with a short operation time of 10 minutes. To overcome the heat barrier at Mach 10, it may be surrounded by a plasma sheath. It would operate in the same fashion as the super-cavitation torpedo VA-111 Shkval. Its solid powder rocket exhaust gases would be diverted to the front, eliminating the shock wave and reducing the heating load. The generated enveloping plasma would be seeded with cesium to enhance its conductivity. The ionization would make it invisible to radar. The same principle of a plasma sheath may contribute to the stealth properties of the B2 bomber.
5. Hypersonic Glide Vehicle (HGV) Mach 20 Avangard

This would be a waverider type of cruise missile reaching Mach 20. It would be launched by a ballistic missile such as the RS-26 Rubezh or the RS-28 Sarmat into a ballistic orbit. It would then glide at high speed in the upper atmosphere with an unpredictable trajectory that is impossible to intercept toward its target “like a meteor”.

It possesses sharp leading edges leading to a non-detached frontal shock wave, in contrast to the space shuttle front. At Mach 10, the temperature immediately behind the shock wave would reach 20,000 degrees Celsius that no material can withstand. That needs the detachment of the shock wave using a plasma sheath. The kinetic energy of the shock wave must be converted into electrical energy along the line of the supersonic Ajax jet design.
Figure 12. Hypersonic ballistic plasma sheath glider would plunge at its target like a meteorite uses satellite guidance. The Hypersonic Glide Vehicle (HGV), dubbed “Avangard” and also called ‘Objekt 4202′, Yu-71 and Yu-74, is fastened onto an intercontinental ballistic missile using scramjet engine technology. Once launched, the Avangard reaches speeds of Mach 20 and is equipped with “onboard countermeasures.” It is still unclear whether the hypersonic glide vehicle will carry explosives, due to the fact that Mach 20 capabilities alone can pack enough energy to annihilate its targets.
The Avangard hypersonic boost-glide system went into production in the summer of 2018 to be operational with the 13th Strategic Missile Forces division by the end of 2019. It is deployed near Yasny, a town 502 kilometers or 312 miles southeast of Orenburg in the southern Urals Mountains. At least two regiments with six systems each are expected to be battle-ready by 2027. According to the state armaments program (GPV2027), twelve UR-100UTTKh (NATO: SS-19 Stiletto) missiles will be integrated into the Avangard hypersonic glide vehicles (HGVs). The deployment of the HGV might begin without additional flight tests. Eventually, the Sarmat RS-28 ICBM could be used to deliver the Avangard, potentially carrying a single, massive thermonuclear warhead with a yield exceeding 2 Mt of TNT equivalent.

The boost-glide weapon can fly at speeds of over Mach 20 or about 15,300 miles per hour or four miles per second. It could reach Washington D. C. in 15 minutes even if launched from Russia. It is hard to intercept it, as it moves in a cloud of plasma "like a meteorite." The weapon is distinctive for its ability to withstand extreme heat during the final phase of its trajectory thanks to its heat-resistant titanium casing. Its in-flight temperature reaches 1,600-2,000° Celsius. Carbon fiber can resist these temperatures.

It is difficult to predict the direction of its approach. Installed on the 200-ton Sarmat, the Avangard could be sent into the desired orbit at an altitude of 100 km from Earth using a pre-booster, gliding to its target at a speed of Mach 20 (5-7 km/s) while maneuvering with the help of stabilizers. It can make rapid course changes in the atmosphere. Its signatures are quite different from those of traditional ICBMs. Advanced countermeasure systems increase its ability to penetrate missile defenses.

The Avangard is the first HGV in the world to have gone into production, as well as the first to travel at great altitude in the dense layers of the atmosphere while deftly maneuvering. According to General John Hyten, head of USA Strategic Command: “We don't have any defense that could deny the employment of such a weapon against us.”

The Serial production of Sarmat ICBMs is scheduled to begin in 2021. The UR-100N UTTKhn and the Sarmat could carry multiple Avangard glide vehicles. Other ICBNs, such as the RS-24 Yars and RS-26 Rubezh, can potentially accommodate smaller Avangard-type vehicles should the New START Treaty not be extended. The tempo of the glide vehicle’s deployment and modernization can be expedited depending on the progress of the talks with the USA on strategic nuclear arms. Since its trajectory renders the Avangard immune to missile-defense systems, the HGV is a powerful argument that at the negotiating table.

Long-range, high-precision hypersonic glide vehicles (HGVs) can be used in conventional conflicts to deliver prompt global strikes, including against those enemies who possess the air- and missile-defense capabilities to counter aerial targets, cruise missiles, and smaller- and medium-range ballistic missiles. The conventional Avangard can be used with the same efficiency as nuclear delivery vehicles, thus making escalation to a nuclear phase unnecessary under certain circumstances. The HGV does not violate the New START Treaty or other international agreements.
6. Mobile Laser Canon

This is similar to the LaWS laser cannon deployed by the USA Navy on the USS Ponce. However, it is a mobile land-based system.

REFERENCES