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The Well-Tempered Astronaut

In the spring of 1959, with the Cold War's space race heating up, doctors screening astronaut candidates for the newly minted National Aeronautics and Space Administration (NASA) decided to include an unannounced test of tolerance to cold. The military test pilots under consideration for the first jobs in space were briefed on the long list of intensive and invasive examinations they would endure – except for one. In a twist on the established »Cold Pressor Test«, doctors surprised their subjects with a basin of ice water, and instructed the puzzled pilots to submerge their bare feet and hold them there for seven minutes. Only one attempt was allowed, and removing their feet early would end the test.

Cold was one of many environmental hazards experts in the emerging field of space medicine predicted for space flight, but this experiment was more than a physiological assessment; the subject's psychological reaction was also evaluated. »This subject was quiet and cooperative and offered no complaints«, noted one doctor. Another prospect did not fare so well: »The subject complained bitterly when presented with this test and stated that he was sure he would be unable to keep his feet in the water […] at the end of 15 seconds he complained of severe pain and withdrew his feet.«[1] For doctors selecting these iconic figures of the Cold War, the ability to face and endure literal coldness was evidence of physical strength, but also of mental and moral fortitude. The experts believed that »those who withdrew their feet were probably less motivated and less cooperative.«[2] And they punished failure harshly: »The candidates who aborted the cold pressor test for psychological reasons were automatically ranked the lowest«.[3] Like other environmental problems facing American soldiers in the early Cold War, the cold of space became a moral as well as a technical challenge. However, the relationship between astronauts and cold did not remain solely antagonistic; as we will show, space medicine experts came to view cold as a potential ally that could also protect humans in space.

In America, the field of space medicine formed a decade earlier in 1949, when four German scientists participating in Operation Paperclip were organized into the first-ever Department of Space Medicine at the United States Air Force (USAF) School of Aviation Medicine (SAM) in San Antonio, Texas.[4] Their initial conception of cold in space – as a hostile enemy to be staved off with technology or physically resisted if necessary – was drawn from late nineteenth- and early twentieth-century military cultures of aviation medicine, polar exploration, and mountaineering. Over the course of the Cold War, a more positive, instrumental view of coldness took root in space medicine: cold-induced hibernation or stasis could offer salvation from nuclear annihilation by enabling long-duration voyages to colonize other worlds.

Depending on where an object is in space, it can get either extremely hot (close to a star) or extremely cold (very far from a star). Since space is essentially a vacuum, the transfer of heat via conduction and convection is impossible; heat can only be transmitted in the form of radiation. For example, spacewalking astronauts can face extremes of 120°C heat in direct sunlight, and -150°C cold when in the Earth's shadow. One of the first to characterize space as a cold place was French mathematician and physicist Jean-Baptiste Joseph Fourier, who in the early nineteenth-century became interested in the planet-warming role of the Earth's atmosphere. »Our solar system is located in a region of the universe of which all points have a common and constant temperature, determined by the light rays and the heat sent by all the surrounding stars«, he wrote in his 1827 treatise »On The Temperatures of the Terrestrial Sphere and Interplanetary Space«.[5] Creating a linkage between space and Earth environments, Fourier stated the »cold temperature of the interplanetary sky is slightly below that of the Earth's polar regions«;[6] an association with a lasting impact in space medicine's reliance on ›earth-analog‹ studies, and the idea of Antarctica as a ›window on space‹.[7]

Space medicine's interest in cold can be traced to a 1951 paper titled »Where Does Space Begin?« by the Air Force's group of German émigrés. Led by physiologist Hubertus Strughold, the former director of the Luftwaffe's Luftfahrtmedizinisches Forschungsinstitut (aviation medicine research institute) in Berlin, they argued the physiological problems of space, including hypothermia, actually present themselves in a nearly identical manner starting at a much lower altitude – roughly 16 kilometers above the Earth, rather than the 100-kilometer boundary for ›space‹ set by physicists. In denser layers of the atmosphere, the heat transferred between the hull and the surrounding air determines an aircraft's internal temperature. In areas of the atmosphere Strughold deemed »space equivalent«, this heat exchange becomes negligible, and »the ship's temperature will be determined solely by the exchange of radiation between the ship's exterior on the one side, and the sun, the earth, and the cosmos on the other«.[8] For Strughold, temperature – »the most characteristic climatic factor« – was a key limit of life on Earth, and a fundamental organizing principle for his early astrobiology studies (the search for life on other planets). In his 1953 book *The Green and Red Planet*, Strughold speculated Mars might have vegetation by employing »temperature as a yardstick«, noting that the planet, although farther from the Sun than Earth, does not fall outside the relatively narrow band of temperatures hospitable for life. By ascertaining the surface temperature ranges for various planets in the solar system, Strughold began to organize the cosmos into places he thought could support life and those that could not.[9]

To explore space medicine's shifting conception of cold – from a hostile threat and limit to life to a useful tool to ensure the spread and survival of life – we engage with the cold research of three German space medicine experts employed by the United States Air Force in the early 1950s: Konrad Büttner, a meteorologist who worked on protective equipment, Bruno Balke, a mountaineer and high-altitude physiologist who studied cold acclimatization, and Strughold, who introduced the concept of cold hibernation to space medicine. This contributes to the growing collection of studies in space history about the origins of astronauts, some of the most mythologized figures of the Cold War, and to work in history of science on the mutual shaping of bodies and extreme environments.[10] In the context of Cold War studies, we show how space joined other extreme environments – the geographic »triad« of Arctic, desert, and the tropics – as a key proxy »battlefield«, and inspired a militarized vision of the body and mind to go along with it.[11] Additionally, the shift in cold from threat to tool also paralleled the metaphorically ›cold‹ war these experts were supporting.

Testing the Space »Race«: Konrad Büttner, Atomic Heat, and the White Suit

In January 1954, Americans flocked to the latest science fiction movie, *Riders to the Stars*. Produced in the early Cold War's competitive climate, the film opened with a voice-over: »Man during his brief existence on the Earth has met every challenge but one, the void of outer space […] a region of deadly radiation, agonizing heat and cold. […] Our government has given us an urgent top priority directive: find out if man can ever survive in space; if he can: our man must be the first.«[12] Dramatizing the future selection and training of America's first astronauts, *Riders to the Stars* adopted a realistic and almost documentary-like tone based on scientific expertise. Konrad Büttner, a former Luftwaffe scientist and Operation Paperclip émigré working for the United States Air Force (USAF), was credited as the film's »Space Medicine Research« advisor. In Germany during World War II, Büttner had been an expert on cold in military aviation, but once relocated to America in the early Cold War he also became interested in protecting against the searing heat of atomic explosions. Perfectly suited to tackle the extreme range of thermal problems in space – the freezing void, and the intense heat of the Sun – he was one of four German scientists led by Strughold who helped the USAF jump-start the first-ever Department of Space Medicine.

The Department of Space Medicine was launched at the behest of American aviation medicine pioneer General Harry G. Armstrong to see if man could survive the extreme environmental conditions of space. This was to guarantee the Air Force's »deterrent effect […] on potential aggressors« and to make »the most efficient utilization of the man-machine complex«, Armstrong declared at one of the field's first conferences in 1951: »One prerequisite for ensuring peak efficiency«, he added, »is to provide combat crews with adequate protection against those environmental hazards inherent in military flying.«[13] Büttner's papers at the symposium focused on »Thermal Aspects of Travel in the Aeropause«, the threat of extreme temperatures, ranging from severe cold to blistering heat, and potentially deadly radiation in space.[14]

When Büttner joined the Department, it was »already gospel in the Air Force« that the »air battles of the future will be fought in the stratosphere«; a region where »man is an alien«, subjected to an unforgiving principle: »the higher we go, the colder it gets. […] Along about 12 miles high we enter a region of constant -67° temperature. That is the arbitrary beginning of the stratosphere.«[15] Since the outbreak of the Second World War, the U.S. military had engaged in cold research to protect pilots sent to fight at freezing heights. Costly »Physiological Strato-Chambers« provided lab space for »proof testing of personnel and personal equipment at conditions simulating various altitudes and corresponding temperatures, and under flight-climb conditions.«[16]

Büttner's interest in cold began on the other side of the Atlantic in Nazi Germany, where he was an enemy rather than employee of the U.S. military. Unlike some of his scientific colleagues who served the Reich from outside official organizations, Büttner joined the Nazi Party in 1933, the year Hitler swept to power, and even became a member of the paramilitary Sturmabteilung (SA). Working in the field of military aviation medicine, Büttner put his expertise in bioclimatology – a novel discipline he called a »science of the daily life«[17] – in service protecting Luftwaffe pilots who were flying higher and faster than ever before. In 1940, he left the University of Kiel's Bioklimatische Forschungsstelle (research institute for bioclimatology) where he had worked since 1931, to continue his studies at the medical department of the Erprobungsstelle der Luftwaffe Rechlin (the Luftwaffe's proving ground). In the context of high-altitude aerial combat, Büttner's »science of daily life« rapidly transformed into studies on life at the extremes. Recalling his wartime work for a post-war U.S. Air Force compendium, he concluded, »in scarcely any other place is man exposed to greater and more sudden changes of climate than in aircraft«, where an »extreme range of the ambient atmospheric temperature from more than 50°C (122°F.) to below -80°C (-112°F.)« could be experienced.[18]

Büttner's research positioned cold among the enemies of the Luftwaffe: frigid cockpits at high altitude seriously threatened a pilot's ability to function as a reliable part of the man-machine system. Far exceeding even the strongest will to resist, these extreme temperatures could not be defeated by military discipline and individual morale alone; protective clothing and heating technologies were required.[19] To explore the effects of cold on humans, Büttner endured frostbite during experimental flights to hostile regions of the atmosphere and conducted experiments in the more controlled laboratory environment of Rechlin's cold chambers. But Büttner was not the only German doctor conducting cold studies. At KZ Dachau, doctors with an interest in aviation medicine performed a series of deadly super-cooling experiments on concentration camp prisoners to determine how long downed Luftwaffe pilots could survive floating in the freezing North Atlantic, and which method was best to rewarm them. Results from these abhorrent experiments were presented by Ernst Holzlöhner at the infamous »Ärztliche Fragen bei Seenot und Wintertod« conference, which was held in Nuremberg in October 1942.[20] Büttner was in the audience along with other future space experts, and even if he did not actively participate in the grisly experiments, he at least knew about them. Whether this gruesome knowledge shaped his cold research remains speculation, but these connections to deadly human experiments complicated the legacies of many important German experts who later worked in space medicine, especially Strughold.

After the war, Büttner took his expertise on temperature and protective clothing to America to support emerging nuclear and space projects. Warmly welcomed at SAM in 1947, he was first assigned to the Department of Radiobiology, and in 1949 was affiliated with Strughold's new space medicine department. At SAM, the Cold War's stratospheric bombers inspired more cold research but also studies of the opposite end of the spectrum: the intense heat of the atomic bomb. In one of his early Air Force reports, Büttner noted, »in Hiroshima, according to newspaper reports, the dark-colored flower patterns of kimonos were copied on the skin as an effect of the heat, while white obviously offered protection by reflection«; therefore, Büttner proposed producing protective white coats, »similar to a priest's mass vestment«.[21] But atomic heat not only affected people on the ground, it also threatened pilots in the air.[22]

Inspired by the shocking reports of flower-patterned burns at Hiroshima, Büttner conducted a series of radiation heat studies to measure the reflective

Fig. 1: Simulating atomic heat: Konrad Büttner experimenting with his custom-made solar reflector at the Air Force School of Aviation Medicine, early 1950s.

properties of different skin colors and pigmentations. But simulating the immense heat of a nuclear explosion required finding a powerful but controllable radiator. Büttner found such a radiator in space. Inside specially modified aircraft flying high above much of the protective atmosphere, Büttner used a converted parabolic military searchlight mirror to harness the powerful rays of the Sun. He then focused the scorching beam onto the skin of different experimental animals, noting that »upon the application of 3.8 cal/cm^2 sec. to the black skin of young anesthetized pigs, blisters began to rise after 2.2 seconds, and they exploded with a light popping noise after 4 seconds. White skin parts of the same pig showed no sign of conversion or loss of material like blistering, fuming etc., even after a 10-second application. […] Its significance in civil defense is obvious when one considers the close microscopic similarity of black pigs and heavy pigmented human skin«.[23]

By 1951, he began experiments on the »absorption of white and colored human skin from an atomic bomb's heat radiation«. In a study carried out »at Randolph Field on six subjects classified as colored with skin color ranging from light to dark brown, and on five white subjects«, he concluded: »Pilot experiments show that heavy pigmented skin exhibits an explosive reaction to high intensity visible light, whereas white (European) skin exposed to the same intensity does not undergo immediate changes, excluding protein denaturation.«[24] Putting a rather egregious spin on Büttner's ideas about priest robes and kimonos, an article in the *Science News Letter* announced »light skin and a Ku-Klux-Klan-like robe will be a help in case an atomic bomb falls. […] Black skin, he found, reflects only 10% of the heat rays to which a man or woman might be exposed by an A-bomb, while white skin reflects 40%. […] He has found that a hooded suit resembling a Klansman's robe and covered with aluminum foil is the best available shield against intense heat.«[25] These experiments extended from early twentieth-century colonial sciences, including tropical medicine and mountaineering, that sought to prove the supposed superiority of white bodies in extreme conditions.[26]

For Büttner, the Sun was not merely a tool to simulate atomic heat. With the advent of space flight, it also became a hostile ›proxy enemy‹ confronting man during the conquest of the upper atmosphere. In addition to cold, future astronauts and spacecraft systems positioned in direct sunlight would need protection from heat. Giving a talk on the »Bioclimatology of Manned Rocket Flight« at an early space medicine conference held in Chicago in 1950, Büttner focused on the combined threats of »Heat and Cold« stating that »the steady state temperatures of any part of a space ship depends essentially on its geometrical arrangement and on the color given to the hull.«[27] One year later at another conference, he extended his atomic skin color studies to space, arguing that white paint and light colors provide the best protection for spacecraft: »Reflectivities of color differ greatly for the two kinds of radiation mentioned. The ratio of reflectivity (solar radiation: to low temperature radiation) varies from ten for ideally polished metals such as aluminum and nickel, to one-tenth for ideal white. The ratio is one by definition for a black body.«[28]

In 1964, one year before the first American spacewalk by Gemini astronaut Edward White, NASA space medicine experts transferred Büttner's ideas about spacecraft hulls to spacesuits, suggesting astronauts exiting their vehicles wear white: »If it be assumed that the astronaut is wearing a black suit which absorbs all the solar radiation falling on it and radiates like a perfect black body to space«, then »the suit will heat up to 81°C (the temperature of piping hot coffee) which is not compatible with human life for any extended period.«[29] Accordingly, the iconic »extravehicular activity« (EVA) A7L Apollo spacesuit was also white.

While aerial combat in the Second World War introduced Büttner to the freezing temperatures of battle in the stratosphere, the intense heat of the Cold War's atomic bombs primed him to tackle high temperatures in space. Relying on aviation medicine's militaristic epistemology, racist and colonial skin color research, and the grisly culture of human and animal experimentation, he helped construct space as an antagonistic geopolitical, techno-scientific proxy battleground that needed to be controlled, dominated, and defended. In a rather abstract sense, Büttner also touched on the question of what kind of bodies future astronauts should have. He thus participated in ›normalizing‹ the ideal white male Cold War persona, capable of enduring the extreme climates of this global conflict's battle zones (be they nuclear or extraterrestrial). In a speech given at the ten-year anniversary of the Space Medicine Department in 1959, Büttner commented on the military origins and future of space medicine: »Whether we like it or not, space has become a military proving ground«[30] – a proving ground, he supported shaping by using the Sun to simulate the heat of nuclear war and recommending whiteness to keep spacecraft and spacesuits well-tempered.

Cold Warriors: Bruno Balke and Cold Acclimatization for Space

Bruno Balke, another German physiologist working at SAM, took a different approach to combating cold in space. Instead of developing protective suits or systems, he worked on the body itself, acclimatizing soldiers to various environmental stresses to strengthen what he predicted would be the weakest link in future spacecraft: the human. Due to weight restrictions, early spacecraft were not able to replicate sea level environmental conditions, resulting in »a compromise between what is ideal and what is tolerable«.[31] But Balke noted, »Experimental evidence exists that the human organism has a great capacity to adapt to superhuman requirements of a biological nature.«[32] To maximize the efficiency of this human-machine pairing, Balke's approach differed from Büttner's work on the astronaut's technological surroundings: »instead of modifying the ship, modify the man.«[33] Balke believed pre-acclimatization to low temperatures could help astronauts live and work in a colder-than-normal cabin environment or to survive a heating system failure. His vision also extended to the future: »the well-acclimatized astronaut, after landing on Mars, could leave the protection of his space ship equipped with the same set of oxygen apparatus aviators are using today, and do some first-hand explorations of the new Planet.«[34]

Balke's background as a mountaineer and military doctor in Germany during the 1930s and 1940s led him to characterize cold as kind of anthropomorphized proxy enemy that could be met and resisted through rigorous physical training and exercise. His studies incorporated practices from colonial and expeditionary medicine, taking the form of racialized comparisons between ›normal‹ white male subjects and groups of environmentally adapted indigenous peoples from cold, high places like the Himalayas and the Andes. Balke's antagonistic view of cold places and cold-adapted people also cast white, male soldiers as best suited to meet this environmental ›enemy‹. Cold acclimatization and indoctrination in space medicine was part of a wider Cold War military effort to make soldiers resistant to actual cold temperatures to defend a new set of strategic places including the Arctic, the upper atmosphere, and space.[35] For Balke, it was not enough for America's Cold Warriors to be kept warm at all times. They also needed to be toughened up to endure literal coldness. Balke's figure of the fully acclimatized astronaut also served to contrast the technologically enabled cyborg in ethical debates about if and how humans should be »improved« for space exploration.[36]

Balke had plenty of first-hand experience with extreme cold. Born in 1907 in Braunschweig, Germany, to a family of skiers and mountain climbers, he received his Doctor of Medicine in 1937 in Berlin at the Humboldt University. His interest in low temperature and low pressure, and his view of these as ›hostile‹ enemies, began in the nationalistic and quasi-military culture of German mountaineering and high-altitude physiology in the 1930s and extended to military aviation medicine in the 1940s. In 1938, he was enlisted by Luftwaffe researcher Ulrich Luft to conduct an acclimatization study as part of the Nazi-funded German expedition to summit Nanga Parbat in the Himalayas (then considered on par with Everest). Balke and the team viewed Nanga Parbat explicitly as an enemy. In 1937, fellow Luftwaffe physiologist Hans Hartmann wrote: »Snow and cold – these are the weapons that Nanga [Parbat] directs against us«.[37] As it turned out, Hartmann was one of 16 German climbers killed in an avalanche that year, and it was his unfinished study Balke was tasked with completing.

In 1941, the results from his Nanga Parbat study enabled Balke, by then a doctor with the Wehrmacht's First Mountain Division, to establish an altitude acclimatization program for the Luftwaffe at a special training station high in the Tyrolean Alps.[38] Here, at 10,000 feet, Balke led fighter pilots through a daily exercise regime designed to train their bodies to function on less oxygen. His experience with long-term acclimatization on Nanga Parbat had convinced him of the value of training in the field, rather than in laboratory-based cold and pressure chambers.[39] Balke boasted that »upon returning to their bases they were able to exceed the altitude tolerance of nonacclimatized pilots by about 3,000 feet, a great advantage in battle.«[40]

After the war, Strughold arranged for Balke to join him in Texas working for the U.S. Air Force where he extended his work on acclimatization to the context of space medicine. In addition to acclimatizing astronauts to low-pressure environments, Balke also considered ways to preempt the effects of cold. »In considering many of the spaceman's future missions requiring activities outside his sheltering ›home‹ – whatever it will be – the limited work capacity of man under extreme cold situations should be kept in mind!«[41] Balke believed cold conditioning could stretch the functional limits of the body: »during many of the imaginable space operations of the future, the adaptability of man to extreme variations in temperatures might become of considerable importance.«[42] Thinking in terms of the integrated human-machine spacecraft system, Balke worried bodies would prove the weakest link, compromising overall reliability. He argued against the notion that automation made the bodies of Cold War soldiers less important than ever. Sounding the alarm on physical complacency, Balke insisted physical fitness was in fact a matter of national security, since America needed to send soldiers to newly strategic cold places like space. A human operator frozen stiff at the controls of an orbiting missile platform now presented a conceivable geopolitical risk.

In 1959, with the astronaut selection program for NASA's Project Mercury underway, Balke lamented that Americans were distressingly out of shape, and thus not physically well equipped to endure exposure to cold.[43] Balke defined »fitness«, a slippery and controversial concept, simply as »the capacity for physical work«, a definition inherited from high-altitude physiology's nineteenth-century military and industrial partnerships focused on soldiers and workers.[44] For Balke, physical fitness was the critical factor determining life or death during exposure to low temperatures, and he worried American soldiers were unprepared. He noted: »The greater part of our population can only tolerate a threefold increase [in metabolic rate brought on by shivering] for a few hours before becoming extremely fatigued. Thus, without adequate shelter, the poorly conditioned individual might not be able to survive […] the physically well-conditioned individual, however, can tolerate extremely cold situations for days and weeks by maintaining just the proper amount of activity.«[45] After assessing the physical fitness of a few hundred airmen, Balke pessimistically concluded »the over-all state of ›physical fitness‹ in Air Force personnel was ›poor‹«.[46] For him, a fit population – especially among the military – had always ensured the success of nations in conflict, and this was no different for America and the Soviet Union in space. Balke cast his concern that America was falling behind in fitness in sharp evolutionary, nationalistic, and moral terms:

> »In most minds, power today rests in ideas, in motives, in organization, and, above all, in technology. According to this thinking, the evolution of the human race should tend toward the development of a strictly cerebral-visceral type of man with more and more neglect of all the body parts and organs which, originally, were vital for survival. Unfortunately, a nation's place among the other nations and its survival in the eternal struggle between them depends largely on the general vitality of the population. History has shown that the great accomplishments of all the ancient nations were destined to perish when a peak of civilization slowly softened the physical resistance of man against the forces of nature, or against the onrush of a more vital enemy. We cannot expect this pattern to change in modern times despite all technologic advancements. Unless one does not care about the destiny of future generations conscious and sustained efforts should be made to maintain the physical capacities of man at high standards.«[47]

In February 1962, Balke expressed this fear of American physical and military weakness in a chilling mountaineering parable about three climbers caught in a frigid storm. Ostensibly about »the close relationship between general physical condition and tolerance for combined work-cold stress«, Balke's story is also a geopolitical morality tale about the kind of people who should fight America's Cold War in space: »Three experienced mountaineers – one of them a mountain guide in top physical condition, the other two, after a long ›inactive‹ winter ›out of shape‹ – climbed a not difficult mountain in the early pre-summer season«. Soaked by freezing rain and sleet, the two »out of shape« climbers decide to rest, while their fitter »leader« continues alone to the summit. Upon rejoining the group, the leader finds the other two shivering uncontrollably and significantly weakened. Determined to save his friends, the leader attempts to carry the weaker of the two but soon finds »a dead body in his arms.« Further down the mountain, he decides to abandon the other shivering climber to seek help. Returning with a rescue party, he finds his other companion »lifeless«.[48]

Balke's evolutionary message is clear: in the cold, the fit survive, and the ›out of shape‹ perish. Taken at the nationalistic level of the Cold War, Balke's story also suggests a physically weak majority threatens the entire group. He felt maintaining physical fitness was a patriotic duty and framed the fine-tuning of bodies for space as a moral imperative as much as a technical challenge. In the story, the immediate enemy was not a Soviet soldier or rival cosmonaut, but rather the hostile environment itself and lack of preparedness. In this way, strengthening soldiers to survive cold environments became a Cold War proxy battle.

Balke's research was framed by a lingering post-war conception of race. His studies often took the form of comparative studies between naturally acclimatized indigenous peoples – most notably high-altitude miners in Peru – and white American airmen. The goal of these comparisons was to recreate the physiological efficiencies of indigenous bodies in white soldiers. As Toby Freedman, a physician and popularizer of Balke's research put it in his 1963 *Popular Science* article »Must Tomorrow's Man Look Like This?«, »all over the world there are people with what are literally superhuman abilities. Tibetan lamas can maintain normal skin temperature in subzero cold. Yogis buried alive manage on a fraction of normal oxygen consumption. Eskimos thrive on a high-fat diet that would give us all coronaries. Peruvian Indians do heavy labor at altitudes where you and I couldn't breathe.«[49] These types of comparisons are problematic, because they take white male soldiers as ›normal‹ to be ›improved‹ by the appropriation of aspects of indigenous bodies. Examples of this kind of racialized experimental design can be found among the 424 studies catalogued in *Space Travel and Human Thermal Limits: A Selected Bibliography* (1962): »Nine Indian men of an arctic village and eight urban white men have been compared in their responses to hand immersion in cold water. […] The Indians withstood the hand immersion in ice water with quicker rewarming and less pain than the whites.«[50] Balke's interest in indigenous peoples' resistance to altitude and cold was purely instrumental; he viewed them as harboring useful secrets for improving American astronauts, but never as potential astronauts themselves. Indigenous people were subtly cast in opposition to this »Man of Tomorrow«, and excluded from visions of this futuristic »improved« humanity.

Balke's cold research also intersected with ethical questions in space medicine about whether humans could or should be improved, and if so, how? During the space race, these debates often centered around the (now iconic) ›cyborg‹, which was introduced in 1960 at a space medicine conference on the »Psychophysiological Aspects of Space Flight« by mathematician and computer expert Manfred E. Clynes and psychopharmacologist Nathan S. Kline as an astronaut whose body could be supplemented with drugs or technological implants to survive in space.[51] Balke's work on conditioning offered a ›natural‹ alternative to this that Freedman popularized under the banner of »Optiman« in the early 1960s.[52] Conjured by doctors rather than cyborg-favoring engineers, Optiman was a human optimally conditioned to hostile environments *without* technology.[53] The idea of creating naturally strengthened Optimen appealed to those worried about the gradual loss of ›humanity‹ implicit in the cyborg idea; when does a human-machine hybrid cease to be ›human‹? Freedman's Optiman was advertised as technology free and recognizable as the classical ›natural man‹. Emphatically not »a mosaic of spare

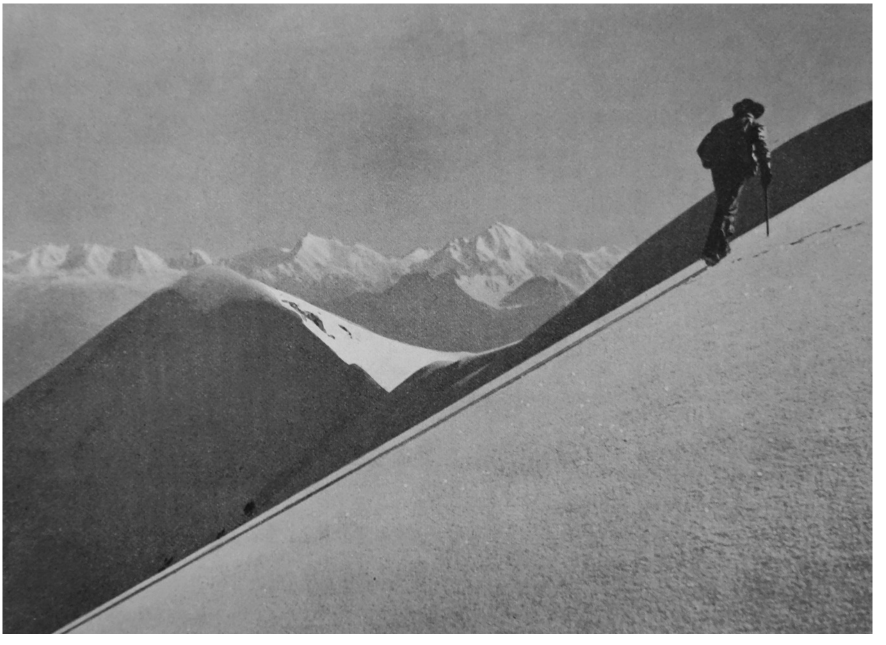

Fig. 2: Challenging nature: Bruno Balke near the summit of Buldar-Peak (5600 meters) during his 1938 Nanga Parbat expedition.

human parts and odd pieces of machinery«, Freedman insisted that Optiman »would be pure man«.[54] He implored American scientists like Balke to make Optiman »in the near future«, because »if we don't, the Russians will«.[55]

Balke's desire to produce cold-resistant soldiers shows one way experts planned for astronauts to face actual coldness. The origin of Balke's Cold War acclimatization practices, in nineteenth-century high-altitude physiology and mountaineering, explains their military, colonial, and nationalistic character as well as Balke's recurring fascination with race and indigenous peoples when contemplating a futuristic ›improved‹ body for space. For Balke, combating cold was more than a technical challenge to aid engineers designing spacecraft; it was both a personal struggle against a hostile environment and a nationalist imperative pitting American bodies against Soviet ones, and ›natural man‹ against machines.

Frozen Women and Hibernating Astronauts

Right from the start, space medicine considered temperature extremes to be hostile enemies, but the idea that cold could also be a useful ally also emerged. In his

1954 article titled »Hypoxia, Hypoxidosis, Hypoxidation, Hibernation, Apparent Death, and Suspended Animation«, Strughold, SAM's space medicine leader, first suggested placing astronauts in a state of suspended animation similar to animal hibernation for the purpose of long-duration space flight. It was not the first time he turned to animals for insight into defending against the elements. Back in Germany, during the war, he had studied animal coats – »Die Kälteschutzfunktion des Haarkleides beim Wild« – to protect Luftwaffe pilots in the cockpit or during distress at sea. But after the war space medicine called for much more than fur-clad astronauts. To support his idea about placing astronauts in »*artificial hibernation*« – a physiological state where »life becomes latent or dormant« – Strughold illustrated his paper with two eerie tales about women who had apparently frozen only to be revived later on.[56]

On October 27, 1919, in the turbulent days of early Weimar Germany, a twenty-three-year-old nurse bought a lethal dose of morphine from a drugstore in Berlin-Charlottenburg. Lovesick beyond all hope, she hid herself in the undergrowth of the Grunewald forest at the edge of town and took the poison. If the morphine failed to kill her, she hoped the winter cold would deliver a coup de grâce. After a wet and rainy night with temperatures near freezing, Berliners out for an early walk discovered her frozen stiff with no apparent vital signs. Pronounced dead by a doctor, she was taken to a morgue where she slowly re-warmed and suddenly began to regain vital functions. When she finally woke from her deep sleep, examining doctors concluded her suspended animation was caused by a combination of morphine and cold. Separately, the poison and cold would have been lethal, but together they were in fact life-saving.

The other story Strughold included took place in 1951. After a night of heavy drinking, a young woman left a bar on Chicago's South Side and passed out in a dark, isolated alleyway. Overnight, temperatures dropped to -23°C, and when she was discovered the next day her body was hard as ice and her core temperature had dropped all the way to 17°C. But just like the ›frozen woman of Berlin‹, she also survived, apparently saved by the misalliance of alcohol and hypothermia, a combination that reduced her metabolism and circulation to a minimum.[57]

These two medical marvels spread quickly among the space medicine community and were retold multiple times. Still struggling with the question about how to protect the »inmates of a hermetically sealed cabin« from the effects of »intense cold« in flight or during »forced landings in polar regions« and »parachute jumps within the stratosphere«,[58] scientists quickly adopted Strughold's idea and began to consider placing future astronauts in artificial hibernation. In September 1958, two British researchers gave a talk on the »Transport of Life in the Frozen or Dried

State« at a meeting of the British Interplanetary Society; two years later three scientists from Northwestern University in Chicago discussed »Prolonged Hypothermia« at one of space medicine's earliest and most influential conferences, »Psychophysiological Aspects of Space Flight«. With USAF funding they had vaguely replicated the ›frozen women‹ cases in animals, focusing on cooling anesthetized and drugged dogs. Despite several dead dogs, they concluded: »Hypothermia would appear to be suitable for the passengers of a space vehicle.«[59]

Artificial hibernation via prolonged hypothermia was intended to solve multiple physiological and psychological problems for space flight. It was thought hibernation would increase resistance to cold (and heat), acceleration, and radiation but also reduce metabolism and circulation, meaning less oxygen, food, and water would be needed for long space voyages. Expanding further on Strughold's initial musings, other researchers noted freezing the crew would eliminate the mental effects of monotony, claustrophobia, and group interactions. Interpersonal tension, hostility, and disputes could be prevented by ›freezing‹ rather than complex conflict management.

»With a man or several men in the hypothermic state, metabolic requirements will be greatly reduced; and the amount of food and oxygen to be stored, or the amount to be processed in a closed ecological system, will be greatly reduced. Since space travel in the far future will involve trips lasting for weeks, months, and years, it seems clear that much of the time spent in such travel will be routine and monotonous; the crew will have little or nothing to do toward the success of the mission. During such periods, it may be quite attractive to have the space crew in a harmless, unconscious, reduced state such as hypothermia, which is easily reversible by rewarming.«[60]

Hibernation also became part of the »cyborg concept« put forth by Clynes and Kline: »To reduce both sensory invariance and action limitation«, they proposed »the use of pharmaceuticals such as are used in Dauerschlaf, with the addition of an amphetamine-like compound to arouse the pilot rapidly« only if an emergency demanded human attention. Besides counteracting sensory deprivation and keeping inter-personal conflicts literally ›cool‹, cybernetically induced ›winter sleep‹ was also expected to substantially extend human life span for long-duration deep space missions. »With the increase of speeds and the lowering of metabolism«, Clynes and Kline noted that »flights running several hundred or even thousands of years cannot be off-handedly dismissed as mere fantasy.«[61] Featured in science fiction films such as *2001: A Space Odyssey* (1968), *Alien* (1979), and *Passengers* (2016), pharmaceutically induced hibernation never got beyond preliminary phases of animal experimentation performed on microorganisms, mice, and dogs.

Nonetheless, this compelling idea remains a persistent dream in space flight communities.[62]

In a 1961 review of »Russian papers on hypothermia«, J. R. Kenyon warned, »Deep hypothermia is now opening a wide field of research and may ultimately be applied to preserving the human body during space travel. There is no doubt that Russian scientists are well aware of these implications.«[63] By that time, space had become a central arena of the Cold War's geopolitical considerations: Yuri Gagarin's flight was only months away, and, since Sputnik I and II, the American public and defense intellectuals assumed they were lagging behind. But hibernation and hypothermia research was driven not only by the antagonistic East-West rivalry; it was also at least partly an effect of 1950s nuclear hysteria.

Inspired by the bombings of Hiroshima and Nagasaki, popular magazines, newspaper articles, and science fiction novels explicitly connected the idea of space colonization to discourses of human survival or extinction in the atomic age. For example, Ray Bradbury's canonical short story collection *The Martian Chronicles* (1950) includes an episode where »humans who have settled on Mars watch in horror as the Earth explodes in an atomic conflagration«.[64] This fear endured; in 1980, American policy planner Louis J. Halle predicted that »human life on earth will […] suffer a global disaster« such as a »nuclear holocaust«, and thus proposed the establishment of »permanent, thriving and proliferating colonies in space«.[65]

The idea of using hibernation technologies on long-duration Mars expeditions was expressed as early as 1954 by German rocket pioneer Wernher von Braun in one of his influential articles for *Collier's* magazine (in this series he also shocked the public by predicting that the future space station »can be converted into a terribly effective atomic bomb carrier«).[66] Imagined to »be valuable for space travel« because »hibernating Man might live 1,400 years« in a dormant state,[67] artificially induced hibernation was regarded as a promising technology for long-duration space travel, deep space exploration, and interplanetary colonization that would ultimately function as a life-extension tool. However, it was also positioned as a survival technology to preserve the human species in a ›frozen‹ state. In case the Cold War finally turned ›hot‹, space hibernation could ensure that some people survived the post-apocalyptic wasteland by abandoning Earth altogether.

Conclusion

Histories of astronauts and space medicine usually avoid the cold. Unlike more novel stresses like pressure, weightlessness, or radiation, cold was familiar and never a top research priority. Instead, it remained a lesser but consistent concern alongside the other environmental challenges. Like the Arctic, space was »fashioned and shaped«, and turned into a landscape of »technical imposition, manipulation, and control«.[68] This approach to the environment extended to humans as well, with space medicine experts facing an almost Hamletian dilemma: »Human engineering or the engineering of the human being – which?«[69]

Efforts to manage cold in space flight did not follow a coherent trajectory during the Cold War but were integrated into complex practices that responded to specific challenges. However, two interesting developments can be singled out: First, as the Cold War progressed, space medicine's characterization of cold evolved from a threatening environmental enemy into a helpful ally and a tool for survival. Second, to mitigate the impact of cold on operations in space, experts were just as interested in engineering bodies as they were in spacecraft systems. Technical means of keeping astronauts warm in climate-controlled spacecraft or spacesuits were joined by efforts to acclimatize them, and – more drastically – freeze their bodies for long voyages. This research provoked sweeping philosophical questions about ethics in space medicine, and the future of humanity. Scientists like Bruno Balke and Toby Freedman debated naturally »improving« humans to withstand cold and other stresses, while Hubertus Strughold, Manfred E. Clynes, and Nathan S. Kline contemplated the wholesale transformation of astronauts into a new kind of hibernating space age organism.

Drawing on aviation medicine, colonial and alpine sciences, Weimar spectacles, KZ victims in Dachau, atomic explosions, and crude animal experiments, cold in space medicine was never simply a technical matter. Approaches to the problem always advocated a vision of the individual and wider society during the Cold War. The knowledge produced supported the Cold War's globally scaled operations[70] but also promoted a distinct idea of humanity itself. As we have shown, Konrad Büttner's work to protect astronauts from the heat of solar radiation with white and light-colored materials was, on the one hand, an attempt to engineer technology to fit human needs, but on the other hand, it was inextricably bound up with the question of skin color and race in America as well as nuclear fear and civil defense. Balke went one step further, turning to nineteenth-century expeditionary and colonial medicine to strengthen the body itself; practices that reveal his wider concern that Americans were physically weaker than their Soviet counterparts. Defining and enforcing nationalistic ideals of a ›normal white male body‹, Balke participated in the broader Cold War project to understand and control human nature. Since the potential failing of people was »understood by many as the greatest standing threat to technology at the heart of the Cold War«, it seemed logical that »people would have to be made reliable«, and acclimatizing bodies to extreme environments was part of this strategy.[71] Balke's appeal for a national focus on fitness – resembling Foucault's »technologies of the self« – was aimed at soldiers and the wider population and advertised a set of Cold War virtues (physical, mental, and moral) to astronauts and everyday Americans. Finally, Strughold's suggestion of using cold to alter humanity's fundamental biological make-up – turning astronauts into hibernating super-humans – was part of a grand vision of humanity's future as a spacefaring civilization colonizing the cosmos.

Notes

1 Charles L. Wilson: *Project Mercury Candidate Evaluation Program*, Wright Air Development Center Technical Report 59-505, Wright-Patterson Air Force Base, OH 1959, pp. 58–59. The cold pressor test has a long history in physiology, and usually involves immersing a hand in ice water, rather than feet. The form used in Project Mercury was developed by Air Force captain F. J. Leary, see ibid, p. 1.

2 Wilson: *Project Mercury Candidate Evaluation Program*, op. cit., p. 103.

3 Ibid., p. 76.

4 For a detailed history of the formation of the U.S. Air Force's Department of Space Medicine, see Maura Phillips Mackowski: *Testing The Limits. Aviation Medicine and the Origins of Manned Space Flight*, College Station, TX 2006.

5 Jean-Baptiste Joseph Fourier: *On the Temperatures of the Terrestrial Sphere and Interplanetary Space*, https://geosci.uchicago.edu/~rtp1/papers/Fourier1827Trans.pdf (accessed: 10.1.2017), p. 3; for the French original, see »Mémoire sur les Températures du Globe Terrestre et des Espaces Planétaires«, in: *Mémoires de l'Académie Royale des Sciences de l'Institute de France* 7, 1827, pp. 570–604.

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15 Harland Wilson: »War in the Stratosphere?«, in: *Flying Magazine* 44 (2), 1949, pp. 30–32 and 75–76, here pp. 31–32.

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19 Konrad Büttner: »Protective Clothing for Heat and Cold«, in: The Surgeon General U.S. Air Force (ed.): *German Aviation Medicine World War II*, vol. 2, Washington, DC 1950, pp. 876–886.

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