Inside SA's hi-tech warbird

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Warbird: These are the single- and two-seater versions of the Gripen, a versatile and formidably equipped fighter that will give the SA Air Force a much-needed boost. *Photos: Popular Mechanics*

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Air warfare is a complex thing. Its effectiveness is determined by a host of factors, among them fighting strategy, aircraft numbers, manoeuvrability, weaponry, defensive capability, communications, maintenance, ground support and intelligence.

Oh, and something the experts refer to as "an edge".

The South African Air Force will soon become one of fewer than a dozen air forces operating fighters of the "4th generation", ensuring that world's second-oldest independent air force keeps its edge through the first decades of the 21st century. Its new Saab Gripen fighters will replace the present Cheetah C between 2007 and 2012, and are likely to remain in service until 2030 or longer.

What makes these 4th generation fighters so special?

The Gripen was the first of the "4th generation" fighters to enter service, and is so far the only light fighter of that generation in operation (the American F-35 Joint Strike Fighter is still in development). The American-built F-22 Raptor, the Eurofighter Typhoon and the French Rafale are much larger and considerably more expensive.

So what makes these 4th generation fighters so special? Stealth technology, for a start, together with fully integrated digital systems and inherently unstable - and thus very manoeuvrable - airframes made flyable by "fly-by-wire" computer-controlled systems.

Development of the Gripen began back in 1982. It first took to the air in December 1989, becoming operational (in the Swedish Air Force) in 1996. The first JAS-39C, on which the SAAF version is based, was delivered in September 2002.

The Swedes chose a light fighter for several reasons, one of the most important being its lower acquisition and operating costs. It also comes with operational advantages: a small aircraft is also a smaller radar and visual target; and is better suited to the dispersed operations of the Swedish Air Force, which regards large bases as too vulnerable. In action, its fighters would disperse to small tactical bases and hardened and prepared stretches of road 800m long and 17m (sometimes only nine metres) wide.

A key requirement was the ability to conduct operations with minimal ground support equipment and technical personnel at these dispersed bases - and here the Gripen excels. It can be turned around between missions by just one technician and five conscripts - within 10 minutes for air defence missions and 20 minutes for strike missions, depending on the weapons load.

A further critical requirement was for a true multi-role fighter that would be equally effective in air combat and ground attack. In fact, the Swedes go further and use the term "swing role", referring to the Gripen's ability to swing from air-to-air to air-to-ground during a mission. In reality, this flexibility would be limited by the weapons already loaded for the mission, but the concept does underline the flexibility of modern digital avionics and mission systems.

The final critical requirement was that the new fighter would fit into the concept of "net-centric" operations, with full data exchange between aircraft and other systems by datalink to gain maximum force flexibility and effectiveness. The aircraft was also required to operate independently of the full command and control system.

All of these factors are important to a small air force that can afford only a few fighters, and one that is not exactly over-endowed with technicians. They will be particularly valuable to the SAAF, which operates a very small fighter force in a very large theatre, and needs all the flexibility that it can squeeze out of its aircraft.

The design that meets this stringent requirement is a single-engine, close-coupled canard delta-wing aircraft that's both small and agile, and makes optimal use of modern technologies. The 45° delta wing is mid-mounted to provide clearance for under-wing weapons. The all-moving 45° delta fore-planes are higher, to optimise the airflow over the wing. They also improve short-field performance by generating lift during the critical nose-high take-off and landing phases, where conventional tail surfaces have to generate a downforce to raise the nose.

They tilt to almost 90° during the landing run to act as enormous airbrakes, allowing the Gripen to do without a thrust-reverser. The main wing has leading-edge flaps and trailing edge "elevons" (combined ailerons and elevators) to enhance short field performance.

This canard layout - coupled with the low wing loading of 341 kg/m² - results in a very agile aircraft with a 30° per second instantaneous turn rate (the F-16 achieves 20° per second), a 20° per second sustained turn rate, and a roll rate of 240° per second.

Power is provided by a Volvo Aero RM-12 turbofan developed from the General Electric F404, a variant of which powers the US Navy's F/A-18s. It has a larger fan to increase the airflow and power, giving 5 400kg of dry thrust and 8 359kg of thrust in afterburner, for a thrust-to-weight ratio of 0,94. Although this is not in the league of some modern fighters, which boast ratios in excess of 1, the Gripen is anything but a wimp, and has plenty of power for good overall agility. As a turbofan it is relatively thrifty, burning 50 litres a minute in dry thrust and 150 litres a minute in afterburner.

A full-authority digital engine control (FADEC) system optimises engine operation and automatically switches to back-up systems when necessary. It also monitors the engine's performance and ongoing condition. The engine is modular is design, which greatly simplifies maintenance and repair in the field. When an entire engine has to be removed, it can be done by a team of four using mini-hoists and normal hand tools.

The Gripen C, developed with BAE Systems, has a retractable in-flight refuelling probe and an on-board oxygen generating system to allow longer missions.

A Lockheed-Martin/BAE Systems full-authority triplex digital "fly-by-wire" flight control system allows full use of the agility inherent in the Gripen's "relaxed" static stability by giving "carefree" handling characteristics: the pilot can throw the aircraft around with abandon, secure in the knowledge that the flight control system will not allow it to depart from controlled flight.

To that end it limits the load factor (the amount of "G"), the angle of attack (the difference between the attitude of the aircraft and its direction of flight), the angle of sideslip and the roll rate. It also prevents the aircraft from entering a spin, and has an auto-recovery function. It harmonises the control surfaces to give good damping and gust alleviation - particularly important during low-level tactical flight.

Given its absolute dependence on the electronic flight control system, the Gripen needs a backup - and it comes in the form of a "get you home" analogue flight control system that disconnects the canard fore-planes to stabilise the aircraft in pitch, enabling the pilot to fly without computer assistance. There is also a multiple power supply backup that includes batteries and an emergency thermal battery pack providing nine minutes of power.

The Gripen has an "all-glass" cockpit with no analogue instruments - not even as backup. Everything is shown on colour flat-panel multifunction displays. The flight controls are more conventional, with a central "mini-stick" and normal throttle and rudder pedals. The seat is raked at 27° for high-G manoeuvring.

All time-critical functions are controlled by buttons and switches on the throttle and the stick, allowing the pilot to keep his hands where they're needed in combat, with no need to reach for switches. That simplifies his task and reduces the risk of a fumble, particularly during high-G manoeuvring. The throttle (also termed "system hand controller") has no fewer than 14 functions.

The core philosophy underlying the avionics and navigation/attack systems is "don't need, don't show", with the pilot selecting what he needs and the system injecting critical or emergency information when necessary.

The cockpit has five displays: wide-angle (297° x 22°) head-up display, three 152mm x 203mm interchangeable colour multifunction displays MFDs), and an integrated helmet-mounted sight and display system. The MFDs are fully compatible with night-vision goggles.

- **HUD (Head-Up Display)** shows weapon aiming data (cannon lead angle and missile firing cues in the air-to-air role; continuously-predicted impact point, continuously-predicted release point and so on in the air-to-ground role).

- **FDD (Flight Data Display)** is usually the left-hand MFD. Shows flight data (speed/ Mach number, rate of climb, angle of bank and so on), fuel status and system status information for the aircraft, the engine and the stores carried (weapons, reconnaissance pod, etc).

- **HSD (Horizontal Situation Display)** is usually the centre MFD. Shows navigation and tactical data on a selectable-scale moving map display.

MSD (Multi-Sensor Display) is usually the right-hand MFD. Shows the radar picture, imagery from the forward-looking infrared or infrared search and track sensors, data from the electronic warfare system, and information from a real-time reconnaissance pod if one is being carried. Flight and fire-control data are superimposed.

IHMD (Integrated Helmet-Mounted Display) shows key flight and weapons data by projecting them into the pilot's field of view, allowing him to monitor critical information while keeping his opponent or a ground target in sight. It can be used to cue sensors and weapons, and can be used with night-vision goggles.

The IHMD is the Cobra system developed by BAE Systems, Saab and the Kentron division of South Africa's Denel. Kentron's element is the unique optical head position sensor sub-system that keeps track of where the pilot is looking, which is essential if accurate data is to be presented regardless of the pilot's head position.

It uses an array of LEDs on the helmet, monitored by receivers in the cockpit, and has proven more accurate than electromagnetic systems. It is also immune to electromagnetic changes in the cockpit when new equipment is installed. The Striker helmet of the Eurofighter Typhoon of the Royal Air Force, German Air Force and Spanish Air Force will also use the Kentron system.

State of the art: The Gripen has an "all-glass" cockpit with no analogue instruments.

The Gripen's datalink allows it to exchange tactical picture and target data with other fighters, command aircraft and ground radars. Quite apart from enhancing the pilot's situation awareness, it enables an aircraft to "illuminate" targets for others, allowing them to approach radar-silent (pilots call this "nose cold"), with no emissions to give them away. One aircraft can also pass updated target data to a ground attack strike package, enabling the mission leader to update the attack plan on the basis of the current situation before his aircraft enter the immediate target area.

The core philosophy underlying the sensor system is data fusion, presenting the pilot with a tactical picture that's compiled by fusing the information gathered using all of the aircraft's own sensors and the information passed to it by other aircraft or the ground command post by means of the datalink. The idea is to give the pilot the best possible situational awareness at all times.

The Gripen's primary sensor is its multi-mode Ericsson radar (it's also equipped with an integral electronic warfare system). It can carry an optronic night navigation and targeting pod, and will in the future have an infrared search and track system. For reconnaissance missions it can carry pods with "wet film" or optronic/digital sensors. In the latter case the imagery can be displayed in the cockpit.

Then there's the radar system. The Gripen's Ericsson PS-05A long-range multi-mode pulse Doppler radar uses the I/J-Band (8 to 20 GHZ) and employs low-, medium- and high-pulse repetition frequency modes for different applications.

The radar is claimed to have excellent "look down" performance, able to distinguish targets in the clutter of ground radar reflections, and has a full suite of electronic counter-counter measures, optimised by using fully programmable signal and data processors.

The Zeiss Optronik Litening pod has been integrated with the Gripen, and can be used for low-level night/poor weather navigation, and for target acquisition and precision engagement. It mounts a high-resolution forward-looking infrared sensor with wide (search) and narrow (acquisition/ targeting) fields of view, a charge-coupled device TV camera for daylight operations, a laser range-finder, and a laser designator for laser-marked-target seeking bombs and missiles. There is also a video downlink that can be used for reconnaissance or surveillance situations.

An on-gimbal inertial navigation sensor establishes line of sight and bore-sighting with the aircraft systems, and an automatic target-tracker provides fully stabilised tracking throughout normal ground target engagement manoeuvres. The pod's sensors can be cued using the helmet display to designate a target.

The Gripen has also been designed to mount an infrared search and track (IRST) system for passive acquisition and tracking of aerial targets, giving the obvious and very real advantage of not announcing to the target aircraft that it has been acquired and is being tracked.

The IRST system will be integrated with the helmet sight to alert and cue the pilot, and can be used to cue the radar and the aircraft's missiles. The system being developed for the Gripen is the Saab IR-OTIS, an imaging IR system that can be used to identify a target. It will be mounted in a dome on the nose ahead of the cockpit.

The Gripen's integrated electronic warfare system warns the pilot of threats, alerts him when his aircraft has been acquired, is being tracked or is being engaged, protects the aircraft against radar acquisition and tracking, and records electronic threats for later downloading and analysis. The SAAF aircraft may receive the standard system, but may alternatively use the South African multi-sensor warning system developed by Avitronics, which offers the same functions and is highly regarded.

The warning portion of the system comprises radar warning receiver, laser warning and missile approach warning sub-systems. The self-protection portion comprises an internal jammer and chaff/ flare dispensers in two weapons pylons.

The Gripen can also carry an external jammer pod, and a BO2D towed radar decoy in place of one of the chaff/flare dispensers. The BO2D is a two kilogram unit towed 100m behind the aircraft. The final element of the electronic warfare suite is an IFF (identification, friend or foe) system, which interrogates other aircraft prior to engagement to prevent "blue on blue" incidents, and identifies the Gripen to other friendly systems. In SAAF service this system will use a transponder developed locally by Tellumat.

The Gripen is intended primarily to use air-to-air missiles and "smart" air-to-surface weapons, but can also deliver "dumb" bombs when these are better suited to a target, and the single-seat variant also has a 27mm Mauser BK27 cannon armed with 120 rounds.

Short-range air-to-air missiles will generally be carried on the wing-tip rails, leaving the centreline station and four under-wing stations free for heavier weapons and fuel tanks. Those stations can be fitted with Nato-standard weapons pylons developed and manufactured in South Africa by Denel Aviation, allowing the Gripen to carry a wide range of weapons.

Among the air-to-air weapons being qualified on the Gripen are the latest generation of the American Sidewinder IR-homing "dogfight" missile, the American AIM-120 AMRAAM beyond-visual-range missile, and the European BVR Meteor and ASRAAM and IRIS-T short-range IR-homing "dogfight" missiles. The SAAF will employ Kentron's V4 BVR missile and may use the V3C U-Darter short-range missile until a new generation weapon is acquired. It is considering the IRIS-T, but might support Kentron's advanced A-Darter project.

Air-to-surface weapons to be qualified on the Gripen include the Saab RBS-15 missile, an anti-ship and anti-land target weapon; the German-developed Taurus KEPD-150 and 350 weapons (with 150km and 350km range respectively); and a full range of laser-marked target and other precision-guided and unguided bombs.

Pilots for the Gripen will first learn to fly on the turboprop Pilatus Astra at the Central Flying School, and then go on to the BAE Systems Hawk lead-in fighter trainer at 85 Combat Flying School to learn the ins and outs of fast jets and air combat, and to gain experience. Once they join 2 Squadron ("Flying Cheetahs"), they will spend time in a full mission Gripen simulator to become acquainted with the aircraft and then fly the dual seat version before transition to the single-seater.

A small group of pilots on the project team has already begun flying the Gripen, but the first formal course will comprise combat instructors with Cheetah C experience, who will be trained in Sweden and who may join a Swedish Air Force Gripen squadron as part of a pilot exchange programme. They will then present the first SAAF Gripen course at AFB Makhado in 2009, training a mixed group of experienced Cheetah C pilots and new fighter pilots fresh from the Hawk.

Technical personnel will initially be trained by Saab, with support from the Swedish Air Force.

Fighter generations

The fighter aircraft since WW II are often divided into "generations" grouped by basic characteristics:

1st Generation: The subsonic/transonic day fighters of the 1950s, which differed from the WW II fighters mainly in being jet powered and much faster - F-86 Sabre, MiG-15, Hunter, Mystere and Saab's J-29 Tunnan.
Generation 1.5: the first supersonic fighters, but still relatively simple day fighters - F-100 Super Sabre, MiG-19, Lightning, Super Mystere.

2nd Generation: The supersonic single-role fighters of the 1960s, which had a limited night and poor weather capability, and which had integrated analogue avionics and weapon systems - F-104 Starfighter, MiG-21, Mirage III and Saab's J-35 Draken.

Generation 2.5: the fighters of the 1970s, which had better secondary role capability but did not mark a real generation change - F-4 Phantom, MiG-23, Mirage F1 and SAAB's J-39 Viggen.

3rd Generation: The multi-role fighters of the 1980s, which had "fly-by-wire" control systems, digital but separate avionics and weapons systems, and which were largely optimised for one role but had capability in the other - F-16 Falcon, MiG-29, Tornado, Mirage 2000.

Generation 3.5: Upgraded 3rd Generation aircraft, much more capable but still with 1970s aerodynamics and separate systems - F-16C, Mirage 2000-5.

4th Generation: The fully-multi-role fighters of the 1990s, developed from the outset as fully integrated digital systems with a databus and standardised interfaces, and also incorporating stealth features - F-22, Rafale, Eurofighter, Gripen.

Maximum Speed
1 400 km/h at sea level (just over Mach 1)
2 120 km/h at high altitude (Mach 2)
Note: The Gripen is supersonic at all altitudes. It can sustain supersonic speed without afterburner at high altitude.

Thrust to weight ratio
0,94

Acceleration
Mach 0,5 to Mach 1,1 in 30 seconds at sea level

Take-off
400 m

Landing
500 m

Climb
100 seconds from brakes-off to 10 000 m
180 seconds from brakes-off to 14 000 m

Roll rate
240 degrees per second at Mach 0,79

Turn rate
30 degrees per second instantaneous
20 degrees per second sustained

360-degree turn
12 to 18 seconds

Load factor
+9G to -3G

Length
14,1 m

Wingspan
8,4 m

Wing area
30 m²

Maximum take-off
14 000 kg

External load
5 000 kg

Air-to-air range
800 km with two medium- and two short-range missiles

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