FUNDAMENTAL LESSONS OF THE FIRST HUMAN VERTICAL ROCKET FLIGHT

Brett Gooden

MD, PhD, FBIS
Lecturer in Space Physiology,
International Space University,
University of South Australia.
Email: bagooden@bigpond.net.au
Mob: 0411 117 935

ABSTRACT

This paper examines the historic but tragic first human vertical rocket flight which took place in south-western Germany on 1 March 1945. The primary lesson learned from the flight was that, as a result of the combination of psychological and physiological stresses, a human pilot could not be expected to fly a vertically launched rocket manually. An autopilot would be essential for the guidance of the Natter rocket interceptor up to its operational altitude. No further human vertical rocket flights took place until 1961 when Major Yuri Gagarin was launched into orbit. In early April 1945 a fully operational Natter flew successfully into the lower stratosphere under the control of a three-axis autopilot and crewed with a dummy pilot. Both dummy pilot and rear fuselage were recovered successfully under separate parachutes. In less than a year the engineers and scientists in collaboration with aviation physicians and physiologists at research institutions across Germany had laid down the basic principles which still apply to human rocket flight today.

INTRODUCTION

By early 1944 the Luftwaffe had lost its dominance of the airspace over Germany. After sustaining heavy losses during its initial daylight bombing campaign the United States Army Air Force (USAAF) was beginning to wreak havoc on strategic targets such as the ball bearing and synthetic fuel production plants. It was clear to the power brokers in the Reich such as Albert Speer the Minister for Armaments that if this destruction continued Germany would lose the war. [1]

Adolph Galland, the general commanding the Luftwaffe Fighter Arm, realised that a quantum leap in technology would be required if the Luftwaffe had any hope of even blunting the devastating USAAF daylight bombing raids. [2] Consequently the German Air Ministry called for tenders for the development of a target defence interceptor. The basic criteria for such an interceptor were that it had to be simple, cheap to build in large numbers and require a minimum quantity of war critical materials. The operational plan was to surround the essential production plants with these interceptors which would attack the Allied bombers immediately upon their close approach to the target. This tactic would hopefully reduce the inefficient use of fuel by conventional fighters flying standing sorties.

Several well-established companies submitted tenders. All chose to power their interceptors with the Walter 109-509 A1 liquid propulsion rocket motor. This motor had already been deployed in the Me 163 Komet rocket aircraft. Although fast, the Komet suffered from the shortcoming that it required an airfield from which to operate. As the war progressed Allied bombing of German airfields became more intense which made the Komet less attractive for specific target defence. All of the designs submitted by the large aircraft companies required operation from an airfield. [3]

One tender however was quite unconventional, in fact it could be called radical. It proposed a vertically launched interceptor which would be guided to its target by radar beam guidance. It would not require a runway at all. After the interceptor had attacked an enemy bomber it would glide back to low level where the pilot would exit the machine and land under his personal parachute. The main portion of the fuselage containing the most expensive part of the machine, the Walter motor, would also be parachuted back to earth for reuse.

This unusual tender came from a small aircraft component factory based in the charming township of Waldsee in south-western Germany. The owner of the factory was a degreed engineer named Erich Bachem who was well known before the war as a pilot and builder of competition gliders. He had written a book on high speed flying and its future possibilities. [4] Before establishing the Bachem-Werk, he had been the head of the advanced projects division of the Fieseler company and had become Gerhard Fieseler's right-hand man. During this time Bachem had directed the design of a series of highly advanced vertical take-off (VTO) rocket interceptors. In 1941 the Air Ministry passed on to the Fieseler Werk a design for such a machine by Wernher von Braun which the Ministry had rejected twice. It so happened that Bachem and von Braun were good friends and Bachem often visited von Braun at Peenemünde during the latter part of the war.

Quite quickly Bachem was able to put together a basic design for a VTO rocket interceptor which, after some political manoeuvring, was accepted by the Air Ministry as the winning tender. Bachem christened the interceptor, the Natter, which is the German word for the adder. The hope was of course that the bite of the Adder would be fatal to US bombers.

The Bachem-Werk received the contract to build the Natter in August 1944 and development moved ahead rapidly. The Natter was classified as Top Secret and was to be given all necessary support to bring it to fruition. Not surprisingly the design of the airframe was straight forward as Bachem was considered one of the pre-eminent engineers in the design and construction of wooden aircraft.

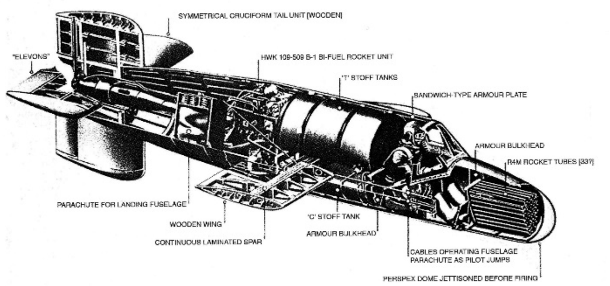

Figure 1

Nonetheless the challenge was to make the timber components of the machine simple enough to be constructed in bulk by local woodwork shops but still built to strict specifications and able to withstand high g loads and velocities up to Mach 0.8.

The Walter rocket motor was not a major problem as much development had gone into this unit during the evolution of the Me 163 Komet rocket aircraft and by late 1944 the motor was in full production. The earlier shortcomings of the Walter motor had been largely solved. To prove this point the motor never failed during the development of the Natter. As the weight of the Natter increased the total rocket thrust required to boost the machine to its operational velocity also increased. In the final design of the A-1 operational machine, four solid booster rockets were required. These slow burning solid propellant rockets, manufactured by the Wilhelm Schmidding company, were mounted towards the rear end of the fuselage, two on each side.

The big unknown for the engineers in relation to the design of the Natter was the human element. How would a pilot cope with being launched vertically off the ground by pure rocket power? The Natter development team were faced with a plethora of physiological and psychological unknowns. The Natter was to operate well beyond the current knowledge base of aviation medicine. The chief aviation medical expert in Germany at the time was Professor Hubertus Strughold. He was well aware of the many challenges faced by the aviation medical fraternity in bringing the Natter project to fruition. [5] In due course the wide variety of medical problems associated with the Natter project required the talents of numerous aviation physicians and physiologists. [6]

THE NATTER TAKTIK

Bachem was always quick to point out that the Natter was unique in the field of interceptor aircraft. He called its operational application - the Natter Taktik.

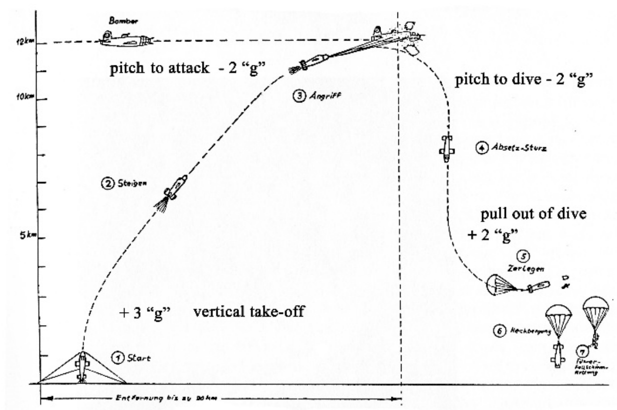

Figure 2

As the enemy bombers flew over the launch pad all of the Natter's rocket motors would be fired simultaneously. The Natter would rise vertically from its launcher and accelerate rapidly up to its maximum velocity of 800 kilometres per hour. At an altitude of 1,500 metres the machine would pitch into an angle which had been pre-calculated by the launch control to allow it to intercept the target bomber from below and behind. It would take only 65 seconds from launch for the Natter to reach the bomber's altitude. The pilot would aim his weapon system at the target and fire the 24 Föhn missile salvo from its nose. He would then dive the little machine, now a powerless glider, to low altitude where he would pull-out into level flight. After unfastening his seat belt and tilting the control column to the floor, he would pull a lever in the front of the cockpit. This action would disconnect the nose which would fly away below the machine. Simultaneously a salvage parachute would be released automatically from the rear fuselage. As the parachute unfurled the fuselage would be decelerated and, as a result of his own inertia, the pilot would separate from the cockpit. Now free from the machine he would open his personal parachute and descend to the ground. The total duration of a mission would be approximately five minutes.

PILOT POSITION AND G-FORCE TOLERANCE

One of the major medical challenges was how to position the pilot in the cockpit.

The planned mission profile would clearly expose the pilot to a range of g-forces. The initial boost phase would subject him to positive g; the pitch into the attack angle and subsequent pitch into the dive, to negative g; and finally, the pull-out from the dive into level flight, to positive g again. How could the seating for the pilot be arranged to best protect him from these different g forces?

The early designs for the Natter envisioned that the pilot would be launched head first in the prone position but this plan was quickly abandoned as it would have exposed him to a positive 3 g force during the boost phase.

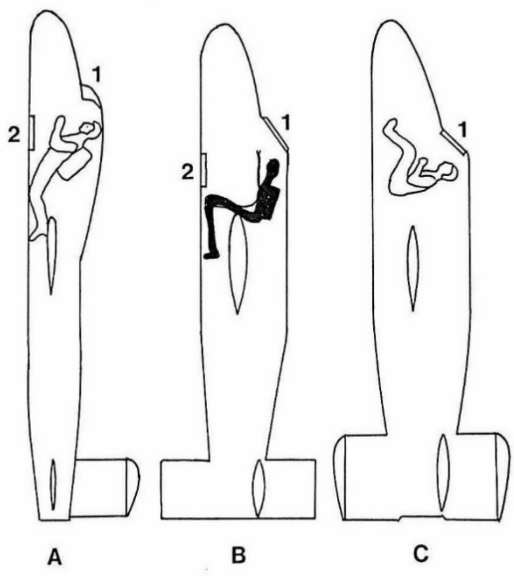

Figure 3

Under these circumstances there was a risk of the pilot suffering from grey out or in a susceptible crewman even unconsciousness. The pilot could be held static in the vertical posture inside the Natter for some time before take-off, a situation not dissimilar to a soldier standing to attention on a parade ground for a long period can lose consciousness.

In addition, if the pilot was to control the flight path of the rocket manually he would need to be able to orientate himself visually by viewing the horizon. In an effort to examine these positional problems the team installed a tilting seat in the cockpit of a Natter mock-up.

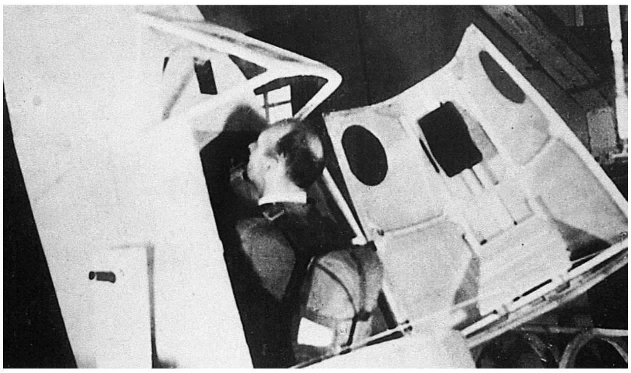

Figure 4

This device was hinged in a wooden cradle so that it could be rotated around a horizontal line through the centre of the cockpit. However, the matter was resolved when it was decided that the Natter would be flown by autopilot. In this case the pilot would no longer be required to view the horizon on take-off. The decision was then made to position the pilot in the usual seated attitude in the cockpit, which would mean that with the Natter mounted in the vertical launcher he would be lying on his back. Thus during the boost phase of the flight he would sustain the g force transversely from his chest to his back, which it was known by that time could be well tolerated by the human body even up to high g loads. Thus the standard position for an astronaut at take-off had been established.

Considerable attention was also paid to the escape of the pilot from a disabled Natter especially at high altitude. The pilot would be supplied with the latest high-altitude bailout system (HAS-16) with a built-in oxygen supply. A ribbon parachute was to be used for the recovery of the pilot which could be opened at high velocity without inflicting a dangerous opening shock on him. To decrease the time of descent to a breathable atmosphere and thereby ensure that the parachute pack's oxygen supply would be adequate, a pilot might have to free fall from an altitude of 10 to 12 kilometres. The B-0 version of the Natter was designed to reach 20 kilometres which had pushed the development of a light weight flexible pressure suit.

Originally Bachem had planned a rigorous programme of 50 test flights. A combination of unmanned and manned glider trials and unmanned VTO trials. The VTO trials and all but one of the unmanned glider trials were undertaken on the troop training ground of the extensive military base adjacent to the township of Stetten am kalten Markt. This small town lay 55 kilometres to the west of Waldsee. These trials would culminate in the launching of fully operational machines crewed with dummy pilots. Remarkably all the functions of the Natter in these unmanned trials would be automated. Data were transmitted by multi-switched FM radio transmission to field receiving stations and all trials were filmed by high speed telephoto movie cameras also located in the field. Only after the successful completion of these 50 trials was a VTO Natter to be manned.

However due to the rapidly deteriorating military situation only half of the trial programme had been completed when "Berlin" demanded a manned flight. Bachem had resisted this pressure for some time but finally he acquiesced and a fully functional Natter was set up in the experimental launch tower equipped with a dummy pilot. On the 25 February 1945 this machine was launched and flew perfectly to altitude, the dummy pilot was released and both the fuselage with the Walter motor and dummy pilot floated to the ground under their parachutes.

THE WORLD'S FIRST HUMAN VERTICAL ROCKET FLIGHT

The central command in Berlin was now adamant that a manned launch be undertaken and four days later another Natter, M23, was standing in the launch tower awaiting its human pilot. A young Luftwaffe test-pilot named Lothar Sieber had volunteered for this historic flight. Sieber was a highly experienced test pilot. He was well known amongst his colleagues for his daring exploits in combat. M23 was considerably heavier than the previous successful unmanned launch as it contained more test equipment and other modifications. By midday on 1 March 1945 the Natter had been loaded with its two propellants, C-Stoff (30% hydrazine hydrate, 57% methyl alcohol and 13% water) and T-Stoff (80% hydrogen peroxide and 20% water). Due to the urgency of this flight, the Natter development programme had not reached the stage at which an autopilot could be installed. The pilot would have to fly the Natter manually from the moment of take-off.

Sieber arrived at the launch pad in a small staff car. On a rise overlooking the launch area he took his final directions from the two chief engineers on the project, firstly with Diplom-Ingenieur (degreed engineer) Willy Fiedler, who had worked earlier on the manned V1 project, and finally with Bachem. [7] They wished him well and with that he strode over to the steel launch tower dressed in his pilot's coveralls, summer helmet on his head and its laryngophones strung around his neck. He climbed up the steel tower and sat there while the ground crew prepared the cockpit for him. He was observed to smoke one cigarette after another as he waited for the call to man the rocket.

The weather forecast had predicted intermittent low-level cloud. Just as he was about to enter the cockpit the ceiling closed in and the launch was put on hold. Frustratingly, aborted take-offs continued throughout the afternoon. The forecast now predicted that a cold front was moving in from the north-east. The time was now around 4.45 pm and dusk drew near. Just then the cloud cover lifted and Sieber entered the cockpit for the final time.

Figure 5

The cockpit canopy was closed and Sieber prepared for the launch. Lying on his back he could only see the high cloud above him through his windshield.

The ground crewmen retreated to their trenches. The engineers and senior military personnel were sheltered in the control bunker. Sieber's voice could be heard over the intercom in the bunker. "All OK. I am starting up. Now 10 seconds to zero, the clock is running". With his left hand on the throttle he started the Walter liquid propulsion motor and over the next few seconds he powered it up to its full thrust of 1,700 kg. Pressing a button with his left thumb he ignited the four Schmidding solid propellant boosters which added another 4,800 kg of thrust. The Natter lifted smoothly up the tower accelerating rapidly under the power of its five motors. It erupted out of a cloud of white smoke generated by the Walter motor and the powder rockets. The Natter was flying free of the tower now, straight upwards into the sky.

Figure 6

All seemed well, but as the onlookers strained to see the machine climbing ever higher, it gradually tilted backwards. Suddenly a black speck was observed flying away from the machine. Then Sieber and the Natter were lost to sight in the clouds. Engineer Fiedler had decided to view the launch from a service road just behind the control bunker. Shortly after the Natter disappeared from view something crashed on the ground close to him. He was shocked to see that it was the cockpit canopy.

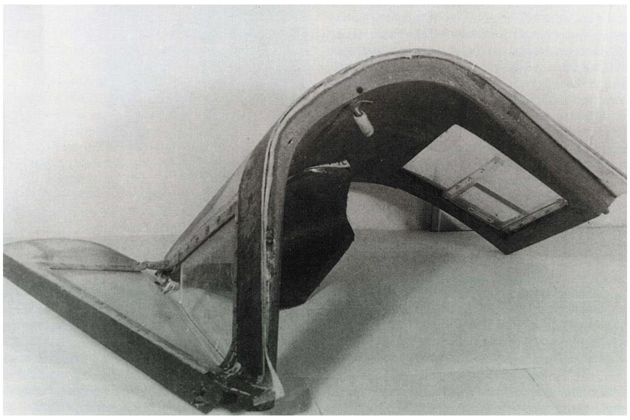

Figure 7

The rumble of the Walter motor could be heard growing ever fainter. After just less than a minute someone spotted a distant object on the south eastern horizon looking like a black bird plummeting straight downwards from the clouds. Shortly after, the assembled onlookers heard a sound like the distant rumble of thunder. What had happened to the brave young pilot? Everyone at the launch area was hoping that he had, as planned, parachuted from the machine at altitude and would be brought back to the base by the recovery crew. An hour or more passed and night was falling. Finally the engineers and ground crew set off in their vehicles in the direction of the last sighting.

Six and a half kilometres from the launch pad the crash site was found in a small wooded glade. Some small boys playing football nearby saw the Natter fly from the clouds and heard a double bang just before it hit the ground. The Natter had apparently made an arcing flight with an approximate apogee of 3,300 metres and after a flight time 55 seconds had crashed near vertically into the ground. Given this flight profile and duration of flight, the velocity at impact was calculated to have been in excess of Mach 1. [8] The tremendous force as the Natter hit the ground rendered the machine into thousands of small fragments. The solid metal casting of the Walter rocket motor was shattered into many pieces. Only the pig iron counterweights in the nose survived intact.

Children were the first to view the devastation. The impact crater was about ten metres in diameter and at least two metres deep. The debris field, still smouldering with small flames licking about it in the darkness, extended about 100 metres from the crater. All that remained of Sieber were a few small body parts which were quickly recovered. A lorry arrived with a coffin and the remains were returned immediately to the military base's hospital. Years later a bush walker accidentally uncovered a piece of bone in the vicinity of the crash site, which was subsequently identified by a police forensic pathologist as portion of a human skull compatible with belonging to Lothar Sieber.

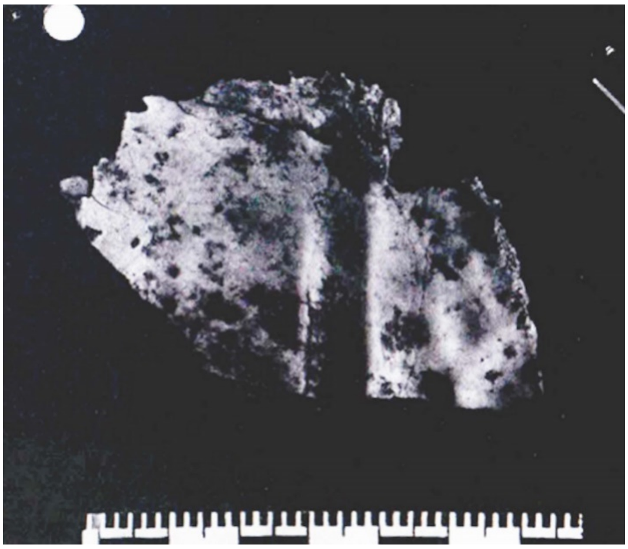

Figure 8

So what went so wrong with the world's first human vertical rocket flight?

ANALYSIS OF THE FLIGHT

The Backward Pitching

The first thing that went wrong was the backward tilting of the Natter. The elevons had been preset to produce a vertical ascent if the control column was maintained in the neutral position by the pilot. It should be recalled that the rocket pilot was lying on his back with the control column above him. As the Natter rose to around 500 metres, the g load on the pilot would have been nearing 3 g. It was agreed by the chief engineers that the g force had resulted in Sieber unconsciously pulling back on the control column. He had no way of orientating his machine visually in relation to the horizon. All he could see through his windshield was the cloud cover above him. He was, however, provided with a gyroscopically stabilised attitude indicator, the Sichtgerät visual display unit, in the centre of the simple instrument panel.

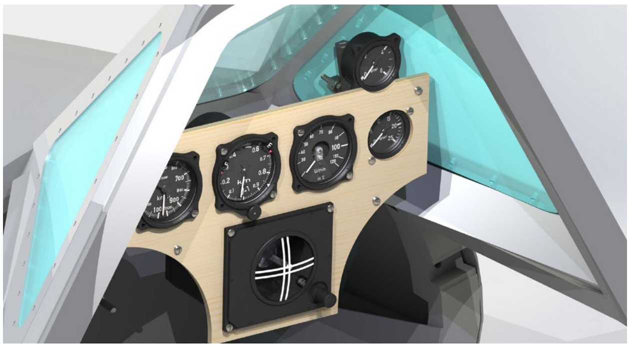

Figure 9

However the Natter was vibrating forcefully in response to the combined influence of the rocket motors. Along with the fuselage, Sieber's head was also vibrating, which would have blurred his vision, making the instrument panel difficult, if not impossible to read. Apollo astronauts reported the same problem during launch from the earth. [9]

Loss of the Canopy

Rising to 1,500 metres in 10 seconds, the Natter was nearing its maximum velocity. It was just before this point in the flight that the canopy flew off. At first Bachem suggested that the problem may have been due to a crack in the hinge joining the canopy to the mid-fuselage. The canopy was hinged at its rear end. He suggested that the hinge might have been fractured during transportation of the Natter to the launch area. However the high velocity slip stream should have held the rear end of the canopy down, not flip it open. Attention was then directed to the forward mounted locking latch as a potential cause of the canopy fly-away. Extensive bench tests of the canopy latch were undertaken, but despite the use of extreme loads the latch held. In addition, during an earlier free glider flight in which the pilot had dived the machine to 600 kilometres per hour, there had not been a problem with the canopy.

PILOT ERROR

It was now dawning on the investigating team that pilot error had to be countenanced as a possible cause of the disaster. Careful examination of the canopy gave an important clue. The tongue of the latch was noted to be bent downwards as if it had been under considerable strain. Yet all the evidence showed that a fully latched canopy should not have failed under the severest flight conditions. The only other reasonable explanation was that Sieber had only partially closed the canopy latch. Only the distal portion of the latch tongue had been inserted into the locking flange in the windshield frame.

THE HEADREST

Once the canopy flew off the flight was doomed. The head rest for the pilot was attached to the underside of the canopy at its rear end. Due to the 3 g acceleration the sudden removal of this support for Sieber's head would have resulted in his head flicking backwards, and hitting the solid rear wall of the cockpit. Bachem admitted that such an impact would either have rendered Sieber unconscious or broken his neck.[10] Either way the Natter was now without pilot control.

FAILURE OF A BOOSTER SEPARATION

The boosters were mounted on the sides of the rear-fuselage in such a way that once their thrust ceased they automatically separated from the fuselage. After the war the crash site was excavated and parts of one of the boosters were uncovered. Even though one booster had failed to separate from the fuselage, previous unmanned trials had demonstrated that such an event did not affect the ability of the Natter to fly on a straight and steady course.

STRESSES ON THE PILOT

Stress	Effect on body function	Impaired pilot function
A. Stresses of take off		
Noise	Overloads hearing function, acute earache	Impairs ability to communicate
Vibration	Shakes head and eyes	Impairs ability to read instruments
Fumes, dust and debris	Induces tearing of eyes Irritates lungs	Impairs reading of instruments Impairs breathing
g force – traverse g	Increases weight of limbs and torso	Impairs ability to operate controls
B. Stresses of ascent		
Reduced air pressure	Expands gas in air-filled spaces causing acute pain in bowel – *altitude meteorism* and in middle ear – barotitis media Joint pain; chest pain – *decompression sickness*	Impairs concentration and ability to continue mission Unlikely to occur on such a short flight
Reduced oxygen pressure	Decrease in brain oxygen – confusion; loss of consciousness – *hypoxia*	Impairs concentration and ability to continue mission
g force – negative g	Blood distends head blood vessels; impairs head circulation – *"red out"*; confusion	Impairs ability to read instruments and ability to continue mission
C. Stresses of high-altitude emergency escape		
Wind blast	Airstream ram pressure on face tears off oxygen mask – *hypoxia* Lung and facial trauma	Impairs vision and ability to land safely
Cold air	Loss of body heat with frostbite – *hypothermia;* confusion	Impairs ability to use hands and to land safely
D. Stress of pull-out from drive		
g force – positive g	Blood moves toward lower body; brain *hypoxia – "grey out";* confusion	Impairs vision and ability to continue the mission

Table 1: *Predicted physiological stresses on a Natter pilot during a mission*

As well as the g-forces, which have been discussed earlier, there were many other stresses on the pilot.

Dust, Exhaust Smoke and Debris

Upon ignition of the Natter's rocket motors, the combined exhausts threw up a large cloud of steam, smoke and dust which enveloped the Natter briefly before it rose above it.

Noise

The Walter motor alone could generate a sound intensity up to 120 decibels. If one adds the thundering sound of the four Schmidding boosters, the pain threshold of the pilot's ears must have been approached if not exceeded.

Vibration

Little was known at the time about the effects of vibration on pilot performance. The violent shaking of the Natter's wooden airframe produced by the rocket motors would have been transmitted to the pilot through his head rest, back rest and seat. This vibration would have been attenuated a little by the padding of the rests and his parachute seat pack. A research programme was initiated at the beginning of 1945 to examine this problem. [6]

Chemical Fumes

Pilots of the Me 163 rocket aircraft had been subjected to fumes of the T- and C-Stoff propellants entering the cockpit and infiltrating under their goggles and face mask causing burning and tearing of the eyes and pulmonary irritation. As a result the rear wall of the Natter cockpit had been carefully sealed off from the mid-fuselage which contained the propellant tanks.

Psychological Stress

The psychological stress on Sieber leading up to his launch was immense. Never-the-less he had said before the flight "I have done much more dangerous things than this. Let me do the worrying". [10] There is no doubt that many of his earlier exploits during the war had shown not only extreme courage, but also a degree of bravado. He was an ace pilot. However he could not ignore the fact that he was to become the first man in history to be launched vertically off the ground by pure rocket power.

The delay in the launch by almost five hours and the repeated go/no-go scenario would very likely have impaired Sieber's performance. It needed only one small error, in this case failure to fully latch the cockpit canopy. The ground crew would have checked that the canopy was closed but they could not see the position of the latch. Sieber's fate was sealed at that point. Like so many disasters one small failure led to a catastrophic outcome.

The Natter launch procedure placed enormous psychological stress not only on the pilot but also on the ground command and ground crew. This factor was recognised by the aviation physicians. "...psychic strain on the crew and commanding staff resulted from the short duration of flight in as much as the attack had to be planned very carefully with due consideration of the velocities and of the best angles of climb." [11]

THE FUNDAMENTAL LESSON LEARNED FROM THE FLIGHT OF M23

1.	Launch and boost phase stresses on a VTO rocket pilot are multiple, rapid in onset and potentially overwhelming.
2.	A pilot cannot be relied upon to manually control a rocket's flight path during the powered ascent.
3.	Flight control by autopilot is essential for reliable and precise powered flight of the rocket.
4.	The pilot should be provided with the facility to monitor the powered flight path and autopilot function and to be able to take over control in the case of autopilot failure.

***Table 2:** Lessons learned from the world's first human vertical rocket flight*

The fundamental lesson learned from the flight of Sieber in M23 was that during the launch and boost phases of a vertical rocket flight, the psychological and physiological stresses on the pilot were overwhelming. [10] The sequence of critical events during the countdown, launch and boost phase of the Natter's mission were timed to the second. To make the situation even more complex the pilot was lying on his back facing upwards with no view of the horizon.

Consequently a pilot, no matter how capable, could not manually control the rocket's flight path during the powered phase of the mission.

From the start of the Natter project Bachem had made it clear that the machine would have to be flown from the ground to the operational altitude by an autopilot.

If the death of Sieber could be seen in any way in a positive light it was the proof that Bachem was right. Flight control by an autopilot was essential for reliable and precise powered flight of a manned rocket. However the pilot should be provided with the facility to monitor the function of the autopilot as well as the flight path and to be able to take over manual control if the autopilot failed.

THE FALLOUT FOLLOWING THE FLIGHT OF M23

Cockpit Canopy and Locking Latch

The pilot's head rest was removed from the underside of the cockpit canopy and repositioned onto a special mounting attached to the rear wall of the cockpit.

The launch latch was completely redesigned. A spring-loaded latch with a long operating handle replaced the small latch. Considerable force was required to stretch the latch spring. Once the tongue of the latch had been inserted into the locking plate in the windshield frame, the latch would automatically locate itself into the fully locked position without any further force being applied by the pilot. A roof window was inserted into the canopy which allowed the ground crew to check that the latch was in the fully closed position prior to launch.

Development of the Autopilot

It was agreed by all parties concerned that no further manned missions should be undertaken until the autopilot had been successfully flight tested. The three-axis autopilot, the K12 Siemens-LGW Kurssteuerung, was chosen to guide the Natter to the operational altitude.

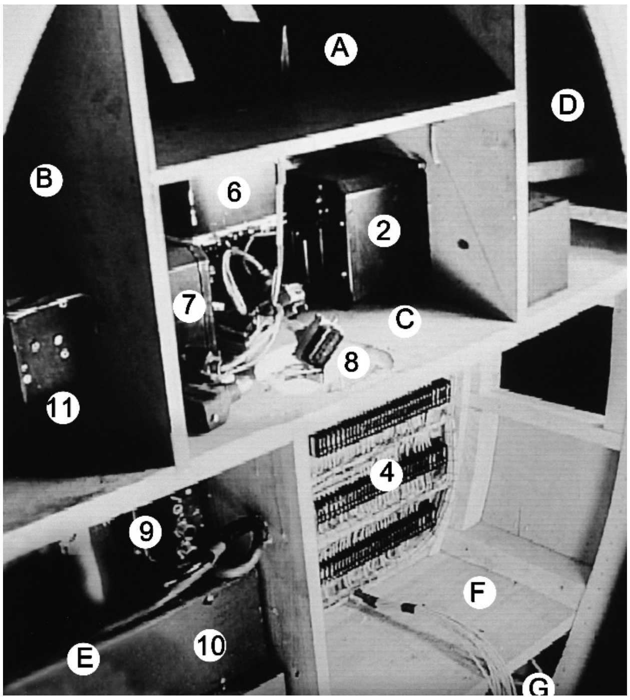

Figure 10

The electronics bay was positioned between the backwall of the cockpit and the wall in front of the propellant tanks in the mid-fuselage. The yaw and roll gyroscopes and three damping gyroscopes were mounted in this bay. The pitch gyroscope was located in the instrument panel in order to indicate to the pilot whether the Natter was responding correctly to autopilot control. On the left side of the cockpit was a switch board which allowed the pilot to disconnect the autopilot and to immediately take over manual control of the machine in the event of autopilot malfunction.

In early April 1945, M52, a fully functioning operational Natter and crewed by a dummy pilot, made a successful mission into the lower stratosphere. Three launch pads had been constructed in a little wood east of Stuttgart. The first operational machines had been constructed and eight highly decorated Luftwaffe pilots, who had been extensively trained to fly the Natter, stood by to man these machines. At that critical moment American tanks approached close to the launch site and the Natter echelon retreated southwards to the Bachem-Werk at Waldsee.

The Natter project established the basic principles for human vertical rocket flight.

1.	It established the safest posture for the crew of a vertical take-off (VTO) rocket.
2.	It established that a crew could not reliably control a VTO rocket manually and that autopilot control of the rocket was essential during powered flight.
3.	It developed a hybrid liquid and solid propulsion system for a crewed VTO rocket.
4.	It developed the first precisely timed countdown and flight mission for a crewed VTO rocket.
5.	It resulted in the development of the world's first light weight flexible pressure suit including flexible glove fingers.

Table 3: *How did the Natter project advance progress towards human spaceflight?*

Although the Natter never flew in anger, in only nine months Bachem and his team of engineers in collaboration with a wide range of aviation medical experts achieved a remarkable advance in aviation technology. They had established the basic principles for all future human vertical rocket flight to come.

IN CONCLUSION

It seems appropriate to allow Bachem to have the final word. In his presentation at the International Astronautical Congress in Stuttgart in 1952 he summed up his team's achievements:
"...within a few months we had to track down, go through and solve numerous problems associated with vertical take-off which the designers of future spacecraft will also have to look at...The attainment of great goals is not possible by a single leap, it is the result of an arduous climb up a steep ladder, step by step! Perhaps through our labour we have constructed one rung on that ladder!" [10]

This paper is based on an invited presentation by the author to the Royal Aeronautical Society at the Society's Headquarters, Hamilton Place, London on 8 July 2019 under the title " Natter - Historic step to human spaceflight".

BIBLIOGRAPHY

1. Speer, A. Inside the Third Reich. London: Orion Books Ltd., 1995: 388-391.

2. Galland, A. The First and the Last. The German Fighter Force in World War II. London: Readers Book Club, 1956: 255-239.

3. Gooden, B. Natter. Manned Missile of the Third Reich. Historic step to human spaceflight. Adelaide: Brett Gooden, 2019:181-210.

4. Bachem, E. Das Problem des Schnellstfluges. Stuttgart: Franckh'sche Verlagshandlung. 1933: 75pp.

5. Strughold, H. Development of aviation medicine in Germany in German Aviation Medicine World War II. Volume 1. Washington, D.C.: U.S. Government Printing Office, 1950: 3-51.

6. Lovelace, W.R. Research in Aviation Medicine for the German Air Force. Combined Intelligence Objectives Sub-Committee, Report No. 251, Publications Board, Department of Commerce, August, 1945: 1-83.

7. Fiedler, W. quoted by H. Steuer in "Berlin Befahl: 'Bemannter Abschuss ist sofort durchzuführen!' Der Todesflug des Leutnants Siebert", Revue. Die Weltillustierte, 21 July 1951; 14, 25.

8. Gooden, Natter. Manned Missile of the Third Reich, Surrey: Ian Allen Publishing, 2006: 519.

9. Stone, R, Andres, A. Chasing the Moon. London: William Collins, 2019: 211.

10. Bachem, E. Einige grundsätzliche Probleme des Senkrechtstarts. In Probleme aus der Astronautischen Grundlagenforschung. Proceedings of the Third International Congress on Astronautics, Stuttgart, 1-6 September, 1952. Stuttgart: Gesellschaft für Weltraumforschung, 1952: 89-96.

11. Beauvais, H. Performance and characteristics of German airplanes in relation to aviation medicine in German Aviation Medicine World War II. Volume 1. Washington, D.C.: U.S. Government Printing Office, 1950: 55-68.

FIGURES

Figure 1. Basic design of the Natter as revealed in a British Intelligence document in 1945. (G.E.F. Proctor, "BP 20B 'Natter'', British Technical Air Intelligence report 2345, 16 May 1945. Gooden, B. Natter. Manned Missile of the Third Reich. Historic step to human spaceflight. © Brett Gooden, 2019.

Figure 2. Bachem-Werk schematic of the Natter mission profile with anticipated g loads appended by the author. Key to German text: 1. Start (Take-off); 2. Steigen (Ascent); 3. Angriff (Attack); 4. Absetz-Sturz (Disengage - Dive); 5. Zerlegen (Dismantle); 6. Heckbergung (Recovery of rear fuselage); 7. Führer-Fallschirm-Rettung (Pilot recovery by parachute). Bottom left: Entfernung bis zu 20 km (Range up to 20 kilometres). Bachem-Werk GmbH, Waldsee, Württemberg, "Projekt Natter" report, 20 September 1944. Gooden, B. Natter. Manned Missile of the Third Reich. Historic step to human spaceflight. © Brett Gooden, 2019.

Figure 3. Evolution of the supine pilot position at launch of Natter. Key to legend: A. Early design with prone position of pilot. 1. Windshield, 2. Belly window for viewing horizon during the boost and ascent stages of flight; B. Intermediate design with crouching pilot; C. Final design with supine pilot. Gooden, B. Natter. Manned Missile of the Third Reich. Historic step to human spaceflight. © Brett Gooden, 2019)

Figure 4. The tilting seat mock-up designed to study pilot position. The fuselage is at an angle of approximately 70 degrees from the horizontal allowing the pilot to view the horizon through a belly window during the climb to altitude. Bachem-Werk GmbH, Waldsee, Württemberg, "Projekt Natter" report, November 1944. Gooden, B. Natter. Manned Missile of the Third Reich. Historic step to human spaceflight. © Brett Gooden, 2019.

Figure 5. Lothar Sieber enters the cockpit of M23 on 1 March 1945. Note the head cushion mounted on the underside of the open cockpit canopy. On that day he became the first human to be launched vertically off the ground by rocket power. Captured German photograph. Gooden, B. Natter. Manned Missile of the Third Reich. Historic step to human spaceflight. © Brett Gooden, 2019.

Figure 6. M23 rises vertically above the launch tower leaving behind a cloud of steam and smoke. The two dark exhaust trails come from the four solid propellant boosters. The white trail between them is the exhaust from the Walter liquid propulsion motor. All seems well at this time. Captured German photograph. Gooden, B. Natter. Manned Missile of the Third Reich. Historic step to human spaceflight. © Brett Gooden, 2019.

Figure 7. The canopy of M23 which fell close to Willy Fiedler, one of the chief engineers on the Natter project, shortly after M23 disappeared into the cloud cover. The front edge of the canopy faces forwards. Top centre is the locking latch with its white handle. Note that the tongue of the latch is

bent downwards. The bent starboard window is fractured diagonally. The port window is intact with its sliding ventilation window closed. The head cushion can be seen still attached on the rear underside of the canopy. Captured German photograph. Gooden, B. Natter. Manned Missile of the Third Reich. Historic step to human spaceflight. © Brett Gooden, 2019.

Figure 8. A skull fragment, found near the crash site of M23 by a bush walker some years after the accident, was assessed by a police forensic pathologist and is believed to have belonged to Lothar Sieber. A 14 centimetre long calibration is at the bottom of the frame. (X-ray from Pathology Report, 27-3-1983, Tübingen courtesy of Lieutenant Marcus Klotz via of Oliver Gortat. Gooden, B. Natter. Manned Missile of the Third Reich. Historic step to human spaceflight. © Brett Gooden, 2019.

Figure 9. Reconstruction of the instrument panel of M23. From left to right: Air speed indicator; altimeter; Walter motor propellant pump turbine speed; high range combustion chamber pressure gauge. On the right top edge of the panel is the low range combustion pressure gauge. Bottom middle is the Sichtgerät, the visual display unit, which was a gyroscopically stabilised device. A white dot painted on the end of a rod attached to the gyroscope's frame indicated pitch (vertical lines on the window of device) and yaw movements (horizontal lines on the window of the device). Graphic supplied courtesy of Stefan Moosburg. Gooden, B. Natter. Manned Missile of the Third Reich. Historic step to human spaceflight. © Brett Gooden, 2019.

Figure 10. Looking into the electronics bay of an unmanned trial machine equipped with the three-axis autopilot. Key to legend: A, B, C, D, E, F and G identify different compartments in the bay; 2. Back of the yaw gyroscope; 4. Distribution board; 6. Mixing unit for roll control; 7. Roll gyroscope; 8. Unattached plugs; 9. Resistance box; 10. Three damping gyroscopes; 11. Possibly the mixing unit for the pitch gyroscope which was mounted in the cockpit's instrument panel. Captured German document. (Bachem-Werk, Waldsee, Württemberg, ca. April 1945 adapted by the author. Gooden, B. Natter. Manned Missile of the Third Reich. Historic step to human spaceflight. © Brett Gooden, 2019.