Further evolution of the S-300P design took place between 1995 and 1997, yielding the S-300PMU-2/SA-10E ‘Favorit’ system, intended to compete directly against the Antey S-300V and Patriot PAC-2/3 systems as an AntiBallistic Missile (ABM) system.

The Favorit incorporates incrementally upgraded 30N6E2, 64N6E2 radars and a 54K6E2 command post, and the 96L6E as its early warning and primary acquisition system. While the system retains compatibility with earlier 48N6 missiles, a new extended 108nm (200km) range 46N6E2 missile was added. The Favorit’s new command post has the capability to control S-300PMU, S-300PMU-1 batteries, and also S-200VE/SA-5 batteries, relaying coordinates and commands to the 5N62VE ‘Square Pair’ guidance and illumination radar.

While the Favorit superficially appears like the SA-10D, it has a wide range of incremental improvements internally, and a range of optimisations to improve performance in the antiballistic missile role. Almaz, the system integrators, and Fakel, the missile designers, claim to have repeatedly caused Scud target vehicle warheads to detonate during test intercepts at the Kapustin Yar range in 1995.

The Almaz S-400 Triumf or SA-20 system is the subsequent evolution of the S-300PMU-2, trialled in 1999. The label S-400 is essentially marketing, since the system was previously reported under the speculative label of S-300PMU-3.

The principal distinctions between the S-400 and its predecessor lie in further refinements to the radar and software, and the addition of three new missile types in addition to the 48N6E/48N6E2. As a result, an S-400 battery could be armed with arbitrary mixes of these weapons to optimise its capability for a specific threat environment.

The first missile added to the system has not been named publicly, but is a long range weapon with a cited range of 215nm (400km), intended to kill high value assets like AWACS and JSTARS. Further details of this weapon remain undisclosed – some sources speculate it is a variant of the Novator KS-172 long range AAM with a bigger booster (AA 08/03).

The further missiles are in effect equivalents to the ERINT/PAC-3 interceptor missile recently introduced to supplement the MIM-104 in Patriot batteries. These are the 96M6E and 96M6E2, largely identical with the latter version fitted with a larger booster. Fakel claims the 96M6E has a range of 21.6nm (40km), and the 96M6E2 64.8nm (120km), with altitude capabilities from 15ft above ground level up to 66,000ft and 100,000ft respectively.

The 96M6 missiles are ‘hittiles’ designed for direct impact, and use canards and thrust vectoring to achieve extremely high G and angular rate capability - they are not unlike a scaled up R-73/AA-11 Archer dogfight missile in concept. An inertial package is used with a datalink from the 30N6E radar for midcourse guidance, with a radar homing seeker of an undisclosed type. The small 24kg (53lb) blast fragmentation warhead is designed to produce a controlled fragment pattern, using multiple initiators to shape the detonation wave through the explosive. A smart radio fuse is used to control the warhead timing and pattern. It is in effect a steerable shaped charge.

The smaller size of these weapons permits four to be loaded into the volume of a single 48N6E/5V55K/R launch tube container – a form fit four tube launcher container is used. So a single 5P85S/T TEL can deploy up to 16 of these missiles, or mixes of 3 x 48N6/4 x 96M6E/E2s, 2 x 48N6/8 x 96M6E/E2s, or 1 x 48N6/12 x 96M6E/E2s. The stated aim of this approach was to permit repeated launches against saturation attacks with precision guided weapons – in effect trading 96M6 rounds for incoming guided weapons. Fakel claims a single shot kill probability of 70% against a Harpoon class missile, and 90% against a manned aircraft.

What future developments can be expected for the S-300P/S-400 series? With the exception of further evolutions in missile and radar technology, and active radar or dual mode seekers, it is likely that additional passive targeting sensors such as wideband interferometers/ESM receivers (external Kolchuga ESM systems are an option already) and FLIR/IRST (already an optional retrofit for S-125/SA-3, 2K12/SA-6) could find their way on to the 30N6E Flap Lid. Modern ruggedised multi-Gigahertz COTS computing hardware is clearly an option for the 54K6E and other system components. At some point, Almaz will transition to active phased array technology, but cost will remain a challenge given the maturity of the current design.

In summary the S-300P/S-400 is in its latest variants a highly capable and modern dual role SAM/ABM system, with exceptionally good mobility and resistance to jamming. While its radar and back end data processing systems may not match the technology in the latest western products, the excellent kinematics of the missiles, and large power aperture capability of the phased array radars make these formidable weapons.
The S-300V system comprises no less than eight vehicles, the 9S457 mobile command post, the 9S15 Bill Board acquisition radar, the 9S32 Grill Pan engagement radar, the 9A82 and 9A83 TELARs (Transporter Erector Launcher and Radar), and the 9A84 and 9A85 TEL/Transloader vehicles.

The fully mobile 9S15 Obzor 3/Bill Board acquisition radar is a mechanically rotated 3D radar system, with electronic beam steering in elevation and an IFF array. It provides long range early warning of aerial threats and low end tactical ballistic missiles (TBMs) such as the Scud A and Lance.

The 9S15 has two basic modes of operation. The first is optimised for a 12 second sweep and is claimed to provide a 50% probability of detecting a fighter sized target at 130nm (240km). The second mode employs a faster six second sweep period, and is used to detect inbound tactical ballistic missiles and aircraft, with a reduced detection range of about 80nm (150km) for fighters, and 50 to 60nm (92 to 111km) for (TBMs) like the Scud A or Lance. Russian sources are unusually detailed on ECCM techniques used, claiming the use of three auxiliary receiver channels for cancelling side lobe jamming, automatic wind compensated rejection of chaff returns, and provisions in the MTI circuits to reject jamming. A facility for ballistic missile force. The order for six S-300VM systems remains in negotiation while the Israeli Arrow and S-300PMU-2/S-400 are evaluated. A marketing drive in the Persian Gulf some years ago fell foul of US influence in the region – Patriots being bought instead, amidst Russian allegations of dishonest marketing tactics by the US.

All principal components of the S-300V system are carried on the MT-TM ‘item 830’ series of tracked vehicle, with gross weights between 44 and 47 tonnes per vehicle – the S-300V is not a lightweight system – and has similar offroad mobility to a medium tank.

The S-300V system comprises no less than eight vehicles, the 9S457 mobile command post, the 9S15 Bill Board acquisition radar, the 9S15 High Screen ABM early warning radar, the 9S32 Grill Pan engagement radar, the 9A82 and 9A83 TELARs (Transporter Erector Launcher and Radar), and the 9A84 and 9A85 TEL/Transloader vehicles.

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precise angular measurement of jamming emitters is included. RMS tracking errors are quoted at 250 metres in range and about 0.5 degrees in azimuth/elevation, with the ability to track up to 200 targets. The system has an integral gas turbine electrical power generator for autonomous operation – a feature of most S-300V components.

This radar provides a highly mobile 3D search and acquisition capability, but is limited in low level coverage footprint by its antenna elevation. Its limited scan rate makes it unusable for high performance IRBM acquisition and tracking, which is the role of the 9S19 High Screen radar.

The specialised 9S19 Imbir is a high power-aperture, coherent, X-band phased array designed for the rapid acquisition and initial tracking of inbound ballistic missiles within a 90 degree sector. To that effect it uses a large passive phase shift technology array, using a conceptually similar space feed technique to the MPQ-53 and 30N6 series radars, producing a narrow 0.5 degree pencil beam main lobe.

The primary search waveform is chirped to provide a very high pulse compression ratio intended to provide very high range resolution of small targets. The design uses a high power Travelling Wave Tube (TWT) source, very low side lobes and frequency hopping techniques to provide good resistance to jamming.

Three primary operating modes are used. In the first the 9S19 scans a 90 degree sector in azimuth, between 26 and 75 degrees in elevation, to detect inbound Pershing class IRBMs within a 40 to 95nm (75 to 175km) range box, feeding position and kinematic data for up to 16 targets to the 9S457 command post. The second mode is intended to detect and track supersonic missiles such as the AGM-69 SRAM, and sweeps a narrower 60 degree sector in azimuth, between nine and 50 degrees in elevation, within a range box between 10 and 90 nautical miles, generating target position and velocity updates at two second intervals.

The third mode is intended to acquire aircraft in severe jamming environments, with similar angular and range parameters to the second mode. The radar is claimed to produce RMS angular errors of around 12 to 15 minutes of arc, and a range error of a mere 70 metres (at max range 0.04%). The peak power rating remains undisclosed.

In function the 9S19 most closely resembles much newer western X-band ABM radars, but is implemented using several generation antenna and transmitter technology, and is fully mobile, unlike the semimobile US THAAD X-band radar and Israeli Green Pine.

The third radar in the S-300V suite is the 9S32 Grill Pan, an engagement radar similar in concept and function to the MPQ-53 and 30N6, but larger with the antenna turret capable of slewing through +/-340 degrees. It will automatically acquire and track targets provided by the 9S457 command post, control the operation of TELAR mounted illuminators and generate midcourse guidance commands for up to 12 missiles fired at six targets concurrently. The S-300V system uses continuous wave illumination of targets and semi-active radar terminal homing, not unlike the US Navy RIM-66/67 SAM series – the illuminators are carried on the 9A82 and 9A83 TELARS.

Like the 9S19, the 9S32 is a high power-aperture, coherent, X-band phased array, but specialised for missile guidance. Cited detection ranges are about 80nm (150km) for fighter sized targets, 40nm (75km) for SRAM class missiles and up to 80nm (150km) for larger IRBMs. The radar uses monopulse angle tracking techniques, frequency hopping in all modes to provide high jam resistance, and chirped waveforms providing a high compression ratio. Three auxiliary receiver channels are used for cancelling sidelobe jamming.

Two basic operating modes are used. In the first the 9S32 is controlled by the 9S457 command post and acquires targets within a narrow 5 x 6° field of view, alternately it can autonomously search and acquire targets within a 60° field of view. A datalink antenna is mounted aft of the array.
stage (4636kg/10,225lb mass in the Giant and circa 2275kg/5000lb the Gladiator) and aerodynamic control of the 1270kg (2800lb) second stage, using four servo driven fins, and four fixed stabilisers. The guidance and control packages, and much of the weapon airframes are identical, the principal distinction being the bigger booster stage of the Giant and its larger stabilisers.

A cold start ejector is used to expel the missile from the launch tube, the first stage burns for about 20 seconds, then the missile transitions to its midcourse sustainer. During midcourse flight the missile employs inertial navigation with the option of command link updates. In the former mode it transitions to its semi-active homing seeker during the final 10 seconds of flight, in the latter three seconds before impact – a technique preferred for heavy jamming environments. Russian sources claim the semi-active seeker can lock on to a 0.05 square metre RCS target from 16.2nm (30km). The midcourse guidance system attempts to fly the most energy efficient trajectory to maximise range. A two channel radio proximity fuse is used to initiate the 150kg (330lb) class 'smart' warhead which has a controllable fragmentation pattern to maximise effect.

The engagement envelope of the baseline Gladiator is between 80ft AGL to 80,000ft, and ranges of 3.2 to 40nm (5.9 to 74km), the Giant between 3200ft AGL to 100,000ft, and ranges of 7 to 54nm (13 to 100km). The system can launch the missiles at 1.5 second intervals, and a battalion with four batteries can engage 24 targets concurrently, with two missiles per target, and has a complement of between 96 and 192 missiles available for launch on TELAR/TELS. A TELAR can arm a missile for launch in 15 seconds, with a 40 second time to prepare a TELAR for an engagement, and five minute deploy and stow times – a genuine ‘shoot and scoot’ capability.

The cited single shot kill probabilities for the Gladiator are 50% to 65% against TBMs and 70% to 90% against aircraft, for the Giant 40% to 60% against IRBMs and 50% to 70% against the AGM-69 SRAM – ballistic missiles with re-entry velocities of up to three km/s can be engaged.

The Soviets were terrified of the USAF’s EF-111A force and equipped the S-300V system with a facility for passive targeting of support jammers. The 9S15, 9S19 and 9S32 have receiver channels for sidelobe jamming cancelation and these are used to produce very accurate bearings to the airborne jammer, this bearing information is then used to develop angular tracks. The angular tracks are then processed by the 9S457 command post to estimate range, and the 9S32 then develops an estimated track for the target jammer. A Giant missile is then launched and steered by command link until it acquires the target.

The S-300V has been supplanted by the enhanced S-300VM, using the 9S15M2, 9S19M, 9S32M and 9S45M7 components, and improved 9M82M and 9M83M missiles. This system has been marketed as the ‘Antey 2500’, intended to highlight its capability to engage 2500km range IRBMs with re-entry velocities around 4.5 km/sec. The 9M82M has double the range of the 9M82 against aerial targets, at 108nm (200km), and increased terminal phase agility - a single shot kill probability of 98% is claimed against ballistic targets. The 9S32M has triple the range of the 9M82 against aerial targets, at 312nm (580km), and increased terminal phase agility - a single shot kill probability of 98% is claimed against ballistic targets. The 9S32M has triple the range of the 9M82 against aerial targets, at 312nm (580km), and increased terminal phase agility - a single shot kill probability of 98% is claimed against ballistic targets.

Commercially the S-300V/VM has been much less successful than the S-300P series, in part due to its higher cost and capability - the Indian sale has yet to materialise, compared to the large number of S-300P systems sold to China. Earlier this year the Russian government authorised a merger between Almaz, Altair and Antey to produce what theoretically is likely to be the world’s largest SAM system manufacturer. However, in typical post soviet tradition a series of murders of corporate executives followed and it is unclear at this stage how the merger will proceed. Novator has been verging on bankruptcy for some time, ostensibly due to the inability of the Russian defence ministry to pay its bills.

In the longer term the S-300V is likely to acquire similar evolutionary enhancements to the S-300P series, if not identical should the Almaz/Altair/Antey merger proceed, increasing its range and already superb lethality. It is likely that GPS aided navigation hardware will be added at some stage to both the S-300P/S-300V to increase the accuracy of the inertial/compass navigation systems on the radars and TELAR/TELS.
CONCLUSIONS

The arrival of S-300P and S-300V missile systems in the region radically changes the strategic environment, both from the perspective of the US and Australia.

These highly capable systems are not invincible, but require significant investment into capabilities to defeat them - prohibitive losses in expensive aircraft and irreplaceable aircrew otherwise might occur. As they are less demanding to operate than modern combat aircraft, operators across the broader region will be able to achieve combat effective proficiency faster than with the Su-27/30.

In practical terms the S-300P/S-300V SAMs are a viable deterrent against air forces without the technological and intellectual capital to tackle them - and in many respects better value for money than the Su-27/30. Their failure to sell in larger numbers reflects more than anything poor marketing and support credibility by Russia's industry.

The US Air Force’s approach to defeating these SAMs is conceptually simple: the F/A-22A exploiting its all aspect wideband stealth, supercruise, high altitude and sensitive ESM warning capability will kill the engagement and acquisition radars using guided weapons. High power standoff support jamming will be provided by B-52Hs equipped with electronically steerable high power jamming pods, and standoff ISR support will be provided by systems such as the RC-135V/W, E-8C and forthcoming E-10 MC2A. Standoff or highly stealthy ISR capabilities will be necessary - the current generation of high altitude UAVs like the RQ-1B and RQ-4A are not survivable in airspace covered by the S-300P/S-300V systems.

Conventional unstealthy, or partially stealthy (ISF) combat aircraft will have difficulty surviving within the coverage of the S-300P/S-300V - the high transmit power, large radar and missile seeker apertures, low sidelobes, generous use of monopulse angle tracking and extensive ECCM features make these systems difficult to jam effectively. Self protection jammers will need to produce relatively high X-band power output, and exploit monopulse angle tracking deception techniques - Digital RF Memory techniques with high signal fidelity are nearly essential. Even so the challenges in defeating these systems with a self protection jammer are not trivial - raw power-aperture does matter in this game.

In practical terms, low level terrain masking to remain below the radar horizon of these systems, combined with good standoff ISR, support jamming and a low radar signature standoff missile, is the only reliable defence for an aircraft with anything greater than insect sized all aspect radar signature. For instance the F-35 JSF’s forward sector stealth is likely to be adequate, but its aft sector stealth performance may not be, especially considering the wavelengths of many of the radars in question - an F-35 driver runs a real risk of taking a 1360kg (3000lb) hypersonic SAM up his tailpipe if he cannot kill the target SAM engagement radar in his first pass. For the JSF, integration of a terrain following radar mode in its AESA radar is not an unusual technical challenge, incurring only modest development cost. The bigger bite will be in shortened airframe fatigue life resulting from fast low level penetration with a modestly swept wing design.

Of the current crop of fighters in western service, the most survivable are those with good TFRs - the F-111, Tornado and F-15E if fitted with the LANTIRN TFR pod - all requiring a high performance EW suite.

A weakness of both the S-300P/S-300V systems is that they are severely radar horizon limited in a fully mobile configuration. The addition of mast mounted acquisition radars to extend their low level footprint severely impairs the mobility of the battery.

The popular idea of shooting cruise missiles, anti-radiation missiles or standoff missiles at the S-300P/S-300V battery, assuming its location is known, is only viable where such a weapon has a sufficiently low radar signature to penetrate inside the minimum engagement range of the SAM before being detected - anything less will see the inbound missile killed by a self defensive SAM shot. The current Russian view of this is to sell Tor M1/SA-15 Gauntlet self-propelled point defence SAM systems as a rapid reaction close-in defensive system to protect the S-300P/S-300V battery by shooting down the incoming missile if it gets past the S-300P/S-300V SAMs.

In conclusion, current RAAF force structure plans do not provide for a robust long term capability to defeat the S-300P/S-300V class of SAMs - weapons which are very likely to be encountered during coalition operations, and most likely, regional operations over the coming two or more decades. If the RAAF wishes to remain competitive in this developing regional environment, further intellectual and material investment will be needed.

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