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Plasma Aerodynamics since the End of the Cold War

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PLASMA AERODYNAMICS SINCE THE END OF THE COLD WAR

By

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To my mother and my wife.

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This journey began back in junior high school around 1970 when I first realized I enjoyed history. Many people helped along the way and I truly wish I could personally thank each and every one of them for the achievement of a life-long dream. They assisted in this long journey and I am forever in their gratitude.

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ABSTRACT

This study examines two former adversarial scientific and technological aerospace constructs created, for the most part, separately during the Cold War and their subsequent meeting and collaboration after the Soviet Union collapse. They both strove first separately, then in unison to create a hypersonic aircraft. In studying this collaboration, one must evaluate each research communities' strengths and weaknesses as well as historians' efforts to explain the exact relationship between science and technology, or applied science. This "international" approach offers some advantages in determining both nations' research capabilities. If one accepts a 'science' and 'technology' as separate entities, I show that it was actually each country's technological or 'applied science' capabilities that defined their 'science' and punctuated the two contending scientific communities views regarding the work together.

CHAPTER ONE

PLASMA AERODYNAMICS

Introduction

I grew up on military bases in Germany primarily with short tours back in the United States. My mother's side of the family had been *Volksdeutscher* farmers in Hungary before World War Two. My grandfather was drafted into the Hungarian Army and captured by Soviet forces and placed in an Odessa POW camp. Unrecognizable to his family when he returned, the communists requisitioned his large farm property and put him and the family on a train to Wertheim, Germany. My grandparents and six children shared one room in a former *Kaserne*, German Army barracks. Later when the *Volksdeutscher* moved into newly built apartment buildings, the US Army moved in as part of NATO's forces. This is how my parents met.

I believe this upbringing gave me an acute sense of different cultures and that ideas, behaviors, definitions, and history itself meant dissimilar things to diverse nationalities. I have always been stunned by how the simplest conversations can reveal hidden assumptions and lay them bare for objective, often times discomforting analysis. For me, understanding these superficial interpretations leads to deeper philosophical issues often premised on the sciences. The argument is that in the search for "objectivity" nature offers some answers with which in turn offer metaphorical guides to understand human thoughts and behavior. While this premise is not universally accepted, it is one that offers some hope against purely subjective incantations. The horrors of the Holocaust and its pseudo-scientific premise, to which I was exposed to at a young age in Germany, the raced-based slave trade and American struggle to come to terms with its internal divisions, women's issues, gays, and others gave me a revulsion toward such incomprehensible rationalizations. For me, beginning with science, using philosophical language, provides a means with which to understand the historical outcomes.

Thermodynamic laws underlie this philosophical look at hypersonic cooperation. Scientists have understood, in general, its outcomes dictating that macro characteristics depend on micro elements. The human race is undergoing a rapid familiarization to thermodynamics in the scientific debates regarding global warming. Every dynamic event involves energy and a loss of heat, or dissipation. This conforms to thermodynamics and has never been disproven – no exceptions. This dissipation is evidenced by our own bodies. We consume food as energy, and some of the material, and heat created by actives and thoughts (electric impulses): and maintaining our core temperature are dissipated. The human race accelerated this heat-dissipation by machine building at the dawn of the industrial revolution and has steadily increased the heat accumulation process as evidenced by melting Polar Regions, glaciers, desertification, and rising temperature. Just open the hood of your car after a trip and stick your head into the engine compartment and ask yourself where is that heat going? Daily news reports warn society of the catastrophic consequences of our micro-behavior on our macro-climate. The science of this micro-macro phenomenon is the same for hypersonic plasma aerodynamics. The other critical thermodynamic characteristic is unpredictability. Whenever energy is added to a closed system to make it open, the behavior resembles chaos.

My interest in this topic began when I became an Air Force historian and was sent to Headquarters Air Force Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio, in 1997. The intern that preceded me had moved on to another assignment and my boss asked me to look into some research she had started on. Lieutenant Colonel Stephen M. Rinaldi, a physicist, had just returned from a stint with the European Office of Research and Development (EOARD) in London. The office has an Asian counterpart and they act as liaisons for Air Force laboratories by attending conferences, meeting foreign scientists, and sponsoring some to the US to work Air Force counterparts. Rinaldi explained that in addition to Europeans, EOARD had been working with Former Soviet Union researchers and that they provided some excellent work. He they showed me a small document collection which I subsequently used to write a study titled "Buying Military Technology from the Former Soviet Union" (1998).

The study focused primarily on Russian technology such as the K-36D ejection seat that had performed flawlessly during a spectacular low-altitude MiG-29 air show demonstration. In addition, the Air Force worked with the Russians on their hypersonic scramjet development and space ion thruster program. In addition to Rinaldi, I interviewed Dr. Mark Maurice who had just returned from Europe as the EOARD aerospace science representative. Maurice relayed the challenges the Former Soviet Union countries presented in reaching out to their now wide open scientific communities. Their scientists faced financial hardships, closed research facilities, and a collapsed banking system. The Russians and their former republics were eager to show their work to foreigners and share their findings that had been closed off to Americans. Maurice stated that their scientists were outstanding and in many cases ahead of similar researchers in the West. I then moved to Eglin AFB, Florida and decided to apply to Florida State University and to use the short study with which to write a dissertation by focusing in on the basic science.

Challenges

This is an ongoing research effort; the challenges of this study are that all participants are still engaged in government contracts. Even when they offered frank opinions or research that countered the Air Force's intention to continue working with the Former Soviet Union scientists, they are quick to add the caveat that they do not want the criticism out in the public. That applied to myself as a US Air Force historian at Davis Monthan Air Force Base, Tucson, Arizona. This reluctance to express frank assessments is even stronger on the Former Soviet Union scientists because even now the relatively small amount of money they earn for research is more reliable than what they might have in their own country. The other issue I face is even if they were to explain their research scientifically; I lack the knowledge or mathematical skills to comprehend it.

Plasma Aerodynamics

Chapter one introduces the US Air Force and Former Soviet Union scientific collaboration after the Soviet Union's demise. The discussion includes several concepts in order to analyze and understand the issues and concepts both parties faced along the way. Even though science professes an international character, Former Soviet Union science and culture presented challenges to their American counterparts. Each side brought strengths and weakness to the partnership based on technological capabilities. The Second Law of Thermodynamics' premise that macro behavior is determined by micro behavior underlies this research. The US's abilities and cultural makeup tended to expedite the shift from basic to applied (technology) science, whereas, Russia's historic productive forces forced researchers to acquire experimental equipment from foreign sources, or go without. Philosophically, empiricism demands verification, scientific realism concedes existence of atomic elements even though they are invisible. The National Aerospace Plane announced by President Ronald Reagan in 1986 was a glaring technological failure because no matter how well-made the hypersonic aircraft was it could not overcome the 'heat barrier'. The effort then spawned basic science research where it had been absent for many years. Finally, the Second Law of Thermodynamics dictates that when energy is added to a system that chaos ensues, such as this collaboration, it leads to an undetermined outcome. This means there is self organization provides unity albeit unpredictable.

This study examines two former adversarial scientific and technological aerospace constructs created, for the most part, separately during the Cold War and their subsequent meeting and collaboration after the Soviet Union collapse. They both strove first separately then in unison to create a hypersonic aircraft. In studying this collaboration one must evaluate each research communities' strengths and weaknesses as well as historians' efforts to explain the exact relationship between science and technology, or applied science. This "international" approach offers some advantages in determining both nations' research capabilities. If one accepts a 'science' and 'technology' as separate entities, I show that it was actually each country's technological or 'applied science' capabilities that defined their 'science' and punctuated the two contending scientific communities views regarding the work together.

In a 1958 National Advisory Committee for Aerodynamics (NACA) publication, Klaus Oswatitsch described the heat problems faced by future supersonic fighter designers in “Extreme Speeds and Thermodynamic States in Supersonic Flight.” He stated that “Typical of all cases is the conversion of high kinetic energy into extreme thermodynamic states with temperatures of several thousand degrees, frequently connected with dissociation and ionization of the gas involved.”[1] This occurs at what now is called hypersonic, approximately greater than Mach 5 speeds. He went on, “The penetration of meteors into the atmosphere of earth at astronomical speeds results in temperatures higher than those of the surface of the sun. Such temperatures may be produced in shock tubes, with light gases used as the driving gas.”[2] Then, perhaps unknowingly, predicted that “For supersonic fighters the problem of propulsion is less difficult to solve that the problem of large heating, on the surface and in the combustion chamber.”[3] It took another 40 years for aerodynamicists and designers to reach Oswatitsch’s conclusion. It is perhaps fitting that plasma is unseen, unless revealed in the wake of a streaking meteor, a laser, or the sun. At the simplest level, plasma is simply a fluid that conducts energy. Instead of a copper wire transmitting electricity, the plasma acts as the conductor.

Reaching this point took a scientific aerodynamic revolution. Traditionally, aerodynamic science deals with fluid dynamics because liquids and fluids flow according to the same laws of nature. Aerodynamicists focus on air stream around the aircraft’s exterior and through the engine. Rocket aerodynamics must include tremendous friction to the assembly as it accelerates to approximately Mach 25 to escape Earth’s gravity. The collaboration described above brought these two previously separate aerodynamic conditions together in plasma aerodynamics which is essential for aerospace aircraft. America’s pragmatic world view hindered hypersonic flight development. The Soviet Union, on the other hand, placed more emphasis on realism and as a result in

[1] Klaus Oswatitsch, Mary L. Mahler, trans., “Extreme Speeds and Thermodynamic States in Supersonic Flight,” (Translation of “Extreme Geschwindigkeiten und thermische Zustande beim Uberschallflud,” *Zeitschrif fur Flugwissenschaften*, 2, Issue ¾, (1956) NACA Technical Memorandum 1434, Washington, April 1958, 1.

[2] Ibid.

[3] Ibid.

mathematical solutions. When the Cold War ended, scientists on both sides combined their best ideas.

On 6 February 2010, the US Air Force published an article titled "AFOSR Initiates Russian and US Scientists' Collaboration in Plasma Aerodynamics."[4] Although well known in aerospace circles, the article included names and a group photograph. The author's title was in itself a bit misleading. The item represented a milestone for 20-year collaboration between USAF and Former Soviet Union scientists since the end of the Cold War. How was this possible for the US to develop such a program with former Cold War enemies? How long has this been going on? Why is the US Air Force paying Russian scientists for work that could no doubt be done by Americans? That money, after all, belongs to the US taxpayer. Some American scientists asked the same question. It also raises an interesting question about Communism: If the political structure and ideology were so bad, then why were their scientists so good? And conversely, if their science was good, then why did the state collapse?

Threat unites the modern military and science. Threat is as old as evolution and in the case of humans linked to materialism. First for basic shelter, sustenance, and protection from the elements, man uses cognition to lessen the unknowns. For the most part, Cold-War Soviet military science remained unknown to United States scientists. Locked away in "closed cities," scientists and their research were tightly controlled in prison-like environments where even children wore identification badges as part of their daily apparel. Local citizens often did not know what went on inside the restricted areas. This secret Soviet scientific culture was incomprehensible to American contract-based science. When the two met, the friction caused heat.

Ironically, the problem they researched is the heat generated on aircraft structures at hypersonic speed. When it comes to hypersonic aircraft design, the "heat barrier" has huge impact on vehicle design and manufacturing. The challenge is similar to 20th Century's efforts to overcome an acoustic shock wave, also known as the "sound barrier"

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[4] Maria Caller, "AFOSR Initiates Russian and US Scientists' Collaboration in Plasma Aerodynamics," *Air Force Print News Today*, 6 Feb 2010.

and to fly at supersonic speeds. These waves, as it turns out, behave just like fluids and investigators analyzed their "fluid dynamics" characteristics. Aircraft designers, using Ludwig Prandtl's 1904 "boundary layer" mathematical solutions, solved the issue by changing aircraft surfaces; heat, for the most part, was not a major issue. However, as scientists explored increasing flight speeds, they discovered that the temperatures generated by sustained Mach 5 and above flight exceeded man-made material melting points. This study focuses on scientific efforts to extend Prandtl's boundary-layer solutions into velocity rates that ionize the air flow into plasma where kinetic, chemical, electrodynamics, and thermodynamics must have simultaneous solutions in hypersonic aircraft design.

This device would take off and land like any other conventional platform, but would then leave the earth's atmosphere into space. The Space Shuttle and normal spacecraft reenter our atmosphere using ablative materials---ceramic tiles in the former, and carbon-based in the latter. Without such measures the man-made materials burn. Aircraft designers usually concern themselves with two heating problems: propulsion and air flow. This study focuses primarily on the second, but also concerns the first.

Consider the 7 February 2012 Eleventh International Workshop on Magneto-Plasma Aerodynamics, 10-12 April 2012, at the Joint Institute for High Temperatures Russian Academy of Science Moscow, Russia. The workshop is sponsored by the Russian Academy of Science, Russian Foundation for Basic Research, and European Office of Aerospace Research and Development (EOARD). Most laypersons reading the announcement might be mildly curious, but if you explained that EOARD is in fact the United States Air Force Office of Scientific Research's (AFOSR) liaison office to Europe they might well be more than surprised because it means that US taxpayers' money is involved. What the bulletin really meant was that the US Air Force was deeply interested in hypersonic 'magneto-plasma' aerodynamics research for the purpose of developing such an aerospace plane.[5] What the announcement did not mention was that these workshops were the Russian counterpart to a similar annual American Institute of Aeronautics and Astronautics (AIAA) conference in which EOARD sponsored Russian

[5] Dr. Valentin Bityruin, "11th International Workshop on Magneto-Plasma Aerodynamics," 7 Feb 2012.

scientists in the Weakly Ionized Gas forum. This particular meeting began in 1997 at the US Air Force Academy, Colorado Springs, Colorado. When it comes to plasma research, the Former Soviet Union scientists were the best. From the time of the first Atoms for Peace conferences which brought together Soviet and western physicists, their knowledge always impressed outsiders.

Science is international. Researchers depend on advances regardless of national origin. Big science, on the other hand, requires big money and is usually managed by bureaucracies. This meant a research project must be translated into economic language which becomes more comprehensible to policy directors. These individuals may or may not be scientists, but regardless they were influenced by non-scientific factors. These included politics, finance, social dynamics, and a host of other things that have nothing to do with the science itself. These cultural impacts steered science in the direction of national issues. Based on overarching priorities, different Big Science institutions developed their own strengths and weaknesses.

Science whether termed pure, fundamental, exact, or basic, depends heavily on non-scientific economic support. The former must make a "Faustian bargain" with the latter. In return, science provides a metaphor to those believing that nature provides a better source to guide their thoughts and actions. Pragmatism guides both parties. This differs somewhat with "applied" science which produces things like technology. The division between applied and basic science is not a firm divide, but rather a sliding border with each party moving one way or the other depending on the particular item under study. Take hypersonic aircraft as an example. Aviation advances serve both civilian and military needs - it is inherently "dual-use." Americans usually support such technology because its success will bring far shorter international flights. Physics and mechanical engineering are two separate entities---the trick is melding the two in terms of time and economics. They join together in thermodynamics.[6]

At present there is a division between aircraft and spacecraft. Visually, there are obvious differences, however for this research it concerns propulsion: aircraft use air-breathing engines and spacecraft use rockets. The US's Shuttle resembles a conventional

[6] Walter G. Vincenti, "Control-Volume Analysis: A Difference in Thinking between Engineering and Physics, *Technology and Culture*, 23, no. 2, (April 1982): 150, http://www.jstor.org/stable/3104129, accessed 15/11/2010.

aircraft, but does not use an engine and becomes a glider when reentering atmosphere. This concerns an international science and engineering effort to unify the two in an aerospaceplane. In order to reach space, these platforms must reach approximately Mach 25 or 18,500 miles per hour (mph). Subsonic refers to aircraft speeds under Mach 1, supersonic means Mach 1-5, and hypersonic is Mach 5 and above which are termed hypersonic vehicles. Technically, the fastest US air-breathing aircraft is the US Air Force Lockheed SR-71 that could fly up to Mach 3.2. The rocket-powered X-15 travelled into hypersonic Mach 6.7 range, but like the Shuttle glided back to its runway. The aviation-space "Holy Grail" is to build one vehicle to fly in both air and space with full power access. This aerospacecraft would be maintained just like conventional aircraft and be available for new flights after refueling and maintenance unlike space vehicles that take months, if not years, to launch and recover. Space launches also discard most of the entire rocket and cannot, except for some designs, be used again. There are strong economic reasons to unify the two different platforms because not only are rockets wasted, for the most part, but add to the alarming amount of space debris that threaten manned or unmanned vehicles orbiting the earth.

Traditionally, propulsion is the biggest issue in aircraft design. The SR-71 used a hybrid turbojet-ramjet engine. The conventional turbojet provided power up to approximately Mach 3 when it approached critical thermal limitations inside the engine. The ramjet used the aircraft's engine intake to compress incoming air, bypassed the turbojet completely. Ramjets operate in the Mach 3-6 ranges. At hypersonic speeds and supersonic ramjet, or scramjet, is needed.

Beyond propulsion, there is another much more difficult problem in overall aerospacecraft design; that is heat – the kind of heat that incinerates any man-made material solutions. It is loosely called the "heat barrier." The X-15 reached the limits of its thermal design at Mach 6.7 (4,000 mph): but beyond that range, the aircraft's skin begins to lose its form and warp – a decidedly unfavorable issue for pilots. Since the challenge is high-heat, the solution lies in the laws of thermodynamics. Looking back over a half-century of science since the discovery of the electron, New York Times science editor stated a truism: "Today no physicist worth his salt believed in laws of nature with the exception of the second law of thermodynamics, which states that the universe is running down like a clock and that order is giving place to disorder."[7]

These science-technology relationships vary from country to country based on their culture which when examined side-by-side help understand both their worldviews as well as one's own. In comparing the United States to the Former Soviet Union countries (primarily Russia because the language of science tends to be Russian): the US leans toward technology while the other toward basic science.

From a geopolitical-military perspective, Russia has experienced invasions many times from the Mongols to Hitler. Its vast expanse and bordering neighbors, some allies and others like China means that the country is constantly vigilant. This gives rise to a strong leader model. One person must have the power to quickly make decisions and the population is more united and communal in responding. Contrast to the United States which has only been invaded during the War of 1812 by England. Steeped in a culture that grew out of the French Enlightenment and written into its Constitution, its people, for the most part, distrust a strong central power. Not surprisingly then, Russian science places more "authoritative" emphasis on theory and those individuals are held in higher esteem than technologists, and consequently basic science receives more emphasis. The US, in contrast, public opinion influences policy makers and they find it far easier, for political reasons, to justify spending on something they can see and touch.

In John D. Anderson's *History of Aerodynamics*, the author, a physicist with historical perspective, divides his eminently readable account between aerodynamic scientists and engineers. The former, he argues, tend to be mathematically inclined (realists): and latter the empiricists. He uses the Germans to show how each time after World War One and Two, the international aviation communities received benefits from scientific advances accomplished during wartime secrecy. After both wars, the victorious Allies fell upon German research and used the knowledge to rapidly advance their own aviation interests. Each conducted programs to exploit German knowhow. After WWI, America's National Advisory Committee for Aeronautics (NACA): forerunner to the National Aviation and Space Administration, sent experts to report German advances.

[7] Waldemar Kaempffert, "Scientist at Centenary Argue that Man Now Must Study to Control His Material Gains, *The New York Times*, 19 September 1948, http://query.nytimes.com/mem/archive/pdf?res=F20D17F63458157A93CBA81782D85F4C8485F9, accessed 6 March 2012.

Similarly, after WWII the US initiated Operation Paperclip in order to gain German rocket expertise. The French conducted the same under the *Office National d'Etudes et de Recherches Aérospatiales* (ONREA): Aerospace Research Center, the Soviets with Operation *Ossavakim,* and the British in Operation Surgeon. Something analogous happened after the Cold War when Former Soviet Union and US Air Force scientists joined in solving hypersonic aircraft boundary layer research.[8]

In an introduction to a NASA publication titled *From Engineering Science to Big Science*, editor Dr. Pamela E. Mack wrote about this science-engineer split. Mack points to Congress' 1994 Supercollider cancellation as heralding the end of big science and big technology funding that had been driven by the Cold War. This coincided with the 1995 end of the National Aerospace Plane (NASP) effort. Between the science and technology, the latter dominated NASA. Building bigger, more powerful rockets to send astronauts to the moon and then the Space Shuttle required a great deal more engineering than theory. In the discussion, Mack combines the two fields into one.[9]

This engineering focus was what killed the NASP program. Larry Schweikart wrote a post-mortem history titled *The Quest for the Orbital Jet: The National Aero-space Plane Program (1983-1995)* in which he analyzes the multiple entities that came together but failed to produce an aircraft. Sponsored by NASA and the Air Force, it was not surprising that groups formed different views on how the plans should be met. Some within the Air Force interpreted it as a way to field an operational hypersonic platform as soon as possible. Others saw it as producing a research aircraft for further hypersonic testing similar to the X-15. This would test and develop technology as a measure of success versus actually flying into space. These presented two very different goals and measurements for success. Lastly, some thought building the aircraft was impossible; they saw it rather as a "way to force-feed technologies into the 'right' questions."[10]

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[8] Pierre Trichet, "Paperclip, French Style," AIAA Aerospace Sciences Meeting, Orlando, Florida, 5-9 January 2009; Asif A. Siffiqi, "Germans in Russia: Cold War, Technology Transfer, and National Identity," *Osiris*, 24, no. 1 (2009): 120-143, http://www.jstor.org/stable/10.1086/605972; Asif A. Siffiqi, "Russians in Germany: Founding the Post-war Missile Programme," *Europe-Asia Studies,* 56. no. 8 (Dec., 2004): 1131-1156, http://www.jstor.org/stable/4147400.

[9] Pamela E. Mack, editor, "Introduction," *From Engineering Science to Big Science*, http://history.nasa.gov/SP-4219/intro.html, accessed 1/31/12.

[10] Larry Schweikart, *The Hypersonic Revolution Case Studies int eh History of Hypersonic Technology, Volume III: The Quest for the Orbital Jet: The National Aero-Space Plane Program (1983-1995)*, Bolling AFB, DC, 1998, iii.

According to Schweikart, NASA and the Defense Advance Research Projects Administration (DARPA), such a series of technological demonstrations would fail; a broad-front approach stood a better means of acquiring the support for such a huge process. He termed this need for an immediate tangible outcome which he termed a "fly something, fly anything" approach to sustaining support. What was needed was a way of "putting 'hype' into hypersonics."[11] Senior managers believed that the NASP effort needed a publicity campaign rather than a scientific approach. The author wrote, "Mobilizing the political support necessary for the program, they concluded, demanded more than boring flight tests of scramjets on rockets or unromantic boundary layer experiments."[12] In other words, this effort would be acutely focused on technology and not science. They had not realized that the heat barrier rather than congressional support stood in their path. Their attitudes and behaviors displayed a distinct techno-determinism that Americans felt comfortable with. Reagan's aero-space plane was just another step in progress and not a moment to conduct basic research and a different approach. The program failed because of this technology world view. To believe the goals could have ever emerged without science and its "unromantic boundary layer experiments" is baffling. In fact what is decidedly 'unromantic' is the history of NASP's demise which Schweikart attributes to structural management, budgets, internecine bickering, and overall failure.

Former Soviet Union Science and Culture

Slava Gerovitch, a 1992 Institute for the History of Natural Science and Technology, Russian Academy of Sciences, Moscow, and 1999 History and Social Study of Science and Technology, MIT, graduate, described just how important Soviet science was to Marxist ideology in an article addressing how Russian history has changed from a black-and-white recount of facts, to one at least for younger historians, to social, cultural, context based history. In 1990, upon learning of this new method, the retired editor of the *Problems in the History of Science and Technology* journal argued that this was "extreme externalism" and it "leads to the slurring over and even erasing the boundary between science and ideology, and this predetermines the end of science and makes it

[11] Ibid., 3-4.
[12] Ibid., 4.

possible to conceive of scientists as proponents of an alien ideology, resulting in grave consequences."[13] This is the kind of power that would make most historians swoon.

Writing in 1949, Lewis S. Feuer points out that "pragmatism" is applied to both the Soviet and US and based the distinction on philosophical and technological grounds. Explaining that Soviet industrial production in 1928 was approximately the US's 1904 rate demanded what Lewis termed the "epistemologic corollary that scientists' efforts should be directed toward practical, socially useful ends."[14] However Feuer points out that this constituted a non-scientific imposition. From this perspective the concept did apply to both countries sciences.

During WWII the Soviets displayed a great deal of pragmatism in spite of historical materialism. The regime invoked the term 'Holy Russia', in appealing to every Soviet citizen to join a united effort to support the 'Great Patriotic War'. Stalin restored the Patriarch, abolished the Communist International (Comintern): and allowed open relations with America. Some Soviet scientists even dared to publish research in US journals. This period of openness was short lived. In August 1946, Andrei Zhdanov, appointed by Stalin to oversee cultural affairs, attacked several Leningrad periodicals and the next year set up the Communist Information Bureau (Cominform).[15]

Pragmatism in philosophy has a unique meaning: "a theory that a proposition is true if holding it to be so is practically successful or advantageous."[16] The proposition, as it turns out, does not necessarily have to be true – if accepted, it is an assumption. Noted historian David Joravsky described it as "practical utility judged by current political authorities arranged in a strict though violently fluctuating hierarchy under Stalin."[17]

In a "Dialogues About Knowledge and Power in Totalitarian Political Culture"

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[13] Slava Gerovitch, "Perestroika of the History of Technology and Science in the USSR: Changes in the Discourse," *Technology and Culture*, 37, no. 1, (Jan., 1996): 133, http://www.jstor.org/stable/3107203, accessed 3/23/10.
[14] Lewis S. Feuer, "Dialectical Materialism and Soviet Science," *Philosophy of Science,* 16, no. 2, (April 1949): 112, http://www.jstor.org/stable/185129, accessed 11/16/09.
[15] Dimitri von Mohernschildt, "Postwar Party Line of the All-Union Communist Party of the USSR, Russian Review, 9, no. 3 (July, 1950): accessed 26 March 2010, http://www.jstor.org/stable/125761.
[16] Thomas Mautner, *The Penguin Dictionary of Philosophy, Second Edition*, (London: Penguin Books, 2005): 485.
[17] David Joravsky, "The Stalinist Mentality and the Higher Learning," *Slavic Review*, 42, no. 4 (Winter 1983): 586, http://www.jstor/.org/stable/2497369, accessed 11/16/09.

(1991): Russian historian Alexei Kojevnikov, Ph.D. a recent graduate (1989) of the Moscow Institute for History of Science and Technology, discussed differences in Cold War perceptions regarding Soviet, now Russian science in the West. He was understandably sympathetic to his native country, but laid bare some critics' notions of history, power, and science. Ideologically, Soviet leadership claimed a science-based doctrine that needed science to legitimize the claim. While this was a flawed notion to many in the West, it was nevertheless true in the USSR. Kojevnikov then challenged readers to examine the validity of western ideology that claimed pure and apolitical science – one that was equally flawed.[18] He argued that what other words but "scientific purge" could one use to describe McCarthyism and Teller's attack on Oppenheimer? Nevertheless, Stalin's purge killed millions which makes it a flawed comparison. In this case, Kojevnikov was guilty of relativity in comparing the two historic episodes only on conceptual versus empirical outcomes.

In 2008, Kojevnikov wrote about "The Phenomenon of Soviet Science" explaining that after WWI, the Bolsheviks believed science was an ideological ally and key to economic, social, and political progress. They believed science provided the "worldview to unseat the power of religion and superstition of the minds of people"[19] and of course, Marxism explained social progress and history. The Soviet Union followed the German model in establishing institutes of pure science for physics and biology. These places attracted the best in the field, received the most modern equipment, and generous facilities. In return, the Bolsheviks imposed the requirement that pure science, a concept they rejected for its exclusionary implications, would support their practical economic goals.[20] This "Faustian bargain" demanded that "scientists lost much of their autonomy and independence but acquired more social prestige and de facto influence on politically important decision making."[21] Additionally, Gerovitch termed this in Cold War language that "Soviet scientists and engineers were caught between the Scylla of

[18] Alexei Kojevnikov, "Dialogues About Knowledge and Power in Totalitarian Political Culture," HSPS, 30:1 (1999): 227-247, http://www.history.ubc.ca/sites/default/files/akojevnikov/documents /1999Dialogues.pdf, accessed 3/16/12.
[19] Alexei Kojevnikov, "The Phenomenon of Soviet Science," *OSIRIS*, Vo. 23, (2008): 115-135, http://www.history.ubc.ca/sites/default/files/akojevnikov/documents/2008Phenomenon.pdf, accessed 13/6/12.
[20] Ibid., 121.
[21] Ibid., 122.

national defense and the Charybdis of ideological purity."[22]

Loren Graham compared and contrasted the US and USSR's overall structures in "Big Science in the Last Years of the Big Soviet Union." Both had large universities with state support, but while the US universities conducted fundamental science, the Soviet Union professors limited their activities to teaching and institutes carried out basic research. While the American Academy of Sciences held a more honorific title and published reports, the Russian Academy of Sciences (RAS) both conducted and regulated basic research and amassed an inordinate, even imperial power in its role. He invoked Alexander Vucinich's detrimental characterization in "Empire of Knowledge: The Academy of Sciences of the USSR (1917-1970)" (1984). Graham explained that this came from Peter the Great's creating the Russian Academy of Science in 1725 because of Russia's lack of basic science establishments. State support remained in place even after Russia established its university and this carried through the Soviet era.[23]

Graham offered up a more historic explanation as compared to those who point at the USSR for empowering the RAS. He explained that Peter aimed his reforms at the Slavophils, representatives of Old Russia, ultraconservative, and suspicious of foreign external influence. Consequently science reform became a means of invoking social change. Addressing the still prevalent assumption that Russian scientists were excellent theoreticians but weak on technical applications, Graham argued that from the beginning of the Industrial Revolution, Russia imported equipment and the scientific support needed which then left the country with no experience to build on. He argued that many successful former Soviet scientists', such as Igor Sikorsky and Alexander P. de Seversky in aviation, just to name a few, did occur in countries with the industrial base to build.[24] This example countered the tech-import explanation for the Russian's applied science weakness and contradicted this Soviet, now Russian, historic technological weakness.

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[22] Slava Gerovitch, "'Mathematical Machines' of the Cold War: Soviet Computing, American Cybernetics and Ideological Disputes in the Early 1950s," *Social Studies of Science*, 31, no. 2, http://www.jstor.org/stable/3183114, accessed 11/16/09.
[23] Loren Graham, "Big Science in the Last Years of the Big Soviet Union," *Osiris*, 2nd Series, 7, (1992): 49-71, http://www.jstor.org/stable/301767, accessed 4/16/09.
[24] Loren Graham, "Science In Russia: Foreign and Domestic Influences," *Comparative Education Review*, 12, no. 3 (1968): 231, http://www.jstor.org/stable/1186392, accessed 11/28/08.

Second Law of Thermodynamics

The second law of thermodynamics is a law because it describes behavior when a closed system at equilibrium is opened and becomes entropy (chaos). Systems can range from an individual atom to the length and breadth of the universe. Energy creates heat and the work done always leads to some dissipation. There is no avoiding this outcome. Entropy is chaos until the energy is dissipated and equilibrium restored.

The scientific term thermodynamics describes this process. The First law of Thermodynamics states that a "closed" system, one which contained boundaries with no energy added or subtracted is in equilibrium and energy is conserved. Its corollary is the moment before the Big Bang which Presidential Science Advisor D. Allan Bromley described as enormously hot, extremely compact, and an extraordinarily strange object some 18 billion years ago."[25] This was a closed system or in equilibrium. The description is only a hypothetical "ideal" condition from which to evaluate energy potential to its dynamic state. The Second Law of Thermodynamics states that energy produces heat. Whether maintaining the body's own core temperature, or moving mountains, there is a residual unused amount of dissipative energy and is termed nonequalibrium. Linear or nonlinear are also used interchangeably to describe the process.

The US Air Force and the US Navy share a common scientific base in fluid dynamics: one operates primarily within the earth's atmosphere and the other in water. Both are joined by common scientific research on how their vehicles interact with the surrounding medium. In 1992, the US Navy contacted the National Research Council and requested a report on the emerging field of nonlinear science. The 1997 report offered insights into the scientific efforts to understand the field. The NRC stated that, "Chaos has become a popular subject for examination in a number of research areas."[26] While most might understand what connecting 'science' and 'chaos' might mean, taken at face value, the concept imply implies a structure that demanded rigorous standards,

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[25] D. Allan Bromley, "Physics: Natural Philosophy and Invention," *American Scientist*, 74, no. 6 (1986): 636, http://www.jstor.org/stable/27854360, accessed 9/27/11.

[26] National Research Council, "Nonlinear Science," *National Academy Press* (Washington DC, 1997): xii, http://wwwna edu/catalog/5833.html, accessed 10/24/11.

careful analysis, and exacting reporting for subsequent research. On the other hand, chaos lacks coherence, structure, or regularity.

The report goes on to characterize what it calls the "nonlinear phenomena."[27] First, the research was inherently interdisciplinary and gained when experts from different programs collaborated based on their expertise. Second, methodology required a balance between modeling, analysis, computation, and experiments. Lastly, the report stated that solutions displayed a "convoluted (nonlinear) path and flourishes best in environments in which basic researchers and applied technologists are encouraged to interact and are rewarded for doing so."[28]

Let's say that life is the constant balancing of knowledge: the known and the unknown; certainty and uncertainty; old and new; or the being and becoming as suggested by Ilya Prigogine's 1980 *From Being to Becoming: Time and Complexity in the Physical Sciences*. From his perspective the 'being' and 'becoming' are explained by the first and second laws of thermodynamics.[29] The first law posits that a closed system will reach equilibrium when left to itself and he uses the example of poring two different fluids together. At the atomic level the particles mix by themselves and reach a static "equilibrium" state. Most scientists are empiricists and the accepting plasma aerodynamics takes a different way of thinking. They are two different world views.

Induction uses probability as the logic of justification it is after the fact. Global warming created an acute awareness of how individual actions impact our world. The heat created in energy consumption has grown to such a concern that energy is becoming a currency, a common denominator for human activities. Industries trade carbon-swap credits, mortgages now include energy-use clauses, and citizens of the world are connected by the simple act of recycling consumer by-products. There is a synchrony with every person in the world aimed at reducing the energy and its heat generating byproduct. Gone are the days when scientists could ignore the process. The stakes are high and most recognize the human race cannot progress along lines that could lead to its

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[27] Ibid., 1.
[28] Ibid.
[29] Ilya Prigogine, *From Being to Becoming*, (New York: W. H. Freeman and Company, 1980).

own extinction. Scientists like Prigogine argue that Newtonian and Quantum Physics do not offer answers because they do not include energy's primary element of irreversible time or the so-called "Arrow of Time."

This essay examines plasma aerodynamics and the adoption of a holistic philosophy within the aerospace community in its efforts to develop a hypersonic aerospace plane. Ilya Prigogine's writings provide the basis of this dissertation's efforts because he backs his philosophical views with references to the laws of thermodynamics which happen to be the foundation of plasma aerodynamics. Prigogine's accomplishments include a 1977 Nobel Peace Prize in chemistry and for his work on the thermodynamics of nonequalibrium. The universe is driven by nonequalibrium and can only be understood in probabilities. He seeks to reestablish time. Evolution follows time, but physics is reversible. Complexity is "systems with given boundary conditions have more than one solution." Prigogine's ideas capture the central issue in hypersonic aerospace development, that of the incredible heat generated by flying at 18,500 miles per hour through the earth's atmosphere.[30] That both Newton and Einstein observed science whereas Prigogine acts within. It is a subtle holistic philosophy with energy transformation by man as its trigger and for man to consider the impact of the transformation on the environment.

The shift from empiricist-engineering focus to realist-thermodynamics philosophy and the resultant energy-based approach bridges empiricists and realists. Prandtl opened aerodynamics to fluid mechanics, but now thermodynamics is needed because the hypersonic boundary layer entailed physics and the creation of air flow unfamiliar to most aircraft designers. This constitutes the introduction of irreversibility into aerodynamics.

There are two ways to overcome the so-called heat barrier generated during hypersonic aerodynamics: specially designed and fabricated material which so far has failed or plasma aerodynamics which offers a method of engineering the phenomenon to generate power and alter the effect. Prior to the Cold War's end, the US aerospace

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[30] Ilya Prigogine and Isabelle Stengers, *Order Out of Chaos: Man's New Dialogue With Nature*, (Toronto; New York, London, Sydney: Bantam Books, 1984): xi.

community approached hypersonic designs through the former; however, since the Soviet Union's dissolution, scientists – specifically United States Air Force scientists, – embraced the latter. Up to that time only the hypersonic propulsion experts worried about thermodynamics, but afterwards the approach encompassed the entire process. In the same manner while the Cold War was over, in Russia chaos prevailed.

Writing in *The Logic of Scientific Discovery*, Karl Popper stated that, "The central problem of epistemology has always been and still is the problem of the growth of knowledge. *And the growth of knowledge can be studied best by studying the growth of scientific knowledge*."[31] True science, according to Popper, whether correct or incorrect, had to be falsifiable; hence, a "pseudo-science" such as astrology could not be disproven. His theory's attraction is in its simplicity. Most agree that science explains some natural truths and that there exists a sharp line between science and un-science. Thomas Kuhn, on the other hand, examined the history of science to proclaim a much broader view that science is more about "paradigms" rather than some irreducible fact. Then there is Ilya Prigogine a Nobel Prize winner in chemistry. I will first deal with the application of Kuhn's theory and then Poppers on the history of Former Soviet Union -Air Force collaboration on plasma aerospace science. This history must embrace elements of both approaches because their collaboration combined two separate national scientific establishments which had to understand each other's separate cultural approaches (Kuhn) before reaching the point of falsification (Popper).[32]

Philosophically, Popper and Kuhn express an intractable dichotomy in efforts to explain how humans think and act. Thinking and action are two distinct and separate entities and however hard man tries they cannot be unified into one rationally unified theory. Plato exemplifies Popper's falsification theory with "realism" that exists only in the mind (cognition) and Aristotle's "Golden Mean" that takes action into consideration. It is simply impossible to weld the two together in one entity so we are left with an imperfect means of expressing ourselves and the world around us. Prigogine sought to

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[31] Karl Popper, *The Logic of Scientific Discovery*, (London; New York: Routledge, 1992): 15.
[32] Michael Ruse, *Mystery of Mysteries*, (Cambridge, Mass: Harvard University Press, 1999): 13-36.

bridge "stillness and motion" based on the Second Law of Thermodynamics.[33]

Consequently, we are left with a not-so-perfect solution that has eluded mankind's greatest thinkers. If dichotomy is a human condition, then reason and action must be connected somehow. Most chose to place these two entities connected on one line such as a scale because neither Kuhn nor Popper can disprove the other's theory. Neither Popper nor Kuhn discard objective and subjective behavior: their differences lie in where they place their emphasis. Critics charge both of extremes; I would argue that their expressions are simply another representation of a flawed human condition which places exactness and uncertainty on a sliding scale, or, as I say probability. How can one use these terms with the exactitude implied with science's "laws" of nature? Such, then is this analysis that agrees with Popper's epistemological assumption regarding knowledge.

Richard P. Feynman, one of the foremost physicists in the twentieth century, stated that the one most important scientific knowledge was that "all things are made of atoms – little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another."[34] All science was based on this fact. Then Feynman made a deterministic statement in that for biology "there is nothing that living things do that cannot be understood from the point of view that they are made of atoms acting according to the laws of physics."[35] It was these single atoms combining that led to the complexity we saw around us. To combine, some kind of energy must be added, heat generated, then diffusion and return to equilibrium. The complexity was explained in chemistry which relied on the second law of thermodynamics.

Science philosopher Nancy Cartwright criticized Feynman for stating there were laws of nature. Atomism was usually the charge when some argue that atoms and their behaviors become deterministic. Her chief contention was that physics' laws did not tell us how things behaved. There are two kinds of laws: one based on realism and

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[33] Ilya Prigogine and Isabelle Stengers, forward by Alvin Toffler, *Order Out of Chaos: Man's New Dialogue with Nature*: 22.
[34] Richard Feynman, "Atom in Motion," in *The World Treasury of Physics, Astronomy, and Mathematics*, ed. Timothy Ferris, (Boston: Little, Brown and Company, 1991): 3.
[35] Ibid., 17; see also, Alexander Rueger and W. David Sharp, "Simple Theories of a Messy World: Truth and Explanatory Power in Nonlinear Dynamics," *The British Journal for the Philosophy of Science*, 47, no. 1 (1996): 96, http://www.jstor.org/stable/3104129, accessed 1/9/12.

supported with mathematics, the other described dynamics. Again the laws of thermodynamics fit these two categories. There were simple physical laws, but in order to phenomenologically describe the outcome (temperature, volume, pressure) it became much more complex and therefore lost its relationship to the law and became simply a model instead.[36] However she seems to confuse a law stated in realism terms and the empirical results which are much more complex. Cartwright mixed two different processes: laws were concepts, whereas in order to describe how things were one must incorporate additional information like energy and dynamics. Two authors analyzing Cartwright's thesis concluded that theory => model => phenomenon blocked the empirical phenomenon feedback to the theory usually by induction. Scientific realism assumed the law's veracity which for Cartwright is another metaphysic assumption.[37]

In a philosophic discussion on quantum mechanics Helmut Tributch provided interesting insights into the challenges both science and philosophy face in comprehending thermodynamic law. He asserted that, "Philosophers today have difficulties following fundamental scientists into a world coexisting with no-causality and non-locality."[38] Lee Smolin elaborated a bit more on the profound implications of the 'closed' first law of thermodynamics. It meant that there was no external organizer. It eliminated the idea of a deity. Most people found this philosophical implication a very uncomfortable idea because humans have a natural inclination to ask who or what made things and often resorted to some sort of ethereal power when all else failed.[39]

If physics investigated fundamental natural laws, then it became fertile grounds for arguing for and against them. These arguments usually centered on cases of determinism or underdeterminism. The first usually implied the law's extension into human behavior, the second that science was granted assumed truth. The second law of thermodynamics was not deterministic because its answers were stated as probabilities.

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[36] Linda Cartwright, "Do the Laws of Physics State the Facts," in Marin Curd and J. A. Cover, eds., *Philosophy of Science: The Central Issues*, (New York; London: W. W. Norton & Company, 1998): 865.
[37] Alexander Rueger and W. David Sharp, "Simple Theories of a Messy World: Truth and Explanatory Power in Nonlinear Dynamics," *British Journal for the Philosophy of Science*, 47, no. 1 (1996): 94, http://www.jstor.org/stable/1215828, accessed 9/1/12.
[38] Helmut Tributsch, "Quantum Paradoxes, Time and Derivation of Thermodynamic Law: Opportunities from Change of Energy Paradigm," *Journal for General Philosophy of Science /Zeitschrift fur allgemeine Wissenschaftstheorie*, 37, no. 2 (2006): 287, http://www.jstor.org/stable/25171348, accessed 7/10/11.
[39] Lee Smolin, "The Self-Organization of Space and Time," *Philosophical Transactions: Mathematical, Physical and Engineering Sciences* 361, no. 1807 (2003): 1081.

Sir Isaac Newton initiated the age of science by examining astronomic observations and explaining universal gravity as the force that held the planet in their orbits. This led to the "clockwork universe" as mechanistic, timeless, and deterministic. However, mathematically, time could be a negative or positive value and still equal the same sum leading to the term "reversibility" or "time symmetry." In 1785 French physicist Charles Coulomb established the theory of electrostatic forces by evaluating the attractive and repulsive forces of electrically-charged objects. In England, Michael Faraday conducted experiments with magnetic fields and electricity and showed that, "Moving charges generate magnetic fields, while magnetic fields in motion produce electric current flow through conducting material."[40] This opened up the possibility of using the movement for work in engineering terms. James Clerk Maxwell proved mathematically that electricity and magnetism were manifestations of the same electromagnetic phenomenon. Maxwell predicted that an electromagnetic signal would move at the speed of light within a vacuum which implied light was a form of electromagnetism.[41] These "action-at-a-distance" findings did not fit in Newton's clockwork, mechanistic world.

Thermodynamics as a science began after James Watts' steam engine invention for the Industrial Revolution and efforts to measure the devices' efficiency. French engineer Sadi Carnot showed that the measure must embrace the idea that heat always flows from a hot environment to a cooler one and the temperature difference indicated the machine's efficiency. In this case, the steam engine converted heat into work; however, he mistakenly assumed no lost heat. Prescott Joule approached the phenomena from the opposite direction by compressing air and creating heat for work. He showed that a "given amount, of whatever kind, produced the same amount of heat,"[42] and to honor him a Joule became the standard measure of energy.

By mid-century the laws of conservation had been formulated and accepted, Rudolf Clausius reexamined Carnot's work and suspected that in the heat transfer cycle, some energy would escape. Based on experiments, Clausius formulated the second law

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[40] Peter Conveney and Roger Highfield, *The Arrow of Time: The Quest to Solve Science's Greatest Mystery*, (Flamingo: United Kingdom, 1991): 35.
[41] Ibid.
[42] Ibid., 150.

of thermodynamics which stands as a "phenomelogical law" because it contained measurable variables like temperature, pressure, and volume independent of theory.[43]

Technology

One way of differentiating national science strengths and weaknesses is to examine each country's boundary between science and technology. The first seeks natural laws in order to better understand nature. The second directs its efforts to making something. Applied science (technology) often uses basic science, but not always and there are many cases in which ingenuity and design played the dominant role. The Wright Brothers, for example, relied on keen observation and engineering to successfully fly the first manned, powered, and controlled flight. Other nations took up the Wright's technological success and progressed far and beyond what American aircraft manufacturers did until the end of World War I. It was only after that war that US policy makers realized aviation required national support in terms of airfields, manufacturers, and scientists. National, cultural examinations of the science-technology boundary displayed country advances or deficiencies and provided insight into the results when two previously separate programs came together.

There is an element of technological determination on science. Aerodynamics investigates airflow around surfaces. Different techniques are used to visualize this dynamic, but in order to analyze what is happening at the atomic level the researcher needs instruments. During the Cold War, western countries either manufactured such devices or acquired them from foreign sources. The West embargoed state-of-the-art instruments and computers to the Soviet Union. This can be seen in the Russians reputation for very simple experiments in order to prove theories. The US, on the other hand, either manufactured technology or bought it which made them better experimentalists. Speaking to the Russian Academy of Science in 1965, Piotr Kapitza proclaimed a "technology gap" and that "we must urgently look for a way to compensate for this lag."[44] Hans Bethe had talked to several Soviet theorist scientists and they commented that they put their best people in high-energy physics, but were disappointed

[43] Ilya Prigogine and Isabelle Stengers, *Order Out of Chaos*, 106; also, Peter Conveney and Roger Highfield, *The Arrow of Time*, 215.
[44] Piotr Leonidovich Kapitza, "Theory, Experiment of Practice [compiled speeches]," Air Force Systems Command: Foreign Technology Division, AD 653561, 13 February 1967, 13. (From an address to the general meeting of the USSR Academy of Sciences 13 December 1965.)

with their experimentalists. Bethe went on to say that he was quite impressed with Kapitza. While at Cambridge, Kapitza followed Rutherford who was an experimentalist and helped Kapitza acquire the technology he needed. Bethe termed the experimentalists as having some sort of apparatus, components, or building such device – for a theorist, resources might not be a major factor.[45]

US Science and Culture

In *The Physicists: The History of a Scientific Community in Modern America* (1978) Daniel J. Kevles suggests that Protestantism and its drive to master nature lies behind the US's focus on applied versus basic science.[46] When most American taxpayers consider Big Science, they combine basic science and technology together. The population is more willing to support the latter over the former. Empiricism reigns in most people because they can see, feel, and hear, in order to ascertain whether it justified the amount of cost. Science, on the other hand, is much harder for laypersons to evaluate in terms of economies. Theory and experiments usually require mathematic skills which are indecipherable to most.[47]

In war the price of science and technology indifference has a ghastly price. On the other hand, tactics can cancel superior weapons. During the Civil War, the armies engaged at first in Napoleonic firing lines based on mass musket fire. These firearms required close ranges to be effective. However, grooved rifle barrels and Minnie balls increased "standoff" range for riflemen. The technology had passed the tactics and led to terrible casualties. World War I saw the horrors of chemical warfare and machine gun fire. Science and technology created these weapons.

During World War II, tanks and aircraft which first appeared in WWI were combined in Blitzkrieg. Poland, France, and England experienced these attacks while the United States watched on. However, the US had learned something from the previous war. Even though the first controlled, powered flight took place in 1903, America had no state-of-the-art combat aircraft when it entered the war. The US pilots flew French and

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[45] Dr. Hans Bethe interview by Charles Weiner and Jagdish Mehra, 27 October 1966, Niels Bohr Library & Archives, *American Institute of Physics*, College Park, MD USA, www.ai org/history/ohilist/LINK, accessed 2/14/12

[46] Daniel J. Kevles, editor, *The Physicists: The History of a Scientific Community in Modern America*, (New York: Knopf, 1977).

[47] Pamela E. Mack, editor, "Introduction," From Engineering Science to Big Science, http://history.nasa.gov/SP-4219/intro.html, accessed 1/31/12.

English planes. As early as 1939, President Franklin D. Roosevelt ordered the Army Air Corps to increase its aircraft inventory from approximately 2,000 to 10,000 in preparations for another war in Europe.[48] However, even with that foresight, the aircraft sent over to fight alongside the Allies were initially technologically inferior to the battle-hardened Germans and Japanese.

This happened because after WWI during the interwar years, the Air Corps embraced the writings of Italian General Giulio Douhet in *Command of the Air*. Based on Italy's use of Caproni bombers against Austrian ports, Douhet foresaw strategic aerial warfare as armadas of long-range bombers striking at the enemy's ability to wage war far behind the front lines. The combat at the front had been supported by industries and workers which stood untouched by attacks. In addition, air assault could bomb civilians who support the conflict and attack the politicians responsible for the conflagration. These attacks could be with bombs, bacteria, or gas.[49] Nations outlawed bi-chemical weapons; however, the idea of overflying trench warfare and striking at the heart of the enemy with high explosives remained. The Air Corps subsequently shaped its doctrine and aircraft to carry out these missions.

The military was well aware of this issue because their concern lies primarily with technology and how it helps prevail over the enemy. At the same time, they were acutely aware that in many cases, state-of-the-art hardware required the same level of basic research. The November-December 1969 *Airpower Journal* included a surprising number of science-related articles (7 of 10). The US Air Force publication, then as now, was the top forum for aerospace power discussions among Air Force leaders, but also open to anyone with thoughts on the issue. Previous editions focused on the Soviet Union, Vietnam, and space as an emerging operational issue. The general feeling among the authors was a crisis in military 'big science' because the escalating costs of the Vietnam War, public outcry against basic research for weapons used in the conflict, Agent Orange defoliant for instance, and overall decline in public support for US military forces in general. One author argued that in contrast to World War II scientific

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[48] Bernard C. Nalty, editor, *Winged Shield, Winged Sword: A History of the United States Air Force, Volume I, 1907-1950*, (USAF: Washington, D.C., 1997): 155.
[49] Giulio Douhet, translated by Dino Ferrari, *The Command of the Air*, (New York: Coward-McCann, 1942): `7.

contributions which garnered support of basic science due to the successful conclusion of the conflagration, the institutions now for the first time underwent scrutiny.[50]

Scientists such as Dr. Arthur Kantrowitz echoed the impact on his work at the time. Kantrowitz joined NACA in 1935 and established himself as a pioneer in fluid dynamics with early wind tunnel tests. He was instrumental in the nascent day's plasma aerodynamic basic research. After the war, he joined the Cornell engineering physics department, taught statistical mechanics, thermodynamics, and gas dynamics to aeronautical engineers. During an interview he stated that in 1969 "we saw the DOD research budget going down, or at least not growing, and we, together with I guess the whole scientific community, got kind of tired of Defense work in that period."[51]

Kantrowitz had great respect for Soviet scientists. He described how he got involved with research for a solution regarding the incredibly high-temperature intercontinental ballistic missiles encountered during reentry. The problem was that the nose cones melted away while transiting through temperatures hotter than the surface of the sun. At a cocktail party he met the head of AVCO Corporation, a company that Theodore Von Karman established after the war. The executive described how the company was working on the challenge and Kantrowitz mentioned he could reproduce the temperatures in the laboratory.[52] Kantrowitz recognized the separation between fluid mechanics and physics. There were scientists with knowledge on both fields, and most had worked on the atom bomb Manhattan Project. As a result, there were just too few in the early 1960s.[53]

All the authors acknowledge the science-technology divide and the difficulty in uniting the two. One problem with justifying research was that this often occurred only in hindsight. World War II was the first war in which scientists played a major role. They provided the theory for technologists to build the atom bomb, proximity fuses, radar, and many other inventions. Justifying the science then was quite simple because it

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[50] Brigadier General Harvey W. Eddy, "Research Planning and Coupling in OAR [Office of Aerospace Research], *Air University Review*, (1969): http://www.airpower.au.af.mil/airchronicles/aureview/1969/nov-dec/eddy.html, accessed 10/11/2011.
[51] Dr. Arthur Kantrowitz interview by Dr. Joan Bromberg Bromberg, 30 October 1984, Niels Bohr Library & Archives, *American Institute of Physics*, College Park, MD USA, www.ai org/history/ohilist/LINK, accessed 2/12/12.
[52] Ibid.
[53] Ibid.

helped built the implements of war. Another writer pointed out that in contrast despite those spectacular successes 99 percent of research were "tiles in a mosaic: individually they are not very meaningful; it is only when they are arranged in the proper pattern that a picture emerges."[54] It often takes many years to transfer the knowledge to technology. While this relationship might be glossed over by politicians and the public during conflicts, basic science results became far more difficult to support during peace time.

One of the articles covered the role of foreign scientists. Their most well-known success came with the Manhattan Project in which many internationally acclaimed minds fleeing the Nazi's reach wound up working on the atomic bomb. In 1969, the Air Force European Office of Aerospace Research (EOAR) issued around 300 contracts to distant researchers. Many were world leaders in their fields and acknowledged in their colleagues' awards and recognition. The author goes on to highlight four scientists and their contributions to Air Force research. Professor Ilya Prigogine was actually born in Russia, but his White Russian father moved the family to Germany then Brussels to escape communism. His pioneering research in statistical mechanics received international recognition and he subsequently taught at Harvard, Columbia, Manchester, and at the time of the writing resided as Director of the Institute of Statistical Mechanic and Thermodynamics, University of Texas. In addition to authoring and coauthoring four standard texts in the field, he also later published several philosophical works based on thermodynamics. In essence, the field observed macro behavior, energy-related flows, by applying micro, in this case atoms, laws. For the Air Force, these issues became relevant in cases of propulsion (engines) and fluid dynamics such as air flow next to an aircraft in flight.[55]

Then as it does now, the Air Force sought non-military science to assist in this uncertain process. First, the service has its own basic research staff and facilities. They often act on behalf of the Air Force in evaluating science outside the military or conduct restricted, classified projects. Secondly, the Air Force supports university, research

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[54] Lieutenant Colonels Joseph Martino and Claude D. Stephenson, "Orienting Today's Research to Tomorrow's Air Force," *Air University Review*, (Nov-Dec 1969): 1, http://www.airpower.au.af.mil/ airchronicles/aureview/1969/nov-dec/martino.html, accessed 10/11/2011.
[55] Colonel Burt R. Williams, "The Foreign Scientist and the Air Force," *Air University Review*, (Nov-Dec 1969): 1, http://www.airpower.au.af.mil/ airchronicles/aureview/1969/nov-dec/williams.html, accessed 10/11/2011.

institutes, and industry. Third, Air Force scientists conduct continuing exchanges in day-to-day contacts, technical meetings, and by attending symposia. Fourth, the researchers work closely with the engineers in their projects. Lastly, Air Force scientists work closely with the services in-house education institutions.[56]

In 2005, Dr. Mark Lewis, USAF Chief Scientist, and Dr. J. Douglas Beason wrote in a similar vein in examining recent science and technology advances since 1969 and their profound impact on war. In addition to the successes mentioned by earlier authors they added precision-guided weapons, semiconductors, computers, stealth technology, global positioning system (GPS): and lasers. Looking into the future they described hypersonic missiles that could strike quickly at far distances and directed-energy weapons that strike at the speed of light. These weapons not only increased the likelihood of destroying a specific target with minimal damage, but also reduced the number of US forces exposed to combat. The writers included research published on the manpower density on the battlefield showing how numbers have dropped from an average of 8,200 during the Civil War, 2,200 in WWII, to 0.5 in Gulf War II.[57]

Science and technology had also dramatically reduced the number of aircraft needed to destroy a target. During WWII, in order to demolish a German 200,000-square-foot factory took on average 108 B-17 bombers with 1,080 crewmembers carrying 648 bombs, and 100 single-engine fighters with reasonably clear weather during daylight. Usually, 15 bombers (150 men) would not return to base that day. Contrast those numbers to present when a B-2 stealth bomber with 2 crewmembers, carrying GPS-guided munitions attacking at any time under the worst weather conditions could not only destroy that factory, but several others during one flight. Not only that, but now remotely piloted systems carry no crew, are remotely controlled, and just as accurate.[58]

The crux of the article was what they call the "intention to innovation" period; the time from discovery to application. Citing several 19th-century findings such as Rudolf Clausius's Second Law of Thermodynamics, James Clear Maxwell's Kinetic Theory of Gases, Louis Pasteur's work in food spoilage, and J. W. Gibbs's chemical

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[56] Brigadier General Harvey W. Eddy, "Research Planning and Coupling in OAR."
[57] Dr. J. Douglas Beason and Dr. Mark Lewis, "The War Fighter's Need for Science and Technology," *Air & Space Power Journal*, (Winter 2005): http://www.airpower.au.af.mil/ airchronicles/apj/ apj05/win05/beason.html, accessed 10/11/2011.
[58] Ibid.

thermodynamics led to many 20th-century technology advances in radio, television, computers, bacteriology, and modern biology. Their point was that scientific discovery to technology was never "direct but long and circuitous, rarely linear, and never straightforward."[59] Reflecting this science, cause and effect exists, but are less than absolute.

At the core of all these articles lay the difficulty of identifying and developing critical scientific discovery for future conflicts. Hypersonic cruise missiles and aircraft fill a military need for quick strikes over long ranges and on-demand space flight versus the months or years needed to launch rockets into space.

Scientific Realism

Scientific Realism assumes theoretical entities, such as electrons and quarks, exist and explain observable phenomena. It is often used with other realist concepts like values, culture, mentalities, and many others.[60] In addition to the invisibility of the atomic world, the concept is also known as scientific underdetermination because of the probabilistic research results. Reflecting this scientific, cause and effect exist, but are less than absolute.

A philosophy-history approach is the best way to explain this topic because it entails a debate among Former Soviet Union and US scientists over a theory and its experimental results. As with the great philosophical debates since Plato and Aristotle, the arguments also exhibit the hallmarks of realism versus empiricism. This is not to say that philosophy remained the same since then. Science continues to bring knowledge and practices that undergo scrutiny in both history and philosophy. Science constantly examines episteme, what we know and how we know it, by exploring nature. In addition within this examination is the impact of different national cultural mentalities. While assigning different values to different cultures can lead to terrible consequences, juxtaposing the different communities can lead to deeper understanding and as it turn out deeper scientific developments.

This research is an effort to follow an approach that Dr. Michael Ruse put forth in *Mysteries of Mysteries*. He opens with the prologue titled Science Wars with a

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[59] Ibid., 7.

[60] Thomas Mautner, *The Penguin Dictionary of Philosophy*, Second Edition, (London: Penguin Books, 2005): 521.

discussion on the test from the now infamous physicist Alan Sokal hoax that he describes as "Nonsense in polysyllables, pretending to be a serious contributions to knowledge."[61] The editors of *Social Text* took the hook line and sinker and published the article as scholarly, only to find out the author had intentionally used nonsensical language as a comment against the journal's cultural studies theme. Ruse points to this event as those eager to attack science because of the Cold War's impetus to fund the researchers. This history takes place at roughly the same time with the unification of Former Soviet Union and US Air Force hypersonic scientists.

Ruse goes on then to argue that these deconstructionists who criticize great scientists for personality traits and whether or not the individual was a good spouse or parent leaves mere mortals feeling quite satisfied that they were now equal to Newton, Einstein, and the rest of the scientific pantheon. His goal is "simply whether science should be considered something different and rather special – something with independent standards which in some way guarantee its truth and importance, which would merit societal support even if individual scientists are as fallible and untrustworthy as critics maintain."[62] Actually, scientists are just as apt to distrust their peers as shall be shown. He points to war and scientists' contribution as the "dark side." Scientists have contributed to the killing grounds, but just as many of them have failed to answer the call. Just think about how impotent science can be when jungles cover the terrain, or against the devilishly simple Improvise Explosive Devise; otherwise known as IEDs. In Iraq and Afghanistan these bombs constructed of nitrate, fuel, and a cell phone or garage door opener, things easily obtained, continue to kill and maim coalition forces despite the billions spent to defend against them. He then poses the fundamental question of philosophy through episteme, "How is one to reconcile the mind-independent reality of existence the obviously mind-dependent nature of so much of what we believe and think and use in everyday life?"[63] In defining exactly what episteme is, Ruse defines what is not: "If not epistemic, one is led at once to ask about the nonepistemic, cultural side of his [Charles Darwin] thinking."[64]

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[61] *Mystery of Mysteries*: 1.
[62] Ibid., 5.
[63] Ibid., 12.
[64] Ibid., 43.

Ruse's method is to examine both episteme and culture as antipoles that dominated 20th century science philosophy: Austrian-born Karl Popper and American Thomas Kuhn. They wrote in response to the Vienna Circle's logical positivism which upheld logic and mathematics according to the Platonic ideal. Their ideals smack of elitism, but Ruse explains their haughtiness as a reaction to the 1930's European instability during those interwar years. Carrying the nationalistic perspective, Kuhn's writings mirror American's distaste for privilege and seem to carry democratic, leveling tendencies. "Kuhn's account", according to esteemed philosopher Ernan McMullin who Ruse cites frequently, "of the paradigm changes that for him constituted scientific revolutions was taken by many to undermine the rationality of the scientific process itself."[65] European's often refer to American's "cowboy" mentality; reckless, averse to danger, impatience with precedence and always questioning authority. Ruse acknowledges that this "nationalistic", cultural aspect can only carry so far. Many Europeans counter American's cowboy cavalier attitudes by invoking the US's treatment of Native Americans and slaves. Popper represents the objective "scientific" truth and Kuhn the cultural influence.[66] Ruse writes that "I am simply claiming that when evolutionary scientists turn to language to express their findings, the words they choose are often laden with metaphors taken from the surrounding cultures."[67] Following Ruse's nation-historic rational, people born and raised during their formative ages in other cultures, like Ruse and this author, are acutely aware of society imprints and the life-long power they assert over individuals.

The crux of his writing is in "argument from design." He explains that Darwin and for at least some part of his early life, Charles believed in deism, the religious belief that God designed the universe like a clock and then allowed it to run autonomously on its own.

Europeans tend to be less religion-bound than Americans. Many find the fact that the number one bestseller in the US is the Bible quite amusing. Ruse, in fact, appeared as an expert witness before the 1981 trial brought by the American Civil Liberties Union

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[65] Ernan McMullin in Marin Curd and J. A. Cover, *Philosophy of Science: The Central Issues*, (New York; London: W. W. Norton & Company, 1998): 119.
[66] *Mystery of Mysterie*s, 236.
[67] Ibid., 239.

against Arkansas Act 590 which required teachers to teach "creation-science" along with evolution in public schools. Science, he argued, must be explanative, predictive, testable, confirmed, tentative, and ethical. The judge apparently agreed with him that creation-science did not meet the criteria and struck down the law. Reading the list all seem to fit into the Popper-Kuhn divide as scientific until one encounters the jarring word "ethical". How does one place a scientific explanation to a value when values come from an equally anomalous word "culture"?

Ruse points to McMullin 1982 "Values in Science" in which it was argued that science did indeed have "non-episteme" subjective character. Providing a 30-year retrospect to the Philosophy of Science Association conference, McMullin stated that values were based on emotions; therefore, "It seems plausible to hold that emotive values are alien to the work of natural science."[68] Then, of course, he proceeds to muddy the waters by saying that value could mean a desirable trait, or characteristic, which requires evaluation. McMullen goes on to say that "where the tension arises between value-judgment and not only the positivistic view of science but the entire classical theory of science back to Aristotle."[69] In other words the "tension" between Plato's realism and Aristotle's empiricism was as old as philosophy itself. He describes the logical positivist Vienna Circle as professing law-like ideals (nomothetic). Ideals, of course are not science. Popper relied on falsifying conjectures based on 'basic statements' he assumed as true rather than laws. These basic statements are, quoting Popper, "'reached in accordance with a procedure governed by rules,'" and the rules are determined by "various investigators, or consensus."[70]

This brings McMullin up to 1950 and what he terms a "watershed between classic theory of science and out as-yet unnamed post-logicist age has been variously defense since then."[71] For McMullin, values rush in where "underdetermined theory" abides. Pierre Duhem was a French physicist and philosopher and his writings were often cited in scientific underdetermination.

Games Gleick's popular *Chaos: Making of a New Science* argues that what made

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[68] Ernan McMullin, "Values in Science," *PSA*, 1982, 2: Symposia and Invited Papers (1982): 4, http://www.jstor.org/sable/192409, accessed 1/13/12.
[69] Ibid., 6.
[70] Ibid., 11.
[71] Ibid., 14.

chaos "new" was physicist's shift from particle properties, as in the continuing quest for the Higgs Boson, or as some call it the "God particle", to how such entities behave in dynamic systems. This research examines how scientists made a similar shift in aerodynamics. Thermodynamics' First and Second Laws describe this evolution. The first law states that in a 'closed' system, the law of conservation prevails; however, the second law dictates that an 'opened' system displays chaotic behavior. My research shows that the process of physicists' reluctant shift to dynamics follows Gleick's model. On the other hand, while Gleick uses Thomas Kuhn's psychological 'groupthink' paradigm model to examine philosophical implications, this work seeks such terms in thermodynamics. This is an evolutionary versus revolutionary examination somewhat analogous to crawl-walk-run. The Twentieth Century saw air-powered aircraft reach the first two stages, but ended before reaching its zenith in Mach 5 and above hypersonic aircraft. It is not that the science did not exist, but rather that the connections between certain research fields had not been unified. Chaos according to thermodynamics accomplished this particular process. The change also required the unification of two previously separated scientific communities. This occurred because two previously 'closed' systems came together after the USSR's collapse. The world and all its behaviors came under the laws of thermodynamics. One can argue that such statements are unrealistic, but stasis exists only in the minds of human beings – such conditions do not exist in Nature, therefore should be recognized as such. As particle and now dynamic physicists plumb the edges of the Universe, the depths of the oceans, and the structure of the brain, the laws of thermodynamics are the first principle.

There is a philosophical parallel in philosophy that matches thermodynamics. The divide is often expressed as Plato-Aristotle, realism-empiricism, cause-effect, seen-unseen, equilibrium-nonequalibrium, linier-nonlinier, positive-negative, fundamental-phenomenological, certainty-uncertainty, hot-cold, black-white, and so on and so forth. The greatest mysteries in life are defining connections, or bridges, between the two. W. V. Quine expressed it in "Two Dogmas of Empiricism" (1951) by discussing this "fundamental cleavage between truths that are *analytic* or grounded in meanings independently of matters of fact and truths which are *synthetic*, or grounded in fact."[72]

[72] W. V. Quine in Marin Curd and J. A. Cover, *Philosophy of Science: The Central Issues*, (New York;

He goes on to say that Kant's analytic-synthetic truth "was foreshadowed in Hume's distinction between relations of ideas and matters of fact, and in Leibniz's distinction between truths of reason and truths of fact."[73] These efforts are often expressed as unification, holism, general theory, singular, commonality, synthesis, but the connections are always tenuous and easily broken because there are always assumed elements. In academia, such endeavors lie in interdisciplinary studies. History labels such expressions as world history, big history, or global history.

One criticism against holism is that the theory is deterministic, but then all theories seem to wind up in this refuge heap with that label. This is a step away from Popper's falsification thesis and Kuhn's social scientific constructivism. In a discussion about the First Law of Thermodynamics, A. J. Ayer points out that critics dismiss it because it cannot be falsified in Popperian terms, but as already mentioned, this principle is a realism statement that serves as a starting point to understanding the second law.[74]

This examination of Former Soviet Union and US science also shows a clear division between science and technology. The former brought along excellent basic science and the latter brought better experimental skills and equipment. The Soviets' equipment suffered from poor workmanship, while their western counterparts developed better instruments with which to experiment. The different scientific communities developed on materialistic grounds.

In a 1986 when the United States began its hypersonic National Aerospace Plane (NASP) effort and on the heels of *glasnost*, Dr. D. Allan Bromley, Yale University physics professor wrote an *American Scientist* article regarding several issues raised in this research: "To a remarkable degree, twentieth-century technology has been based on our ability to manipulate electrons and atomic structure."[75] Hypersonic aircraft development has progressed to the point of manipulating electrons and atoms. He also stated that, "One of the most intractable problems in all of physics has been that of turbulence…. Such motion, at the interface between ordered and chaotic, has defied

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London: W. W. Norton & Company, 1998): 280.

[73] Ibid.

[74] A. J. Ayer in Marin Curd and J. A. Cover, *Philosophy of Science: The Central Issues*, (New York; London: W. W. Norton & Company, 1998): 809.

[75] D. Allan Bromley, "Physics: Natural Philosophy and Invention," *American Scientist*, 74, no. 6 (1986): 626, http://www.jstor.org/stable/27854360, 9/27/11.

numerical analysis and yet has enormous importance" because it creates aerodynamic drag and at Mach 5 and above can burn away solid control surfaces.[76]

Humans spend most of their lives trying to bring order to a seemingly chaotic universe in what American physicist Heinz R. Pagels defined as determinism: "The world view that nature and our life are completely determined from past to future – reflects the human need for certainty in an uncertain world."[77] Whether seeking simple necessities or exploring the meaning of life, the species engages in constant thoughts and behaviors aimed at controlling uncertainty. This is because the universe is dynamic, not in stasis. This research begins with the Big Bang theory, the event that created the universe and the stars we see or detect at the edge of space. Movement, momentum, and constant change are the fundamental force in nature. The religious corollary would be theism, the belief that God created all things, but does not intervene. According to scientists and engineers, movement requires energy and while humans cannot create matter, they can convert it into various other energies. Mankind has become quite adept at using energy in the quest to control chaos, but there is a growing awareness that this comes with cost so severe that it may lead to extinction of the human race.

Science precedes the humanities; however, since the former's rise in costs, philosophy, history, politics, economics, just to name a few, seek understanding according to their discipline's conventions which to most laymen must seem like a "Tower of Babel." In *The Scientist's Atom and the Philosopher's Stone* (2009): Alan Chalmers calls this "evidence-transcendence", or overstatement, effort to separate science and philosophy. He posits that philosophy engages in the activity while science must be based strictly on facts.[78] While accepting the term, I would argue, based on this research that everyone engages in evidence-transcendence. A 'fact' does not necessarily dictate the conclusion. The question is how to avoid relativism.

National Aerospace Plane

During his 1986 State of the Union address, President Ronald Reagan announced, "We are going forward with research on a new Orient Express that could, by the end of

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[76] Ibid., 635.

[77] Heinz R. Pagels, "Uncertainty and Complementarity," in *The World Treasury of Physics, Astronomy, and Mathematics*, ed. Timothy Ferris, (Boston: Little, Brown and Company, 1991): 97.

[78] Alan F. Chalmers, *The Scientist's Atom and the Philosopher's Stone: How Science Succeeded and Philosophy Failed to Gain Knowledge of Atom*s, (Dordrecht: Spring, 2009): 4.

the next decade, take off from Dulles Airport, accelerate up to 25 times the speed of sound, attaining low Earth orbit or flying to Tokyo within two hours." Building such a single-stage to orbit aero-spacecraft--- rather than using rockets that for the most part are destroyed after performing their function—is the next step in aviation evolution. Reagan's initiative resulted in the X-30 National Aero-Space Program (NASP). The speech came shortly after the 28 January 1986 Space Shuttle Challenger disaster that dramatically highlighted the dangers in rocket-propelled unpowered aero-space craft. Despite efforts to achieve the goal, it quickly became apparent to officials, engineers, and scientists that the vehicle's technical challenges prevented Reagan's vision. However, the program's demise prompted some Former Soviet Union scientists to propose "experimental solutions"[79] that the U.S. Air Force decided to investigate what is generally known as "Plasma Aerodynamics," "Fluid Dynamics," and specifically "Weakly Ionized Gases."

While this offer of cooperation from what Reagan described as "the Evil Empire" might surprise some, Guy Norris, *Aviation Week & Space Technology* Senior Editor, described several different international efforts to engineer a hypersonic aircraft. The technical difficulties, budgets, and limited or non-existing test facilities drove many countries to similar arrangements including China, France, Germany, India, Italy, Japan, Russia, and the United Kingdom. Each cooperative program brings a different approach. The U.S and Australia worked together on the Hypersonic International Research Flight Research Experiment (HIFIRE). The European Union's Long Term Advanced Propulsion Concepts and Technologies (LAPCAT) project brought together 12 industrial and academic partners from six nations. The European Space Research and Technology Center manages the program.[80] Hypersonic research and development was simply too risky for any one country based on the costs it would take for uncertain results.

This research is premised on a scientific effort to control a particular kind of boundary layer of turbulence, chaos, and disorder that aircraft encounter at hypersonic speeds, approximately Mach 5 and above. The boundary layer describes the thin layer of

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[79] George C. Mantis and Dimitri N. Marvis, "A Bayesian Approach to Non-Deterministic Hypersonic Vehicle Design," *AIAA*, (2001): 2.
[80] Guy Norris, "Going Global," *Aviation Week & Space Technology*, 169, no. 2, 14 July 2008, 128.

air in contact with the aircraft. During World War II aircraft began to fly at speeds in excess of the sound barrier, pilots encountered severe buffeting and an inability to control that sometimes meant death. Since then, the aviation 'sound barrier' has been conquered, but now endeavors to overcome an obstacle even more formidable – the 'heat barrier'. This problem is well known and in fact broken every time a rocket pushes its payload to approximately 18,5000 mph (miles per hour), escaping Earth's atmosphere into space. The relatively short transition through air allows the rocket to shed the heat; however, the phenomenon is spectacularly displayed if the occupants or cargo returns in a flaming spectacle. Ablating heat shields designed to create an insulating shock wave and 'shed' heat protect the projectile it because must reduce speed to survive impact. Unfortunately, the Space Shuttle Challenger catastrophic ceramic tile failure exposed its occupants to the heat barrier's tragic consequences.[81] According to the Columbia Accident Investigation Board, when the damaged tiles exposed the underlying wing spar to approximately 5,000 F, whereas aluminum melts at 1,220 F.[82]

The history of hypersonic aircraft research is well documented in technology terms. That is in efforts to design and produce advanced heat-resistant matter. In fact, hypersonic aircraft designs, NASP for instance, assumed the availability of such material. Many authors commented on the concept's spectacular failure on costs, management, and a host of other procedural shortcomings when in actuality, it was the 'heat barrier' that led to its cessation and not a technological problem. What was needed and what has actually happened since then is a shift to basic science to provide a solution to the problem. According to hypersonic scientists and engineers this constituted a 'philosophical' view. Scientifically, on the other hand, it meant the unification of branches separated since the space age aerodynamics and thermodynamics, in this case plasma aerodynamics. Thomas Kuhn discussed dynamics as a process that linked "the theory of energy conservation provides just such links between dynamics, chemistry, electricity, optics, thermal theory and so on."[83]

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[81] New York Times, "Loss of Shuttle; Excerpts from Report of the Columbia Accident Investigation Board," *The New York Times*, 27 August 2003, http://www.nytimes.com/2003/08/27/us/loss-shuttle-excerpts-report-columbia-accident-investigation-board.html?scp=115&sq=hypersonic &st=cse&pagewanted=print, accessed 2/27/12.
[82] NASA, "Columbia Accident Investigation Board: Volume 1," *NASA*, 1 August 2003, 12.
[83] Thomas S. Kuhn, *The Structure of Scientific Revolutions: Second Edition*, Enlarged, (University of

In 1979, Dr. Hans W. Liepmann, an esteemed Professor of Aeronautics and Applied Physics at Caltech, wrote an article titled, "The Rise and Fall of Ideas in Turbulence" in which he looked back over the approximately one-hundred years of turbulent flow research. During that time the greatest names in physics, mechanics, and engineering had taken a "crack at the problem."[84] This led him to write that "all difficulties in dealing with fluid flow, from reactor heat transfer to aerodynamics, are bound up with the turbulence problem."[85]

One way to provide some historical background regarding boundary layer studies is to examine articles by Dr. Dennis M. Bushnell, Chief Scientist, NASA Langley Research Center, who over several decades wrote articles that provided an overview of physics-based aerospace research at that time. In 1983, he stated "skin friction reduction is currently considered a major 'barrier problem' to the further optimization of most aerodynamic and hydrodynamic bodies, whether platforms or weapons."[86] He argued that even a 20 percent aircraft fuselage drag reduction would save the US civilian transport industry fuel costs of approximately $1,000,000,000 dollars and as such this more than justified "high risk" research aimed at reducing the phenomena. His article included Soviet scientists' research.[87]

In 1997, Bushnell published an article discussing aerodynamic flow control in the American Institute of Aeronautics and Astronautics (AIAA) stating that, "In general, the research community is not sufficiently knowledgeable regarding the myriad metrics of the technological filter and therefore 'non (application) useful' research is not carried far enough to allow technological evaluation."[88] At first glance, the article implied the need for greater integration or communication between aerospace research (scientists) and application (engineers): but what the author actually expressed was a much deeper

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Chicago Press, Chicago, 1970): 94.

[84] Dr. Hans W. Liepmann, "The Rise and Fall of Ideas in Turbulence: Research in turbulence still the most difficult problem of fluid mechanics, continues to produce technological advances, but the path of progress is anything but straight," *American Scientist*, 67, no. 2, (1979): 221.

[85] Ibid.

[86] Dr. Dennis M. Bushnell, Chief Scientist, NASA Langley Research Center, "Turbulent Drag Reduction for External Flows," AOAA=83-0227, (13 January 1983): 1.

[87] Ibid.

[88] Dr. Dennis M. Bushnell, Chief Scientist, NASA Langley Research Center, "Application Frontiers of 'Designer Fluid Mechanics' – An Attempt to Answer the Perennial Question 'Why Isn't it Used?'", AIAA-97-2110, 1.

problem. The technology had progressed through its first generation encompassing the simple variations of rigid fuselage shapes and geometry to increase power, cut fuel consumption, enhanced safety, and reduce noise levels.

The next year, Bushnell wrote another overview of flow control titled "Frontiers of the 'Responsibly Imaginable' in Civilian Aeronautics."[89] He characterized technological improvements an "incremental/evolutionary" paradigm with revolutionary reductions in design cycle time and manufacturability improvements.[90] As a result, he stated there existed an impression within the community that aerospace had plateaued as a mature industry; however, a wealth of alternate concepts could lead to a Renaissance. Bushnell then went on to describe several proposals that included plasma control and electro-gas-dynamics, "Research in Russia and the US indicates unexpectedly large experimental effects for a 'new arena of shock-plasma interaction, namely weakly ionized plasmas."[91] He cites G. I. Mishin's 1992 "Sonic and Shock Wave Propagation in Weakly Ionized Plasmas."[92] The overall paradigm shift meant moving from aerospace's historical reliance on 'closed' systems approach defined as "no energy added within the control volume."[93] An 'open' thermodynamic system portrayed aerodynamic properties with added energy that demanded much higher airframe, propulsion, and structures integration to operate in such high temperatures.[94]

An object moving through air equal to Mach 5 or greater begins to cause electrons to disassociate and exhibit behaviors very different from normal air in what scientists call equilibrium. The scientific proposal's novelty lay not in any new scientific discoveries, but rather how it proposed the joining of two previously separate, in aerospace research terms, scientific research areas. Reactions to the proposal itself ranged from high praise to charges of incredulity. Nevertheless, it spawned a new aerospace research area. There are several reasons for the proposal's success in stimulating scientific research in this area, but more than those is that it dealt with thermodynamics and a growing concern with global warming. Timing also played a large role in the proposal's impact. The

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[89] Dennis M. Bushnell, NASA-Langley Research Center, "Frontiers of the 'Responsibly Imaginable' in (Civilian) Aeronautics," *AIAA*, 1997.
[90] Ibid., 1.
[91] Ibid.
[92] Ibid., 18.
[93] Ibid., 3.
[94] Ibid., 13.

much-heralded NASP had gone down in flames produced by not-so-ready technological innovations and lack of hypersonic aerodynamics knowledge and experience.

From a strictly materialistic perspective, the hypersonic flight conditions pushed leading-edge structures to their melting points. Up until this time spaceflight aerodynamic heating utilized heat shields made of ablating material that protected the craft transitioning from space vacuum conditions into air filled with tiny particles. However, this ablation destroyed the structure. On the other hand, the X-15 rocket-powered test aircraft had also pushed this heating limitation when flying above Mach 5 and reaching the Mach 6.7 limit.

In the wake of yet another crash into the heat barrier, why did it take a small group of Former Soviet Union scientists to drag US aerospace researchers to finally taking the problem head on? It did not occur because of a stunning scientific discovery, but rather the extension of one research area into another. Serious air force boundary layer research emerged after the AJAX, proposal not before. There needed to be an intellectual shift from an empiricist focus on a barrier to one of energy.

Chaos

During the Cold War, outside observers often spoke of Soviet scientific prowess; however, this occurred because of the USSR's, and now Russia's, technological limitations, rather than experimental work. This counter intuitive model, then, contradicts logic and the neat linear movement from theory, to experiment, prototype, and final product. The USSR gained a reputation for scientific, theoretical research because of its technological limitations, whereas the US moved cutting-edge science to its applied phase quicker because of its technological strengths. From this perspective, perceived Soviet scientific advantage actually highlighted a liability and limitation. Authors such as the esteemed historian Loren Graham who has made a career of Soviet science historical studies, argues the Soviet Academy of Sciences and its now Russian successor's intransigence and elitism stifled new scientific enterprises because of their awe-inspiring achievements in theoretical and experimental work. The Soviets, lacking capitalism's corrupting drive for profit, pushed theory to higher levels, especially mathematical-driven solutions.

The friction between the two scientific communities was not only caused by discussing solutions to a phenomenon such as aerodynamic heating, but by political, cultural and social differences. These emerge in simple communications, assumptions, promises, perceptions, goals, language; in other words human behavior. Scientific advances take both heat producing processes.

CHAPTER TWO

SAVING SOVIET UNION SCIENCE

Chapter two examines Big Science issues. As states erect structural systems to manage economic, political, judicial, and the many other elements that commercial or individuals cannot administer, science has also become such an entity. These bureaucracies navigate the shoals of political, diplomatic, and financial circumstances. While national scientific collaboration is a widely embraced concept, former enemies must undergo reconciliation then reestablishment of foreign ties before such partnerships can exist.

The West's interest and concern with the fate of the former Imperial Russia, then Soviet science came soon after the 1917 Bolshevik Revolution. On 23 April 1920, *Science* published a letter from Professor Boris Petrovitch Babkin, Physiological Laboratory, University of Odessa, who wrote: "The Bolshevik revolution has brought Russia into such a state that not only has scientific work come to a standstill, but even our lives are in danger."[95] He appeals for help in finding a position in which to carry on his research. He does leave the Ukraine in 1922 and makes numerous contributions. In 1930, he became a Fellow in the Royal Society of Canada, and in 1950 a Fellow in the Royal Society of London. He was a protégé of Ivan Petrovich Pavlov, one of Russia's most revered scientists, awarded the 1904 Nobel Prize in Physiology or Medicine. The letter highlights numerous issues seen throughout Russia's History of Science. First, the appeal for positions in the West a phenomenon is labeled as emigration or "brain drain" in post-Cold War references to Former Soviet Union researchers. Second, the West's inclination to "save" Russian science, in this case, Vernon L. Kellogg, National Research Council Secretary, through *Science* solicited contributions and scientific journals for distribution in Russia. He was assisted by the American Relief Administration.[96]

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[95] Boris Babkin, "The Situation of Scientific Men in Russia," *Science*, 51, no. 1321, (1920): 414.
[96] Vernon Kellogg, "Relief for Russian Scientists: Final Report," *Science*, 58, no. 1501, (1923): 264.

Soviet Union Opening

The Soviets first demonstrated their new aviation glasnost at the 1988 Farnbourough Air Show when they brought a Mikoyan—Gurevich MiG-29 for public display. The next year, they raised the topic of hypersonic scientific cooperation research at the 1989 Paris Air Show. [97] The official exchanges, first begun in 1990, evolved over several years and mirrored many other organizational efforts from all over the world. Everyone, including the US Air Force, sent experts to determine the extent and breadth of heretofore opaque and hidden work. For Department of Defense (DoD) personnel this was both exhilarating and novel in a manner beyond their wildest dreams. To walk into Former Soviet Union facilities and discuss projects was intoxicating. The Former Soviet Union scientist's openness was driven certainly by pride, but also economic desperation. Despite their extreme lack of funds, in these first contacts, the need to establish personal relationships with the Russian host overrode Popper's scientific radical reductionism. These personnel contacts were more important to the Russians because they worked in a Soviet system in which one had to know someone to get funding and to grease the wheels of the bureaucracy. However, the Soviet emphasis on personal influence was unclear to Americans whose success depended primarily on a contractual relationship which created its own momentum. Both felt these relationships also somewhat nebulous because both communities struggled with political, economic, and even military concerns.

Inevitably, however, this "honeymoon" period came to an end. The polite discussion meant to engender personal contacts ended and scientific falsification began. Several USAF scientists, for these and several other reasons, describe the period as the "Wild, Wild West" for its lack of state oversight or procedural guidance. I believe this moment occurred first during the 9-13 June 1997 "Workshop in Weakly Ionized Gases October" at the USAF Academy, Colorado Springs, Colorado. General Chairman Mr. W. Lee Bain, Air Force Wright Laboratory Advanced Power Propulsion Directorate, explained that the agenda included 12 Russian subject matter papers. Up to this point, USAF scientists had found their experiment results very interesting, but found their

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[97] *Aviation Week & Space Technology*, n. a., "Soviets Seek Cooperative Role in Western Hypersonic Programs," 130, no. 25, (1989): 38.

processes, or just “how” they reached such numbers, difficult to understand. The defining moment occurred with Dr. William F. Bailey’s presentation based on Major William M. Hilbun’s “Shock Waves in Nonequilibrium Gases and Plasmas.” In Hilbun’s doctoral dissertation, he examined specific Former Soviet Union work that had intrigued many USAF scientists. It was a watershed moment because he stated a specific finding rather than previous “inconclusive” results. It was the first real western-style, fact-based, science examination since the Air Force first entered the Former Soviet Union. This workshop revealed the newly formed American- Former Soviet Union scientific community (which in Kuhn’s paradox model emerged when anomalies appeared) was now split based on Popper’s falsification theory. One side accepted the Russian’s experiments as “interesting,” while some on the other side went so far as to call their findings “plasma magic.” While aimed at a specific finding, the charge carried far more serious implications for the USAF-sponsored efforts.

In the Popper-Kuhn spectrum, the process of bringing Former Soviet Union and US Air Force scientists together definitely falls on Kuhn's side because the two communities had to understand each other's cultural approaches before they could begin to falsify the results of each other's research. Another distinction in how these contacts came about is the *ad hoc* and the official arrangements. The extempore connections came before finalization of formal policy. This happened as the Soviet Union opened its doors to outsiders, but also because as the union dissolved so did its means to support such scientific interaction.

One can gain a perspective on early contact that pre-dates official DoD contacts but nevertheless benefitted the meeting of the two entities by examining the career of a member of the University of Michigan Aerospace Engineering Department. Doctor William C. Kauffman provided his experience and expertise to many businesses, corporations, and US agencies efforts to enter the newly opened USSR. In the heartland of America’s automotive manufacturing industry, University of Michigan was often assisting for-profit and not-for-profit organizations in their efforts to improve their products and bring business to their clients.

Bill Kauffman’s introduction to the Soviet Union came early in his academic training. In 1957, while majoring in physics, the Russians launched Sputnik. Ironically, four years later on 12 April 1961, before Dr. Kauffman's baccalaureate graduation, they sent Yuri Gagarin, the first man into space. The events stunned the world and Kauffman became quite interested in learning all he could about their rockets. He related, "you have to pay attention to these people; they did earth-shaking things, so what's going on over there? What do they know that we don't? How do they have such good rockets --- how do they have such good engineers? That interest led me into going to work for an agency that was interested in the subject too."[98]

After graduating he worked for Martin on the Apollo command module program then for HRB Singer which is now part of Raytheon. Because many explosive experts examine the hypersonic boundary layers created within blasts as do aircraft engineers, his post-graduate work introduced him to classified U.S. government work. This was where he first entered the world of secret and classified material and gained security clearances while analyzing Soviet space vehicles.[99]

Without direct access to Soviet rockets, the CIA analyzed telemetry and optics produced during flight testing to learn their capabilities and intent. The rocket radioed performance data for its major systems and sub-systems to engineers and scientists. In previously classified intelligence study "The SS-8 Controversy," former CIA national intelligence officer for strategic programs David S. Brandwein described how "Some scientists working under contract to the Air Force were able to combine the optical data with data telemetered during re-entry to calculate the drag of the re-entry vehicle as well as other ballistic parameters related to size and shape."[100] From this information they could infer the size, weight, and purpose of the rocket payload.

When Kauffman went back to graduate school he studied explosions such as occur in grain elevators and coal mines, and he noted the Russians were also very good in that particular field of expertise. But his contacts with Russian scientists were not purely academic. He also met Soviet foreign exchange students from whom he gained insights into Russian as well as Soviet culture as a teacher and as a fellow student. Such ad hoc contacts were unusual at the time, but understanding each other's culture would prove

[98] William C. Kauffman, interview with Dennis C. Mills, 17 May 2009.
[99] C. William Kauffman, interview by Dennis C. Mills, 29 Oct 2008, 5.
[100] David S. Brandwein, "The SS-8 Controversy," CIA, Jun 1969, 29.

important to the success of formalized contact.[101]

In 1980, now a professor, Soviet explosion experts invited him to visit the USSR based on his research. During that time he and his wife visited St. Petersburg and other Soviet Union explosive research sites. He returned in April 1986 shortly after the Chernobyl nuclear reactor disaster. He remembers his counterpart meeting him at the airport. They then traveled to a large RMBK-1000 (*Reactor Bolshoy Moshchnosti Kanalniy*) where his escort explained exactly how the explosion happened. This new openness, according to Kauffman, was a change from the old Soviet secrecy. Kauffman commented that, "I thought that was pretty interesting and indicative of Gorbachev coming to power."[102]

The USSR military aviation community announced itself to the West at the 1988 Farnborough Air Show, United Kingdom, when the Mikoyan-Gurevich (MiG) Design Bureau presented MiG-29 aerial flight demonstrations led by Mikoyan's chief test pilot Valery Menitskii.[103] The air show likewise provided General Dynamics' Richard D. Ward, Advanced Design Project Engineer, an opportunity for official discussion with a Soviet fighter firm. The organizations agreed to explore exchanging delegations to each other's design and manufacturing centers for the first time. At the 1989 Paris Air Show where the Soviets first brought up the topic of cooperation, in attendance were Gennady P. Dementyev, general designer for the Soviet Ministry of Aviation, and Greogiy Svishchev, director for the Soviet Central Aerohydrodynamics Institute (TsAGI), and met with NASP, NASA, and the German hypersonic Sanger program.[104] At that Ward took it upon himself to invite Rostislav Apollosovich Belyakov, MiG General Designer, to present a paper in Ward's place at the University of Michigan's 75th Anniversary of the Aerospace Engineering Program's "Aeronautical Design Symposium: The Lessons Learned," 1-3 November 1989, with Professor C. William Kauffman, as Symposium Chairman. Belyakov was joined by several other prominent Soviet Aviation leaders including Apollon Sergevich Systsov, Soviet Minister of Aircraft Ministry, German

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[101] C. William Kauffman, interview by Dennis C. Mills, 17 May, 2009.
[102] Ibid.
[103] Benjamin S. Lambeth, "From Farnborough to Kubinka: An American MiG-29 Experience," *RAND*, (Santa Monica, CA, 1991).
[104] *Aviation Week & Space Technology*, n. a., "Soviets Seek Cooperative Role in Western Hypersonic Programs," 130, no. 25, 19 Jun 1989, 38.

Ivanovich Zagainov, Central Aero-Hydrodynamics Institute Director, and Pyotr Vasilyevich Balabuyev, General Designer, Antonov Design Bureau. This spontaneous invitation on Ward's part resulted in an unplanned cooperative symposium.

A further example of the importance in this early stage of personal contacts is the fact that during a subsequent U.S.S.R trip, Kauffman hand-delivered Belyakov's invitation to visit General Dynamics' Fort Worth location which in turn resulted in his MiG trip. [105]

August Coup and Jaquish's Promise

During the DoD approval process for travel to the Soviet Union, John K. Welsh, Jr., Assistant Secretary of the Air Force for Acquisition and his staff took over the arrangements and added Kauffman to the list, thus connecting Kauffman officially to the Air Force, something that was made easier because Kauffman had done previous government work and had security clearances. The delegation included representatives from the Department of State, General Dynamics, Pratt and Whitney, and General Electric. The visitors arrived in Moscow on 24 May 1990 onboard a USAF C-135 transport.[106] In August 1991, the Grauman Flight Test Research Institute invited Kauffman and others to attend their 50th Anniversary Celebration which included an air show 17-18 August. The group included Lieutenant General John E. Jaquish, USAF Principal Deputy Assistant Secretary (Acquisition). General Jaquish was there, according State Department Deputy Spokesman Richard Boucher, on a military-to-military exchange visit.[107] On 19 August, the Russian Coup kicked off. No one wanted the spectacle of an American Lieutenant General involved in what was seen as an internal matter. According to Kauffman, the general stated that if the both of them survived, he would send the professor back to survey the Russian's science and technology centers.[108] True to his word, almost two years later on 26 July 1993, General Jaquish signed a Letter of Introduction stating "Because Dr. Kauffman is a highly recognized and respected scientist, the United States Air Force has engaged his services with ANSER Corporation

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[105] Richard D. Ward, "Trip Report: The Visit to the Soviet Union from 4 May Through 6 June 1990, *Soviet & Eastern European Studies*, General Dynamics: Fort Worth, 15 September 1990, 1; Symposium Agenda, "Aeronautical Design Symposium: The Lessons Learned," 1-3 November 1989.
[106] Ibid.
[107] Richard Boucher, "US Department of State Daily Press Briefing #123," [USSR Coup], 19 Aug 1991.
[108] C. William Kauffman, interview by Dennis C. Mills, 29 Oct 2008, 8.

to identify and assess scientific and technological activities in the FSU."[109]

The first word of the U.S.S.R. science and technology opportunities came not from Air Force sources, but began filtering in through U.S. Army and Navy channels. Reporting on the 6 February 1991 Joint Service Meeting on Eastern European Science and Technology Acquisition meeting at AFOSR, Dr. Julian Tishkoff wrote, "The Russians appear to be very anxious to sell us virtually all of their military science and technology at very low cost. For example, a year of research at a Russian institute can be 'rented' for $35K. Dr. Ufimtsev, mentioned above, heads one such institute."[110] Many considered Pyotr Ufimtsev the "father" of stealth aircraft because the U.S. based its Lockheed F-117 and Boeing B-2 designs on wave diffraction he accomplished in the 1960s and 70s. The fact that his entire facility could be rented for a secretary's wage in the U.S. shows how flat on their backs Soviet scientists were.

The Air Force Office of Scientific Research was trying to figure out a means to "interact" with the Former Soviet Union and since the first Joint Service Meeting on Eastern European Science and Technology Acquisition, things had not changed all that much because the Air Force didn't have a way to pay Russians or enter into a contractual agreement with them. On 20 December 1991, Tishkoff, now the AFOSR Eastern European Science Program manager, wrote, "Large portions of the former Soviet military science and technology are virtually for sale, and the militarily and economically, with the Western European nations and Japan to acquire these capabilities. Inadequate efforts by DoD already have resulted in losses to these competing nations and to American private industry."[111]

One of the barriers to acquiring Soviet science at this time was the hopeless way any personnel capable of evaluating that science was tied to military intelligence. Captain Edward Pope, U.S. Navy Office of Research, hosted the meeting, and Tishkoff described him as "responsible for intelligence-related activities at the Office of Naval Research."[112] The concern with intelligence and public scrutiny remained a part of these

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[109] Lt. Gen. John E. Jaquish, USAF, "Letter of Introduction," 26 July 1993.
[110] Julian Tishkoff, "Joint Service Meeting On Eastern European Science and Technology Acquisition," AFOSR, 7 Feb 1991.
[111] Julian Tishkoff, "Joint Service Meeting On Eastern European Technology Transfer," AFOSR, 20 Dec 1991.
[112] Ibid.

interactions, but not for the most obvious reasons. Overcoming Cold War suspicion of communists and the skepticism about contracting with them and paying them with US taxpayers dollars would take some time, but on the other hand, exploring a potential adversary's strengths and weaknesses is a crucial factor in shaping, and paying for, one's military establishment. Additionally, since taxpayers fund the military and its Big Science elements, there is the possibility of public scrutiny. In fact, during the 6 February 1991 Joint Service Meeting on Eastern European Science and Technology Acquisition meeting at AFOSR, minutes show a reference to the "Bromley article in *Physics Today*: encourage contacts with individuals rather than institutions in view of current instabilities."[113] Physicist Dr. D. Allan Bromley had served on President Ronald Reagan's White House Science Council and was now President George H. W. Bush's Science Advisor. According to the AFOSR meeting minutes, Bromley's article indicated the highest level of interest on this issue and the belief that any public relations mistakes would mean serious repercussions indeed.

Within Tishkoff's files, the first hypersonic reference was the 30 March 1992 Aviation Week & Space Technology article titled "Russians Want U.S. to Join Scramjet Tests," by Stanley W. Kandebro. Donat A. Ogorodnikov, Central Institute of Aviation Motors (CIAM) Director, invited his U.S. counterparts to join in "an upcoming test flight of a subscale ramjet/scramjet that has demonstrated supersonic combustion in flight."[114] Vyacheslav A. Vinogradov, CIAM Engine Gas Dynamics Department Chief, described their successful 28 November 1991 ramjet/scramjet flight test near the Baikonur Cosmodrome in Kazakhstan. According to Vinogradov, the test vehicle powered itself to Mach 8. Ogorodniko stated that CIAM had received requests for test data from NASA, the U.S. Air Force, and France's Societe Europeenne de Propulsion. He also said that he had hoped for U.S. collaboration from the program's beginning, adding that "CIAM managers believe that even if the current government passes a budget in the next several months, there could be little money available for funding scramjet test flights."[115] Shortly thereafter, 7 days to be exact, Tishkoff gave a slide presentation to the Joint

[113] Julian Tishkoff, "13 Dec 91 Meeting at AFSC [Air Force Systems Command]," 13 Dec 1991.
[114] Stanley W. Kandebo, "Russians Want U.S. to Join Scramjet Tests," *Aviation Week & Space Technology*, 130, no. 25, 30 March 1992, 18.
[115] Ibid.

Director of Laboratories (JDL) titled "JDL Joint Program Plan Reviews," regarding Russian projects and among future opportunities appeared 'Basic Research in Hypersonic Flow'.[116] This was the first direct reference to cooperation with Russians on plasma aerodynamics.

Subsequent to these events, the 24 September 1992 EOARD newsletter announced that "Three eminent Russian scientists were invited by AEDC [Arnold Engineering Development Center] to participate in the AIM [Aerothermodynamic Integration Model] Ground Testing and Joint propulsion conferences that took place in Nashville on 6-8 July 1992."[117] The document went on to say that Dr. Donald C. Daniel, Chief Scientist at AEDC, was "instrumental" in bringing the Russians to the conference. Dr. Calarese, EOARD, accompanied the visitors and chaired their presentation panel. Calarese wrote "The papers presented by the Russians were of high quality. They were honestly willing to share information without obvious reservations. In later talks at AEDC, they were enthusiastic and hoping to collaborate with U.S. scientists on problems of common interest."[118]

By May 1992, policy makers sensed the need to differentiate between technology acquisition and basic science. The evaluation of technology involved the complicated process of evaluating weapons by the intelligence community while buying foreign technology that competed with domestic producers. Basic science, foreign and domestic, is available, for the most part, without this scrutiny through academic and industrial contacts, as Kaufmann and other American and Russian scientists and engineers were discovering. The communities involved, therefore, had very different levels of openness: Military, secret. Academia and industry, open. Every country understands that military technology, killing machines, is restricted because of their military use. All communities involved were struggling to share basic science without violating this boundary. To this end, it was believed that technology and basic science had to be separated.

However, to achieve this differentiation, there were, first, bureaucratic hurdles to overcome. After a 12 May meeting, Tishkoff wrote: "This discussion was initiated at the direction of Lt Gen Jaquish, Mr. Welch's Principal Deputy. After much discussion, it

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[116] Julian Tishkoff, "JDL Joint Program Plan Reviews," AFOSR, 6-8 April 1992, 9.
[117] EOARD Newsletter, "EUROGRAM," 24 September 1992, 2.
[118] Ibid.

was clear that an absence of a clear division of responsibilities among SAF/AQ, SAF/IA, and AF/XO, as well as other possible Air Force interests, inhibited this exercise."[119] Second, language at the Office of Secretary of Defense reveals that there was not clearly cleaved understanding of 'research' from 'technology.' On 21 May, Mr. Robert Bruce, Assistant Deputy Under Secretary (International Development & Production Programs): wrote, "There are an increasing number of proposals from within the Department of Defense (DoD and from outside DoD, including organizations in the Republics of the USSR, for DoD acquisition of technology or products and for cooperative research and development (R&D)."[120] 'Research' (basic science) and 'development' (technology) remained inexorably linked at this point. The memorandum listed potential projects stating, "This list will then be used in developing a strategy for exploring cooperative opportunities with these nations."[121] Among others, Tishkoff forwarded the list to Dr. Kirk Hackett, whose position at the London office of EOARD as Chief of Physics, whose job it was to interact with foreign scientists on behalf the USAF, made him particularly suited to observe that "When formulating policy visa vie the Former Soviet Union, separate policies should be created which differentiate basic research and exploratory development activities from the acquisition of system level technology."[122]

On 5 June, Colonel George W. Criss III, Chief, International Programs Division, Assistant Secretary of the Air Force (Acquisition): wrote a memo that while still showing confusion over 'research', did clarify the Air Force's policy on 'technology'. Without defining the former, he stated, "It is important to ascertain more exactly the capabilities and status of ongoing research efforts in Eastern Europe and the FSU." Perhaps 'exploratory' might have been a better word. He went on "Acquisition of current hardware/technology that is beneficial to our current research efforts and technological base should be considered before negotiation of any potential areas of cooperation. Examples of these 'do now' acquisitions are attached. We view 'cooperation' (in the

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[119] Julian Tishkoff, AFOSR/NA, "Air Force Coordination Group for Activities with the Former Soviet Union (FSU) and Eastern Europe." 12 May 1992.
[120] Robert Bruce, Office of Secretary of Defense, "Potential Areas of Cooperation with the Former Soviet Union (FSU): 21 May 1992.
[121] Ibid.
[122] Dr. Kirk E. Hackett, AFOSREOARD, "S&T/Acquisition Policy visa vis the Former Soviet Union," n. d.

NATO) sense as a downstream possibility."[123] Curiously, revealing some awareness of EOARD's previous October 1991 visit to Moscow, the memo added "However, the Window on Science cannot be used for FSU scientists."[124] The U.S. Air Force's European Office of Aerospace Research and Development (EOARD) Windows on Science invited and sponsored distinguished foreign scientific and technological experts whose work was of interest to Air Force personnel and their projects.[125] On 13 July, Dr. George Abrahamson, Chief Scientist of the Air Force, met with his USAF Chief Scientist Working Group regarding Former Soviet Union and Eastern European interactions. So far, according to the minutes, "The extraordinary opportunities for new types of direct interaction with FSU organizations and individuals in the U.S., in allied countries, and even in the FSU, has left the USAF R&D community uncertain regarding policy and procedures regarding such interactions as well as frustrated by the tedious and time-consuming task of trying to obtain the proper approval for such activities."[126] With that said, the memo went on to shine a bright light on EOARD "The working group did recognize the value of the EOARD Windows On Science (WOS) program; however, as pointed out during Lt Col Lisowski's presentation (Atch 10): there are significant procedural and application limitations associated with WOS funding."[127]

The surprise came when Mr. Albert H. Boudreau, AEDC Director of International Affairs, revealed that Dr. Daniel had started interactions with his Russian counterparts, Dr. Sosounov on 25 July 1990, that is shortly after the Russians signaled their new openness. An AEDC team traveled to Russia and visited CIAM, TsAGI, and TSNIIMASH on 18-23 August 1991. It was the following October when Dr. Calarese visited Moscow and presented his report in the June 1992 EOARD Newsletter. Dr. Zagainov, TsAGI Director, reciprocated on 5 December to AEDC. The culmination came at the AIAA July Conference in Memphis, Tennessee.[128]

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[123] Col George W. Criss III, "Review of Proposals for Exploration of Cooperative Opportunities with Former Soviet Union and Eastern Europe – INFORMATION MEMORANDUM," 5 June 1992; Atch, n. a., "Eastern Europe/Former Soviet Union issues," n. d.
[124] Ibid.
[125] Air Force Factsheet, "AFOSR: International – SOARD – WOS," http://www.wpafb.af.mil/library/factsheets/factsheet.asp?id=9534, accessed 3/22/10
[126] Dr. Joe E. Dollar, Chief Scientist Foreign Aerospace Science and Technology Center (FASTC): "Summary of Key issues: 13 Jul 1992 Chief Scientist Working Group Meeting at FASTC," 24 July 1992.
[127] Ibid.
[128] Ibid. Attachment 10, Mr. Albert H. Boudreau, AEDC, "AEDC Activities with Russian Ground Test

While DoD continued efforts to manage its Former Soviet Union opportunities, other U.S. government agencies began contacting the services with collaborative ideas. As early as 2 March 1992, when the Joint Laboratory Directors began addressing the issue, Mr. Art Jones, Air Force Systems Command (AFSC): wrote an "Information Papers on Russia and Technology Acquisition" stating that cooperation with the Department of Energy [DOE] on assessing Russian space technology might be possible.[129] For the moment, the opportunity slipped by the wayside as Jones added, "No approval to date for AFSC to pursue any of the above listed opportunities. This is partly due to lack of definitive OSD policy for working with Russia."[130] Later that month, Tishkoff attended the "Breakfast Club" he described as led by Office of the Secretary of Defense, Defense Research & Engineering with each service counterpart in which he learned DOE actually approached AFSC in January about collaborating on Former Soviet Union technology. They had already discussed TOPAZ, a nuclear reactor for space use, and had already coordinated with the National Space Council, NASA, Strategic Defense Initiative Organization, and others. He added that for the time being, the Air Force could not support the venture.[131] However, despite the inability to support this particular effort, there were other Air Force efforts underway.

In the notes he took that day he described that during the 1991 Paris Air Show, Dr. Guy Severin, Zvezda K-36D ejection seat designer and manufacturer that had performed so spectacularly during a low-level MiG-29 crash, approached Dr. John M. Fabian, President Analytic Services Corporation (ANSER) about the technology. Dr. Fabian approached Major General Robert R. Rankine Jr., then the AFSC Deputy Chief of Staff for Technology, recommended acquiring the seat. Subsequently, the Mr. Brinkley, Arnold Laboratory wrote they would advocate the acquisition and test the device. The mechanism proposed for the test would be "FCT – Foreign Cooperative Testing---not tech issue---means to do test program from special funding source."[132]

Seemingly unbeknownst to most Air Force people at this time was that EOARD had already traveled to Russia and written a report. The method proposed focused on the

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Installations," 13 July 1992.

[129] Mr. Art Jones, AFSC/XTI, "Information Paper on Russia and Technology Acquisition," 3 March 1992.

[130] Ibid.

[131] Dr. Julian Tishkoff, AFOSR/NA, "Breakfast Club [handwritten notes]," 24 March 1992.

[132] Ibid.

U.S. Air Force's (USAF) European Office of Aerospace Research and Development (EOARD). This London-based office, never more than a dozen people, acted as liaisons to the Air Force Office of Research and Development (AFOSR). Each person's expertise represented an Air Force scientific field of interest. They travelled to European and Asian sites and conferences to speak and hear foreign scientists and relay those findings to the Air Force and its scientific and technical entities. The office published its findings in the EUROGRAM a bulletin describing the visits and the subject matter leaders.

In October 1991, Dr. Wladimiro Calarese, EOARD Chief Aeronautical Engineering, describe his first Russian findings with the following:

> It is known that the German hypersonic technology community wants to use the FSU [Former Soviet Union] facilities to develop their Sanger aircraft (two-stage to orbit vehicle). The Germans are impressed and believe that the FSU facilities are more advanced, larger, and better equipped than other European facilities currently in operation.[133]

As the first official U.S. Air Force EOARD aerospace science visitor to Former Soviet Union, Dr. Calarese provided descriptions of what his counterparts faced in their dire economic circumstances and how the Air Force might benefit. At the Central Aerohydrodynamics Institute (TsAGI): Director Professor German Zagainov explained that the aerospace wind tunnel research center once employed 12,000 scientists and technicians working three shifts and 24-hours a day, but due to lack of funding, testing had almost ceased. The report also reported on the Moscow Aviation Institute, Russia's premier aerospace science studies program, the Research Institute of Machine Building, the space center for rockets, spacecraft, hypersonic aerodynamics, materials strength heat transfer, and heat shields, and the Academy of Science's High Temperature Institute where scientists researched thermodynamics, heat transfer, gasdynamaics, and plasma physics. This led Calarese to state that "The Air Force could profit from this situation," and "Maybe a way to interact with the Russians should be found to better support the NASP effort."[134]

The report's appearance revealed another obstacle in the Air Force's efforts to work with Former Soviet Union scientists. Not only was there a silence between AFOSR

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[133] Wladimiro Calarese, "EOARD Report: Visit to Experimental Facilities in Moscow," EOARD LR 92-009, October 1991.

[134] Ibid.

and the laboratories, but also between AFOSR's office with the primary mission to visit foreign conferences, research institutes, and their scientists. The process dictated EOARD chose its visits based on the needs of the Air Force. These came not from Dr. Tishkoff, but those working in the field---the researchers. Maj Gen Rankine inadvertently recognized this information breakdown when he spoke to Col "Doc" Dougherty from the Defense Advanced Research Projects Agency (DARPA) who was collecting a list of what technology U.S. researchers would like to see and what they did not want to see in another country's hands. Rankine requested such an effort within the USAF research community.[135]

Since then, the office has become the standard means of working with Russians and other nations that emerged after the USSR's dissolution who previously worked as erstwhile enemies of the West. Although each community speaks a common science language, understandingly, they have also had to contend with cultural, social, educational, economic, political, and military obstacles. Despite the barriers, their collaborative efforts have brought concrete successes.

In June 2007, the Air Force Research Laboratory (AFRL) Propulsion Directorate released the *HVEPS Scramjet-Driven MHD Power Demonstration Test Results* stating that "The integrated scramjet-driven MHD [magnetohydrodynamics] power demonstration ground test program was successfully accomplished in December 2006."[136] Magnetohydrodynamics (MHD) is a promising plasma-based technological advance for producing megawatt electrical power without moving parts. The report's footnotes identify several Russian scientists whose basic scientific research helped make this test possible. Unlike conventional aircraft engines, both piston and jet, a scramjet (supersonic combustion ramjet) has no moving parts; instead, in order to mix air and fuel it relies on Mach airspeed above a ramjet's capability to direct the air flow into channels for combustion using conventional fuel.

Russians have a saying that "Moscow is far away" implying that while policy makers dither with decisions, their organizations find circuitous means to get things done---this applied to Air Force scientists in laboratories far away from DC. On 13 April

[135] Maj Gen Rankine, AFSC DCS/TECH, [DARPA technology list], 19 February 1992.
[136] J.T. Lineberry, et. al., "HVEPS Scramjet-Driven MHD Power Demonstration Test Results (Preprint):" AFRL-PR-WP-TP-2007-23, June 2007, i.

1992, for instance, Dr. Tom Mahefkey Wright Laboratory Aerospace Power Division reported that "Since before the collapse of the Soviet Union, the Aerospace Power Division of Wright Laboratory (WL/POO) has been active in initiating the reverse transfer of specific technologies from Institutes within the Republics to the United States."[137] A Soviet single crystal molybdenum refractory alloy evaluation was done by Space Power Inc. through a SDIO add-on contract. The Air Force Phillips Laboratory acquired a Tacitron, technology designed to evaluate heat created during electronic emissions, from the Kurchatov Institute of Atomic Energy through a subcontract with Kiser Research Inc., and delivered to the University of New Mexico (UNM). The contract also paid for two Russian researchers travel and labor. Once at the university, another subcontract with the Southeastern Center for Electrical Engineering Education funded UNM researchers. The laboratory stated "This work has great applicability to high heat flux electronic and aircraft electrohydraulic/electromechanical actuator cooking and spacecraft thermal management."[138] All that is to say that even while the policy makers struggled with bureaucratic inertia, those in the hinterlands found the ways and means to work with the Russians.

Another passage contained the first inklings another project that would lead to an acquisition "20 Feb letter to FAF/AQX to do collaboration with Russians in magneto-technology which would couple to U.S. … magneto-cumulative generator technology with American plasma flow switch technology to demonstrate fast switching of pulse power and to produce very high density plasmas approaching fusion conditions."[139] Mr. Steve Adams, Wright Laboratory Aerospace Power Division, reported that representatives from the Ioffe Physico-Technical Institutes, St. Petersburg, Russia were at Howard University, Washington DC, on a limited-duration visiting scientist program. He engage Dr. Vladimir Dmitriev, a renowned scientist and "found that he is extremely interested in the continuation of his team's research effort, which has been jeopardized under the circumstances in his new country."[140] As it turn out, Mrs. Galina Kelner, a

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137 Dr. Thomas Mahefkey, Wright Laboratory, "Memo for the Record: WL Efforts to Acquire/Evaluate Russian Technology," 13 April 1992.
138 Ibid.
139 Ibid.
140 Mr. James S. Cloyd, "Russian Activities in SiC processing for Power Semiconductor Devices," 23 Mar 1992.

U.S. citizen working for the Naval Research Laboratory, was "intimately familiar" with Russian high-power device research for their More Electric Aircraft cooperative initiative with Russian scientists.[141] Ioffe scientists would play an important role in the eventual plasmas aerodynamic collaboration.

Academic and Military Culture

Lieutenant General John E. Jaquish's 19 August 1991 decision to hire Dr. C. W. Kauffman seemed like such a good idea, but in hindsight it was a fiasco for the Air Force. By 3 June 1993 when the professor started his contract to "identify and assess scientific and technological activities in the FSU,"[142] the Air Force's science and technology community had made slow but steady progress toward working directly with Former Soviet Union scientists. Approximately twenty Former Soviet Union scientists were now traveling to Air Force laboratories to share their expertise with their USAF counterparts. The administrative lines for such interaction had been clarified and information flowed more easily than two years prior. Additionally, President Clinton's administration gave a favorable nod to its agencies to push for cooperation.

Kauffman's goals were grandiose; he thought his new position included saving the Former Soviet Union's entire scientific and technology community. He leaned on his experience as an academician who worked closely with students, industry, state and U.S. Government officials in finding funds to improve education and employment for UM students. This perspective did not prepare him to work in a military system that was only interested in Former Soviet Union scientists who conducted research in Air Force projects. With the Cold War ending, the Department of Defense engaged in force cuts because the specter of Soviet tank armies crashing through the Fulda Gap had receded along with U.S. military forces needed to counter this threat. As a consequence, the Air Force, with its funding limited to ongoing operations, exercises, training, and personnel costs, was pressed to keep its own S&T infrastructure running --- saving millions of S&T workers in a foreign country was not on the agenda. But as a University of Michigan professor, Dr. Kauffman stated "you as an educator at the University of Michigan which

[141] Ibid.
[142] Lt Gen John E. Jaquish, SAF/AQ, "[Kauffman] Letter of Introduction," 26 July 1993.

is a state-supported university, you have an obligation to the children of Michigan and Michigan industry."[143] He regularly met with manufacture's leadership and designed and taught courses based on their feedback. In an interview, he used the example of the automotive industry saying that "Look, we get these kids from the U of M and supposedly they have had a course in engines, but it's nothing but mathematics. If you go out and ask them why won't that engine start, they can't even get the hood open. So would you mind giving a course on engines that teaches them something?"[144] They gave Kauffman nine crated engines and toolboxes and taught them from the ground up. He found the experience gratifying: "I had more kids than I could take care of and they told me they were getting jobs because of the course."[145] The other group he regularly communicated with was Michigan political leaders also very interested in employing students for which taxpayers had contributed to their education. Kauffman listed day-book appointments with Senator Carl M. Levin's Michigan and DC office during his visits. The professor's experience in industry, political leadership, cooperating with scholars, seeking grant dollars, and his international scientific cooperative efforts gave him a far broader S&T worldview than the Air Force could afford.

Responsibility for Kauffman's employment beyond Jaquish's office, came to Dr. Julian Tishkoff's about the same time as things were looking up for AFOSR- Former Soviet Union cooperation through EOARD. Tishkoff, as the program manager for Former Soviet Union science, became the link between the Air Force laboratories and AFOSR. On 19 November 1992, Colonel Hal Rhoads, AFOSR, sent a message to Mr. Timothy Briggs, AFOSR, that he had a recent conversation with Lt Col Parris Neal, EOARD, and Dr. Helmut Hellwig, Air Force Chief Scientist, and that Dr. Hellwig supported the idea behind his efforts and that AFOSR should do "whatever's needed to support Dr. Kauffman's proposal."[146] But at the same time Dr. Hellwig also expressed concern that "there might be better ways of doing the job (for example, we might benefit from other experts participating): but agreed that this was the best approach we're aware

[143] Dr. C. W. Kauffman and Dennis C. Mills, [FSU-US Air Force Science], 17 May 2009
[144] Ibid.
[145] Ibid.
[146] Email, Col Hal Rhoads, AFOSR, to Mr. Timothy Biggs, AFOSR, "Re: Prof Bill Kauffman's 'Sabbatical' in Russia," 10 November 1992.

of today."[147] Three weeks later on 1 December, Col Rhoads sent another email to Biggs stating that, Dr. Hellwig "wants to do whatever's necessary to make Kauffman a happy camper---let's strive to support, be helpful, etc."[148] In other words, this was not our decision, Kauffman's employment was not AFOSR's doing, but since it came from a three-star we have to make it work whether it makes sense or not.

On 21 January 1993, Gerri Zarbo, AFOSR International Programs, emailed Dr. Hellwig, "On 12 Jan, I had a meeting with Capt Ewing, SAF/AQT [Jaquish's office], regarding Dr. Kauffman's proposed trip to Russia in May. I expressed my concern that nothing concrete was in place yet and time is slipping away."[149] Zarbo wanted to know if the arrangement spelled out the specifics, goals, plan, or include some sort of guidance? On the day Zarbo sent the email, she had spoken to Capt Ewing who passed on that "Dr. Kauffman has a big problem---evidently he did not have the concurrence of his Dean for this trip."[150] For Ewing, the inability to work well within an organization should have raised a red flag for a military structure based on a rigid "chain-of-command." Biggs replied with some additional details on what was happening at SAF/AQ. First, the funds supporting Kauffman would come out of Air Force S&T money. Second that Kauffman would be instructed to "work closely with EOARD through all aspects of the trip."[151] Biggs added, "This arrangement is apparently being pursued in this manner because Gen Jaquish (SAF/AQ) instructed AQT [making the arrangements] to make it work."[152] Dr. Hellwig worked indirectly for Lt Gen Jaquish, so that might explain why he did not pursue specifics. However, according to Kauffman, Jaquish had apparently consulted with Air Force Science Advisory Board (SAB).[153] The SAB provided some legitimacy for the hiring decision and perhaps compensated for the generals own lack of scientific

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147 Ibid.
148 Email, Col Hal Rhoads, AFOSR, to Mr. Timothy Biggs, AFOSR, "Re: Prof Bill Kauffman's 'Sabbatical' in Russia," 1 December 1992.
149 Email, Geri Zarbo to Dr. Helmut Hellwig, et. al., "Dr. Kauffman's Sabbatical to Russia," 21 January 1993.
150 Ibid.
151 Ibid.
152 Ibid
153 Ms. Gerri Zarbo, AFOSR/NI, "Dr. Kauffman's one-year Assignment in Russia," 1 April 1993; Attachment, [discussion with Kauffman], n. d.

research training.[154] Although there was no official record of the SAB meeting, Kauffman noted the next day, "General Jaquish can arrange the visit through 2 colonels…. Air Force Science & Technology Scientific Advisory Board."[155] So, he had figured out how to work the system and the system had no concrete plan and involved Jaquish, Tishkoff, and ANSER.

A month later, SAF/AQ backed off the Kauffman-EOARD connection. On 26 May, Lt Col Stephen Marino emailed Tishkoff saying after meeting with Tishkoff and an ANSER representative regarding Kauffman's impending assignment that "we do not want to 'reinvent the wheel, nor do we want to step on EOARD's toes.'"[156] The light had finally gone on at SAF/AQ, that the Michigan professor's tasking was duplicating a process already in existence. In addition, Marino's understanding of Kauffman's job was rather vague; he wrote that Kauffman would conduct a "technology assessment on a broad range of Russian technologies as well as determining and compiling a list of Russian technological agencies."[157] This came directly out of Jaquish's letter of introduction and not from specific tasks the professor would carry out and means to measure progress or deficiencies.

On 5 November 1993, Brigadier General Richard R. Paul, AFMC Director, Science and Technology tasked all Air Force Laboratories and AFOSR to provide Former Soviet Union interaction details regarding funding and an estimate of "your best estimate (rough order of magnitude) of the cost avoidance to the Air Force by using the FSU technology."[158] Kauffman's contract was listed last of 20 as "Fifteen month assessment of science and technology assessments in Russia"; however, unlike the other entries, there was no comment on how this assignment related to USAF 'cost avoidance.'[159] The general asked for accountability and reminded everyone that the money given to the

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[154] Biography sheet," Lt Gen John E. Jaquish," 1 September 2011, http://www.af.mil/information /bios/bio.asp?bioID=5935; BA Economics, Rutgers (1959).
[155] C. W. Kauffman, "Lab Book 19 Aug 91 – 3 July 93," 2 April 1993 entry.
[156] Lt Col Stephen Marino to Ms. Janet Johnston, AFOSR, et. al., "Dr. Kauffman's Task Assignment in Russia," 26 May 1993.
[157] Ibid.
[158] BGen Richard R. Paul, AFMC/ST, "Summary of Former Soviet Union (FSU) Technology Activity," 5 November 1993.
[159] Dr. Julian Tishkoff, "FY 1992-93 Activities in Russia for AFOSR and EOARD," 5 November 1993, 3.

Former Soviet Union had to have direct impact on the Air Force's mission.[160]

On 12 September 1993, Kauffman left Moscow on a scheduled trip back to the U.S. [161] In Dr. Tishkoff's trip report, he explained that this was the first of "three return trips to the United States to coordinate his activities with SAF/AQT, HQ AFMC, and the Air Force laboratories."[162] Tishkoff arranged for him to visit the Air Force laboratories to "serve as guidance for his future efforts in Russia" in order to bring his efforts in line with Air Force needs. This translated into two airline fares and lodging in New Mexico, Tennessee, Texas, New York, and Ohio, plus the follow-on to London. Tishkoff gave an overall positive report; however, in hindsight it became abundantly clear that he was trying to reign in a "loose cannon."[163]

In his trip report that included Dr. Kauffman's and Col Crimmel's briefings as attachments, Tishkoff began by highlighting the comments and impressions he garnered during the laboratory visits and from others at the London meeting. First he wrote that Major Tom Petzold, formerly U.S. Military Attaché, U.S. Embassy Moscow, and now with the Central and Eastern European Defense Studies Department, Supreme Headquarters, Allied Power Europe (SHAPE) thought that "there would be strong interest in Dr. Kauffman's assignment in Russia, possibly extending to Gen [John M.] Shalikashvili."[164] He added that Dr. Hildebrand (temporarily at the U.S. Embassy, Moscow, from Los Alamos National Laboratory): had "indicated his enthusiasm for Dr. Kauffman's effort."[165] Tishkoff wrote that he expected Kauffman to "add to his biweekly reports to ANSER Corporation both critiques of the institutes and persons whom he meets and indications of his planned activity to the extent possible."[166] He added, "I accepted responsibility to see that this information is communicated promptly

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160 Ibid.
161 C. W. Kauffman, "Weekly –Minder: 1993 Appointment Book," 12 September 1993.
162 Dr. Julian Tishkoff, "Trip Report, European Office of Aerospace Research and Development, (EOARD): London, United Kingdom, 18-20 October 1993," 19 November 1993; Atch 1. "Schedule for EOARD Visit"; Atch 2. Dr. C. William Kauffman, "Building Bridges with Russian Colleagues in Science, Engineering, and Technology: 1 June 1993 – 31 August 1994," 23 September 1993; Atch 3. Col Bill Crimmel, EOARD Commander, "European Office of Aerospace Research and Development," 18 October 1993; Atch 4. "Attendance [sheet]," 19 October 1993.
163 Dr. Julian Tishkoff interview with Dennis C. Mills, [AFOSR-FSU Science], 18 June 2008, 19.
164 Tishkoff Trip Report, 1.
165 Ibid, 2.
166 Ibid, 3.

to EOARD's point of contact with FSU activities, Ms. Janet Johnston, and other interested parties."[167] Again in hindsight, Tishkoff's report provided a positive description, but it is also contained a clear set of expectations for the official record, lest there be some sort of future misunderstanding.

The 'honeymoon' did not last long – 11 days after Tishkoff wrote his trip report he received a SAF/AQ complaint regarding Kauffman's latest transgression; he went directly the USAF Chief of Staff for a letter of introduction to Russia's aviation S&T. Looking at Kauffman's briefing attached to Tishkoff's 19 November Trip Report the professor presented to the laboratories and at EOARD contains a very interesting clue that he was first and foremost an academician and therefore the tedious military bureaucracy stood in the way of his noble goal. Titled "Building Bridges with Russian Colleagues in Science, Engineering, and Technology," he then identified himself as "Dr. C. William Kauffman, Department of Aerospace Engineering, University of Michigan Ann Arbor, Michigan 40109," but then claimed to be "Supported by the United States Air Force – Assistant Secretary of the Air Force (Acquisition) Office of Scientific Research Air Attaché, US Embassy, Moscow."[168] A casual observer might think that U.S. Air Force Acquisition, Office of Scientific Research, the US Embassy Air Attaché, and indeed the entire US Embassy "supported" a university professor in his extravagant plan to build bridges with thousands of Russian scientists, engineering, and technologist---all by himself. Certainly Kauffman's assessment of FSU scientists reflected this flamboyant role for himself by asserting "Lessons and Observations: They would welcome Westerners to *save* [emphasis added] Russian science."[169]

Kauffman's slides went on to give an historical perspective beginning with a Polish Combustion Meeting in 1973 and a Russian Combustion Meeting in 1981 showing his connections to countries behind the Iron Curtain. But then he added a bullet that his contacts included "Government Politicians from St. Petersburg, Moscow, Kransnoyarsk, Zhukovshi"[170]---which was a huge red flag for U.S. military and civil service employees

[167] Ibid.
[168] Ibid, Atch. 3.
[169] Ibid., 10.
[170] Ibid., 3.

who were forbidden against political activity during official business unless it came under official duties. No one at the mid-level employment range that Kauffman addressed would dare approach a U.S. Government political figure, let alone a Russian and now AFOSR had to impose its desires on someone who flaunted it. In addition, Kauffman stated that "Visits to defense industries are getting difficult, but we hope letters from the embassy will be effective."[171] He then listed six prominent Russians beginning with Vice President of Russia, Oleg N. Soskovets, Russian Minister of Defense, Andrei A. Kokoshin, head of the Russian Space Agency, Yuri n. Koptev, General Petr S. Deinekin, Chief of the Russian Air Force, and two Defense-Related Industries committee members. Again, to Tishkoff and EOARD's Col Crimmel, these contacts seem far too powerful and politicized for the task of contacting and arranging with Former Soviet Union scientists on an individual basis.

There was also a matter of whom Kauffman represented during his tour. He argued that he provided Former Soviet Union colleagues access to the entire U.S. aerospace science, technologies, and funding processes; monograph and textbook publication; a documentary; participation in a student exchange program; and a professional exchange program. He believed that he represented several perspectives including the U.S. Navy, the American Institute of Aeronautics and Astronautics (AIAA): University of Michigan Business School, EOARD, the Public Broadcasting Service (PBS): and the U.S. Information Agency (USIA).[172] It was one thing to have these other programs in mind while dealing with Former Soviet Union scientists, but the Air Force paid for a 14-month, all expenses, travel, and room and board to find scientists that could work with the laboratories on specific Air Force projects --- not the grand schemes to 'save' Russian science. However, papers, notes, and correspondences clearly show him working directly for other organizations to do just that.

Colonel Crimmel's EOARD briefing followed Kauffman and was also attached to Tishkoff's Trip Report. His organization mission statement outlined a far more manageable role to, "Seek out and evaluate scientific discoveries and technologies that

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[171] Ibid., 9.
[172] Ibid., 8.

impact the U.S. Air Force mission. Communicate these findings to the U.S. scientific community and create opportunities for beneficial collaboration."[173] Crimmel then listed what individual support the program offered: S&T coordinator site visits and liaison reports; "Window on Science" and "Window on Europe"; research contracts and grants; workshop and conference support; and engineer and scientist exchange programs. The organization acted as the laboratories international outreach program. Once EOARD carried out its role, the labs made recommendations on whom and how to continue the relationships with foreign researchers or institutes based on the Air Force mission. Crimmel finished by explaining that in FY 93 (fiscal year 1 Oct 1992 – 30 Sep 1993, EOARD awarded 16 contracts up to $25,000 for a total of $373,000,): the first Russian contracts ever, emphasizing that the funding bought research, access, credibility, reciprocity, and goodwill on behalf of Air Force laboratories.[174] The EOARD Fall Eurogram, approved by Crimmel, stated the following about Kauffman: "The U.S. Air Force is sponsoring Professor C. W. Kauffman, University of Michigan, for an 18-month assessment study in Russia."[175] Then to explain the purpose of Kauffman's efforts Crimmel stated "He is currently in Moscow and is defining the scope of the study at present."[176] In other words, EOARD's commander came away from the 18-20 October meeting in which Tishkoff had paid for a lot of travel money to focus the professor on EOARD's efforts, was not really convinced enough to announce that Kauffman was in Moscow working for his organization.

What then did Kauffman think when he arrived in Moscow after the EOARD meeting? On 4 November Kauffman sent a report to Mr. Dudley Schwarts at ANSER in which he summarizes his recent activities and provides insights into what he understood after the London conference. Apparently, Kauffman's laboratory visits gave him the impression that the Air Force scientists wanted to work with Russians, but funding them was a problem. When was it not? He did not pass on any specific interests and failed to make specific referrals based on Tishkoff's guidance despite taking copious notes (42

[173] Ibid., Atch. 4, 2.
[174] Ibid., 8-11.
[175] EOARD Newsletter, "EUROGRAM, #93-03 (Fall 93):" c. December 1993, 3.
[176] Ibid.

hand-written pages) during the Air Force laboratory visits.[177] Clearly he felt that the money the Air Force had to offer was insufficient and he was dismissive. The comment about EOARD "doing their own thing" revealed he had not been listening to Crimmel's comments connecting EOARD's efforts directly to Air Force laboratories. What was needed in his opinion was foreign aid. Perhaps he was thinking about the Russian's own fond memories of Lend-Lease which they often evoked when discussing their present circumstances. Referring to himself as 'the Moscow branch of EOARD,' without explaining exactly what that meant, implying clarification was not needed. What was worth passing on however, was that the Moscow Model Airplane Club had learned that the Pentagon had such an organization and they wished to establish a "sister club" relationship.[178] Readers must have been stunned to see this as noteworthy and justifying sending Kauffman to Russia, all expenses paid, but instead of Former Soviet Union S&T, he reported the concerns of a Moscow model airplane club. On the other hand, it did have something to do with aviation.

Kauffman noted that he no longer had as much clout at the U.S. Embassy as he used to. He wrote, "Now, the famous letter introducing me from General Jaquish with an Embassy cover letter has not gone out to the officials of the defense industry due to a screw up within the Embassy. The Military Attaché Col Gary Rubus was not happy to hear this and has asked that it be resolved."[179] Lt Gen Jaquish had retired on 1 September 1993 and Kauffman surmised, "I think the feeling of Col Rubus is that a retired general is no longer a player."[180] On 1 and 4 November, he tried to generate a similar letter of introduction after meeting Caroll Jones and Col Jack Manclark at the Moscow Radisson Hotel. Both were on U.S. Air Force Chief of Staff, Gen Merrill McPeak's staff. Kauffman continued to insist his need for another letter to continue his work. The next week, Kauffman added another comment about the matter saying, "TsAGI - [located in] Zhokovski [German] Zagainov is puzzled as to why (the) letter of introduction from U.S. Embassy has not gone out to the leaders of the Russian aerospace industry as he

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177 C. W. Kauffman, "Lab Book 7 Sept 93 – 18 Nov 93," 27 Sep 6 Oct 1993.
178 Dr. C. W. Kauffman to Mr. Dudley Schwartz, ANSER, "First Report, 2nd Quarter," 4 Nov 1993, 2.
179 Ibid.
180 Ibid.

suggested in July 93."[181] Not only was the professor adept in Russian politics, but he also made recommendations regarding U.S. politics: "5 Nov 93: Vladimir Simbaev – Science Attaché. Get funding earmarked in Foreign Aid Bill for Russian science. Go to Senator [Carl M.] Levin and others with this request. The White House will be unable to take $ from any other agency."[182]

Dr. Kauffman had no idea of the firestorm his presentation to McPeak's staff member had just created. This was the kind of academic and military culture clash that he could not have imagined and the consequences almost got him fired. On 29 October he wrote in his Lab Book "Gary Rubus would like to take me to Russian AF, but needs a good letter from D.C."[183] Rubus probably assumed Kauffman would follow protocol and contact SAF/AQ, the same office that the original Jaquish letter came from, but that was not what happened when he approached Gen McPeak's office. To begin with, McPeak was not just any Air Force general---he was the highest ranking Air Force general. Rubus probably also had in the back of his mind that final approval of any USAF correspondence had to come before the top U.S. Government official in Russia---the U.S. Ambassador. The Ambassador stood above any military chief of staff that entered the country. That meant also that the Department of State had final say over any military member's visit. Col Rubus, in fact, as Military Attaché reported directly to the Ambassador and his staff. Going directly to the top reflected poorly on himself as Military Attaché and SAF/AQ. No one in any office wanted to be put in the position of having a four-star general ask a question and they could only respond with "deer-in-the-headlight" eyes or shrugs.

At that particular moment Hellwig tried to push the issue back, "Kauffman was SAF/AQT's creation; if AQT want to discontinue, it's their decision."[184] More than likely, what happened was that McPeak's staffers mentioned their meeting with Kauffman and his desires for another letter of introduction either to their boss, or went to the office that originated the Jaquish letter, his predecessor. That general would have

[181] Ibid., 2.
[182] Ibid.
[183] C. W. Kauffman, "Lab Book 7 Sept 93 – 18 Nov 93," 26 Oct 1993.
[184] Ibid.

immediately ceased anything he or she was doing because Chief of Staff of the Air Force just inquired about some professor in Moscow requesting a letter of introduction to the Russian aviation community. That general, who probably had no clue about why or how this came about, would have called a colonel, and told him or her to straighten this mess out. Once those colonels figured out that the individual in question was an ANSER contractor working actually for AFOSR---those colonels would have contacted AFOSR; hence, Tishkoff's report to Hellwig. What the professor should have done was push it up the chain-of-command for a solution at the lowest possible level and not gone directly to the CEO and avoid these problems for them and more importantly, their boss. Kauffman's professional experiences simply did not include this regimented military culture.

On 7 January 1994, Dr. Tishkoff and Dave Bardash (who oversaw Kauffman's contract with ANSER) met with Dr. Kauffman to discuss his "Quarterly Report October 1993 to December 1993: Building Bridges with Russian Scientists, Engineer, and Technologists."[185] This was Kauffman's second trip back to the U.S. and the second Tishkoff effort to direct the professor to more Air Force laboratory Former Soviet Union cooperative effort. After this meeting, Tishkoff emailed Col Crimmel: "Among these concerns were poor communication and the *frivolous* [emphasis added] generation of proposals."[186] Frivolous was not a word taken lightly in the military. It implied fraud, waste, and abuse of taxpayer's money and could result in serious consequences. Kauffman must have known he was skating on thin ice before they met.

Dr. Gorimir Gorimirovich Chernyi was not only a Member of the Presidium, Russian Academy of Sciences (RAS): but had written an *Introduction to Hypersonic Flow* in 1959 which Ronald F. Probstein translated into English and was published by the Academic Press in 1961. Chernyi literally "wrote the book" for early Soviet hypersonic

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[185] Dr. C. W. Kauffman, "Quarterly Report October 1993 to December 1993: Building Bridges with Russian Scientists, Engineers, and Technologists, USAF-SAF/AQ," c. December 1993, with three attachments; Academician G. G. Chernyi, RAS, [endorsement letter], 16 December 1993; Academician Alexander Merzhanov, RAS, and Professor Nikolai Kidin, RAS, to Dr. Julian M. Tishkoff, [endorsement letter], 14 December 1993; Professor German I. Zagainov, TsAGI Director, to Dr. Julian M. Tishkoff, [endorsement letter], 16 December 1993.

[186] Dr. Julian Tishkoff, SAF/AQ, to Col William Crimmel, EOARD/CC, "Bill Kauffman Update," 11 January 1994.

research.[187] In his RAS position he oversaw the Engineering Mechanics and Central Processed Division, the largest of 12 with 130 of 1000 academicians and 20 institutes.[188]

The Chernyi connection developed entirely through Kauffman's academic activities while selecting Russian scholars to visit the University of Michigan. In his "19 Aug 91 – 3 July 93 Lab Notebook" under the 19 August 91 entry he wrote "Request cooperation MSU [Moscow State University] in letter to Chernyi; MIT, Princeton, Rice, Purdue; Prof Bogdonoff."[189] Princeton University's Professor Seymour M. Bogdonoff probably suggested the Academician to Kauffman for the exchange program. According to an article dedicated to Bogdonoff after his death, Chernyi wrote "Our first scientific publications were devoted to the problem of highly loaded compressor stages and we both very soon became the heads of gas dynamics laboratories, he – at the Princeton University, I – at the Central Institute of Aviation Engines in Moscow."[190] Chernyi went on to describe their first 1961 meeting at Princeton "'well known in USSR famous research and famous center. Of course at the time I was already very well acquainted with the publications of Professor Bogdonoff in hypersonic flows." No doubt Bogdonoff knew of Chernyi's work which by now included his book, but also a 1958 article translated by NASA titled "Effect of Slight Blunting of Leading Edge of an Immersed Body on the Flow Around it at Hypersonic Speeds" in which he addressed the necessity of using a blunt-nose body versus a thin wings or airframes without sharp edges that would not withstand the tremendous heat. The article cites Bogdonoff and several other leading international hypersonic researchers' experiments at that time.[191]

Just in case Chernyi's letter did not impress the military audience, he attached two other letters of endorsement that, unlike the first, was addressed directly to Dr. Julian M. Tishkoff in his temporary position at the Pentagon. The second letter came from

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[187] G. G. Chernyi, translated by Ronald F. Probstein, Introduction to Hypersonic Flow (New York: Academic Press, 1961.

[188] Memo, Dr. C. W. Kauffman to Dr. Jim Duderstadt, "15 Feb 93, Monday, 9:30 AM Meeting with President Duderstadt," 15 February 1993, Kauffman Papers.

[189] C. W. Kauffman, "Lab Book 7 Sept 93 – 18 Nov 93," 26 Oct 1993.

[190] Gorimir G. Chernyi, "Professor S. M. Bogdonoff's Early Pioneering Work on Hypersonic Flows," 12 January 2006, 1.

[191] Gorimir G. Chernyi, "Effect of Slight Blunting of Leading Edge of an Immersed Body on the Flow Around it at Hypersonic Speeds," NASA "Technical Translation F-35: Translated from Izvestia Akademical Nauk USSR, Otdelenie Tekhnicheskikh Naud, no. 4 1958, p 54-66," (June 1960): 1.

Alexander Merzhanov, Corrresponding Member of the Russian Academy of Sciences, Chairman of the Scientific Council on Combustion, and Director, Institute of Structural Macrokinetics, and Professor Nikolai Kidin, Vice-Chairman of the Russian Section of the Combustion Institute stating, "Prof. Kauffman is a very good selection for this position because he has had a very long positive association with Russian scientists."[192]

Kauffman topped off the report with a letter of endorsement from Professor German I. Zagainov, TsAGI Director, who added, "He is a well-known person in Russia's scientific circles. His excellent skill, professional integrity, and knowledge of Russia contribute to the success of this enterprise and benefits the USA and Russia."[193] High praise indeed from the *de facto* chief of all Russian aviation science and technology because TsAGI provided the wind tunnels to both run experiments and test hardware.

Tishkoff's email went on to say, "I remain astonished at what happened after our morning meeting last Friday. In the afternoon we took Bill to meet Jim Mattice, Secretary of the Air Force, Acquisition. He, in turn arranged for Bill to meet Dr. Anita Jones, DoD Director, Defense Research & Engineering (DDR&E): and also is arranging an appointment with Dr. [Sheila] Widnall [Secretary of the Air Force, 1993-1997]! Mr. Mattice is advertising Bill's effort as a prototype for future DoD activity. I am uncomfortable with both the pace and scope of what has happened."[194] In essence, what Kauffman had done was to brush Tishkoff aside and display his considerable clout not only with the Russians, but even with the entire Air Force. Tishkoff had no more control over Kauffman than the Man on the Moon.

In the same 11 January 1994 email to Crimmel mentioning Chernyi's endorsement letter, Tishkoff also mentioned that Dr. Anita Jones began to restructure DoD's efforts to work with the Former Soviet Union. After attending a November Joint Laboratory Director meeting, Dr. Jones directed a new committee to replace the JDL to be led by Dr. Dwight Dustin, former Deputy Director, Ballistic Missile Defense Office. According to Tishkoff, "My impression of this group is much more favorable than its

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[192] "Building Bridges."
[193] Ibid.
[194] Dr. Julian Tishkoff, SAF/AQ, to Col William Crimmel, EOARD/CC, "Bill Kauffman Update," 11 January 1994.

predecessor. Dustin is an experienced Russian hand, including involvement with TOPAZ."[195] In a separate email to Dr. Hellwig sent the same day, Tishkoff added that "It is refreshing to experience Dr. Jones' support of this activity in relation to the attitude of the previous administration. I believe it is now realistic to attempt collaborative research with the Russians."[196]

On 19 January, without informing Col Rubus, Dave Bardash, or Tishkoff, Kauffman sent a memo to Jim Mattice, Air Force Acquisition at the Pentagon, in which he prefaced with "I have consolidated some thoughts as you had requested."[197] If confronted by anyone, he could at least claim that he was directed by someone in high authority. In the memo he expressed his thoughts and overall philosophy on U.S. science and technology funding efforts aimed at assisting their Former Soviet Union counterparts. After mentioning the Soros Foundation's $100M grant and Nunn Leuger $75M he added, "The Russians agree that these amounts of funding are of the level to provide hope in difficult times."[198] When did he assume the role as official representative of the Russian S&T community? He then recommended the three services seek $50M, $40M dedicated to $25K grants, and $10M to three-month U.S. and Russian exchange visits because "this is how we are going to interlock on a working bases as well as politically, economically, and socially. If we really want to know what they did in science, engineering, and technology, we will not find out by walking past the store window!" The $25K grants would support "a senior scientist, two junior people, and a graduate student as well as provide a modest amount of equipment and/or travel."[199] He ended the letter by saying that in conversations, the Russians invoke the spirit of the U.S. World War Two Lend-Lease Program and that such an effort was needed now because "the importance of their scientific, engineering, and technological community cannot be over estimated."[200] Kauffman's reference to "political, economic, social, and community" mirrored Thomas

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[195] Ibid.
[196] Dr. Julian Tishkoff, SAF/AQ, to Dr. Helmut Hellwig, AFOSR, "Update on Items of Interest," 11 January 1994.
[197] C. W. Kauffman to Jim Mattice, "Cooperative Efforts in Russian Science Engineering and Technology," 19 January 1994.
[198] Ibid.
[199] Ibid.
[200] Ibid.

Kuhn's approach and solutions had to be aimed at satisfying several factors even before scientific work could commence.

Kauffman's next gambit came in April when he wrote a memorandum to Col Rubus recommending he organize a committee involving "those who know about Russian science from hands on experience and those who can affect policy."[201] Interestingly enough, he seemed to be the only one on the list that had "experience." The others included Secretary of the Air Force Sheila Widenall, and representatives from the Soros Foundation, congressional staffers, universities, and aviation industry. The letter even included a veiled challenge to the Air Force saying, "As I had noted before the USAF is in a position to assume the leadership role in this effort --- if they desire."[202] The only thing he had learned about the Air Force by this time was that he sent the memo to Col Rubus before going directly to leadership.

As early as January 1994, there began discussions about a follow-on position in Moscow to continue Air Force efforts to seek and establish relations with Former Soviet Union scientists.[203] Kauffman did not exactly ask for the job, he did request that the Air Force extend his August contract to December so he could "provide a meaningful final report and to provide a corporate memory for the new individual."[204] According to the memo all it would take would be adding $20,000 to the $200,000 the Air Force had already paid ANSER for his services. In fact, he argued, this amounted to just one $25K grant in addition to the eight that went into his contract. The money would pay for travel and "to buy out my [UM Fall] aircraft design teaching requirement."[205] Col Crimmel had gotten his hands on the correspondence and in a note to Tishkoff stated he thought Kauffman's efforts threatened the Air Force's efforts to acquire Former Soviet Union S&T Nunn-Lugar funding at the Secretary of Defense level. He added that, "SAF/AQT leadership feels that at this stage we should just leave him alone and distance ourselves as

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201 Memorandum, Kauffman to Col Rubus, "Retreat on Russian Science," 13 April 1994.
202 Ibid.
203 Dr. Julian Tishkoff, SAF/AQ, to Col William Crimmel, EOARD/CC, "Bill Kauffman Update," 11 January 1994.
204 Memorandum, Kauffman to Rubus, "Science Effort for FY 95," 13 April 1994.
205 Ibid.

much as possible for potentially damaging jesters on his part."[206] That was it; the Air Force had just thrown in the towel.

Kauffman came back to the U.S. in April and part of May for his finial scheduled visit under the ANSER contract. Subsequently, Tishkoff wrote a memo to Dr. Hellwig about Kauffman's activities. Overall, he commented, "The time that he spent here was a non-event as far as Air Force S&T interests were concerned."[207] Someone had made time on the USAF Science Advisory Board's agenda for Kauffman to brief "a long term study in Russian aerospace,"[208] at the Pentagon, but his presentation was cancelled. Somehow Dave Bardash had talked to the staff officer arranging speakers and they both agreed Kauffman could not provide detailed technical information, so the SAB briefing would be unjustified.[209] Kauffman's machinations had just caught up with him.

Kauffman's most concise guiding principle statement came from his "Quarterly Report October 1993 to December 1993: Building Bridges with Russian Scientists, Engineer, and Technologists" in which Tishkoff had asked the professor to explain "Your perception of the objective of your assignment?" to which Kauffman replied "It is my desire to meet with as many different Russians as possible – both a discipline and geographic diversity -- to deliver this message. In some ways perhaps I could be thought of as a missionary for USAF science and technology interests."[210] Tishkoff and Bardash were trying to tear him away from this self-ordained immeasurable, vague 'missionary' role to one with direction, specific tasks, and outcomes. After Kauffman delivered his presentation, the Former Soviet Union scientists or institutes usually provided facility tours, discussions, and reciprocated with literature, books or manuscripts, and in some cases research proposals. Instead of analyzing the material, and directing the information to the appropriate Air Force laboratory, Kauffman explained "some information which seems of particular interest is passed to the USAF Embassy Staff and put in the reports

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[206] Facsimile, Col Crimmel, EOARD/CC, to Dr. Julian Tishkoff, [Kauffman funding and extension proposals], 22 April 1994
[207] Memorandum, Tishkoff to Dr. Hellwig, "Russian Update," 17 May 1994.
[208] Agenda, "USAF Scientific Advisory Board Ad Hoc Committee Study on Air and Space Technologies for Year 2020 Meeting 4-5 May Pentagon, Washington, D.C." c. April 1994.
[209] Ibid.
[210] Dr. C. W. Kauffman, "Quarterly Report October 1993 to December 1993: Building Bridges with Russian Scientists, Engineers, and Technologists, USAF-SAF/AQ," c. December 1993, 8.

sent to ANSER for distribution in USAF channels."   In so many words, I show up, hand out literature, take tours, eat and drink whatever was offered, including visits to homes, gather literature, throw it in a box, and move on to the next site visit.

Tishkoff's next question was "The approach that you have followed to meet that objective?"[211] To which Kauffman listed seven different initiatives he supported, but only two of seven handout elements contained anything to do with the Air Force. According to Kauffman's notes recorded during the meeting, they instructed him to "Try to stay with basic science" and recommended prior to visiting a site to send a "preproposal letter of inquiry; statement of objective, approach; qualifications of institute; description of timetables."[212] In other words, do research, compose a plan, provided measurable goals, execute, and report the results back to the Air Force---all of which he ignored. It turns out that the only "report" he had in mind was a final one when he completed the contract in August 1994.

Dave Bardash had also written up something on the 7 January meeting with Tishkoff and Kauffman that went into specifics in which he laid down requirements, objectives, approach, Air Force Actions.[213] Actually, it was a record of the running dialogue between Tishkoff, the Laboratories, and Kauffman's reports. The "understanding" asks that Kauffman "Identify, document, and assess the knowledge products, and capabilities of individuals and organizations within the FSU who have developed or are developing scientific knowledge or aerospace technologies relevant to the Air Force."[214] Next in pursuit of that objective, "seek to identify 3 to 5 novel or technically significant opportunities which may result in the formation of a close working relationship between USAF and FSU." Addressing Kauffman's belief that he worked for other agencies Bardash wrote "Other 'big picture' concerns or areas of other-Service emphasis may be used as appropriate for conversation starters, but contacts should clearly understand who Professor Kauffman's client [are], and what are their scope of interests

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[211] Ibid.
[212] C. W. Kauffman, "Lab Book 19 Nov 93 – 9 Feb 94," 7 January 1994.
[213] Dave Bardash, ANSER, "Understanding of objectives and approach for Professor Kauffman's assignment for SAF/AQT in the Former Soviet Union," 25 January 1994.
[214] Ibid , 1.

and possible future involvement."[215] Then came the statement that he "will emphasize opportunities for interchange and establishment of the linkages for future funded initiatives, but will de-emphasize interest in immediate receipt of grant proposals."[216] Some Former Soviet Union scientists had complained that despite having given Kauffman a grant proposal that they had not received any funding. Welcome to capitalism and Western science and research. Kauffman passed out literature, but no money.

Kauffman the academician saw the money the Air Force paid ANSER for his contract service as just another grant. He saw the guidance Tishkoff gave him in the London EOARD meeting as parochial and perhaps even quaint. In his 7 May 1991 correspondence to Major Wendel he set forth a proposal, actually a solicitation, "We are of course looking for financial support for the program from agencies, organizations, and corporations which have aviation related interests."[217]

Among Kauffman's notes and date books, there was one thread names and visits that did lead to the Air Force's hypersonic research. Dr. Hellwig directed that EOARD compile the proposals and literature Kauffman collected, create a digital database, and forward the material to the Air Force laboratories. Fred W. Johnson, Liaison Officer Assistant, reported that the collection contained 260 proposals from 51 institutes, education establishments, and private for-profit and non-profit companies. Unfortunately, many Former Soviet Union scientists and researchers thought their applications would be quickly funded to the total amount of $6.5M. The misunderstanding created problems for subsequent Air Force representatives for those in the unfunded category.

About a month after Kauffman began his assignment he noted a meeting with Academician Chernyi who explained how he could help NASA with their hypersonic flow problem.[218] On 6 July 1993 he visited TsAGI and learned that Ilyushin and Tupelov

215 Ibid, 2.
216 Ibid, 3.
217 Dr. C. W. Kauffman, UM, to Maj Rick Wendel, AFOSR, [Proposal], 7 May 1991.
218 C. W. Kauffman, "Weekly –Minder: 1993 Appointment Book," 6 July 1993.

had conducted 15 years of hypersonic research, but were now at a dead end.[219] Two days later he wrote the name "Mishin" in his appointment book. Gennadiy I. Mishin played a key role in the subsequent USAF Weakly Ionized Gas research conducted by the Johns Hopkins University Applied Physics Laboratory.

[219] Ibid., see also C. W. Kauffman, "Lab Book 7 Sept 93 – 18 Nov 93," 6 July 1993.

CHAPTER THREE

PHYSICS AND AERODYNAMICS

Chapter three examines previous scientific collaborations with former enemy nations, primarily Germany. While not the same as post-Cold War efforts, they do show some commonality. In addition, US-USSR scientific peaceful atomic energy cooperation did occur. The Soviets applied their plasma-energy expertise to closed military research which became available after the USSR's collapse.

Science After WWI and WWII

The practice of recruiting former enemy country scientists, some dragooned, occurred at the end of World War One and World War Two. During those times, Germany was seen as the most advanced aerodynamic science center in the world. After each period, international aviation received huge scientific windfalls.[220] Ludwig Prandtl had much to do with this, but also the Germans were also known for "thoroughness and accuracy."[221] Even at this early period, the Germans conducted "scientific" flights designed to measure atmospheric ionization.[222]

Much like the post-Cold War foreign relations, Former Soviet Union and US scientists had to navigate through the treacherous shoals of Big Science and governmental politics. The impetus for an international meeting actually came just after World War I. At that time, a William Knight, a mechanical engineer appointed by National Advisory Committee for Aeronautics (NACA) to survey European aerodynamic laboratories advocated the need for a congress to coordinate and standardize for the new science "without any discrimination between former enemies and former allies."[223] He argued that aircraft engineers and manufacturers needed clear measures and a common language to avoid catastrophe in the air. Safety should outweigh the nationalistic hatred created the war against the Germans and the Austro-Hungarian Empire. During his

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[220] John D. Anderson, *A History of Aerodynamics and Its Impact on Flying Machines*, (Cambridge University Press, 1999).
[221] William Knight, et. al., "Standardization and Aerodynamics," NACA Technical Notes no. 134, March 1923, 28.
[222] NACA, "Sixth Meeting of the Members of the German Scientific Association for Aeronautics," NACA Technical Memorandum no. 20, April 1921, 2.
[223] Ibid., 1.

travels to various aerodynamic centers, he saw bewildering definitions, mathematical formulae, and inconsistent symbology. The subsequent findings were published in *Aerial Age*, an early aviation trade magazine. This effort occurred because the world's best aerodynamic knowledge resided in Europe and before incorporating that knowledge, the lack of a common forum and standards needed to be addressed.

Knight provided editorial oversight for nine articles by several prominent European scientists printed over 18 months from June 1921 to December 1922 and published together in NACA Bulletin no. 134 (March 1923). He urged that NACA to take the lead for this effort because the US was "free from post-war hatred and we would not be inclined to discriminate between scientist of formerly allied nation and scientists of former enemy nations …."[224] His early optimism waxed and waned during the publication period. In deference, Professor Ludwig Prandtl of the University of Gottingen, the man who established aerodynamics as a science was the first author and was followed by his student, Hungarian-born Professor Theodore von Karman, who now taught at the University of Aachen and first suggested the collaboration idea should be an international society. Karman's reply showed sensitivity to the anti-German atmosphere throughout Europe by stressing safety and practical issues over scientific matters. Writing from Rome, Colonel Ing. G. Costanzi endorsed the idea and added "the necessity of inviting the Germans to participate in any international settlement of the various questions affecting aerodynamical research work."[225]

Electrons and Quanta

Prandtl's impact carried scientific aerodynamics up to the heat barrier. The next great leap came with Former Soviet Union scientist's theories with American pragmatism. This advance came in response to aircraft forming "shock waves and other inherently compressible phenomena that occur in atomic blasts and in the flow around ballistic projectiles."[226]

No one expressed the new age of physics in more understanding terms than *The New York Times* science editor Waldemar B. Kaempffert. Born in 1877, he earned a

[224] Ibid., 10.
[225] Ibid., 28.
[226] Walter G. Vincenti, "Control-Volume Analysis: A Difference in Thinking between Engineering and Physics, *Technology and Culture*, 23, no. 2 (1982): 159, http://www.jstor.org/stable/3104129, accessed 15/11/2010.

bachelor's degree in science and was elected to Phi Beta Kappa. During a speech to Amherst College faculty and undergraduates on "Scientists and the Journalist" he defined his role as popularizing scientific accomplishments because of increasing public awareness in their everyday lives.[227] He began his career as assistant editor of *The Scientific American*, and in 1903 earned a law degree at New York University. In 1911, Kaempffert was named managing editor of the *Scientific American* and four years later moved to become the editor of *Popular Science Monthly* until 1920. He became a freelance writer until 1927 when *The New York Times* hired him as science editor. In 1937, the National Association of Science Writers elected him president. In 1954, the British Association of Science Writers awarded him the Kalinga Prize worth $28,000 and the Albert and Mary Lasker Foundation special award for medical reporting. For this particular award he had been preceded by French physicist Louis de Broglie, evolutionary biologist Julian Huxley, and followed later by philosopher Bertrand Russell, just to name a few. Except for a three-year hiatus as Director of the new Museum of Science and Industry at Chicago, he wrote for the *Times* until his death in 1956.[228]

Up to the time J. J. Thompson discovered the electron (1897): scientists believed that the atom was the smallest form of matter and many eminent scientists, including Ernst Mach, supported the theory. During this time William Crooks and other researchers used sealed glass tubes to explore properties of matter. He devised an experiment in such a device in which he proposed to test the conductivity of the air with separated anode and cathode. Each was connected to an electric transformer so that to complete the current the air inside the cylinder would have to be conductive. The experiment did not work with air, but he discovered that by pumping out the air a green phosphorus glow appeared and took on the name of 'cathode rays' (television tubes). In 1895, Wilhelm Rontgen, using such a devise discovered that high-voltage cathode rays placed on heavy metal radiates a kind of ray that penetrates solid materials – later known

[227] *The New York Times*, "Kaempffert, in Amherst Talk Urges Greater Space for Subject in Newspapers," *The New York Times*, 20 February 1938, http://query.nytimes.com/mem/archive/pdf?res=F10915F83555117289D DA90A94DA405B888FF1D3, accessed 2/28/12.

[228] *The New York Times*, "Waldemar B. Kaempffert Dies: Science Editor or *The Times*," *The New York Times*, 28 November 1956, http://query.nytimes.com/mem/archive/pdf?res=F00812F9385C147B93CAAB178AD 95F428585F9, accessed 2/29/12.

as X-rays. [229]

In England, Joseph John (J. J.) Thompson, set up a Crooks tube with two parallel plates and found he could alter the cathode ray's streams with electricity. He compared the electrode charge to the atom's mass with the angle of deflection and concluded that atoms must have sub particles he called 'corpuscles' or later electrons.[230] His discovery ushered in the end of Newton's machine-like cosmos of immutable laws into the age of relativity and quantum theory.[231]

In France, Henri Becquerel observed that pitchblende, uranium ore, released a material that would pass through photographic plate holders and fog the plates inside. He called it 'radioactive'. Pierre and Maria Curie also investigated radium maintained at a slightly higher temperature than it surroundings and found that its radioactivity contaminated everything around it and no material seemed to stop it.[232]

Max Plank announced that instead of the prevailing theory that light travels through ether waves, that it shoots out in particles he called 'quanta'. He also noted that more quanta came from atoms that radiated blue or violet light than atoms emitting dull red. Albert Einstein asked how much energy existed in the atom. In 1905, he came up with a simple algebra equation that energy equaled mass times the speed of light squared. According to Kaempffert, "Einstein found that it is much easier to understand what we see if we assume that matter is not merely something placed in space but something that actually affects space."[233]

In 1954, long after the birth of particle physics, atomic bombs, and nuclear power, Kaempffert looked back in retrospect and compared Einstein's work to quantum

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[229] Malcolm W. Browne, "Finding 'Corpuscle' of electricity Shaped Knowledge of Matter," *The New York Times*, 29 April 1997, http://www.nytimes.com/1997/04/29/science/finding-corpuscle-of-electricity-shaped-knowledge-of-matter.html?scp=26&sq=j+j+thompson+electron&st=cse&pagewanted=print, accessed 2/29/12

[230] Ibid.

[231] Waldemar Kaempffert, "Sir Joseph Thomson of Electron Fame," *The New York Times*, 28 March 1937, http://query.nytimes.com/mem/archive/pdf?res=F60711FB3E5A157A93CAAB1788D85F438385F9, accessed 2/27/12.

[232] Waldemar Kaempffert, "The Revolution that Radium Began," *The New York Times*, 26 December 1948, http://query.nytimes.com/mem/archive/pdf?res=FB091EFE3F5E167B93C4AB1789D95F4C8485F9, accessed 2/27/12.

[233] Waldemar Kaempffert, "Changing Conceptions of the Universe: A Riddle Still," *The New York Times*, 17 April 1932, http://query.nytimes.com/mem/archive/pdf?res=F10714F63C5A13738DDDAE0994DC405B828FF1D3, accessed 2/29/12.

mechanics. Princeton had just published Einstein's fourth edition of *Generalization of Gravitational Theory* which constituted yet another attempt at a unified theory. The theory works for explaining the earth's movement around the sun, but not for electrons shifting from one orbit to another: "Relativity could not explain the leaping of the electrons from orbit to orbit and the emission of light and heat as they did so."[234] A unification theory would provide some sort of deterministic law based on physics, but with quanta light projectiles and not waves, "There is no possibility of stating what particle will do within an atom. Hence atomic events are treated statistically somewhat in the manner that a life insurance actually treats life and death."[235]

Ernst Rutherford, a student of Thompson, thought that in order to draw correct conclusion on atoms they must be broken apart. He found that radium emitted alpha and beta rays and Pierre Villard discovered gamma rays shortly thereafter. He decided to use radium to break up atoms because it radiated billions of alpha particles a second. Using a gold leaf, Rutherford found that something in atoms deflected alpha particles which he called protons. With his discovery, the model that Thompson found was replaced by a positively charged nucleus surrounded by negatively charged electrons. A crisis emerged because if the conditions were correct, all electrons would fall into the nucleus – according to Newtonian laws – it was obviously incorrect.[236]

Niels Bohr took what Plank and Einstein had decided in that when quanta struck an atom, the energy transferred to the atom which it could give up later, and stated that when an electron absorbs energy it moves to an outer orbit and when losing quanta, the electrons move to an inner orbit. This prevented the electron from disappearing into the nucleus. But his theory applied only to a hydrogen atom. Physicists like Wolfgang Pauli, Louis de Broglie, Erwin Schrödinger, Werner Heisenberg, Max Born, and Paul Dirac added improvements for more complex atoms. In 1925, when things were not complex enough, Werner Heisenberg announced that in the atom's subatomic world experiments meant much less than before. He argued that one could not measure velocity and position

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[234] Waldemar Kaempffert, "Einstein Improves His Unified Field Theory, His Answer to the Quantum Physicists," *The New York Times*, 5 April 1953, http://query.nytimes.com/mem/archive/pdf?res=F2081FFF395D177B93C7A917 8FD85F478585F9, accessed 2/29/12.

[235] Ibid.

[236] Waldemar Kaempffert, "The Revolution that Radium Began."

at the same time. If you measured one, you could not accurately measure the other. It was up to James Chadwick working in Rutherford's laboratory to discover a neutron in 1932.

In December 1938, Otto Hahn, Lise Meitner, and Strassmann Fritz conducted an experiment to bombard uranium with neutrons. In successfully doing so, they had carried out the first nuclear fission experiment that led to the atomic bomb. This was the world that von Karman, Tsien, and Arthur Kantrowitz stepped into just before WWII.[237]

Once discovered in laboratories, scientists turned to examining the source of 'cosmic rays' for information on the stars and the age of the universe. Kaempffert went about explaining this history with his usual zeal and clarity: "Wherefore physical science engages in an adventure that has all the excitement and demands all the courage that we associate with the quest of buried treasure." [238] Starting with alpha, beta, and gamma ray discoveries in the laboratory, he explained that radioactivity, electrically conductive, was also found in rocks, and scientists began to take measurements at high mountains, lake bottoms, and all over the world. No appreciable increase or decrease was found until balloons were used and found radioactivity increased with altitude which led to the conclusion that the rays came from outside the earth. Robert A. Milliken contravened the theory that the universe was losing energy and proposed that somewhere in space was the creation of new matter. Kaempffert explained the meaning of the assertion in that while science could not measure 'cosmic rays' directly, "We can judge them only by their effects on the air – on gases in general."[239] The quote expressed a fundamental fact that gases and the molecules they contain were easier to examine scientifically because they require less energy to isolate.

Dr. Jean-Pierre Petit, an astrophysicist who has conducted many years of experiments, provides a modern-day gas dynamics explanation for non-scientists. Using light bulbs for his demonstration, Petit compares the light emissions of a tungsten filament and neon. The solid filaments' electrons are closer and thus require more

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[237] Ibid.
[238] Waldemar Kaempffert, "The Cosmic Riddle That Awes Science," *The New York Times*, 13 November 1932, http://query.nytimes.com/mem/archive/pdf?res=F50A16FA3A5513738DDDAA0994D9415B828FF1D3, accessed 2/2812.
[239] Ibid.

electricity to vibrate enough to emit light and consequently shed some of the energy in heat. Neon, on the other hand, acts as a conductive filament because the electrons are further apart and as a result requires less energy to emit. Between the cathode and anode in a neon light when you flip the switch on the power, gas molecules begin to gain kinetic energy and when collisions occur, the negatively charged electrons separate from their positively charged ions. Petit calls this an "electronic avalanche." Light is the result of the excess energy when the electron and ion reunite. In a neon light, electrical energy makes this a continuous splitting and uniting process. As long as power is added this ionizing and deionizing continue in creating plasma.[240] The process is chaotic: "The high-pressure plasmas are extremely unstable. They tend to kink, bend, break up, and otherwise escape from the magnetic vise and to contact the container in which they are confined."[241]

Problems of Cosmical Aerodynamics

The merger between astrophysics and aerodynamicists came incrementally. Dr. Johannes Martinus Burgers, co-founder of the International Union of Theoretical and Applied Mechanics (IUTAM): described that he had met Von Karman in 1921and discussed turbulence.[242] During and after World War II, aerodynamicists all over the world focused primarily on jet aircraft and solving a whole host of new challenges. At the same time, they along with others sought to extend the German's rocket capability. In August 1949 some of the world's most prominent physicists gathered to discuss common scientific phenomena. For instance, astronomers sought out shock wave research from their counterparts to understand observed heat waves from the sun and super nova. In summing up the presentations at the end of the conference, Johannes M. Burgers stated that one of the most important points learned was that "it has become evident that magnetic phenomena may play an important part in turbulence."[243] We

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[240] Jean-Pierre Petit, "The Adventures of Archibald Higgins: For a Fistful of Amperes," *Association of Knowledge Without Borders*, http://www.savoir-sans-frontieres.com/JPP/telechargeables/English/For_a_fistful_of_ amperes.pdfm , accessed 11/10/10.
[241] Harry Schwartz, "Toward Controlled Fusion Power," New York Times, 26 October 1969.
[242] Dr. Johannes M. Burgers interview by Thomas S. Kuhn and M. Kline, 9 June 1962, Niels Bohr Library & Archives, *American Institute of Physics*, College Park, MD USA, www.ai org/history/ohilist/LINK, accessed 2/15/12.
[243] *Problems of Cosmical Aerodynamics*, Proceedings of the Symposium on the Motion of Gaseous Masses of Cosmical Dimensions held at Paris, France, August 16-19, 1949, organized by IUTAM and IAU:

know now that his observation was a huge understatement. The 52 participants included thirty-four astronomers and eighteen physicists or fluid mechanists. Chief among the aerodynamicists stood Theodore von Karman, but he was joined by Werner Heisenberg and Carl F. von Weizsacker, both who had worked on Germany's wartime nuclear program, and von Neumann who worked on the Manhattan Project for the US.[244]

Dr. Hans Bethe described a similar 1938 conference that brought together separate research fields. Edward Teller and George Gamov brought together astrophysicists and theoretical physicist at the Carnegie Institution for the first time. Bethe thought that the astrophysicists were at a loss of what was expected of them. In discussions, the group came up with different measurements for the sun's temperatures. Between the two groups, they discovered the mistaken assumption that the sun was made of the same materials as the earth. Whereas the latter was composed of heavy elements, the astrophysicists pointed out that the former was primarily the much lighter hydrogen. Both disciplines knew that the stars were nuclear reactions, but not exactly what sort of atomic actions took place.[245]

After WWII, went back to Cornell and worked on nuclear power. Nuclear fusion was first proposed by Friedrich Houtermans and Robert d'Escourt Atkinson in 1929.[246] In 1938, Hans A. Bethe and C. F. von Weiszaecker, Gottingen, answered the riddle of how the sun changed hydrogen into helium and energy.[247]

Magnetohydrodynamics

Most magnetohydrodynamic aeronautical articles begin with a presentation by Edwin. L. Resler, Jr., and William R. Sears, both from Cornell. First discussed at the June 1957 National Summer Meeting, International Nautical Sciences, the *Journal of the*

Central Air Documents Office, Army-Navy-Air-Force, UB Building, Dayton 2, Ohio (USA): 234.

[244] Denis Serre, "Von Neumann's Comments About Existence and Uniqueness for the Initial-Boundary Value Problem in Gas Dynamics," *Bulletin of the American Mathematical Society*, 47, no. 1, (2010): 149.

[245] Dr. Hans Bethe interview by Charles Weiner and Jagdish Mehra, 27 October 1966, Niels Bohr Library & Archives, *American Institute of Physics*, College Park, MD USA, www.ai org/history/ohilist/LINK, accessed 2/14/12

[246] Hans A. Bethe, The Road from Los Alamos, (New York: Simon & Schuster, 1991): 246.

[247] Waldemar Kaempffert, "Science in Review: new Concept of How the Sun and the Stars Create their Vast Stores of Energy., *The New York Times*, 5 August 1951, http://query.nytimes.com/mem/archive/pdf?res= F30B12FA355D177A93C7A 91783D85F458585F9, accessed 2/29/12.

Aerospace Sciences published the article the next year. [248] Sears received an aeronautical engineering degree in 1934 and moved to the California Institute of Technology in Pasadena, California, for his graduate work under Hungarian physicist Theodore von Karman.[249] The article's importance was in recognizing the emerging research that combined electromagnetic aerodynamic effects.[250] "The research of shock wave propagation in plasma was rejuvenated in Russia in the 1980s – the AJAX concept, and more recently by Ganguly et. al."[251]

In 1942, Hannes Alfven, a Swedish physicist, explained the basics of this new science called magnetohydrodynamics. He observed that if "a conducting liquid is placed in a constant magnetic field, every motion of the liquid gives rise to an E.M.F. [electromagnetic force] which produces currents. Owing to the magnetic field, these currents give mechanical forces that change the state of motion of the liquid. Thus a kind of combined electromagnetic-hydrodynamic wave is produced which, so far as I know, has as yet attracted no attention."[252] Alfven presented similar material at the "Problems of Cosmical Aerodynamics" in 1949 where the opening speaker ventured to say that "Electromagnetic forces may possibly play a role,"[253] and that Hannes Alfven and Hendrick C. van de Hulst lecture would speak to that issue.

Subrahmanyan Chandrasekhar, and future Nobel Laureate physicist for his work on black holes, explained that during the 1940s, after expressing a desire to take up a new research field, it was van de Hulst that told him that turbulence was an emerging field. The early 1950s was a time when plasma physics and the confinement of ionized gas in magnetic fields emerged.[254] Chandrasekhar started in that area and shifted after some

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[248] E. L. Resler Jr. and W. R. Sears, "The Prospects for Magneto-Aerodynamics," *Journal of the Aerospace Sciences*, 25, no.4, (1958): 235-245.
[249] Nicholas Rott "William Rees Sears, 1913-2002" Washington, DC: National Academy of Sciences, 86,(2005).
[250] J. S. Shang, W. Canupp, and D. V. Gaitonde, "Computational Magneto-Aerodynamic Hypersonics," *AIAA*, 9th International Space Planes and Hypersonic Systems and Technologies Conference and 3rd Weakly Ionized Gases Workshop, 1-5 November 1999 Norfolk, VA, (1999): 12.
[251] J. S. Shang, B. Ganguly, R. Umstattd, J. Hayes, M. Arman, and Bletzinger, "Developing a Facility for Magneto-Aerodynamical Experiments," *AIAA*, 38th Aerospace Sciences Meeting & Exhibit, 10-13 January, Reno, NV, 1.
[252] Hannes Alfven, "Existence of Electromagnetic-Hydrodynamic Waves," Nature, no. 3805, 3 October 1942, 405-406.
[253] *Problems of Cosmical Aerodynamics, 3.*
[254] Eugene N. Park, "Subrahmanyan Chandrasekhar, 1910-1995: A Biographical Memoir," National Academies Press: Washington, DC, 1997, http://www.na edu/html/biomems/schandrasekhar.pdf, accessed

time to stability on the hydrodynamic phenomenon. [255]

The Resler-Sears magnetohydrodynamic (MHD) announcement an on-board device to mitigate shock waves must have stunned the crowd at the conference. Up to that time MHD had been considered for power generation."[256] The US and the Soviet Union had worked together on MHD as a source for electricity for many years. Before and after WWII, Westinghouse Research Laboratories pursued developing a magnetohydrodynamic generator. This research stimulated others like Hans Bethe and Arthur Kantrowitz to build such a device. The Soviet Union also became interested in the technique. In 1958, the US's MHD secrecy veil was lifted and the Avco Corporation and the American Electric Power Service Corporation set out to develop a coal-fired MHD plant.

Fusion and MHD International Cooperation

In July 1955, President Dwight D. Eisenhower and Soviet General Secretary Nikita Khrushchev met at the Geneva Summit in Switzerland, also known at the 'atoms for peace' conference. This meeting after Josef Stalin's death opened up scientific exchange opportunities. In a sign of the times, later that year, the Great Soviet Encyclopedia indentified Academician Igor V. Kurchatov as the director and subsequent 'father of the Soviet atomic bomb'. [257] At the February 1956 Communist Party Congress in Moscow, it was Kurchatov that announced ambitious plans for the peaceful use of atomic energy and that Soviet scientist were ready to cooperate with US physicists in an effort to harness thermonuclear reactions for peaceful purposes. He appealed to the US to accept Soviet proposals for banning atomic and thermonuclear weapons.[258] During a

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[255] Subrahmanyan Chandrasekhar interview by S. Weart, 17 May 1977, http://wwwai org/history/ohilist/4551, 57, accessed 2/16/2012.

[256] J. T. Lineberry, et. al., "Results of Nonequalibrium Plasma Experiments," AIAA 95-1935, 22 June 1995, 1; see also, Carlson C. Pian, Robert Kessler, and Edwin W. Schmitt, "Magnetohydrodynamic Generator Design for a Combined-Cycle Demonstration Powerplant," Journal of Propulsion and Power, Vo. 12, no. 2, March-April 1996, 390-397; Ron J. Litchford, John T. Lineberry, Bor-Chyuan Lin, and Valentin A. Bityurin, "High-Temperature Current Layer MHD Power Generation, AIAA 96-2357, 1-15.

[257] Harry Schwartz, "Soviet Identifies Atomic Physicist," *The New York Times*, 14 November 1954, http://query.nytimes.com/mem/archive/pdf?res=FA0F1FFF3A5D13728DDDAD0994D9415B8489F1D3, accessed 2/26/12.

[258] Harry Schwartz, "Soviet is Pushing Atom Power Plan," *The New York Times*, 4 March 1956, http://query.nytimes.com/mem/archive/pdf?res=F10912FB395816738FDDAD0894DB405B8689F1D3, accessed 2/26/12; see also, Welles Hangen, "Soviet Bids US Cooperate in Nuclear Work for Peace," *The New York Times*, 2 February 1956,

subsequent visit by Khrushchev to Great Britain, Kurchatov went even further and explained controlling thermonuclear explosions with fusion to a group of British scientists stunned by the openness. He handed out typewritten copies of the lecture and answered all questions without hesitation. Dr. B. J. F. Schonland, Deputy Director of Britain's atomic research at Harwell, commented that not only was he impressed by the quality of the work, but also that Kurchatov had discussed science data not yet released by Britain or the United States. [259]

The Atoms for Peace Conferences caused western scientists to reset their perceptions of Soviet science. First, they had great mathematicians. James Gleick, the author of the groundbreaking book *Chaos: Making a New Science* (1987) that introduced chaos theory to the public, wrote that:

> Western scientists have often repeated work that already existed in the Soviet literature…. Soviet mathematicians and physicists had a strong tradition in chaos research, dating back to the work of A. N. Kolmogorov in the fifties.[260]

Andrei N. Kolmogorov founded modern probability theory and theory on the flow of energy in fluids.[261] In 1962, T*he New York Times* commented on the rising number of Russian mathematics text appearing in US universities.[262]

The ideas Kurchatov chose to discuss with British physicists came as a surprise to American scientists also. The Soviets had also heard about the MHD reactor idea and Professor Meredith W. Thring's work at the University of Sheffield in England. In 1961, V. A. Kirillin, Chairman of the Committee for Science and Technology, authorized a MHD-research development program under the Director of the Institute of High Temperatures Alexander. E. Sheidlin. The Institute had previously worked on high-

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http://query.nytimes.com/mem/archive/pdf?res=F30C17F63F58157B93C3AB1789D85F428585F9, accessed 2/26/12.

[259] *New York Times*, "Russian Research In Fusion Control Impresses Britain," *The New York Times*, 26 April 1956, http://query.nytimes.com/mem/archive/pdf?res=FA0D14FA3B58157B93C4AB178FD85F428585F9, accessed 2/26/12.

[260] James Gleick, *Chaos: Making of a New Science*, (New York: Viking 1987): 76.

[261] James Gleick, "A.N. Kolmogorov Dies at 84; Top Russian Mathematician," *The New York Times*, 23 October 1987, http://www.nytimes.com/1987/10/23/obituaries/an-kolmogorov-dies-at-84-top-russian-mathematician.html? scp=1&sq=kolmogorov&st=cse, accessed 3/2/12.

[262] *New York Times*, "Use of Soviet Mathematics Texts Is on the Rise in US," *The New York Times*, 20 May 1962, http://query.nytimes.com/mem/archive/pdf?res=F10B14FD3D5A13778DDDA90A94DD405B828AF1D3, accessed 3/2/12.

temperature materials, but with MHD it had to research gas dynamics.[263]

The West learned that the Soviets were interested in MHD when Sheindlin and Evgeny P. Velikhov, Deputy Director of the Kurchatov Institute of Atomic Energy (appointed director 1959): attended the First International Conference on MHD in England. Velikhov presented a paper on measuring ionized plasma instability which subsequently became known as the "Velikhov instability."[264] The Soviets also announced they would engage in effort to develop MHD for power production.[265]

Many have speculated on why the Soviet Union possessed such a drive for energy and big projects. Irving Langmuir, Nobel Prize in Chemistry (1934): visited the Soviet Union by invitation to the Soviet Academy of Sciences 220th anniversary in June 1945. He met with Kapitza and reported his superbly equipped laboratory in top condition and carrying on research. Soviet science had maintained its fundamental research capability during the war, and he credited planning for placing science in a position to support future projects. He also stated that their researchers wanted world peace and were open to foreign guests.[266]

In January 1956, Kantrowitz was appointed vice-president of Avco Manufacturing Company and Director of the Avco Research Laboratory.[267] In 1962, Pravda announced that they had completed the design and were ready to begin construction. They claimed the MHD process would bring thousands of kilowatts at a time when the largest steam turbine generators could only manage hundreds of thousands of kilowatts. The technology produced "low temperature" plasma, about half the temperature of the sun's surface, rather than hundred million degrees centigrade produced by a thermonuclear fusion reactor. At the time US and British MHD experiments had only produced about 700 kilowatts. He was asked to comment about the Soviet's MHD claims and thought that the US could build such a plant, but added presciently, that a

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[263] G. Rudins, "US and Soviet MHD Technology: A Comparative Overview," RAND, R-1404-ARPA, January 1994, 3.
[264] J. Petit, J. Geffray, "Non Equilibrium Plasma Instabilities," Proceedings of the 2nd Euro-Asian Pulsed Power Conference EAPPC, Vilnius Lithuania, 2008, 1.
[265] G. Rudins, "US and Soviet MHD Technology: A Comparative Overview."
[266] Irving Langmuir, "Science and Incentives in Russia," *The Scientific Monthly*, 63, no. 2, (1946): 85-92, http://www.jstor.org/stable/3106951, accessed 4/14/09.
[267] The New York Times, "Cornell Teacher Joins Avco As Vice President," *New York Times*, 24 January 1956, http://query.nytimes.com/mem/archive/pdf?res=F10914FE3C58157B93C6AB178AD85F428585F9, accessed 2/26/12.

system that appeared economically suitable for the Soviet Union might not be in the US.[268] The same year Kantrowitz announced that the Avco Laboratory had conducted MHD experiments and managed 1,350 kilowatts.[269]

In the US, the Department of Defense pursued MHD for short-term, high-power as Resler and Sears had proposed in their 1957 article. In 1960, a RAND report described using a rocket's exhaust, which reaches approximately 3,000 K as the ionizing catalyst to generate from 1000 to 1000,000 megawatts in microbursts. While not a long period it would be almost instantaneous. The report explained that the total steady-state capacity of the US at that time was 150,000 megawatts.[270]

The issue of aerodynamic heating on aircraft at high Mach speeds also became a topic for MHD research at this time. In 1958, a researcher at Ramo-Wooldridge Corporation under an Air Force Ballistic Missile Division, stated that at approximately Mach 15, a shock wave produced ionization and that it is "possible to alter the characteristics of the flow, by means of externally applied magnetic fields."[271] In 1964, Kantrowitz's Avco-Everett Research Laboratory produced a report that stated this new concept:

> The obvious combination of the thermally ionized gases surrounding a vehicle in this environment, and strong magnetic fields, offers the attractive possibility of producing significant forces and other alterations of the natural flow about the vehicle without contact between a solid surface and the hot gas, with the attendant reduction of heating.[272]

The paper also cited researchers who had conducted experiments on the possibility of using magnetic fields to produce lift. This usually entailed thermal changes that

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[268] The New York Times, "Russians Design Heat-Power Unit," *New York Times*, 18 July 1962, http://query.nytimes.com/mem/archive/pdf?res=FA0B17F83C59137B93CAA8178CD85F468685F9, accessed 2/26/12.
[269] The New York Times, "Research Generator Reaches 1,350 Kilowatts, The New York Times, 21 October 1962, http://query.nytimes.com/mem/archive/pdf?res=F00F1EFD3A55177A93C3AB178BD95F468685F9, accessed 2/26/12.
[270] RAND Corporation, "A Brief Study of Rocket-Powered Magnetohydrodynamic Generators and Energy-Storage Devices," (1960): 1.
[271] Rudolf X. Meyer, "Magnetohydrodynamics and Aerodynamic Heating," Ramo-Wooldridge Corporation, (1958): 1.
[272] E. Locke, H. E. Petshek, and H. Ross, "Experiments with Magnetohydrodynamically Supported Shock Layers," Avco-Everett Research Laboratory, July 1964, 1.

increased temperatures, decreasing air density and air resistance.[273] After the 1960s, the idea for MHD power generation faded away except for some isolated research, and aerodynamicists hoped for high-heat materials to solve hypersonic aircraft problems.

An electric field holds atoms together so the idea of magnetic confinement as a means to control plasma reactors took hold and provided the next-generation physicists electromagnetic field research that would come back into hypersonic flight. Fusion required confinement of fully ionized plasmas much hotter than MHD reactors.

In 1957, Lewis L. Strauss, chairman for the US Atomic Energy Commission, announced that they had approved construction of a large experimental device for controlled thermonuclear research. The Model C Stellarator would be built at Princeton University. Within the 20,000,000 to 30,000,000 degrees Centigrade temperatures a helium nuclei proton would be fused into four hydrogen atoms. The positive charged hydrogen nuclei will normally repel the helium protons, but in fusion they were forced together at high speed proton-proton reaction. In 1938, Hans Bethe and Carl Weizsacker discovered this dynamic in explaining the sun's constant energy creation cycle. The four hydrogen atoms weigh slightly less than the one helium and the excess was released as energy. The sun combined 600,000,000 tons of hydrogen and 596,000,000 tons of helium every second with an equivalent energy mass of approximately ten quadrillion tons of coal. Scientists proposed a "magnetic bottle" concept to replicate the sun's energy cycle on earth. The magnetically created forces squeezed into a narrow confine like a discharge tube. Just like an electrified neon light, the gas became plasma and created tremendous heat close to the sun's temperature and fusion to release the excess energy for other uses.[274]

In the early 1950s, Igor Tamm and Andrei Sakharov, like their western counterparts, were considering how to capture atomic power. The Russians thought a torus, or Tokamak, offered a means to alleviate the binding and added a magnetic field to stiffen the plasma. The "magnetic bottle" design lost heat along its axis and the magnetic waves tended to kink and bind causing efficiency loss. Lev Artsimovich led the research

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[273] Ibid.

[274] William L. Laurence, "New A.E.C. Project Brings Nearer the Day of Useful Thermonuclear Power," *The New York Times,* 7 April 1957, http://query.nytimes.com/mem/archive/pdf?res=F40A1EFC345A137A93C5A9178 FD85F438585F9, accessed 2/29/12.

and subsequent Tokamak reactor designs. The Princeton Stellarator used a circular figure eight configuration, but it had other problems. The scientists traveled to an international conference in September 1965 and reported the reactor lost heat and that increasing the size would not offset the problem. During the meeting, Artsimovich and his team reported ten times more efficiency than the Stellarator which met some skepticism.[275]

In August 1968, the next meeting was held at Academic City Novosibirsk, Siberia. The Soviet's reported their newest Tokamak energy levels thirty times more than previous designs. Twice before they had claimed startling effects only to be challenged and forced to retract the statements. This time Artsimovich invited a British team visit the reactor and take its own readings. The next year, the British reported that indeed, the Soviets had achieved their claims which opened up the way for more such international visits. The process also confirmed the Tokamak design and the best way to achieve a controlled-fusion reactor for power production.[276]

During the 1972 Fifth European Conference on Controlled Fusion and Plasma Physics, the US announced that it would build a Low-Beta Toroidal Research Facility at Princeton, also known as a Tokamak.[277] In 1979, the Soviet Union invaded Afghanistan and put a chill on scientific exchange programs. Mark J. Ablowitz, Professor of Mathematics and Computer Sciences at Clarkson College, spoke on the importance of cooperation on the Tokamak exchange program. He wrote there are "recognized areas of science that have been strongly influenced by the Soviet Union as well. One such field is that of plasma physics."[278] The MHD and the fusion magnetic field studies during the fifties and sixties provided the groundwork for the work to spread out into other fields of physics, notably plasma aerodynamics.

In 1956, John Turkevich described "Soviet Science in the Post-Stalin Era" as hobbled because of "its domination by Marist and Stalinist ideology" resulting in the

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[275] T. Kenneth Fowler, *The Fusion Quest*, The Johns Hopkins University Press, 1997) 24; see also, Boris Belitsky, "Soviet Science: Fusion Power – A Step in the Right Direction," *New Scientist*, 71, no. 1015, (1976): 447.
[276] Ibid.
[277] Roy W. Gould, "Research and Prospects on Controlled Thermonuclear Fusion in the USA," US Atomic Energy Commission, Washington, DC, 2, (1972).
[278] Mark J. Ablowitz, "Soviet and US Ties in Science," *The New York Times,* 21 August 1980, http://query.nytimes. com/ mem/archive/pdf?res=F40E13F93D5D12718DDDA80A94D0405B8084F1D3, accessed 2/3/12.

distortion of scientific truths. However, after Stalin's death, Russian science underwent a renaissance of sorts in that, "Science is being discussed in the Soviet Union not as an expression of a Communist ideology but as a science having its own principles, traditions, and universality."[279] At the same time the author places science as a Cold War threat mentioning their importance in the "atomic age" and declaring the scientist's primary responsibility "the defense of his country."[280]

The Russian Academy of Sciences (RAS) reflected the USSR's highly-centralized state structure. The Academy's president "occupies a position of prestige and power in the Soviet Union unlike that of any other scientist in any other country."[281] Turkevich then draws a military-like hierarchy to state, "The Academy still represents the 'elite guard' organization; its presidium, the general staff of Soviet Science."[282] The president then, becomes the general marshal or scientific commander-in-chief. All the republics coordinated their research with the RAS. The author goes on to highlight the Soviet's scientific achievements in mathematics, astronomy, physics, chemistry, geology, and engineering sciences. Genetics, however, suffered virtual collapse under Trofim Denisovich Lysenko and his so-called Marxist philosophy.

Lysenko oversaw the All-Union Academy of Agricultural Sciences 1938-1956 and became the personification of Stalinist politically influenced pseudo-science. Turkevich explains "Lysenkoism" as conformity with dialectic materialism rather than scientific truth that not only destroyed the field, but also caused the deaths of several prominent Soviet geneticists.

As a result, western scientists thought that Soviet science had lost considerable strength because of its isolation from the international community. However, since Stalin's demise Turkevich sensed the impervious barrier of intellectual exchange and criticism had melted away. Within the Soviet Academy of Science he saw no change and still "represents the 'elite guard' organization."[283] Another writer called them 'top

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[279] John Turkevich, "Soviet Science in the Post-Stalin Era," *Annals of the American Academy of Political and Social Science*, 303, Sage Publications, Inc., (1956): 139-151, http://www.jstor.org/stable/1032298, accessed 11/16/09.
[280] Ibid., 139.
[281] Ibid., 140.
[282] Ibid.
[283] John Turkevich, "Soviet Science in the Post-Stalin Era."

mandarins'.[284] In physics, names like Lev Artsimovich, Igor Tamm, Andrei Sakharov, and Piotr Kapitsa conducted both theoretical and experimental energy production work.[285]

Gleick quotes Ralph Abraham, Professor of Mathematics, University of California at Santa Cruz, on the relationship between mathematics and physics in the early 20th century. According to Abraham, the "romance between mathematician and physicists had ended in divorce in the 1930s."[286] Sir Arthur Eddington expressed disdain for mathematicians arguing that the brain and its ability to sense defined nature rather than just mathematical symbols. Eddington and Sir James Jeans supported the theory the stars created matter by annihilation and that the universe was not expanding. The annihilation theory simply did not hold up to atomic theory or telescope observations.[287]

Loren Graham gave insights into the growing international US-USSR exchange programs after Détente and the Strategic Arms Limitation Talks in 1972 and the Helsinki Accords in 1975. In "How Valuable Are Scientific Exchanges with the Soviet Union," he surveyed seven major US institutional surveys in accordance with twelve US-USSR governmental agreements at that time. Two antedated détente, the earliest in 1959, and the others after 1972. The number of scientists involved in the exchange program varied from a low of 508 in 1972 to a high of 2284 in 1975.[288] Based on questionnaires to US scientists, they gave overall positive inputs as to how the exchanges benefited them. One thing Graham emphasized was that the programs make it more difficult for Soviet authorities to quench dissenters – no doubt based on Sakharov and Russian Jewish emigration. Graham's article seemed a reaction to deteriorating bilateral governmental relations at that time and deteriorating public support for such programs.[289]

Linda L. Lubrano counters Graham's positive view and interprets the post-détente era as tumultuous for Soviet scientists. She addressed exchanges arguing that domestic

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[284] *The Economist*, "Russia's Research Harvest," 30 May 1981.
[285] John Turkevich, "Soviet Science in the Post-Stalin Era."
[286] James Gleick, *Chaos: Making of a New Science*, 52.
[287] Ferdinand Kuhn, Jr., "Scientists Clash Over Annihilation," The New York Times, 30 September 1931, http://query.nytimes.com/mem/archive/pdf?res=F50E15F63D5F157A93C2AA1782D85F458385F9, accessed 3/2/12.
[288] Loren Graham, "How Valuable Are Scientific Exchanges with the Soviet Union," *Science*, New Series, 202, no. 4366, 27 October 1978, 383, http://www.jstor.org/stable/174341, accessed 11/21/08.
[289] Ibid.

politics impact foreign relations, and consequently science. This came about from the growth of cross-border political and economic interdependence of world communities.[290] Beginning in 1978 with the trials of physicist Yuri Orlov and computer specialist Anatoly Shcharansky, US scientists had cancelled their planned USSR visits. In January 1980, reacting to the public and political outrage after the Soviet Afghanistan invasion, President Jimmy Carter ceased SALT II talks, embargoed grain sales to the USSR, and postponed cultural and economic exchanges. Later that month, Soviet officials arrested Andrei Sakharov for his open criticism for the military incursion. In the US, scientists organized the Committee of Concerned Scientists and the Scientists for Orlov and Shcharansky to speak to US policy makers and appeal for the Soviet counterparts. Lubrano concludes with the observation that science during this period, instead of a forum for free exchange of information between countries, had been reduced to an instrument of foreign policy.[291] This continues today. While governments avoid direct attacks on the science itself, its power comes from authorizing visas, monetary policy, and communications between individuals and those they invite in their respective countries.

From that point on, Velikhov's life became a barometer for US-USSR and Russian Federation Science. In 1968, he became a Correspondent of the USSR Academy of Sciences and in 1975 a full member with the right to be called "Academician." From 1978-1991, he was appointed Vice-President to the RAS and in 1991 to the Russian Academy of Sciences. In 1988, as Soviet President Mikhail S. Gorbachev's top science advisor, he insisted that Sakharov be allowed to travel abroad, something that the Politburo had denied.[292]

James R. Hansen, editor of NASA's *Wind and Beyond: A Documentary Journey into the History of Aerodynamics in America*, points out that US aviation owes a great deal to other countries. In addition to von Karman, he notes Igor Sikorsky, Wladimir Margoulis, and Alexandre Seversky from Russia; Max Munk and Adolf Busemann from

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[290] Linda L. Lubrano, "National and International Politics in US-USSR Scientific Cooperation," *Social Studies of Science*, 11, no. 4, (1981): 451, http://www.jstor.org/stable/284777, accessed 4/16/09.
[291] Ibid.
[292] Celestine Bohlen "Applause for Sakharov; Caveats from Sakharov," *New York Times.* Nov. 12, 1988. http://www.nytimes.com/1988/11/12/world/applause-for-sakharov-caveats-from-sakharov.html?scp=1&sq=applause+for+sakharov%3B+caveats&st=nyt

Germany; Alexander Lippisch from Switzerland; Theodore Theodorsen from Norway; Antonio Ferri from Italy; Tsue-Tsen Tsien from China all left a profound impact. They all followed the path set by Germany's Ludwig Prandtl, Switzerland's Jokob Ackeret, England's Frederick William Lanchester, Russia's Dimitri Riabouchky, and Nicolai Joukowski, and others before them.[293]

Max M. Munk studied under Prandtl at the University of Gottingen and graduated with doctorates in physics and engineering in 1919. Munk preceded von Karman arrival at GALCIT by ten years. Munk convinced NACA to build a wind tunnel that turned NACA from "second-rate player into a world leader in aerodynamic research."[294] While touring Prandtl's laboratory, Jerome C. Hunsaker, MIT and future NACA Director, spoke to Munk and he expressed his desire to come to America. Hunsaker convinced the NACA chairman to hire the German aerodynamicist. Munk's arrival brought with him a vast scientific-engineering knowledge that the institution was unprepared for; in addition Munk was not terribly suited for the task. His arrival brought the engineer-dominated NACA its first theorist engineer. During his six-year tenure, Munk expressed the need for theory in his reports that his peers and aerodynamic international community read.[295]

In order to understand aerodynamics before Munk's arrival, NACA reports up to that time are beneficial. Written in 1918, Lieutenant Colonel Edgar Gorrell Major H. S. Martian, US Army Signal Corps commenting on the state of aerodynamic research stated that, "Mathematical theory has not, as yet, been applied to the discontinuous motion past a cambered surface [wing] …. We are able to design aerofoils only by consideration of those forms which have been successful, by applying general rules learned by experience and by then testing the aerofoils in a reliable wind tunnel." [296] Testing without mathematics and learning by trial and error was not the preferred method, but the only one available in the US at that time. They stated that Great Britain and France were

[293] James R. Hansen, et. al., *The Wind and Beyond: A Documentary Journey into the History of Aerodynamics in America: Volume 1: The Ascent of the Airplane*, (Washington, DC, NASA, 2003): xxv.
[294] Ibid, 255.
[295] Mark Levinson, "Gleanings of Oft-Neglected Sources: Institutional History from Technical Documents – The Case of the NACA," *Technology and Culture*, 28, no. 2 (1987): 213-323, http://www.jstor.org/stable/31055569, accessed 11/20/10.
[296] Lt Col Edgar S. Gorrell and Maj H. S. Martin, "Aerofoils and Aerofoil Structural Combinations, NACA no. 18," NACA, 343, http://naca.central.cranfield.ac.uk/reports/1918/naca-report-18.pdf.

conducting tests and that someday mathematics will bring knowledge to the testing.[297]

It is also interesting to note that engineering focus applied to Prandtl's first NACA translated report published in September 1920. The "Gottingen Wind Tunnel for Testing Aircraft Models" came from a presentation he had done the previous year in Hamburg. Funding came both from a growing number of aviation groups and the Gottingen Society for the Promotion of Applied Mathematics and Physics. In fact, Professor Felix Klein, Gottingen Mathematics and Physics Department, suggested the idea to further scientific knowledge.[298] The engineering aspect of this first publication mirrors the emphasis US expressed when the USSR's institutions opened to the West. Klein made profound mathematical advances and taught them to Prandtl and European students at a time when American engineering graduates barely understood differential and integral calculus.[299]

The science-engineering divide is evident in Munk's technical reports. From the beginning, he recognized that his American audience did not understand the role of aerodynamic science. Munk wrote his first NACA technical report on the airworthiness of a Caproni seaplane that on its first flight had crashed nose down into a lake. He opens by stating that science had not yet advanced to guarantee successful first flight; there is always a risk in execution. On the other hand, science should be used to minimize the hazards beforehand. It is recognition that his audience did not, according to Munk, understand theory's proper role. He then goes to his calculations to state that the Caproni's unfortunate maiden flight was not surprising or unexpected.[300] Some took the remarks as arrogant, smacking of elitism. This led him to clash with his American peers and to end his NACA employment after six years.

In his report on a new type of tunnel he reveals a divide between designers who "declare that the results of wind tunnel tests are valueless for purposes of design." While explaining the benefits of such devices, he expresses, almost as a second thought, the

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[297] Ibid.

[298] Ludwig Prandtl, "Gottingen Wind Tunnel for Testing Aircraft Models," NACA no. 66," NACA, 1920, http://naca.central.cranfield.ac.uk/reports/1920/naca-tn-66.pdf.

[299] Mark Levinson, "Gleanings of Oft-Neglected Sources: Institutional History from Technical Documents – The Case of the NACA," 317, http://www.jstor.org/stable/31055569; Anderson, *History of Aerodynamics*, 292.

[300] Max Munk, "The Caproni Seaplane," NACA no. 57, (1921): 1, http://naca.central.cranfield.ac.uk/reports/1921/naca-tn-57.pdf.

benefits to the aircraft designer and “could be used with advantage for scientific investigations.”[301]

Theodore von Karman was not the only foreign influence on American aerodynamicists. Hugh L. Dryden wrote the National Academy of Sciences biographical memoir for his fellow aerodynamicist pioneer. At only six years old, von Karman could multiply six-figure numbers in his head. He attended an open educational gymnasium founded by his father that included Edward Teller, Leo Szilard, and John von Neumann. At sixteen, he was awarded the Eotvos Prize as the top mathematics and science student in the country. He graduated from the Royal Joseph University of Polytechnics and Economics in Budapest with a degree in mechanical engineering. In 1906, he enrolled in the University of Gottingen and received his doctorate under Professor Ludwig Prandtl after two years. From there von Karman became the Director of the Aachen Aerodynamics Institute. As von Karman’s boundary layer and wing theory research began to reach distant shores, he received an invitation from the California Institute of Technology (Cal Tech) President, Nobel Laureate physicist Robert Milliken, President of the Daniel Guggenheim Fund for the Promotion of Aeronautics. Millikan invited him for a lecture tour and to recruit him for the new Guggenheim Aeronautical Laboratory at Cal Tech (GALCIT). He moved to Pasadena, California, in 1930 to take up the challenge and because he saw the gathering storm clouds over Europe.[302]

Richard Rhodes included a special chapter noting the powerful influence Hungarian scientists made beginning in the 1930s and beyond. *In Making of the Atomic Bomb*, the chapter titled “Men from Mars” presents the lives of ennobled Jewish middle class students von Karman, George de Hevesy, Michael Polanyi, Leo Szilard, Eugene Winger, John von Neumann, and Edward Teller.[303]

Von Karman’s impact on science came early in his career primarily up to WWII.

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[301] Max Munk, “On a New Type of Wind Tunnel, NACA no. 60,” NACA, May 1921, 1, http://naca.central. cranfield .ac.uk/reports/1921/naca-tn-60.pdf; James R. Hansen, Engineers in Charge: A History of the Langley Aeronautical Laboratory, 1917-1958, NASA SP-4305, http://history.nasa.gov/SP4305/sp4305.htm, accessed 2/22/12.

[302] John D. Anderson, *A History of Aerodynamics and Its Impact on Flying Mach*ines. Kik A. Daso, *Architects of American Air Supremacy: General Hap Arnold and Dr Theodore von Karman*, (Maxwell AFB, AL: Air University Press, 1997): 97; Hugh H. Dryden, “Theodore von Karman, 1881-1963,” (Washington, DC: National Academy of Sciences, 1965): 345-384.

[303] Richard Rhodes , *The Making of the Atomic Bomb*, (New York: Simon & Schuster, 1986): 106.

His time after the war was spent as US Air Force Chief Scientist and founder of the NATO Advisory Group for Aerospace Research and Development (AGARD). John D. Anderson examines von Karman's contribution with physicist-engineering eye and points out that he brought Prandtl to America and pushed the applications to the subsonic limits, but the next step to supersonic came from other Europeans. Von Karman's scientific successes came from applying Newtonian physics to incompressible flows – shock waves constitute compressed flows and became an issue as aircraft approached the sound barrier. This translates to primarily straight wing propeller aircraft. He helped build a secure foundation for supersonic speeds.

Walter Vincenti argues that while Yeager broke the sound barrier in 1947, supersonic theory took another five to six years to catch up. Fortunately, the engineering worked, but it came before science understood the process. Even though the Germans had proved the swept-wing design, the X-1 had straight wings. He points out that there were doubts between the Army Air Corps that saw the aircraft a step toward supersonic flight and NACA that saw the opportunity to collect supersonic research data. The extent of theory until the end of the war was utilizing two-dimensional flow such as single-direction air passing along a flat plane or a straight wing utilizing linear equations. These techniques were deterministic with no random factors. Even though the air moved in a wave pattern, chemically it stood in equilibrium because its molecules retained their overall relations to each other. However, as speeds approach the sound barrier engineers needed the introduction of nonlinear equations to provide a result. These were necessary because there are several flows intertwined at the higher speeds. The equations become so complicated that they became unsolvable. In addition, air chemistry changed as it began to heat due to friction and became a state of nonequalibrium. In fact, the X-1 wing ailerons locked up, just as for the aircraft had done before and crashed. The engineer fix was in using the tail horizontal tabs to control the aircraft until its speed dropped and the ailerons could again operate. Vincenti credits the reunification of Adolf Busemann and Gottfried Guderley under Operation Paperclip with developing a mathematical technique to simplify non-linear equations. The irony being that Busemann had presented his swept-wing ideas at the 1935 Volta Conference in Rome.[304] The sentiment was echoed

[304] Walter G. Vincenti, "Engineering Theory in the Making: Aerodynamic Calculation 'Breaks the Sound

in a 1950 report that up to Mach 5 the two-dimensional linear supersonic wing theory, but for higher speeds two-dimensional gas dynamics could be use for a "hypersonic approximation."[305]

Von Karman also missed the approaching "heat barrier" until Sputnik and the subsequent missile building programs in the United States to catch up with the Soviets. William R. Sears wrote in anthology to account for the shortcoming. He wrote that Dr. von Karman was not at ease with the state of combustion work in the late 1940s. In other words, he thought the experiments and theory still applied only to engines. In addition, his administrative duties carried him far from the laboratory. His mentor recognized the lack of knowledge and went about working with younger scientists who had already accomplished a great deal. In 1952, he presented an overview of high-speed research up to that time in "The theory of the laminar boundary layer in compressible fluids, initiated by A. Busemann, L. Crocco, H. S. Tsein, and the writer, has been considerably developed by many authors in recent years."[306] The next year, he used the term "aerothermodynamics" for the research and credited G. A. Crocco combing 'fluid mechanics' and 'thermodynamics'."[307] Finally, in a 1956 article he wrote "Recently the attention of many researchers became focused on boundary layer phenomena coupled with dissociation effects. Dissociation and recombination are of course fundamentally chemical reactions. The problem arises, for example, in investigation of the aerodynamic heating of bodies moving through air at hypersonic speed."[308] The issue had not gone unnoticed by others in the aerodynamicist community.

Hsue-Shen Tsien worked under von Karman at GALCIT. Tsien credited a paper written in 1935 by Albert Zahm on rocket flights as creating the high interest in rarified gases.[309] In a later paper he gave an early definition to the "aerodynamics of rarefied

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Barrier,'" *Technology and Culture*, 38, no. 4 (Oct., 1997): 825, http://www.jstor.org/stable/3106951, accessed 11/20/10.

[305] G. Grimminger, E. Williams, and G. B. W. Young, "Lift on Inclined Bodies of Revolution in Hypersonic Flow," *Journal of Aeronautical Sciences*, Vo. 17, no. 11, (1950): 675, http://www.aiaa. Org /jaPreview/PSJA/1950/ PVJAPRE1775.pdf, accessed 2/23/2012.

[306] Theodore von Karman, "On the Foundations of High Speed Aerodynamics" 1952 in *The Collected Works of Theodore von Karman: 1952-1963*, Rhode-St-Genèse : Institut von Karman de dynamique des fluides, (1975): 21.

[307] Ibid., "Aerodynamics and Combustion Theory," 67.

[308] Ibid, "Fundamental Equations in Aerothermalchemistry," 132

[309] Hsue-Shen Tsien, "Superaerodynamics, Mechanics of Rarefied Gases," *Journal of Aeronautical*

gases or superaerodynamics."[310] The fluid aerodynamicist's led the charge into hypersonic studies and continued to prevail. In a 1953, Tsien announced "Physical Mechanics, a New Field in Engineering Science." The purpose of the new subject was to "predict the macroscopic behavior of matter … from the known microscopic properties of the constituents of matter."[311] The constituents were atoms which were further divided into protons, neutrons, and electrons. The knowledge applied to jet propulsion, aerodynamics, and atomic power which created incredible thermodynamic issues.

Tsien's article provided historical insight into the state of physics at the time and divided the period into two phases: the Curie's discovery of radiation and successful manipulation of atomic structure and the new science it had spawned. The new challenge concerned thermodynamics of matter at equilibrium and transport properties of matter at a non-equilibrium state. These statements came from the first and second law of thermodynamics.[312] The article announced that thermodynamics now had a firm place in aerodynamics.

Tsien was born in Shanghai in 1909. He earned his undergraduate degree in mechanical engineering at Chiaotung University, Shanghai. In 1935, he attended MIT and three years later earned his PhD at Cal Tech under Theodore von Karman. In 1950, he was arrested as an alien Communist for taking a large amount of technical material on a planned trip to Hong Kong. None of the papers were classified. He was deported in 1955 and at that time was Goddard Professor of Jet Propulsion at Cal Tech.[313]

During his career in the US, his research made him one of the top physicists in the world. His work provided valuable insights for others in hypersonics and gas dynamics. He worked on US classified rocket programs and was given the rank of colonel and placed on the Operation Paperclip team along with von Karman to evaluate German

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Sciences, 13, no. 12, (1946): 653, http://www.aiaa.org/jaPreview/PSJA/1946PVJAPRE11476.pdf, accessed 1/13/10.

[310] Hsue-Shen Tsien, "Wing-Tunnel Testing Problems in Superaerodynamics," *Journal of Aeronautical Sciences*, 15, no. 10, (October 1948): 653, http://www.aiaa.org/jaPreview/PSJA/1948/PVJAPRE11658.pdf, accessed 2/23/2012.

[311] Hsue-Shen Tsien, "Physical Mechanics, a New Field in Engineering Science," *American Rocket Society*, 1953, 23, no. 1, (1946): 14, http://www.aiaa.org/jaPreview/PSJA/1953PVJAPRE4525.pdf, accessed 1/13/2010.

[312] Ibid.

[313] The New York Times, "A Top Chinese Scientist Was Deported by US," *The New York Times,* 17 Oct 1964, http://query.nytimes.com/mem/archive/pdf?res=FB0A15FF385E147A93C5A8178BD95F408685F9, accessed 2/27/12.

rockets. He was so trusted that the US appointed him the head of the National Defense Scientific Advisory Board. Although he possessed no classified material when arrested, the judge ruled that the knowledge he had necessitated a delay in deportation which did not happen until 1955. Once deported, he became the head of China's NACA-like establishment and was thought to have contributed to their first nuclear explosion test in 1964.[314]

Dr. Francis H. Clauser, Chairman, Department of Aeronautics, The John Hopkins University was one of the few to criticize von Karman. During a 1947 aerodynamic conference, Clauser began by paying homage to von Karman, but then said "I cannot help expressing a feeling of regret that in this lecture Dr. von Karman has dealt so little with the nonlinear problems of compressible flows."[315] Clauser presented a paper titled "Ramjet Diffusers at Supersonic Speeds" at the 1946 Supersonic Aerodynamics at Johns Hopkins. He was instrumental in bringing in US Navy contracts to investigate high-speed fluid dynamics.[316] Some interpreted the von Karman presentation as a triumph, but buried in the discussion, there was at least one scientist pushing for more answers and more than likely represented a group of others.

In 1956, Clauser wrote "The Behavior of Nonlinear Systems" in which he essentially describes Chaos Theory years before it became a cultural phenomenon. He began with stating that many things and events around us were governed by nonlinear relationships. Linear systems and the accompanying mathematics were inadequate to give more than a superficial description. Scientists used concepts like resonance, waves, feedback, boundary layers, turbulence, shock waves, and many more such terms, but did not understand them completely. He went on to state that, "We find that there are certain nonlinear concepts which at first appear complex, but which, when understood, are found to have universal applicability."[317]

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[314] The New York Times, "Key Chinese Scientist," *The New York Times,* 17 Oct 1964, http://query.nytimes.com/mem/archive/pdf?res=F50D11F73958107B93CAAB178BD95F428685F9, accessed 2/27/12.
[315] Francis H. Clauser, "Supersonic Aerodynamics: Discussion of the Lecture," *Journal of Aeronautical Sciences*, (1947): 403.
[316] Francis H. Clauser, "Ramjet Diffusers at Supersonic Speeds," *Jet Propulsion*, 24, no.2, (1954): 79, http://www. aiaa.org/jaPreview/PSJA/1948/PVJAPRE6460.pdf, accessed 2/23/12.
[317] Francis H. Clauser, "The Behavior of Nonlinear System," *Journal of the Aeronautical Sciences*, 23, no. 5, (1956): 79, http://www. aiaa.org/jaPreview/PSJA/1956/PVJAPRE6460.pdf, accessed 2/23/12.

Foreign scientists have made extraordinary contributions to American science. After WWI, Germany's Ludwig Prandtl's aerodynamic scientific findings provided the basis of the field up to the heat barrier. On the other hand, Hungary-born Theodore von Karman perfected Prandtl's theories, but he failed to recognize the new field of plasma aerodynamics.

CHAPTER FOUR

SOVIET SCIENCE HISTORY

In order to come to some sort of conclusions about Russian science, it's worth examining how previous historians interpreted Soviet research during and after the Cold War. After World War Two, outsiders delved into Marx striving for some philosophical-ideological foundations to understand what occurred under Stalin and Khrushchev.

In grappling with Russia-Soviet technological weakness one must appreciate that Karl Marx's writings are inherently Newtonian in that there existed laws for examining labor and capital. Capital purchased technology which in turn, enslaved labor. Craftsmen once had an intimate relationship with their work making products from start to finish, giving the craftsman a sense of worth and satisfaction. Instead of participating in each production step, technology automated and increased production by minimizing worker involvement to repeating only one job which meant they no longer saw the product from beginning to end. Technology became the enemy that alienated the worker. These circumstances arose from private property and the accumulation of capital. Marx wrote, "The worker becomes poorer the more wealth he produces and the more his production increases in power and extent."[318] This came as a reversal to natural law according to evolution. Capital reduces the worker to an animal concerned only with "eating, drinking, and procreating."[319] In addressing the poverty of currency and souls in production that depended on technology, Marx cast a negative connotation for accepting the implements. This placed a shadow on those who worked with their hands and those who worked with their brains. Since this process occurred according to natural law, science would play an important role in determining its course. Nikolai Bukharin agreed with this sort of separation in theory and practice. Waldemar Kaempffert gave Marx credit for his important service of "indicating the kind of social pressure to which scientists are subject and of which they are usually unaware."[320] Since Marx, historians

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[318] Marx, Karl, and T. B. Bottomore, *Early Writings*, (New York: McGraw-Hill, 1964): 121.
[319] Ibid., 125.
[320] Waldemar Kaempffert, "Development of Science," http://query.nytimes.com/mem/archive/pdf?res=F2081FFF395 D177B93C7A9178FD85F478585F9, 3 April 1949, accessed 2/29/12.

have explained this connection between ideology and its impact on Soviet science progress and setbacks. Arguing that Russia-Soviet shortcomings came from Marx' writing goes too far in that Marx wrote from a German-English industrial revolution perspective; however, it could be said that he reflected the tendency in the culture that became synonymous with his name.

Alexander Vucinich's Soviet and subsequent Russian science history spanned fifty years. He wrote from a sociological perspective with multiple elements contributing to explain its historical path. His two-volume *Science in Russian Culture* begins with Peter the Great's efforts to bring his subjects' knowledge into concert with Western powers and ends with the 1917 Bolshevik Revolution. His works provide insights into the Russian historical mindset beginning with struggles between the Slavophiles, deep foreigner distrust, and a need to maintain some intellectual and technological parity with other nations.

Russia is well known as a mathematical powerhouse and in "Mathematics in Russian Culture" (1960) Vucinich speaks to Soviet science historians on several points. Beginning the article with the sentence "The great mathematical tradition in the Soviet Union is the legacy of the ancient regime."[321] More specifically, Peter the Great's recognition that mathematics proved necessary for his modernization efforts in terms of "gunnery, cartography, land surveying, and navigation," all essential to state power and control. Initially, Germans provided teachers and populated the Russian Academy of Sciences, imprinting their academic expertise until Russian scholars emerged. Not satisfied with the simple chronological explanation, Vucinich adds the philosophic-cultural element that Russians were also reacting against German romanticism with their own mathematical expertise. Addressing the modern audience, he states that by 1820, mathematics developed more rapidly and was less susceptible to metaphysics and ideological interference. However, after the 1825 Decembrists' Revolt, Nicholas I ruthlessly controlled biology, physiology, and geology. This speaks to the generally accepted notion that Soviet physicist's enjoyed far less interference because of its mathematical foundation. Vucinich concludes that "There is no single event or

[321] Alexander Vucinich, "Mathematics in Russian Culture," *Journal of the History of Ideas*, 21, no. 2, (April-June 1960): 161.

development which holds the key for the understanding of the role of mathematics in Russian culture." Rather, the success should be sought "in a combination of events and developments and not in any peculiarities of the Russian 'psyche.'"[322]

In "Marx and Parsons in Soviet Sociology" (1974): Vucinich explains that during Stalin's era, "sociology was a capitalistic theory which rejected the notion of social progress as a value judgment incompatible with scientific objectivity."[323] In doing so, he marks his scholarly transition from ancient regime to what he terms the "post-Stalinist intellectual revival" when some sociologists drew a line separating their disciple from historical materialism, on the one hand, to Marxist sociologists "compelled" to integrate Marxist historicism and modern Western structural-functionalist models.[324] Parson structural-functional theory examines formal subsystems and the dynamic outcomes in historical cause and effect terms. However, according to Vucinich, historical materialism determines outcomes and not "social causation." Across the discipline, one group argues that sociologists must maintain the historical materialistic touchstone. A second avoids the Marxist influence by separating the sociologic philosophic and scientific as two distinct and separate entities. A third group argues that sociology must combine philosophic, high-order theory, and scientific, low-order data, elements to make the totality. The last, Markarianism, examines human activity, including culture, in institutions, mechanisms, and subject-group terms by minimizing historical materialism.[325] In addition to Stalin's demise, these changes came as a scientific reaction to Lysenkoism and familiarization with Western sciences. The article speaks to Soviet scientific ideological diversity and implies its acceptance across its many disciplines.

In 1980, Vucinich examines struggle between Stalin's philosophers and physicists and the attempt to unify the dictator's ideology, Marxism, and modern science. He states that unlike other authors who point to the scientist's indispensability in Stalin's quest for an atomic weapon, that "because of new developments in the theory of matter, [physics] generated the strongest opposition to Leninist epistemology."[326] The philosopher's

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322 Ibid., 174.
323 Alexander Vucinich, "Marx and Parsons in Soviet Sociology," *Russian Review*, 33, no. 1, (January 1974): 1.
324 Ibid.
325 Ibid., 9.
326 Alexander Vucinich, "Soviet Physicists and philosophers in the 1930s: Dynamics of a Conflict," *Isis*,

campaign sought to both validate Leninism and justify its importance to Soviet ideological and intellectual development. Accused as "mechanists" and "dialectical orientations," the philosophers claimed the concepts led to skepticism or idealism and did not follow Lenin's stricture that philosophical materialism existed in an epistemological sense outside the mind. Historical materialism provided causation without human interference. However, the Copenhagen quantum mechanics interpretation explained matter as interaction between the scientist and the measuring instrument which Leninists defined as subjective, inherently non-scientific, and guilty of Western physical idealism. The author cites Paul Forman's seminal article regarding Weimar physicist's efforts to mirror Germany's retreat from causality-dominated materialism to cultural restoration.[327]

Similar to his 1974 article, Vucinich presents the two extremes to describe the philosopher's Copenhagen school opposition. He states that in the philosophers viewed "'statistical causality' reflected an absence of not absolute causality in nature but of adequate mathematical procedures in quantum mechanics."[328] In other words, the physics did not possess sufficient knowledge to make cogent historical materialism contributions damning with faint praise rather than criticize on scientific terms. Vucinich argues that while the physicists aimed to minimize Marxist-Leninist dialogue, the philosophers sought to broaden their influence on the field. He concludes that this 1930s intellectual "standoff" and open debates continued because of Stalin's reluctance to side in the debate.

In 1982, Vucinich turned his eye to "Soviet Marxism and the History of Science." He begins this essay in the inchoate 1920s when Marxist scholars first began examining scholarly disciplines through Marxist-Leninist philosophic lenses. At this time there was a certain degree of pre-revolutionary, pre-Marxist academic liberty due to the new philosophic demands. Vucinich credits the newly created Commission on the History of Knowledge chaired by RAS Academician geochemist and mineralogist V. I. Vernadskii as one such scholar. Vernadskii authored *Essays and Addresses* (1922) describing Newtonian natural science publications that included references to Kant, Buffon, religion, and the history of science. In quantum physics, Vernadskii saw scientific discontinuity

71, no. 2, (June 1980): 236.
[327] Ibid., 239.
[328] Ibid., 241.

and Newton's negation. He also argued that science resulted from both intellect and socio-economic conditions. Both challenged historical materialism's permanence based solely on economic conditions.

The author explains the next step in this intellectual takeover as the Russian Academy of Science's election of its first Marxist scholars and their strategic placement in the hierarchy. This came with the creation of Institute of the History of Science and Technology headed, unfortunately, Vucinich states, by N. I. Bukharin who came under increasing attack for Marxist deviations. The institute led the Marxist scholars presenting papers at the Second International Congress of the History of Science and Technology, in London 29 June to 3 July 1931.[329]

Vucinich makes two "incontrovertible" statements on Boris Hessen's paper on Newton's *Principia*: "First, it was not only the first but also the last effort to cast a historical epoch in the development of science in the mold of classical Marxism. Second, no serious historian of science in the West was ready to ignore Hessen's provocative mode of historical explanation," because he attributed Newton's brilliance to genius and Victorian socio-economic causation. [330] Since 1931, Western historians have debated the merits of "internalism," scientific progress, and "externalism," non-science factors. Vucinich explains that this duality has become a common theme in the West.[331]

Physicist and engineer Academician Piotr Leonidovich Kapitza addressed the science-technology split many times during his career. His training made him both theorist and experimentalist. Unlike what occurred to Soviet genetics under Trofim Denisovich Lysenko, physics progressed under more favorable political conditions. In fact, it some areas, such as high-temperature physics surpassed the West. Early in his profession, Kapitza worked under Abram Fedorovich Ioffe a giant in Soviet physics. Ioffe received his Ph. D. at Munich University in 1905 under Wilhelm Roentgen who had discovered x-rays. Ioffe played a prominent role in educating an outstanding future cadre of Soviet physicists and receiving government permission to send Kapitza to Cambridge for further studies in 1921 when most governments had no relations with the post-

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[329] Alexander Vucinich, "Soviet Marxism and the History of Science," *Russian Review*, 41, no. 2, (April 1982): 129.
[330] Ibid., 128.
[331] Ibid., 129.

revolutionary Communist government. Ernest Rutherford, by now a Nobel laureate, ran Cavendish Laboratory and allowed Kapitza to enter for a period over the winter---he wound up staying 13 years.[332]

His Cavendish experience subsequently shaped his views of Soviet science. In England, he enjoyed teaching promising students which he came to understand were the key to keeping his beliefs and practices fresh and challenging. He also enjoyed open discussions with his peers from all over the world.

Certainly, culture was important to the Soviet Union. When workers had more free time, they could improve their knowledge in the arts; attend ballet and poetry readings, visit museum, and the like. In fact, to Marx and Kapitza, this was science and technology's roles.

According to Lewis S. Feuer's "Dialectical Materialism and Soviet Science," Marx's claim that class struggle was historic and therefore natural law was rather "the projection of one's social world or values as defining the nature of reality itself."[333] At the time he wrote the article, Feuer claimed the laws of dialectic applied to biology and engineering, but not to physics. Kapitza pushed the assertion aside and applied evolution on all science even referring to Herbert Spencer who developed an evolutionary philosophy based on Darwin's writings.

This does not mean Kapitza was a capitalist. His reference to Spencer conformed to Marxism. He points to the intellect-labor division in dinosaurs as disproportionate in its giant body and tiny brain. This imbalance, he asserts, led to their extinction. A very interesting perspective from a physicist because he was not really qualified to make such comments. Again using Marxist language, he claimed that "In the struggle for existence only an individual with the head weight of approximately 5-10% of its body weight had a future."[334] Feuer did not necessarily disagree with this comparison. He pointed out that Darwin and Wallace's evolution analogy was a theory to be tested and not a "dominant

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[332] D. Shoenberg, "Piotr Leonidovich Kapitza," *Biographical Memoirs of Fellows of the Royal Society*, 31 (Nov., 1985): 327-347, http://www.jstor.org/stable/769929, accessed 11/16/09..

[333] Lewis S. Feuer, "Dialectical Materialism and Soviet Science," *Philosophy of Science*, 16, no. 2 (Apr., 1949): 106, http://www.jstor.org/stable/185129, 11/16/09.

[334] Piotr Leonidovich Kapitza, "Theory, Experiment of Practice [compiled speeches]," Air Force Systems Command: Foreign Technology Division, AD 653561, 13 February 1967, 4. (From a speech at the International symposium on the Planning of Science held in Prague in September 1959.)

analogy."[335] In other words, a social phenomenon became a categorical imperative based on natural law and not the other way around. Darwin and Wallace relied on Reverend Thomas Robert Malthus' demographic economic studies that implied equilibrium based on population and available food sources. This was based on English empiricism whereas Marx' historical law was based on German Romanticism. While other nations had experienced revolutions, Germany for the most part had not. But according to "the historical school of law" emanating from the primeval Tectonic forests, according to Marx, Germany was certainly headed for just such an event.[336] Marx relied on an emotive example to justify the proletarian revolt, rather than mathematical analysis.

Just days before the Nazi invasion, in Kapitza's June 1941, "The Unity of Science and Technology," *Pravda*, he discussed how to increase production by centralizing both science and technological assets. This included not only institutes and laboratories, but experienced workers. One of his justifications was to decrease the gap between theory and life. "In fact," he wrote, "as we have become even more convinced, it becomes more difficult to say where science ends and its direct connection with life begins."[337] Technology connected theory and practice, but Marx declared it as alien to man's true spontaneous nature.[338] Feuer cites a speech Kapitza made in 1943 upholding the international, open nature of science as an exception to Marxism fueled by the allied nature of WWII. However, Kapitza made the same assertion in 1941.

Mixing philosophy, history, and science has its pitfalls. Some insist on the old political hard lines. Michael D. Gordin and Karl Hall's historiography "Intelligentsia Science Inside and Outside Russia" state the reason for studying Soviet science remain in terms of old-fashioned nation-states.[339] First, the Cold War institutionalized Russia and Soviet studies in western universities. Second, they succeeded in the production of nuclear weapons, the launch of Sputnik, and solidification of science-military connection. Third, the lesson of the Lysenko Affair's pernicious ideological effect and subsequent destruction of several Soviet science fields as proof of Marxist/Leninist irrationality.

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[335] Feuer, 107.
[336] *Early Writings*, 45.
[337] Kapitza, 23.
[338] *Early Writings*, 125.
[339] Michael D. Gordin and Karl Hall, "Intelligentsia Science Inside and Outside Russia," *OSIRIS*, (2008): 11.

Loren R. Graham, who many say "is almost singe-handedly responsible for the maintenance of a community of Western historians concerned with Russian science,"[340] wrote "Quantum Mechanics and Dialectical Materialism," which brought the esteemed Paul K. Feyerabend's criticism. Praising Graham's article as "well informed, clear, and straightforward narration," he finds it, "however, a purely description account such as his cannot suffice."[341] He states that "one cannot disregard the fact that party lines are not restricted to politics but occur right in the center of science." Graham replies that "the greatest need was for a no polemical description of the development of Soviet attitudes toward quantum mechanics."[342]

Whether Feyerabend correctly characterized Graham's article or not, in "Science and Values: The Eugenics Movement in Germany and Russia in the 1920s" Graham clearly states that they exist side by side.[343] By examining genetics and value-driven eugenics, he concludes that while the "science *qua* science" remained value-free, the resulting national social-political theories became vulgarized, but remarkably different. In short, Germany with its strong socialistic character went on to apply hereditary theory to humans while the Soviet Union denounced such practices. He explains this in Marxism's "nonreductive and qualitatively distinct nature of man," adding parenthetically, "In that way many difficult problems could be avoided."[344] As such he makes the distinction from Feyerabend's politics in science and value-free knowledge besides value judgments arguing that "second-order" affects like technology, economics, politics, and ideology determine the relationship between science and values.

In 1978, Graham brought his Russian history expertise to US-Soviet science exchange programs social commentary because, "As these programs have become more prominent and expensive and as US-Soviet relations have become more complicated, their value has frequently been questioned."[345] Basing his views on five studies published

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340 Ibid.
341 Paul R. Feyerabend, "Dialectical Materialism and the Quantum Theory," *Slavic Review*, 25, no. 3, (September 1966): 414.
342 Loren R. Graham, "Reply," *Slavic Review*, 25, no. 3, (September 1966): 418.
343 Loren R. Graham, "Science and Values: The Eugenics Movement in Germany and Russia in the 1920s," *American Historical Review*, 82, no. 5, (December 1977): 1133-1164.
344 Ibid., 1154.
345 Loren R. Graham, "How Valuable Are Scientific Exchanges with the Soviet Union?," *Science*, 202, no. 4366, (October 1978): 383.

the previously year, it is an excellent Cold War-detente snapshot. The study focuses on science and technology exchange bilateral agreements from 1959-1977. His primary resource is the National Academy of Sciences' "Review of US-USSR Interacademy Exchanges and Relations." He participated as a panel member and in considering their own findings, reviewed other studies. As such, the article is very clear on its limitations. The Russian Academy of Sciences declined sending their participating scientists questionnaires claiming a concern for interference in RAS's "internal affairs."[346]

The US-USSR government science and technology exchange programs came from 12 formal agreements. The National Academy of Sciences and the International Research and Exchanges Board managed the US programs. From 1972 to 1977, total US and USSR exchange varied from 508 in 1972, the highest 2284 in 1975, and 1425 in 1977. The author claims that while the parties engaged in important science, they also gained political and cultural experience in the programs. As such, Graham emerges as a strong exchange advocate.

In "When Ideology and Controversy Collide: The Case of Soviet Science" (1982): Graham clearly emerges as one able to compare and contrast US and Soviet "Big Science" structures on philosophic, social and political issues.[347] While examining the US's recombinant DNA debate he provides acute Soviet science insights. First noting the American's review boards and nonscientist involvement, he sees no similar USSR oversight. While the US uses a "principle investigator projects and grants" primary university approach, the Soviets support Russian Academy of Sciences'' individual RAS institute "block funding". As such, American science must deal with public concerns and congressional funding while their Soviet counterparts tend to maintain steady financial support and much less public scrutiny. In addition, Graham writes "public accountability is weak, and a formal system of peer review of research applications is not deemed necessary."[348]

In "The Socio-political Roots of Boris Hessen," Graham points to the Soviet scholar's 1931 London Second International Congress of the History of Science Sir Isaac

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[346] Ibid., 384.
[347] Loren R. Graham, "When Ideology and Controversy Collide: The Case of Soviet Science," *The Hastings Center* Report, 12, no. 2, (April 1982): 26-32.
[348] Ibid., 29.

Newton presentation as significant in developing the “externalist” interpretation of science.[349] Hessen explained Newton in his social, political, and economic, or “external” influences apart from the science he founded. The article’s tone is an appeal of sorts. Graham asks the reader to apply the concept to temper the tendency to see Soviet science through an ideological template. Following this “externalist” idea, by 1985 the Soviet Union has buried three General Secretaries in quick succession and Mikhail Gorbachev is bent on continuing the post-Brezhnev liberalization and domestic policy changes designed to quell a growing internal discontent. Using an external interpretation, one can see the individual’s importance aside from contextual issues---in this case communism.

In 1978, Peter Kneen authored “Why Natural Scientists are a Problem for the CPSU” to examine the dissenting Soviet intellectual issue. Scientists present a special problem for rigid centralized political control and their efforts to impose *partiinost* or party mindedness. He points out that the Soviet’s most common means of power comes from checking work performance and controlling job security and promotions. Science, however, is difficult to standardize and quantify. In addition, scientific advances come from international researchers. Kneen argues that this increases Soviet scientist’s resistance to restrictive controls. However, the state can only push so far because it relies on the same individuals for military and economic advances. He concludes that Party dominance reduces economic and scientific output.[350]

However, Graham’s and the West’s Soviet-Russia science and technology assessments underwent some changes as the USSR fell and radical reforms took their toll. In 2002, he and Irina Dezhina co-authored Carnegie Endowment for International Peace “Russian Basic Science After Ten Years of Transition and Foreign Support” and declared that “While Russian science has significantly changed in the last ten years, it retains many of the characteristics of the Soviet period.”[351] First providing a common historical perception, the Soviets developed world-class physicists and mathematicians as evidenced in their successful nuclear, rocket, and space programs. However, Communist

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[349] Loren R. Graham, “The socio-political Roots of Boris Hessen: Soviet Marxism and the History of Science,” *Social Studies of Science*, 15, no. 4, (November 1985): 705-722.
[350] Peter Kneen, “Why Natural Scientists are a Problem for the CPSU,” *British Journal of Political Science*, 8, no. 2, (April 1978): 197, http://www.jstor.org/stable/193498, accessed 4/16/09.
[351] Irina Dezhina and Loren Graham, “Russian Basic Science After Ten Years of Transition and Foreign Support,” *Carnegie Endowment for International Peace: Russian and Eurasian Program*, no. 24, (2002): 5.

Party political restrictions, organization, and command economy stifled their overall success. In exchange, scientists received higher status, better pay, education, and other amenities unavailable to most Soviet citizens. In addition, the state provided "block grants" and contracts without peer review. The Russian Academy of Sciences stood at the peak of the infrastructure's top-down structure. The system allowed narrow focus and full funding for selected fields, but distorted overall research that by 1990 provided 75% to the military.[352]

Graham laments that 10 years after the Soviet Union's stunning demise, Russian science exhibited an "evolutionary" rather than "revolutionary" reforms. Despite the dramatic state collapse, changes came slowly and painfully. Scientists' wages fell, inflation rose, and state funding ceased. Institutes laid off workers, turned off electricity, and staff scrambled for any kind of income. International foundations and governments provided support, but likewise found Russian infrastructure broken. Foreign help often arrived in cash because banks and the scientific community had no means to convert financial aid. In addition to their monetary problems, the science community had to digest and embrace a more openly competitive and economically driven system than a command driven state.

In 2006, Graham published a semi-autobiographical *Moscow Stories* which gave some interesting insights into his scholarly career researching and writing about Soviet, then Russian science. He wrote his dissertation on the Soviet Academy of Sciences (1927-1932) which became a touchstone for his subsequent works. He lays blame on the now Russian successor and its failure to abandon the authoritative Soviet model for a more Western one. He describes its role as "the Soviet Academy was a sort of National Science Foundation, Harvard, Berkeley, Michigan, Indiana, Stanford, and Columbia all rolled into one."[353] The implication, of course, that diverse institutional backgrounds provide more flexibility in determining scientific issues than a single source.

In 2008, Graham and Irina Dezhina co-authored *Science in the New Russia: Crisis, Aid, Reform*, another retrospective on Russian Science since 1991. Typical of Graham's writings, he begins with the Soviet's huge scientific manpower force ---

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[352] Ibid., 6.
[353] Loren R. Graham, *Moscow Stories*, (Bloomington: Indiana University Press, 2006), 105.

estimated at10-30 percent greater than the U.S. During and after the breakup, state funding dropped 80 percent causing huge restructuring issues. Many educated Russians looked abroad to support their families and their careers. Graham states "During the last fifteen years the Former Soviet Union (FSU) has be the object of the largest international scientific aid program in history."[354] However, reform faced much more fundamental issues than economic assistance. In addition to new funding issues, the Russians had to develop new administrative, financial, and legal systems in which to sustain the scientific community. How well had they done: Graham concludes "Not very well."[355]

The Russian Academy of Science still monopolized authoritative research issues. The RAS reinforced its power by maintaining its links to institute directors who together decided what researchers received funding. Graham describes the three scientific pyramids, RAS, industry/defense, and universities, as still distinct and resistant to joint efforts. In other areas, there has been progress. Previously, the RAS and institute directors decided the importance of a scientist's work, the system now has become open to Western style research grants and in concert, a demand for peer review. This shift is perhaps one of the most dramatic changes moving from an authoritative overview to one controlled by one's collogues , and has been perhaps the most important. It represents a shift from the collective to the individual's performance.

In 1989, Kneen provides a critical science and technology analysis since *glasnost* and *perestroika* because of its strategic role in Soviet economic modernization. The article aims to evaluate the shift from the former reliance on quantity to the new qualitative approach by fostering closer industry and science links. Beginning in 1985, the Soviets became members of The Comprehensive Programme of Scientific and Technical Progress international organization and in 1986 formed the State Committee for Science and Technology (GKNT). He does, however, fault the Russian Academy of Sciences for not opening it directorships to the rank and file elections, rather than the RAS leadership.

In 1995, Kneen switched focus from Gorbachev's "Big Science" changes to Yeltsin's post-Cold War science policy in "Science in Shock: Russian Science Policy in

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[354] Loren Graham and Irina Dezhina, *Science in the New Russia: Crisis, Aid, Reform*, (Bloomington: Indiana University Press, 2008), 89.
[355] Ibid., 163.

Transition." He posits that since the West had seen Russia's vast scientific assets, there had been a change in outsiders' perceptions. Instead of blaming Soviet oppression as chief cause to lack of economic progress, the problem stemmed from bureaucratic malaise and military-centric science. To illustrate he compares the Ministry of Science, Higher Education and Technology Policy's (Minnauka) 1992 "A Draft Conception of a Science and Technology Policy for the Russian Federation" and the Organization for Economic Cooperation and Development's (OECD) 1994 "Science, Technology and Innovation Policies: Federation of Russia" report. Kneen points out that since the 1960s, Soviet scientists and policy makers knew their system needed reform, but the Russian Academy of Sciences and defense spending stood in the way. To begin, Soviet and foreign critics pointed out that despite its huge science and technology infrastructure, the costs did not justify its actual progress on the international stage. Instead of advancing, the S&T hierarchy had become bureaucratized and stifled more talented scientist and engineers. The OECD report also focused on the oversized and imbalanced S&T community. While the Soviets excelled in some areas, the defense industry employed 40% of their manpower and 70% of the state's research and development funding leaving a small fraction for non-military economic development.[356]

In addition, Russia lacked an internationally competitive scientific culture. The Russian Academy of Science oversaw a strict review process and determined priorities unlike the West where funding came from the state, but also industry and private sources. The RAS established institutes overseeing projects, but the hierarchical command structure with these centers reported directly to the Academy which hindered consortiums and information sharing. The directors, then, held power over the scientists under their control. Although Soviet scientists did publish internationally, this arrangement provided a Russian form of peer review.

Kneen also highlights efforts introducing the peer review process in Russia's science reforms. He points to the 1993 Russian Foundation for Fundamental Research funding selections based on group assessments. However, scientists complained that selections favored RAS based on 85% institute funding when they only accomplished

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[356] Peter Kneen, "Science in Shock: Russian Science Policy in Transition," *Europe-Asia Studies*, 47, no. 2, (1995): 286, http://www.jstor.org/stable/152611, accessed 11/121/08.

50% fundamental research. He cites renowned physicist Academician Vitalii Ginzburg for pointing out that Russians had little experience in the "narrow publications race generated by American funding procedures."[357] Also that foreign funding procedures might be "more sensitively related to characteristics of the Russian system where the equivalent of the American post-doctoral researcher would generally have been appointed to a permanent post and encouraged to develop a broad perspective on his or her discipline, usually within the framework of a long-term project."[358] This observation, however, came with a caveat: "Whatever the real scale of foreign funds entering Russia may be, the complexities of assimilation and implementation, especially where large-scale foreign packages are concerned, can be considerable."[359]

In 1998 Kneen publishes "Physics, Genetics and the Zhdanovshchina" in which ideology shattered Soviet genetics, but did relatively little harm in physics. Zhdanovshchina began during the Cold War infancy and demanded that all cultural and scientific fields adhere to Soviet doctrine. He attributes Lysenko's rise to power on several factors. First, he came from a peasant background and fit Stalin's collectivization social image. Agricultural work demanded a lower education level, so ideology and propaganda easily melded with Lysenko's pseudo-scientific theories. Finally, Stalin supported Lysenko in his debate with geneticists. Physics, however, was a different story. Kneen argues against the prevailing thought that Stalin protected those working desperately to produce a Soviet atomic weapon. Rather, since physicists relied on mathematics, rigorous experimentation, and received a higher level of education, they formed somewhat of a protective shield to philosophy and politics.

Linda Lubrano's 1981 "National and International Politics in US-USSR Scientific Cooperation," speaks to the Cold War scientific exchange political aspects by stating "Nowhere is the merging of science, foreign affairs, and domestic politics more evident than in the area of scientific cooperation between the USA and the USSR, especially in the aftermath of the Soviet invasion of Afghanistan and the arrest of Andrei Sakharov."[360] Lubrano provides an interesting political science definition in "Politics, we are told, is the

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[357] Ibid., 293.
[358] Ibid.
[359] Ibid.
[360] Linda L. Lubrano, "National and International Politics in US-USSR Scientific Cooperation," *Social Studies of Science*, 11, no. 4, (November 1981): 451, http://www.jstor.org/stable/284777, accessed 4/16/09.

authoritative allocation of values."[361] In the Soviet's case, the Russian Academy of Sciences controlled the exchanges.

A later 1993 Lubrano article titled "The Hidden Structure of Soviet Science," article displayed a post-Soviet shift from a Russian Academy of Sciences' "systems dominant" authoritarian approach to a "formal-informal" sociological one. According to the author, "A study of informal networks in the Soviet scientific community reveals the development of a complex system of interlocking and overlapping channels of professional communication that cut across the formal, hierarchical chains of command in the USSR Academy of Sciences."[362]

In 1996 Alexei Kojevnikov wrote "President of Stalin's Academy: The Mask and Responsibility of Sergei Vavilov" who served as Stalin's head of the Russian Academy of Sciences from 1945-1951. He terms 1928-1932 and Vavilov's RAS advancement to a "cultural revolution" with the end of compromising with the bourgeoisie scientists and demand for new Communist specialists and created a "short period of chaotic institutional changes, reforms, and social mobility."[363] By 1932, Vavilov was one of the first "new" physicists elected to the RAS; however, he was the last non-party president. Kojevnikov describes Vavilov's tactics when dialectical materialism philosophers attacked physics as the RAS president emphasizing "dialectics" in science and the philosophers emphasizing the "materialism" as a means to avoid serious ideological damage. Kojevnikov sees Vavilov as "protective mediator between physicists and the demands of the outer society.[364]

After World War Two, establishing Party control over academia took place in linguistics as ideological discussions. Kojevnikov calls these "games" drawn from interparty democracy that allowed grassroots initiatives within Party structure. This meant a society and culture with specific rituals, mores, and styles. *Diskussiia* (disputes) provided a public forum for unresolved theoretical debates. "*Kritika i samokritika*" (critique and self-critique) provided a forum for grassroots criticism. The author

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[361] Ibid., 452.
[362] Linda L. Lubrano, "The Hidden Structure of Soviet Science," *Science, Technology, & Human Values*, 18, no.2, (Spring 1993): 148, http://www.jstor.org/stable/960064, accessed 4/16/09.
[363] Alexei Kojevnikov, "President of Stalin's Academy: The Mask and Responsibility of Sergei Vavilov," *Isis*, 87, no. 1, (March 1996): 21, http://www.jstor.org/stable/20060341, accessed 4/16/09.
[364] Ibid., 35.

concludes that Vavilov's success at these "games" went further in preserving Soviet physics than the atomic bomb.[365] In other words, Vavilov was the consummate bureaucrat.

In "Rituals of Stalinist Culture at Work: Science and the Games of Intraparty Democracy circa 1948" Kojevnikov examines the "Philosophical Dispute of 1947" arguing that the dispute should be examined through "the level of formal rules and rites of public behavior rather than in the contents and results of the dispute."[366] He contends that Communist political culture or "interparty democracy" games using *Diskussiia* and *Kritika i samokritika* provided the party the tool to impose ideology on academic disciplines by examining its success in biology and failure in physics. This steers the power away leadership to a much deeper cultural source.

These "games" prevented bureaucratic power entrenchment. Subordinates and peers criticized while cultural norms dictated the subject respond with self-criticism. This dialogue served as "self-cleansing" analogous to penance in other cultures. Unwilling to accept external examination, the party devised the games as a self-correcting technique.[367]

Kojevnikov concludes that these "games," as the term implies, had unpredictable outcomes. The party "prescribed certain operative procedures with open agendas and outcomes, which provoked initiatives, criticism, and conflicts."[368] However, the Communist's attempt to impose ideology, while portraying total control, was often sporadic and determined more by a "constellation of circumstances" rather than logic. The results resembled chaos rather than careful planning. The author concludes that portraying the Soviets as omnipresent and evil, Manichean came from political and moral desire to defeat totalitarianism.

In "The Phenomenon of Soviet Science" (2008): Kojevnikov continues his thoughts against Soviet science polarity and opposition interpretations driven by stereotypes and East-West fears he regards as still pervasive. He contends that these

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[365] Ibid., 49.
[366] Alexei Kojevnikov, "Rituals of Stalinist Culture at Work: Science and the Games of Intraparty Democracy circa 1948," *Russian Review*, 57, no. 1, (January 1998): 28, http://www.jstor.org/stable/131690, accessed 4/14/09.
[367] Ibid., 35-36.
[368] Ibid., 50.

irrational worldviews mask Soviet Marxist contributions to the discipline. Big Science emerged first, according to the author, in the Soviet Union because of its Marxist strictures against religion and superstition and the Bolshevik's need to industrialize and modernize the country. Second, the Soviets separated "pure science" teaching from "productive" institutes engaged in benefiting the nation staffed by civil servants and governmentally funded. He leaves out the West's combination of academia, private industry, and public contributions that combined to produce science and technological feats often superior to the Soviet method.

Other observations are worth noting, even if to appreciate the Soviet's, now Russian's, science self-image. Kojevnikov explains that the Soviets denounced eugenics as early as 1931 before any other national scientific community because racism, anti-Semitism, forced sterilizations, and Nazi adherence to hierarchical ethnic structure. However, it took the Holocaust's exposure in 1945 before the international community renounced the concept.[369] The author argues that Soviet science also helped define World War Two as did General Leslie Groves, and left-wing J. Robert Oppenheimer atomic in the US Big Science weapon collaboration.[370] Lastly, he credits Sputnik for stimulating America's own space program's triumphs.

In 1992, Slava Gerovitch received his Ph. D. from the Russian Academy of Sciences. While working on a second doctorate at MIT in Science, Technology, and Society with Loren R. Graham he published "Perestroika of the History of Technology and Science in the USSR: Changes in the Discourse," examining the evolution in Marxist historiography. Boris Hessen offered the first "externalist" interpretation after the 1921 Russian Academy established the Commission on the History of Knowledge. However, Bukharin and Hessen are purged and a distinct "internalist", deterministic approach replaces the social-political methodology. Gerovitch writes "The new scholarship was not Marxist, but rather 'Marxy,' that is, imitating Marxist language without any substantial correlation with the teachings of Marx." Soviet internalism demanded objectivity, or "grounding narrative in solid facts rather than speculative

[369] Alexei Kojevnikov, "The Phenomenon of Soviet Science," *OSIRIS*, (2008): 127, http://www.history.ubc.ca/sites/default/files/akojevnikov/documents/2008Phenomenon.pdf, accessed 3/26/10.
[370] Ibid., 125.

interpretations."[371] Soviet "externalism" evaluated historians based on their ideological adherence to the Party's dictates. Perestroika and newfound archival resources, however, did not unleashed a Russian historical "revolution", but like Kuhn's evolutionary change, has taken longer as the "internalist" approach fades away.

Gerovitch's 2001 "'Mathematical Machines' of the Cold War," writes specifically about the early Cold War's impact on US and USSR military computer science and technology. He declares that Soviet scientists balanced Stalin's ideological and military priorities to "'overtake and surpass' science in the capitalist countries, and to 'criticize and destroy' Western scholarship for its alleged ideological flaws."[372] This 'Scylla of national defense and Charybdis of ideological purity' damaged the Soviet's efforts to match the US by focusing solely on computer's mathematical-military applications in contrast to the US which moved into non-military cybernetics and sociological scholarship.[373]

He assumes a sliding boundary between objective knowledge science as and subjective ideology. In the case of biology, Lysenko and his ideological followers succeeded by painting their adversaries science as Western and easy targets for attack. In contrast, the 'de-ideological' separated objective 'core' from the philosophical 'shell'. In computers, Soviet scientists resorted to value-neutral language such as 'data', 'storage', and 'tracking device', instead of 'information', 'computer memory', and 'servomechanism'. They also avoided public philosophical debates by maintaining military and classification walls. Gerovitch concludes that the boundary shift phenomenon affected both Cold War adversaries. In the case of computer science and technology, both Cold War adversaries developed under military auspices under a veil of secrecy, but the USSR fell behind because scientists feared the field would fall prey to ideologues.

Over the years, Russia-Soviet science historians have expressed a wide variety of historical interpretations. Power and knowledge are common currency whether it

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[371] Slava Gerovitch, "Perestroika of the History of Technology and Science in the USSR: Changes in the Discourse," *Technology and Culture*, 37, no. 1, (January 1996) 106, http://www.jstor.org/stable/3107203, accessed 3/23/10.

[372] Slava Gerovitch, "'Mathematical Machines' of the Cold War: Soviet Computing, American Cybernetics and Ideological Disputes in the Early 1950s," *Social Studies of Science*, 31, no. 2, (April 2001): 257, http://www.jstor.org/stable/3107203, accessed 4/14/09.

[373] Ibid., 255.

involves state or individual. How much will the state impose non-scientific issues on researchers and how important is knowledge in resisting such pressures? Lysenko certainly disproved expertise as defense against nonsensical attacks. On the other hand as evidenced in the US, most people react to biological debates because of their own makeup. Physics conversely, examines matter, often unseen, and is much more difficult for the untrained to understand. Also, states need physicist for developing weapons making it far less likely to lock them away.

CHAPTER FIVE

AJAX

Chapter five details the integration of Former Soviet Union science and investigation into their findings. Air Force and other scientists examined their findings and ran their own tests. Criticism and how the Russians reacted provides fascinating insight into how their science reached a high state of maturity in the Soviet Union. A radical plasma-based hypersonic aerospace proposal brought claims of a revolution and charlatanism.

In the latter part of 1993, ANSER began reporting emerging information regarding Former Soviet Union hypersonic space plane designs. The hypersonic communities' efforts to examine this concept began the journey that officially brought the science under falsification review at the October 1997 Weakly Ionized Gas (WIG) conference at the Air Force Academy. Up to that time, AFOSR had worked with Russians on the scramjet and wind tunnel testing. The WIG research and concept offered a revolutionary new approach to hypersonic aircraft. Instead of relying on passive materials or active cooling systems to manage the heat barrier, scientists offered plasma control to protect the airframe and its occupants. Why did AFOSR pursue this research? For one thing, the idea offered another option to a seemingly stagnated hypersonic research.

All flight depended on manipulating air pressure and air flow. Conventional aircraft used appendages (wings, fins, ailerons, rudder, etc.) to lift and direct a flying body---all this came from altering air pressure. In addition to doing the same for hypersonic applications, plasma aerodynamics could carry out the same functions *and* provide a thermal barrier management by WIG. If not, as Dr. John D. Anderson, Jr. described in *A History of Aerodynamics* results "hot enough to cause the nitrogen and oxygen molecules in air to dissociate, literally tear apart, leading to various chemical reactions."[374]

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[374] John D. Anderson, Jr., *A History of Aerodynamics and Its Impact on Flying Machines*, (Cambridge, U.K.; New York: Cambridge University Press, 1997), 439.

The 8 October 1993 ANSER Moscow Office Report provided early reports of Former Soviet Union proposals. It described discussions with Vladimir Krementsov, Chief of the Research Institute of Radio Device Engineering Plasma Laboratory, and Anatoly Klimov, Chief of the Moscow Radio-Technical Institute Plasma Gas Dynamics regarding several possible U.S./Russian cooperative programs. Kremenstov and Klimov described a plasma discharge device that allowed the aircraft to travel with up to 60 percent more air-drag efficiency. The add-on device projected a plasma discharge a head of its leading edges that altered atmosphere and kinetic energy leading to less energy consumption and faster flight---from Mach 1 to Mach 6. They specifically referenced its possible use in the unconfirmed Air Force Aurora program as a replacement to the SR-71, Mach 3.5 spy plane.[375]

The 25 October 1993 ANSER report included more information about an alternative approach "to increase aerodynamic efficiency by influencing the gas dynamics around the vehicle."[376] The Russian scientists stated they could drastically reduce hypersonic shock impact in the presence of a weak ionized cold non equilibrium plasma field. At hypersonic speeds, air deviated from its normal or 'equilibrium' and by using a weakly ionized plasma 'gas' could offer shockwave mitigation. Weakly ionized gas contained the energy released when shock tore electrons from their nuclei and created a collective behavior within the magnetic field created. They proffered that by placing small plasma discharge devices strategically placed around critical shock-wave areas would enhance stability, control, and engine efficiency. The Russians believed it would contribute to the NASP and USAF Aurora programs. They estimated four to five years in development and a $20M cost.[377]

In 1994, Notre Dame fluid dynamicist Mohamed Gad-el-Hak addressed the possibilities of such research in "Interactive Control of Turbulent Boundary Layers: A Futuristic Overview." He explained that boundary layer control could be applied to aircraft or submarines. He explained the "Butterfly Effect," the idea that an insect's wings could impact a future storm thousands of miles away. The implication was that a

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[375] ANSER, "ANSER's Russian Activities Moscow Report #52, October 8, 1993," 3.
[376] ANSER, "ANSER's Russian Activities Moscow Report #55, October 25, 1993," 3.
[377] Ibid., 4.

tiny microscopic action had such huge or macro-impact meant that change needed to focus on the smaller disturbances because changes increase exponentially for that level. Invoking the language of Chaos theory to draw analogies with electric power grids, telephone systems, and computer networks he infers that modifications need to be at the micro- not macro-level.[378]

The Soviet then Russian Ministry of Defense had sponsored the research, but it was discontinued due to financial resources. This seemed like a fantastical "Star Wars" solution and in fact had started soon after Ronald Reagan's Strategic Defense Initiative in the early 1980s.[379] During a January 2008 interview with Professor Vladimir L. Bychkov, Moscow State University, Dr. Igor I. Esakov, Deputy Executive Director on Science, Radiotechnical Institute, RAS, and Dr. Anatoli I. Klimov, Institute of High Temperatures, RAS, they identified themselves as former weapons scientist working in the Soviet version of "American…antimissile program."[380] They considered themselves as leaders in plasma ballistic research and attributed their expertise to other Russian scientists. Dr. Klimov had written an article about Academician Ramiliy Fedorovich Avramenko, Chief Designer at the Scientific Research Institute of Radio Instrument Making and the scientific director for Russian plasma weapons. Avramenko proposed creating an ionized region using microwave or laser based system generating electromagnetic energy in front of a hypersonic vehicle around 30 miles altitude. The aircraft or missile would encounter a region of reduced air pressure than what it had been traveling through and cause the device to tumble and break apart.[381] The significant aspect of his proposal was that instead of focusing the energy on the projectile to ablate or burn material, this method altered air pressure. AJAX designers like Klimov then used the idea of altering the medium ahead of the spaceplane and this idea became a major topic in the1997 First WIG at the Air Force Academy which he attended under an EOARD contract.

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[378] Mohamed Gad-el-Hak, "Interactive Control of Turbulent Boundary Layers: A Futuristic Overview," AIAA Journal, 32, no. 9 (September 1994): 1753-1765.
[379] Roald Z. Sagdeev, *The Making of a Soviet Scientist*, John Wiley & Sons, Inc., 99.
[380] Interview, Professor Vladimir L. Bychkov, Dr. Igor I. Esakov, and Dr. Anatoli I. Klimov with author [USAF collaboration], 6 January 2009, 5.
[381] Moscow OGONEK, "Ogonek Report on '21st Century Weapons' – Plasma Shield Able to Protect Entire Planet From Nuclear Threat," April 1995, No 16, 35. http://www.fas.org/news/russia/1995/tac95060.htm

This was not the first time an injection method was proposed in order to modify Mach 10 and above conditions on man-made objects. The early Intercontinental Ballistic Missile (ICBM) and sounding rocket programs discovered the radio communication "blackout" problem as an issue. Both during a rocket's launch and reentry, the hot gases created by the missile's plume and the ionized sheath blocked telemetry during critical minutes in the flight regime. Engineers countered the effect by moving ground relay sites farther away from the plume's expansion, but the blocked reentry signals remained. During early Scout sounding rocket launches, designers noticed partial radio signal strength restoration when the missile's hydrogen peroxide control jets fired. Some hypothesized that the corrective action's byproducts, negative-charge water vapor and oxygen, recombined with the exhaust plume's positive-charge ions thereby reducing the "blackout" influence. Manned spaceflight confirmed the blocked radio signal phenomenon that lasted up to five minutes in the Mercury and Gemini programs. On 23 March 1965, Gemini 3 astronauts carried out a water injection anti-blackout experiment with some success.[382]

In 1981, Avramenko, et. al., published a research article titled "Structure of a Shock Wave in a Weakly Ionized Nonisothermal Plasma."[383] The 'nonisothermal' in this case meant uneven vibrational and rotational plasma temperature at the atomic level. The idea of using the weapon for anti-ballistic missile defense proved impractical because it required 1 gigawatt to operate which came usually from nuclear power plants.[384] Klimov stated that Avramenko was a leading specialist in radars microwave, and plasma aerodynamics.[385]

The other scientist frequently mentioned during the interview was Gennady I.

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[382] Jonathan Eberhart, Piercing the Silent Curtain," *Science News*, 94, no. 18 (Nov. 2, 1968): 448; http://www.jstor.org/stable/395380. See also, R. A. Hartunian, et. al., "Causes and Mitigation of Radio Frequency (RF) Blackout During Reentry of Reusable Launch Vehicles," Aerospace Corporation: Aerospace Report no. ATR-2007 (5309)-1, xiv, http://www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/media/ATR-2007(5309)-1.pdf.

[383] R. F. Avramenko, et. al., "Structure of a Shock Wave in Weakly Ionized Nonisothermal Plasma," JETP Letters, 34 (9): 463-466, 1981.

[384] Yuriy Medvedev, "Dig an Air Pocket," Moscow TEKHNIKA I MOLODEZHI, No 8, 19 August 1995, p 2-3. http://www.fas.org/news/russia/1995/druma192_s95028.htm;

[385] Anatoli Klimov, et. al., "R. Avramenko and Development of Plasma Aerodynamics in Russia," c. 2002. http://mhd.ing.unibo.it/Wsmpa/WSMPA%202000/DIVISIONE%20PDF/SESSION%20I/3.pdf

Mishin. Mishin also attended the Academy WIG conference and listed his affiliation as Johns Hopkins University Applied Physics Laboratory (JHU/APL). According to Klimov, Mishin presented the first WIG plasma ballistic experiments to his U.S. counterparts. They commented that Mishin had dropped out of sight in Russia until Klimov received an invitation to join him in the U.S. to conduct research. Mishin had emigrated to the U.S. and been working at JHU/APL under contract with Dr. Dave M. Van Wie who had seen his work.[386] Van Wie related that beginning in 1994, he began learning more about Russian research that had "invested a lot of effort looking into related with the generation of plasmas for changing aerodynamics or enhancing engine performance and things like that."[387] Since the end of World War II, the JHU/APL had worked alongside the U.S. Navy and U.S. Air Force in developing missile ramjet and scramjet technology.[388] Van Wie work with other well-know JHU/APL hypersonic experts such as Dr. Paul J. Waltrup and Dr. Frederick S. Billig.

The timing could not have been better for the Former Soviet Union scientist's ideas because NASP had just declared 'dead-on-arrival'. In 1956 even before hypersonic properties impacted space vehicles, Dr. Klaus Oswatitsch described flying conditions that occurred when objects like meteors enter the earth's atmosphere at approximately Mach 100 and create temperatures higher than the surface of the sun. The At these speeds, air cannot get out from the front of the meteor creating a shockwave characterized by a stagnation point where the air theoretically stops causing increased density, temperature, and pressure. Normal, or ideal, air is composed on 20% oxygen and 80% nitrogen and begins to disassociate by the high temperature when electrons are torn away from atoms creating an ionized gas.[389]

Oswatitsch also discussed other issues raised when flying air-breathing aircraft at

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386 Email, Dr. Dave L. Van Wie, JHU/APL, to author, "Mishin," 26 September 2011.
387 Interview, Dr. Dave L. Van Wie, JHU/APL, and author, [FSU-US Plasma Research], 12 November 2008.
388 Dr. Paul J. Waltrup, et. al., "History of Ramjet and Scramjet Propulsion Development for U.S. Navy Missiles," JHU/APL Technical Digest, 18, no. 2, 1997.
389 Klaus Oswatitsch, Mary L. Mahler, trans., "Extreme Speeds and Thermodynamic States in Supersonic Flight," (Translation of "Extreme Geschwindigkeiten und thermische Zustande beim Uberschallflud," *Zeitschrif fur Flugwissenschaften*," 2, Issue ¾, 1956) NACA Technical Memorandum 1434, Washington, April 1958, 5.

such high temperatures. First, stating that even at Mach 3, a relatively low speed---not even hypersonic---stagnation temperature triggered the ionization process. He dismissed harnessing the energy released as being insignificant because the distance between freed ions did not create a powerful enough force.[390] Prigogine describes a similar historic period in the nineteenth century when, "Irreversible processes were looked down on as nuisances, as disturbances, as subjects nor worthy of study."[391] The analogy between the maturation of thermodynamics and its application to early hypersonic aerodynamics seems startling. "Recent work has formalized the explicit and analytical relationship between actual vehicle performance and entropy generation for aerospace systems. It should be noted, however, that Oswatitsch first formulated the overall entropy/drag balance for nonpowered aerodynamic shapes (i.e., wings) as early as the 1950s."[392]

The Russian research connected Prandtl's legacy to hypersonic aircraft through the Second Law of Thermodynamics. Up to that time, hypersonics explored the largest heat issues in propulsion and inlets where air has to be slowed down for combustion. The air-breathing science-technology connection had stagnated at the heat barrier. Thermodynamic investigations did not cease, but turned to space vehicles and reentry challenges for Intercontinental Ballistic Missiles (ICBM) warheads. According to NASA's Mercury program study *This New Ocean* ICBMs reached an altitude of 900 miles and a 6,500 mile range when the shock wave drag nose cone temperature rose to 12,000 degrees (2000 degrees beyond the Sun's surface) and 10 times beyond the X-15 surface temperature.[393] These were the hypersonic conditions described by Ostwatitsch.

In 2005, Dr. Richard P. Hallion, former Air Force Chief Historian and author of a three-volume study on the history of hypersonic development, presented a paper titled "The History of Hypersonics: or, 'Back to the Future – Again and Again'" argued that since the 1995 NASP failure and despite an upsurge in hypersonic research, there had

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[390] Ibid., 6.
[391] Ilya Prigogine and Isabelle Stengers, forward by Alvin Toffler, Order Out of Chaos: Man's New Dialogue with Nature, Toronto; New York, N.Y.: Bantam Books, 1984, 12.
[392] Jose A. Camberos and David J. Morehouse, Exergy Analysis and Design Optimization for Aerospace Vehicles and Systems, Reston, VA: American Institute of Aeronautics and Astronautics, 2011, 231.
[393] Loyd S. Swenson Jr., et. al., The New Ocean: A History of Project Mercury, (NASA History Series, 1989).

been no progress toward manned-hypersonic aircraft.[394]

What did happen is the extension of Ludwig Prandtl's air boundary revolution which had been stopped by the "heat barrier" to hypersonic flight. This happened because Former Soviet Union scientific boundary-layer research previously blocked by Cold War hostilities became available the West and Air Force scientists. It is evolutionary versus revolutionary but still a profound change. The change process more aptly followed H. W. Leipmann's 1979 article titled "The Rise and Fall of Ideas in Turbulence" that discusses a 100-year long evolutionary effort by renowned physicists and engineers to attack 'turbulence problems.'[395] In terms of hypersonic speeds for reentering spacecraft, the technological solution came in ablating surfaces; however, no such solution existed for hypersonic air-breathing aircraft. I believe Theodore von Karman would agree that his statement that, "It is a rare example of co-operation between 'men of mathematics'…and creative engineers."[396]

Karman does mention that since aerodynamics involved mathematicians and physicists there is a certain amount of philosophizing and indeed this extension is described in those terms that are roughly divided between what I call the empiricists (applied science/technology) and theorist or experimentalist.

Leninetz AJAX Proposal

In 1994, the Leninetz Holding Company, St. Petersburg, became the first Russian military defense organization to become a stock holding company and sold shares domestically and internationally.[397] The firm had invested heavily in the hypersonic aerospaceplane concept they titled AYAKS (AJAX). At that time they were very frustrated with the international community's curtailment of hypersonic investments such

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[394] Richard Hallion, "The History of Hypersonics: or, 'Back to the Future – Again and Again,'" 43rd AIAA Aerospace Sciences meeting and Exhibit, 10-13 January 2005, 1.
[395] H. W. Liepmann, "The Rise and Fall of Ideas in Turbulence: Research in turbulence, still the most difficult problem of fluid mechanics, continues to produce technological advances, but the path of progress is anything but straight," American Scientist, 67, no. 2, (March-April 1979). 221-228, http://www.jstor.org/stable/27849154, accessed 21 Sep 2011.
[396] Theodore von Karman, Aerodynamics, Cornell University Press, New York, 1963, 2.
[397] Mark S. Maurice, Chief Aeronautical Sciences, "EOARD Tour Report, 15 Jul 93-15 Feb 97," USAF, 46.

as the US's NASP program.

Dr. David Van Wie, Johns Hopkins Applied Physics Laboratory, provided several interesting insights into the AJAX program and Former Soviet Union science in general. He had worked directly with the NASP program from beginning to end. He recalled his first meetings with Russian at the American Institute of Aeronautics and Astronautics in 1989. His boss Frederick Billig, a very highly respected hypersonic scientist, was interested in Central Institute for Aviation Motors work on scramjets. The Air Force began sponsoring activities at APL to engage Former Soviet Union scientists to learn more about their research institutes. The laboratory contracted with them to conduct experiments and write a report. Through these contacts Van Wie and his counterparts began to hear about plasma generation to influence engines and aerodynamics. In 1996, Mark Maurice, then the EOARD aerospace representative, brought Drs. Anatoli Klimov, Russian Academy of Sciences Moscow Radio-Technical Institute and Vladimir Bytchkov, RAS Institute of High Temperatures where much of Soviet fusion research had been conducted, to Air Force laboratories. Klimov and Bytchkov explained the AJAX plasma ideas and what the American heard was intriguing, so they set up a meeting in Moscow. Van Wie commented that "You know these concepts behind these plasma-generation schemes where something that hadn't been looked at very much in the United States and it was obviously different things occurring and they were very intriguing."[398] The Russians presented physics-based solutions "that [were] not classic aerodynamics."[399]

Another example of what the Former Soviet Union accomplished was their hydrocarbon-fuel vehicles. Prior to NASP, the US had dropped its hydrocarbon-fuel research in favor of hydrogen-fuel, but after NASP and based on discussion with the Russians, the US switched back to hydrocarbon. They, unlike the US had continued such research in the 1980s and had tremendous amounts of test data to research. They used the information to do some very interesting things in terms of engines, fuel injectors, flame holders, and inlet design. In addition to using plasma to decrease drag, within a

[398] David Van Wie interview with author, [FSU-USAF Cooperative Program], 13 November 2008, 4.
[399] Ibid.

scramjet, plasma can be used to modify the flow field into the engine. Designers can set up magnetic forces to compress the flow into a higher degree which increased the scramjet's efficiency. [400]

In May 1996, Lee Bain, Chief of the Air Force Propulsion Division, and Van Wie, APL, travelled Moscow to visit propulsion groups at TsAGI and CIAM. They asked for a meeting at Leninetz to discuss the AJAX proposal and were surprised by what happened. The US contingent arrived with the idea that because NASP funding had collapsed they would set establish centers at their universities for basic research which would led to research publication. Since the first meeting, the Leninetz meeting had somehow grown into a much bigger affair. Russian attendees included the minister of aviation industry, the Mikoyan-Gurevich chief aerodynamicist, the Sukhoi chief aerodynamicist, and the Minister of Moscow Radio Technical Institute. They could see that their hosts were expecting a bit more than discussions and the meeting ended with an agreement to travel to the company in St. Petersburg.[401]

At this three-day meeting, Julian Tishkoff joined Bain, and Van Wie and spent the morning presenting their slides and had lunch with the appropriate vodka toasts. This time, Bain came with a $400,000 budget and offered the amount to the AJAX Leninetz group. They were shocked when the company vice-resident "took the floor and read us the riot act."[402] He believed the Americans came to sign on to the AJAX as paying partners. The Russian replied that based on the amount offered, they could not be serious. Van Wie stated that the group said, "You can take your $400,000 back and lobby your Congress … use it to lobby your Congress for a real program."[403]

Their response changed dramatically six months later. Guessing that perhaps the Leninetz AJAX program had fallen apart, they now expressed that the amount would be desirable and it had been a misunderstanding. But it was too late. Since that meeting, the USAF contingent had decided to take the $400,000 and divided it up into small amounts

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[400] Ibid., 17.
[401] David Van Wie interview, 15.
[402] Julian Tishkoff interview with author, [FSU-USAF Cooperative Program], 16 June 2008, 12.
[403] David Van Wie interview, 9.

for various research groups.[404]

At the end of this conference, the Americans were faced with another cultural hurdle when the Russians insisted that someone from the US sign a "Protocol of the Meeting" document. Tishkoff and Bain were US Government employees and knew they could not possibly sign the document. Van Wie, on the other hand, worked for Johns Hopkins Applied Physics Laboratory and was technically not directly connected to the Government. He signed the document and everyone seemed happy.[405]

The Former Soviet Union scientists published two AIAA papers that attracted interest from not only the Air Force and APL, but also the entire international aviation community. The first, "On a Perspective of MHD Technology in Aerospace Applications" was co-written by two RAS Institute of High Temperatures and one Leninetz scientist. The article stated that, "One of the first proposals for such an MHD aerospace application was considered by A. Kantrowitz."[406] They proposed using the ionization occurring at hypersonic, high-altitude flight along with magnetic field induction to modify external flow, reduce heat flux, decrease drag, generate electrical power, and increase scramjet engine performance.

The second article titled "AJAX: new Directions in Hypersonic Technology," was written by another Leninetz scientist and one Rockwell North American Aircraft Division program manager. The philosophy behind the AJAX proposal was to recycle the energy created during flight that would otherwise be discarded. They argued that "the benefits of such exploitation would be huge, so that the plasma phenomenon can be characterized as a high-risk, high-payoff technology."[407] They use references to "revolutionary" and "synergistic" to describe the proposal's full impact.

The next year, one Italian and two US university aerospace professors took two semesters and travelled to various Russian and Ukrainian sites to evaluate the AJAX

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[404] Ibid.
[405] Ibid., 10.
[406] V. A. Bityurin, V. A. Zeigarnik, and A. L. Kuranov, "On a Perspective of MHD in Aerospace Applications," AIAA (June 1996): 1.
[407] Evgeniy Gurijanov and Philip T. Harsha, "AJAX: New Directions in Hypersonic Technology," AIAA Paper 96-4609, 1.

proposal provided any real advantages. They stated that the concept came out of the State Hypersonic Systems Scientific Research Enterprise in St. Petersburg headed by Vladimir Freistadt. They describe five elements in the MHD scheme: MHD to direct kinetic energy and reduce entropy in the flow to the engines; ionizing to reduce vortices into the engine; reducing drag by injecting plasma at the vehicle nose; plasma injecting to increase combustion efficiency; and reforming hydrocarbons to cool the vehicle. After examining the data and according to their calculations, the system seemed to meet the designer's claims.[408]

Anomaly and Its Discontents

There was however, something in the AJAX regarding shock waves that sparked a controversy and surprisingly it was not the provocative wording, but an assertion and citation for research conducted by Gennady Mishin. He described it as "the author's research into the significant consequence of the discovery of anomalous shock wave parameter in weakly ionized gases."[409] What he actually meant was shock weakening and shock-wave splitting and spreading which had profound implications for hypersonic flight.[410] The controversy was essentially what "anomalous" really meant. What Mishin and other Russians claimed would constitute a tremendous scientific discovery. If reproduced by others, it could be seen as authentic, but to some it seemed fraudulent to the point of claiming mysticism as experimental results.

The Air Force asked Kevin Kremeyer and two other scientists to investigate some of the experimental finding done by Mishin, Klimov, and others. They had added plasma upstream to a cone-shaped model in hypersonic flow. They claimed that after doing so the shock wave split into two or more smaller waves. Kremeyer, et. al, wrote that, "However, an outstanding issue still is the extent to which the observed shock splitting

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[408] Claudio Bruno, Paul A. Czysz, and S. N. B. Murphy, "Electro-Magnetic Interactions in a Hypersonic Propulsion System," AIAA, 9 July 1997, p 1-2.
[409] Gennady Mishin, "Experimental Investigation of the Flight of a Sphere in Weakly Ionized Air," AIAA, 1997, 1.
[410] Igor V. Adamovich, Vish V. Subramaniam, J. William Rich, and Sergey O. Macheret, "Phenomenological Analysis of Shock-Wave Propagation in Weakly Ionized Plasmas, AIAA, 36, no. 5, (1998): 1-2.

and attenuation are due to plasma electromagnetic effects or to the gas heating which accompanies the introduction of the nonequilibrium plasmas."[411]

In 1988 leading up to the issue, the word 'anomaly' and "non-equilibrium' had already been discussed within the Air Force and then published by J.S. Shang and Eswar Josyula, Wright Laboratory, Wright-Patterson AFB. Using computational analysis they researched the hypersonic shock wave phenomenon because in those flight ranges, chemical and thermodynamic equilibrium states easily became non-equilibrium flows. They noted that the "numerical results reveal some anomalies in the simulations of the flow in the stagnation region."[412] In what appears to be a seminal article, they begin their references to hypersonic research stimulated by the Resler-Sears research without touching upon the Soviet work during the same period.

In 1993, Josyula published "Computation of Hypersonic Flow Past Blunt Body for Nonequilibrium Weakly Ionized Air." He conducted research on Mach ranges from 16-35 at altitudes up to 42.5 miles where individual atoms existed much further apart than at sea level. At those speeds oxygen disassociation begins at 2500K and increases to completion at 4000K. Nitrogen becomes fully disassociated at 9000K and nitric oxide forms as the result of the combined dissociation between 4000K-6000K. This effort was aimed at making "accurate computations of this complicated physics in the vicinity of the blunt-nosed forebody in regimes where thermodynamic nonequilibrium effects are present."[413] He reports again that anomalies continued at the blunt body stagnation point.[414]

In 1996, the Air Force announced its interest in the Russians' anomaly work in B.N. Ganguly and P. Bletzinger, both from Wright Laboratory, examining Mishin's 1981 and subsequent findings in an article titled "Anomalous Relaxation and instability of Shock Waves in Gases." They announced that they confirm these "new effects" but that

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411 Kevin Kremeyer, Sergey Nazarenko and Alan Newell, "The Role of Vorticity in Shock Propagation Through Inhomogeneous Media," AIAA Paper 99-0871, 14 January 1999, 1.
412 J.S. Shang and Eswar Josyula, "Numerical Simulations of Non-Equilibrium Hypersonic Flow Past Blunt Bodies, AIAA 88-0512, 14 January 1988.
413 Eswar Josyula, "Computation of Hypersonic Flow Past Blunt Body for Nonequilibrium Weakly Ionized Air," AIAA 93-2995 (Jul., 1993): 2.
414 Ibid.

"anomalous dispersion and shock wave attenuation in weakly ionized non-equilibrium plasmas are not understood."[415]

In 1997, the Air Force aerodynamics laboratory asked then student Major William M. Hilbun mentioned earlier, conduct research on the anomaly in his Ph.D. dissertation "Shock Waves in Nonequilibrium Gases and Plasmas" at the Air Force Institute of Technology, Air University, Dayton, Ohio. Hilbun noted that research conducted in the 1970s and 1980s for the Space Shuttle had focused primarily on shock waves in a media in a state of thermodynamic equilibrium; however, research into a media in a state of nonequilibrium revealed interesting effects not seen at equilibrium.[416] He noted that this constituted the merging of two separate disciplines: aeronautical engineering and plasma physics. Hilbun essentially looked at the Russian experiments, some to 1981 that had already been done for anti-Star Wars weapons, and found that it was the temperature of the plasma that created some standoff distance and not the ionized fluid. This contradicted the Russian's claim that the plasma itself created the effect. This controversial finding was the focus of the 1997 first WIG Air Force Academy conference in which the Russians introduced their version of peer review which meant stopping the speaker to discuss their criticism.

The Air Force also asked the Department of Energy's Lawrence Livermore National Laboratory (LLNL): Livermore, California, to analyze the early 1980-present Soviet scientific work on plasma-shock wave modification by Mishin, Klimov, and others. The LLNL stood at the pinnacle of all US Government scientific laboratories for basic plasma science, so their finding would be very crucial to the ongoing research program. They specifically addressed providing an explanation for the "'anomalous relaxation' of a bow shock wave, resulting in a major reduction in drag…" regarding the hypersonic AJAX proposal.[417] The Russian experiments cited practically matched the ones evaluate in the 1996 Ganguly- Bletzinger research that termed it a 'new effect'. The LLNL evaluated 15 Russian 1989-1990s experiments performed in shock tubes, ballistic

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415 B.N. Ganguly and Bletzinger, "Shock Wave Dispersion in Nonequilibrium Plasmas," AIAA 96-4607 (Nov., 1996): 1.
416 William M. Hilbun, Shock Waves in Nonequilibrium Gases and Plasmas, October 1997 Dissertation, 2, accessed 4 February 2010, http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA331770.
417 Bernie Penetrante and John Sherohman, "Feasibility Study for Analyzing Plasma Aerodynamic Effects," DOE-LLNL, 7 May 1999, 1.

ranges, and wind tunnels. The laboratory confirmed shock standoff distance increases, drag reduction, and thermal ranges potentially reduces. They confirmed that the "effects are present, but there is controversy on what is causing these effects.[418] They attributed this to lack of shock wave propagation in nonequilibrium, weakly ionized plasmas model; and a sparse database for model validation. Some results could be explained by various thermal effects, but in other experiments, heat alone could not explain the results.

Evidence of the dispute emerged the next year at Princeton University Plasma Physics Laboratory, AFOSR-sponsored "Understanding and Control of Ionized High-Speed Flows," 26-27 February 1998. The subsequent proceedings stated that "This interest is, in part, motivated by experiments conducted in Russia and in the United States which indicate shock propagation in weakly ionized air plasmas is at a higher velocity than would be predicted by presently understood models."[419] The attendees included US academia, private industry, Air Force, NASA, Analytic Services (ANSER): and Defense Advanced Research Projects Agency (DARPA) personnel brought together to present and discuss the AYAKS proposal. This also included the $14.8 million for 32 Air Force technologies to receive basic research support in fiscal year FY 1997.[420] Under "Rules of Engagement" it stated the following:

- Let's keep this science-oriented but relevant; we'll let someone else actually AJAX [AYAKS]
- Let's critique the work, but not criticize the people
- Please don't say, "It's just a thermal effect"; prove it[421]

If it is true that journalists provide the first cut of history, then Justin Mullins provided the foundation in "Plasma Magic" in *New Scientist* on 28 October 2000. The article generally tells the story I presented in explaining the AYAKS concept built around solving hypersonic aerodynamic challenges. "Plasma Magic" has different meaning to

[418] Ibid., 3.
[419] Proceedings, "Understanding and Control of Ionized High-Speed Flows," Princeton University, 26-27 February 1998.
[420] Ibid., p 15.
[421] Ibid., p 21.

different people.[422]

J. Daniel Kelley also doubted the Russian plasma claims. During the time their work began to surface in the west, he worked for McDonnell Douglas Research Laboratories which Boeing had acquired. Warren Beaulieu, his former colleague at North American Rockwell, now Boeing, asked him to use his theoretical chemist expertise to appraise claims of drag reduction with plasma generation in front of the vehicle. Kelley had already conducted investigations into hypersonic combustion and lasers. Beaulieu had done research with Bityurin and Klimov on plasma discharges for F-15 flight tests and described the work to Kelley. What the chemist termed as "corporate types" had seen the AJAX concept and were also pushing hard to find out if it actually worked.[423]

Kelley looked at the numbers and they did not seem to make sense. He expressed his doubts to Beaulieu who suggested he travel to Russia and see their laboratories. In 1997, he made the trip and was unimpressed with what he saw. The experiments were crude and their presentations did not support their claims. Despite his doubts, Boeing continued to support the research and Kelley was invited to the first Weakly Ionized Gases conference at the Air Force Academy in 1998. Kelley felt that there was a consensus at that time and that he and others felt that EOARD's funding the Former Soviet scientists to the conference was a naiveté coupled with wishful thinking. Their plasma claims were scientifically unsound. The Russians had simply figured out how capitalism worked and no one was blaming them. It was actually the Air Force that had consented to the pretense.[424]

Kelley described the first WIG as raucous. Many stood up stood up and disputed the Russian's findings and implied their work was more or less "baloney."[425] The conference seemed to split into camps that supported the plasma injection for all sorts of ideas like drag reduction, combustion enhancement, and reentry control. But since then, according to Kelley, these ideas have fallen away. The idea of generating plasma spikes

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[422] Mullins, Justin, "Plasma Magic," New Scientist, Issue 2262, http://www.newscientist.com/article/mg 16822624.000-plasma-magic.html, 28 October 2000.
[423] J. Daniel Kelley interview by author, [FSU-USAF cooperation], 7 January 2009.
[424] Ibid.
[425] Ibid., 7; see also, Ingrid Wysong interview by author, 17 December 2008, 8. Wysong also mentions funding as a stimulus for heated conference discussions.

off the aircraft's nose simply takes too much power. Also, the WIG forum moved from the Air Force to AIAA conferences and international scrutiny had pared back the Russian's claims. To Kelley it seemed that hiring the FSU [Former Soviet] scientists was a way to keep them from working on weapons or other military projects: "It's a WPA project for Russian scientists."[426]

Kelley did not so much object to the funding, but he thought it was bad science. There were plenty of scientists doing genuine work and not this "mystery stuff where these tremendous hypothetical benefits which no one has ever seen are being proposed."[427] The Air Force people did not really understand the science that well if you pushed them on the point. What the Russians presented as evidence was not concrete. There was enough ambiguity to accept it, but not for Kelley and others. On the other hand, he thought Bityurin was very good with MHD.[428]

In 1890, P. K. Mokievsky published "Philosophy in Russia," in *Mind* that presented a survey of philosophical trends. He states "the more intelligent part of Russian society followed the French Encyclopedists." However, "the French Revolution, the struggle with Napoleon and other causes evoked a reaction, which took the form of a strong mysticism."[429] Subsequently, he divides the works into positivists, logical reason, and "the subjective method, thanks to which the philosophy of history appears in his work as a kind of scientific theodicy of progress."[430] Later, he contended that "there is no such thing as Slavophil philosophy because of the want of amongst all the Slavophils capable of severely logical reflection."[431] This duality is a clash, then, of progress based on reason and subjectivity. In this case, wars pushed Russians to a heightened vulnerability sense.

This Slavophil-Western (positivist) divide was echoed by Elena Z. Mirskaya in "Russian Academic Science Today,"[432] by examining science in terms of Russia's

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[426] Ibid., 9; WPA Works Progress Administration established in 1935 Depression Era agency to fund employment in public works projects.
[427] Ibid.
[428] Ibid., 13.
[429] K. Mokievsky, "Philosophy in Russia," *Mind*, 15, no. 57, Jan. 1890, 155.
[430] Ibid., 156.
[431] Ibid., 159
[432] Elena Z. Mirskaya, "Russian Academic Science Today: Its Societal Standing and the Situation within the Scientific Community," *Social Studies of Science*, 25, no. 4, 705.

"traditional society in which attempts at modernization usually arise in an 'organic' way, and roll through in waves without reforming the social mindset --- its principles of integration and its mentality."[433] She compares the Slavophil as analogous to Fundamentalism.

Loren Graham religion and how it benefited the development of Moscow School of Mathematics. While French mathematicians worked on the same set theories in a culture that segregated science and religion, the Russians sought the influence of mystics and their Name Worshipers sect. Graham argues that the practice infused a certain amount of creativity because their dissent toward the Orthodox Church and the Communists.[434] Russian mysticism might be one explanation as to why the Former Soviet scientists named the new effect as anomalous. The word appears in several titles during their early research. Anomaly however meant something different to Americans. The word implied failure on the researcher's part.

In an article addressed both philosophy and history, Imre Lakatos wrote about scientific anomalies and his ideas on how research programs handled them. He describes fellow Hungarian émigré Karl Popper's 'falsification' method as a powerful tool, but in its dogmatic version it assumed that facts disprove theories. Radical inductivists point to the Newton, Maxwell, Einstein revolutionary research and how they dramatically superseded the previous theory which Lakatos term "naïve falsification."[435] In some cases false results came from true theories or true results came from false theories.

Lakatos proposed that great scientific achievements came from 'research programs' with progressive or degenerating problemshift. Pure scientific or internal knowledge maintained a positive, external heuristic defining problems, maintaining a belt of auxiliary hypotheses, accepted anomalies, and set them aside as long as the program progressed. Anomalies themselves did not define the process. A progressive problemshift occurred as long as theory growth anticipated empirical growth. A degenerating problemshift meant a lag between theory and empirical growth. When one research program progressively explains more than the rival one, it superseded the rival

433 Ibid., 707.
434 Loren R. Graham, "A Comparison of Two Cultural Approaches to Mathematics: France and Russia, 1890-1930," ISIS, 97 (2006): 70.
435 Imre Lakatos, "History of Science and Its Rational Reconstructions," Proceedings of the Biennial Meeting of the philosophy of Science Association, 1970 (1970):

or was shelved. Lakatos stepped away from Popper-Kuhn anomaly-centered philosophy to more pragmatic construct. Anomaly falsification occurred but not immediately or waiting for a paradigm shift, but over a long period when the rival program lost out to the other. In perhaps a tongue-in-cheek manner, Lakatos says the Popperian need for immediate confirmation-falsification has more to do with psychological needs, which he defines as external, rather than hard-core science. He goes on to say the problem with Kuhn Gestalt-shift paradigm model was it could applied to science or pseudo-science with no way to discriminate a progressive or degenerative. Eugenics seems to fit the latter, for example.

Valentin A. Bityurin, RAS Institute of High Temperatures IVTAN, went to work at a space and rocket center after graduating. While there he worked on MHD and rocket propulsion then moved to IVTAN for creating energy in 1964. According to him the Soviets and the US shut down the MHD-energy production efforts during the 1980s, but at his institute he continued working on MHD. He mirrored the US-MHD experience emerging out of space applications during the 1950s. He made reference to a very great scientist's pioneering work from New York which must have been Arthur Kantrowitz. Over time, he would come back to aerospace applications and found the physics very interesting in terms of plasma chemistry and plasma gas discharges. At that time Klimov came to work for him and "developed shock wave propagation through the plasma air, so this is very, very important and the first plasma magic effect so-called was observed for this particular case and Klimov was involved in this study."[436]

One of the first AJAX empiricist evaluations came from Dr. Mark Lewis, University of Maryland, and representatives from ANSER, Lockheed Martin Skunk Works, Flight Unlimited, and McKinney Associates. After assessing the concept, they concluded that, "The idea of creating a 'virtual' aerospace craft with respect to the flow field around vehicle and the engine performance, represents a basic change in aircraft design *philosophy* [author's emphasis]."[437]

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[436] Valintin A. Bityurin interviewed by author, [FSU-USAF cooperation], 8 January 2009, 7.
[437] Ramon L. Chase, Mark Lewis, et. al., "An AJAX Technology Advanced SSTO Design Concept," AIAA 1998, 6.

In the early meeting between the US and Former Soviet scientists, many Westerners would be shocked by how the Russians behaved during conferences. They would interrupt the speaker and begin to criticize the work. The communist model for these instances came from the doctrinal demand that members engage in 'self-criticizing'.[438]

According to Sergey Bobashev, atomic physicist and Head of the Ioffe Gas-Dynamics Laboratory, what seemed shocking to the Americans that the Former Soviet scientists interrupted presentations and stopped to discuss finer points of the research was quite normal to Russians. In 1979, Bobashev had spent time at the Joint Institute for Laboratory Astrophysics in Boulder, Colorado. The University of Colorado and the National Institute of Standards and Technology managed the Institute. Its first director, theoretical physicist and cosmologist George Gamov had been one of the youngest corresponding members accepted to the USSR Academy of Sciences at 28. He defected and made his way to the US in 1934.

Bobashev commented on each other's scientific mannerism saying that yes, in American people listen to all the presentation and then ask questions. However, in Russia "the discussion can start very fast and everybody forget [sic.] about this guy who really (chuckles) give a talk, to discuss this problem."[439] He felt that it was exciting and could produce very good results and was appreciative when someone stood up, stopped to correct a mistake, and then went on. The author witnessed such discussions several times during the January 2008 AIAA Former Soviet WIG presentations. I questioned other Former Soviet scientists who had taken positions in the US and they confirmed the behavior. One stated that it did not matter whether the speaker was a Nobel Laureate, anyone could be interrupted. Bobashev called it a cultural issue.

He thought that when American scientists visited Russian counterparts, they lacked experience in the fields they wished to talk about and felt compelled to believe they knew best about the Former Soviet's capabilities. The Americans became quite frustrated when told their ideas had already been tried 20 years ago in the Soviet Union. Daniel Kelley and Kevin Kremeyer cited such comments about vague references to

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[438] G. Brown, "The Discussion on Physics," Soviet Studies, 6, no. 2 (Oct., 1954): 128, http://www.jstor/.org/stable/149007.
[439] Sergey V. Bobashev interview with author, [US-FSU cooperation], 8 January 2009, 3.

research conducted when they were adolescence. This was another cultural issue; Bobashev commented "what I learned from interactions with Americans you have to estimate yourself very high. You have to keep this feeling that you are very educated, very energetic…it's American style – it is not Russian style."[440] The other aspect on this issue was that most Former Soviet scientists spent their entire careers in one place. Bobashev had worked at Ioffe since 1963 and Bityurin at IVTAN since 1964.

During another interview Drs. Vladimir L. Bychkov, Igor I. Esakov, and Klimov, raised other issues in bringing the different scientific communities together. They pointed out that Americans never put money into basic research unless it led to specific results in terms of application or technology. They believe it had more to do with business practices rather than science. Bychkov stated that, "In Russia we have absolutely different situation. In Russia there is [sic] investigations, wide-range investigation, there are not only experimental, but they also have [to] support theoretical."[441]

The Russians make it a point to express their dissatisfaction for what the Air Force paid them for their work. Bychkov pointed out that, "Americans pay to their own scientist thirty-eight times more than us."[442] He went on to imply this inequality was intentional because "Russian scientists cannot reject or refuse because they don't have salary in their country."[443] What was beneficial about working with the US was, according to Klimov, the availability of very expensive diagnostic instrumentation. No one in Russia could afford the equipment. The philosophy under the Soviet system was to invest in fundamental science and apply the knowledge to a broad range of technologies, whereas the saw the opposite in American where application took priority which left basic science only for that single project. There needed to be more fundamental research in plasma because it made up 90 percent of the universe.[444]

Prominent historians trace this alien concept of "self-criticism" to various sources. Science demands criticism but what made a profound difference in western and Soviet

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[440] Bobashev interview, 2; also Kevin Kremeyer (7 February 2010) and Daniel Kelley (7 January 2010) interviews with author.
[441] Vladimir L. Bychkov, Igor I. Esakov, Anatoli I. Klimov, [US-FSU cooperation], 6 January 2009.
[442] Ibid., 24.
[443] Ibid.
[444] Ibid., p 30-31.

research is the method this process was applied. Lewis Feuer interpreted this technique as negative by pointing to the Trofim Lysenko affair. Lysenko professed that imposed agricultural characteristics like grafting would then emerge in the next generation plant rather than being based Mendelian genetic inheritance. Nikolai Vavilov, prominent botanist and geneticist, "criticized" Lysenko's weak scientific claims. Lysenko used his political ties to have Vavilov jailed in 1940 where he died in 1943. Feuer's explanation for the nefarious episode was that dialectical materialism's claim as laws applied to social issues and not scientific laws. The three dialectic laws were the systems behavior of interactive forces; emergence of new laws; and negation of negation. Anything related to bourgeoisie, capitalism, and even science, had to be overthrown. Natural evolutionary laws did not necessarily contradict a previous one. The Soviets imposed dialectic laws which constituted "the projection of one's social world or values a defining the nature of reality itself."[445] Feuer believed that this put philosophy over science and led to "disunity between theory and practice."[446] This became abundantly clear when the Former Soviet and American scientists came together. The Russians found bringing theoreticians and experimentalists together a novel idea.[447]

In 1950, Dimitri von Mohrenschildt examined *partiinost's* historical background beginning with the Soviet's tremendous 1942 manpower and geographic losses. He argues that the Communist Party relaxed Marxist-Leninist doctrinal oversight and activity to gain support for the war and "Holy Russia." This included dissolving the Comintern and restoring the Patriarchate. However, as Soviet victory became more and more apparent, the Party aggressively reinstituted the party mindedness. The author states that nowhere was this more acute then on the scholarly front where during the war many Soviet intellectuals had expressed friendship and Western culture admiration. This came at the Marxist-Leninist's expense and threatened their power. The term "cosmopolitan" became a derisive term for someone that admired the West and by doing so rejected one's own country; synonymous to treason.[448] This created a distinct problem because "In

[445] Lewis S. Feuer, "Dialectical Materialism and Soviet Science," *Philosophy of Science,* 16, o. 2, April 1949, 106, http://www.jstor.org/stable/185129, accessed 11/16/09.
[446] Ibid., 122.
[447] Sergey V. Bobashev interview with author, [US-FSU cooperation], 8 January 2009, 3; Vladimir L. Bychkov, Igor I. Esakov, Anatoli I. Klimov, [US-FSU cooperation], 6 January 2009.
[448] Dimitri von Mohrenschildt, "Postwar Party Line of the All-Union Communist Party of the USSR,"

science cosmopolitanism implies an erroneous assumption of the universal character of science."[449] The content supports John Turkevich's theme of a post-Stalinist scientific renaissance of sorts.

In August 1946, Andrei Zhdanov attacked several Leningrad periodicals and the next year the Comintern was reinstated. The Party then was not averse to using world events to circumscribe its fundamental theories. Zhdanov found his source for the attack in Lenin's "Development is the 'struggle' of opposites." [450] Lenin argued that:

> Progress is achieved through the struggle of opposites; in a class-divided society, the struggle is between classes, but in Socialist society, such as the Soviet Union, the struggle is between the old and the new, and the form it takes is found in the process of criticism and self-criticism."[451]

The Party organized this "militant" outlook around the term "partiinost." [452] The campaign aimed at the press, periodicals, radio, theater, art, and literature. It aimed at creating ways to restore a Soviet consciousness. All intellectuals came under scrutiny and susceptible to charges of "cosmopolitanism" because they purported a "universal" character meaning distinctly anti-Soviet. It implied that any successful venture had more to do with socialism, rather than individual success.[453]

In 2006, Jonathan Coopersmith wrote a retrospect regarding the accuracy of our pre-glasnost Soviet science and technology understanding. He blames what he terms the "imperial and imperious" Academy of Sciences for setting itself apart from industry and universities thereby exacerbating the Soviet Union's "glaring" technological faults. Soviet engineers emerged with very narrow training in a "risk averse" society.[454]

There was historical precedence in this retrenchment against western influence. The 1825 Decembrist Revolt was organized by military officers who fought to the gates of Paris during the Napoleonic Wars. During WWII, Soviets fought their deep into

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Russian Review, July 1950, 176.

[449] Ibid.

[450] Josef V. Stalin, "Dialectical and Historical Materialism," September 1938, http://www.marxists.org/reference/archive/stalin/works/1938/09.htm, accessed 3/11/12,.

[451] Dimitri von Mohernschildt, "Postwar Party Line of the All-Union Communist Party of the USSR," *Russian Review*, 9, no. 3 (July, 1950): 175, http://www.jstor.org/stable/125761, accessed 3/26/10.

[452] Ibid., 174.

[453] Ibid., 176.

[454] Jonathan Coopersmith, "The Dog That Did Not Bark During the Night: The 'Normalcy' of Russian, Soviet, and Post-Soviet Science and Technology Studies," *Technology and Culture*, 47, no. 3, (2006): 631.

Central Europe and the backwardness of their own country became evident. This left Russia and the Soviet Union with the problem of "how can societies catch up technologically and industrially with the West without being contaminated ideologically or losing their economic and political independence?"[455]

David Joravsky,s 1955 "Soviet Views on the History of Science" provides an excellent background on the post-Revolution period leading up to Lysenko's emergence with the remark that in all the influences regarding Soviet science, that above all, one must consider the specific views of Marx, Engels, Lenin, and Stalin.[456] These writings provided the basis of Lenin's term "*partiinost*", party spirit or party mindedness. The other element Joravsky presents is Russian backwardness and its greatness. The former he characterizes as xenophobic and exacerbated during World War II by comparisons to its western allies.

David Joravsky calls this "vulgar sociology."[457] Partiinost's demand for unlimited energy, work, enthusiasm, and pride in Russian history harks back to pan-Slavism and an inferior sense when compared to the West. However science depends on international transfer of information and ideas. Limiting science to Marxist-Leninist laws and self-criticism only within the Soviet Union only made the former incompatible with the latter.[458] The internal struggle and self-hatred should promote self-improvement.[459] The Party passes on the ideology to the managers and they to the workers who have displayed their historical tsarist-peasant animosity back in substandard technological achievements. Joravsky's emphasis on Russia's historical inferiority complex make sense because in despite Stalin's death self-criticism lived on.

A few dissident Soviet scientists authored critiques; Zhores A. Medvedev is one such notable writer. In *The Rise and Fall of T. D. Lysenko* (1971): he blames Stalin's "cult of personality" for destroying biology, agronomy, and scientists over ideology and its resultant pseudoscience. Science, according to the author, is fertile ground for such fakeries. He echoes a Popper interpretation that by their nature, the majority of

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[455] Ibid., 631.
[456] David Joravsky, "Soviet Views on the History of Science," *Isis*, 46, no. 1 (March 1955): 3-13, http://www.jstor/.org/stable/226819, accessed 3/26/10.
[457] Ibid., 4.
[458] Ibid., 13.
[459] David Joravsky, "The Stalinist Mentality and the Higher Learning," Slavic Review, 42, no. 4 (Winter 1983): 580, http://www.jstor/.org/stable/2497369, accessed 11/16/09.

hypotheses must be incorrect because they are the lifeblood of scientific cognition. The scientific intellectual spectrum ranges from genius to pathological. On rare occasions, other factors lead to disastrous results. He lists contributing reasons as the Soviets propagandistic war on a "bourgeois" intellectualism, agricultural problems, politics, isolation from international contacts, an overly centralized administrative body.

Peter Kneen wrote on how partiinost functioned in science and technology. The Communist Party of the Soviet Union consisted of 150,000 apparatchiks, or functionaries, attached to party committees at various levels. Then there were approximately 15 million members throughout the population. Placed primarily in production, they exercised direct Party influence on the workers by establishing production level, job security, and promotions. Partiinost required scientists to present political lectures, write philosophical tracts, and engage in non-scientific communal tasks as a sign of their party spirit. The system worked best in heavily planned process with clearly defined outcomes, but not well in science where results less readily apparent to apparatchiks. According to Kneen, this created a problem for the Party because it required "senior scientists who can combine scientific skills with acceptable philosophical knowledge and party commitment."[460]

Kneen later went on to address "Physics, Genetics and the Zhdanovshchina" focusing on the fact that Lysenko's victory over genetics came at the August 1948 after the Lenin All-Union Academy of Agricultural Sciences conference, but a similar planned physics meeting in 1949 had been cancelled. He argues that physics presented a far more mathematical topic requiring a higher level of education and therefore less vulnerable to political attack. Kneen acknowledges that there are different explanations in the physicists' importance to Stalin's atomic weapons program which subsequently caused the cancellation. Others have proposed the political, administrative skills of Sergei Vavilov, president of the Soviet Academy of Sciences (1945-1951) in preventing the same vicious attacks that doomed his geneticist brother Nikolai.[461]

According to Loren Graham, Soviet physicist Boris Hessen was one of the

[460] Peter Kneen, "Why Natural Scientist Are a Problem for the CPSU," British Journal of Political Science, 8, no. 2 (Apr, 1978): 186, http://www.jstor/.org/stable/193498, accessed 11/16/09.
[461] Alexei Kojevnikov, "President of Stalin's Academy: The Mask and Responsibility of Sergei Vavilov," Isis, 87, no. 1 (Mar, 1996): 18-50, http://www.jstor/.org/stable/235733, accessed 3/14/09.

internal-external approach's founders; unfortunately it also led to his imprisonment and death in 1938. Internal influences meant the issues centered strictly on science and technology points. External were the social, culture, political, economic, and multitudinous other things that indirectly impacted research. In fact, of the eight Soviet delegation members, only two survived Stalin's reign. Nikolai Bukharin and famous geneticist Nikolai Vavilov, the target of Lysenko's designs, perished. [462] At the time of the conference physics, relativity theories, and quantum mechanics, were under attack by Marxists claiming the science came from bourgeois, external sources. Einstein had used Ernst Mach's work to build his theory, but Lenin had attacked Mach in *Materialism and Empiriocriticism* (1927). Quantum mechanics' statistical solutions cast doubt on dialectical materialism's universal doctrine and Einstein mass-energy conversion formulation similarly undermined the Marxists claim to Newtonian certainty of matter itself. Graham points out a certain irony in Hessen's portrayal of Newton's science emerging in 17th century capitalistic England, with all its bourgeois devices and that the Marxist's assumptions relied on Newtonian physics, which of course they overlooked.[463] Hessen hoped that showing the context had nothing to do with the content; something that Marxism found intolerable and heretical.

Aleksei Kozhevnikov (Kojevnikov) provided fresh insight into the Russian-Soviet Union's history of science. A graduated of Moscow University, he immigrated to Canada to assume an academic position after the USSR's demise. In an article regarding Piotr Kapitza and Stalin, he describes the hostility Kapitza faced after a 13-year stint at Cavendish Laboratory under Rutherford. State NVKD agents approached him as a stranger and a potential enemy and he felt surrounded by hostility and suspicion. During the scrutiny, he wrote that, "During great historical moments there are always victims, such is life…."[464] He notes that Soviet leadership put enormous pressure on scientists and engineer in the 1930s. The major research institutes belonged to "narkomat," (NKTP) ministry of heavy industry. Scientists had to convince the NKTP to fund basic versus applied science projects. In addition, since production centered on government

[462] Loren R. Graham, "The Socio-political Roots of Boris Hessen: Soviet Marxism and the History of Science," *Social Studies of Science*, 15, no. 4 (Nov., 1985): 708 , http://www.jstor.org/stable/285401, accessed 11/16/09,.
[463] Ibid., 171.
[464] Ibid., 140.

projects, any novel science competed for technology support. The easiest way to obtain experiment devices was to connect it to a military project which meant immediate fulfillment.

Kojevnikov's explanation for Lysenkoism takes a very different track than post-glasnost science history. He argues that what looked chaotic to outsiders were rather the outcome of Communist games of *diskussiia* and *kritika i samokritika* (disputation; criticism and self-criticism) constituting interparty democracy. On the importance of the process, he quotes a discussion between Joseph Stalin and Maxim Gorky in 1930: "We cannot do without self-criticism, Aleksei Maksimovich. Without it, stagnation, corruption of the *apparat*, and an increase of bureaucratization would be inevitable."[465] These public rules focused on behavior rather than content which he states were not predetermined and led to different outcomes in different professions. First and foremost, the rules decreed that the person being criticized could not use a defensive tone. Public self-promotion became a moral sin with the assumption that those on high would recognize and promote the right persons. Citing anthropology, the action constituted a ritual of Stalinist society. A *diskussiia* allowed discussions on theoretical political matters with temporary, public disagreement, but once concluded no other disagreements were allowed. *Kritika i samokritika*, on the other hand, usually dealt with personal rather than theory issues. The rite demanded subordinating individual view to those of the collective. The Party used it for purging and accusing internal enemies. Kojevnikov points out the method's cultural power in the act of confessions from even those facing death while the whole time professing innocence in letters to Stalin. What started as a means to control Party members was then imposed on academia to solve disputes within disciplines led to abuses such as Lysenko, but the outcomes depended heavily on how one play the games. Those that excelled in the play had to master the art of recognizing "where the ritual part ended and the improvisation began."[466]

Kojevnikov admired Paul Forman and his cultural approach to history. In describing how culture explains science, I would begin with the divergent paths of Thomas S. Kuhn and

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[465] Alexei Kojevnikov, "Rituals of Stalinist Culture at Work: Science and the Games of Interparty Democracy circa 1948," Russian Review, 57, no. 1 (Jan., 1998): 25, http://www.jstor/.org /stable/131690, accessed 3/14/09.

[466] Alexei Kojevnikov, "President of Stalin's Academy: The Mask and Responsibility of Sergei Vavilov," Isis, 57, no. 1 (Mar., 1986): 25, http://www.jstor/.org /stable/235733, accessed 3/14/09.

Paul Forman. They, along with John L. Heilbron and Lini Allen, coauthored *Sources for History of Quantum Physics* (1967). The project emerged in the late 1950s from physicists' discussions concerning the urgent need to preserve memories and documents regarding the origins of quantum mechanics. The American Physical Society and the American Philosophical Society organized a committee to address the need and, not surprisingly appointed Kuhn director.

Forman wrote "The Doublet Riddle and Atomic Physics circa 1924" showing deference to Kuhn's classic *Structure of Scientific Revolutions* by using terms such as dilemma, schisms, and schools. These terms approximate Kuhn's descriptions of scientists' allegiance to a particular theory, the appearance of anomalies, and subsequent group fracture. However, Forman's 1973 often-cited "Scientific Internationalism and the Weimar Physicists" displayed a distinct shift from scientists in general to science and its cultural influence. Kuhn only mentions cultural issues tangentially in his postscript to the original 1962 version as another barrier to scientific communications while maintaining his inclusive "paradigm" focus. While not minimizing the problem, he simply restates the importance of mutually agree upon definitions. He does however, acknowledge that, "To translate a theory or worldview into one's own language is not to make it one's own. For that one must go native, discover that one is thinking and working in not simply translating out of, a language that was previously foreign."[467]

Forman's 1973 "Scientific Internationalism and the Weimar Physicists" article describes "A republic of science---an activity and body of knowledge which transcends national boundaries and loyalties---with the most acute consciousness of national origin or affiliation of individual scientist and scientific achievements."[468] The "republic of science" is international or a "supranational agreement on the ground rules."[469] This is especially important in physics where the large data quantities from diverse geographical locations, divisions of labor, and profit sharing become necessary.[470] He points out that Weimar used its world renowned scientists, Albert Einstein and Max Plank, as a form of *Kulturpolitik* and *Kulturpropoganda* because after losing World War I, disarmament, and

[467] Thomas Kuhn, *The Structure of Scientific Revolutions*, (Chicago, 1973), 204.
[468] Paul Forman, "Scientific Internationalism and the Weimar Physicists," *Isis*, 64, no. 2, June 1973, 153.
[469] Ibid., 154.
[470] Ibid.

world condemnation, science was one thing that the world still admired.

However, the scientist's claim to high professional standings did not make them adverse political, distinctly national, activity. Forman goes on to highlight the German-Soviet scientific cooperation based on the country's rapprochement after the German's eastern land grab while the Soviet Union lay prostrate during its civil war. However, the German scientists did not allow their professed "internationalism" to interfere with political action when they threatened to boycott the Russian Academy of Sciences' two hundredth anniversary celebration over Moscow trials of alleged German terrorists. In the end, Forman concludes, that despite their "international" apolitical claim, national culture pressure always won out. He uses Einstein as the example and Weimar scientific support.

Slava Gerovitch, who received his Ph.D. from the Russian Academy of Sciences in 1992, writes similarly by utilizing an internal-external science and technology perspective. Gerovitch begins with one of the first attempts at an internal-external Soviet science interpretation by Boris Hessen, a Soviet physicist, at a the 1931 London Second International Congress of the History of Science conference in which he argued that Isaac Newton's scientific activity was the result of social-economic needs of England at the time. Unfortunately, Hessen's paper suggested a clear-cut divide between society and science and he paid dearly for the crime. Gerovitch defines the Soviet version of externalism as scientist "judged by the most up-to-date party line."[471]

Why Whither

How important did USAF scientists believe the Russians work? In December 2000, the USAF Scientific Advisory Board provided such assessment in "Why and Whither Hypersonics Research in the US Air Force."[472] The board stated that to "ensure that the usual unbridled enthusiasm the SAB has for new technology did not overwhelm the results, the study included its own red team to identify and assess alternatives."[473] Their task was to analyze hypersonic systems in terms of operational need. Quite simply,

[471] Slava Gerovitch, "Perestroika of the History of Technology and Science in the USSR: Changes in the Discourse," *Technology and Culture*, 37, no. 1 (Jan., 1996): 119, http://www.jstor.org/stable/3107203, accessed 3/23/10.

[472] US Air Force Scientific Advisory Board, "Why and Whither Hypersonics Research in the US Air Force," USAF SAB-TR-00-03, December 2000.

[473] Ibid., v.

this meant looking specifically at what the capability delivered to combat forces in the field. Not surprisingly, they determined if they even wanted such technology. The report pointed out that at Mach 5-15, 1000-nautical mile range effectiveness was limited to a 13-minute window; if more than 20 minutes was acceptable subsonic or supersonic were acceptable; if 7 minutes or less were required, a system's speed needed to be greater than Mach 15.[474]

The report made it abundantly clear that their advocacy was based on the Russian plasma research. The SAB wrote:

> the technology base for plasma applications by aerospace vehicles is the most advanced in Russia but is also being pursued in Europe and Japan. The US effort is judges to be significantly behind the Russian effort in many critical areas.[475]

The report did not use the term "heat barrier" but did state that the highest speed possible was determined by heating and material limitations. Prior to the Former Soviet Union scientist's participation, the Air Force focused almost exclusively on propulsion. In fact, the SAB pointed out that foreign influence, beginning with Sanger's first hypersonic vehicle designs, had been "near-constant" and the Russians had flight-tested the technology before 1992 and continued ever since then.[476] Some sort of revolutionary thermal protective system was needed and the plasma solution offered the hope to continue the program. It seemed that the entire document was written about the Russian AYAKS solution with diagrams and many pages discussing the concept. They announce that Air Force Office of Science Research and Air Force Research Laboratory (former Wright Laboratory)

> has been focusing on technologies associated with the Russian AYAKS concept. These technologies include WIGs for drag reduction and flow control around a hypersonic aircraft. AFOSR has been spending $2 million to $5 million per year on these technologies.[477]

Critics say the science is overstated, misstated, lies, or "plasma magic." It is not my intent to take sides, but the fact remains that the "heat barrier" up until the Russian's work emerged after the Soviet Union's demise continued to squash any solution and

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474 Ibid.
475 Ibid., viii.
476 Ibid.,11.
477 Ibid., 29.

perhaps hope is all that the AYAKS proposal provided. The Russians continued the controversial claim in research published in 2001 allowing that only "partially confirmed" results dictated that continuous investigations were needed. They continued to argue that the new effect could not be explained by heat only."[478]

In January 1966, the American Institute of Aeronautics and Astronautics (AIAA) published an editorial titled "Whence and Whither" making oblique reference to the Aero versus Astro separation occurring because of space activities. After observing the huge increase in rocket-lift capability, they asked, "Are we at the threshold of a new period whose emphasis will be in the *utilization* of the remarkable 'state of the art' we have helped achieve?"[479] In other words, now that we have entered space are we to simply build bigger, more powerful rockets? What about the scientific aspect of our profession? Indeed in America the aeronautical science took a twenty-year hiatus while technology ran its course. When Reagan announced plans for a hypersonic aerospace plane the technology could not met requirements and science came to the forefront. During the period of rest, on the other hand, the Soviets had made great strides and stepped in to provide their expertise.

Exergy

Some Air Force scientists accepted the Russians plasma aerodynamic claims and invested in further research while others began to consider a new design concept based on the second law of thermodynamics called exergy. This represented the first glimmer that aerodynamics had recognized the heat barrier and that it meant merging with an area that had diverted into spacecraft, but that it now offered a means to fly the next hypersonic aircraft. Edward T. Curran, Wright Laboratory, first suggested an overall exergy approach to hypersonic vehicles. Although the research focused on propulsion he wrote "an Exergy based approach can be used to address total vehicle thermodynamics."[480]

A 1992 AIAA paper titled "Thermal Management of Air-Breathing Propulsion Systems" advanced the idea that "air-breathing propulsion systems for high-speed flight can benefit from the integration and analysis of all the heat sources and sinks throughout

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[478] V.M. Batenin, "EM Advanced Flow/Flight Control," AIAA 2001-0489, (11 January 2001): 13.
[479] AIAA, "AIAA Journal – Whence and Whither," AIAA, 4, No 1,(January 1966): 1.
[480] Edward T. Curran, "The Potential and Practicality of High Speed Combined Cycle Engines," AGARD-CP-479, (June 1999): k-6.

the vehicle."[481] Where conventional designs relied on fuel driven coolant technology, exergy would recover heat from hot surfaces using the fuel as a heat sink for thermal cooling devices and save fuel consumption and weight. According to the article, the exergy method entailed the overall vehicle basic data compilation and system evaluation. Not explicitly stated, the temperatures changed the air flow into plasma flow and this was something never done before in aircraft design. While the paper focused on propulsion, it opened the door to plasma aerodynamics.

Another paper given at the same conference, expressed where the majority of scientists stood regarding the heat barrier. The author points to radiating ablation materials that had already been used on ICBM nose cones and the Mercury, Gemini, and Apollo manned spacecraft programs. He calls for resorting to reentry heat solutions with some updates, but the proposal was not anything like the exergy proposal. To make a point, he mentioned water as an ablator, heat protective surface designed to vaporize or erode, as an example. This meant water had a low vaporization temperature, but contained a lot of energy. In this case, a fluid acts as heat protection versus a heat-resistant material solution.[482]

In 1996, David Riggins, Professor of Mechanical and Aerospace Engineering, Missouri University, wrote a paper on the need to use the laws of thermodynamics for analyzing engine thrust, irreversibility, and combustion. He invoked Arthur Eddington's Arrow of Time concept that when it comes to energy, the process one way and not, as in physics, reversible. The concept stayed with discussions on the engine, but the idea of application to the issue as a system by a aviation scientist showed the concept making some headway.[483]

To explain the phenomenon an experiment would show that while the water remained relatively cool, the heat would be in the steam it created and not the surface the water lay on Take a large glass beaker, fill it three-quarters full, and heat to cooking temperature. The put your hand in it – with your other hand dial 911 and wait for the ambulance. However, it you apply water to the hand before you dip in the oil, the

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[481] J.E. Ahern, "Thermal Management of Air-Breathing Propulsion Systems," AIAA 92-0514, (1992):1.
[482] Jose A Camberos and Leonard Roberts, "Engineering Analysis of Internal Ablation for the Thermal Control of Aerospace Vehicles," AIAA 92-0853, (1992): 7.
[483] David Riggins, "Optimization for Maximum Performance High-Speed Engines," AIAA 96-4518 (Jun., 1996): 1-10.

water/steam combination holds the high temperature away from skin. . In other words, you create two boundary layers: water next to skin and water next to oil. This is why water is a good ablator. It provides a thermal cushion until it boils away. It is the same basic principle in exergy and into plasma physics. The engineer can use the bow shockwave standoff with energy collected in the heat produced around the vehicle. This takes the conventional aerodynamicist out of air and its normal constituents into plasma airflow.

Exergy principles came with implications for more than aircrafts design. They could also be applied to economics and destruction of the environment. Macroeconomics evaluated the environmental damage and microeconomics would establish where taxes would help in minimizing the losses by taxing specific areas. Designers recognized that natural resources were finite, but energy demands continued to rise. Those demands not only used resources, but the work to create energy created work, which according to thermodynamics, caused heat to dissipate adding to global warming. The first law does not show the irreversible process.[484] These tiny heat additions, by millions all over the globe are the Butterfly principle in action.

In 1999, an AIAA article written about computer modeling spoke to the synergistic effort to apply electrically conducting and flow control fields on that brought together aerodynamics, electromagnetic, chemical physics, and quantum physics to describe the ionized gas flow. The article cited Gennady Mishin and the AJAX proposal along with the Resler-Sears magneto-hydrodynamic proposal. The writers emphasized the important role of computers in bringing the different disciplines together.[485] This report displayed the maturation of the exergy concept.

The next year Dr. David J. Moorhouse, AFRL, wrote "The Vision and Need for Energy-Based Design Methods" which was the first research and statement connecting "energy-based methods such as exergy and thermo-economics."[486] He acknowledges the concept's debt to stationary systems such as refrigeration and power plants and that the

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484 Mei Gong and Goran Wall, "On Exergetics, Economics and Optimization of Technical Processed to Meet Environmental Conditions," TAIES (Jun., 1997): 453-460, accessed 11/16/10, http://www.exergy.se/ftp/execopt.pdf.
485 J.S. Shang, J.A. Camberos, M.D. White, "Advances in Time-Domain Computational Electromagnetics," AIAA 99-3731, (July 1999): 1-10.
486 David J. Moorhouse, "The Vision and Need for Energy-Based Design Methods," AIAA 2000-4850, 8 (September 2000): 1.

idea of applying the same method to air vehicles was relatively new. The challenge came in merging individual aerospace technical solutions with physic-based modeling.[487]

In a later article, Moorhouse made specific reference to exergy and hypersonic aircraft design. He argued that conventional approaches had failed because their singular sub-system solutions had reached their evolutionarily limitations and that the "plasma-based hypersonic vehicle" demanded a compressive thermodynamics approach.[488]

Conclusions

Science and technology are separate disciplines, but closely related. While the former examines nature by extrapolating laws and expressing them in mathematic computations, the latter uses mathematics to design and construct material things that are easier to see and comprehend. As civilizations progressed basic scientific research and applied sciences became more and more sophisticated and expensive. At the beginning of the Scientific Revolution individuals relied on their own knowledge, ingenuity, and pocketbooks searching for rational explanations of nature's secrets. These investigators were often very religious and trained as clerics, to begin with. The Industrial Revolution made these researchers and builders more and more necessary and created institutions dedicated to their non-religious training. By the 19th Century universities began offering science and technology degrees.

During the First World War, basic and applied science joined producing chemical and air warfare along with many other applications. By World War Two, they were indispensible and remain that way today. Germany's Ludwig Prandtl's work provided the first scientific approach to early 20th Century aerodynamics. Prior to his use of fluid dynamics to comprehend airflow, aircraft builders relied on experience and guesswork to conquer flight. However, as aircraft became faster and more expensive, this method became less favorable. Rocketry opened up and entirely new aerodynamic field and stretched Prandtl's work to its limits. Applications up to that time relied on the properties of air; however, at hypersonic speeds common to rockets, the air became energized, separated, and became prohibitively hot. As a result, air and rocket aerodynamics split. Aircraft, except for a few experimental models, remained within Prandtl's air-based

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[487] Ibid., 5.

[488] David J. Moorhouse and Charles F. Suchomel, "Exergy Methods Applied to the Hypersonic Vehicle Challenge," AIAA 2001-3063, (June 2001): 1.

scientific realm while rocketry relied on ablative, or material that melted to shed the incredible heat generated to escape and reenter earth's gravity. The mechanism also relies on a relatively short transit periods, but cannot sustain prolonged hypersonic flight. As a result, most rocket launching technology is destroyed in this process. A hypersonic aerospace plane, on the other hand, like a conventional aircraft would fly its missions, land, refuel, and launch on another flight. This application of science once reserved for space vehicles on true aerospace planes is the next aerospace revolution. Rockets take months to prepare, are very expensive, and sadly only good for one-time flights. During the Cold War, both the US and the USSR made huge strides into space and base-based technology. Manned and unmanned satellites orbit earth continuously. Both military and industry rely heavily on these devices.

The Soviet Union's dissolution opened up a scientific structure and research community to the world. Their previously heavy state-sponsorship work lost its financial support and was told to open themselves to outside customers. Former Soviet Union scientist threw open their previously closed, secret facilities to any and all visitors. For American scientists, the new openness and lack of state oversight was called "The Wild, Wild West." They discovered that the Russians had pursued hypersonic aerospace plane science and advanced beyond US capabilities. The US Air Force employed some Former Soviet Union researchers and continues the relationship today.

To understand the different US and Former Soviet Union scientific expertise one must ironically examine their respective cultural values. America's cultural values are closely tied to economic circumstances. Capitalism dictates productive forces generate commodities and afford a market for profits. Currency becomes a means to generate more production and that can create science, if and when needed, but primarily technology. Technology is something consumers can readily see, feel, or even hear and people are far more inclined to spend or invest their money on. Individuals and governments act similarly in this regard. An government aerospace plane investment carries well for most Americans who fly long distances and dread overseas travel. The question "what will it do for me" is much more difficult to answer when explanations come in differential equations, graphs, and probabilistic findings. The danger, however, is losing research expertise when it is needed.

Russia, then the Soviet Union developed a different science-technology cultural construct. Various authors argue that because of Russia's historic struggle between the Slavophiles, ultra-conservative, anti-modernization group against efforts started by Peter the Great to import western knowledge and education created a perpetual crisis between the educated, laypersons, and power holders. Others argue that when political repression threatened intellectuals, especially the French Enlightenment, they turned to subtle, opaque language and in the case of science to mathematics. While physicists could follow this path of residence, the wretched case of Trofim Lysenko and the death of notable geneticists to pseudo-scientific quackery gives chilling evidence the Soviet science was indeed different than many other nations.

On the other hand, this research is a case study in integrating thermodynamics into an existing science and technology field. Both US and Former Soviet Union experts had to integrate aerodynamics and plasma into plasma aerodynamics. It's no wonder, political and the non-scientists among us struggle with global warming. It's is a classic micro (individual humans) impact on global macro weather patterns. Each person's daily efforts are miniscule, but added up over centuries the warming trend could lead to self-extermination. It is far, far easier to justify technology expenditures over electrons and quarks basic science.

In addition to global warming, thermodynamics emerged in other disciplines and then into metaphor status. Evolutionists such as E.O. Wiley and Daniel R. Brooks applied Ilya Prigogine's research in nonequilibrium thermodynamics to examine progression in terms of organism origin and development, species mating and material bonds, and energy. Information and cohesion are necessary to sustain the species because decreasing either one lead to less energy in the system and stagnation or death of the system: "Evolution is an anamorphic or complexity generating process. If no change occurs in an information system, evolution is not possible."[489]

The article prompted an explanation by David J. Depew, University of Iowa, titled "Nonequilibrium and Evolution: A Philosophical Perspective" with a cautionary note that while Prigogine opened the way to exploring nonequilibrium's evolutionary

[489] E.O. Wiley and Daniel R. Brooks, "Victims of History – A Nonequilibrium Approach to Evolution," *Systematic Zoology*, 31, no. 1 (Mar., 1982): 12, http://www.jstor.org/stable/2413410, accessed 10/7/11.

implications, he did not offer up thermodynamics as a "rival casual and explanatory principle to it (Prigogine et. al., 1972)."[490] What Prigogine then Wiley and Brooks proposed was synthesizing biology and physics via thermodynamics. The Darwinian 'modern synthesis' evolved from question as to whether natural selection theory alone explained evolution. The synthesis added genetics which became known as Neo-Darwinism, but it relied on Newtonian equilibrium systems. Stephen Jay Gould spoke about Neo-Darwinism and the challenges he saw for the theory. The idea implied gradual change but as a paleontologist, Gould pointed to extinctions and their rapid change as one counterargument and the species genetic inability to achieve fitness. But hidden behind his argument were new discoveries in molecular biology and the less deterministic 'selective' results. Depew believed the advantage of Wiley and Brooks' proposal was that it increased randomness in the biological selection process and minimized any definitive intent in evolution.[491]

In a 1997 book review of Depew and Bruce Weber's *Darwinism Evolving: Systems Dynamics and the Genealogy of Natural Selection* (1994): Michael Ruse provided an update on molecular biology and evolution. Beginning with a confession that as someone "firmly in the grip of the Darwinian paradigm…"[492] he might not be the right person to review the book, he concedes their scientific acumen, but wishes they had focused more on that particular skill. What was a proposed linkage between thermodynamics and evolution had now changed to a definitive cause based on 'self organization'. When open systems open they exhibit non-linear behavior, but even in this state, they 'self organize'. It might take a high-powered computer to show this rather weak deterministic character, but it was there nevertheless. In physics, the nonequilibrium 'self organizing' plasma characteristic occurs when electrons separated

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490 David J. Depew, "Nonequilibrium Thermodynamics and Evolution: A Philosophical Perspective," Philosophica, 37, no. 1 (1986): 27, http://logica.ugent.be/philosophica/fulltexts/37-3.pdf, accessed 10/24/11.
491 Ibid.
492 Michael Ruse, "Darwinism Fleurit! Darwin et l'apres-Darwin: Une histoire de l-hypothese de selection naturelle by Jean Gayon: Darwinism Evolving: Systems Dynamics and Genealogy of Natural Selection by David J. Depew; Bruce H. Weber," *Isis*, 88, no. 1 (Mar., 1997): 116, http://www.jstor.org/stable/235828, accessed 3/21/12.

from atoms become an electromagnetic attractor for 1 billion other atoms in weakly ionized gas.[493]

In Prigogine's 1980 *From Being to Becoming*, he proposed philosophic language to examine the implications of his work as a chemist. Static in thermodynamics would represent 'being' and irreversibility would translate into 'becoming'. His stated goal was to examine the physics of being and the physics of becoming.[494] The self-organizing concept occurred in between the two scientific and philosophic poles meaning once a system opened, the microscopic elements became disrupted by global features such as the system's size, form, and boundary conditions. In social-philosophical-cultural language the phase was also termed context – what, besides the individual pieces, impact its behavior. In philosophy, this could also be called pragmatism in terms of accepting those ancillary forces to understand the chaotic, nonlinear behavior and the diffusion the system creates.

The thermodynamic metaphor made its way into several other disciplines through an elevation of interest in global warming. Historical data reveals earth's rising temperature beginning with the Industrial Revolution and continuing to this day. Receding glaciers, crop failures, desertification, extinctions, and powerful storms seem to prove the theory. In fact if ignored, the human species may be the first to cause its own disappearance. The science has become part of everyday conversation and its fundamental causes clear. People who deny the phenomenon cannot cite science for legitimacy. Recycling in homes often is the first place people encounter the process of changing behaviors. Earth is seen as a system and individual's can make changes, however miniscule, to improve prospects for a solution. If millions of discrete household participate the effect can make a difference.

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[493] Kevin Kremeyer interview by author, [US-FSU science cooperation], 12 February 2010.
[494] Ilya Prigogine, *From Being To Becoming,* (New York: W. H. Freeman and Company, 1980): 13.

APPENDIX A

DISCLAIMER

The views expressed in this dissertation are those of the author and do not reflect the official policy or position of the United States, Department of Defense, or the U.S. Government.

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BIOGRAPHICAL SKETCH

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