Command and Control of India’s Nuclear Arsenal

Lauren J. Borja\textsuperscript{a} and M.V. Ramana\textsuperscript{b}

\textsuperscript{a}Center for International Security and Cooperation, Stanford University, Stanford, CA, USA; \textsuperscript{b}School of Public Policy and Global Affairs, University of British Columbia, Vancouver, Canada

\textbf{ABSTRACT}

Despite long-standing debate about the challenges of establishing command and control of India’s nuclear weapons, few details about the structure and organization of such a system exist in the public domain. Objectives for effective command and control have been laid out in India’s Draft Nuclear Doctrine of 1999, which was followed by the more official statement from 2003 that described some of the organizations governing the new arsenal. It is now almost twenty years later, and many changes have occurred within Indian nuclear force structure. This article documents these evolutions and details some of the similarities and differences between how nuclear weapons might be controlled in India as compared to states that developed nuclear weapons earlier. It specifically examines some of the relevant infrastructure and capabilities, such as military command centres, satellites, and delivery vehicles, that have been developed in the last two decades that are important to nuclear command and control. This article also identifies continuing challenges, such as risks due to the entanglement of conventional and civilian infrastructure with nuclear systems, associated with command and control of nuclear weapons in India.

\textbf{ARTICLE HISTORY}

Received 29 October 2019
Accepted 20 April 2020

\textbf{KEYWORDS}

Command and control; nuclear weapons; India; nuclear threats; unauthorized use; nuclear infrastructure and capabilities

\textbf{Introduction}

In the roughly two decades since the nuclear weapon tests by India and Pakistan in May 1998, the two countries have had at least two direct military confrontations and one major military crisis that lasted many months. There have been reports that during these periods of heightened tensions, nuclear delivery vehicles were readied for potential use, especially during the battle over Kargil in 1999 (Chengappa 2000, 437; Riedel 2002). In February 2019, during the height of the standoff following the militant suicide bombing in Pulwama, the Indian navy deployed a number of vessels, including possibly a nuclear-armed submarine (Indian Navy 2019). Mobilization of Indian nuclear forces raises questions about who ultimately controls these weapon systems and how that control is exerted. Could they have been used by military personnel in the event of an attack from the other side, or were they tightly controlled by the political leadership?
Any answer to these questions from the outside is necessarily speculative. There is little information in the public domain on the command and control of nuclear weapons in India. In general, there has been a history of secrecy surrounding all nuclear matters in the country (Ramana 2009). Others have argued that “the level of opacity surrounding India’s nuclear posture is extraordinary, and held tightly by just a handful of senior civilian officials, scientists, and officers in a dedicated Strategic Forces Command” (Narang 2013). Retired Indian military officials speak out on nuclear issues, including command and control, but separating existing capabilities from recommendations in these statements is challenging (Nagal 2014). Therefore, obtaining reliable information on the command and control of nuclear weapons is extremely difficult.

The limited literature on Indian nuclear command and control largely focuses on the institutional aspects, as opposed to the technical characteristics, and relies on interpretations of the 2003 doctrine in light of either public comments made by retired military officials in op-eds, quotes from unnamed sources in news articles on military developments, or interviews with current anonymous Indian military personnel. Analysts also often compare India’s nuclear weapon developments to the historical trajectories of other nuclear weapon countries.

While these are certainly important contributions, we take a different approach by examining the technical developments, such as military command centres, satellite capabilities, and nuclear delivery systems, to inform our discussion of the Indian nuclear command and control system. Instead of comparing Indian command and control to the trajectories of other nuclear weapon states (R. Kumar 2006; White 2014; Shaheen 2019), who built their systems in a different era, we discuss military communications advances, along with their potential implications for nuclear communications. To give context, we also present a historical discussion.

In this paper, we argue for the possibility that India’s nuclear command and control system might have a large overlap with conventional systems. This raises the risk of entanglement and, in some cases, a greater possibility of unauthorized or accidental use. Concerns about the risk of nuclear escalation due to a conventional attack in a war between American and Chinese or Russian forces exist, because, in some cases, the same command and control infrastructure is likely to be used to direct both conventional and nuclear forces (Talmadge 2017; Acton 2018). In India, it is certainly possible that the command and control infrastructure we identify serves both a conventional and nuclear role. But less is known about potential conventional attacks from Indian enemies that would jeopardize command and control infrastructure and Indian response to attacks on such infrastructure. Because of this uncertainty, we do not speculate further on the possibility of escalation beyond just mentioning this possibility.

Even if the conventional or civilian systems are not entangled with Indian nuclear command and control capabilities, there is value in studying this infrastructure. Similar technology can be used in both nuclear and non-nuclear command centres and satellites. And the Indian defence industrial base used to construct conventional command and control systems is likely to be one and the same.

We begin by discussing the differences between the older nuclear weapon states and India, followed by a brief history of the nuclear command and control debate in India. Afterwards, the paper details three kinds of technical developments that would be the most relevant for the command and control of nuclear weapons: command centres,
satellite capabilities, and nuclear weapon configurations. We conclude with a very brief discussion of some potential dangers associated with the current state of nuclear command and control in India.

**Similarities and Differences of Indian Command and Control to Other Countries**

How Indian nuclear planners conceive and eventually construct their command and control system will have similarities to other nuclear weapon states, such as the United States and Russia. In the first decade following the development of the atomic bomb, nuclear weapon states, such as the United States and Russia, initially relied upon their existing military and civilian telephone and telegraph networks to execute the command and control of nuclear forces. The reliability (command can be expected to reach the weapon), efficiency (speed at which the command can be sent), and confidentiality (command cannot be intercepted and decoded) requirements of nuclear communications soon grew beyond the capabilities of the available networks in the 1950s and 1960s. Additional requirements of survivability (must continue to operate, even after a nuclear detonation) and redundancy (many separate channels must be established, making it harder for an enemy to destroy all communications) were soon added. As a result, the United States and the Soviet Union developed and built separate communication channels specifically for nuclear command and control (Yarynich 2003).

The emphasis on redundancy meant that nuclear weapon states deployed multiple options for sending messages to their nuclear forces, which resulted in the development of new communication technologies and infrastructure. The most outstanding example was the development of satellite communications, that offered a completely different way of communicating from the older medium of ground-based radio and telephone channels. Countries also developed targeting strategies and integrated nuclear early warning systems into their nuclear command and control networks.

Alongside the development of nuclear command and control networks, modern militaries have also increased the sophistication of the command and control systems for non-nuclear military forces. Many states are expanding their military’s capability for network-centric operations or the use of technology and computers to share data and information in real-time to optimize force deployment. With these developments, it is likely that some of the constraints on reliability, redundancy, and efficiency that plagued early military communications are less of a constraint to countries looking to develop nuclear command and control today. Cyber attacks will always be a security challenge for nuclear and non-nuclear command and control, and the technical barriers to fielding these capabilities are being reduced.

In addition to broad advances in military communications, civilian communications have also developed significantly since the 1950s and 1960s. This includes the spread of internet and fiber optic communications systems that enable many civilian sectors, such as the global financial system and social media. Some of these advancements, such as the use of open-source internet intelligence, have impacted the field of nuclear security (Bracken 2016). While these communications channels often have significant security concerns that would impede effective use for nuclear command and control, it is clear that the communications and information environment have changed significantly since
the development of the first nuclear command and control networks. Furthermore, modernization of archaic nuclear networks in nuclear weapon states has integrated information from and connections to conventional systems. Such entanglement increases the possibility of inadvertent nuclear escalation (Arbatov et al. 2017; Talmadge 2017; Acton 2018).

Given that India has embarked on constructing a nuclear command and control infrastructure primarily in the last two decades, how much resemblance would it bear to the complex and, by today’s standards, antiquated nuclear networks of the 1950s? The contrast between the communications environment between the mid-twentieth century and today implies that India would take a different approach towards nuclear command and control rather than simply reproduce the models provided by other states, potentially building off an existing conventional military command and control network or integrating government satellite data. Modernization and development of nuclear delivery vehicles also impact Indian nuclear command and control development.

Beyond information sharing, the skills and technologies that enable these command centres overlap with those needed to construct a national command post. For example, most Indian Air Force and Naval communications centres are capable of integrating images collected via radars, earth-observation satellites, and drones. The algorithms used to integrate and present this data are developed by the Bharat Electronics Limited (BEL), an Indian aerospace and defence company. These centres can communicate using fiber optic networks, which enables data-intensive tasks such as video conferencing, and satellite communications networks. By analyzing the reported capabilities of other Indian military command centres, we automatically collect information on potential capabilities of an Indian nuclear command centre.

**History of Command and Control in India**

To contextualize our discussion of the recent changes in India’s nuclear command and control, we start with a little history. Even before the 1998 Indian nuclear weapon tests, early debates acknowledged the challenges of building a robust nuclear command and control system. As early as the 1960s, when discussing whether India should acquire nuclear weapons after the first Chinese nuclear weapons test in 1962, Major General Som Dutt listed command and control systems as one of the many elements that India would need to match China (Perkovich 1999, 129). Dutt would later become the first director of the Institute for Defence Studies and Analyses, an Indian defence thinktank that frequently comments on Indian nuclear policy. His views are therefore influential.

This challenge was reiterated nearly two decades later by analyst Inder Khosla: “Maintaining a nuclear deterrent requires a very high level of managerial ability. It becomes necessary to maintain an early warning system; to indulge in wargaming nuclear scenarios; to maintain security of launchers/warheads/communications; to prevent an unauthorised launch; and to maintain a national command authority. Given the way India generally functions, is it necessary to go in for a tool so dangerous that the slightest error can be catastrophic?” (Khosla 1981).

By that time, however, those advocating the development of nuclear weapons in India professed greater optimism about the feasibility of establishing an adequate command and control system. A prominent proponent of nuclear weapons, General K. Sundarji,
who later went on to become the country’s Chief of the Armed Forces, argued in 1984 that “Land based [missile] systems can be more effectively and reliably tied into C³ [command, control and communications] systems, with plenty of built-in redundancy. SSBNs [nuclear powered ballistic missile submarines] on the other hand pose serious problems” (Sundarji 1984, 26). We will elaborate more on the complications created by nuclear-armed submarines in a later section.

The second major challenge identified by Indian analysts concerned a potential conflict between the civilian government and the military over the control of nuclear weapons, specifically whether the military would dominate decision-making. But this concern might have been overstated because the military had been largely excluded from decision-making in Indian nuclear weapons matters until at least 1998 and perhaps even much later. According to Gaurav Kampani, an analyst who has conducted interviews with Indian military officials, “the military was told neither of the exact number of nuclear weapons that India might have, nor how they would be employed in a nuclear war. But the civilians drew up detailed instructions to deal with problems in the absence of a formally articulated nuclear doctrine” (Kampani 1998, 15).

At the time of the May 1998 nuclear weapon tests, no new information about command and control had been offered. At an official press conference featuring the top scientific and technical leaders involved in the tests, Abdul Kalam, the scientific advisor to the Prime Minister, responded to a question by saying, “As for command and control systems, we have different forms presently, and are moving towards that” (DAE 1998). One magazine story by a knowledgeable journalist with high-level policy contacts from July 1998, just two months after the nuclear tests, reported: “it is learnt that the Government is setting up a national command post outside Delhi which would not only have all communication and radar facilities but also the strength to withstand a direct hit. Measures have also been taken to ensure proper coded security to authorise a strike. Instead of the press of the button it is more likely to be agreed codes sent over several separate communication channels so that the armed force in charge of nuclear weapons knows it is an authentic order” (Chengappa 1998). We offer this statement to illustrate the kind of overconfidence found in Indian official statements about command and control, even though the claim about the ability to withstand a direct hit by a nuclear weapon strains credibility, both in 1998 and today.

The 1999 Draft Nuclear Doctrine also mentions nuclear command and control systems and included a number of stipulations. The most important of these were: “Nuclear weapons shall be tightly controlled and released for use at the highest political level. The authority to release nuclear weapons for use resides in the person of the Prime Minister of India, or the designated successor(s); An effective and survivable command and control system with requisite flexibility and responsiveness shall be in place. An integrated operational plan, or a series of sequential plans, predicated on strategic objectives and a targeting policy shall form part of the system; For effective employment the unity of command and control of nuclear forces including dual capable delivery systems shall be ensured; The survivability of the nuclear arsenal and effective command, control, communications, computing, intelligence and information (C4I2) systems shall be assured” (NSAB 1999). The three armed service headquarters were subsequently reported to be “drawing up detailed schemes for inducting a variety of nuclear armaments and ancillary and support equipment in their orders-of-battle . . . [and] appropriate command and control frameworks” (Karnad 2002, 108).
Although these claims about survivability are asserted in official doctrines, it is apparent that these are just a set of desirable objectives, not achieved realities in 1999 or today. Even in a state with decades of experience in deploying nuclear weapons, it is hard to believe that anything, including survivability, can really be assured. One particular assertion that we take issue with later on is the claim about tight control residing at the level of the Prime Minister; in the case of submarines, that might be at odds with the reality of trying to store nuclear weapons underwater in a delivery system that might not be confident of reliably communicating with the main command centre.

Despite these inherent vulnerabilities, the Indian government continued to project confidence in its nuclear command and control structure. In 2003, when the official version of the doctrine was announced, the press release read “The Cabinet Committee on Security (CCS) . . . reviewed the existing command and control structures, the state of readiness, the targeting strategy for a retaliatory attack, and operating procedures for various stages of alert and launch. The Committee expressed satisfaction with the overall preparedness” (Prime Minister’s Office 2003).

At the same time, India might also have received some technology from the United States, although there is no confirmation of this. In the “Next Steps in Strategic Partnership” agreement of January 2004 between the United States and India, the two countries promised to “expand cooperation” in civilian nuclear activities, civilian space programs, and high-technology trade, as well as on missile defence (Bush 2004). John Gershman and Zia Mian point out “the obvious, namely that cooperation in this context is a euphemism for the United States providing to India access to aid, information and technology in these areas” (Gershman and Mian 2005). While speaking about this agreement, a State Department spokesman explained that the United States was ready to “help India” with command and control, early warning and missile defence and noted that “Some of these items may not be as glamorous as combat aircraft, but I think for those of you who follow defense issues you’ll appreciate the significance” (AFP 2005).

In a widely reported 2013 speech discussing developments in India’s nuclear arsenal, Shyam Saran, a career diplomat and former chairman of the National Security Advisory Board, stated that the Indian government “has had to create a command and control infrastructure that can survive a first strike and a fully secure communication system that is reliable and hardened against radiation or electronic interference. A number of redundancies have had to be created to strengthen survivability. In all these respects, significant progress has been achieved. To expect that these should have emerged overnight after May 1998 is a rather naïve expectation” (Saran 2013a). This suggested, first, that the process of coming up with a command and control system predated the May 1998 tests and, second, that redundancy is a feature desired by the designers of the system. Yet Saran’s statement did not clarify what constituted “significant progress”, leaving the details of Indian nuclear command and control developments open to speculation.

The speech is important because it has been seen as being an officially sanctioned record of developments in nuclear policy. Indeed, one newspaper report described Saran’s talk as “placing on record India’s official nuclear posture with the full concurrence of the highest levels of nuclear policymakers in New Delhi” (Bagchi 2013).
Infrastructure and Capabilities

We now turn to three sets of developments that are key to the recent evolution of command and control of nuclear weapons in India: the creation of military command centres, the expansion of satellite capabilities, and the handling of nuclear weapons.

Although many of these command centres are focused on conventional military assets it is possible that some of these installations serve multiple purposes, especially considering reports that India’s defence budget only covers upkeep of existing capabilities (Raghuvanshi 2020). For confirmed military bases or capabilities, this means having both a conventional and a nuclear mission. Observers of Indian nuclear forces have estimated that aircraft with both conventional and nuclear missions conduct operations from the Nal (Bikaner) Air Force Station and the Ambala and Gorakhpur air force bases (Kristensen and Korda 2018). Satellites, too, are likely to serve both a civil and military role. As we will discuss later, analysts are divided on whether or not India’s hyperspectral imaging satellite plays a primarily civilian or military role (Ramesh 2018a). That being said, there is evidence that the military command and control structure incorporates information from civilian sources, such as data from radars at civilian airports (Pandit 2015).

Due to their classified nature, only a preliminary assessment of the survivability of these capabilities is possible. Fiber optic networks can reportedly survive an above-ground blast that takes out land-based communications such as telephone lines, but all land-based communications are vulnerable to local nuclear detonations on land (Fairchild Space Company 1986; J. A. Hull 1987). Historically, secure military satellites have been considered the best option for survivable command and control (Fairchild Space Company 1986), although the rise of antisatellite weapons certainly threaten their use during wartime. Hardened, underground command centres could survive nuclear blasts. Nuclear submarine forces have long been considered the most survivable of the three delivery options, although the land-based Very Low Frequency (VLF, sometimes referred to as Extremely Low Frequency or ELF) transmitting stations that would be necessary to send nuclear launch orders are likely to be susceptible to nuclear blast (Unnithan 2018).

Reliance on civilian information and foreign hardware could also be a problem for Indian command, control, and communications. It is well documented that Indian military relies on or incorporates civilian information and data into their military networks (TNN 2008; Koithara 2012; Clary and Narang 2019). Civilian systems could fail in a crisis, which could leave the command centres operating with less information during critical times. The use of foreign components in Indian command and control centres could also be problematic. Many countries, such as the United States (T. Hull 2018), are worried that adversaries could introduce vulnerabilities into nuclear command and control infrastructure via the global supply chain.

Command Centres

India’s official doctrine states that the civilian government, specifically the Prime Minister, controls the nuclear arsenal but that there are “alternate chains of command for retaliatory nuclear strikes in all eventualities” (Prime Minister’s Office 2003). Hence,
there must be people other than the Prime Minister who are authorized to order the use of nuclear weapons when the Prime Minister cannot do so. Additionally, members of the NCA might need to be present or in communication to give counsel to the Prime Minister (Koithara 2012). In this respect, India could be similar to other nuclear weapon states that rely on national command centres or posts to physically host or facilitate conferences to discuss and authorize nuclear plans.

Information on the location and construction of an Indian National Command Post for nuclear attack planning is not publicly available. In 2004, an unnamed defence official complained that a permanent headquarters for nuclear forces had yet to be built (Pandit 2004). In recent years, however, India has unveiled many new military command and control centres. Indian nuclear authorities at a national command centre may rely on these force-specific command and control centres for information and situational awareness, even though an explicit connection has not been made.

In his 2012 book, Managing India’s Nuclear Forces, retired Indian Vice Admiral Verghese Koithara asserts that some overlap is necessary between nuclear and conventional command centres, because those on the NCA will also have responsibilities in the conventional domain. He also states that a national command centre “from where the PM/NCA can control both nuclear operations and conventional operations” does not yet exist (Koithara 2012, 138–39). On the other hand, another Indian nuclear scholar, who has conducted interviews with many military officials, has argued that there is a “bifurcation of conventional and nuclear command and operations”. His discussion focused mostly on oversight of nuclear planning and the organization of the nuclear forces, not on the command and control systems (Kampani 2016). Therefore, we do not presume that India will have two separate sets of command centres.

**Force-Specific Command and Control Infrastructure**

All the three wings of India’s armed forces have been building facilities for managing the command and control of weapons. Upgrades to the Indian Navy command and control infrastructure began with the inauguration of a coastal command and control centre in 2014. As the development of a nuclear-powered and nuclear-capable submarine, which will be discussed later, continues, India has also expanded its submarine communications infrastructure. The Navy inaugurated the National Command Control Communication Intelligence (NC3I) network, an interconnected coastal command and control system capable of collecting data from various coastal radars and satellites in Gurgaon, a city just outside the capital city of Delhi (Pandit 2014c). The Indian Navy has also constructed multiple communication centres for transmitting messages in the VLF bandwidth to its submarines (Pandit 2014b; Special Correspondent 2017); some of these locations are also reported as having “elaborate communication infrastructure including modern satellite communications facilities” (Mahesh 2017).

The Indian Air Force has also upgraded its command, control and communications infrastructure. In 2010, the Indian Air Force launched a secure digital network, called AFNET, that is based on a national fibre-optic grid (Bhatia 2010). It has a reported data transfer speed of 500 megabits-per-second (Mbps), which is capable of supporting data-intensive tasks such as voice-over-IP conferencing (IndraStra Global Editorial Team 2015). This is also over ten times larger than the average global internet download speed of 46.25 Mbps in 2018 (NCTA- The Internet & Television Association 2018). This network forms
“the backbone” for a system of command centres, called the Integrated Air Command and Control System (IACCS). The IACCS is an automated air defence system, capable of synthesizing and presenting information from various radars, satellites, mobile observation posts, airborne early warning centres, and aerial drone video (Pandit 2012a; IndraStra Global Editorial Team 2015). Some of this data is provided by civilian radars, such as those at major Indian civilian airports (Pandit 2015). These centres reportedly run on indigenously developed algorithms, which are mostly developed by the BEL company; although some sources report that hardware from international companies, like CISCO and Raytheon, was also used (Raghuvanshi 2015). While certainly not confirmation of the company’s involvement, Raytheon delivered a pitch for using its command and control systems for the IACCS control centres at the 2012 Defexpo defence conference (Bhatia 2012). New command centres continue to be added to the IACCS infrastructure (India Strategic 2018), and BEL has recently invested in a “world class laboratory . . . dedicated to the integration and testing of IACCS” (“Annual Report 2017-2018” 2018, 51). These indicate that development in the IACCS is an ongoing effort receiving much attention.

Some reports also indicate that information from the IACCS can be sent to higher-level operational and national command posts (Bhatia 2012; TNN 2015). It is not clear if this is the national command post that could be used for nuclear authorization or if this is the national command post for the Indian Air Force. The former option is plausible given the call by a prominent retired Air Force defence official for the integration of ballistic missile defence systems into the IACCS “with simultaneous dissemination of [IACCS] information in real time to the Strategic Forces Command (SFC) and National Command Post” (Kukreja 2015). Such an integration, the official argues, would mean that “a fully integrated aerospace defence capability would be developed from sea level to the exosphere, against a vast multitude of targets such as the very low speed UAVs, through subsonic and supersonic range of manned aircraft, to hypersonic ballistic missiles, in a cost-effective manner”.

Less information is available on the command and control infrastructure of the Indian Army. As early as 2008, Army has expressed interest in underground tunnels for troop shelter, ammunition storage, and command centres (Pandit 2008). Other sources indicated that these would be completed by 2010–2011 (Karnad 2008, 102). According to Indian news sources, preliminary work began in 2012 on seven tunnels with plans for eleven more (Pandit 2012b). The Indian Army has ordered a digital communications network from Tata Power SED and BEL that will connect deployed troops to battalion headquarters (Cohen and Dasgupta 2012; Katoch 2018). More recent reports indicate that progress has stalled on some of these plans (Pandit 2019), and some army officials are critical of its success due to delays in the fielding of the various components (Lt and General 2018).

**Satellite Capabilities**

India has long been interested in acquiring satellite capabilities as part of its efforts to develop a nuclear arsenal. The draft nuclear doctrine of 1999 included a call for “early warning capabilities,” such as “space based and other assets” for “early warning, communications, damage/detonation assessment” (NSAB 1999). This goal has been followed and early warning has been one of the motivations for the acquisition of various space assets (Rajagopalan and Prasad 2017, 193–212).
Since 2003, Indian space imaging capabilities have increased dramatically (Clary and Narang 2019). Speaking in 2019, an Indian Air Force official remarked on this progress: “Do we need more satellites? Yes. But nearly 70% of our demand has been met and we are on track” (C. Kumar 2019a). A list of satellites whose military role has been confirmed is provided in Table 1. Since the 14 February 2019 suicide bombing that killed many Indian paramilitary police personnel, Indian officials have been more forthcoming about satellite capabilities, sometimes claiming that these satellites were used to plan and carry out the subsequent airstrikes in Balakot, Pakistan (Singh 2019a).

The Cartosat constellation is a series of five optical imaging satellites with the ability to capture images with sub-meter resolution. This constellation plays a dual military and civilian government role, providing information for natural resource management and urban planning. It is possible that these satellites alone can provide images of over 80% of Pakistan’s land area (C. Kumar 2019a). These capabilities, however, do not necessarily translate into constant surveillance of Pakistani territory; India’s capacity for doing that are unclear. The Indian Space Research Organization (ISRO) spent many years developing an updated Cartosat-3 (D.S. 2017). After several years of delays, the Cartosat-3 was launched on 27 November 2019 (India Today Web Desk 2019).

India also operates radar-frequency earth-observation satellites. Instead of capturing visible light, radar satellites create images from radio frequencies, which can penetrate cloud cover. Examples are the Risat-2, Risat-2B, and Risat-2BR1, three X-band synthetic aperture radar satellites (Chakraborty 2018; Singh 2019b, 2019c). One other radar satellite, the Risat-1, uses a lower radio frequency (Chakraborty 2018), which provides better images in tropical climates that experience high rainfall (European Space Agency 2018). In May 2019, the ISRO head announced plans to launch five more similar satellites within the next year (Singh 2019b). These radar-imaging satellites also perform a dual civil-military role; an unnamed source from ISRO stated that “At least four Risat satellites in space are required for security forces to keep surveillance on a particular spot on a daily basis”, and images from Risat satellites have been used to conduct Indian airstrikes on Pakistani territory (Singh 2019c).

In addition to radar-imaging capabilities, India also operates satellites with infrared and hyperspectral imaging. The Microsat-TD far-infrared military imaging satellite can also take images at night, though not when there are clouds covering the object being studied (Tejonmayam 2018). The HySIS satellite can capture images across the visible, near-infrared, and shortwave infrared spectrum. While some reports have claimed it plays a military role (Singh 2018), other outside sources have pointed out that its capabilities are much more suited for agriculture and resource management (Ramesh 2018a).

In addition to its fleet of imaging satellites, which tend to be for both military and civilian use, India has also recently acquired some satellites used for only military purposes. The GSAT-7 Naval communications satellite, nicknamed the “Rukmini”, was launched in 2013. It is capable of sending encrypted messages over multiple frequencies (Pandit 2014a). These messages can be received by transponders in warships, submarines, and aircraft developed by the Bharat Electronics Limited (BEL) company (“Annual Report 2015-2016” 2016, 14). Launched in December 2018, the Air Force operates GSAT-7A (Rohit 2018), which connects airbases and ground radar stations, airborne early-warning and control aircraft, and drones (Airforce Technology n.d.). GSAT-7B is a
Table 1. A list of current and planned Indian military satellites. Unless indicated, information is from the UCS Satellite Database. Blank spaces indicate that the data could not be found for that particular satellite. (*UCS Satellite Database* n.d.).

| Name               | Launch Date | Anticipated Lifetime | Use                                      | Capabilities/Details                                                                 |
|--------------------|-------------|---------------------|------------------------------------------|---------------------------------------------------------------------------------------|
| GSAT-7             | 8/29/2013   | 7                   | Naval Communications                      | Multiband communications satellite with UHF, S, C, AND Ku transponders                |
| GSAT-7A            | 12/19/2018  | 8                   | Air Force Communications                 | Multiband communications satellite that networks airbases with radars and Airborne warning and control (AWACS) aircraft (Chakraborty 2018) |
| CartoSat-2A        | 04/28/2008  | 5, still in orbit  | Earth Observation                        | Panchromatic Optical imaging; resolution: <1 m, 9.2 km                                |
| CartoSat-2B        | 07/12/2010  | 5                   | Earth Observation                        | Optical imaging satellite for resource mapping, urban planning, transportation studies, water monitoring |
| CartoSat-2C        | 06/22/2016  | 5                   | Earth Observation                        | Optical imaging satellite with lower orbit for military applications                  |
| CartoSat-2D        | 02/15/2017  | 5                   | Earth Observation                        | Optical imaging satellite for resource mapping, urban planning, transportation studies, water monitoring |
| CartoSat-2E        | 01/11/2018  | 5                   | Earth Observation                        | Optical imaging satellite for resource mapping, urban planning, transportation studies, water monitoring |
| CartoSat-3         | 11/27/2019  | Unknown             | Earth Observation                        | Optical imaging satellite with alleged 25 cm resolution for cartographic and high-resolution mapping (Raj 2013) |
| RISat-1            | 04/25/2012  | Unknown             | Earth Observation                        | Imaging satellite that uses C-band synthetic aperture radar for agricultural resource management (Chakraborty 2018) |
| RISat-2            | 04/20/2009  | Unknown             | Earth Observation                        | Radar imaging with Israeli-built X-band synthetic aperture radar (Chakraborty 2018), with up to 1 m resolution (Singh 2019a); used primarily defence, but can also help with agriculture management and disaster management (PTI 2009) |
| RISat-2B           | 05/22/2019  | 5                  | Earth Observation                        | X-band synthetic aperture radar satellite (Singh 2019b) used for agriculture, forestry, disaster management support (*"Indian PSLV Launches RISAT-2BR1 Military Satellite 2019", as well as surveillance (Singh 2019b)) |
| RISat-2BR1         | 12/10/2019  | 5                    | Earth Observation                        | X-band synthetic aperture radar satellite used for geographic and military monitoring ("RISAT 2B, 2BR1, 2BR2" 2020), with 0.35 m resolution over 5 to 10 km swaths, day and night visibility (Singh 2019c) |
| RISat-2BR2, RISat-1A, RISat-1B, RISat-2A | Within 1 year of 05/2019 (Singh 2019b) | Unknown                              | To increase surveillance of border with Pakistan and Chinese ships in Indian Ocean (Singh 2019b) |
| Microsat-TD        | 01/11/2018  | Unknown             | Earth Observation                        | Optical imaging satellite that can create panchromatic, color and near-infrared imagery |
| HySIS              | 11/29/2018  | 5                   | Earth Observation                        | Hyperspectral Imaging for agriculture and resource management; Disputed military role (Ramesh 2018a); can collect data across 316 bands in the visible, near-infrared and shortwave infrared spectra |
| EMISAT             | 04/01/2019  | Unknown             | Military (C. Kumar 2019b)               | Detects radar and microwave signals for defence intelligence (Singh 2019a) |
forthcoming for the communications satellite for the Indian Army (Ramesh 2018b). On 1 April 2019 India launched the EMISAT, which is aimed at collecting electromagnetic signals from foreign radars, potentially helping understand their capabilities (C. Kumar 2019b).

To be sure, we cannot determine whether any of these are used for nuclear command and control. But it is plausible that at least some of these will be used. For example, imaging satellites could be used to pass on information about Pakistani nuclear capabilities or be used for border surveillance. Communications satellites could be used to direct or command conventional and nuclear forces, given that sometimes those capabilities are co-located. It is plausible that India may choose to use these for nuclear command and control, rather than develop an entirely independent system. While this cannot be confirmed, Indian military have a history of relying on civilian and, in some cases, international satellite intelligence before dedicated military spacecraft could be launched. For example, in building the IACCS network, India chose to also integrate information from civilian radar networks (Pandit 2015). Even if a separate nuclear command and control network has been constructed, we suspect that this nuclear network will integrate information from other military command and control and satellite networks. Again, we emphasize that the entanglement of nuclear and conventional capabilities could be a source of inadvertent nuclear escalation.

**Nuclear Delivery Vehicles and Weapon Configurations**

In recent years, there have been changes to the configurations of nuclear weapons and how they are stored relative to delivery vehicles. Historically, it is reported, the fissile cores of the nuclear warheads were kept separated from the rest of the warheads, with the former being in the custody of the Department of Atomic Energy (DAE) and the latter with the Defence Research and Development Organization (DRDO) (Kampani 2014, 99). The delivery vehicles were under the control of the armed forces. This separation, it is believed, meant that “neither the DAE nor the DRDO nor the uniformed military would be able to launch a nuclear weapon independently, since none of the organizations – acting autonomously – would have all the necessary components to assemble a completed weapon and deliver it to target without explicit authorization from the national leadership” (Tellis 2001, 431–32). Clearly, keeping nuclear weapons in this demated configuration reduces the pressures on the command and control system by making it less likely that there might be an accidental or unauthorized launch. But this posture might increase concerns that during conflicts, it might not be possible to bring together the different parts quickly.

This concern should not exist with the most recent versions of the Agni missile. Some more recent tests of this missile are said to be from a canister (Bagla 2018). Canisterising refers to storing missiles inside a tube, called a canister, so that the missile can be protected from the elements while being transported. This makes for easier handling of the missile (Subramanian 2015). If appropriately designed, the tube can also function as the location for missile launch.

The significance of this configuration is explained by strategist Bharat Karnad: “the ongoing process of canisterising Agni missiles ... provides the country not only with a capability for launch-on-warning but also for striking pre-emptively should reliable intelligence reveal an adversary’s decision to mount a surprise attack ... Nuclear missiles
in hermetically sealed canisters are ready-to-fire weapons and signal an instantaneous retaliatory punch to strongly deter nuclear adventurism” (Karnad 2017). If quick launching is indeed the purpose, then the nuclear warheads should be mated to the missiles. We describe below the potential command and control implications of this configuration.

Another indication of decreasing separation between nuclear warheads and their delivery vehicles is in the case of nuclear-armed submarines (Mian, Ramana, and Nayyar 2019). Some analysts have claimed, on the basis of interviews with military officers, that physical mating happens only in crisis situations and that “India has developed an elaborate command and control apparatus to maintain firm political control over its sea-based nuclear assets” (Joshi 2019). However, other analysts have pointed out that even if the warheads are not loaded into the missiles, the submarine crew must have access to them while out on patrol (Sidhu 2013). And that although it is possible “to insert final components or mate a warhead in an SLBM tube while on deterrent patrol, they are complicated,” meaning “the SLBM will almost surely have to be deployed in a pre-/mated state” (Narang 2013).

Indian officials have used the No First Use policy to justify the acquisition of nuclear submarines: In 2009, then Defence Minister A. K. Atony stated, “Our voluntary commitment to ‘no first use’ nuclear weapons policy also necessitated acquiring a credible second strike capability [i.e. nuclear-armed submarines] to safeguard our national interest” (Pubby 2009). However, the constraints in nuclear-armed submarines discussed above actually make it more difficult to detect any changes in India’s stated No First Use policy. The ambiguous nature of India’s No First Use policy has been previously discussed in this journal (Sundaram and Ramana 2018).

We know little about the command and control procedures for India’s nuclear-armed submarines. A recent description about the INS Arihant stated that “the SSBN can be ordered to launch its weapons after receiving a coded signal from India’s nuclear command post”, and that the Nuclear Command Authority headed by the PM could communicate with the Arihant using an Extremely Low Frequency (ELF) radio communications facility, INS Kattaboman, in Tamil Nadu (Unnithan 2018).

The cause for concern is that the stealth requirements of submarines can strain nuclear command and control and increase the pressure for delegation of nuclear authority in advance. One analyst has noted that “constant communication [between the submarine and military or civilian leadership] may be undesirable, as many forms of communication make the submarine more likely to be detected” (Wueger 2016, 83).

These concerns exist for all nuclear weapon states that deploy submarines. In the United States, analyst Bruce Blair, when describing typical nuclear submarine operations, said that while on patrol submarines “observed strict radio silence” and that “no one except the crew itself knew the exact location of a missile submarine” (Blair 1985, 119). Blair has also highlighted the fact that “submarine crews … possessed the physical capacity to launch nuclear weapons on their own” and that under “some circumstances, the exact nature of which remain secret, a conditional grant of launch authority … extended to the lowest rung of the submarine command hierarchy” (Blair 1985, 101).

Across all types of nuclear delivery platforms, the insertion of fissile cores into warhead and the mating of warheads into delivery vehicles makes it easier, even if not always possible, for a lower-level official to launch a nuclear weapon without authorization. That said, officials and military officers have been quoted by researchers asserting that “highly
centralized procedural control still exists over India’s nuclear arsenal. Every movement, or arming of a system, is still subject to at least a two-/man rule, requiring at least two separate personnel to release a nuclear weapon, and can only be authorized directly by the NCA (i.e. an arming code with the targeting package would be communicated directly in the final step, preventing any one person from releasing a nuclear system without it)” (Narang 2013, 149).

Little is known about whether nuclear weapons are kept in configurations that require personnel to use codes transmitted from central command and control centres. Because of the need for higher authentication, confidentiality, and the mobilization of elaborate plans within short timescales, other countries have developed many complicated code instructions or automated systems needed to launch weapons (Carter 1987). Even less is known about India’s nuclear targeting (Clary and Narang 2019).

However, an important procedural element was discussed in Saran’s 2013 speech, namely the requirement for two separate individuals in nuclear launch facilities to sign off on the use of any nuclear weapons. Saran said that the “National Command Authority works on a two-person rule for access to armaments and delivery systems” and that “Regular drills are conducted to examine possible escalatory scenarios, surprise attack scenarios and the efficiency of our response systems under the no first use limitation. Thanks to such repeated and regular drills, the level of confidence in our nuclear deterrent has been strengthened. Specialized units have also been trained and deployed for operation in a nuclearized environment” (Saran 2013a). Shortly thereafter, in a newspaper article, Saran explained that these measures are “clearly not the record of a state which regards its nuclear arsenal as having only symbolic value” (Saran 2013b).

**Conclusion**

In this paper, we have suggested that the “update” of the “scheme” for controlling nuclear weapons in India has evidently continued and may have metamorphosed significantly in the past ten years. A number of command and control centres associated with specific military forces have been built and a large number of satellites have been launched. Although it has not been confirmed that these command and control centres are involved in nuclear decision-making, the expertise needed to field these capabilities is similar to the expertise needed for nuclear command and control.

As briefly discussed earlier, using command and control networks for both conventional and nuclear roles will expose India to new dangers, especially if they are also connected to civilian infrastructure. Even in countries that originally developed separate nuclear command and control channels, nuclear analysts have noticed an “entanglement” of nuclear and non-nuclear command, control and communication capabilities (Talmadge 2017; Arbatov et al. 2017; Acton 2018). These include early-warning satellites, radars or aircraft that perform both nuclear and non-nuclear missions. The entanglement of nuclear and non-nuclear capabilities brings a potential increase in the risk of nuclear escalation. Because they perform multiple roles, a country looking to strike conventional communications could also threaten an opponent’s nuclear network, which could result in a nuclear retaliation.

In addition to increasing the risk of nuclear escalation, hackers could use connections with civilian and conventional infrastructure to access nuclear weapons systems.
Cyberattacks on secret Indian government communication channels and Indian nuclear power plants have occurred (Yadav 2017; Ramana and Borja 2020). If nuclear and conventional and civil systems are interlinked, these problems might be amplified.

We have also described technical developments in India’s nuclear delivery vehicles, specifically land-based missiles that can be launched in new configurations and submarines carrying nuclear weapons, that would have implications for the command and control of those sections of the nuclear arsenal. These developments, ironically, reinforce the perception during the early years of the debate over nuclear weapons in India, that effective command and control of nuclear weapons continues to pose a significant challenge. In particular, there remains the risk of unauthorized or accidental use.

**Disclosure Statement**

No potential conflict of interest was reported by the authors.

**Notes on Contributors**

*Lauren J. Borja* is Stanton Nuclear Security Postdoctoral Fellow at the Center for International Security and Cooperation at Stanford University. She received her Ph.D. from the University of California, Berkeley and was previously a Simons Postdoctoral Research Fellow at the School of Public Policy and Global Affairs, University of British Columbia.

*M.V. Ramana* is the Simons Chair in Disarmament, Global and Human Security at the Liu Institute for Global Issues in the School of Public Policy and Global Affairs, University of British Columbia and the author of The Power of Promise: Examining Nuclear Energy in India (Penguin Books, 2012) and co-editor of Prisoners of the Nuclear Dream (Orient Longman, 2003). He is a member of the International Panel on Fissile Materials and the Global Council of Abolition 2000. He is the recipient of a Guggenheim Fellowship and a Leo Szilard Award from the American Physical Society. Security and Cooperation at Stanford University.

**ORCID**

M.V. Ramana [http://orcid.org/0000-0003-1332-930X](http://orcid.org/0000-0003-1332-930X)

**References**

Acton, J. M. 2018. “Escalation through Entanglement: How the Vulnerability of Command-and-Control Systems Raises the Risks of an Inadvertent Nuclear War.” *International Security* 43 (1): 56–99. doi:10.1162/isec_a_00320.

AFP. 2005. “US Unveils Plans to Make India ‘Major World Power.’” Agence France-Presse, March 26, 2005.

*Airforce Technology*. n.d. “GSAT-7A: A Military Communications Satellite Developed by ISRO for IAF.” Accessed 21 June 2019. https://www.airforce-technology.com/projects/gsat-7a/

*Annual Report 2015-2016*. 2016. “Bharat Electronics.” Bangalore, India. http://www.bel-india.in/Documentviews.aspx?fileName=Annual%20Report%202015-16.pdf

*Annual Report 2017-2018*. 2018. Bharat Electronics. Bangalore, India: http://www.bel-india.in/Documentviews.aspx?fileName=annual-report-2017-18-28918.pdf
Arbatov, A., V. Dvorkin, P. Topychkanov, T. Zhao, and L. Bin. 2017. “Entanglement: Chinese and Russian Perspectives on Non-Nuclear Weapons and Nuclear Risks.” Washington, D.C.: Carnegie Endowment for International Peace. https://carnegieendowment.org/2017/11/08/entanglement-chinese-and-russian-perspectives-on-non-nuclear-weapons-and-nuclear-risks-pub-73162

Bagchi, I. 2013. “Even a Midget Nuke Strike Will Lead to Massive Retaliation, India Warns Pak.” The Times of India, April 30, 2013. http://timesofindia.indiatimes.com/articleshow/19793847.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

Bagla, P. 2018. “Agni 5 Missile That Can Strike China Set To Enter India’s Arsenal.” NDTV.Com, January 19, 2018. https://www.ndtv.com/india-news/agni-5-missile-that-can-strike-china-set-to-enter-india-arsenal-1802188

Bhatia, V. K., Air Marshal (Retd). 2010. “AFNET Kick-Starts.” SP’s Aviation, October 2010. http://www.sps-aviation.com/story/?id=582

Bhatia, V. K., Air Marshal (Retd). 2012. “Raytheon’s Project Athena Multi-Domain Awareness System.” SP’s Aviation, May 2012. http://search.proquest.com/docview/1017859991/abstract/774599C9FFAB4267PQ/1

Blair, B. 1985. Strategic Command and Control. 1st ed. Washington, D.C: Brookings Institution Press.

Clary, C., and V. Narang. 2019. “India’s Counterforce Temptations: Strategic Dilemmas, Doctrine, and Capabilities.” International Security 43 (3): 7–52. doi:10.1162/isec_a_00340.

Cohen, S. P., and S. Dasgupta. 2012. Arming without Aiming: India’s Military Modernization. 2 edition ed. Washington, DC: Brookings Institution Press.

European Space Agency. 2018. “Satellite Frequency Bands.” European Space Agency. October 3, 2018. https://www.esa.int/Our_Activities/Telecommunications_Integrated_Applications/Satellite_frequency_bands

Fairchild Space Company. 1986. “Survivability Enhancement Study for C3I/BM Ground Segments.” DOE/SF/15929-1. San Francisco: U.S. Department of Energy. https://www.osti.gov/servlets/purl/6588985

Gershman, J., and Z. Mian. 2005. “A Story of Leaders, Partners, and Clients.” Washington, D. C.: Institute for Policy Studies. https://ips-dc.org/a_story_of_leaders_partners_and_clients/

Hull, J. A. 1987. “NSEP Fiber Optics System Study, Background Report: Nuclear Effects on Fiber Optic Transmission Systems.” NTIA Report 87-227. Washington, D.C.: U.S. Department of Commerce. https://cryptome.org/2012/09/ntia-87-227.pdf
Hull, T. 2018. “Air Force Space Command Supply Chain Risk Management of Strategic Capabilities DODIG-2018-143.” https://media.defense.gov/2018/Aug/16/2001955109/-1/-1/1/DODIG-2018-143_REDACTED.PDF

India Strategic. 2018. “Air Officer Commanding In Chief, Central Air Command, Inaugurated,” August 2018. https://www.indiastrategic.in/2018/08/03/air-officer-commanding-in-chief-central-air-command-inaugurated/

India Today Web Desk. 2019. “Isro Successfully Launches CARTOSAT-3, 13 Nano-Satellites from Sriharikota.” India Today, November 27, 2019. https://www.indiatoday.in/science/story/isro-launches-earth-imaging-satellite-cartosat-3-13-nano-satellites-from-1622889-2019-11-27

Indian Navy. 2019. “Naval Commanders’ at Kochi for Operational Discussions,” March 17, 2019. https://www.indiannavy.nic.in/content/naval-commanders-kochi-operational-discussions

Indian PSLV Launches RISAT-2BR1 Military Satellite. 2019. NASASpaceFlight.Com (blog). December 11, 2019. https://www.nasaspaceflight.com/2019/12/indian-pslv-launch-risat-2br1-military-satellite/

IndraStra Global Editorial Team. 2015. “ANALYSIS | India’s Integrated Air Command & Control System (IACCS) : A NCW Milestone” IndraStra, September 28, 2015. https://www.indrastra.com/2015/09/ANALYSIS-IACCS-257.html

Joshi, Y. 2019. “Angles and Dangles: Arihant and the Dilemma of India’s Undersea Nuclear Weapons”. War on the Rocks. January 14, 2019. https://warontherocks.com/2019/01/angles-and-dangles-arihant-and-the-dilemma-of-indias-undersea-nuclear-weapons/

Kampani, G. 1998. “From Existential to Minimum Deterrence: Explaining India’s Decision to Test.” The Nonproliferation Review 6 (1): 12–24. doi:10.1080/10736709808436732.

Kampani, G. 2014. “New Delhi’s Long Nuclear Journey.” International Security 38 (4): 79–114. doi:10.1162/ISEC_a_00158.

Kampani, G. 2016. “India’s Evolving Civil-military Institutions in an Operational Nuclear Context.” Carnegie Endowment. https://carnegieendowment.org/2016/06/30/india-s-evolving-civil-military-institutions-in-operative-nuclear-context-pub-63910

Karnad, B. 2002. “India’s Force Planning Imperative: The Thermonuclear Option.” In Nuclear India in the Twenty-First Century, edited by D. R. SarDesai and R. G. C. Thomas. New York: Palgrave. doi:10.1057/9780230109230_5.

Karnad, B. 2008. India’s Nuclear Policy. Westport, Conn: Praeger.

Karnad, B. 2017. “Why Concerns about an India-Pakistan Nuclear War are Highly Exaggerated.” Hindustan Times, March 30, 2017. http://www.hindustantimes.com/analysis/concerns-about-an-india-pakistan-nuclear-war-are-highly-exaggerated/story-rnKGEO3qZ0oCPmHR1edRqL.html

Khosla, L. 1981. “Use of Nuclear Weapons.” IDSA Journal XIII 4: 463–478.

Koithara, V. 2012. Managing India’s Nuclear Forces. 1 Edition. Washington, D.C: Brookings Institution Press.

Kristensen, H. M., and M. Korda. 2018. “Indian Nuclear Forces, 2018.” Bulletin of the Atomic Scientists 74 (6): 361–366. doi:10.1080/00963402.2018.1533162.

Kukreja, A., and M. Dhiraj. 2015. “Integrated Air Defence for the Indian Airspace.” Indian Defence Review, January 29, 2015. http://www.indiandefencereview.com/news/integrated-air-defence-for-the-indian-airspace/

Kumar, C. 2019a. “Isro Satellites Can Map 87% Land Area of Pakistan, in HD.” The Times of India, February 28, 2019. https://timesofindia.indiatimes.com/india/isro-satellites-can-map-87-land-area-of-pakistan-in-hd/articleshow/68196974.cms

Kumar, C. 2019b. “Days after A-SAT, EMISAT Adds to India’s Defence Capability.” The Times of India, April 1, 2019. https://timesofindia.indiatimes.com/india/days-after-a-sat-emisat-add-to-indias-defence-capability/articleshow/68669542.cms

Kumar, R. 2006. Indian Nuclear Command and Control Dilemma. Masters, Monterrey, CA: Naval Postgraduate School. https://calhoun.nps.edu/handle/10945/2639

Lt, K., and P. C. General (Red). 2018. “Army’s Battlefield Management System — Dumped?” SP’s Land Forces, January 8, 2018. http://www.spslandforces.com/experts-speak/?id=326&h=Army-s-Battlefield-Management-System-Dumped
Madhumathi, D. S. 2017. “India Gets a Sharper Eye in the Sky with ISRO’s Cartosat-2E.” *The Hindu*, June 29, 2017. https://www.thehindu.com/sci-tech/science/india-gets-a-sharper-eye-in-the-sky/article19180628.ece

Mahesh, K. 2017. “Navy to Reach Ships and Subs from Pudur.” *The Times of India*, December 26, 2017. https://timesofindia.indiatimes.com/city/hyderabad/navy-to-reach-ships-and-subss-from-pudur/articleshow/62261258.cms

Mian, Z., M. V. Ramana, and A. H. Nayyar. 2019. “Nuclear Submarines in South Asia: New Risks and Dangers.” *Journal for Peace and Nuclear Disarmament*:1–19. doi: 10.1080/25751654.2019.1621425

Nagal, B. S., Lt Gen (retd). 2014. “Nuclear No First Use Policy.” *Force National Security and Aerospace Newsmagazine*, December 2014. http://forceindia.net/guest-column/guest-column-b-s-nagal/nuclear-no-first-use-policy/

Narang, V. 2013. “Five Myths about India's Nuclear Posture.” *The Washington Quarterly* 36 (3): 143–157. doi:10.1080/0163660X.2013.825555.

Prime Minister’s Office. 2003. “Cabinet Committee on Security Reviews Progress in Operationalizing India’s Nuclear Doctrine.” New Delhi: Government of India. http://pib.nic.in/ Archieve/Ireleng/lyr2003/rjan2003/04012003/r040120033.html

PSLV-C46/RISAT-2B MISSION. 2019. “Launch Kit.” Bengaluru, India: Indian Space Research Organization. https://www.isro.gov.in/pslv-c46-mission/launch-kit
PTI. 2009. “India to Launch Spy Satellite on April 20.” *The Times of India*, April 8, 2009. https://timesofindia.indiatimes.com/india/India-to-launch-spy-satellite-on-April-20/articleshow/4374544.cms

Pubby, M. 2009. “India in N-Sub Club, Arihant to Be Inducted in Next 2 Yrs.” *The Indian Express*, July 26, 2009. https://indianexpress.com/article/india/latest-news/india-in-nsub-club-arihant-to-be-inducted-in-next-2-yrs/

Raghuvanshi, V. 2015. “Challenges Await Completion of Indian AF Net-Centric System.” *Defense News*, October 10, 2015. https://www.defensenews.com/air/2015/10/10/challenges-await-completion-of-indian-af-net-centric-system/

Raghuvanshi, V. 2020. “New Weapons Purchases Suffer under India’s Latest Defense Budget.” *Defense News*, February 4, 2020, sec. Asia Pacific. https://www.defensenews.com/global/asia-pacific/2020/02/04/new-weapons-purchases-suffer-under-indias-latest-defense-budget/

Raj, N. G. 2013. “ISRO Plans a New High-Resolution Earth Satellite.” *The Hindu*, March 6, 2013, sec. Science. https://www.thehindu.com/sci-tech/science/isro-plans-a-new-high-resolution-earth-satellite/article482404.ece

Rajagopalan, R. P., and N. Prasad. 2017. *Space India 2.0: Commerce, Policy, Security and Governance Perspectives*. New Delhi: Observer Research Foundation.

Ramana, M. V. 2009. “India’s Nuclear Enclave and the Practice of Secrecy.” In *Nuclear Power and Atomic Publics: Society and Culture in India and Pakistan*, edited by I. Abraham, 41–67. Bloomington: Indiana University Press.

Ramana, M. V., and L. J. Borja. 2020. “The Computer Infection of Kudankulam and Its Implications.” *India Forum*, January 10, 2020. https://www.theindiaforum.in/article/computer-infection-kudankulam-and-its-implications

Ramesh, S. 2018a. “The Militaristic Claims of ISRO’s Latest Satellite Have Been Greatly Exaggerated.” *ThePrint*, December 4, 2018. https://theprint.in/science/the-militaristic-claims-of-isros-latest-satellite-have-been-greatly-exaggerated/158545/

Ramesh, S. 2018b. “ISRO to Launch Advanced GSAT-7A Satellite for IAF and Army Today.” *ThePrint*, December 18, 2018. https://theprint.in/science/isro-to-launch-advanced-gsat-7a-satellite-for-iaf-and-army-today/165548/

Riedel, B. 2002. “American Diplomacy and the 1999 Kargil Summit at Blair House.” Center for the Advanced Study of India, University of Pennsylvania.

RISAT 2B, 2BR1, 2BR2. 2020. “Guenther’s Space Page.” January 13, 2020. https://space.skyrocket.de/doc_sdat/risat-2b.htm

Rohit, T. K. 2018. “GSAT-7A, ISRO’s ‘Angry Bird’, Takes to the Skies.” *The Hindu*, December 19, 2018, sec. Science. https://www.thehindu.com/sci-tech/science/isro-successfully-launches-gsat-7a/article25781226.ece

Saran, S. 2013a. “Is India’s Nuclear Deterrent Credible?” presented at the India Habitat Centre, New Delhi, April 24. http://www.armscontrolwonk.com/files/2013/05/Final-Is-Indias-Nuclear-Deterrent-Credible-rev1-2-1-3.pdf

Saran, S. 2013b. “Weapon that Has More than Symbolic Value.” *The Hindu*, May 4, 2013.

Shaheen, S. 2019. *Nuclear Command and Control Norms: A Comparative Study*. 1st ed. New York: Routledge. https://www.routledge.com/Nuclear-Command-and-Control-Norms-A-Comparative-Study-1st-Edition/Shaheen/p/book/9781138349292

Sidhu, W. P. S. 2013. “Whose Finger on the Nuclear Trigger at Sea?” *Livemint*, August 4, 2013. https://www.livemint.com/Opinion/FesGy5sItj3WTJywQdfiKO/Whose-finger-on-the-nuclear-trigger-at-sea.html

Singh, S. 2018. “Isro to Launch Hyperspectral Imaging Sat with 30 Foreign Satellites on Nov 29.” *The Times of India*, November 26, 2018. https://timesofindia.indiatimes.com/india/isro-to-launch-hyperspectral-imaging-sat-with-30-foreign-satellites-on-nov-29/articleshow/66801810.cms

Singh, S. 2019a. “Isro Satellite that Could Have Scanned JeM Camp after Bombing.” *The Times of India*, March 6, 2019. https://timesofindia.indiatimes.com/india/risat-2-that-can-see-through-clouds-could-have-scanned-jem-camp-after-bombing/articleshow/68294290.cms
Singh, S. 2019b. “Hi-Tech Antenna of Risat-2B, Developed in Record 13 Months by Isro, Deployed.” *The Times of India*, May 22, 2019. https://timesofindia.indiatimes.com/india/hi-tech-antenna-of-risat-2b-developed-in-record-13-months-by-isro-deployed/articleshow/69453184.cms

Singh, S. 2019c. “Isro to Launch Another ‘Eye in the Sky’ Risat-2BR1 on December 11, Will Help Boost Border Surveillance.” *The Times of India*, December 3, 2019. https://timesofindia.indiatimes.com/india/isro-to-launch-another-eye-in-the-sky-risat-2br1-on-dec-11-will-help-boost-border-surveillance/articleshow/72340281.cms

Special Correspondent. 2017. “India to Be Second Country to Use ELF Facility.” *The Hindu*, May 20, 2017. https://www.thehindu.com/news/cities/Hyderabad/india-to-be-second-country-to-use-elf-facility/article18517424.ece

Subramanian, A. P. 2015. *Agni V: Incremental Capability Addition*. New Delhi: Centre for Air Power Studies. http://capsindia.org/files/documents/CAPS_Infocus_AS_12.pdf

Sundaram, K., and M. V. Ramana. 2018. “India and the Policy of No First Use of Nuclear Weapons.” *Journal for Peace and Nuclear Disarmament* 1 (1): 152–168. doi:10.1080/25751654.2018.1438737.

Sundarji, G. K. 1984. “Strategy in the Age of Nuclear Deterrence and Its Application to Developing Countries.” Simla: Unpublished Manuscript.

Talmadge, C. 2017. “Would China Go Nuclear? Assessing the Risk of Chinese Nuclear Escalation in a Conventional War with the United States.” *International Security* 41 (4): 50–92. doi:10.1162/ISEC_a_00274.

Tejonmayam, U. 2018. “Isro Releases Images Captured by Microsat and Nanosatellite.” *The Times of India*, January 23, 2018. https://timesofindia.indiatimes.com/home/science/isro-releases-images-captured-by-microsat-and-nanosatellite/articleshow/62622667.cms

Tellis, A. 2001. *India’s Emerging Nuclear Posture*. Santa Monica: Rand.

TNN. 2008. “IAF Plan to Link Civilian, Defence Radars Takes Off.” *The Economic Times*, December 20, 2008. https://economictimes.indiatimes.com/iaf-plan-to-link-civilian-defence-radars-takes-off/articleshow/3865728.cms?from=mdr

TNN. 2015. “Nod for Rs 8,000 Crore Air Force Radar System.” *The Times of India*, September 23, 2015. https://timesofindia.indiatimes.com/india/Nod-for-Rs-8000-crore-Air-Force-radar-system/articleshow/49083074.cms

UCS Satellite Database.” n.d. “Union of Concerned Scientists.” Accessed July 9, 2019. https://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database

Unnithan, S. 2018. “INS Arihant Returned Yesterday from 20-Day Deterrent Patrol.” *India Today*, November 5, 2018. https://www.indiatoday.in/india/story/ins-arihant-returned-yesterday-from-20-day-deterrent-patrol-1383188-2018-11-05

White, R. B. 2014. “Command and Control of India’s Nuclear Forces.” *The Nonproliferation Review* 21 (3–4): 261–274. doi:10.1080/10736700.2014.1072994.

Wueger, D. 2016. “India’s Nuclear-Armed Submarines: Deterrence or Danger?” *Washington Quarterly* 39 (3): 77–90. doi:10.1080/0163660X.2016.1232636.

Yadav, Y. 2017. “Hackers from China Break into Secret Indian Government Video Chat.” *The New Indian Express*, November 19, 2017. https://www.newindianexpress.com/nation/2017/nov/19/hackers-from-china-break-into-secret-indian-government-video-chat-1705010.html

Yarynich, V. E. 2003. *C3: Nuclear Command, Control, Cooperation*. Washington, D.C.: Center for Defense Information.