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Editor's Note

This issue of *Space & Defense* builds on our initiative to explore broader questions of political economy on the technological frontier of defense policy. The lead feature by Armin Krishnan, "Attack on the Brain: Neurowars and Neurowarfare," lays the groundwork for a new specialty field of defense studies. In the world of engineering and technology, advances in brain mapping, information science, and nanotechnology have prompted a convergence of traditional research programs in biology, chemistry, materials science, and electrical engineering. This synthesis creates a crisis in the sense that investments we make now might bring a rich harvest of new products that spur economic development, revolutionize health care, and play an important role in expanding the quotient of human happiness during the twenty-first century; at the same time, as in the prominent cases of nuclear, cyber, and space technologies, devices for mastering a new domain, in this case the collective mind of an army or its sponsoring society, could lead to catastrophic conflict. Krishnan argues we have already reached the point where many staple concepts from International Security—offense, defense, deterrence, civil-military relations, crisis, and war—are quite relevant to neurowarfare. He urges us to apply our strategic reasoning now and with great care if the international community as a whole is to successfully manage challenges and reap the benefits of expanding neuro-technology.

Our second and third features continue our series of articles on the significance of space for developing countries. The previous issue of *Space and Defense* included a discussion of Argentina space, remarking on the steadfastness of that country's technological effort to build indigenous launch capability in spite of dramatic swings across elections in ideology of political leadership as well as Argentina's economic fortunes. In this volume, Gills Vilar Lopes, "Brazil Space: Military Dependency and the Case of the Geostationary Satellite for Defense and Strategic Communications," is not so sanguine about the future of Brazil's space program while this rising power enters a period of political turbulence and stagnant economic growth. Lopes explores as a critical case Brazil's Geostationary Satellite for Defense and Strategic Communications (SGDC). For him, space becomes something of a political football as Brazil's civilian space agency (AEB) and its Ministry of Science and Technology (MCT) cannot muster the necessary fiscal or intellectual capacity to establish autonomy from Brazil space's Air Force (FAB) heritage. Certainly, military and civilian agencies must work together to move forward, but he notes that the "Strategic" qualifier of SGDC's satellite communications has as much to do with Brazil's national development as it does with strategic launchers for national defense. Brazil itself will survive current presidential scandals and eventually restore its growth in export revenues, but neither SGDC nor efforts to recover from the Alcântara launcher disaster of 2003 will amount to much until the government finds a way to reform its civil-military legacy on space.

Mónica Casalet's feature contribution takes us from Brazil to Latin America's other rising power, Mexico, in particular the fast growing, centrally located state of Querétaro, north of Mexico City. "Meeting Growth Challenges of Mexico Aerospace: The Queretaro Cluster" expertly dissects Mexico's effort at the regional level of analysis, working with Mexico's federal system of governance and drawing strength from high-level national support as well as city-based concentrations of talent. In a political context almost the obverse of Brazil's, Mexico's commercial sector seeks entry into the global aerospace market with only a very faint presence of home military demand for space products and services. At this time, Mexico's maturing democracy also wrestles with fast rising societal demand emerging from conditions of stark inequality (the "two Mexicos" thesis). Casalet argues that under sharp material constraints, institutional networking and soft connections among businesses, civil associations, multiple levels of government, and universities—anchored at the regional level—are far from epiphenomenal.

Indeed, they merit greater attention from analysts as a critical factor in international political economy & development, especially for multi-use industrial sectors on the frontier of knowledge & technology.

In addition to our peer-reviewed feature articles, readers of this issue will enjoy topical essays from the leadership of the Eisenhower Center at USAFA. Director Deron Jackson reviews a popular new primer on the international politics of space, *Crowded Orbits: Conflict and Cooperation in Space* (Columbia University Press, 2014), by Professor Clay Moltz of the Naval Postgraduate School, Monterey, California, and in the latest edition of Publisher's Corner, Ambassador Roger Harrison asks whether diplomats confronting today's challenges from rising powers can find positive inspiration for a SALT moment in space arms control.

Following our recent space panel at ISA-Atlanta, "Prospects for Peace on the Final Frontier," it is clear our journal, *Space & Defense*, is not alone calling for new thinking in anticipation of greater political and economic interaction, among both state and non-state actors, in increasingly crowded orbits. Professor Daniel Deudney, in Atlanta, conjured the term "planetary politics" to remind us of how moves made as far away as geostationary orbit, at an altitude of some 23,000 miles, can have large-scale political effects here on earth. Rather than politics in a new domain, Deudney conjured us to think in terms of a tightly-coupled, highly interactive system of global actors on the surface expanding their menu of political options out to geostationary range. In addition to inviting readers to correspond with us regarding controversies raised by our articles, we at *Space & Defense* renew our call for papers that refine our perspective on planetary politics. If our readers are working new submissions that address space arms control, commercial-military alliances for national security, hypersonics, missile defense, cyber deterrence, and preventive commercial-military regimes for cyber security, we encourage them to send their contributions for peer review to the Eisenhower Center for Space and Defense Studies, U.S. Air Force Academy.

Damon Coletta
USAFA
` April 2016

Attack on the Brain: Neurowars and Neurowarfare

Armin Krishnan

Is neurotechnology leading nation-states toward a new domain of war?

Neuroscience is on the verge of deciphering the human brain.[1] As a result, brains will become a part of the battlefield against which attacks will be directed.[2] As neuroscientist James Giordano argued: "the brain is the next battlespace."[3] It is foreseeable that this will have tremendous implications for warfare and could amount to a true military revolution in the sense of military historian Williamson Murray: it would completely change the characteristics of conflict, as well as transform state and society.[4]

Neuroscience will lead to the development of 'neuroweapons,' which can remotely manipulate mental states, emotions, perceptions, thinking, and behavior of adversaries. As argued by Vladimir Putin, "[s]uch high-tech weapons systems will be comparable in effect to nuclear weapons, but will be more acceptable in terms of political and military ideology."[5] In a coming age of neurowarfare traditional military conflict may no longer take place or may become ancillary to the goal of psychologically manipulating or subverting enemy leaders and even entire societies. States and other actors could be coerced with no resort to open violence and conflicts could be suppressed before they can ever break out. At the same time, neurotechnologies and sophisticated methods of psychological influencing could also be used offensively against enemy societies with the goal of "collapsing the enemy internally rather than physically destroying him."[6] In the worst case, neuroscience and neurotechnolgies (neuro S/T) could be abused for torture, genocide, and high-tech repression. The ethical implications of brain and mind manipulation are inescapable and would require a wider debate.

However, the purpose of this paper is to introduce the concept of neurowarfare in its two basic meanings: 1) the application of neuro S/T to warfare and security and 2) neurowarfare as war in 'neurospace', an emerging and distinctive domain of war, where combat may take place and victory may be achieved. The paper will therefore outline some of the neuro S/T applications relevant to war and conflict. Secondly it will sketch and define the new emerging domain of war. Finally, it is argued that a neurowarfare strategy is needed for coming to terms with issues relating to targeting, deterrence, and threshold to war, before neuroweapons are introduced.

MILITARY NEUROSCIENCE

Military brain and behavioral research goes back to at least the 1920s and dramatically expanded in the U.S. in the 1950s because of the desire to understand Communist brainwashing and to develop methods that surpassed those of the Communist mind programmers. The Artichoke/ MK ULTRA documents of the early 1950s to the early 1960s leave no doubt that the CIA and the U.S. military aimed for the hypnotic

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[1] Armin Krishnan is Assistant Professor for Security Studies, East Carolina University, Greenville, NC.
[2] Laura Sanders, "Brains May Be War's Battlegrounds," *Science News* 180 (2011): 14.
[3] Tim Requarth, "This Is Your Brain. This Is Your Brain as a Weapon," *Foreign Policy* (September/ October), http://foreignpolicy.com/2015/09/14/this-is-your-brain-this-is-your-brain-as-a-weapon-darpa-dual-use-neuroscience/ (accessed September 18, 2015).
[4] Williamson Murray, "Thinking about Revolutions in Military Affairs," *Joint Forces Quarterly* (Summer 1997): 71.
[5] Christopher Leake and Will Stewart, "Putin Targets Foes with 'Zombie' Gun Which Attacks Victim's Central Nervous System," *The Daily Mail*, March 31, 2012, http://www.dailymail.co.uk/news/article-2123415/Putin-targets-foes-zombie-gun-attack-victims-central-nervous-system.html (accessed September 8, 2015).
[6] William S. Lind, Keith Nightengale, John F. Schmitt, Joseph W. Sutton, and Gary I. Wilson, "The Changing Face of War: Into the Fourth Generation," *Marine Corps Gazette* 73 (1989): 23.

and physical control of enemy minds, both in the context of intelligence operations as well as in 'psychochemical' warfare operations directed against entire societies.[7] Although these efforts were apparently not particularly successful, there has been since 2001 in the aftermath of 9/11 a renewed interest by DARPA and other agencies to develop and leverage brain research for the national security sector. This was also encouraged by new brain imaging technology developed and perfected in the 1990s, such as fMRIs, that have given neuroscientists unprecedented insights into the processes occurring inside a living human brain.

Bioethicist Jonathan Moreno drew attention to the topic of military neuroscience through his 2006 book *Mind Wars*, which also discussed some of the related ethical issues.[8] Since then the DIA commissioned a National Research Council study on military applications of neuroscience research in 2008 and the U.S. Army commissioned another study on neuroscience opportunities for the Army in 2009.[9] This was followed by a Royal Society study on *Neuroscience, Conflict and Security* published in 2012.[10] These studies mostly highlighted potential contributions of neuro S/T to human enhancement, strategic intelligence, security and interrogation, and neuroscientific methods of influencing an adversary. In 2013 Special Operations Command (SOCOM) announced the creation of a *Center for Excellence in Operational Neuroscience* at Yale University, which did not go ahead because of the controversy over using neuroscience research for interrogation and the 'ethical risks' inherent to such research.[11]

However, it is mostly civilian academic and commercial research that is currently driving the advancement of neuroscience. President Obama announced the American BRAIN Initiative in April 2013 that aims to revolutionize our understanding of the brain. The President explained that it will be a long-term scientific effort comparable to the human genome project and that it could impact "the lives of not millions, but billions of people on this planet."[12] The plan is to spend $100 million dollars in federal money and $200 million dollars in private sector money on neuroscience research for ten years. The project will be led by the National Institutes of Health, the National Science Foundation, and DARPA in conjunction with private sector partners such as the Allen Institute for Brain Science, the Howard Hughes Medical Institute, the Kavli Foundation, and the Salk Institute for Biological Studies.[13] According to the White House:

> The BRAIN Initiative will accelerate the development and application of new technologies that will enable researchers to produce dynamic pictures of the brain that show how individual brain cells and complex neural circuits interact at the speed of thought. These technologies will open new doors to explore how the brain records, processes, uses, stores, and retrieves vast quantities of information, and shed light on the complex links

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[7] U.S. Congress, "Project MKULTRA, the CIA's Program of Research in Behavioral Modification," Joint Hearing Before the Select Committee on Intelligence and the Subcommittee on Health and Scientific Research of the Committee on Human Resources, United States Senate, Ninety-Fifth Congress, August 3, 1977, Appendices, pp. 65-171.
[8] Jonathan Moreno, *Mind Wars: Brain Research and National Defense* (New York: Dana Press, 2006).
[9] National Research Council, *Emerging Cognitive Neuroscience and Related Technologies* (Washington, DC: National Academies Press, 2008); National Research Council, *Opportunities in Neuroscience for Future Army Applications* (Washington, DC: National Academies Press, 2009).
[10]; Royal Society, *Brain Waves Module 3: Neuroscience, Conflict and Security* (London: The Royal Society, 2012).

[11] Roy Eidelson, "Neuroscience, Special Forces and Yale," *Counterpunch*, March 6, 2013, http://www.counterpunch.org/2013/03/06/neuroscience-special-forces-and-yale/ (accessed August 28, 2015).
[12] White House, "Fact Sheet: BRAIN Initiative," *Press Release*, April 2, 2013, https://www.whitehouse.gov/the-press-office/2013/04/02/fact-sheet-brain-initiative (accessed August 28, 2015).
[13] T.R. Insel, S.C. Landis, and F.S. Collins, "The BRAIN Initiative," *Science* 340 (2013): 687-688.

> between brain function and behavior.[14]

This neuroscience funding comes on top of the normal research funding in related disciplines and commercial research funded by major corporations in the health and IT/ communications sectors. The great importance of private sector research is indicated by the tremendous growth in neuroscience patents that are mostly filed by corporations. In 2010 alone 800 neurotechnology patents have been filed – a doubling of patents per year from the previous decade. Interestingly, most patents were filed by the marketing research company Nielsen (100) and by software giant Microsoft (89), which shows that neurotechnology has already gone beyond medical applications and is poised to proliferate across society.[15]

Similar efforts of 'unlocking the brain' are underway across the world. For example, the European Union has inaugurated a similar neuroscience research effort called the Human Brain Project (HBP) in October 2013. The EU pledged to spend €1 billion euros over ten years to "gain fundamental insights into what it means to be human, develop new treatments for brain diseases, and build revolutionary new Information and Communications Technologies (ICT)."[16] Canada has joined the race with an announcement of dedicating $100 million dollars over five years to brain research.[17] In 2014 Japan launched the Brain/ MINDS Initiative, which also seeks to map the brain.[18] Overall, it has been estimated that public and private sector neuro S/T investment is around $150 billion annually worldwide.[19] Most worryingly, it is projected that Asia and South America will outspend the United States and its western allies by 2020.[20] Neuro S/T could proliferate to nonstate actors, including criminal organizations, terrorist groups, and even individuals, and may result in novel security and criminal threats.[21]

What follows is an overview of some of the applications and technologies that have the greatest potential for usage in war and conflict. It is important to keep in mind that neuro S/T has numerous civilian applications, ranging from medical/ health applications to recreation and enhancement to name a few. The technology will spread quickly across societies and create like the Internet a new arena or battleground where conflict will take place. The *Royal Society* report suggested dividing military applications of neuro S/T into two primary types: performance enhancement and performance degradation, which will be used, here, as a basic structure.[22] Of course, all enhancement technologies can be in principle also used for degradation.

ENHANCEMENT TECHNOLOGIES

A major UK Ministry of Defence assessment of global trends speculated that "A range of technological enhancements have the potential to transform human identity by improving sensory perception, physical performance and perhaps even giving us the ability to control fear and other emotional

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[14] White House, "Fact Sheet."

[15] A. Griffin, "Patents for Technology to Read People's Minds Hugely Increasing," *The Independent*, May 8, 2015, http://www.independent.co.uk/life-style/gadgets-and-tech/news/patents-for-technology-to-read-peoples-minds-hugely-increasing-10236211.html (accessed August 28, 2015).

[16] Henry Markram, "The Human Brain Project: A Report to the European Commission," Human Brain Project, April 2012, https://www.humanbrainproject.eu/documents/10180/17648/TheHBPReport_LR.pdf/18e5747e-10af-4bec-9806-d03aead57655 (accessed August 28, 2015).

[17] "Ontario Leading Brain Research," Office of the Prime Minister, Press Release, March 5, 2013, http://news.ontario.ca/opo/en/2013/03/ontario-leading-brain-research.html (accessed December 12, 2014).

[18] Requart, "This Is Your Brain."

[19] Sarah Canna, "Leveraging Neuroscientific and Neurotechnological Developments with a Focus on Influence and Deterrence in a Networked World," Carnegie Endowment Neurodeterrence Workshop, October 18, 2013, http://carnegieendowment.org/files/U_NeuroDeterrence_Workshop_Approved_for_Public_Release_31Jan14v2.pdf (accessed November 6, 2014).

[20] Ibid.

[21] M. Goodman, *Future Crimes: Everything Is Connected, Everything Is Vulnerable and What We Can Do About It* (New York: DoubleDay, 2015), pp. 261-288.

[22] Royal Society, *Brainwaves Module 3*: III.

states."[23] In the future, military commanders may have the ability to monitor and control the mental states of their soldiers, who may be able through enhancements to perform well without rest for days, to manage their emotions under stress, and to respond faster and smarter to emerging threats. There are three basic approaches to enhancement that seem to be particularly promising: neuropharmacology, brain stimulation, and brain-computer interfaces. It seems a foregone conclusion that enhancement technologies would spread quickly beyond the military and across societies that emphasize competitiveness and individual achievement.

Neuropharmacology

Throughout history, militaries have drugged their soldiers to keep them happy, to master their fear, to keep them awake, and to make them better able to endure gruesome conditions. Most militaries used alcohol, caffeine, and nicotine, Yemeni and Somali tribesmen chewed khat, and Prussian soldiers were given cocaine in the late 19th century. The Nazis infamously put amphetamine under the brand name Pervitin into chocolate and handed them out to soldiers to make them fearless and more energetic, while Nazi leaders such as Hitler and Goering took amphetamines for better coping with the stress of decision-making in war.[24] The U.S. Air Force has handed out 'go pills' (e.g. Dexedrine) to pilots since World War II. The concept of military drug use for performance enhancement is therefore nothing new, but it has certainly become more controversial. In recent times there has been growing concern over the routine non-treatment medication of U.S. soldiers, which has already resulted in some tragic lapses of judgment, apart from the other obvious problems associated with the long-term use of pharmaceuticals such as addiction and permanent damage to the soldiers' health.[25]

The hope is that neuroscience will develop new drugs that are both far more effective and also safer than the ones that currently exist, which would also make the medication of soldiers with psychotropic drugs more acceptable. Neuroscientists have gained over the last decades an excellent understanding of brain chemistry, which has already led to the development of many new psychotropic drugs such as Prozac, first approved by the FDA in 1987. Researchers hope to not only cure depression, PTSD, and other mental disorders but to ultimately enhance mental capabilities through so-called nootropic drugs and special nutrition that can improve memory, cognitive functions, motivation, and attention.[26] Better computer models based on new methods of neuroimaging could enable researchers to better predict the effects of certain drugs on the brain. Greater precision of drug delivery to specific areas of the brain could also produce very precise psychological and behavioral effects. Nanotechnologies could deliver drugs across the blood-brain barrier and make drugs more effective.[27]

One particular cognitive enhancement drug that is currently being reviewed by several militaries around the world is modafinil. The drug has already been approved by the FDA for treating narcolepsy and sleep disorders (known under the brand name Provigil). What makes modafinil especially interesting for armed forces is its feature of improving alertness and wakefulness instead of merely suppressing tiredness.[28] Other drugs could reduce stress or anxiety and make it thereby also less likely that soldiers will suffer from PTSD at some later point. Roger Pitman from Harvard University uses the beta-blocker propranolol for suppressing the formation of painful memories of veterans.[29] Soldiers could be

[23] "Global Strategic Trends – Out to 2045," London, UK Ministry of Defence, 2014, p. 83.
[24] Mick Farren, *Speed-Speed-Speedfreak: A Fast History of Amphetamine* (Port Townsend, WA: Feral House, 2010), pp. 22-51.
[25] Kim Murphy, "A Fog of Drugs and War," *Los Angeles Times*, April 7, 2012, http://articles.latimes.com/2012/apr/07/nation/la-na-army-medication-20120408 (accessed December 29, 2014).
[26] Kenneth Ford and Clark Glymour, "The Enhanced Warfighter," *The Bulletin of Atomic Scientists* 1 (2014): 43-53.
[27] National Research Council, *Emerging Cognitive Neuroscience and Related Technologies*, p. 5.
[28] Richard Martin, "It's Wake-Up Time," *Wired* 11.11, November 2003, http://archive.wired.com/wired/archive/11.11/sleep_pr.html (accessed December 12, 2014).
[29] Moreno, *Mind Wars*, p. 152.

medicated through implanted chips that release a variety of drugs directly into the brain and the drug release could be activated in response to a measured brain state or through a wireless remote signal. A Massachusetts company has already patented such a drug release chip that can be inserted through a tiny whole in the skull via a syringe.[30]

Brain Stimulation

The idea of electrical brain stimulation for therapeutic purposes is also not new. Medical doctors and psychiatrists have used the electrical stimulation of the brain for treating mental illnesses since the 18th century, with electrotherapy becoming popular in psychiatry in the late 19th century.[31] The modern electroconvulsive therapy, in which an electrical current is applied to the brain through electrodes, has been widely used since the 1940s and 1950s. Despite its frequent portrayal as a cruel form of treatment in popular culture, the American Psychiatric Association considers it safe and effective for treating major depression, schizophrenia, and bipolar disorders.[32] Since the early 1980s psychiatrists have developed newer methods for electrically stimulating the brain.

The Transcranial Magnetic Stimulation (TMS) method applies strong electromagnetic fields of thousands of volts through a helmet-like device above the brain to activate specific brain regions. TMS has shown promise in terms of treating depression and other mental disorders, but there are still some concerns for the safety of the treatment.[33] TMS might improve cognitive functions, alleviate pain, and reduce the need for sleep. TMS has been demonstrated to enable external control of a person's hand movements by stimulating the motor cortex and to enable the transmission of simple information encoded in Morse code directly into the brain.[34] The downside of TMS is that it requires a large coil and power source, which are difficult to miniaturize and to make portable. TMS can also not reach deeper areas of the brain and may therefore only have some limited medical applications.

Other brain stimulation methods include transcranial Direct Current Stimulation (tDCS) and Transcranial Pulsed Ultrasound Stimulation: both might be suitable for integration into a soldier's combat helmet and are therefore of particular interest to the military. tDCS applies a weak current through electrodes to the scalp, which has shown to significantly increase concentration and cognitive capabilities in test subjects.[35] The U.S. Air Force has already tested "external stimulant technology to enable the airman to maintain focus on aerospace tasks and to receive and process greater amounts of operationally relevant information" and has found that "it can help pilots better pick out targets from radar images."[36]

Researchers from Arizona State University are already working on a Transcranial Pulsed Ultrasound device that can be fitted into a helmet and that could be used for controlling the mental

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[30] Rob Matheson, "Deal Reached to Commercialize Microchip Drug-Delivery Implant," *Tech Swarm*, June 29, 2015, http://www.techswarm.com/2015/06/deal-reached-to-commercialize-microchip.html (accessed August 28, 2015).

[31] Adam Keiper, "The New Age of Neuroelectrics," *The New Atlantis*, 2006 (Winter): 6.

[32] Robert H. Blank, *Intervention in the Brain: Politics, Policy, and Ethics* (Cambridge, MA: MIT Press), p. 27.

[33] Ibid.: 30.

[34] R. Rao, A. Stocco, M. Bryan, D. Sarma, T.M. Youngquist, J. Wu and C.S. Prat, "A Direct Brain-to-Brain Interface in Humans," *PLOS One* 10.137 (2014); C. Grau, R. Ginhoux, A. Riera, T.L. Nguyen, H. Chauvat, M. Berg, J.L. Amengual, A. Pascual-Leone and G. Ruffini, "Conscious Brain-to-Brain Communication in Humans Using Non-Invasive Technologies," *PLOS One* 10.1371 (2014).

[35] Gary E. Marchant and Lyn M. Gaudet, "Neuroscience, National Security, and the Reverse Dual-Use Dilemma," in James Giordano, *Neurotechnology in National Security and Defense* (Boca Raton, FL: CRC Press 2014), p. 172.

[36] Noah Shachtman, "Air Force Wants Neuroweapons to Overwhelm Enemy Minds," *Wired Blog*, November 2, 2010, http://www.wired.com/2010/11/air-force-looks-to-artificially-overwhelm-enemy-cognitive-capabilities/ (accessed December 29, 2014); "Brain Hacking Is Having Incredible Effects and It Is Just Getting Started," *Business Insider*, August 16, 2014, https://www.yahoo.com/tech/brain-hacking-is-having-incredible-effects-and-its-94844111639.html (accessed December 29, 2014).

states of soldiers, boosting alertness, and relieving pain from injuries.[37] The pulsed ultrasound would be also able to reach deeper regions of the brain. Brain stimulation methods could have numerous benefits in terms of treatment and enhancement for people across society, and the technology could spread very quickly as indicated by the great commercial success of a tDCS device called Foc.us that is being marketed as a 'gaming device.'[38]

Brain-Computer Interfaces

The ultimate goal in the development of neural devices is to build a brain-computer interface that enables a person to receive information from a computer or device, as well as transmit information from the brain to a computer either as a computer input device or for controlling machinery. Primitive BCIs already exist. They come in two varieties: invasive BCIs that require implanting an electrode or chip into the brain and non-invasive BCIs that rely on measurements taken from outside the head.

The great pioneer of BCIs was Yale scientist Jose Delgado, who implanted animals and also some humans with a device he called 'stimoceiver' in the late 1960s. The stimoceiver enabled Delgado to very reliably trigger behaviors bypassing conscious decision-making by electrically stimulating a particular area of the brain, although he admitted that the method was generally incapable of programming new behaviors.[39] Of course, invasive methods as used by Delgado are ethically highly controversial: they could permanently affect human personality and require medically risky procedures. For this reason invasive BCIs can currently only be considered for purely therapeutical purposes that treat an existing medical condition. For example, currently under development by DARPA is Deep Brain Stimulation (DBS) based on implanted microchips that function as pacemakers for the brain of Parkinson's disease patients and for individuals suffering from PTSD. About 100,000 patients have up to now received DBS implants, and DARPA has recently made $70 million dollars available for further research into DBS.[40] Another example is neuroprosthetics, in particular those implants that restore lost sensory abilities such as cochlea and retinal implants or that enable neural control over robotic prostheses.

The current focus of BCI research is on non-invasive BCIs that are small, transportable, and low-cost. In particular, two approaches seem most promising in this respect: Functional Near-Infrared Spectroscopy (FNIRS), which measures changes in brain tissue associated with neuronal activity, and Electroencephalography (EEG), which measures fluctuations of voltage on the scalp. EEGs are more popular with researchers, who have used them in a variety of ways. It has already been demonstrated that equipped with an EEG a paralyzed person can move a cursor on a screen by simply imagining the movement beforehand.[41] For example, a monkey could operate a robotic arm through a BCI to get food.[42] There are many applications for this technology. Major IT companies such as Google and Intel are working on BCIs as new computer input devices, making mouse and keyboard obsolete as early as

[37] Clay Dillow, "DARPA Wants to Install Ultrasound Mind Control Devices in Soldiers' Helmets," *Popular Science*, September 9, 2010, http://www.popsci.com/technology/article/2010-09/darpa-wants-mind-control-keep-soldiers-sharp-smart-and-safe (accessed November 6, 2014).

[38] Kate Murphy, "Jump-Starter Kits for the Mind," *The New York Times*, October 28, 2013, http://www.nytimes.com/2013/10/29/science/jump-starter-kits-for-the-mind.html?_r=0 (accessed December 12, 2014).

[39] This is described in his book: Jose Delgado, *Physical Control of the Mind* (New York: Harper & Row Publishers, 1969).

[40] James Gorman, "Agency Initiative Will Focus on Advancing Deep Brain Stimulation," *The New York Times*, October 24, 2013, http://www.nytimes.com/2013/10/25/science/pentagon-agency-to-spend-70-million-on-brain-research.html?_r=0 (accessed December 29, 2014).

[41] Jeremiah D. Wander et al., "Distributed Cortical Adaptation during Learning of a Brain-Computer Interface Task," *Proceedings of the National Academy of Sciences* 110 (2013): 10818-10823.

[42] Ian Sample, "Monkeys Use Mind Control to Move a Virtual Arm and Experience Touch," *The Guardian*, October 5, 2011, http://www.theguardian.com/science/2011/oct/05/monkeys-mind-control-virtual-arm (accessed January 2, 2015).

2020.[43] An Air University dissertation claims "[i]t is likely that BCI technology will dominate military systems in 2032."[44]

A much more ambitious goal is to build a mind reading device that can translate actual thoughts in a manner that a computer can understand them. For example, one could measure and catalogue EEG responses to specific words and simply match brain activity to thoughts. Such research is indeed undertaken by scientists at the University of California, Irvine. Researcher Mike D'Zmura believes that it would take 15 to 20 years to develop thought-based communication.[45] Special Operations Forces soldiers use the technology to silently and efficiently communicate with each other just by thinking (hence the project name 'synthetic telepathy'). Neuroscientist Thomas Naselaris opined that "[t]he potential to do something like mind reading is going to be available sooner rather than later…It's going to be possible in our lifetimes."[46] Although the Royal Society report claims that "[t]here are very limited prospects for a universal thought reading machine," because of the uniqueness of each brain and the brain's general plasticity (tendency to change over time), the technology does at the very least raise some concerns about the prospect of new weapons systems with direct neurological control.[47]

The potential advantage of BCI-controlled weapons is that they could immerse soldiers better in the battlespace when remotely controlling an unmanned system for better situational awareness. BCIs could also significantly improve threat detection and identification accuracy, as well as substantially reduce human response times.[48] In particular, DARPA is developing the 'Cognitive Technology Threat Warning System' (CT2WS), which uses an EEG that detects unconscious brain responses to potential threats appearing on a monitor and flags them to the operator. Via BCI, soldiers will be better able to control complex machinery such as robotic exoskeletons or unmanned systems. This kind of research has already stimulated a heated debate on the legality of 'neuroweapons' based on using a soldier's brain processes as input for detecting a threat and activating a weapon without requiring a conscious decision on the part of the soldier whose brain has been wired to the weapons.[49]

DEGRADATION TECHNOLOGIES

While enhancement seems to offer exciting opportunities for gaining an advantage by making soldiers smarter, they are also more speculative. As a rule of thumb, enhancement tends to be much more difficult than degradation. However, enhancement is at the focus of the academic literature since much of it is developed more or less openly while degradation methods such as more exotic nonlethal weaponry are often portrayed as fictional or aspirational. FAS researcher Steven Aftergood has mocked the Pentagon over its excessive secrecy in this respect, suggesting that it could allow little more

[43] Nick Bilton, "Disruptions: Brain-Computer Interfaces Inch Closer to Mainstream," *The New York Times*, April 6, 2013, http://bits.blogs.nytimes.com/2013/04/28/disruptions-no-words-no-gestures-just-your-brain-as-a-control-pad/?_r=0 (accessed December 29, 2014); Sharon Gaudin, "Intel: Chips in Brains Will Control Computers by 2020," *ComputerWorld*, November 19, 2009, http://www.computerworld.com/article/2521888/app-development/intel--chips-in-brains-will-control-computers-by-2020.html (accessed December 29, 2014).

[44] Brian E. Moore, "The Brain-Computer Interface Future: Time for a Strategy," Research Report, Air University, February 14, 2013.

[45] Eric Bland, "Army Developing 'Synthetic Telepathy,' " *NBC News*, October 13, 2008, http://www.nbcnews.com/id/27162401/ns/technology_and_science-science/t/army-developing-synthetic-telepathy/#.VEF0x2es_8U (accessed November 6, 2014).

[46] Requarth, "This Is Your Brain."

[47] Royal Society, *Brain Waves Module 3*, pp. 16, 20.

[48] "Weapons of Perception: Neuroscience and Mind-Controlled Weapons," *Army-Technology.com*, May 22, 2012, http://www.army-technology.com/features/featureweapons-of-perception-neuroscience-mind-controlled-weapons-and-the-military/ (accessed November 6, 2014).

[49] Stephen White, "Brave New World: Neurowarfare and the Limits of International Humanitarian Law," *Cornell International Law Journal* 41 (2008): 194-196.

than mumbo jumbo to prosper in the closed off world of black projects.[50]

The reality of secret nonlethal weapons is probably more complex. Regardless of what may or may not exist at the present time, there is clearly a potential for future neuroscience-based nonlethal weapons that could be best described as 'neuroweapons' (sometimes referred to as 'RF weapons', 'psychotronic weapons', or 'influence weapons'). Robert McCreight suggests the following definition: "Neuroweapons are intended to influence, direct, weaken, suppress, or neutralize human thought, brainwave functions, perception, interpretation, and behaviors to the extent that the target of such weaponry is either temporarily or permanently disabled, mentally compromised, or unable to function normally."[51] These weapons generally target the human brain and the central nervous system; they can impact on mental and emotional states, mental capacity and response times, and potentially higher cognitive functions supporting thought, perception, memory, and learning. These effects could be achieved through a variety of means: biochemical agents, directed energy weapons (DEW), and even information/software (going beyond normal PSYOPS).

Biochemical Agents

Most of the publicly available information about offensive neuroweapons currently relates to the potential use of biochemical agents as incapacitants and potentially for otherwise influencing the behavior of an adversary. While chemical and biological warfare are internationally outlawed, there are several legal gaps that could allow the usage of biochemical neuroweapons in specific contexts. A frequently cited case is the use of the opioid fentanyl by the FSB during the Moscow theater siege in October 2002. The chemicals were intended to put the Chechen terrorists to sleep, which also accidentally killed 128 hostages (out of over eight hundred) because of a delayed and wrong medical emergency response.[52]

Nevertheless, researchers have made the claim that biochemical calmatives and malodorants could play an important role in future conflicts as a nonlethal technique and could provide a humanitarian alternative to the use of lethal force.[53] Militaries around the world have shown interest in biochemical incapacitating agents for counter-insurgency and counterterrorism operations.[54] Biochemical incapacitants could be dispersed from the air or covertly introduced into the water and food supply to assist in winning 'the hearts and minds' and in neutralizing various threats within a population. This is in principle a very old idea that goes back at least to 1949 when 'psychochemical warfare' was proposed by Army Chemical Center scientist L. Wilson Greene.[55] There could be a range of new neuropharmaceuticals under development that could produce relatively predictable behavioral effects and could prove suitable even for large area psychochemical warfare attacks.

One biochemical agent that seems to have caught the interest of the military is the neurohormone oxytocin, which is naturally produced by the brain and stimulates love or trust. Oxytocin could be used for manipulating adversaries into (temporarily) trusting us and thereby reduce the

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[50] Steven Aftergood, "The Soft-Kill Fallacy," *The Bulletin of Atomic Scientists* (September-October 1994): 40-45.

[51] Robert McCreight, "Brain Brinksmanship: Devising Neuroweapons Looking at Battlespace, Doctrine, and Strategy", in: James Giordano (ed.), *Neurotechnology in National Security and Defense: Practical Considerations, Neuroethical Concerns* (Boca Raton, FL: CRC Press, 2014), pp. 117-118.

[52] David A. Koplow, *Non-lethal Weapons: The Law and Policies of Revolutionary Technologies for the Military and Law Enforcement* (Cambridge: Cambridge University Press, 2006), pp. 100-112.

[53] Martin Furmanski, "Historical Military Interest in Low-Lethality Biochemical Agents: Avoiding and Augmenting Lethal Force," in Alan M. Pearson, Marie Isabelle Chevrier and Mark Wheelis, *Incapacitating Biochemical Weapons* (Plymouth, UK, Lexington Books, 2007), pp. 35-66.

[54] Alan Pearson, "Incapacitating Biochemical Agents: Science, Technology, and Policy for the 21st Century," *Nonproliferation Review* 13 (2006): 151-188.

[55] Raffi Khatchadourian, "Operation Delirium," *The New Yorker*, December 17, 2012, http://www.newyorker.com/magazine/2012/12/17/operation-delirium (accessed December 29, 2014).

occurrence of resistance.[56] Oxytocin is commercially marketed as 'Liquid Trust'. The U.S. military even investigated the possibility of a 'gay bomb', which was meant to distract enemy forces by inducing sexual arousal and disrupt morale.[57] Even a 'zombie bomb' is imaginable: the alkaloid drug scopolamine (also known by its street name burundanga) can put people exposed to it in a highly suggestible state, in which they lose their free will.[58] Bioethicist Jonathan Moreno seems to be also concerned about future 'brain targeted bioweapons' that could alter behavior. Genetic bioweapons have been a concern for some time, but a new nonlethal twist could be added to them. Microbiologists have recently discovered mind-controlling parasites that can manipulate the behavior of their hosts according to their needs by switching genes on or off.[59] Since human behavior is at least partially influenced by their genetics, nonlethal behavior modifying genetic bioweapons that spread through a highly contagious virus could thus be, in principle, possible.

Directed Energy Weapons (DEWs)

DEWs are no longer the stuff of science fiction, but have already been gradually transitioned to the battlefield.[60] They form a very broad class of weaponry, which includes any type of weapon that uses energy for producing a weapons effect, most importantly lasers, high-powered microwaves (non-nuclear EMP), high energy radio-frequency weapons, and also sound or acoustic weapons.

Although much of DEW research is secret, especially when it comes to antipersonnel DEWs, there are a couple of weapons systems that have been presented to the public and that are operational. For example, it is documented that it is possible to induce motion sickness, nausea, disorientation, and seizures through stroboscopic dazzling lights ('Bucha effect'), or to produce similar effects using certain acoustic or radio frequencies.[61] The Department of Defense (DoD) has developed various laser dazzlers that temporarily blind adversaries. Recently a company has patented a new type of stun gun that overstimulates the brain with bursts of lights and thereby disorients people for up to 20 minutes.[62] DoD has also developed acoustic weapons such as the Long Range Acoustic Device (LRAD) that can produce sounds that are still painful at distance of a hundred meters.[63] Another example is the Active Denial System (ADS), which uses microwaves of 95 GHz to create a burning sensation on the skin over a distance of at least 300 meters and which can force hostile crowds to disperse.[64]

Other antipersonnel DEWs are up to now more hypothetical. A frequently cited declassified Army document that summarizes some research into biological effects of nonlethal weapons indicates that microwaves could be used for transmitting sounds directly into brains (the so-called 'Frey-effect') or for causing pain or death when the brain is targeted due to the thermal effect of microwaves.[65] Jonathan Moreno also claims: "Electromagnetic waves may be used to disrupt an

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[56] Giordano and Wurzman, "Neurotechnologies as Weapons in National Security and Defense," p. 59.
[57] "U.S. Military Pondered Love Not War," *BBC News Online*, January 15, 2005, http://news.bbc.co.uk/2/hi/4174519.stm (accessed October 25, 2014).
[58] Jose de Cordoba, "In Colombia, the Drug Burundanga Is Street Thugs' Weapon of Choice," *Wall Street Journal* (July 7, 1995): 1.
[59] Carl Zimmer, "Parasites Practicing Mind Control," *The New York Times* (August 28, 2014), http://www.nytimes.com/2014/08/28/science/parasites-practicing-mind-control.html (accessed December 29, 2014).
[60] John Antal, "Phasers on Stun: A Status Report on Directed Energy Weapons Programmes," *Military Technology* 7 (2011): 66-73.
[61] Timothy Thomas, "The Mind Has No Firewall," *Parameters* (Spring 1998): 84-92.
[62] Valerie Ross, "'StunRay,' a Light Weapon that Overstimulates the Brain," *Discover Magazine*, April 5, 2011, http://blogs.discovermagazine.com/sciencenotfiction/2011/04/05/stunray-a-light-weapon-that-overstimulates-the-brain/#.VKQxQ3stFZ4 (accessed December 29, 2014).
[63] Juliette Volcler, *Extremely Loud: Sound as a Weapon* (New York: The New Press, 2013), p. 104.
[64] Moreno, *Mind Wars*, p. 176.
[65] U.S. Army, "Bioeffects of Selected Nonlethal Weapons," http://www.metatexte.net/docs/index-6.html (accessed January 2, 2015).

enemy soldier's nervous system, to cause epileptic seizures, or to warm their body fluids as though they were inside a microwave oven."[66] In the 1980s animal experiments with directed energy weapons have shown promise in terms of affecting mental states (changing EEGs) and behavior.[67] The possibility of radio frequency (RF) weapons that target the brain has been discussed more openly back in the 1980s. References to them still appear in a few military publications and declassified documents, which suggests that research into this technology continues.[68] Analyst James Dunnigan claimed that there "are radio transmitters that jam and short-circuit the human nervous system. This temporarily disables people the radio beams are aimed at."[69]

Microwaves could also be used for inducing sensory hallucinations over distance. For example, a 'voice-of-good weapon' that projects voices directly into the heads of individuals in support of PSYOPS could be possible and has been referred to on a U.S. Army website.[70] It has been reported in the press that "previous research has shown that low-frequency waves or beams can affect brain cells, alter psychological states and make it possible to transmit suggestions and commands directly into someone's thought processes. High doses of microwaves can damage the functioning of internal organs, control behaviour or even drive victims to suicide."[71] In the future it might be possible to influence moods and mental capacity of people in a larger geographic area using the electromagnetic spectrum, and thus induce passive, peaceful, riotous, or any other desirable behavior.

Information/ Software Based Neuroweapons

Not all neuroweapons need to be of a physical nature – some might just consist of information that is designed to manipulate behavior or there could be software that hacks neural devices or implanted chips. DARPA has within its Biological Technologies Office a neuroscience-based project called Narrative Networks, which aims "to understand how narratives influence human cognition and behavior, and apply those findings in international security contexts."[72] The context for national security is to understand why certain narratives are believed and others not and how narratives can support terrorism. The methods include research into how the brain responds to certain narratives and the development of computer models of how narratives affect individuals and social networks.

A related effort is the Minerva Initiative, which "seeks to build deeper understanding of the social, cultural, and political dynamics that shape regions of strategic interest around the world."[73] Another project is the Sentient World Simulation, which can simulate the behavior of entire societies and thereby enable wargaming of PSYOPS.[74] DARPA

[66] Jonathan Moreno, *Undue Risk: Secret State Experiments on Humans* (New York: W.H. Freeman & Co., 2000), p. 289.

[67] Douglas Pasternak, "Wonder Weapons: The Pentagon's Quest for Nonlethal Arms is Amazing," *U.S. News and World Affairs* (June 29, 1997): 38-46.

[68] E.g., Paul E. Tyler, "The Electromagnetic Spectrum in Low-Intensity Conflict," in David J. Dean (ed.), *Low- Intensity Conflict and Modern Technology* (Montgomery, AL: Air University Press, 1986), pp. 249-260; Thomas, "The Mind Has No Firewall"; Dennis M. Bushnell, "Future Strategic Issues/ Future Warfare [Circa 2025]," NASA Langley Research Center, 2001, pp. 49-50.

[69] James F. Dunnigan, *Digital Soldiers: The Evolution of High-Tech Weaponry and Tomorrow's Brave New Battlefield* (New York: St. Martin's Press, 1996), p. 223.

[70] Sharon Weinberger, 'The Voice-of-God Weapon Returns', *Wired Blog*, December 21, 2007, http://www.wired.com/2007/12/the-voice-of-go/ (accessed November 6, 2014).

[71] Christopher Leake and Will Stewart, "Putin Targets Foes with 'Zombie' Gun Which Attacks Victims' Central Nervous System," *Daily Mail Online*, March 31, 2012, http://www.dailymail.co.uk/news/article-2123415/Putin-targets-foes-zombie-gun-attack-victims-central-nervous-system.html#ixzz2DPaQUNBO (accessed January 2, 2015).

[72] DARPA, "Narrative Networks," Biological Technologies Office/ DARPA, http://www.darpa.mil/Our_Work/BTO/Programs/Narrative_Networks.aspx (accessed October 21, 2014).

[73] "The Minerva Initiative," http://minerva.dtic.mil/ (accessed 28 August 2015).

[74] T. Cerry and A. Chaturvedi, "Sentient World Simulation: A Continuously Running Model of the

also funded research in the context of its Social Media in Strategic Communications project, exploring how emotions of users can be manipulated through social media.[75] Ultimately, the various information/software initiatives focus on social and behavioral research for understanding "cultural and political environments…where threats develop."[76] Such research can potentially be used for the political and psychological subversion of other societies or for social engineering, which was a concern for the older and similar Project Camelot.[77]

A further extension of PSYOPS is the use of sophisticated battlefield illusions to directly manipulate enemy perceptions. For example, DARPA has made $4 million dollars available for research into how the brain processes sensory perception information so that perceptions can be managed to "confuse, delay, inhibit, or misdirect [the enemy's] actions."[78] Around the world defense establishments are also working on invisibility cloaks and holograms that can make an object disappear or to create a convincing illusion of a non-existent object. Enemies might be easily manipulated into surrendering if they saw endless columns of holographically projected soldiers marching towards them or divine apparitions (a 'Face-of-Allah' weapon).[79]

Real World," W. Lafayette, IN: Purdue University, August 22, 2006.

[75] Ben Quinn and James Ball, "US Military Studied How to Influence Twitter Users in Darpa-funded Research," *The Guardian*, July 18, 2014, http://www.theguardian.com/world/2014/jul/08/darpa-social-networks-research-twitter-influence-studies (accessed December 29, 2014).

[76] "The Minerva Initiative," U.S. Department of Defense, http://minerva.dtic.mil/ (accessed September 8, 2015).

[77] Robert A. Nisbet. "Project Camelot: An Autopsy," *The Public Interest* (Fall 1966): 45-69.

[78] Noah Shachtman, "Darpa's Magic Plan: 'Battlefield Illusions' to Mess with Enemy Minds," *Wired Blog*, February 14, 2012, http://www.wired.com/2012/02/darpa-magic/ (accessed December 29, 2014).

[79] Sharon Weinberger, "The face of Allah Weapon Returns," *Wired.com*, May 13, 2008, http://www.wired.com/2008/05/the-face-of-all/ (accessed September 8, 2015).

Military Information Support Operations already intersect heavily with cyber security and cyber operations because of the possibility of conducting PSYOPS on and via the Internet. Once neural devices are more commonly used as computer input and brain stimulation devices directly connected to computers, they could be hacked just like any other piece of electronics, the difference being that it is not just the normal functioning of an external device that is at stake but the functioning of a user's brain. A hacker of a neural device could alter brain waves, moods, mental state and capacity of the user, and might even take control of a user's body through a BCI to perform an unintended action.[80] Such neural hacking could even permanently 'rewire' the brain of the user or 'brainwash' them.

Less technologically sophisticated methods of 'mind hacking' are imaginable. Malicious software might attack the minds of users by manipulating the flicker rate of the monitor and by displaying subliminal messages on the screen that cannot be consciously perceived.[81] Although the effectiveness of subliminal messages has been often dismissed, neuroscientists have found indications that subliminals do work in the sense of somewhat affecting the behavior of people who have been exposed to them – at least sometimes.[82] It is uncontroversial that the advertising industry has experimented with subliminals as described in Vance Packard's 1957 book *The Hidden Persuaders*.[83] Subliminal advertising has sparked enough concerns to prohibit them in many countries, including the United States. The Russian government has even decided to automatically scan media for subliminal messages after it was reported in 2002 that a Russian TV station included subliminals in their programming

[80] Hedley Leggett, "The Next Hacking Frontier: Your Brain?" *Wired.com*, July 9, 2009, http://www.wired.com/2009/07/neurosecurity/ (accessed 4 November 2014).

[81] Thomas, "The Mind Has No Firewall."

[82] Gráinne Fitzsimons, Tanya L. Chartrand and Gavan Fitzsimons, "Automatic Effects of Brand Exposure on Motivated Behavior: How Apple Makes You 'Think Different'," *Journal of Consumer Research* 35: 21-35.

[83] Vance Packard, *The Hidden Persuaders* (New York: D. McKay Co., 1957).

to manipulate their viewers to keep watching it.[84] Research has shown that people can emotionally respond to subliminal cues and that this can affect attitudes and behaviors.[85] The danger in subliminals may not lie in directly causing action, but in their capability of slowly shifting perceptions, attitudes, and beliefs after an extended period of exposure to them.

THE MIND AS A NEW DOMAIN OF WARFARE

There is little doubt that neuro S/T has numerous military and security applications, but does this amount to any revolutionary change or create a new domain of war? Is neurowarfare just an evolution of existing methods of war and technologies, or does it actually introduce a new quality? Some may argue that psychological warfare goes back to Ancient times and was already advocated by military theorist Sun Tzu, who counseled in *The Art of War* that "[t]o subdue the enemy without fighting is the acme of skill."[86] Neurowarfare might be just a refinement of PSYOPS with some marginal improvements in this area. However, modern PSYOPS still remains limited to using *communications* for influencing the "emotions, motives, objective reasoning, and behavior" of a target audience,[87] while neurowarfare promises something different: direct external control of human consciousness through targeted manipulation of the brain. As Robert McCreight has argued, "[t]houghts, beliefs, perceptions, ideas, and behaviors could be made directly vulnerable to external threat and control for the first time in human history."[88] If it can be achieved, states and other actors will aim to dominate 'neurospace', bypassing conventional military capability and other traditional defenses of society, in order to gain a decisive advantage in a conflict.

Neocortical Warfare

RAND analyst Richard Szafranski proposed in 1997 the term 'neocortical warfare' to describe a new paradigm of war. Szafranski criticized the Clausewitzian paradigm for being overly focused on the need for violence as the main instrument of coercion. Szafranski suggests "the intellectual energy consumed by devising newer and better ways to kill and destroy distracts us from the real object of war: subduing hostile will. Lopping the limbs off an enemy's body, or even precisely excising muscles from it, undoubtedly sends a message to the enemy's brain. Might there not be other ways to communicate with hostile brains?"[89] He goes on to further delineate neocortical warfare from the older paradigm:

> Neocortical warfare is warfare that strives to control or shape the behavior of enemy organisms, but without destroying the organisms. It does this by influencing, even to the point of regulating, the consciousness, perceptions and will of the adversary's leadership: the enemy's neocortical system. In simple ways, neocortical warfare attempts to penetrate adversaries' recurring and simultaneous cycles of 'observation, orientation, decision and action.' In complex ways, it strives to present the adversary's leaders—its collective brain—with perceptions, sensory and cognitive data designed to result in a narrow and controlled (or an overwhelmingly large and disorienting) range of calculations and evaluations. The product of these evaluations and calculations are adversary choices that correspond to our desired choices

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84 Robyn Dixon, "Abusing the Power of Suggestion in Russian Ads," *Los Angeles Times*, August 25, 2002, http://articles.latimes.com/2002/aug/25/world/fg-russtv25 (accessed December 29, 2014).

85 A. Sharma, "Subliminal Perception: Conceptional Analysis and Its Rampant Usage in Advertisements and Music Industry," *Indian Journal of Health and Wellbeing* 6 (2015): 640-643.

86 Sun Tzu, *The Art of War*, Chapter 3.

87 U.S. Army, "Psychological Operations, Tactics, Techniques, and Procedures," FM-3-05.301: 1.2.

88 McCreight, "Brain Brinkmanship," p. 117.

89 Richard Szafranski, "Neocortical Warfare: The Acme of Skill," in David Ronfeldt and John Arquilla, *In Athena's Camp: Warfare in the Information Age* (Santa Monica, CA: RAND, 1997), p. 398.

> and the outcomes we desire. Influencing leaders to not fight is paramount.[90]

What Szafranski is calling neocortical warfare is referred herein as neurowarfare: the manipulation of enemy brains for the goal of subduing their will. Similarly, Australian defense analysts Chloe Diggins and Clint Arizmendi have argued that neurowarfare is "about *involuntarily* penetrating, shaping, and coercing the mind in the ultimate realization of Clausewitz's definition of war: compelling an adversary to submit to one's will."[91] This goes clearly beyond PSYOPS and can be aimed at degrading mental capacity, altering mental states, altering emotions, and potentially impacting higher cognitive functions of perception, thinking, memory, and learning (Fig. 1). Neurowarfare is also culturally agnostic in the sense that people can be influenced at a level of the brain, potentially bypassing cultural factors and peculiarities.

The Human Domain

In recent years the U.S. military adopted the concept 'human domain', which is added as a sixth domain of war apart from land, sea, air, outer space, and cyberspace. The human domain comprises 'human factors' and the 'human terrain'. Human factors deal with aspects of human nature and human capability that are difficult to measure but that are critically important in war and its conduct, namely, culture, motivation, morale, emotions, training, leadership, and so on. The 'human terrain' is "the human population in the operational environment ... as defined and characterized by sociocultural, anthropologic and ethnographic data and other non-geographical information."[92] The U.S. Army continues to develop HTS by combining it better with geographic information systems so that everybody and all activities can be tracked and referenced to a geographic location for better situational awareness in the human domain.

A 2012 DoD white paper on 'Strategic Landpower' declared the central importance of the human domain to all warfare and argued "[w]hat we know and project about the future operating environment tells us that the significance of the 'human domain' in future conflict is growing, not diminished."[93] The paper emphasizes the continued importance of landpower and the growing importance of conflicts short of war, where lethal power may not be the most effective way to meet U.S. strategic goals. It clearly hints at possibly covert methods of influencing other societies so that actual warfare becomes unnecessary.

A subsection of the human domain that could emerge in the future could be called 'neurospace': the technical interface at which brains and minds interact with their environment. Chloe Diggins and Clint Arizmendi have argued that neural interfaces such as neural devices and BCIs could become ubiquitous and that they could therefore become targets of cyber attacks:

> "The possibilities for damage, destruction, and chaos are very real. This could include manipulating a soldier's BCI during conflict so that s/he were forced to pull the gun trigger on friendlies, install malicious code in his own secure computer system, call in inaccurate coordinates for an air strike, or divulge state secrets to the enemy seemingly voluntarily."[94]

In light of the rapid advances in neuro S/T it no longer seems far-fetched that militaries will seek to dominate neurospace by hacking the human brain and by devising new technologies that harden own personnel against neurowarfare attacks. In many respects neurowarfare would be fairly similar to cyber warfare with the exception that attacks are not directed against technical systems and networks, but against biological cognitive systems, which may occur through some neuro-cyber interface or BCI and which would aim to steer consciousness. Some researchers have

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[90] Ibid.: 404.

[91] Diggins and Arizmendi, "Hacking the Brain."

[92] J. Kipp, L. Grau, K. Prinslow, and D. Smith, "The Human Terrain System: A CORDS for the 21st Century," *Military Review* (September-October 2006): 9.

[93] U.S. DoD, "Strategic Landpower: Winning the Clash of Wills," White Paper, November 2012, p. 5.

[94] Diggins and Arizmendi, "Hacking the Brain."

even suggested the creation of an 'Internet for minds,' thereby creating a 'noosphere' that could one day form a super-intelligent hive mind.[95] Combat in neurospace would become a struggle over the formation and direction of collective consciousness. What follows in the final section is brief discussion of key strategic problems related to neurowarfare.

Approaches to Neurowarfare

In principle, neurowarfare can be waged defensively and offensively. In a defensive function neurowarfare may be used to suppress conflicts before they can break out. A potentially hostile society may be calmed and hostile attitudes or perceptions adjusted accordingly. For example, defense analyst Henrik Friman has pointed out, perceptions of winning and losing are central to all forms of warfare. So if one could somehow manipulate enemy leaders into believing that they have won, they would terminate hostilities before they have actually gained the advantage they originally sought or they may never see the need for resistance in the first place.[96] In an operational environment, where *"[t]he most compelling future defense-relevant shocks are likely to be unconventional,"* the importance of managing perceptions of potentially hostile populations grows.[97]

Occupied populations could be more easily pacified and incipient insurgencies could be more easily suppressed before they gain any traction. Calmatives could be put into the drinking water or populations could be sprayed with oxytocin to make them more trusting. Potential terrorists may be detected using brain scans and then chemically or otherwise neutered.[98] This obviously creates the possibility of creating a system of high-tech repression, where in the words of writer Aldous Huxley "a method of control [could be established] by which a people can be made to enjoy a state of affairs by which any decent standard they ought not to enjoy."[99]

Offensive neurowarfare would be aimed at manipulating the political and social situation in another state. It could alter social values, culture, popular beliefs, and collective behaviors or change political directions, for example, by way of regime change through 'democratizing' other societies – a complaint that is frequently heard from Russia.[100] A Special Operations Command White Paper claims "Russia, China, and Iran currently conduct political warfare activities to further their individual goals" and suggests a "strategy enabling the U.S. to influence local struggles in a positive direction" should be developed.[101] However, offensive neurowarfare could also mean collapsing adversarial states by creating conditions of lawlessness, insurrection, and revolution, for example, by inducing fear, confusion, or anger. Adversarial states could be destabilized using advanced techniques of subversion, sabotage, environmental modification, and 'gray' terrorism, followed by a direct military attack.[102] As a result, the adversarial state would not have the capacity to resist the policies of a covert aggressor. Neurowarfare could take down a

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[95] George Dvorsky, "How Much Longer Until Humanity Becomes a Hive-Mind?" *IO9 Magazine*, March 15, 2013, http://io9.com/how-much-longer-until-humanity-becomes-a-hive-mind-453848055 (accessed August 29, 2015).

[96] Henrik Friman, "Perception Warfare," Swedish National Defense College: Stockholm, Discussion Paper.

[97] Nathan Freier, *Known Unknowns: Unconventional 'Strategic Shocks' in Defense Strategy Development* (Carlisle Barracks, PA: US Army War College Strategic Studies Institute, 2008), p. 14.

[98] Sharon Weinberger, "Mind Games," *The Washington Post*, January 14, 2007, http://www.washingtonpost.com/wp-dyn/content/article/2007/01/10/AR2007011001399.html (accessed September 8, 2015).

[99] Aldous Huxley, "Interview with Aldous Huxley," Berkeley Language Center, March 20, 1962, http://www.informationclearinghouse.info/article31319.htm (accessed September 8, 2015).

[100] Andrew Korybko, *Hybrid Wars: The Indirect Approach to Regime Change* (Moscow: Institute for Strategic Studies and Predictions, 2015).

[101] U.S. Special Operations Command, *Counter-Unconventional Warfare*, White Paper, September 26, 2014, p. 12.

[102] S.G. Chekinov and S.A. Bogdanov, "The Nature and Content of a New-Generation War," *Military Thought* 4 (2013): 19-20.

strategic competitor permanently without nuclear war and the risk of devastating nuclear retaliation.

Targeting

Like cyber warfare bypasses the battlefield, neurowarfare bypasses the state altogether and might target individual civilians (political leaders), societal subgroups, or entire societies. As a result, the traditional distinction between combatants and noncombatants may become meaningless. There is already a legal debate over the question whether and under what conditions civilians can be targeted with nonlethal weapons, for example, in the context of counterterrorism and counterinsurgency operations.[103] This debate is bound to intensify once neuroweapons mature.

A further complication with respect to noncombatant targeting arises from the tendency that neuroweapons may be employed covertly without the target of the attack ever being aware of the attack.[104] A neurowarfare attack may not even cause any physical harm to a person subjected to it and may in this respect be akin to targeting civilians with propaganda, however, with more drastic and immediate effects. Enemy leaders could be targeted to degrade their ability to make sound decisions or to steer their decisions into a particular direction. Individuals may be driven insane and manipulated into random acts of violence. Societal subgroups may be manipulated into rising against their government, and whole societies may be thrown into political turmoil and chaos.

While such methods of war seem intuitively objectionable from an ethical point of view, they increasingly represent the current reality of ‘hybrid warfare’, ‘political warfare’, and other forms of societal destabilization that are being employed with great effectiveness by several major nations.[105] There is currently no legal protection against mind manipulation, although one can argue that covert mental coercion would violate human dignity and by extension human rights.[106]

Deterrence

How can we deter neurowarfare attacks? Deterrence can be defined as “the use of threats to dissuade an adversary from initiating an undesirable act.”[107] Its success depends on two factors: the threat needs to be clearly communicated to the adversary and secondly, the threat needs to be credible. The credibility of the threat again depends on two factors, namely, the capability of the coercer to carry out the threat and the likelihood that the threat will actually be carried out when the undesirable act occurs.

‘Neurodeterrence’ can have two meanings: 1) deterrence based on insights gained from neuro S/T and 2) deterrence with neuroweapons or against neurowarfare. In the first meaning, neurodeterrence is clearly possible: neuroscience can gain great insights into foreign cultures and how S/T affects brain functions and decision making as pointed out by the NRC study.[108] In this sense, neuroscience can help understand the true motivations of an opponent in order to find a punitive strategy that would most strongly influence an adversary’s behavior.[109] Secondly, nations will want to deter the use of neurowarfare against them, or they might use neuroweapons for deterrence more generally as part of their defense posture.

Currently, there are some key problems with deterring a possible neurowarfare attack by an adversarial state. A threat may be communicated in secret using diplomatic channels saying that if neuroweapons are used by the adversarial state it will produce a certain unfavorable response. The

[103] John W. Lango, “Nonlethal Weapons, Noncombatant Immunity, and Combatant Nonimmunity: A Just War Theory,” *Philosophia* 38 (2010): 475-497.

[104] McCreight, “Brain Brinkmanship,” p. 117.

[105] U.S. Special Operations Command, *Counter-Unconventional Warfare*, p. 3.

[106] J.C. Bublitz and R. Merkel, “Crimes against Minds: On Mental Manipulations, Harms and a Human Right to Mental Self-Determination,” *Criminal Law and Philosophy* 8 (2014): 51-77.

[107] L. Freedman and S. Raghavan, “Coercion,” in P.D. Williams, *Security Studies: An Introduction* (London: Routledge, 2008), p. 217.

[108] NRC, *Emerging Cognitive Neuroscience and Related Technologies*, p. 9.

[109] Canna, “Leveraging Neuroscientific and Neurotechnological Developments,” pp. 3-4.

problem is that unless the public is made aware that an invisible or indirect attack with neuroweapons against a state's leader or population has occurred, it will not support any open punitive action against the aggressor. The response would therefore have to be limited to some covert action, possibly a response in kind, attacking the minds of the adversary's leaders and population, which risks escalation. Furthermore, secret weapons would unlikely deter an aggressor for the simple reason that capabilities have to be demonstrated in order to make a threat credible. Secret military capabilities have little deterrence value.

Unfortunately, there are few incentives for any nation that succeed in developing neuroweapons to openly declare that they have them and might use them. Such a declaration would be counterproductive for several reasons: the declaration might spark a neuroscience arms race as more powers would seek these capabilities, the advantage of surprise would be lost, and other states may find effective countermeasures. Not surprisingly, many states have kept their research into potentially revolutionary nonlethal weapons secret from the public for decades.[110] The result may be that governments adopt by default an opaque posture with respect to their neurowarfare capabilities, which could potentially result in a failure of deterrence and subsequent disaster. Some nations may be able to use a perceived capacity for developing neuroweapons as leverage in international relations, getting concessions from much more powerful states.[111]

Threshold to War

There is a common problem with respect to all nonlethal approaches to warfare, be it cyber warfare, economic warfare, financial warfare, or ideological subversion, and that is the question under what circumstances the threshold to war has been crossed and when a kinetic response to the nonlethal attack could be justified. Neurowarfare directed against enemy leaders, enemy forces, and an enemy's society could be conducted in peacetime or outside a declared armed conflict. Just like cyber warfare, neurowarfare is inherently difficult to define and regulate since both methods of war could be generally conducted covertly, are difficult to attribute, and often cause no visible effect or damage. Up to now cyber war has only been able to produce a limited degree of societal disruption by making targeted web services temporarily unavailable and by causing financial damage.

However, cyber warfare is still seen as being potentially able to bring a nation to its knees through sophisticated attacks against critical infrastructure such as the electricity grid, mass transportation systems, and stock markets. For this reason an emergency conference-call system that includes all key cyber war decision-makers has been set up for the event of a major cyber attack on the nation, including a dedicated emergency communications line from Washington to Moscow.[112] The authority for engaging in offensive cyber operations outside of an armed conflict rests with the President, which again indicates that cyber warfare activities are indeed considered 'war' and not merely an extension of espionage that does not require such authorization.[113] The rationale for these restrictions for offensive cyber operations is based on the risk of unwanted escalation and the risk of unintended large-scale collateral damage, which would also apply to neurowarfare and other methods of subversion.

Currently, arms control agreements do not cover neuroweapons, as the technology could fall in between the CTC and BWC.[114] The use of neuroweapons might be treated similarly to cyber warfare activities and could be correspondingly restricted, both domestically and internationally. A 'no first use' doctrine might make sense with respect to offensive neurowarfare. Governments

[110] Pasternak, "Wonder Weapons."

[111] McCreight, "Brain Brinkmanship," p. 121.

[112] Shane Harris, *@War: The Rise of the Military-Internet Complex* (Boston, MA: Houghlin Mifflin Harcourt, 2014), p. 60.

[113] David E. Sanger and Thom Shanker, "Broad Powers Seen for Obama in Cyberstrikes," *The New York Times*, February 3, 2013, http://www.nytimes.com/2013/02/04/us/broad-powers-seen-for-obama-in-cyberstrikes.html?pagewanted=all&_r=0 (accessed December 12, 2014).

[114] Requart, "This Is Your Brain."

and other organizations also would be well-advised to think about effective 'neuro-defenses' that can protect leaders, personnel, and society at large from sophisticated attacks on their minds, including their perception, emotions, and consciousness. Unfortunately, the great secrecy surrounding neuroweapons can be detrimental, as it could lead to underestimating a very real and growing threat. So one can ask the question, "Should we risk waiting until the tangible first evidence of neuroweapons research has landed on the front page of our major newspapers and CNN [before we start thinking about the threat]?"[115] Governments need to make it clear under what conditions they would use neuroweapons and how a neuroweapons attack by a foreign power would be answered. In short, a neurowarfare doctrine is needed and should be developed before neurowarfare becomes a reality and a tangible threat.

CONCLUSION

Neuroscience research will have a substantial impact on warfare and security in numerous ways, ranging from the enhancement of personnel, the improvement of strategic intelligence, new screening devices that can detect hostile intentions or guilty knowledge, thought-controlled weapons, and offensive neuroweapons that can directly influence mental capability, perception, emotions, and thoughts of people. The sum total of the military applications of neuro S/T can be called neurowarfare, and it may become a distinctive domain of warfare in its own right. Ultimately, there is no higher valuation in war than subversion of the enemy's mind. If this can be achieved through targeting the enemy's brain directly, it would be the most powerful weapon that has ever been devised by humanity. Considering the dangers of neuroweapons and the prospect of governments and terrorist groups secretly wielding neuroweapons against individuals, groups, or society in pursuit of strategic goals within a decade or so, it is time to think seriously about how to protect leaders, government personnel, and society at large – and about how neurowarfare can be governed.

[115] McCreight, "Brain Brinksmanship," p. 125.

Figure 1 (*Source*: Author).

The Spectrum of Neurowarfare			
	Technique	Target	Objectives
Neurowarfare	Manipulation of the brain	Attack on consciousness	• Directly control human behaviour • Insert/ manipulate thoughts, perceptions, dreams • Manipulate emotions
		Attack on mental capacity	• Degrade cognitive functions • Interfere with perception • Alter mental states
	Predictive algorithms, simulations, brain imaging	Brain functions/ consciousness	• Steer society at large • Influence individual or collective behaviour • Predict threats/ developments/ behaviours • Access memory • Deception detection
PSYOPS	Communication (mass media, Internet)	Attack on perception	• Influence behaviour • Influence beliefs • Influence perceptions • Influence emotions

Brazil Space: Military Dependency and the Case of the Geostationary Satellite of Defense and Strategic Communications

Gills Vilar Lopes

In Brazil, there has been no transition model of space capabilities promoted by the military sphere (especially the Brazilian Air Force) for nurturing the civil one (Brazilian Space Agency). Drawing upon official documents and legislation as primary sources, the case study of the Geostationary Satellite of Defense and Strategic Communications (SGDC) is analyzed in light of the space strategic sector. Main factors that impede the PEB are related to military-technological dependence and poor resource management, with draconian budget cuts and projects canceled before having achieved realistic milestones.

Brazil is the largest economic power in South America and has one of the world's best places to launch rockets, the Alcântara Launching Center (CLA).[1] But when it comes to space operations via own satellites, it is Argentina that leads in the subcontinent.[2] Why, then, does the Brazilian Space Program (PEB) not take off? [3] Answering that question is the main goal of this article.

Many believed that, after Brazilian military rule (1964-1985) and the end of the Cold War, the PEB would be demilitarized, as had happened with other important programs and organs of the regime such as the Brazilian secret service. However, over the years, the military – especially the Brazilian Air Force (FAB) – continued to play a central role in Brazil's space activities.

With the Brazilian Space Agency's (AEB's) creation in 1994, it was also expected that PEB civil programs would gradually become more autonomous, and expertise in space accumulated during the military regime would transfer to the Agency. In practice, however, PEB languished in a comprehensively dependent relationship – in technological, operational, and human resource terms – with respect to FAB. The Brazilian logic of refusing to ween and strengthen their civil space activities goes against the current world trend: main counterexamples are the National Aeronautics and Space Administration (NASA), the European Space Agency (ESA), and Argentina's National Commission for Space Research (CONAE) here in South America.

Furthermore, an oft-made assertion, both by the National Policy for Development of Space Activities (PNDAE) and the PEB itself, is of the need to synchronously array and connect private, academic, and governmental sectors in order to attain space excellence. But, as this article shows, that is the theory, or, in legal terms, only the programmatic norm. The reality is that one of the major problems hindering the development of Brazilian space activities is precisely the fact that state policy to boost important variables such as domestic industry for this sector practically does not exist. Despite some tax exemptions, which are directed to the very few private Brazilian companies operating in the space sector, the current political and economic crisis facing the country can bring devastating consequences for PEB.

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[2] Alejandro G. Belluscio, "ARSAT-2: Argentina consolidates as Latin American satellite leader", *NASA SpaceFlight*, 21 September 2015, http://www.nasaspaceflight.com/2015/09/arsat-2-argentina-consolidates-latin-american-satellite-leader (accessed 22 September 2015).

[3] Formally and legally, the PEB is called National Program of Space Activities (PNAE). See: Brazil, *National Program of Space Activities (PNAE)* (Brasília: Ministry of Science, Technology and Inovation, 2012), 9.

This work examines the claim that even after the end of both the Cold War and military rule, as well as a broadening of the security concept in Brazil, there is still no transition model of space capabilities from the military sphere (FAB) to the civil one (AEB).[4] While the PEB, officially, is supposed to synthesize public policy (civil and military), there is no professional *esprit de corps* that can underwrite the development of independent civil space activities.

To corroborate such a thesis, a history of the AEB's public documents demonstrates strong military dependence for development of Brazil's space activities, with a crucial nexus being creation of the strategic space industry – by the Ministry of Defense. This paper also analyzes the case of Brazil's first geostationary satellite. Once live, the satellite will produce vital information for both the civil and military fields, providing on the one hand, Internet access for all Brazilian territory, and the other, safer ways to exchange strategic and meteorological information.[5] But for all that to happen, the Geostationary Satellite of Defense and Strategic Communications (SGDC) must arrive in space. That is where the AEB comes in.

With respect to the Brazilian military sector, it is worth emphasizing that important documents of the Brazilian Ministry of Defense (MD) – the National Defense Policy (PND), National Defense Strategy (END), and Defense White Paper (LBDN) – rank the space sector as a strategic sector for national development. As to the civil field, Brazilian legal documents spell out the role of space activities for development. This paper, then, illuminates the dialog between civilians and the military and how this relation shaped and ultimately hindered the Brazilian space program.

Despite the international context of Brazil space and the lingering likelihood of using force in the international environment, guiding documents of Brazilian defense and space policies lack, at many junctures, a sufficiently Hobbesian view of international relations.[6] A strong hint of liberal institutionalist aspirations lies in the fact that the two main END (National Defense Strategy) promoters were the former Minister of Defense Nelson Jobim (a non-military politician who was congressman, minister of justice, and minister of the Brazilian Supreme Court) and the then Minister of the Presidency of the Republic's Secretariat of Strategic Affairs (SAE) Mangabeira Unger (a professor of Law at Harvard University). Indeed, PEB's directive explicitly encourages a space culture in Brazil, and END asserts that national defense must not be military-restricted subject matter.[7]

THE BRAZILIAN SPACE PROGRAM (PEB) & AGENCY (AEB)

In order to analyze the Brazilian space program's (PEB's) strengths and weaknesses, today, it is essential to understand how the Brazilian Space Agency (AEB) was created and the distribution of space competences with other agencies and institutions, mostly military. Eyeing previous professional schools of the Brazilian Navy and Army (1910s), as well as the Brazilian Air Force's school for Military Aviation (1941), the PEB has its beginnings in the mid-1950s, with the creation of the Aeronautics Institute of Technology (ITA) and the Aeronautics and Space Institute (IAE), both belonging to Aeronautics Command's (COMAER's) Aerospace Science and Technology Department (DCTA).[8] Still, it

[4] Barry Buzan, Ole Wæver and Jaap de Wilde, *Security: a New Framework for Analysis* (Boulder: Lynne Rienner, 1998), 239; Brazil, *Política Nacional de Defesa (PND) e Estratégia Nacional de Defesa (END) (Brasília: Ministry of Defense, 2012)*, 13.

[5] Brazil. *Defense White Paper* (Brasília: Ministry of Defense, 2012), 208.

[6] Everett C. Dolman and Henry F. Cooper Jr, "Increasing the military uses of space," in *Toward a Theory of Spacepower: Select Essays*, edited by Charles D. Lutes et al. (Washington, DC: NDU Press), 99-101; Robert L. Pfaltzgraff, "International Relations Theory and Spacepower," in *Toward a Theory of Spacepower: Select Essays*, Edited by Charles D. Lutes et al. (Washington, DC: NDU Press), 47.

[7] Brazil, *PNAE, 8;* Brazil, *PND e END*, 7.

[8] Hermelindo Lopes Filho, *Nas asas da história da Força Aérea Brasileira* (Higienópolis: FAAP, [s/d]), http://faap.br/hotsites/asas-da-historia/livreto%20Nas%20Asas%20da%20Hist%C3%B3ria%20Da%20For%C3%A7a%20A%C3%A9rea%20Brasileira.pdf (accessed 22 September 2015), 20.

was only with NASA-FAB cooperation in the early 1960s that Brazil began to explore space in earnest.[9] Under military rule in Brazil, the PEB received the ambitious challenge of mastering the full access-to-space cycle through the Brazilian Complete Space Mission (MECB) although the initiative was subsequently abandoned without reaching its main goal.[10]

Returning to democracy in the late-1980s and 1990s, Brazil tried to deconstruct the whole repressive apparatus erected by military rule. Accordingly, Fernando Collor de Mello's first presidential act was extinguishing the main repressive organ of the old regime, the National Information Service (SNI). And his successor, Itamar Franco, tried to give civilian airs to the militarized PEB.

According to the Brazilian Constitution (1988), it is solely for the Union to legislate over Aerial/Space Law[11]. On 10 February 1994, using this legal premise, President Itamar Franco created the AEB, which succeeded the Brazilian Commission for Spatial Activities (COBAE), which in turn had been linked to the Armed Forces General Staff (EMFA).[12] Unlike its predecessor, AEB sat as a federal, civil, and independent body.[13] Originally reporting directly to the Presidency of the Republic, within less than a decade, that institutional bond was transferred to the Ministry of Science, Technology and Innovation (MCTI), which was formed to oversee, among other things, national space policy.[14]

As a comparison, Argentina's space activities followed a quite similar path: Argentina's National Commission for Space Research (CONAE) was also created in the early 1960s and incorporated into the armed forces, and at the beginning of the 1990s was recreated as a civilian body.[15] The difference was that CONAE received growing financial and political investments during the 2000s[16].

Like Argentinian CONAE, Brazil's space agency has the overall task of promoting development of space activities in the national interest.[17] Despite having its head office and forum located in Brasilia's Federal District, AEB is better known for using the world famous Alcântara Launching Center (CLA), which is tied to the COMAER (Aeronautics Command) in the state of Maranhão, in Brazil's Northeast Region.[18] This base's overarching function is to ensure satellite-launching vehicles (SLVs) can be safely sent to space.

The Agency's most important project in the SLV area is the *Projeto VLS-1*, which conveys the strategic import of producing a national vehicle of such kind – though for pacific ends.[19] Figuring as one of FAB's leading projects, it nevertheless aims to strengthen the national aerospace *defense*

Ivanil E. Barbosa, *Carta aberta do SindCT ao Ministro Aldo Rebelo* (São José dos Campos: SindCT, 4 September 2015), http://www.sindct.org.br/files/Carta%20Aberta%20Aldo%20Rebelo.pdf (accessed 22 September 2015), 1.

[9] Lopes Filho, *Nas asas da história*, 23.

[10] Barbosa, *Carta aberta*, 1.

[11] Brazil, "Federal Constitution" (Brasília: Presidency, 1988). Going further in the juridical field, Space Law is not a novel theme in Brazil; it is listed in the exhaustive hall of the traditional Brazilian Universal Decimal Classification of Law. *Vide*: Doris de Q. Carvalho. *Classificação Decimal de Direito*, 4th Ed (Brasília: Presidency, 2002), 10, 46.

[12] Brazil, "Law nº 8.854/1994" (Brasília: Presidency, 10 February 1994).

[13] Brazil, "Law nº 8.854/1994"; Brazil, "Decree nº 4.718/2003" (Brasília: Presidency, 4 July 2003).

[14] Brazil, "Law nº 8.854/1994." Brazil, "Decree nº 4.718/2003." Brazil, "Decre nº 5.886/2006" (Brasília: Presidency, 6 September 2006).

[15] Daniel Blinder, "Argentina Space: Ready for Launch," *Space & Defense*, Vol. 8, No. 1 (Spring 2015), 34-46.

[16] Blinder, "Argentina Space," 36.

[17] Brazil, "Law nº 8.854/1994"; Brazil, "Decree nº 4.718/2003."

[18] Brasil, "Decree nº 4.718/2003."

[19] The technicians that died in the CLA accident in 2003 were working exactly at this project. For more details: "Acidente em Alcântara começou com incêndio, diz Comandante", *Folha Online*, 23 August 2013, http://www1.folha.uol.com.br/folha/ciencia/ult306u9906.shtml (accessed 22 September 2015). Brazil, *PNAE*, 11.

industry.[20] Through VLS-1, the civil and military spheres coalesce more and more towards a single purpose: make a satellite and successfully place it in geostationary orbit, so it can provide across Brazil's regions broadband Internet access and secure military communications.[21] Even so, due to sizeable budget cuts in the PEB during 2015, VLS-1 runs the risk of being paralyzed.

It is worth noting that AEB is the central body in the National System of Space Activities Development (SINDAE)[22], being a coordinator of it and its titular leader.[23] This system exists to allow military and private institutions to participate actively in the development of Brazilian space activities. SINDAE comprises three formal classes of organs: central, sectoral, and participant.[24] Concerning the composition of that second class – responsible for sector coordination and execution of actions contained in the PEB – a strong demand for greater dialogue between the civil and military spheres can be perceived in national legislation, the military sphere being represented by DCTA (Aerospace S&T Department under the Brazilian Air Force).

Figure 1 presents SINDAE's composition, by which it can be observed that both launching centers – at Alcântara and Barreira do Inferno – and the IAE are organs attached to the Air Force Command's DCTA.

There are examples showing how SINDAE components relate to each other. Although the space and defense industries are suffering with high budget cuts, one of the Brazilian projects with potential for commercial use is the Microsatellite Launch Vehicle (VLM) project, as a result of the successful partnership between IAE and the German Aerospace Center (DLR).[25] Currently VLM seeks, in the national aerospace industry, companies able to manufacture the rocket to put it on the international market and increase the pace of production. As part of the Academy, the AEB sponsors some programs to encourage relevant space research, including scholarships and guided tours.[26]

As shown in **Figure 1**, AEB is SINDAE's central organ, and because of that it has in its basic structure a Superior Council, which is the deliberative organ responsible for approving the entry of participants in the system.[27] The relation between civil and military spheres is nominally strengthened here. However, despite the fact that SINDAE's central organ is an independent civil agency, the system's functioning depends on partnership with the military. In this vein, of nineteen representatives who are below the President of AEB on the Advisory Board, only two come from Universities and Industry, and five are related to the military sector. The Ministry of Defense (MD), the former Presidency of the Republic's Institutional Security Cabinet (GSI) – now called *Casa Militar* – and the commands of Navy, Army and Air Force are also present in SINDAE.[28]

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[20] Luiz Guilherme Sá da Silva, "Indústria de defesa aeroespacial e os projetos da Força Aérea Brasileira", *Revista ADESG*, Vol. 267, No. 2 (2012): 4-5.

[21] Brazil, *Estratégia Nacional de Ciência, Tecnologia e Inovação (ENCTI): 2012-2015* (Brasília: MCTI, 2012), 16.

[22] By the 4th article of the Law nº 8.854/1994, the former President Fernando Henrique Cardoso instituted – by Decree nº 1.953/1996 – the Brazilian space system, whose incumbency is to organize the execution of activities aiming at space development in the national interest. See: Adilson da S. Lemos Junior, *Implantação do Programa Estratégico dos Sistemas Espaciais Brasileiro* (Rio de Janeiro: ESG, 2014), 16; Brazil, "Law nº 8.854/1994"; Brazil, "Decree nº 1.953/1996" (Brasília: Presidency, 10 July 1996), http://www.planalto.gov.br/ccivil_03/decreto/1996/D1953.htm (accessed 22 Setember 2015); Brazil, "Decree nº 4.718/2003."

[23] Brazil, *ENCTI*, 120. Brazil, *PNAE*, 7.

[24] Brazil, "Decree nº 1.953/1996."

[25] Sergio Vieira, and Sylvio Guedes, "Crise pode causar perdas irreversíveis na Defesa, dizem especialistas," *Senado Notícias*, Brasília, 17 September 2015, http://www12.senado.leg.br/noticias/materias/2015/09/17/crise-pode-causar-perdas-irreversiveis-na-defesa-dizem-especialistas (accessed 22 September 2015).

[26] AEB, "Programas da AEB", http://www.aeb.gov.br/programas-da-aeb (accessed 22 September 2015).

[27] Brazil, "Decree nº 4.718/2003." Brazil, "Decree nº 1.953/1996."

[28] Brazil, "Decree nº 4.718/2003."

The law responsible for AEB's creation also foresaw the updating of the 1994 National Policy for Development of Space Activities (PNDAE).[29] PNDAE incentivizes public-private partnership, including closer exchanges with the military. As proof, primary directives of PNDAE are rather interesting: three of them address capacity training for strategic technology of dual usage – they emphasize employment of space technology in the solution of problems like *security and defense* of national territory.[30] Also, by accentuating that space activities must necessarily promote national development, PNDAE reinforces ambitions laid out in documents representing high political consensus – the National Defense Policy (PND) and the National Defense Strategy (END).[31]

PNDAE establishes the following conceptualizations that are indispensable to understanding development of PEB:

space systems: devices meant either to operate in space or to permit space operating of equipment that will grant access to information or services;

space infrastructure: installations, systems or surface equipment, plus associated systems that provide necessary support to effective operations and usage of space systems;

space activities: systematic efforts to develop and operate space systems, as well as related infrastructure, to grant mankind expansion of knowledge about the universe; especially planet Earth and its atmosphere; and exploring, for employable ends, the availability of these new devices[32] [Emphasis in original, our translation].

Figure 2 shows how concepts elaborated by PNDAE recognize AEB's role in supporting the military *space strategic sector*. Putting concepts in **Figure 2** to work, the Geostationary Satellite of Defense and Strategic Communications (SGDC) can be defined as a space system of both military (defense) and civil (communications) uses, to be launched in Earth orbit (geostationary) by a space infrastructure – specifically an SLV launching-center – in order to develop space *activities* of strategic value to the Brazilian state and society.

By promoting the development of *space systems* and ground infrastructure, PNDAE endeavors to implement Brazilian space activities like SGDC that can only be put into practice via a national space program such as PEB, a long-term approach with projects spanning nearly a decade (2012-2021).[33] In order to support ambitions of PEB, Brazil invested an average of R$ 385 million (about U$ 96 million) per year in space activities thru 2012.[34] Planned investment over the next ten years is approximately R$ 900 million (about US$ 225 million) per year, an increase of nearly 250 percent.[35] The SGDC alone is anticipated to cost R$ 716 million (about US$ 179 million)[36].

In 2012, the fourth version of PEB was prematurely cast due to the fact that its authors understood the federal government at the time provided salient opportunities to rethink the space program.[37] Among these opportunities was the SGDC project. Of course, PEB reality is quite different from that provided by laws and official documents. PEB maintains very strong dependence on the military sector to pay for major projects in space. PEB still suffers from poor

[29] Brazil, "Decree nº 1.332/1994" (Brasília: Presidency: 8 December 1994).
[30] Brazil, "Decree nº 1.332/1994."
[31] Brazil, "Decree nº 1.332/1994."
[32] Brazil, "Decree nº 1.332/1994."

[33] Brazil, "Decree nº 1.332/1994."
[34] As a result of currency fluctuation which is currently in Brazil, the Real-Dollar parity reached in September 2015 the highest rate in its history (1: 4). Because of this unpredictable variation, it is reported the original amount in Reais (R$). Brazil, *PNAE*, 16.
[35] Brazil, *PNAE*, 17.
[36] Brazil's Federal Senate, *Em Discussão*, Year 3, No. 10 (2014), http://www.senado.gov.br/noticias/jornal/emdiscussao/Upload/201201%20-%20marco/pdf/em%20discuss%C3%A3o!_marco_2012_internet.pdf (accessed 22 September 2015), 64.
[37] The other three are from 1996, 1998 and 2005 (Brazil, *PNDAE*), 4, 7. Brazil, *PNAE*, 3. Such statements are echoed by the Brazilian Minister of S&T: "the current stage of the country's development has demands for space applications that only a bolder set of projects can attend" (Brazil, *ENCTI*, 66 [our translation]).

management and heavy budget cuts.[38] Regarding the lack of civilian technicians and bureaucrats dedicated to the space program, consider that the first AEB-sponsored public competition only occurred in late-2014, i.e., a full twenty years after its creation.[39]

One could hope that the more military space projects were boosted, the more AEB and PEB would also be boosted. But the Brazilian armed forces have their own Strategic Space Systems Program (PESE), of which AEB is not a part.[40] While implementation of the so-called space strategic sector engendered by PND and END has indeed helped PEB and AEB, it also increased the civil agency's dependency on the military sector, as the next section seeks to demonstrate.

THE (MILITARY) SPACE STRATEGIC SECTOR: FAIR WINDS FOR THE BRAZILIAN (CIVIL) SPACE PROGRAM?

National Defense was never a pulsating theme in Brazilian political discussions because, as the saying goes, "Defense does not generate vote" ("*Defesa não dá voto*"). In 2005, the first National Defense Policy (PND) was published, followed in 2008 by the first National Defense Strategy (END) in Brazil's history. It was the first time the Brazilian state – not only its government – thought in a formal, public, and strategic way about defense in the medium and long term.

The 2012 versions of PND and END designated three sectors as "strategic" to the national defense and *development* of Brazil: nuclear, cyber, and space.[41] These three interlinked strategic sectors, moreover, transcend the partition between civil and military boundaries.[42] When the strategy documents combine nuclear, cyber, and space sectors, then "visualizing *the country itself not [any longer] depending on foreign technology* is possible – and having the three forces working in synthesis, coordinated through *monitoring that is done, too, from space"* [emphasis added, our translation].[43]

Another example of synergy between strategic objectives and different actors is the making of the Geostationary Satellite of Defense and Strategic Communications (SGDC). Besides this project, Brazilian airspace control entails dialogue between space and cyberspace, especially for the modernization of the Air Defense Operations Center (CODA) and for aircraft upgrades to the new Communication, Navigation and Surveillance/Air Traffic Management (CNS/ATM) control system and satellite navigation.[44] Although these tasks have special significance for the Brazilian Air Force (FAB), END sets specific goals and milestones for each service in the Armed Forces.

For example, the Brazilian Army must modernize its brigade modules, which requires a broad spectrum of technological means, from the least sophisticated to *the most advanced means of communication between land operations and space monitoring.*[45] This is the first indicator that the SGDC will serve not only purposes of the FAB, but the other armed forces, too, reinforcing interdependency of the strategic sectors. The Brazilian Ministry of Defense, through END, establishes *four strategic goals* and *three strategic directives* to FAB. For space as a strategic sector, the first objective and the third directive are relevant, respectively, prioritizing aerial

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[38] For an idea of AEB's annual budget, view the expected and settled values per year in: http://www.aeb.gov.br/programa-espacial/investimentos. Check also a criticism of this subject in: Barbosa, *Carta aberta*.

[39] AEB, "Concurso AEB", 2014, http://www.aeb.gov.br/concurso-aeb (accessed 12 September 2015).

[40] Lemos Junior, *Implantação*, 69.

[41] Brazil, *PND e END*, 93-7; Gills Lopes, "A emergência do tema ciberguerra: contextualizando a criação do Centro de Defesa Cibernética à luz da Estratégia Nacional de Defesa." In: *Concurso de Artigos sobre o Livro Branco de Defesa Nacional* (Brasília: Ministry of Defense, 2011), http://www.defesa.gov.br/projetosweb/livrobranco/arquivos/apresentacao-trabalhos/artigo-gills-lopes.pdf (accessed 22 September 2015).

[42] Brazil, *PND e END*, 49; Carlos Newton, "Três setores estratégicos: cibernético, espacial e nuclear," *Revista ADESG*, Vol. 273, No. 2 (December 2012), 6-7.

[43] Brazil, *PND e END*, 49; Newton, "Três setores estratégicos," 6.

[44] Brazil, *White Paper*, 203.

[45] Brazil, *PND e END*, 77.

surveillance and integrating space activities in FAB operations.[46]

With respect to the first strategic goal, END counts space as a domain – like its marine, terrestrial, and aerial predecessors – so Brazil, in order to surveil its national territory and jurisdictional waters, will have to rely on its own *platforms* and *systems* for monitoring.[47] Among other projects, here is where the SGDC enters the picture; in the absence of a one hundred percent national geostationary satellite, it is nearly impossible to exert effective surveillance.

Besides satellites, END anticipates other kinds of monitoring technologies such as satellite launching vehicles (SLVs) and intelligence aircraft.[48] These strategic tools form a "monitoring complex" by layers, called the Brazilian Aerospace Defense System (SISDABRA), administered under the Brazilian Aerospace Command (COMDABRA), with the mission of assuring sovereignty over Brazil's national airspace.[49] The development and refinement of SISDABRA will mark Brazil's bid for national autonomy, specifically as it relates to foreign systems such as the U.S. Global Positioning System (GPS).[50] Once operative, the SGDC should be a key element in SISDABRA.

As to its third strategic directive, END states that FAB's organic functions ineluctably depend on monitoring via space. In this sense, development of national SLVs shall serve as a broad instrument, not only to support foreign *space programs* but to develop national technology for the design and manufacturing of missiles.[51]

In geopolitical terms, the Ministry of Defense accepts that the possession of long-range missiles – derived from the use of rockets, for example – remains a crucial factor in international relations, sharply altering the calculus for national defense and security.[52] With this presumption, developing SLVs can cause a spillover effect in other policy areas as well as branches of the armed forces. This, indeed, makes the Brazilian Army's case; the Army is already developing the missile and rocket system *ASTROS 2020*, costing R$ 1.1 billion (about U$ 277 million).[53]

Now, since PND and END assign implementation of the strategic space sector to FAB, nothing is more logical than having information and technology sharing among sectors. But in proposing three strategic sectors (nuclear, cyber, and space) for both defense and national development, the Ministry of Defense assigned each of the three armed services responsibilities for boosting them.[54] There are historical and logistical reasons behind this distribution of competencies. For example, the Brazilian Navy has been developing the nuclear-powered submarine project since 1979.[55] So nothing is more reasonable than having the nuclear strategic sector borne by the Navy while the space strategic sector goes to the FAB's stewardship. Residually, then, the cyber strategic sector was awarded to the Brazilian Army, which in any case already possessed expertise with electronic warfare.

Figure 3 presents this distribution of roles and missions, identifying the three strategic sectors according to END. In implementing the national defense strategy, however, there were two major surprises, namely, the economic crisis and the relative lack of civil or business interest in the space area.[56]

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46 Brazil, *PND e END*, 85-91.
47 Brazil, *PND e END*, 85.
48 Newton, "Três setores estratégicos", 7.
49 Brazil, *PND e END*, 86. Brazil, "Decreto-Lei nº 1.778/1980" (Brasília: Presidency: 18 March 1980), http://www.planalto.gov.br/ccivil_03/decreto-lei/1965-1988/Del1778.htm (accessed 22 September 2015).
50 Brazil, *PND e END*, 86.
51 Brazil, *PND e END*, 91.
52 Brazil, *White Paper*, 38.
53 Brazil, *White Paper*, 200. For more information about ASTROS 2020, visit: http://www.epex.eb.mil.br/index.php/projetos/astros-2020.html.
54 Brasil, *White Paper*, 68-9; Newton, "Três setores estratégicos", 7.
55 "Submarino nuclear brasileiro: Quo Vadis?", *Poder Naval*, 29 December 2008, http://naval.com.br/blog/destaque/submarinos/submarino-nuclear-brasileiro-quo-vadis (accessed 22 September 2015).
56 There are some rare exceptions, such as Embraer, the Grande ABC Local Productive Arrangement (APL) of

With regard to the political and economic crisis, it can be said that its harbinger occurred in late 2014 – an election year in Brazil – with serious budgetary consequences in mid-2015. This caused many investment losses and subsequent cancellation of governmental programs and projects, including strategic ones.

For example, budget cuts in the Defense Ministry were 25%.[57] Specifically in regard to PEB, the most important sign of the economic crisis appeared in July 2015, when the Federal Administration waivered a ten-year agreement with Ukraine, extinguishing thereby the binational company Alcântara Cyclone Space (ACS), which was intended "to launch satellites aboard Ukrainian Cyclone-4 rockets from Brazil's Alcântara spaceport..."[58] It is noteworthy that the Brazilian-Ukraine partnership had already consumed R$ 1 billion (about U$ 250 million).[59]

Besides its own organizational budget cuts, PEB had to adjust to space strategic sector cuts because, as seen, the interrelationship is very close. However, among space strategic sector priority projects – SLVs; satellites; satellite-based communications, command and control technologies; and satellite-driven geographic information systems – if there is one that should *not* be canceled amid the crisis, it is precisely the SGDC. This is justified by reasons analyzed in the following section.[60]

Defense (http://www.industriadefesaabc.com.br) and the Brazilian Association of Defense and Security Industries Materials – Abimde (http://www.abimde.org.br).

[57] Roberto Godoy, "Corte na Defesa é a metade do previsto," *O Estado de S. Paulo*, 6 July 2015, http://politica.estadao.com.br/noticias/geral,corte-no-ministerio-da-defesa-e-a-metade-do-previsto,1701021 (accessed 22 September 2015).

[58] Brazil, "Decree nº 8.494/2015" (Brasília: Presidency: 24 July 2015). "Brazil's space programme: ten, nine, tem," *The Economist*, São José dos Campos, 8 Aug. 2015, http://www.economist.com/news/americas/21660572-rocket-science-hard-rocket-diplomacy-harder-ten-nine-ten (accessed 22 September 2015).

[59] Barbosa, *Carta aberta*, 1.

[60] Brazil, *PND e END*, 93.

CASE STUDY: THE MAKING OF THE GEOSTATIONARY SATELLITE OF DEFENSE AND STRATEGIC COMMUNICATIONS (SGDC)

This case study of the making of Brazil's first geostationary satellite has two main objectives, namely: i) to demonstrate the need for a fully national satellite for Brazilian strategic communications; and ii) to support the main hypothesis that there is no functioning transition model of space capabilities from the military to civil sphere in Brazil.

Brazil decided to manufacture the Geostationary Satellite of Defense and Strategic Communications (SGDC) in 2011 in order to address the national security demand for strategic – civil and military – communications.[61] As its name foretells, it is a *geostationary* satellite, that is to say, its operating orbit – navigating above Earth's equator – is almost 36,000 km.[62] This kind of satellite contrasts with the so-called low earth orbit ones on altitudes between 500km and 800km.[63]

According to France and Sellers, a general rule for this type of satellite is that geostationary constellations employ three or more satellites with ground infrastructure and cross-linking to accomplish global coverage.[64] This is not the case for SGDC as it is only one satellite that can map a portion of the globe (across the longitudinal range of Brazil) without the process of triangulating. This ends up being one of the SGDC's best advantages: provision of independent strategic and civil communications for Brazil without the cost of a full constellation borne by other space powers.

In light of PEB, the SGDC was a structuring and mobilizing project the implementation of which was on schedule until the last day of 2014 when it

[61] Brazil, *PNAE*, 9.

[62] Federal Senate, *Discussão*, 64.

[63] Newton, "Três setores estratégicos," 7.

[64] Martin E. B. France and Jerry Jon Sellers, "Real constraints on spacepower." In: *Toward a theory of spacepower: select essays*, Edited by Charles D. Lutes et al. (Washington, DC: NDU Press, 2011), 91.

was postponed to 31 December 2016.[65] In 2012, all forty geostationary satellites operating in Brazil were actually foreign. Brazilian enterprises were limited to supplying ground equipment and antennas for control stations serving television, telephony, tracking, and broadband Internet, as well as *military activities* and image generation.[66] The independent creation of a satellite with strategic attributes – combined with the custom that international technological cooperation is usually not marked by bountiful sharing of valuable information – would benefit Brazil, granting it autonomy in monitoring its sovereign territory.[67]

Though the Brazilian Space Agency (AEB) foresees the possibility of international cooperation, it is only plausible by means of working through the Ministry of Foreign Affairs and taking into account MCTI (Ministry of Science, Technology & Innovation).[68] For example, one of the main AEB initiatives for international cooperation was the Brazilian-Ukranian enterprise ACS, demonstrating that international cooperation is – or was until July 2015 – vital to the development of PEB, with or without SGDC.[69]

As to management, the SGDC project deals with two organs: the steering committee and the executive group. The former is led by Brazil's Ministry of Communications (MC) and includes the Ministry of Defense (MD) as well as MCTI.[70] The executive group is comprised of the following entities: Telebras, MD, MC, AEB, and the National Institute for Space Research (INPE).[71] Telebras, beyond presiding over the executive group, is also responsible for running, jointly with MD, the SGDC operation after its launch while AEB – specifically its Satellite Directorate, Applications and Development – will retain intellectual property rights on the satellite's technology transfer.[72]

For SGDC's manufacturing *per se*, a new enterprise called Visiona Tecnologia Espacial emerged in 2012 from the cooperation between Telebras and Embraer Defense and Security.[73] Once again, the civil-military component is highlighted here in order to demonstrate how Brazilian space aspirations are indeed dependent upon high profile projects connected to the military and national defense.

As shown in **Figure 4**, the public/government sector – represented by Telebras – oversees arrangements with private enterprise to implement SGDC's manufacturing. The present idea is that Brazil's Defense Industrial Base (BID) will be stimulated and rewarded in the production of d*efense products* (PRODE).[74] Indeed, it is a

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[65] Brazil, *ENCTI*, 119; Brazil, *PNAE, 12.* Brazil, "Decreto nº 7.769/2012" (Brasília: Presidency, 28 June 2012), http://www.planalto.gov.br/ccivil_03/_Ato2011-2014/2012/Decreto/D7769.htm (accessed 22 September 2015); Brazil, "Law nº 12.598/2012" (Brasília: Presidency, 21 March 2012); Brazil, *ENCTI*, 68; Federal Senate, *Discussão*, 64. Brazil, "Decree nº 8.153/2013" (Brasília: Presidency, 12 December 2013), http://www.planalto.gov.br/ccivil_03/_Ato2011-2014/2013/Decreto/D8153.htm (accessed 22 September 2015).

[66] Brazil, *PNAE*, 9. Federal Senate, *Discussão*, 63.

[67] Brazil, "Decree nº 1.332/1994."

[68] Brazil, *PNDAE*, 11. Brazil, "Decree nº 4.718/2003." Brazil, *ENCTI*, 12.

[69] Brazil, *ENCTI*, 66.

[70] Brazil, "Decree nº 7.769/2012."

[71] Attached to MC, the "new" Brazilian Telecommunications S.A. (Telebras) is a mixed economic society reinstated in 2010, after being privatized in 1998. INPE "is fit to do scientific researches, technological development, operational activities and the training of human resources in the fields of Space and Atmosphere Sciences, Earth Observing, Weather Forecast and Climate Studies, and Space Technology and Engineering." See: Brazil, "Decree nº 5.886/2006," (Brasília: Presidency, 2006), Art. 21 [Our translation]).

[72] Brazil, *ENCTI*, 67-68. Brazil, "Decree nº 4.718/2003", Art. 13, II.

[73] Embraer Defense and Security is a segment of Embraer S.A. – former Brazilian Aeronautic Enterprise S.A. – privatized in the Itamar Franco administration. It is "the only national enterprise amongst the hundred greatest in the industry of defense ranking" (Federal Senate, *Discussão*, 72 [Our translation]). Brazil, *PNDAE*, 10; Federal Senate, *Discussão*, 64; Visiona Espacial, "Quem somos," http://www.visionaespacial.com.br/sobre.html (accessed 22 September 2015).

[74] PRODE is "every good, service, work or information, including weaponry, ammunition,

necessary action, considering that according to the Brazilian Senate, "since Embratel's privatization, satellite services used by the Armed Forces are supplied by private enterprises".[75] Visiona's creation directly addresses three of PEB's strategic lines of action, namely, commit industry at all stages of space project development; encourage the creation of integrator enterprises; and stimulate critical technologies.[76] Nevertheless, the joint venture, Visiona, is being widely criticized – especially by the Brazilian Union of Federal Civil Servants in Aerospace Sector Science and Technology (SindCT) – in the sense that it "is acting only as an intermediary in the acquisition, entirely abroad, of SGDC, throwing out of its development not only INPE, but the whole domestic industry which serves PEB."[77]

Unlike most Brazilian space programs, the SGDC project might yet survive threats of cancelation and reach its goals. However, negotiations for acquisition of both components and satellite launch are in train with foreign powers: Franco-Italian Alenia Space (TAS) and the French enterprise Arianespace.[78] If the SGDC project was designed, among other purposes, to strengthen the incipient Brazilian space industry, in practice it is doing the opposite: strengthening foreign defense companies by providing stimulative contracts at the expense of national enterprises central to the future autonomy of Brazil.[79]

CONCLUSION

Brazil is part of a select group of nations in possession of a strategic space program, but there are several factors that limit this program short of a viable strategic space *capability*, which comprises satellite operations, manufacture, and launch.[80] Among the obstacles, this article highlighted the following: strong technological and logistical dependence in relation to the military sector and consequent deficiencies in human capital, particularly among Brazilian Space Agency (AEB) personnel; PEB mismanagement of resources, especially those dedicated by law to development of the national space industry; premature project cancellations before an endeavor can reach useful milestones; and substantial recurring budget cuts. Added to this are deficiencies in regional cooperation – even interest – for pooling resources to advance space programs during times of economic crisis in South America.[81]

After the demise of the ACS agreement with Ukraine, Brazil should consider a medium-term strategic partnership with any country at a more advanced stage in the space strategic sector. One possible candidate is Argentina, which, while facing political and economic crises for years, nevertheless shepherds a more organized space program than Brazil's and already operates its

transport means, uniforms, and materials of individual or collective usage for activities intended for defense, with a caveat for those of administrative usage" (Brazil, "Decree nº 7.769/2012").

75 Federal Senate, *Discussão*, 63.

76 Brazil, *PNDAE*, 11. In the realm of PEB, the so called critical technologies are split in: leveling, being the ones already dominated by the nations, and hence easily obtained; the advanced, being currently developed by nations and thus hardly obtained; and disruptive, being those sprung from revolutionized technological innovations, yet to be pursued by the PEB (Brazil, *PNDAE*, 12), under AEB's coordination (Brazil, *ENCTI*, 66).

77 Barbosa, *Carta aberta*, 2 [Our translation].

78 Embraer, "Geostationary satellite will ensure the security of Brazilian communications", 28 November 2013, http://www.embraer.com.br/en-us/imprensaeventos/press-releases/noticias/pages/satelite-geoestacionario-vai-garantir-a-seguranca-das-comunicacoes-brasileiras.aspx (accessed 22 September 2015).

79 Isso se torna ainda mais notório ao analisar o recém-publicado Edital de Seleção Pública encabeçado pelo MCTI e pela AEB, que prevê a contratação de empresas brasileiras para apoiar projetos referentes à transferência das tecnologias previstas no Acordo de Transferência de Tecnologia Espacial firmado entre a AEB e a TAS. Cf.: "Edital de Seleção Pública MCTI/AEB/FINEP/FNDCT – Subvenção Econômica à Inovação – Transferência de Tecnologia do SGDC – 01/2015" (Brasília: FINEP, 15 September 2015).

80 Lopes Filho, *Nas asas da história*, 24.

81 To get an idea of this lack of South American interest, just remember that the UNASUR considered the creation of a regional space agency, but the project was not even drafted. See: http://www.infoespacial.com/latam/2011/11/13/noticia-los-ministros-de-defensa-de-unasur-plantean-crear-una-agencia-espacial-conjunta.html.

own geostationary satellite.

Major powers are working behind the scenes to fill the vacuum left by Ukraine. For example, Russia has been angling to launch its new *Angará* rocket from the Alcântara Launch Center (CLA). Similarly, China wants to expand its ongoing partnership with Brazil through the China-Brazil Earth Resources Satellite (CBERS), in order to build a binational partnership for its *Longa Marcha* family of launchers. Despite good intentions toward PEB as well as the desire to launch satellites from Brazil, a regulatory agreement on technological cooperation with the United States remains to be signed so that satellites with U.S. components may be launched from Brazilian soil; without agreement, there is no hope of a commercial joint project in the space sector.

Now, with the Brazilian Complete Space Mission (MECB) abandoned, it is expected that the SLV-1 Project is on a slower development path than SGDC. In the midst of the current economic crisis, the German-Brazilian Microsatellite Launch Vehicle (VLM) can be considered the design with the greatest commercial potential. Aspirations of stimulating a Defense Industrial Base (IDB), and specifically a robust space industry, conflict with economic demands now facing the country. But this financial reality is not exactly new, as "It is easy to see that the Brazilian government does not have available funds for years when compared with other major centers of space programs."[82]

Given the current crisis and lack of public investment, academic-university partnerships present an excellent opportunity, not only to reduce research and development (R&D) costs but to create a space culture among future Brazilian scientists and produce homegrown technology. Of course, this is not a solution to the PEB barriers, but it is a medium-to-long-term alternative that Brazil needs to seriously consider.

As seen, two major initiatives of PEB concerned (i) launching satellites from national soil and (ii) aligning the National Policy for Development of Space Activities (PNDAE) with broader priorities of the national budget. Only after these accomplishments can it be said that there is genuine geopolitical and strategic enthusiasm for augmenting Brazilian autonomy through space exploration.[83] Building Brazil's first geostationary satellite (SGDC) coheres with this sympathetic interpretation of PEB and also with the National Defense Policy (PND) and the National Defense Strategy's (END's) convergence on the Brazilian space strategic sector. Ironically, reducing space dependency on Brazil's own military programs, as well as foreign corporate champions, can go a long way toward supporting Brazil's national autonomy through independent strategic monitoring and communications.

As SINDAE's central organ, AEB endeavors, through space activities, to integrate and *coordinate* civil and military interests. In practice, authentic coordination is hampered by AEB's near total dependence on the military. SGDC exemplifies Brazil's imbalanced civil-military relations when it comes to the strategic space sector – crucial for national development as well as national defense. The space program is codified in official documents under both priorities of the Brazilian government, but SGDC, like other large projects in technological and budgetary terms, is spearheaded by a defense company.[84] In addition, AEB presides over Brazil's space complex by contracting with foreign companies for acquisition and, more ominously, for the very launch of SGDC.

Space is indispensable for Brazil; it "is, and will continue to be, a critical environment for both civilian and military operations."[85] In Brazil's case, however, the strategic space sector is out of balance. Given the current state of affairs, the perplexing underperformance of Brazil space is likely to continue beyond the economic crisis, that is, until lawmakers can address the political-institutional causes of its arrested development.

[82] Lemos Junior, *Implantação*, 23 (our translation).

[83] Brazil, *PNDAE*, 10.

[84] Brazil, *ENCTI*, 65.

[85] Brazil, *PNDAE*, 9. Stephen Shea, Mathew Johnson, and Alfredo Zurita, "Terror on High: Deterring ASAT," *Space & Defense*, Vol. 8, No. 1 (Spring 2015): 60-8.

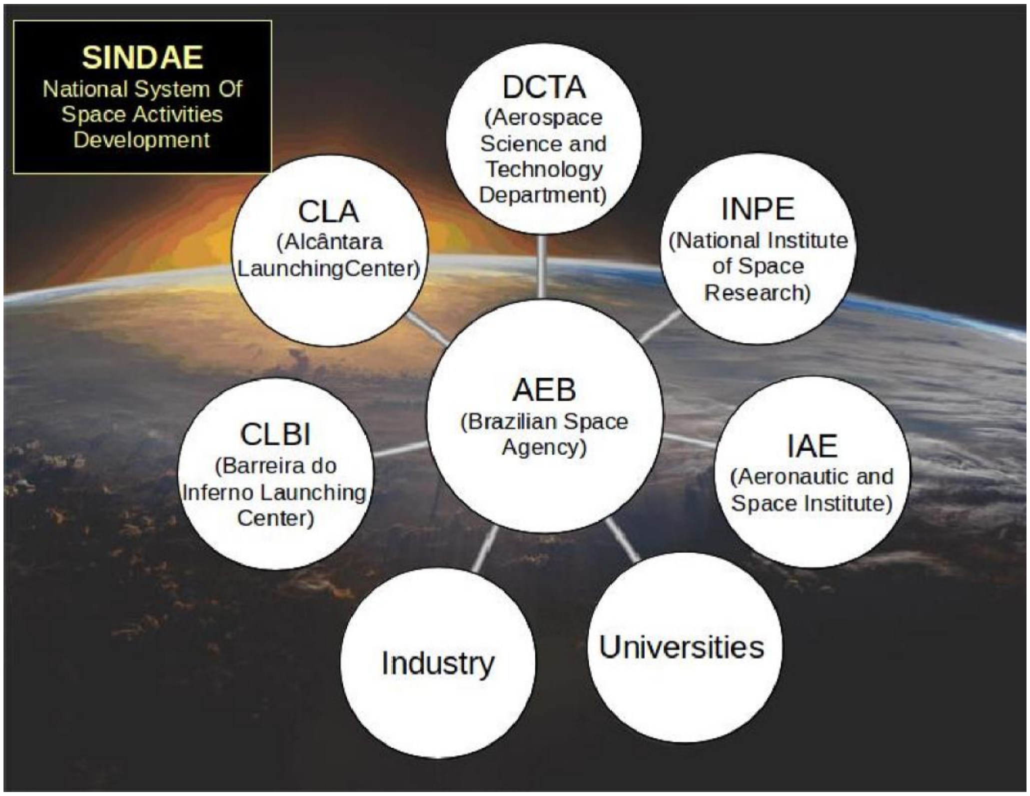

Figure 1 – SINDAE's composition
Source: http://www.aeb.gov.br/wp-content/uploads/2013/03/manual_identidade.jpg (with adaption).

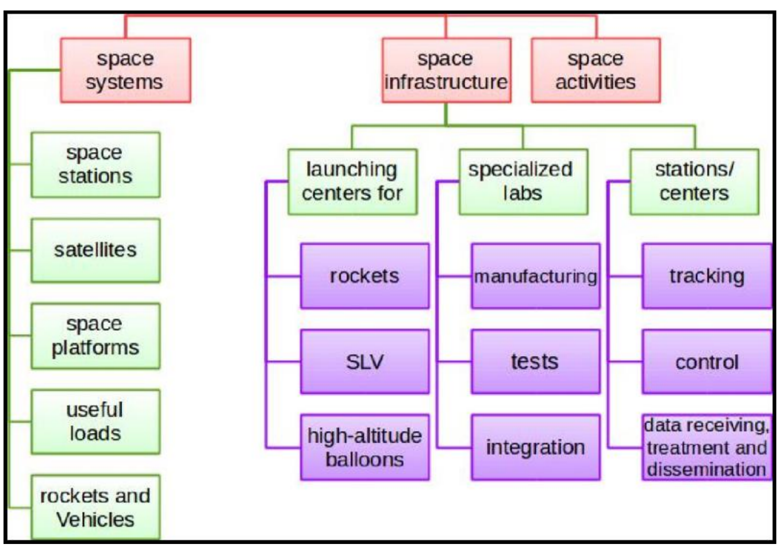

Figure 2 – Arch concepts held by PNDAE
Source: Vilar Lopes, "To Infinity and Beyond", 183.[1]
Legend: SLV = satellite-launching vehicle.

[1] Gills Vilar Lopes, "To Infinity and Beyond! AEB and the Case of Geostationary Satellite in Light of the Space Strategic Sector," *Coleção Meira Mattos – Revista das Ciências Militares*, Rio de Janeiro, Vol. 9, No. 34 (Jan./Apr. 2015): 177-88.

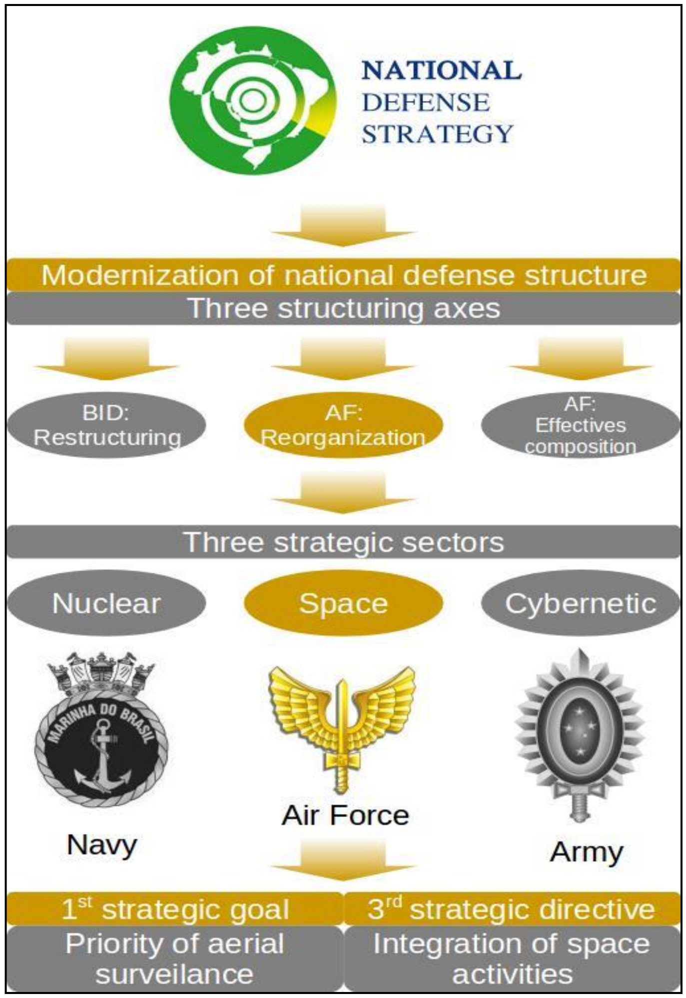

Figure 3 – Strategic Sector (END)
Source: Vilar Lopes, "To Infinity and Beyond," 181 (with adaptation).[2]
Legend: BID = Defense Industrial Base; AF =Armed Forces.

[2] Gills Vilar Lopes, "To infinity and beyond," 177-88.

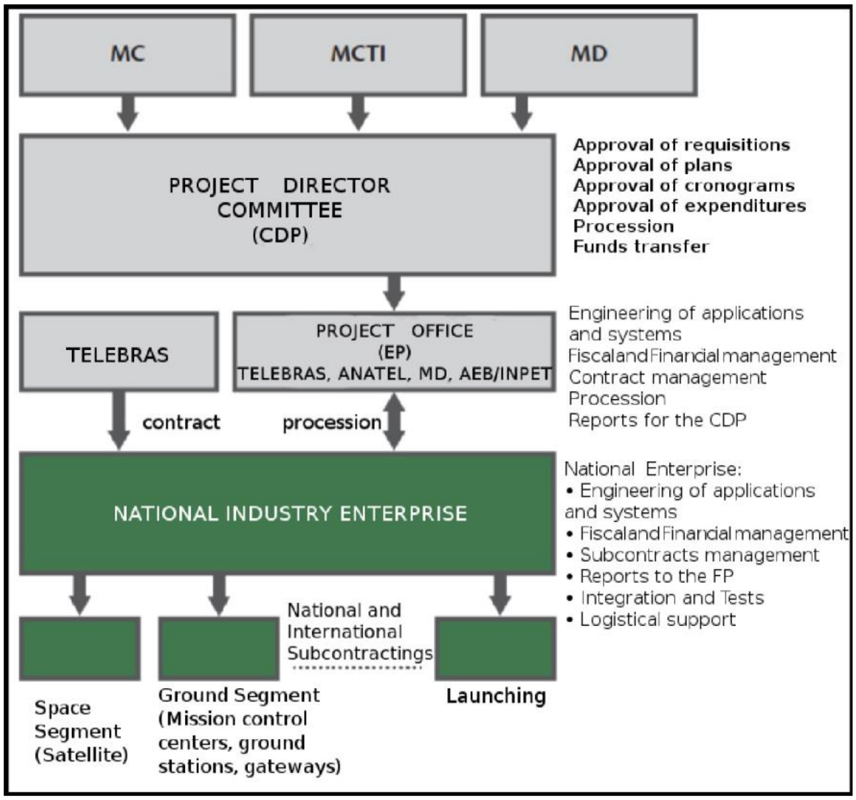

Figure 4 – Project and attribution structure on the SGDC Program
Source: Brazil, *ENCTI*, 206.

APPENDIX A - Acronyms and Abbreviations

Acronym/abbreviation	Meaning (in English)	Translation (if applied)	Nature
Abimde	Brazilian Association of Defense and Security Industries Materials	Associação Brasileira das Indústrias de Materiais de Defesa e Segurança	civil
ACS	Alcântara Cyclone Space		civil
AEB	Brazilian Space Agency	*Agência Espacial Brasileira*	Civil
BID	Defense Industrial Base	*Base Industrial de Defesa*	military
CBERS	China-Brazil Earth Resources Satellite	*Satélite Sino-Brasileiro de Recursos Terrestres*	Civil
CLA	Alcântara Launching Center	*Centro de Lançamento de Alcântara*	military
CNS/ATM	Communication, Navigation and Surveillance/Air Traffic Management		military
Cobae	Brazilian Commission for Spatial Activities	*Comissão Brasileira de Atividades Espaciais*	military
CODA	Air Defense Operations Center	*Centro de Operações de Defesa Aeroespacial*	military
COMAER	Aeronautics Command	*Comando da Aeronáutica*	military
COMDABRA	Brazilian Aerospace Command	*Comando de Defesa Aeroespacial Brasileiro*	military
CONAE	National Commission for Space Research	*Comisión Nacional de Actividades Espaciales* (Argentina)	Civil
DCTA	Aerospace Science and Technology Department	*Departamento de Ciência e Tecnologia Aeroespacial*	military
DLR	German Aerospace Center	*Deutsches Zentrum für Luft- und Raumfahrt*	Civil
EMFA	Major-State of Armed Forces	*Estado-Maior das Forças Armadas*	military
END	National Defense Strategy	*Estratégia Nacional de Defesa*	military
ESA	European Space Agency		civil
FAB	Brazilian Air Force	*Força Aérea Brasileira*	military
GPS	Global Positioning System		civil

GSI	Presidency of the Republic's Institutional Security Cabinet	*Gabinete de Segurança Institucional da Presidência da República*	civil-military
IAE	Aeronautics and Space Institute	*Instituto de Aeronáutica e Espaço*	military
INPE	National Institute for Space Research	*Instituto Nacional de Pesquisas Espaciais*	civil
ITA	Aeronautics Institute of Technology	*Instituto Tecnológico de Aeronáutica*	military
LBDN	Defense White Paper	*Livro Branco da Defesa Nacional*	military
MC	Ministry of Communications	*Ministério das Comunicações*	civil
MCTI	Ministry of Science, Technology and Innovation	*Ministério da Ciência, Tecnologia e Inovação*	civil
MD	Ministry of Defense	*Ministério da Defesa*	military
MECB	Complete Brazilian Space Mission	Missão Espacial Completa Brasileira	military
NASA	National Aeronautics and Space Administration		civil
PEB	Brazilian Space Program	*Programa Espacial Brasileiro*	civil
PESE	Strategic Space Systems Program	*Programa Estratégico de Sistemas Espaciais*	military
PNAE	National Program of Space Activities	*Programa Nacional de Atividades Espaciais*	civil
PND	National Defense Policy	*Política Nacional de Defesa*	military
PNDAE	National Policy for Development of Space Activities	*Política Nacional de Desenvolvimento das Atividades Espaciais*	civil
SAE	Secretariat of Strategic Affairs of the Presidency of the Republic	*Secretaria de Assuntos Estratégicos da Presidência da República*	civil
S&D	search and development		civil-military
SGDC	Geostationary Satellite of Defense and Strategic Communications	*Satélite Geoestacionário de Defesa e Comunicações Estratégicas*	civil-military

SINDAE	National System of Space Activities Development	*Sistema Nacional de Desenvolvimento das Atividades Espaciais*	civil-military
SindCT	Union of Federal Civil Servants in Aerospace Sector Science and Technology	*Sindicato Nacional dos Servidores Públicos Federais na Área de Ciência e Tecnologia do Setor Aeroespacial*	civil
SISDABRA	Brazilian Aerospace Defense System	*Sistema de Defesa Aeroespacial Brasileiro*	military
SLV	satellite-launching vehicle		civil-military
SNI	National Information Service	*Serviço Nacional de Informações*	military
TAS	Thales Alenia Space		civil
Telebras	Brazilian Telecommunications S.A.	*Telecomunicações Brasileiras S.A.*	Civil
VLM	Microsatellite Launch Vehicle	*Veículo Lançador de Microssatélite*	civil-military

Meeting Growth Challenges of Mexico Aerospace: The Querétaro Cluster

Mónica Casalet

Growing the Aerospace sector in Mexico requires multilevel agreement between original equipment manufacturers (OEMs), including foreign companies, and national and sub-national governments to stimulate programs and instruments for sector growth. In addition, space for local learning must be cultivated within a process of production organized hierarchically and highly regulated on the international level. The case of the Queretaro cluster is important due to the density of networks created, extensive public-private collaboration, and the emergence of specialized institutions to train and shape highly skilled (professionals and technicians) in the aerospace industry. Ultimately, there remains an important vacuum to fill in the future, in particular, integration of Mexican small and medium-size enterprises (SMEs) in the international value chain of the sector.

High technology in the design and manufacture of products within the aerospace industry (AI), combined with international certification, encourages centralized management and close business-government relationships for companies looking to compete in the global economy.[1] Domestic concentration of the industry is very high; in every subsector there are but few competitors. Aeronautics and astronautics demand heavy investment up front and are characterized by exceptionally long production cycles. Financing product development is a critical factor for companies' success, which affects not only small suppliers but also the big contractors, although the latter have more possibilities to share risks and costs.

From the beginning, AI has been considered strategic by national governments, especially with frequent and close interdependence between the industry's civil and defense markets, where state support and market protection have functioned as instruments for organization and financing. Widespread national efforts to maintain technological development and the role of high salaries for attracting specialized human capital lead to globalization of the sector: new emerging countries line up to make an incursion as manufacturers or as assemblers along the AI value chain. Evolution of the global aerospace industry has become a kind of microcosm for understanding the national politics behind strategic international development. In emerging markets as well as industrialized countries, the aerospace sector is supported by government strategies, which have nurtured strong commercial support (on quality, price, and service) to sustain this industry.

Expanding attention towards emerging markets for both aerospace products and services represents a growth opportunity for the sector globally as well as emerging countries. New national players in the sector have become conversant in specialized production processes involving multidisciplinary discoveries; an accelerated innovation process facilitated by novel management methods; and multisector spillover applications available in general platforms.[2] Advanced manufacturing within industrialized countries contributed to a global paradigm for AI in the organization of production and institutional structure. This triggered multiple political strategies oriented towards the development of R+D programs and reinforcing approval of public funds to stimulate research—in close collaboration with productive sectors—all while increasing industrial competitiveness.

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[2] Roco, M., W. S. Bainbridge, and B. Whitesides, "Convergence of Knowledge, Technology and Society," *Science Policy Reports,* 2013.

Among other things, aerospace research drove applications of new models with a high percentage of composite materials for fuel efficiency and lower maintenance costs, and engine innovation to diminish noise, fuel consumption, and carbon emissions. At the same time, institutional structure became dynamic with new modes of professional and technical training to guarantee the acquisition of better skilled labor, which raised qualifications across a broad range of workers and managers, as well as tapped into professional experience from retired professional personnel in developed countries with an aerospace tradition.

Construction of complex multilevel networks intertwined domestic technology in emerging regions like Latin America with the global production chain. As these networks continue to expand and deepen, emerging countries are playing an increasingly important economic role because of the opportunities they offer AI with respect to established companies, at home and abroad, as well as a growing number of small, highly innovative enterprises.[3]

DEVELOPMENT OF THE AEROSPACE SECTOR IN MEXICO

In various policy studies completed by public and private institutions within Mexico such as the "road maps," which arose to orient growth of the sector, the name, aerospace industry, was adopted even prior to growth of Mexico's aerospace production or sales.[4] The single label for the sector conceals differences in growth and consolidation among industries, including how close each has approached international technological standards and concentration of sales around a single product or platform. The structure of knowledge networks, for example, prevailing in the aeronautics versus space sub-sectors is quite distinct, the space industry being linked more with knowledge based on science while aeronautics tends toward knowledge in engineering and new materials.[5] In spite of these differences, the rapid growth of the *aeronautical* industry in Mexico contributed to sophistication of the demand for commercial space products and services, boosting the growth and institutionalization of the *space* sector.[6] The goal of this essay is to identify the advantages that AI clusters operating at the sectoral and regional level generate for Mexico's development.

In 2003, the Ministry of Economy decided to invest in the development of the *aerospace sector* in Mexico, launching a strategy to attract international companies and to facilitate their location in Mexican regions with productive and entrepreneurial maturity. The National Program for Trailblazing Companies boosted by ProMexico sought in conjunction with the Ministry's outreach to develop productive clusters

[3] In much of Latin America PME stands for *pequeña y mediana empresa* (small and medium enterprise); as in the United States, it represents a business sector with high potential for job growth and innovation, contingent upon effective public policies.

[4] The map for the technological route of AI in Mexico, was elaborated by a group of public and private organizations—ProMéxico, Consejo Nacional de Ciencia y Técnologia (Conacyt) (National Council for Science and Technology), Secretaria de Economia (SE) (Ministry of Economy), Dirección General de Aviación Civil (DGAC) (General Direction of Aviation), Federación Mexicana de la Industria Aeroespacial (FEMIA) (Mexican Federation of the Aerospace Industry), Consejo Mexicano de Educación Aeroespacial (COMEA) (Mexican Council of Aerospace Education) and Fundación Mexico-Estados Unidos para la Ciencia (FUMEC) (U.S.-Mexico Foundation for Science). Casalet, Mónica, "Chapter III-Actores Y Redes Públicas Y Privadas En El Desarrollo Del Sector Aeroespacial Internacional Y Nacional: el Clúster De Querétaro, Una Oportunidad Regional (Public and Private Actors and Networks in the Development of the National and International Aerospace Sector: the Queretaro Cluster)." *La Industria Aeroespacial. Complejidad Productiva E Institucional (The Aerospace Industry. Productive and Institutional Complexity)* (D.F., Mexico: FLACSO and Conacyt, April 2013), p. 105.

[5] Broekel, Tom, and Ron Boschma, "Aviation, Space or Aerospace? Exploring the Knowledge Networks of Two Industries in the Netherlands," *European Planning Studies* Vol. 19, No. 7 (December 2010): 1205-1227.

[6] In 2010 the Agencia Espacial Mexicana (AEM) (Mexican Space Agency) was created to guide the formation and research of the sector, and orient the formation of public-private consortiums.

of aerospace firms specifically at the state level within (federal) Mexico and linked to the world market. The arrival of investments from Canada, France, and Spain created opportunities for Mexican businesses to raise revenue and ascend the sector production chain, stimulating the income of Mexican companies. The installation in the country of world class companies such as Honeywell, Bombardier, Grupo Safran, EADS, and ITP complemented aerospace sector development policies of the national and state governments; this was especially true with respect to industrial groupings in central and northern regions. The modern Mexico Aerospace sector is now formed by companies dedicated to manufacturing, maintenance, engineering repair, design, and auxiliary services.[7] In the most recent data by ProMexico (2013), the sector registered a growth of 17.2% per year since 2004. Nowadays there are 287 companies. 28% are big companies; 43% correspond to medium-sized companies; and 29% to small and micro-businesses.

Although there is interest from companies in acquiring certification (according to international standards such as the 9100 Series), which is necessary to access the global chain of production, not all companies have this seal for quality management of systems in the aerospace sector. The AS9100 standard includes addendums for approval and handling of suppliers. The NADCAP norms managed by the Performance Review Institute (PRI) control special processes and products, besides promoting continuous improvement in industries like automobiles and aerospace. Not all Mexican companies with possibilities of participating in the chain of production have the conditions or interest, or find a viable niche in the aerospace sector, even if they have acquired manufacturing experience in the automobile industry.

Entry into the Aerospace sector requires favorable technical and production conditions for reconversion, and certification demands expenses up front for local companies to be part of the chain of suppliers, which presents an important income barrier. At the same time, Mexico subscribed to international agreements such as the Bilateral Air Security Agreement (BASA) and Wassenaar Arrangement in order to guarantee certification, confirm security of processes, and reduce expenses of local companies in the certification of products and labor.[8]

The hope was that participation in these club-like groups would attract new investments, open access to the latest technology, and increase exports. National and entrepreneurial agencies estimated the number of jobs generated at more than 31,000 professionals. The level of Mexico’s exports in 2012 rose to 5.04 billion USD, with 76% of production exported to the United States. According to data from the U.S. Department of Commerce, in 2009 Mexico supplied products for the Aerospace sector in the value of 604 million USD, marking 127% growth compared to 2006.[9] Secondary destinations for exports mapped to Germany and France, then Canada and the United

[7] Secretaría de Economía (Ministry of Economy), *Sector Aeroespacial Mexicano (Mexican Aerospace Sector)*, 2011.

[8] The accepted worldwide standard for the aerospace industry is the 9100 Series. Its application is decisive for entering the supply chain of parts and components. The 9100 Series is a model for quality management systems in the Aerospace sector based on the standard ISO 9001:2000 guideline. Its implementation is under the International Aerospace Quality Group (IAQG), which is under the Society of Automotive Engineers (SAE). This guideline emphasizes quality, security, and technology in all stages of the supply chain and is applied in all aspects both military and civilian. SE-DGIPAT, 2012 (Economy Ministry – Heavy Industry and High Technology General Directorate).
In the case of the Aerospace sector, NADCAP (National Aerospace & Defense Contractors Accreditation Program) certification is required by the main manufacturers of motors and planes for the entire network of suppliers. Obtaining NADCAP certification exempts the company from other audits by manufacturers that recognize it (SE-DGIPAT, 2012).
In 2012 Mexico joined the Wassenaar Arrangement (WA). This has two fundamental implications. One is that Mexico adheres to the non-proliferation of conventional arms; the other is it joins the club of high technology countries, which allows it access to new markets and technology. WA membership improves competitiveness and attracts investment from different sectors.

[8] SE, 2011. U.S. Department of Commerce, Bureau of the Census, 2009.

Kingdom. Meanwhile, imports for the same year were a healthy 4.36 billion USD. In 2012, investment in the sector rose to 1.3 billion USD, totaling more than 4 billion USD over the last four years.[10]

Of the strategic pillars of development for the Mexican Aerospace sector, the northeast region (Baja California, Sonora, Chihuahua) stands out: It includes more than half of the national industry specialized in electric-electronic systems and boasts a regional niche in avionics. Meanwhile the central-northern region (Mexico City, Queretaro, and Nuevo Leon) specializes in the assembly of value-added components, located near the main airports of the country, as well as repairs and maintenance of aircraft.[11] More detailed information on aerospace clusters forming in Mexico after the government's economic policy initiatives of 2003 is displayed in Table I, below.

MEXICO AEROSPACE: TOWARD A NEW MODEL OF GOVERNANCE BASED ON INTER-INSTITUTIONAL COLLABORATION

In the creation of productive aerospace clusters across different industrialized countries, a distinct geographic space draws companies, suppliers, research centers, and professional and technical training institutes, together with support undertaken by national and sub-national governments. Intermediary organizations link the various elements of an aerospace cluster, building a mutual field of influence, the strength of which depends upon the density of established links connecting production, research, and training of specialized labor. In Mexico's case, despite a decade of policy efforts to develop the Aerospace sector, the public-private framework is still incipient. Strong microeconomic differences place barriers to learning among companies; some do not have the minimum competitive thresholds to take advantage of positive externalities cultivated by government. Again, from the mid-2000s, public institutions, entrepreneurial partnerships, and state governments promoted technology development and constructive competition, looking to combine relationships of cooperative partnership and market incentives to support the Aerospace sector. In this context, the needs of state and local companies are served when they acquire new knowledge and become part of a high-technology system of production; international companies meanwhile seek new investment opportunities with lower costs of production and competent labor, not to mention the incentive of having the American market close by.

The line of action of public policies since 2003 has been oriented towards mobilizing new instruments created and executed by the 'Secretaria de Economía' (SE) (Ministry of Economy); Conacyt; NAFIN; and Pro Mexico. Meanwhile, international organizations such as BID (Inter-American Development Bank); the OCDE (Organization for Economic Cooperation and Development); and PNUD (UN Development Program) promoted upgrades in production standards, supported decentralization and competition among financial sources for creation of aerospace clusters, and stimulated training of specialized engineers in the sector.

The foresight, at both public and private levels, to plan the growth of a sector, rather than a single firm anointed as aerospace champion for Mexico, was remarkable, perhaps unprecedented in the country's development strategy. Apart from sparking collaboration on framing challenges and determining priorities for the regions among public and private actors, universities, and public research centers, a new, dynamic market for intermediary organizations was created.[12] On the state and sectoral levels this new breed of firm thrived in the interstices between traditional companies, supplying communication channels and negotiating structures to new-style members of the aerospace network-cluster: universities,

[9] Secretaría de Economía (Ministry of Economy), *Industria Aeronáutica en México (Aeronautical Industry in Mexico)*, 2012.

[10] FEMIA, Secretaría de Economía (Ministry of Economy), *Pro-Aéreo 2012-2020 Programa Estratégico de la Industria Aeroespacial (Strategic Program of the Aerospace Industry)*, 2012, pp. 99.

[12] Examples include business chambers such as FEMIA, CANIETI, and other linking institutions such as FUMEC.

technology centers, and government officials. In linking the scientific community with the public and private sectors, they performed relationship-building functions that substituted and in some cases surpassed the old efforts of government offices for knowledge transfer.

Table II (below) flows from the Mexican government's strategic decision to construct a structure of governance at the Aerospace sector level that would nurture fundamental networks of collaboration, research, training, and investment. Subsequent public policies mobilized private sector investment across several dimensions (connectivity, collaboration for training and research, financial resources, specialization of small and medium enterprises in supplier development programs) to sustain creation of productive groupings within the sector.

Governmental attention shifted toward collective strategies of intervention that could exploit certain advantages for sector growth: improved standards for competition, targets for critical mass within a cluster, increased R&D to consolidate investment on regional priorities, and preferential tariffs for importing and exporting of goods. Assembly thereby encouraged in Mexico included aircraft, components, machinery, and equipment. The structure of incentives also influenced the location of OEMs and foreign direct investment (industrial parks, improved airport runways to receive heavy airplanes, a loading and passenger terminal, an interior customs house, and the fiscal precinct).

Application of these incentives was sustained by public resources and the contribution of large international integrating companies anchoring the clusters. "Brick and mortar" articulation of sector infrastructure indirectly affected mainstream operations. New paradigms of knowledge, advanced manufacturing, and diffusion of information technologies revealed the next rung of novel challenges in processes of production and in cognitive abilities for workers as well as managers: these are non-trivial problems to resolve in order to expand complex production environments with multidisciplinary platforms.

In general, macro-, meso- and micro-complexity will increase in a fractal pattern so that barriers to production do not get easier as one scales down to subcontractors or even divisions within firms. The need for appropriate state intervention to develop synergies and organize priorities around a vision of educational, relational, and productive growth has been greater than it first appeared from a macro perspective. An example of this complexity would be the sectoral change contingent on transformations in the management of universities to adapt to challenges of knowledge transfer, such as incentivizing progress of research groups toward commercialization of new technology in the Aerospace sector once there is an integrated overall vision linking ICT policies with industrial, educational, and research activity.

AN AEROSPACE CLUSTER WITH HIGH-DENSITY INSTITUTIONAL NETWORKS

In the state of Queretaro, which has experienced robust industrial growth, traditional sectors like the manufacture of parts and metal components coexist with sectors that have greater technological intensity like automobile and electronics manufacturing, specialized chemicals, and food biotechnology.[13]

[13] The state of Queretaro, located in the center of the country, has a total population of 1,827,937, of which 70% reside in urban areas; in 2012-13 it had an education average of 9.2, above the national average of 8.9, and a low rate of illiteracy (5.5%) compared to the national total (6.1%), according to figures from the Instituto Nacional de Estadística y Geografía (INEGI) (National Institute of Statistics and Geography). The value of Queretaro's exports reached an amount of 7.4 billion USD, which represented 2.3% of national GDP; the manufacturing industry stood out as the main activity, and the subsector with the most participation was manufacturing of transport equipment, which represented 54% of manufactured exports (Ministry of Economy, 2012). See also, Daniel Villavicencio, Juana Hernández, and Leonardo Souza, "Capacidades y oportunidades para el desarrollo de la industria aeronáutica en Querétaro- (Capacities and opportunities for development of the aeronautical industry in Queretaro), in Casalet M, *La Industria Aeroespacial. Complejidad Productiva e Institucional (The Aerospace Industry. Productive and Institutional Complexity)* (DF, Mexico: FLACSO and Conacyt, April 2013), pp. 49-92.

The Queretaro State Development Plan, as well as its S&T program established the Aerospace sector as a priority for state development together with the automobile sector. Both sectors received government support through productivity and financial incentives. The prior establishment and high performance record of the Mexican automobile industry provided a solid foundation for development of the Aerospace sector, for it trained engineers and accelerated the pace of industrial production.[14]

Queretaro concentrates production on products and machining processes of complex components, manufacturing of aero-structures, manufacturing of components for engines, manufacturing of brake systems, MRO (maintenance, repair and overhaul) for propulsion engines, manufacturing of landing gear and MRO, and technical treatment and manufacturing of components for complex materials.

In order to stimulate high-tech entrepreneurship, the State of Queretaro set aside the Fund for Competitiveness of SMEs (Ministry of Sustainable Development, 2009); sponsored programs previously mentioned, including ISO 9000 certification, that fostered development of small and medium enterprises; and granted specialized consulting and coaching for business. To maintain the ISO 9000 standards, for example, Queretaro state government still covers 33% of the financial cost; the federal administration contributes another 33%; and the rest is paid by the company that wishes to obtain certification (Council of Science and Technology of the State of Queretaro, 2010).

Relationships with educational institutions are another pillar for consolidation of the aerospace cluster in Queretaro, for those understandings result in a reliable and less expensive supply of qualified labor (technicians, engineers, IT personnel), essential for foreign investors, especially companies that initially demanded coaching or training of Mexico's technicians outside the country. Diversity is manifest in the integration of local companies into development programs of global suppliers. Most local companies first enter AI at a competitive disadvantage in terms of investment capital, infrastructure, and a critical mass of skilled labor to attend the demands of this high-tech market; these deficits present formidable obstacles to fulfilling production deadlines according to international demand and to the new entrants' long-term survival.

Thickening of innovation networks manifests in frequent collaboration between universities, public research centers (PRCs), and companies of the Aerospace sector, which gradually strengthens bonds of trust – building social capital and facilitating acquisition and transfer of new knowledge (Table III, below). The use of diverse channels for knowledge transfer presents peculiarities and, again, added complexity.

Among the most significant challenges are the sheer number of component parts and the technology level of tools for design and assembly. Intriguingly, financial consulting; worker training; information technology; and commercialization support – all with integration of local suppliers – plus linkages of research groups and experienced international partners in exchanges with industry, these opportunities have evolved in some cases from informal relationships based on academic interest of researchers to formal agreements that resolve incentives for long-term, institutionalized transactions.[15]

Market entry of Mexican systems and subsystems supply for transnational AI companies has occurred, and these phenomena are tied to dynamic global value chains on an international scale. Where the geographic proximity of the American market plays a determining role, transport and time costs are reduced; benefits provided by NAFTA and innumerable incentives offered by state and national governments for sector growth also have an impact.

Engineering and manufacturing companies that make up the aerospace cluster in Queretaro actively participate and receive counseling in state

[14] This was included among the *top ten* best producers in the world, putting together 2,261,000 vehicles from January to December 2010.

[15] Casalet, 2013, p. 94.

programs. They also maintain good communication with local research centers (e.g., Ciateq, Cidesi, Cideteq and especially with UNAQ), and most of them have asked for support from national innovation programs within Conacyt (National S&T Council).

The development structure for suppliers has not had the same success however. On one hand, there are not enough trained personnel. Despite having multiple institutions working on it, many potential supply companies from the aerospace value chain do not have appropriate certification, due to the investment costs and trained personnel required up front. In this sense, Mexico is still remote from the market interactions of competitive countries.

Brazilian aerospace companies, for example, receive à *la carte* credits from the Banca de Desarrollo (BNDES) (Development Bank) while smaller companies from Mexico do not have the technological, financial, or managerial capacities to qualify for loans as viable risk partners.[16] Figure 1, below, depicts the ecology of an important support network created with a governmental eye toward specialized worker training, research, and knowledge transfer. This AI network, with its potential for cultivating information exchanges and new products, is a sign of commitment from both state and private actors. It carries the hopes in some sense for future foreign investment and consolidation of the Aerospace sector in Queretaro, Mexico.

FINAL REFLECTIONS

In this work, the efforts of different agents to incorporate and expand the Aerospace sector (AI) in Mexico have been identified. In elaborating this complex web of interests and dynamics among participating actors, two basic claims have been made:
1) On one hand, the process of production and organizational management in AI, which determines the level of international competitiveness reached, has been characterized by mergers, new acquisitions, and continuous international engagement to maintain competitive advantages. In the Aerospace sector, the local entrepreneurial network of suppliers links through an assembler that operates as *leading company* and establishes vital connections to the outside world. This sector leader organization in Mexico allowed companies to enter the aerospace business at multiple access points along the global value chain.

2) On the other hand, the case of Mexico, especially in the state of Queretaro, shows how *national and state policies* combine with the efforts of small companies and larger businesses to create favorable conditions for development and growth of the Aerospace sector, articulating effective networks to link with research and specialized training that can meet international standards.

ProMexico and the Ministry of Economy played an important role as trailblazers of specialized demand, promoting the insertion of anchor companies in a sector of strategic importance for the country. Conacyt, through various national programs, has strived to strengthen the demand for knowledge, together with state-level institutions (UNAQ, CEDIA) and Public Research Centers (Cidesi, Ciateq, Cideteq,CIAT) that, in addition to supporting joint public-private research projects, provided training for highly qualified personnel in AI.

Changes in the design of public policies can support new strategies to promote priority sectors. In the case of Aerospace, ProMexico's studies transcended the macroeconomic dimension, for they included programs and proactive incentives to generate changes in the structural nature of institutions, in the behavior of companies, and in the scientific community. This expanded scope of activity for public policy was nevertheless anchored around strategic objectives:

[16] Flor Brown and Lilia Dominguez-Villalobos, "¿Tiene la industria aeronáutica mexicana las condiciones para integrarse a la cadena de valor internacional de alto valor agregado? (Does the Mexican aeronautical industry have the conditions to become part of the international value chain of high added value?)." In Casalet Monica, *La Industria Aeroespacial. Complejidad Productiva E Institucional (The Aerospace Industry. Productive and Institutional Complexity)*. (DF, Mexico: FLACSO and Conacyt, April 2013), pp. 135-162.

1) Establishing growth priorities in productive sectors.
2) Promoting the proliferation of public-private networks of collaboration on a regional and sectoral level, stimulating the formation of industrial clusters.

3) Favoring the mobility of post-graduate students and researchers in companies within priority sectors such as Aerospace.

4) Generating public support to increase capacity of companies to innovate, improve productivity and quality, and restructure *networks* for transforming educational institutions, public research centers, and technology institutes.

The preliminary success of these initiatives indicates that across-the-board, broad brush policies are not sufficient. Selective policies are necessary, oriented towards defining a specialization profile, or niche, across the global value chain of a high-tech industrial sector. Despite progress in the creation of public programs to support Mexico Aerospace, obstacles persist in systematization of information on results ("sector assessment"), and on the effectiveness of communication and collaboration initiated between companies and specialized researchers.

Improved coordination implies strategic action for the future growth of Mexico Aerospace that goes beyond current innovations in government policy. In this vein, two policy objectives are fundamental: ensuring financial resources for incorporation of local suppliers, and strengthening management of specialized knowledge. For these, it is necessary to have more information to track the different stages of various regional concentrations in AI; the needs for leading companies in each region; and the coincidence among national and regional policies for integrating local suppliers into the global value chain.

Systematized data is lacking to design a comprehensive strategy that fully integrates private companies; the public sector; linked intermediate institutions; educational institutions; and public-private research centers. Such an information-intensive strategy could prove indispensable to diverse actors within the AI support network for resolving specific problems posed by the Aerospace sector in Mexico – and for capturing any lessons beneficial to the cause of international development in general.

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Chapter III- Actores Y Redes Públicas Y Privadas En El Desarrollo Del Sector Aeroespacial Internacional Y Nacional: el Clúster De Querétaro, Una Oportunidad Regional (Public and Private Actors and Networks In the Development of the National and International Aerospace Sector: the Queretaro Cluster)." *La Industria Aeroespacial. Complejidad Productiva E Institucional (The Aerospace Industry. Productive and Institutional Complexity)*. DF, Mexico: FLACSO and Conacyt, April 2013, p. 105.

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TABLE I: M*ain Aerospace Clusters in Mexico*[1]

MAIN CLUSTERS	SPECIALTY	MAIN PLAYERS
In Baja California • Mexicali • Tecate • Tijuana	Electric-Electronic Parts manufacturing.	51 companies among which these stand out: • Honeywell • Gulfstream Interiores Aéreos (Air Interiors)
In Chihuahua: • Chihuahua • Ciudad Juarez	Manufacturing of parts and fuselages, electric-electronic, mechanized interiors.	28 companies among which these stand out: • Labinal, de Grupo Safran • Cessna Aircraft • Textron International • Grupo American Industries
In Queretaro • Queretaro	Manufacturing of motor components and landing gear. Assembly of components and airplane fuselages, MRO.	32 companies among which these stand out: • Bombardier • ITP Ingeniería y Fabricación. • SNECMA, from Grupo Safran • GE-IQ • Aernova
In Sonora • Hermosillo • Guaymas • Ciudad Obregon	Manufacturing of components for motors and turbines, fuselage and composite materials.	43 companies among which these stand out: • Goodrich Aerostructures of Mexico • ESCO
In Nuevo Leon • Apodaca • Monterrey • Santa Catarina	Forging and machining, manufacturing of components, assembly of fuselages for helicopters.	29 companies among which these stand out: • Frisa Forjados • MD Helicopters.

[1] Secretaría de Economía (Ministry of Economy), Dirección General de Industrias Pesadas y de Alta Tecnología (General Management of Heavy Industries and High Technology), *Industria Aeronáutica en México (Aeronautical Industry in Mexico),* June 2011, pp. 54.

TABLE II: ***Institutional Framework for Strengthening Mexico Aerospace***[2]

PUBLIC AGENTS	PROGRAM	PRINCIPAL ACTIONS
National/Civil Bodies Ministry of Economy	Sectoral program 2007-2012	Formation of productive chains; Company partnerships; Supply creation; Technological export and reconversion of sectors; Company boosting; Factors
	SME (small and medium sized companies) fund.	Financing. Company management. Technological innovation. Training. Commercialization. Strengthen value chains in Mexico. Link suppliers with supplies in global chains. Increase national supply and exports.
ProMexico.	Productive linking program. National Program for Trailblazing Companies. Alliance model with transnational companies.	Applied in multiple automobile and aeronautical companies. Initiatives to generate prospective studies of industrial sectors.
Dirección General de Aviación Civil (DGAC) (General Management of Civil Aviation), assigned to the Ministry of Communication and Transport.	Aeronautical authority. 1950 first regulations for civil aircraft; Regulation for Aeronautical Telecommunications and Radio Asst.; Regulation for Search and Salvage. 1952 Mexico signed an agreement with the ICAO. Supervises daily operations of the sector.	Verify aeronautical and airport security measures (Safety and Security). Guard airports, issue permits, authorizations, licenses and certificates to air transport companies. Compile information and statistics about air transport.
Conacyt. (National S&T Council).	Programa Estímulos a la innovación (PEI) (Innovation Stimulus Program). Innova SME programs. Pro Innova. Innovatec.	Financial support programs for big companies, SMEs and C.P.I.(Engineering Preparatory Courses) to generate jobs linked to innovation. Support for aerospace and aeronautical sectors.

[2] Based on author interviews and analysis of documents from said institutions.

PUBLIC AGENTS	PROGRAM	PRINCIPAL ACTIONS
	Alianzas estratégicas de redes de innovación para la competitividad (AERIS) (Strategic alliances of networks of innovation for competitiveness).This program ended but it was important to boost the formation of aerospace clusters.	Interinstitutional coordination to stimulate innovation networks. Prospective and market studies.
	Thematic networks.	Exchange platform between researchers, entrepreneurs and the public sector.
	Red Temática de Conocimientos Tecnológicos Espaciales (RTCTE) (Thematic Network for Technological Space Knowledge).	Competitiveness of the mexican aerospace industry UNAM, IPN, Ciateq, Cicese, UABC, INAOE, Global Star Mexico, Satmex, AMC, Cinvestav (Guadalajara).
Agencia Espacial Mexicana (AEM) (Mexican Space Agency)	Law created in 2010	Construction of a work agenda with public and private actors and academics in order to elaborate a state policy in the matter of space, for training, scientific research and space development.
Consejo Mexicano de Educación Aeroespacial (Comea) (Mexican Council of Aerospace Education), autonomous academic body, created in 2007.	1st national academic research network linked with the aerospace sector.	Analysis of the aerospace industry. Determine professional competitiveness. Program for joint updating and training (Comea and Femia).
International Bodies (PNUD) Mexico	Program for supplier development.	Methodology to reduce the learning curve and generate a greater impact in the training of human resources.
	Special processes certification program.	SME integration into the aerospace, automobile, electric and electronic sectors.
	Collaboration agreement with the Programa Integral de Apoyo a las Pymes (Piapyme) (Integral Support Program for SMEs) Mexico-European Union.	Mexican SMEs and European companies collaboration, aerospace sector jointly with Femia. Certification of space processes for SMEs. Nadcap standards, SAE, AS9100.
- -	- -	- -

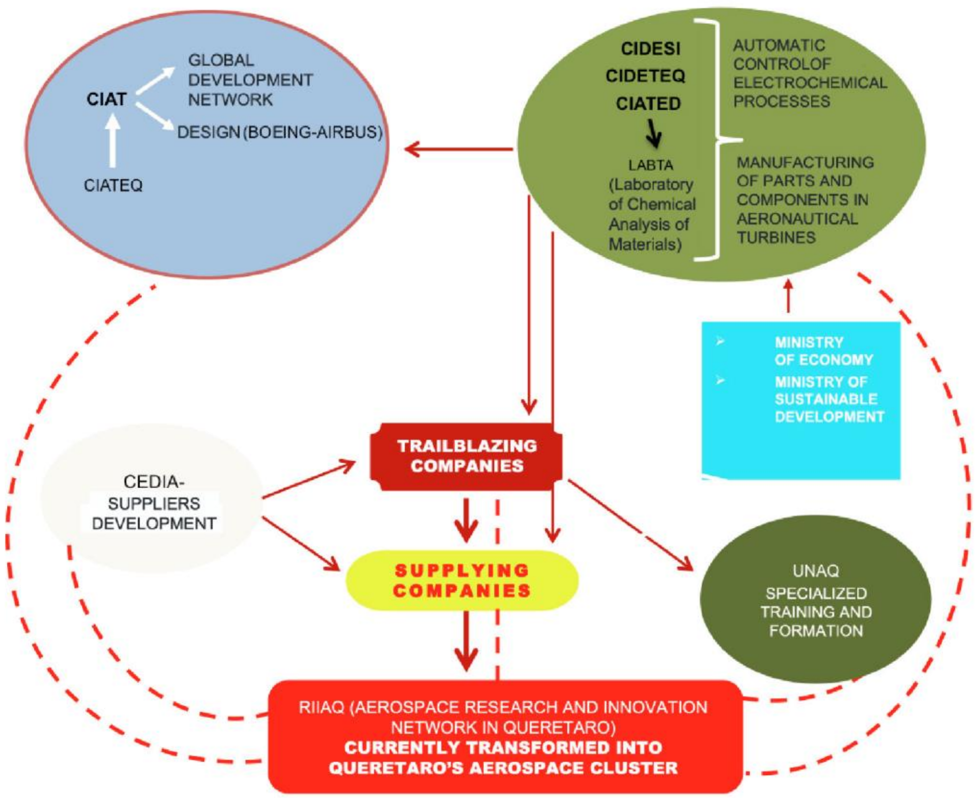
PUBLIC AGENTS	PROGRAM	PRINCIPAL ACTIONS
Entrepreneurial bodies with public/private action.		
Federación Mexicana de la Industria Aeroespacial (Femia) (Mexican Federation for the Aerospace Industry), non-profit civil partnership (2007).	Establish a strategic national aerospace plan. Support integration of the national aerospace industry. Obtain incentives and tariffs for aerospace products. Events and seminars.	Products for maintenance and manufacture. Analysis of legislative trends in the matter. Diagnosis of the sector on an international and national level. Lobbying to organize a sole government agency in charge of acquisitions in the sector.
Intermediate organizations with state and national action		
Fundación México-Estados Unidos para la Ciencia (Fumec)(U.S.-Mexico Foundation for Science.	Programs in emerging niches with high potential.	Support for the aerospace sector: Diagnosis of strengths and opportunities. Financial advice to link companies with investments. Consultancy to advice an international business – ICT, financial plans and manufacturing. Linking with TechBa for business units in Seattle and Montreal.
	TechBa – Business accelerator program (SE) (Ministry of Economy).	TechBa is installed in highly competitive strategic environments: Silicon Valley, Austria, Montreal, Madrid, Michigan, Vancouver, Seattle.

TABLE III: ***Trailblazing Companies in the State of Queretaro*** [3]

Trailblazing companies	***Principal products***	***Motives for installation in Mexico***	***Competitive opportunity in Queretaro***
Aernova	Aeronautical structures: design, development, certification test, prototypes and active support. Manufacturing of composite and metal parts. Assembly plant. Metal components plant.	Interest in the American aerospace market. Facility in Mexico as part of FTA. Interest in creating a currency mix dollar, euro, peso.	Precedent of commercial relations of the state of Queretaro with the Basque Country's Autonomous Community, where the company is from. Training of workers; some were sent to Spain. Active exchange with Femia. Uses CENAN's test laboratories in Queretaro. Supports training programs from the UNAQ.
Industrias Turborrectores (ITR)	Air transport, engineering, manufacturing and maintenance of gas turbines.	Closeness of Mexico with the United States' market, Mexico's participation in NAFTA, facility to save on tariffs.	Manufacturing of the first static seal T900 motor in Mexico.
Bombardier: three plants	Manufacturing of regional aircraft, executive jets.	Reduction in production costs. Importance of Mexico's participation in the integration of the FTA, with Japan and the EU.	Work was moved from Toronto to Mexico, manufacturing of harnesses and electric systems for Challenger 300, 605, 850, 870, 890 models. Active relationship with the UNAQ. Integrated few direct Mexican suppliers because of certification problems.
Grupo Safran: eight production and maintenance plants in Mexico. Messier Services Messier Dowty Sncema Sames in Queretaro	Aeronautical propulsion and equipping, defense and security. MRO landing gears with machining and treatment. Generation of biofuels.	Interest because of Mexico's participation in NAFTA. Maintenance of Airbus 320 and Boeing 737 components.	Heads French-Mexican campus of aviation. Active participation in the UNAQ.

[3] From author interviews conducted with said companies.

Figure 1: ***Institutional Network Supporting the Aerospace Cluster in Queretaro*[4]**



[4] Information provided by Casalet, M. 2013.

The Centro de Ingeniería Avanzada en Turbomáquinas (CIAT) (Center of Advanced Engineering in Turbomachines) began its activities as an engineering services provider for General Electric (GE), specifically assisting two companies that belong to GE—GE Power Systems and GE Aircraft Engines—with design, drawing, engineering, and analysis activities. The CIAT evolved into the biggest and most important aviation engineering center outside the United States, as part of a global network of development centers from GE.

El Centro de Desarrollo de la Industria Aeronáutica (CEDIA) (Development Center of the Aeronautical Industry) depends on the Tecnológico de Monterrey, Queretaro Campus. Among its objectives are development of the aeronautical industry and training of high-level professionals. CEDIA also offers solutions to technical problems for companies that seek to become part of the chain of production in AI.

The Universidad Nacional Aeronáutica de Querétaro (UNAQ) (The National Aeronautical University of Queretaro): Created in 2007 to respond to the needs of highly skilled labor, it has teaching personnel from aerospace companies (OEM, Tier 1) and the support of Public Research Centers such as the Centro de Ingeniería y Desarrollo Industrial (Cidesi) (Center of Industrial Engineering and Development). Oriented towards electronic and advanced manufacturing, the Centro de Investigación y Asistencia Técnica del Estado de Queretaro A.C. (Ciateq) (Technical Research and Assistance Center of the State of Queretaro) offers technical training to companies and technical assistance services specialized in measuring systems, machinery and equipment design, monitoring and control systems, process engineering, and advanced manufacturing. The Centro de Investigación y Desarrollo Tecnológico en Electroquímica (Cideteq) (Center for Technological Research and Development in Electrochemistry) offers accredited services to the industry in chemical analysis, material analysis, and environmental technologies.

Laboratorio de Pruebas y Tecnología Aeronáutica (LaBTA) (Aeronautical Testing and Technology Laboratory): Created jointly by the Cidesi, Ciateq, and Cideteq, it has support from Conacyt and the State of Queretaro to carry out specialized services for aeronautical companies. LabTA offers laboratory services (chemical analysis of materials and composites, physical-chemical and behavior testing in services of composite materials, vibration diagnosis, and noise analysis) and assistance in product development, including design and manufacturing of testing prototypes and devices (design and manufacturing of process and testing equipment; design of metal, polymers, and composite products; design, manufacturing and activation of testing devices: hydraulics, pneumatics, mechanical, and fatigue).

Red de Investigación e Innovación Aeroespacial del Estado de Querétaro (RIIAQ) (Aerospace Research and Innovation Network of the State of Queretaro) emerged in calls by Conacyt to stimulate the formation of alliances between public and private agents in critical areas of knowledge, research, and creation of productive capacities. RIIAQ led to the formation of the Aerospace Cluster in Queretaro financed by OEMs and made up of companies, public research centers, and intermediate companies in Queretaro (Casalet, 2013, op. cit.).

Book Review
Crowded Orbits: Conflict and Cooperation in Space
by James Clay Moltz (Columbia University Press, 2014)

Deron Jackson

A popular space primer serves both the policy and academic communities.

Human beings have perceived outer space as infinite for centuries, and since the observations of Edwin Hubble in the 1920s, scientists have studied phenomena that suggest the universe itself is expanding. However, as the title of Clay Moltz's most recent book points out, the region of space most important to the economic and physical security of residents on Earth is increasingly viewed as far from infinite.

In *Crowded Orbits*, the author introduces readers to the many ways in which orbital space around the Earth is in fact distinctly limited by principles of physics as well as politics. This discussion is of value not only to scholars and students of space policy but to those concerned more broadly with questions of international cooperation and conflict in the early 21st Century. Our journal, *Space and Defense*, represents the Eisenhower Center's continuing effort to broaden scholarship on issues of space policy and security. With the publication of *Crowded Orbits*, Clay Moltz again demonstrates his leadership as a scholar and expert in this field, which has already benefitted from his previous books: *Asia's Space Race* (2011) and two editions of *The Politics of Space Security: Strategic Restraint and the Pursuit of National Interests* (2008 and 2011).

The first hurdle encountered in presenting space security issues to a wider audience, to include those in the policy-making community, is dealing with a subject that requires a certain degree of understanding of abstract scientific principles. This challenge is addressed in the first chapter of *Crowded Orbits.* There Moltz surveys characteristics of the orbital domain which make it intrinsically different from land, sea, or air as venues for human activity. Understanding these principles helps explain why orbital space can be considered "crowded," as the title suggests, whether from the perspective of the limits of the electromagnetic spectrum used to gather and communicate information with satellites or the three distinct orbits they inhabit. Moltz gives his readers just enough of an overview of the scientific principles in order to make sense of the political challenges discussed in greater detail in the chapters that follow. Those interested in more science can consult *The Physics of Space Security* by Wright, Grego, and Gronlund (Cambridge, MA: American Academy of Arts and Sciences, 2005), which is the near perfect complement of Moltz's approach, beginning with one section on policy implications and following up with twelve sections discussing technical operations in space.

While the description of orbital space as "crowded" takes top billing in the title, in reality the book's real emphasis is not so much on what contributes to that congestion but on the political implications of that congestion as evidenced by the subtitle: *Conflict and Cooperation.* Both conflict and cooperation are possible outcomes from operating in a space environment that the United States has called both "congested" and "contested" in its recent space strategy documents. The dual nature of conflict and cooperation in space is not a new development, as outlined in Moltz's second chapter which charts the politics of the space age.

The use of space by the United States and Soviet Union was made possible through development of long-range ballistic missiles primarily intended for delivery of nuclear weapons. However, discovery of the effects of nuclear weapons on the space environment led to the first arms control treaty of the Cold War, the Partial Test Ban Treaty (PTBT) of 1963, which banned further atmospheric testing (p. 40). Although their terrestrial arms race and intense political strategic competition continued throughout the 1960s and 70s, the two superpowers were nonetheless able to establish the basic international legal framework governing activity in space, in particular the 1967 Outer Space Treaty (OST).

The OST and other agreements which followed it represent a high water mark in the use of formal treaties to regulate space activity, a practice that has declined in recent decades. Although certain aspects of the cooperative paradigm established by the OST have continued, when the Cold War heated up one last time at the end of the 1970s and into the 1980s, the prospect for conflict in space began to rise. Both the U.S. and U.S.S.R. engaged in testing anti-satellite weapons (ASATs) and debated the role of space systems in defending against ballistic missiles (p. 50). Such weapons were never used against the other side, however, and the framework for space established in the first half of the Cold War was still intact when the Berlin Wall was torn down and the Soviet Union passed into the dustbin of history.

It may very well be time to consign the term "post-Cold War" to that same historical dustbin and search for a new label to assign the world of today, which has seen significant changes in the number and nature of the actors and challenges confronting leaders and citizens in the 21st Century. Although the nature of the physical environment of space is inherently the same in 2016 as it was in 1957, 1967, or 1989, the political environment is transforming rapidly. The number of states with the capability to launch objects into orbit has continued to grow, and the number that make use of space for civil, commercial, or military purposes has expanded far beyond the elite club of two space-faring states in the late 1950s. Compounding the problem of crowded orbits is the advance of technology making possible the proliferation of even smaller satellites, down to the size of "picosats" weighing in at only one kilogram (p. 103). While these new systems make it possible to lower the cost of exploring and using space, they simultaneously complicate the political problem of "crowded orbits" by raising the number of objects in play. A one-kilogram picosat may be viewed as an innovative platform for allowing students or emerging nations to study the uses of space for their first time; this same satellite may be viewed by an established operator as "debris." Among the questions to be answered is how to ensure the increasing number of small vehicles do not collide with larger (and more expensive) satellites operated by governments or private companies. What degree of responsibility must be borne by any satellite operator to ensure their vehicle does not collide with another while active and is removed from orbit when it reaches the end of its useful life? Although the United States leads the international community in tracking orbital debris and providing data to avoid collisions, America is neither a global policeman nor an orbital garbage collector. Debris mitigation and remediation remain tasks requiring a cooperative response from all spacefaring states, working against the temptation to be a "free rider" and leave the consequences to other nations or future generations.

As Moltz draws toward his concluding chapter on "Trends and Future Options," a number of questions emerge out of the preceding sections for consideration, which may prompt individual states to work cooperatively to avoid conflict and find their "SALT moment," as discussed in this issue's essay by our publisher. Will crowded orbits place pressure or limits on military activity as more states integrate the use of space into their armed forces? Civil space activities have been one area of cooperation among allies and between former adversaries. However, it is possible that the civil sector may see a trend toward re-nationalization, away from collaborative projects and back toward national space programs working alone. It is also possible we will see de-nationalization of space activities with a rise in privately funded ventures aiming at putting humans in orbit and eventually on Mars. The reality is we will probably see more of both, making the urgency for dealing politically with *Crowded Orbits* even more critical.

Publisher's Corner
Space Policy's SALT Moment

Roger G. Harrison

The market for a leap forward in space arms control is open. Now, who's buying?

The United States is facing a fundamental decision about space policy which arises from a question: does our national interest in an ordered space environment trump our absolute insistence on a policy of freedom of action? Or is the looming threat of over-crowded orbits, frequency interference and debris – of contested, congested and competitive space – so pressing that we must accept some greater transparency for our national security space operations, even greater information sharing with China, Russia, and commercial space operators, and perhaps some limits as well on activities affecting satellites in orbit?

A reader familiar with space operations will immediately object that freedom of action in space is more apparent than real. In fact, space is a heavily regulated environment, where most operators observe a host of rules most of the time. The question is, rather, whether the current, largely voluntary regulatory environment is robust or comprehensive enough to cope with an overall satellite population growing ever larger and more technically and politically complex?

The crisis point has not yet been reached. Disputes about things like assigned frequencies and orbital position are still relatively rare and, with some exceptions, peacefully resolved. The commercial players in particular are a great deal more cooperative with each other than they were even ten years ago, a phenomenon exemplified by the Space Data Association, an information sharing agreement to which companies operating 90% of satellites in orbit are now party. Thanks to the agreement establishing the SDA, there are for the first time real penalties for disruptive activities in orbit, which can amount to tens of millions of dollars in particularly egregious cases. The result is a much more orderly environment for commercial activity in space than ever existed before. But national satellite operators are not party to the SDA, and not governed by its provisions. Commercial companies saw reason to be more transparent about the location and functioning of their satellites because it was good business; like any frontier, including frontiers opened by new technology, the era of the gunslinger had to yield to the more settled and more sustainable era of law and order; anarchy in space might have been acceptable when the domain was still relatively empty. But gunslingers still lurk down every ally in national security space. The commercial example is therefore no precedent.

Some impetus toward order nevertheless applies to national space actors. The same conditions of increasing debris, crowded orbits, and electromagnetic interference apply to them; all swim in the same increasingly polluted stream. But there are obvious inhibitions to self-restriction, which apply particularly to national actors. Threats to profits are a minor matter compared to threats to national security. So while the SDA has been a success and shown the way, there are other problems that may inhibit the major national players from joining the fold.

These begin with mutual suspicion. The eras of relative progress in international space cooperation have coincided – roughly speaking – with eras of increased cooperation within the atmosphere. Indeed, sometimes, as in the Nixon Administration, space was used as a stalking horse for detente. The first high profile instance of U.S.-Soviet scientific collaboration, emerging from the depths of the Cold War, was the joint mission bringing U.S. and Soviet astronauts to the orbiting manned Soviet Soyuz satellite in 1972. Cooperation on the International Space Station, which flourished after the demise of the old Soviet Union, was a great leap forward in the same direction, and has continued even as relations between a resurgent Russia and a wary United States have worsened.

To this must be added the debut of a new and very secretive China to the list of major actors in space. China's policy has for the last decade explicitly rejected the idea of greater transparency, not to mention any hint of restrictions on freedom of action. "We are like a man with a knife; you are like a man with a gun." No American who has dealt with a Chinese interlocutor has been spared this fatuous simile. Those Chinese having interaction with the West on space – which means, those who parrot but hardly influence Chinese policy – use that line as an all-purpose response to any initiative from the United States for greater information sharing about space. These smiling individuals repeat to the point of exasperation that the Chinese cannot hold transparency discussions with the United States until they achieve parity in space, to include control of space on the peripheries of their country.

Whatever parity means – and this is never detailed – the goal of achieving it seems to be ever receding into the future. And control of space on the peripheries of the Central Kingdom means the capability of controlling it everywhere. In short, Chinese policy on space is as proprietorial and aggressive as that of the most hardline and paranoid of American space control advocates. It doesn't take much to imagine that knife about which they prattle slipping silently between our ribs.

Donald Rumsfeld was once presented with a policy paper that described space as a "commons." The word apparently conjured for the Defense Secretary an image of flower children in communes; it is claimed by those who suffered his wrath on that occasion that as soon as he encountered the word, their cause was lost. It isn't, of course, the only thing Secretary Rumsfeld got wrong. Space is a commons for better or worse.

The present Administration recognized this early on. The word "cooperation" appears 13 times in the first Obama Administration space policy document, and the word "collaboration" twice. "Space Control," on the other hand – the mantra of the neo-conservatives who tried and failed to make it a reality – appears only once, in an annex. There was hope as this new Administration took office that the other major space actors would see the same looming danger we did. Since we were far and away the predominate power in space, and since we depended on no one except ourselves for space situational awareness, our willingness to cooperate should have been seized on by the other actors.

That didn't happen. The United States leaned forward almost to the point of toppling over on space with the PRC, only to be greeted with implacability, impenetrable suspicion, and some nonsense about knives and guns. There might have been a new beginning with President Xi. Instead, the lines of communication on space – never humming – went completely dead. And so the situation remains. The EU tried to jump start a dialogue about sensible order in space by proposing vague and entirely voluntary "rules of the road," which were far less onerous and restrictive than mandatory limitations of the Outer Space Treaty to which all major players were statutorily bound. Repeated offers to further empty the new "rules" of content failed to create the barest hint of consensus.

It is tempting – indeed, it is almost required – to conclude that international cooperation in space will not soon move beyond the stage it has reached. The momentum seems to be in the opposite direction. What can change? A change in Chinese attitudes would give some hope; but there is no sign of that. Some grand disaster affecting everyone and showing the vulnerabilities and weaknesses of the current structure may be necessary. While we await that catastrophe, whatever it may be, the present, deeply flawed system will just have to cope. RGH

Notes for Contributors to *Space & Defense*

Space & Defense seeks submissions that will contribute to the intellectual foundation for the integration of space into overall security studies.

Indeed, the emergence of space as a unique and critical element in national security, economic security, homeland security, cyber security, environmental security, and even human security has persuaded us that this line of inquiry is vital to innovation for international security.

Contributions are welcome from academic scholars and policy analysts at think tanks and research institutes; senior management and policy officials from international and governmental agencies and departments relevant to space and security issues; senior management and policy officials from organizations responsible for critical national and international infrastructures that rely upon space; major aerospace corporations; scientists and engineers interested or involved in space and security policy issues; military officers and operators in relevant units, commands, and in staff colleges and service academies.

The journal welcomes submissions of scholarly, independent research articles and viewpoint essays. There is no standard length for articles, but 7,500 to 10,000 words, including notes and references, is a useful target for research articles, and viewpoint essays should be in the range of 2,500 to 5,000 words. The opinions, conclusions, and recommendations expressed or implied within *Space & Defense* are those of the contributors and do not reflect those of the Eisenhower Center for Space and Defense Studies, the Air Force Academy, the Air Force, the Department of Defense, or any other agency of the United States Government.

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Details of the author's institutional affiliation, full address, and other contact information should be included in a separate file or cover sheet.

Contributors are required to submit all articles electronically by email attachment as a Microsoft word file (.doc or .docx format).

Contributors should not submit PDF files. All manuscripts submitted to *Space & Defense* need to be double-spaced with margins of 1 inch or 2.5 cm, and all pages, including those containing only diagrams and tables, should be numbered consecutively. It is the author's responsibility to ensure when copyrighted materials are included in a manuscript that the appropriate copyright permission is received by the copyright holder.

Address manuscripts and all correspondence to:
Dr. Damon Coletta, Damon.Coletta@usafa.edu (e-mail),
or 719-333-8214.

On the basis of peer reviews for research articles, the academic editors will make a final decision for publication. If required, the author(s) will be required to make additional changes and corrections as a result of the external peer review.

TABLES AND FIGURES

All maps, diagrams, charts, and graphs should be referred to as figures and consecutively numbered and given appropriate captions. Captions for each figure should be submitted on the same page as the figure to avoid confusion. Tables should be kept to a minimum and contain only essential data. Each figure and table must be given an Arabic numeral, followed by a heading, and be referred to in the text. Figures and tables are not to be embedded in the text. Each table and figure should be clearly labeled. In the text, make sure and clearly explain all aspects of any figures or tables used.

STYLE

Authors are responsible for ensuring that their manuscripts conform to the style of *Space & Defense*. The editors will not undertake retyping of manuscripts before publication. Please follow the Chicago Manual of Style.
Listed below are some additional style and writing guides:

- Dates in the form: 1 January 2009.
- Headings (bold, ALL CAPS, title case and centered).
- Subheadings (bold, italic, title case and centered).
- Acronyms/abbreviations should always be spelled out in full on first use in the text.
- The 24-hour clock is used for time, e.g., 0800, 1300, 1800.
- Use percent rather than % except in figures and tables.
- For numbers, spell out numbers less than 10.
- Make use of 21^{st} style where appropriate.
- Keep capitalization to a minimum.
- Concise paragraphs and sentences are desirable.
- Avoid a paper that is just descriptive; rather engage the literature and provide analytical rigor and assessment.
- Avoid policy recommendations in the analysis part of paper; leave this, if applicable, for a separate section at the end of the paper.
- Define all new terms used in paper.
- Avoid hyphenated words when possible (e.g., low Earth orbit).
- Avoid the use of passive voice when possible.
- Footnotes, numbered consecutively with a raised numeral in the text, use the Insert-Preference-Footnote function of Word.