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Chapter Four

The Organizational Deployment of Posthumanizing Neuroprostheses: Motivating and Inhibiting Factors for Military Organizations and Other Early Adopters

Abstract. This text examines the types of organizations that are already working to intentionally deploy neuroprosthetic technologies for human enhancement among their workforce (or are expected to do so), factors that affect their adoption of such technologies, and the organizational roles that such neurotechnologies may play.

The current state of therapeutic neuroprosthetic device use is presented, along with an overview of posthumanizing neuroprostheses and the types of enhanced capacities that they offer human workers that may be relevant to organizations. A range of factors incentivizing or discouraging the organizational deployment of posthumanizing neuroprostheses is identified and discussed. The organizational roles of therapeutic and posthumanizing neuroprostheses are then analyzed. Many organizations already unknowingly incorporate workers possessing therapeutic neuroprostheses, while two key paths for the organizational deployment of posthumanizing neuroprostheses are highlighted. First is the 'transitional augmentation' of human workers as a stopgap measure on the path to eventual full automation of business processes through the use of AI. The second path involves retaining human workers in particular positions because exogenous factors (such as legal, ethical, or marketing requirements) mandate that human agents fill them, while augmenting the workers so that they can perform more competitively.

It is noted that military organizations play a key role among organizations likely to be early adopters of posthumanizing neuroprostheses. Known and hypothesized military programs for neuroprosthetic enhancement are discussed, along with characteristics of military organizations that remove obstacles that render the deployment of neuroprostheses impractical for most organizations. Other types of organizations are highlighted that share some traits as potential early adopters. Finally, enterprise architecture (EA) is discussed as a preferred management tool for many organizations that are likely to be early adopters; while EA does not directly address the serious ethical and legal questions raised by posthumanizing neuroprostheses, it can facilitate the functional aspects of integrating neuroprosthetically augmented workers into an organization's personnel structures, business processes, and IT systems.

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I. Introduction

To date, neuroprosthetic technologies have been employed primarily for therapeutic medical purposes – to restore some sensory, cognitive, or motor capacity that is present in typical human beings but which is absent in a particular individual due to illness or injury. In that context, decisions about whether to implant neuroprosthetic devices have been driven largely by the medical needs and personal motivations of the individual patients to whom they are being provided – not the operational needs or strategic objectives of the businesses or other organizations for whom such individuals might work.

However, a growing range of neuroprosthetic technologies is being developed whose purpose is not therapy but human enhancement: such 'posthumanizing' neuroprostheses are expected to provide their human hosts with sensory, cognitive, or motor capacities that dramatically surpass or differ from those that are possible for unmodified human beings. For most contemporary organizations, the notion of intentionally deploying such advanced neuroprostheses among their human workers is a far-fetched one: the purposeful exploitation of such technologies would appear to be more appropriate as a plot device in a work of science fiction than as an element of a serious business model. And, indeed, the implantation and maintenance of such devices creates not insignificant dangers to the health and safety of the human beings who receive them, as well as generating high costs and raising complex ethical and legal issues – all while offering extremely limited business value in return. Thus, for the overwhelming majority of organizations, the possibility of actively deploying neuroprosthetic technologies among their workforce does not currently possess strategic, operational, or tactical relevance.

Nevertheless, a small but growing number of specialized organizations – primarily military research agencies and departments[1] – are actively seeking to develop posthumanizing neuroprostheses and deploy them among their personnel. For these organizations, the possibility of improving their employees' ability to operate safely and effectively in very dangerous and difficult situations and to successfully accomplish critical tasks is perceived to outweigh the high costs and medical risks involved with the use of such technologies. Moreover, the nature of neuroprosthetic technologies is evolving rapidly as their power and sophistication increases: as posthumanizing neuro-

[1] Chief among them is DARPA, the Defense Advanced Research Projects Agency of the US Department of Defense; this organization does not maintain extensive in-house research and development capacities but primarily commissions outside entities such as university research laboratories or commercial firms to develop strategically, operationally, or tactically important technologies. For an overview of the organization's work relating to neurocybernetic human enhancement, see Part IV of this text and its discussion of military organizations as early adopters of posthumanizing neuroprostheses.

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prostheses become less dangerous (e.g., through the use of non-invasive technologies) and less costly and offer clearer business value, it is anticipated that the range of organizations actively deploying such technologies will grow.

In this text, we identify factors that are expected to incentivize or discourage the acquisition and use of posthumanizing neuroprostheses and investigate the types of organizations that are likely to be 'early adopters' of such technologies. Taking into account the characteristics typical of such organizations, we argue that the discipline of enterprise architecture is likely to provide them with a useful approach to managing the creation and maintenance of organizational units whose members include neuroprosthetically augmented human personnel.

II. The Current State of Neuroprosthetic Device Use

The overwhelming majority of neuroprosthetic devices have been implanted for therapeutic medical purposes. In this section, we consider the nature of such devices, the number of therapeutic neuroprostheses in use, and key factors that limit the adoption of such technologies.

Basic Types of Neuroprosthetic Devices

A neuroprosthesis can be defined as *an artificial device that is integrated into the neural circuitry of a human being*.[2] Such devices typically participate in or directly support the sensory, cognitive, or motor processes of their human host,[3] however, they may also be employed, for example, to gather real-time data about their host's biological processes and transmit it to a hospital to allow round-the-clock patient monitoring and the remote administration of health care.[4] In principle, neuroprostheses may be either 'invasive' (i.e., surgically implanted in the brain of a human host) or 'non-invasive' (e.g., consisting of an external device worn by a human host); however, a number of obstacles currently make it difficult for non-invasive technologies to become truly integrated into the neural circuitry of a human being.[5] Thus, as the term

[2] See Lebedev, "Brain-Machine Interfaces: An Overview" (2014), and Gladden, "Enterprise Architecture for Neurocybernetically Augmented Organizational Systems" (2016).

[3] See Lebedev (2014).

[4] See, e.g., Lorence et al., "Transaction-Neutral Implanted Data Collection Interface as EMR Driver: A Model for Emerging Distributed Medical Technologies" (2009), and Gladden, "Managing the Ethical Dimensions of Brain-Computer Interfaces in eHealth: An SDLC-based Approach" (2016).

[5] See Gasson, "Human ICT Implants: From Restorative Application to Human Enhancement" (2012), p. 14, and Panoulas et al., "Brain-Computer Interface (BCI): Types, Processing Perspectives and Applications" (2010).

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is used in this text, contemporary 'neuroprostheses' can generally be identified with invasive 'neural implants.'

Given their nature, neuroprostheses are not presently provided to employees by their employers in the way that an employer might furnish a desktop computer or smartphone for use by an employee in effectively completing work-related tasks. Instead, neuroprostheses are generally provided by healthcare organizations to patients experiencing a particular medical condition that can be treated through the use of such devices.[6] In these cases, neuroprostheses are generally employed to restore some capacity that is found in typical human beings but which is absent in a particular patient as a result of injury or illness. For example, cochlear implants, auditory brainstem implants, and retinal prostheses can restore sensory functionality to those who have lost the ability to hear or see; robotic prosthetic limbs can replace natural biological limbs that have been amputated; robotic exoskeletons and thought-controlled wheelchairs can grant a degree of mobility to the paralyzed; and deep brain stimulation (DBS) devices can treat tremors in those suffering from Parkinson's disease.[7]

Total Global Installed Base of Neuroprosthetic Devices and Rate of Growth

The adoption of therapeutic neuroprosthetic technologies has thus far been slow but steady. The best estimate is that more than one million neuroprosthetic devices have been implanted worldwide, including 350,000 spinal cord stimulation (SCS) devices,[8] 324,000 registered cochlear implants,[9] more than 135,000 DBS devices,[10] and 1,000 auditory brainstem implants.[11] It can thus be estimated that at present, roughly one out of every 7,000 people

[6] For production neuroprostheses that are in general use, organizations involved in the provision of such devices may include hospitals, insurance companies, and government healthcare agencies. In the case of experimental devices, commercial or university research laboratories may play a key role in the process. For an overview of such institutional actors, see Gladden, "Information Security Concerns as a Catalyst for the Development of Implantable Cognitive Neuroprostheses" (2016).

[7] See, e.g., Gasson et al., "Human ICT Implants: From Invasive to Pervasive" (2012); Ochsner et al., "Human, non-human, and beyond: cochlear implants in socio-technological environments" (2015); Weiland et al., "Retinal Prosthesis" (2005); Viola & Patrinos, "A Neuroprosthesis for Restoring Sight" (2007); and *Deep Brain Stimulation for Parkinson's Disease*, edited by Baltuch & Stern (2007).

[8] See "Chronic Pain and Spinal Cord Stimulation (SCS): Frequently Asked Questions" (2013).

[9] The figures are as of 2012. See "Cochlear Implants" (2016).

[10] See "Products and Procedures" (2016) and Patoine, "Progress Report 2010: Deep Brain Stimulation – The 2010 Progress Report on Brain Research" (2010).

[11] See "Surgeons Publish Study on Auditory Brainstem Implant Procedure" (2015).

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worldwide has received a neuroprosthesis. It is also worth noting that – while such devices are not neuroprostheses – more than 10,000 human beings worldwide are estimated to have received implantable RFID chips intended to allow access to secure facilities, to support the safe and accurate provision of medical care, or for other purposes.[12]

More than 100,000 new neuroprosthetic devices are implanted each year, including up to 50,000 SCS neurostimulators,[13] 50,000 cochlear implants (including 30,000 for children),[14] and around 6,000 DBS devices.[15] The annual rate of growth in the number of DBS implantation surgeries has recently been greater than 20% per year.[16]

Factors Limiting Adoption of Therapeutic Neuroprostheses

A variety of factors combine to limit the number of individuals who have thus far acquired neuroprosthetic devices for therapeutic medical purposes.

High Costs

A major constraint limiting the number of neuroprostheses that can be implanted worldwide each year is the significant cost of implantation surgery. For example, cochlear implant surgery can cost between $40,000-$100,000 per person,[17] while DBS implantation surgery can cost between $35,000-$100,000 per recipient.[18]

Required Surgical Expertise

Another factor limiting the rate of adoption is the number of doctors and facilities capable of performing neuroprosthetic implantations. For example, even in countries where DBS implantation surgery is funded by government health agencies, the lack of trained surgeons qualified to perform such complex and risky operations may result in waiting lists of 2-3 years for eligible device recipients.[19]

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[12] See Min Neo & Fonsegrives, "For these 'cyborgs,' keys are so yesterday" (2015).

[13] See "Spinal Cord Stimulation" (2008).

[14] See Hochmair, "Cochlear Implants: Facts" (2013), and "Cochlear Implant Quick Facts."

[15] See Christen & Müller, "Current status and future challenges of deep brain stimulation in Switzerland" (2012), p. 2, and "Studies Find Disparities in Use of Deep Brain Stimulation" (2014).

[16] Christen & Müller (2012), p. 2.

[17] See "Cochlear Implant Quick Facts."

[18] See Okun, "Parkinson's Disease: Guide to Deep Brain Stimulation Therapy" (2014).

[19] For example, see Fayerman, "Funding, doctors needed if brain stimulation surgery to expand in B.C." (2013).

Limited Population of Potential Users

Finally, given the fact that current neuroprostheses are generally used to treat particular medical conditions, the number of individuals suffering from such conditions worldwide creates an upper limit on the number of neuroprostheses that are likely to ever be implanted for purposes of treating those conditions. For example, it has been estimated that the number of new individuals experiencing hearing loss who could benefit from implantation of a cochlear implant is roughly 134,000 persons per year;[20] while the current implantation rate of roughly 50,000 new cochlear implants sold and implanted per year does not yet match the level of potential demand, it can be seen that already the commercial, governmental, and societal mechanisms for manufacturing cochlear implants, implanting them surgically, and funding their use are capable of satisfying a significant portion of the total global demand for such technologies.

III. An Overview of Posthumanizing Neuroprostheses

Some organizations have a direct interest in providing therapeutic neuroprostheses to their employees, insofar as the types of injuries that makes such devices necessary may occur regularly as a result of employees' work for the organization. Thus military forces have an immediate interest – deriving from their social responsibility as employers – in providing neuroprosthetic limbs to their soldiers who have lost a natural biological limb in combat.[21] Other organizations have a less direct interest in supplying therapeutic neuroprostheses to employees; they may ensure that organizationally sponsored insurance plans subsidize the cost of employees' therapeutic neuroprostheses (and other medical care) as a general means of enhancing employees' wellbeing and retaining highly qualified workers, even if such devices do not improve the employees' job performance and do not treat an illness or injury acquired as a result of the employees' work for the employers.

[20] See Hochmair (2013).

[21] Regarding DARPA's coordination and funding of research programs to develop sophisticated robotic neuroprosthetic limbs that can restore motor and sensory capacity to, e.g., soldiers who have lost limbs as a result of wounds suffered during their military service, see Dellon & Matsuoka, "Prosthetics, exoskeletons, and rehabilitation" (2007); Ling et al., "Surgical innovations arising from the Iraq and Afghanistan wars" (2010); and Hutchinson, "The quest for the bionic arm" (2014). For a broader discussion of the philosophical and even theological implications of such research programs, see Keenan, "Enhancing Prosthetics for Soldiers Returning from Combat with Disabilities" (2013). The US Department of Veterans Affairs has also provided millions of dollars to fund the development of 'biohybrid' prosthetic limbs for amputees; see Evans-Pughe, "Smarter Prosthetics: Researchers Are Working to Develop Artificial Limbs with Almost Life-like Levels of Functionality and Control" (2006).

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The relationship of employers to their workers' neuroprostheses that are used for therapeutic medical purposes is fairly straightforward; it resembles employers' interest in supporting the use of other long-established non-neuroprosthetic medical technologies. However, a range of emerging neurotechnologies designed for purposes of *human enhancement* is now transforming the ways in which employers assess the nature – and potential business value – of neuroprostheses. Efforts are underway to develop and deploy a broad range of 'posthumanizing' neuroprostheses[22] whose purpose is not to restore some capacity that is found in typical human beings but to grant their human hosts sensory, cognitive, and motor capacities that far exceed or differ from those that are possible for natural biological human beings.[23]

By providing knowledge, skills, and proficiencies that are otherwise absent in the human workforce, such posthumanizing neuroprostheses can create a powerful competitive advantage for their human hosts – and for the organizations that employ them. In this section we explore in more detail the new or enhanced capacities that posthumanizing neuroprostheses may grant to human workers and the forms that such devices might take.

Neuroprosthetically Enabled Capacities of Potential Relevance for Organizations

The human host of a neuroprosthesis can be viewed on three levels: 1) as a sapient metavolitional agent, a unitary mind that possesses its own conscious awareness, memory, volition, and conscience (or 'metavolitionality'); 2) as an embodied organism that inhabits and can sense and manipulate a particular environment through the use of its body; and 3) as a social and economic actor who interacts with others to form social relationships and to produce, exchange, and consume goods and services. A posthumanizing neuroprosthesis may generate new capacities for its human host at any or all of

[22] 'Posthumanizing' technologies can be understood as those that bring about an ecosystem in which entities other than natural biological human beings exist as intelligent agents and social actors that create meaning in the world. Technologies relating to artificial intelligence, artificial life, virtual reality, genetic engineering, and neuroprosthetic augmentation are a catalyst for processes of posthumanization; however, non-technological forces of posthumanization also exist. For more details, see Ferrando, "Posthumanism, Transhumanism, Antihumanism, Metahumanism, and New Materialisms: Differences and Relations" (2013); Herbrechter, *Posthumanism: A Critical Analysis* (2013); Miah, "A Critical History of Posthumanism" (2008); Birnbacher, "Posthumanity, Transhumanism and Human Nature" (2008); and "A Typology of Posthumanism: A Framework for Differentiating Analytic, Synthetic, Theoretical, and Practical Posthumanisms" in Gladden, *Sapient Circuits and Digitalized Flesh: The Organization as Locus of Technological Posthumanization* (2016).

[23] See, e.g., McGee, "Bioelectronics and Implanted Devices" (2008); Warwick & Gasson, "Implantable Computing" (2008); Gasson (2012); and Gladden, "Neural Implants as Gateways to Digital-Physical Ecosystems and Posthuman Socioeconomic Interaction" (2016).

these three levels that may create value for the individual as a worker and for his or her employer.[24]

Impacts on the Neuroprosthetically Augmented Worker as Sapient Metavolitional Agent

Below we describe potential new cognitive capacities that a neuroprosthesis might create for its human host when he or she is viewed as a sapient metavolitional agent and which positively affect that individual's ability to interface with organizational information systems, carry out work-related tasks, and participate in broader socioeconomic interaction.

Enhanced memory, skills, and knowledge stored within the mind (engrams)

Building on current technologies tested in mice, future neuroprostheses may offer human users the ability to create, erase, or otherwise modify memories stored within their brains' natural biological memory systems in the form of engrams.[25] This could potentially be used not only to affect a host's declarative knowledge but also to enhance motor skills or reduce learned fears. More speculative (but not yet clearly ruled out theoretically) is the possible use of a neuroprosthesis that is closely integrated with the brain's organic neural network to provide supplemental storage space for memories which the brain will be able to retrieve and experience as though they were engrams stored within the brain itself rather than treating them as exograms stored within an external system.

Enhanced creativity

A neuroprosthetic device may be able to enhance a mind's powers of imagination and creativity[26] by facilitating processes that contribute to creativ-

[24] Not considered here in detail is the fact that a neuroprosthesis may also create for its human host significant new impairments, including: a loss of agency; loss of conscious awareness; loss of information security for the user's internal cognitive processes; an inability to distinguish a real experience from an ongoing virtual one; an inability to distinguish true from false memories; other psychological side-effects; a loss of control over sensory organs, motor organs, or other bodily systems; other biological side-effects (such as poisoning); a loss of ownership of one's own body and intellectual property (including thoughts and memories); the creation of financial, technological, or social dependencies; subjugation of the user to external agency; social exclusion and employment discrimination; and vulnerability to crimes such as data theft, blackmail, and extortion. For more details regarding such potential impairments as well as possible advantages arising from the use of posthumanizing neuroprostheses, see Gladden, "Neural Implants as Gateways" (2016), from which this section draws heavily.

[25] Experimental memory-altering technologies currently being tested in mice are described in Han et al., "Selective Erasure of a Fear Memory" (2009), and Ramirez et al., "Creating a False Memory in the Hippocampus" (2013). For a broader perspective, see McGee (2008) and Warwick, "The Cyborg Revolution" (2014), p. 267.

[26] See Gasson (2012), pp. 23-24.

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ity, such as stimulating mental associations between unrelated items. Anecdotal increases in creativity have been reported to result after the use of neuroprosthetic devices for deep brain stimulation.[27]

Enhanced emotion

A neuroprosthetic device might provide its host with more desirable emotional dynamics.[28] The ability to affect the emotions of their users have already been seen, for example, in neuroprosthetic devices used for DBS.[29]

Enhanced conscious awareness

Funded in large part by military research agencies,[30] efforts are being undertaken to develop neuroprosthetics that would allow the human mind to, for example, extend its periods of attentiveness and limit the need for periodic reductions in consciousness (i.e., sleep).[31]

Enhanced conscience

One's conscience can be understood as one's set of metavolitions, or desires about the kinds of volitions that one wishes to possess.[32] Insofar as a neuroprosthesis enhances processes of memory and emotion that allow for the development of the conscience, it may enhance one's ability to develop, discern, and follow one's conscience.

Impacts on the Neuroprosthetically Augmented Worker as Embodied Embedded Organism Interacting with an Environment

Neuroprostheses may affect the ways in which their hosts sense, manipulate, and occupy their environment through the interface of a physical or virtual body. Potential new capacities that a neuroprosthesis might create for its host when he or she is viewed as an embodied embedded organism are described below.

Sensory enhancement

A neuroprosthesis may allow its host to sense his or her physical or virtual environment in new ways, either by acquiring new kinds of raw sense data or

[27] See Cosgrove, "Session 6: Neuroscience, Brain, and Behavior V: Deep Brain Stimulation" (2004), and Gasson (2012).

[28] See, e.g., McGee (2008), p. 217.

[29] See Kraemer, "Me, Myself and My Brain Implant: Deep Brain Stimulation Raises Questions of Personal Authenticity and Alienation" (2011).

[30] Regarding DARPA's multimillion-dollar investment in its Continuous Assisted Performance program, see, e.g., Falconer, "Defense Research Agency Seeks to Create Supersoldiers" (2003).

[31] See Kourany, "Human Enhancement: Making the Debate More Productive" (2013), pp. 992-93.

[32] See Gladden, "Neural Implants as Gateways" (2016), and Calverley, "Imagining a Non-biological Machine as a Legal Person" (2008).

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new modes or abilities for processing, manipulating, and interpreting the sense data provided by natural sensory organs.[33]

Motor enhancement

A neuroprosthesis may give its host new ways of manipulating physical or virtual environments through his or her body.[34] It may grant enhanced control over one's existing biological body, expand one's body to incorporate new devices (such as an exoskeleton or vehicle) through body schema engineering,[35] or allow the user to control external networked physical systems such as drones or 3D printers or virtual systems or phenomena within an immersive cyberworld.

Enhanced memory, skills, and knowledge accessible through sensory organs (exograms)

A neuroprosthesis may give its host access to external data-storage sites whose contents can be 'played back' to the host's conscious awareness through his or her sensory organs or access to real-time streams of sense data that augment or replace the natural sense data received through one's biological sensory organs.[36] The ability to record and play back all of the sense data that one has received could provide perfect audiovisual memory of one's experiences.[37]

Impacts on the Neuroprosthetically Augmented Worker as Social and Economic Actor

Neuroprostheses may affect the ways in which their hosts connect to, participate in, contribute to, and are influenced by the kinds of social relationships and structures that make workplace collaboration possible and the kinds of economic networks and exchange that facilitate and are generated by organizational business models. Potential new capacities that a neuroprosthesis might create for its host when he or she is viewed as a social and economic actor are described below.

Ability to participate in new kinds of social relations

A neuroprosthesis may grant the ability to participate in new kinds of technologically mediated social relations and structures that were previously

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[33] See Warwick (2014), p. 267; McGee (2008), p. 214; and Koops & Leenes, "Cheating with Implants: Implications of the Hidden Information Advantage of Bionic Ears and Eyes" (2012), pp. 120, 126.

[34] See McGee (2008), p. 213, and Warwick (2014), p. 266.

[35] Such possibilities are explored in Gladden, "Cybershells, Shapeshifting, and Neuroprosthetics: Video Games as Tools for Posthuman 'Body Schema (Re)Engineering'" (2015).

[36] See Koops & Leenes (2012), pp. 115, 120, 126.

[37] See McGee (2008), p. 217.

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impossible, perhaps including new forms of merged agency[38] or cybernetic networks with utopian (or dystopian) characteristics.[39]

Ability to share collective knowledge, skills, and wisdom

Neuroprostheses may link their human hosts in a way that forms communication and information systems[40] that can generate greater collective knowledge, skills, and wisdom than are possessed by any individual member of the system.[41]

Enhanced job flexibility and instant retraining

By facilitating the creation, alteration, and deletion of information stored in engrams or exograms, a neuroprosthesis may allow its host to download new knowledge or skills needed to perform some work-related task or to instantly establish relationships for use in a new job.[42]

Enhanced ability to manage complex technological systems

By providing a direct interface to external computers and mediating its host's interaction with them,[43] a neuroprosthesis may grant an enhanced ability to manage complex technological systems – for example, for use within an organization in the production or provisioning of goods or services.[44]

Enhanced business decision-making

By performing data mining to uncover novel knowledge, executing other forms of data analysis, offering recommendations, and alerting the host to potential cognitive biases, a neuroprosthesis may enhance its host's ability to execute rapid and effective business-related decisions and transactions.[45]

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[38] See McGee (2008), p. 216, and Koops & Leenes (2012), pp. 125, 132.

[39] For a discussion of such possibilities, see Gladden, "Utopias and Dystopias as Cybernetic Information Systems: Envisioning the Posthuman Neuropolity" (2015).

[40] Regarding such possibilities, see McGee (2008), p. 214; Koops & Leenes (2012), pp. 128-29; and Gasson (2012), p. 24.

[41] This fact regarding the generation and storage of information by social systems was raised in Wiener, *Cybernetics: Or Control and Communication in the Animal and the Machine* (1961), loc. 3070ff., 3149ff., and is discussed further in Gladden, "Utopias and Dystopias as Cybernetic Information Systems" (2015).

[42] See Koops & Leenes (2012), p. 126.

[43] See McGee (2008), p. 210.

[44] Such possibilities are discussed in McGee (2008), pp. 214-15, and Gladden, "Enterprise Architecture for Neurocybernetically Augmented Organizational Systems" (2016).

[45] See Koops & Leenes (2012), p. 119, and Gladden, "Enterprise Architecture for Neurocybernetically Augmented Organizational Systems" (2016).

Storage mechanism for monetary value

By storing cryptocurrency keys, a neuroprosthesis may allow its host to store money directly within his or her brain for use on demand in financial transactions.[46]

Qualifications for specific professions and roles

Neuroprostheses may initially provide persons with abilities that enhance job performance in particular fields[47] such as computer programming, art, architecture, music, economics, medicine, information science, e-sports, information security, law enforcement, and the military; as expectations for employees' neural integration into workplace systems grow, possession of neuroprosthetic devices may become a requirement for employment in some professions.[48]

Examples of Posthumanizing Neuroprostheses

Posthumanizing neuroprostheses may take a number of forms. In this section we present examples of such devices whose development is already being pursued or which has been foreseen by researchers.[49]

An Artificial Ear with Full Recording, Playback, and Streaming Capacity

Researchers anticipate the development of future cochlear implants whose internal computers possess the ability to record everything that their human host hears and to play back this audio on demand, effectively providing the host with perfect auditory memory.[50] Such devices could also potentially download and play music, podcasts, or other audio content for their host or receive live audio through radio transmissions or the Internet.[51] By wirelessly transmitting a live stream of all the environmental audio input that

[46] Such applications of neuroprostheses are discussed in Gladden, "Cryptocurrency with a Conscience: Using Artificial Intelligence to Develop Money That Advances Human Ethical Values" (2015).

[47] See Koops & Leenes (2012), pp. 131-32.

[48] See McGee (2008), pp. 211, 214-15, and Warwick (2014), p. 269.

[49] For a discussion of such devices in the context of their potential organizational use, see Gladden, "Enterprise Architecture for Neurocybernetically Augmented Organizational Systems" (2016), from which this section draws much of its material.

[50] Such devices (or technologies that are expected to facilitate the development of such devices) are discussed, e.g., in Merkel et al., "Central Neural Prostheses" (2007); Robinett, "The consequences of fully understanding the brain" (2002); Koops & Leenes (2012); McGee (2008); and Gladden, "Enterprise Architecture for Neurocybernetically Augmented Organizational Systems" (2016).

[51] Koops & Leenes (2012), pp. 115, 120, 126; Gladden, "Enterprise Architecture for Neurocybernetically Augmented Organizational Systems" (2016).

it detects, such a device could allow others listening around the world to experience all that the host was hearing in real time.

An Artificial Ear with Superhuman Types of Perception

An artificial ear could also allow its host to perceive sounds whose frequencies fall outside of the range that is normally perceptible for human beings. For example, a cochlear implant could detect sounds that possess ultrasonic frequencies but utilize an algorithm to present such sounds as ones possessing frequencies that fall just within the range perceptible to human beings when transmitting signals to the cochlear nerve or brain of its human host.

Moreover, by employing a process of sensory substitution,[52] an implant could detect any number of environmental phenomena and convert them into particular patterns of auditory data, thereby allowing its host to 'hear' light, colors, smells, temperature, radiation levels, or other characteristics of the host's environment. Similarly, an implant could be employed to allow its host to 'hear' his or her current blood pressure, blood glucose level and other blood chemistry characteristics, body temperature, and the status of other internal biological processes.

An Artificial Eye with Full Recording, Playback, and Streaming Capacity

An advanced retinal prosthesis might be able to record, remotely store (via wireless transmission), and play back on demand everything that its host sees, thereby effectively granting the host perfect visual memory. Such an eye could potentially also allow its host to download and view films and other visual content without other people in the immediate vicinity realizing it, and by supplying live video from a remote camera the device's host could virtually 'inhabit' the environment in which the camera is located.[53] Conversely, by wirelessly transmitting a live stream of the video recorded by its camera, the implant could allow viewers around the world to experience the host's environment from his or her perspective.

An Artificial Eye with Superhuman Types of Perception

Future successors to contemporary retinal prostheses may give human beings the capacity to sense and interpret their environments in new ways, for

[52] As noted previously, technologies for sensory substitution were suggested as early as in Wiener (1961), loc. 2784ff. See also their discussion in the context of posthumanizing neuroprostheses in Gladden, "Cybershells, Shapeshifting, and Neuroprosthetics" (2015).

[53] For discussion of the InfoSec implications of the use of such technologies by an organization's senior personnel, see Gladden, "Implantable Computers and Information Security: A Managerial Perspective" (2016).

example through telescopic zoom or night vision functionality[54] or by using augmented reality displays to overlay the external visual data perceived by the implant's camera with supplemental information about the host's environment or internal biological processes, the contents of incoming text or video messages, or other information.

An Implantable Smartphone

An implantable neuroprosthesis with functionality similar to that of a miniaturized smartphone might offer its host wireless communication capacities including access to the Internet, GPS functions, and cloud-based software and data-storage services.[55] Depending on its level of sophistication, such a device might respond to voice or thought commands and present visual or auditory information to its host's mind by means of sensory neuroprosthetic components similar to those found in cochlear implants, auditory brainstem implants, or retinal prostheses.

An Implanted Controller for Vehicles, Games, and Other Systems

A neuroprosthesis might provide its host with a direct link to external systems such as desktop computers, vehicles, smart buildings, 3D printers and other manufacturing systems, domestic robots, microphones and speakers, cameras and displays, game systems, or systems within a virtual environment that allows such external devices to be controlled by the host's thoughts.[56]

A Thought-controlled Exoskeleton or Physical Cyborg Body

A neuroprosthesis might allow its host to control via his or her thoughts an external articulated exoskeleton or even an electromechanical cyborg body that largely (i.e., apart from the brain) replaces the host's natural biological body. Such a body could potentially be radically nonhuman in its form and functionality.[57]

An Implantable Memory Chip for Acquiring New Skills or Knowledge

Building on experimental technologies developed for creating and altering memories in mice,[58] future implantable mnemoprostheses for human beings

[54] See Gasson et al. (2012); Merkel et al. (2007); and Gladden, "Enterprise Architecture for Neurocybernetically Augmented Organizational Systems" (2016).

[55] Such a device is discussed in Gladden, "Enterprise Architecture for Neurocybernetically Augmented Organizational Systems" (2016).

[56] See, e.g., McGee (2008), pp. 213-15; Gladden, "Neural Implants as Gateways" (2016); and Warwick (2014), p. 266.

[57] The extent to which neuroprostheses may allow the adoption of nonhuman bodies is explored in Gladden, "Cybershells, Shapeshifting, and Neuroprosthetics" (2015).

[58] As noted previously, such technologies are described in Han et al. (2009) and Ramirez et al.

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might take a number of forms – from that of a chip that allows its host to download content in order to acquire new knowledge or skills[59] to that of an ingestible 'knowledge pill' whose contents (perhaps a web-enabled nano-robot swarm[60]) travel to the brain, where they stimulate neurons to modify or create memories.[61]

Neural Scaffolding for Enhanced Cognitive Processing and Expanded Storage

Instead of producing or regulating specific behaviors, some neuroprosthetic devices might simply comprise a large set of artificial neurons that are connected to the natural biological neural circuitry of their host's brain in order to provide additional raw, general-purpose neural capacity that can be used, for example, for storing short- or long-term memories or processing information.[62]

A 'Savant Mode' Enabler

A neuroprosthesis may temporarily grant its host the ability to perform extraordinary mental feats of calculation or other savant skills by, for example, disrupting the functioning of the left anterior temporal lobe by means of magnetic stimulation in order to provide the host conscious access to and control over low-level cognitive processes that are normally hidden from the mind's conscious awareness.[63]

An Attention Booster

A neuroprosthesis may be able to enhance its host's conscious awareness and attentiveness by, for example, reducing the brain's need for sleep.[64] Such

(2013).

[59] Such possibilities are noted in McGee (2008).

[60] See Pearce, "The Biointelligence Explosion" (2012).

[61] See Spohrer, "NBICS (Nano-Bio-Info-Cogno-Socio) Convergence to Improve Human Performance: Opportunities and Challenges" (2002); and Gladden, "Enterprise Architecture for Neurocybernetically Augmented Organizational Systems" (2016).

[62] The extent to which such a device is theoretically possible is not yet clear and depends, e.g., on whether or not certain holographic models of memory are correct. For a discussion of such questions, see, e.g., Longuet-Higgins, "Holographic Model of Temporal Recall" (1968), and Pribram, "Prolegomenon for a Holonomic Brain Theory" (1990).

[63] The nature of savant skills is discussed in Treffert, "The savant syndrome: an extraordinary condition. A synopsis: past, present, future" (2009), and Rodriguez, *Autism Spectrum Disorders* (2011), pp. 36-39. The use of techniques such as transcranial magnetic stimulation (TMS) to artificially induce temporary savant skills is discussed in Snyder et al., "Savant-like skills exposed in normal people by suppressing the left fronto-temporal lobe" (2003), and Snyder, "Explaining and inducing savant skills: privileged access to lower level, less-processed information" (2009).

[64] See Kourany (2013), pp. 992-93.

technologies might potentially allow soldiers operating in hostile territory or the solo pilots of aircraft or watercraft to function for days without sleep.

An Emotional Regulator

A neuroprosthetic device might be able to regulate its host's moods, emotions, feelings, and desires in order to reduce or eliminate unwanted emotional phenomena and produce or strengthen desirable emotional behaviors.[65]

An Internal Advisor and Personal Consultant

A neuroprosthesis may be able to serve as a strategic consultant, business advisor, concierge, or even supplemental 'conscience' for its host – for example, by researching options and providing information through an augmented reality display to support decision-making or by warning its host when he or she is about to make a flawed decision that is influenced by some human cognitive bias.[66]

A Portal to Long-term Inhabitation of a Virtual World

A neuroprosthetic device could replace all of its host's sense data with real-time data depicting a virtual world (and the user's interactions with it), while the host's real physical body is maintained in a healthy state for an extended period of time in an artificial life-support system. Within such a fabricated virtual environment, the host might be given a radically nonhuman body and the laws of physics and biology may or may not apply, depending on the creative decisions made by the world's designer.[67]

A Hive Mind

Neuroprostheses may link the brains of multiple human beings in a manner that enables direct instantaneous communication between them,[68] the sharing of information, and the development of collective thoughts, desires, and decisions in a way that reduces the agency of each individual participating mind while simultaneously creating a form of combined agency and a

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[65] Regarding such possibilities, see McGee (2008), p. 217; Kraemer (2011); and Gladden, "Neural Implants as Gateways" (2016).

[66] Such a device is discussed in Gladden, "Enterprise Architecture for Neurocybernetically Augmented Organizational Systems" (2016).

[67] The implications of long-term immersion in VR environments are discussed, e.g., in Bainbridge, *The Virtual Future* (2011); Heim, *The Metaphysics of Virtual Reality* (1993); Koltko-Rivera, "The potential societal impact of virtual reality" (2005); and Gladden, "Cybershells, Shapeshifting, and Neuroprosthetics" (2015).

[68] Such possibilities are discussed from different perspectives in Rao et al., "A direct brain-to-brain interface in humans" (2014), and Gladden, "Utopias and Dystopias as Cybernetic Information Systems" (2015).

collective mind whose knowledge, skills, and wisdom may exceed those of individual members of the system.[69]

III. Factors Incentivizing Organizational Deployment of Posthumanizing Neuroprostheses

In addition to providing a competitive advantage to individual workers, there are a number of ways in which posthumanizing neuroprostheses might grant a distinct overall benefit to organizations that purposefully deploy such technologies. In this section we consider a few of these factors that may create an incentive for the organizational adoption of posthumanizing neuroprostheses.[70]

Neuroprostheses Provide Tools for Gathering Information

The information needed to successfully manage an organization includes not only easily quantifiable data relating to IT performance, financial transactions, production processes, or resource consumption but also more elusive qualitative data. In particular, the amount of cultural and social knowledge (much of which is hidden within the thoughts, beliefs, and behaviors of employees and other stakeholders) that must be captured in order to design and manage an enterprise is immense and is not always fully appreciated even by enterprise architects.[71] If an organization has access to the sensory, cognitive, and motor data recorded or generated by neuroprostheses implanted in its employees, each of those individuals becomes a suite of sensors that can be used to gather real-time data about such phenomena and allow live monitoring of ongoing organizational change.

For example, in-depth analysis of the social networks existing within an organization facilitates the development of an effective enterprise architecture for it.[72] An organization that includes neuroprosthetically augmented employees could gather information about its social networks by collecting and analyzing communications and other data from the employees' neuroprostheses; this may reveal actual network topologies and pathways of communication within the organization that differ greatly from the formal reporting relationships described in an official organizational chart. Indeed, it may

[69] For different aspects of this issue, see McGee (2008), p. 216; Koops & Leenes (2012), pp. 125, 132; Wiener (1961), loc. 3070ff., 3149ff.; and Gladden, "Utopias and Dystopias as Cybernetic Information Systems" (2015).

[70] For further analysis of these factors, see Gladden, "Enterprise Architecture for Neurocybernetically Augmented Organizational Systems" (2016), from which this section draws extensively.

[71] See Liu et al., "A Design of Business-Technology Alignment Consulting Framework" (2011).

[72] See Kazienko et al., "Social Network Analysis as a Tool for Improving Enterprise Architecture" (2011).

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be possible to configure neuroprostheses to automatically perform the tracing and (re)construction of organizational social networks; some neuroprosthetic devices (such as those designed to enable massively multiuser virtual environments or hive minds) may include such functionality as a core feature.

Neuroprostheses Facilitate the Generation of Organizational Self-awareness

A particular aspect of information-gathering within an organization is its role in creating organizational self-awareness. Caetano et al. argue that in order to create and maintain alignment between an organization's electronic information systems, human resources, business processes, workplace culture, mission and strategy, and external ecosystem, the organization must be self-aware; this requires "knowledge to be shared and understood in such a way that the mismatch between the actual state of affairs and the state as perceived by its different organizational stakeholders is continuously minimized."[73] While organizations are not 'alive' in the same sense as biological organisms and are not conscious or sapient in the way that a typical adult human being is, an organization does display at least some degree of implicit functional self-awareness, which is necessary for the that entity to organize its internal structures and processes, regulate the 'metabolism' reflected in its component activities, and maintain homeostasis.[74] Such activities are supported by the organization's assimilation of real-time feedback and information-gathering to create and maintain an internal representation of the current and target state of all the organizational elements that must be managed and aligned;[75] the deployment of posthumanizing neuroprostheses could facilitate that work of gathering and processing information. Such devices might also give an organization's employees unlimited real-time access

[73] Caetano et al., "A Role-Based Enterprise Architecture Framework" (2009), p. 253.

[74] In formulating a definition of life that could be employed to determine whether artificial entities (such as robots and AIs) are 'alive,' Friedenberg (*Artificial Psychology: The Quest for What It Means to Be Human* (2008), pp. 201-03), draws on the criteria for biological life presented in Curtis, *Biology* (1983): namely, a living being manifests organization, metabolism, growth, homeostasis, adaptation, response to stimuli, and reproduction. See Gladden, "The Artificial Life-Form as Entrepreneur: Synthetic Organism-Enterprises and the Reconceptualization of Business" (2014), for a discussion of the application of such criteria to businesses and other human organizations understood as viable systems.

[75] This is one of the key practices of enterprise architecture. See Caetano et al. (2009), p. 253. The role of internal models and representations is highlighted in the field of cybernetics in Conant and Ashby's Good-Regulator Theorem. See Conant & Ashby, "Every Good Regulator of a System Must Be a Model of That System" (1970), and elaborations of such thought within the field of management cybernetics in texts such as Beer, *Brain of the Firm* (1981); Barile et al.. "An Introduction to the Viable Systems Approach and Its Contribution to Marketing" (2012); and Buckl et al., "A Viable System Perspective on Enterprise Architecture Management" (2009).

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to the organization's centrally maintained (and continuously updated) internal representation of its full range of structures and dynamics, thereby allowing employees to more effectively identify opportunities for increasing organizational alignment or reducing misalignments and for carrying out actions to generate such improvements.

Neuroprostheses Allow the Creation of New Organizational Forms

During recent decades, new forms of information and communications technology (ICT) have enabled the development of novel organizational structures that were previously impossible or impractical. For example, email, videoconferencing, instant messaging, online commerce platforms, cloud computing (including tools for collaborative online document editing), and mobile apps have facilitated the creation of new types of organizational forms such as virtual organizations.[76] Insofar as posthumanizing neuroprostheses allow new forms of thought, physical action, communication, and collaboration to exist among an organization's workers, they are expected to enable the creation of new types of organizational forms and structures (such as hive minds capable of real-time, spatially dispersed, collective decision-making) that will both enable and require new types of organizational architectures that may provide competitive advantages over organizations employing more traditional architectures.

Neuroprostheses Can Enhance Information Security and Cyberwarfare Capacity

Few organizations require – and can legally and ethically justify – the possession of offensive cyberwarfare capacities used to proactively disable or destroy external computer systems perceived to pose a threat. National military agencies may desire such capacities in order to preemptively disrupt impending attacks by state or non-state actors that threaten to destroy critical infrastructure or imperil the health and safety of their nation's residents, while police agencies may desire such capacities in order to disrupt criminal conspiracies and apprehend suspected criminals.[77] Commercial organizations

[76] Various aspects of virtual organizations are discussed in Fairchild, *Technological Aspects of Virtual Organizations: Enabling the Intelligent Enterprise* (2004); *Virtual Organizations: Systems and Practices*, edited by Camarinha-Matos et al. (2005); and Shekhar, *Managing the Reality of Virtual Organizations* (2016).

[77] Regarding potential uses of offensive cybersecurity and cyberwarfare capacities by police and other security agencies in order to prevent various types of criminal activity (including cyberterrorism), see, e.g., Maitra, "Offensive cyber-weapons: technical, legal, and strategic aspects" (2015), and Leed, *Offensive Cyber Capabilities at the Operational Level: The Way Ahead* (2013).

such as large corporations may maintain competitive intelligence (CI) operations that exploit competitors' information security weaknesses to obtain information about their business operations and plans through lawful – if ethically questionable – means.[78] However, the legal ability of private organizations to actively compromise and disable threats such as botnets (which may involve thousands of computers belonging to entirely innocent third parties) is limited.[79] For an organization that does conduct legally and ethically permissible offensive cyberwarfare or cybersecurity operations, the deployment of posthumanizing neuroprostheses may significantly enhance the organization's capacity in those areas by merging in each host-device unit the speed, power, precision, and scope of automated cybersecurity technologies with the ability of a human agent possessing appropriate decision-making authority and legal responsibility to monitor, authorize, and guide such actions in real time.

For a broader range of organizations, the deployment of posthumanizing neuroprostheses might serve a legally and ethically permissible defensive role in enhancing information security by contributing to the prevention, detection, and mitigation of cybersecurity threats and vulnerabilities. The use of such technologies could potentially expand an organization's capacity for gathering real-time data about its processes and systems, analyzing that data to identify threats and vulnerabilities, and addressing risks by protecting personnel against social engineering, hardening electronic systems, establishing redundancy and failover capacity, creating honeynets, and executing other standard InfoSec practices.[80]

IV. Factors Discouraging Organizational Deployment of Posthumanizing Neuroprostheses

While posthumanizing neuroprostheses have the potential to create competitive advantages for the individuals who use them and the organizations in which such persons are employed, such technologies also present serious

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[78] For discussions of ethical issues inherent in the acquisition and use of competitive intelligence, see Collins & Schultz, "A review of ethics for competitive intelligence activities" (1996); Comai, "Global code of ethics and competitive intelligence purposes: an ethical perspective on competitors" (2003); Crane, "In the company of spies: When competitive intelligence gathering becomes industrial espionage" (2005); and Giustozzi et al., "The new competitive intelligence agents: 'Programming' competitive intelligence ethics into corporate cultures" (2011).

[79] For a discussion of such issues, see, e.g., Leder et al., "Proactive Botnet Countermeasures: An Offensive Approach" (2009).

[80] An overview of such information security practices can be found in *NIST Special Publication 800-53, Revision 4: Security and Privacy Controls for Federal Information Systems and Organizations* (2013) and Rao & Nayak, *The InfoSec Handbook* (2014).

disadvantages, problems, and dangers. Below are listed some factors that may discourage or preclude the organizational deployment of posthumanizing neuroprostheses.

Biomedical Factors

- The risk of a host's injury or death during implantation surgery and the risk of psychological or physical harm resulting from later use of the device.[81]
- A lack of the specialized biomedical expertise needed to safely operate and maintain such devices.
- An inability to monitor device hosts' medical status in real time (e.g., because the hosts operate in remote environments outside of communication range) in order to ensure ongoing device safety.

Business and Operational Factors

- The time and effort needed to train new hosts in the safe and effective use of their neuroprostheses, which may divert their attention from other work activities and result in a loss of related knowledge or skills.
- The failure of posthumanizing neuroprostheses to add substantial value to key organizational activities.
- The ability to successfully achieve business objectives and fulfill an organization's mission without the use of such complex neurotechnologies.
- A lack of the specialized neurocybernetic expertise needed to identify meaningful business applications for such technologies.
- Marketing and public relations concerns regarding the potential negative impact of neuroprosthetic deployment on an organization's brand image – for example, in cases in which a firm's use of neuroprostheses might be perceived as exploitative, unnatural, or otherwise 'sinister.'[82]

[81] Even relatively 'simple' implantation surgery for devices such as passive RFID chips involves risks; more complex invasive surgery for implantation of devices into the brain is even more dangerous. See, e.g., Rotter et al., "Passive Human ICT Implants: Risks and Possible Solutions" (2012), and Clausen, "Conceptual and Ethical Issues with Brain–hardware Interfaces" (2011), p. 499.

[82] In recent decades, the complex dynamics regarding public acceptance or active rejection of emerging technologies have been clearly witnessed and studied, for example, in the case of genetically modified organisms (GMOs) and their use as food for human beings; see, e.g., Frewer et al., "Societal aspects of genetically modified foods" (2004); Frewer et al., "Public perceptions

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- The creation of new information security vulnerabilities arising from the use of such devices by organizational personnel.

Financial Factors

- The high initial costs of acquiring neuroprosthetic devices and surgically implanting them in their human hosts.[83]
- The high and uncertain long-term costs of maintaining implanted neuroprostheses and ensuring the health of their hosts (perhaps for decades, throughout the remainder of their natural lifespan).

Legal and Ethical Factors

- The potential existence of national or local laws and regulations or international treaties that explicitly ban the use of certain types of posthumanizing neurotechnologies or which create doubt regarding the legality of their use.
- Legal concerns regarding the propriety of an employer requiring, encouraging, or enabling employees to acquire neuroprostheses for work-related purposes.
- Legal uncertainties about whether intellectual property that is produced by employees (e.g., during their own free time) with the aid of employer-provided neuroprostheses is owned by the workers' employer, the workers themselves, or third-party firms that produced and maintain the devices.
- The creation of financial and legal liability for an organization for any future accidents or illicit behavior involving neuroprostheses that it has provided to its employees.
- Ethical concerns regarding the moral permissibility of implanting devices that alter basic human capacities and the creation of a workplace environment in which employees feel compelled to submit to

of agri-food applications of genetic modification – A systematic review and meta-analysis" (2013); and Patel et al., "Genetic engineering in agriculture and corporate engineering in public debate: risk, public relations, and public debate over genetically modified crops" (2005). More recently, such debates have also begun to emerge regarding technologies such as self-driving vehicles, caregiving social robots, and military robots. See, e.g., Woisetschläger, "Consumer Perceptions of Automated Driving Technologies: An Examination of Use Cases and Branding Strategies" (2016); De Graaf, & Ben Allouch, "Exploring influencing variables for the acceptance of social robots" (2013); and Royakkers & Van Est, "A literature review on new robotics: automation from love to war" (2015).

[83] As noted above in Part II's discussion of factors limiting the adoption of therapeutic neuroprostheses, the implantation surgery for such a device may cost up to $100,000.

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such augmentation in order to preserve their jobs or receive promotions.

Tools such as a PESTLE analysis[84] may be employed to identify and weigh the risk that future changes to an organization's political, economic, social, technological, legal, and environmental context might render the use of implanted neuroprostheses undesirable or even untenable.

IV. Organizational Roles of Therapeutic vs. Posthumanizing Neuroprostheses

In this section, we consider the difference between the presence of therapeutic neuroprostheses among an organization's workforce and the organization's intentional deployment of posthumanizing neuroprostheses.

Organizations Already Unknowingly Include Neuroprosthetically Augmented Workers

The impacts of neuroprosthetic devices on organizations are most visible and significant when an organization intentionally deploys among its human workers neuroprostheses that are explicitly incorporated into the organization's enterprise architecture as elements of institutional information systems. However, such occurrences are not yet commonplace; far more frequent is the introduction of neuroprostheses into the workplace by individual workers who have acquired such devices of their own volition for their own personal reasons (e.g., as therapeutic devices to treat particular medical conditions). Today, such devices includes cochlear implants, auditory brainstem implants, retinal prostheses, or deep brain stimulation devices; in the future, they might also include new types of cognitive neuroprostheses such as implantable neural bridges intended to restore memory function in those suffering from hippocampal damage.[85]

Such personally acquired neuroprosthetic devices are already present in countless organizations, as it is estimated that more than one million neuroprosthetic devices have been implanted in human beings worldwide,[86] and some of the individuals possessing such devices are employees of organizations into whose workplace they bring their neuroprostheses on a daily basis. Thus many organizations already possess a workforce that includes neuro-

[84] See Cadle et al., *Business Analysis Techniques: 72 Essential Tools for Success* (2010), pp. 3-6, for a description of common variations on this analytic tool.

[85] Work on such a hippocampal mnemoprosthetic implant is described in Soussou & Berger, "Cognitive and Emotional Neuroprostheses" (2008).

[86] A more detailed breakdown of this estimate is found in Part II above, in the discussion of the total global installed base of neuroprosthetic devices and rate of growth.

prosthetically equipped individuals; however, the presence of such neuroprostheses may not be known to those organizations. Indeed, medical privacy and employment discrimination laws may make it illegal for an organization to even attempt to discover which of its employees (if any) possess such neuroprostheses.

Therapeutic Neuroprostheses Do Not Directly Affect Organizational Architectures

While such therapeutic neuroprostheses can have a tremendous positive impact on the lives of the individuals who possess them, their existence does not directly affect the organizational architectures of the organizations within which such persons are employed, as there is typically little incentive (and few practical means) for such devices to become explicitly integrated into the organizations' personnel structures, business processes, and electronic information systems and IT infrastructure. There are indeed cases in which an employer is aware of the fact that its employees possess specific therapeutic neuroprostheses: for example, a military department that supplies robotic prosthetic limbs to its soldiers who have been injured during their tours of duty will be aware of the fact that they possess such therapeutic neuroprostheses, and the devices may – at some level – become incorporated into the organization's information systems (e.g., if the organization's own medical personnel remotely monitor the devices' functioning and provide ongoing maintenance services). To that extent, such neuroprostheses would indeed become components of an organization's enterprise architecture plan and might force changes to some of the elements governed by such plans (e.g., to safeguard the information security of such devices and their hosts). However, the possession of such therapeutic neuroprostheses does not provide their human users with sensory, cognitive, or motor capacities that significantly differ from those of typical employees, and thus the organization will generally not need to dramatically revise its enterprise architecture plans in order to account for the presence of such technologies.[87]

[87] Some changes to an enterprise architecture might be required, e.g., in the sphere of information security, to address the unique InfoSec vulnerabilities possessed by neuroprosthetic devices. Hoogervorst identifies information security as a component of the element of 'quality' within the information architecture domain. Other EA frameworks, such as the Siemens Framework described by Rohloff, do not explicitly identify information security as a domain or building block – not because it is unimportant, but because it underlies *all* of the architectural building blocks. See Hoogervorst, "Enterprise Architecture: Enabling Integration, Agility and Change" (2004), and Rohloff, "Framework and Reference for Architecture Design" (2008). For the unique InfoSec challenges presented by neuroprosthetic devices, see Denning et al., "Neurosecurity: Security and Privacy for Neural Devices" (2009), and Gladden, *The Handbook of Information Security for Advanced Neuroprosthetics* (2015).

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Two Models for Organizations' Deployment of Posthumanizing Neuroprostheses

There are at least two general types of reasons why an organization might wish to intentionally deploy among its personnel posthumanizing neuroprostheses that enhance the capacities of such personnel or integrate them more intimately into the organization's business processes and IT infrastructure; each of these reasons is likely to yield its own model or path for deployment.[88]

'Transitional Augmentation' as a Stopgap Measure on the Path to Full Automation via AI

First, there may be cases in which posthumanizing neuroprostheses are deployed as a stopgap measure because an organization wishes to eventually remove human workers from the equation and fully automate some process. As soon as a robot or other artificially intelligent system can perform the job better than a human worker, the organization will replace the human worker with the robot; however, sufficiently sophisticated AI does not yet exist that can handle the particular task with the necessary degree of effectiveness, efficiency, and reliability and at a competitive cost. And yet, neither is it possible (or possible *any longer*) for an unmodified human worker to do the job that needs to be done in a satisfactory and competitive manner. In some such cases, augmenting a human worker with neuroprosthetically enhanced sensory, cognitive, and motor capacities may enable him or her to perform the work at a more competitive level. Through the process of neuroprosthetic augmentation, the core structures and functionality of the human worker's brain are being retained, because they provide the worker with the wisdom, good judgment, and experience needed to make complex work-related decisions – but the rest of the brain and body *surrounding* those critical neural structures is upgraded in order to enhance the person's capacities.

In essence, the core of the worker's brain would be used as the 'CPU' of a hybrid biological-electronic system while the organization waits for more capable AIs to be developed that can match the human brain's performance in the full range of necessary activities; neuroprostheses constitute new 'upgrades' or 'peripherals' that are added to the brain to expand or improve its range of capacities. In these sorts of organizational roles, the use of posthumanizing neuroprostheses is expected to be only temporary. They represent a form of 'transitional augmentation' that lies on the path to an eventual full

[88] Here we do not directly address the legal or ethical permissibility or propriety of these activities; indeed, such intentional deployment of posthumanizing neuroprostheses poses complex legal issues and grave moral and ethical problems that must be carefully considered. The discussion offered here highlights the fact that such legal and ethical analyses are urgently needed, insofar as operational factors exist that provide at least some organizations with a strong business incentive to consider exploiting such emerging neurotechnologies.

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automation to be achieved through the use of robots and AIs. Yesterday, a natural biological human worker could adequately perform such tasks; tomorrow, an AI will perform them; in the meantime, a neuroprosthetically enhanced human worker is perceived to offer the most desirable mix of human rationality and flexibility and computerized speed, scope, and precision.

Augmentation of Personnel Where Exogenous Factors Mandate Involvement of Human Agency

Even if a robotic agent exists which – from a purely functional perspective – is able to perform a particular set of tasks better than a natural biological or neuroprosthetically augmented human being, there may be factors that effectively bar an organization from assigning a robotic agent to fill that position. For example, the laws and regulations governing corporations in a particular country may explicitly mandate (or implicitly assume) that corporate offices such as president and CEO be filled by particular human beings who must regularly submit forms to the government documenting their organization's legal, financial, and operational status and that those individuals bear legal responsibility for the accuracy and completeness of the documents that they sign and submit. Under currently existing legal regimes, robotic agents would be excluded from filling such organizational roles, insofar as they are not human legal persons who can, for example, be prosecuted and punished for perjury or fraud.

Similarly, there may be many jobs within professions such as law, medicine, accounting, health care, and education which – for reasons relating to regulation and licensing – can only be filled by human beings possessing particular professional qualifications. Many positions within military or police organizations may be restricted to human beings due to the fact that the agents holding such positions must make life-and-death decisions, and it is considered essential that human judgment – as flawed as it may be – bear ultimate responsibility for such choices. In other cases – such as work involving artistic creativity and performance, spirituality, or athletic competition – there may be no legal requirements that mandate the use of human agents in such roles; however, from a marketing perspective there may be a strong incentive for an organization to employ human rather than robotic agents, insofar as such work is perceived to involve a distinctly 'human' element, and the use of artificial agents in such roles would defeat the purpose for which the activities are undertaken.

In all of these situations, while legal, ethical, business, or cultural factors block organizations from employing *wholly* artificial robotic agents to perform such tasks, organizations might wish to exploit the gains in productivity and efficiency that can be achieved by employing at least *partially* artificial

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hybrid human-robotic agents. The neuroprosthetic incorporation of electronic, robotic, artificially intelligent elements into a human worker may represent a sort of compromise between competing interests: a robot cannot be handed the position in its own right, but by incorporating robotic capacities into the human worker who nominally holds the position, it allows the organization to ostensibly meet its legal and ethical obligations and employ humanistic marketing and advertising strategies, while simultaneously obtaining many or all of the perceived benefits of robotic and artificially intelligent workers. For natural biological human workers who already fill important roles within an organization, the acquisition of posthumanizing neuroprostheses may allow them to fill those roles in in a more effective, efficient, and reliable manner. In contrast to cases of 'transitional augmentation,' the use of neuroprosthetically augmented human workers to fill these positions might persist even after AIs exist that can perform the jobs better than human beings from a functional perspective. An eventual move to the use of robotic or artificially intelligent agents in such roles would depend on legal and cultural shifts that may occur only slowly, if at all.

IV. Military Organizations as Early Adopters of Posthumanizing Neuroprostheses

The intentional deployment of neuroprostheses within the workforce is not a pursuit that is necessary, feasible, or appropriate for the vast majority of contemporary organizations. As we have seen, it would raise complex (and potentially insurmountable) ethical and legal issues, typically requires invasive and risky surgeries, and oblige an organization to provide ongoing medical support and device maintenance – all for whatever limited organizational benefits, if any, would be gained in return. However, for a small range of specialized organizations, the deployment of posthumanizing neuroprostheses is an objective that is not only considered desirable but which is being energetically pursued. Chief among such organizations are military agencies and departments that envision the development of 'supersoldiers' who possess neuroprosthetically facilitated capacities such as the ability to carry heavy loads without fatigue, leap over walls, see in the dark and with telescopic vision, communicate silently with one another via their thoughts, and operate for days without sleep. Such organizations may find ready volunteers who are willing to undergo neurocybernetic augmentation in order to support an institutional mission that they value highly and for which they are willing to sacrifice their health, safety, and even – if necessary – their lives.[89]

[89] Regarding potential military applications of neurotechnologies for human enhancement, see, e.g., Falconer (2003); Moreno, "DARPA On Your Mind" (2004); Coker, "Biotechnology and War:

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Known and Hypothesized Military Neuroprosthetic Programs

In some cases, current efforts by military organizations to develop such futuristic technologies can only be hypothesized, as the extreme levels of secrecy maintained within the research and development process make it impossible for outside observers to assemble an accurate account of the ongoing pursuit of such technologies through publically available information. However, a number of contemporary programs led by military agencies with the goal of developing posthuman neuroprostheses are publically known to exist. In some cases, agencies such as DARPA actively explain and promote their efforts to develop such technologies and organize public competitions seeking input and collaboration. Known initiatives created and funded by DARPA to develop technologies relating to neurocybernetic enhancement include:

- The Cognitive Technology Threat Warning System (CT2WS) program for developing computerized binoculars that detect potential threats in a soldier's field of vision by analyzing the soldier's own neural signals.[90]
- More than $100 million dedicated to the Revolutionizing Prosthetics program for developing bidirectional sensorimotor neuroprosthetic robotic limbs.[91]
- $20 million devoted to the Continuous Assisted Performance program designed to create technologies that allow soldiers stay awake and alert for up to seven days.[92]
- $40 million for the Exoskeletons for Human Performance Augmentation program that utilizes haptic interfaces to control an exoskeleton through the detection of minute muscle movements.[93]
- The multimillion-dollar Warrior Web program for developing a lightweight, flexible exoskeleton.[94]

The New Challenge" (2004); Clancy, "At Military's Behest, Darpa Uses Neuroscience to Harness Brain Power" (2006); Graham, "Imagining Urban Warfare: Urbanization and U.S. Military Technoscience" (2008), p. 36; Schermer, "The Mind and the Machine. On the Conceptual and Moral Implications of Brain-Machine Interaction" (2009); Brunner & Schalk, "Brain-Computer Interaction" (2009); Wolf-Meyer, "Fantasies of extremes: Sports, war and the science of sleep" (2009); Kourany (2013), pp. 992-93; and Krishnan, "Enhanced Warfighters as Private Military Contractors" (2015).

[90] See Weinberger, "Pentagon to Merge Next-Gen Binoculars with Soldiers' Brains" (2007), and Tennison & Moreno, "Neuroscience, Ethics, and National Security: The State of the Art" (2012).

[91] See Erikson, "Thought-Controlled Robotic Arm 'Makes a Big Negative a Whole Lot Better'" (2013), and "Prosthetics: Sponsor."

[92] See Falconer (2003).

[93] Falconer (2003).

[94] See Kusek, "The $3 Million Suit: Wyss Institute Wins DARPA Grant to Further Develop its Soft

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- $19 million for the Brain Machine Interfaces program (which later become the Human Assisted Neural Devices program) with a goal of allowing thought-controlled manipulation of vehicles, weapons, and computer and downloading of information directly into a soldier's brain.[95]
- $4 million for the Silent Talk project to enable soldiers to exchange information silently on the battlefield through analysis of their neural signals and direct brain-to-brain communication.[96]

Apart from DARPA's efforts, $4 million has been allocated as part of the Multidisciplinary University Research Initiative program of the US Department of Defense to develop 'synthetic telepathy' facilitating communication among soldiers.[97]

Military Organizations Possess Unique Traits That Make Them Likely Early Adopters

Military departments and specialized military agencies are likely to be among the most notable 'early adopters' that proactively deploy posthumanizing neuroprostheses at an organizational level. While the unclear benefits and considerable obstacles involved with the use of such technologies are likely to dissuade most organizations from considering their use, military organizations (and especially those within more economically and technologically advanced nations) possess a range of characteristics that may cause the development and use of posthumanizing neuroprostheses to be viewed by national policymakers as something that is not only legally permissible but also strategically desirable and even a key part of the military's most essential mandate to counter all potential threats and safeguard a nation's security. Such characteristics displayed by military organizations that can facilitate the use of posthumanizing neuroprostheses include:

Biomedical Factors

- Access to premier medical facilities and biomedical and surgical experts needed for the successful implantation and maintenance of neuroprostheses.
- The ability to develop cutting-edge neurotechnologies based on in-house R&D expertise and longstanding relationships with leading external researchers and manufacturers.

Exosuit" (2014), and Cornwall, "In Pursuit of the Perfect Power Suit" (2015).

[95] See White, "Brave new world: Neurowarfare and the limits of international humanitarian law" (2008), and Falconer (2013).

[96] See Drummond, "Pentagon Preps Soldier Telepathy Push" (2009).

[97] See "Mind over Mouth? Study Could Lead to Communicating via Thoughts" (2008), and Bogue, Robert, "Brain-Computer Interfaces: Control by Thought" (2010).

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Business and Operational Factors

- A mandate to protect national security and the well-being of an entire society that may ethically justify the governmental use of dangerous technologies whose use by private commercial interests would be considered impermissible.
- A wide range of organizational tasks for which the performance of human agents in hostile and stressful circumstances is critical to success and can be enhanced through the use of posthumanizing neuroprostheses.
- A critical need to anticipate, understand, and counteract the effects of posthumanizing neurotechnologies that could potentially be developed and deployed against a country by adversarial states or non-state actors.
- A demonstrated track record of successfully developing and employing innovative technologies.

Financial Factors

- Budgets sufficiently large to fund the development, deployment, and maintenance of such complex technologies.
- The ability to create and maintain mission-critical technology programs that do not demonstrate short-term 'profitability' in a commercial sense.
- Access to secret government-funded research relating to posthumanizing neuroprosthetics that is generally inaccessible to engineers at universities or private companies.

Legal and Ethical Factors

- Exemptions from many national legal and regulatory requirements that create obstacles for private commercial organizations attempting to develop, test, and deploy such technologies.
- A highly skilled workforce whose members are willing to take significant personal risks (including the risk of injury or death) in order to advance their organization's mission.
- The ability to legally conceal from public view the development and deployment of posthumanizing neurotechnologies that may be considered dangerous, overly expensive, or ethically repugnant by significant segments of society.

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Other Types of Organizations Share Some Traits with Military Organizations

Other governmental organizations (such as specialized police agencies, space agencies, and health agencies) may share some but not all of these characteristics. While such organizations might deploy and benefit from such posthumanizing neuroprosthetic technologies after they have been developed, they are presumably less likely than military organizations to be the originators of such technologies. University research laboratories and private companies may participate in the development and production of posthumanizing neuroprostheses as contractors supporting military agencies, and as such they may occasionally attempt to incorporate advanced neuroprostheses into their own organizational structures, processes, and systems on a limited basis for experimental purposes – without, however, being the intended end users of such products.

IV. Enterprise Architecture as a Preferred Management Tool for Early Adopter Organizations

Much has been written about the implications of posthumanizing neuroprostheses from the perspectives of biomedical engineering, philosophy, ethics, and law; however, almost no direct attention has been given to the management implications of intentionally integrating such devices into organizations. There are many lenses through which one might analyze the likely management impacts of posthuman neuroprosthetics on organizations, including those of marketing and sales, production management, HR management, finance and accounting, information security, and ethics and compliance. However, we would suggest that the management discipline of enterprise architecture provides an especially relevant and useful lens through which to analyze, plan, and manage the creation of posthumanizing neuroprosthetic supersystems within organizations.

There are two primary reasons for this – one of which relates to the nature and origins of EA and the other of which relates to the types of organizations that are likely to become early adopters of posthuman neuroprosthetic technologies. First, enterprise architecture provides a ready array of conceptual frameworks and tools through which to plan and administer the incorporation of advanced neuroprosthetic technologies into organizations, as it is a management discipline that was created explicitly to facilitate the successful integration of innovative IT into organizational structures, processes, and systems. The entire history and practice of EA has refined its capacity to be employed for such a purpose. Second, as large, complex, technology-intensive organizations, the military agencies and departments that are likely to be early adopters of posthumanizing neuroprostheses are just the types of or-

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ganizations for which enterprise architecture is already a favored management approach – a key mechanism for integrating advanced IT seamlessly and effectively into the organizations' workforce.[98]

Managing the Integration of Neuroprosthetically Augmented Workers into Organizational IT Systems

Insofar as an organization such as a military department provides its employees with work-related neural implants, the organization's IT infrastructure will extend directly into the bodies and minds of those employees. Increasingly, biosensor networks and other kinds of remotely controlled or remotely accessible implantable devices are expanding the possibilities for external agents and systems to monitor and control the activities of those human beings in whom they are implanted;[99] on a functional level, the network of 'IT systems' subject to an organization's operational control might thus include not only the neuroprostheses implanted within organizational employees but the host-device systems that the employees form with their implants – and even the hosts themselves, in their role as biological organisms and information systems with which their neuroprostheses offer a convenient interface. While traditional EA approaches can aid organizations with the oversight of such phenomena, they do not in themselves offer an adequate framework: administering organizational IT will thus no longer be simply a matter of technology management but a matter of neuroscience, biomedical engineering, and healthcare. The fact that posthumanizing neuroprostheses may allow human persons to be incorporated into an organization's IT infrastructure in such ways raises profound philosophical, ethical, and legal questions that are not directly addressed by enterprise architecture.

IV. Conclusion

The world around us does not include a broad wave of organizations rushing to provide their human personnel with performance-enhancing neuroprosthetic devices, nor is such a phenomenon likely to be witnessed anytime soon. As has been discussed in this text, there exist a range of factors that make the deployment of posthumanizing neuroprostheses not only difficult but undesirable or impossible for most contemporary organizations. And yet there is an array of organizations which – having weighed the legal and ethical

[98] For example, in the 1990s the US Department of Defense developed the Command, Control, Communications, Intelligence, Surveillance, and Reconnaissance (C4ISR) Architecture Framework, which evolved in the early 2000s into the Department of Defense Architecture Framework (or DoDAF); Version 2.02 was released in 2010. See *C4ISR Architecture Framework Version 2.0* (1997); *DoD Architecture Framework Version 2.02* (2010); and Bergey et al., "U.S. Army Workshop on Exploring Enterprise, System of Systems, System, and Software Architectures" (2009).

[99] Gill, "Socio-Ethics of Interaction with Intelligent Interactive Technologies" (2007), p. 293.

considerations and evaluated the business value of such technologies – are moving forward energetically with the development and anticipated eventual deployment of posthumanizing neuroprostheses. Chief among these are military organizations for which the perceived benefits of such neurotechnologies are perceived to outweigh the dangers. Some such organizations may implement a 'transitional augmentation' of human personnel as a stopgap measure on the path to full automation of business processes through the use of AI; others may retain human workers in particular positions because factors such as legal, ethical, or marketing requirements mandate that human agents fill those roles, while simultaneously augmenting the workers so that they can perform more competitively. In many cases, the same characteristics that make such organizations likely to be early adopters of posthumanizing neurotechnologies also lead them to employ enterprise architecture as a key management practice. However, while EA can provide a valuable tool for integrating neuroprostheses into an organization's structures and dynamics at a technological level, in itself it does not directly address or resolve the serious ethical and cultural questions raised by the intentional organizational exploitation of technologies that promise to dramatically alter human workers' basic mental and physical capacities and relationship to the world. It is hoped that the introduction to such issues presented in this text can provide a foundation for further analyses of such questions both by the organizations that are contemplating the internal deployment of posthumanizing neuroprostheses as well as by device manufacturers, policymakers, philosophers of technology, individual consumers and citizens, and competing organizations that may be affected by the introduction of neuroprosthetically facilitated human enhancement into their sectors and industries.

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