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**TOWARD A FORCE-IN-BEING (II): ASSESSING THE  
REQUIREMENTS AND ADEQUACY OF  
THE EVOLVING DETERRENT**

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It has long been a staple of strategic wisdom that all nuclear arsenals embody one solution or another to the competing trade-offs facing their possessors. The shapes of emerging nuclear arsenals in particular are held to be especially sensitive to the character of civil-military relations and to the time urgency of retaliation.<sup>1</sup> In India's case, these considerations—if present trends offer any indication—will most likely result in a nuclear posture that, taking the form of a force-in-being, will emphasize opaque and granularly distributed ingredients, assertive command structures, and more or less delayed retaliation. Such a posture could in principle satisfy India's national security requirements, but having a splendid conceptual solution does not an effective deterrent make. An effective deterrent ultimately requires appropriate material capabilities of various sorts, all organized coherently in terms of specific procedural frameworks and organizational structures. This chapter seeks to assess in preliminary fashion whether India possesses the ingredients the force-in-being concept necessitates, and it then attempts to identify what capabilities the country is likely to develop in the future if this evolving concept is to be successfully incarnated as a viable system of deterrence. This analysis therefore serves to identify the areas of activity in which India's strategic managers will probably engage over the next two decades—areas that the United States would do well to monitor. It

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<sup>1</sup>Feaver, "Command and Control in Emerging Nuclear Nations," pp. 160–187.

concludes by examining whether the force-in-being, once complete, will satisfy certain critical demands that any system of nuclear deterrence would generate.

## PUTTING THE PIECES TOGETHER: WHAT INDIA HAS, WHAT INDIA HASN'T

### Fissile Materials

Among the first requirements for the creation of a nuclear capability, in whatever form it takes, is the availability of fissile materials. From its inception, the Indian nuclear program focused on the creation of a plutonium economy in order to sustain a three-stage production cycle aimed at exploiting mixed oxide fuels and, eventually, fast breeder reactors to create full self-sufficiency in the generation of low-cost nuclear power.<sup>2</sup> In consonance with this goal, India harnessed the natural uranium-fueled, heavy-water-moderated research and power reactors used in the first phase of the cycle to create a significant stock of the by-product plutonium. This plutonium was to be mixed with thorium—a resource India possesses in abundance—to fuel a series of second-stage reactors intended to produce uranium 233 (U<sup>233</sup>) as a further by-product. In the third stage, fast breeder reactors using combined U<sup>233</sup>-thorium fuels were to be constructed with the intention of “breeding” more U<sup>233</sup> than would be consumed in the operation of such reactors. This three-stage cycle—derived from the grandiose vision of Homi Bhabha<sup>3</sup>—was intended to make India self-sufficient, since the country's abundant thorium reserves, when complemented by the continuous breeding of U<sup>233</sup>, essentially promised an unlimited supply of nuclear fuel for the cheap generation of electricity. The centrality of plutonium in such an energy cycle, however, also implied that no matter how it was eventually used for the production of U<sup>233</sup>, plutonium would always be available in the interim for the creation of nuclear weapons were

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<sup>2</sup>The three-stage plan is briefly described and assessed in G. S. Bhargava, “Nuclear Power in India,” *Energy Policy*, 20:8 (August 1992), pp. 735–743. See also Perkovich, *India's Nuclear Bomb*, pp. 26–34.

<sup>3</sup>See Ganesan Venkataraman, *Bhabha and His Magnificent Obsessions* (Hyderabad, India: Universities Press, 1994) for further details about Bhabha's plans.

India to embark on such a course of action.<sup>4</sup> Weapons-grade plutonium—Pu<sup>239</sup>—thus came to constitute the principal fissile material for New Delhi’s nuclear weaponry, even though India would develop two experimental, pilot-stage ultracentrifuge plants for the production of highly enriched uranium along the way.<sup>5</sup>

Any attempt to understand the shape and structure of the future Indian deterrent raises three critical issues relating to fissile materials: First, what kinds of fissile materials does India possess, and what is it likely to seek? Second, what is the size of its fissile-material inventory? And third, what is the relationship between the size of its fissile-material inventory and its weapon stockpile?

**What kinds of fissile materials does India possess, and what is it likely to seek?** It is now widely known that India possesses a significant inventory of weapons-grade plutonium. Also understood is the fact that India has attempted to produce highly enriched uranium in the form of U<sup>235</sup> through the centrifuge process, although the extent to which this has been accomplished remains unclear, as does the size of this inventory. One RAND analysis suggests that, at most, India “could currently produce only 10 kg of HEU per year.”<sup>6</sup> India is also believed to have produced “kilogram quantities of U-233 by irradiating thorium in its power reactors.”<sup>7</sup> The desire for small quantities of HEU—that is, uranium containing more than 20 percent U<sup>235</sup>—traditionally arose from the need for a fuel source for the nuclear reactors being developed to power India’s future nuclear submarines. This need by itself is certain to propel India’s desire for more HEU, although its claim to have tested a thermonuclear device in May 1998 could justify further acquisition of this material. Many advanced weapon designs use some combination of thermonuclear fuel and HEU in order to, as one analyst put it, “provide an extra

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<sup>4</sup>The centrality of plutonium in India’s early nuclear power and weapon plans has been examined in great detail in Perkovich, *India’s Nuclear Bomb*, pp. 13–59.

<sup>5</sup>Spector et al., *Tracking Nuclear Proliferation*, pp. 89–95.

<sup>6</sup>Jones, *From Testing to Deploying Nuclear Forces*, p. 8.

<sup>7</sup>Ibid.

'kick' to get the fusion reaction going."<sup>8</sup> If the thermonuclear device tested in May 1998 was of such a design and if New Delhi seeks to "serial produce" this design for its inventory, India will have to greatly expand its capability to produce either U<sup>233</sup> or U<sup>235</sup>, since its present annual production capacity of these materials has been judged to be "significantly less than the amount needed for nuclear weapons."<sup>9</sup>

To be sure, there are obviously thermonuclear weapon designs that use only weapons-grade plutonium in combination with materials such as lithium deuteride.<sup>10</sup> There are also boosted fission designs (which reportedly served as the "primary" in India's May 1998 thermonuclear test)<sup>11</sup> that use weapons-grade plutonium and deuterium-tritium, usually in gaseous form.<sup>12</sup> If India's weapon designs are of this sort, New Delhi will likely concentrate largely on producing weapons-grade plutonium—as it has traditionally done—as well as lithium deuteride and deuterium-tritium, leaving its experimental centrifuge facilities to produce whatever HEU they can for the submarine program or other research purposes. In fact, at least one report has suggested that India has begun stockpiling highly concentrated tritium extracted from the heavy-water moderator in India's power reactors for weapon applications<sup>13</sup> in addition to the tritium it otherwise produces by irradiating lithium in its research reactors.<sup>14</sup> When combined with other information about India's continuing lithium 6 purification and production program,<sup>15</sup> these re-

<sup>8</sup>David Albright, "India and Pakistan's Nuclear Arms Race: Out of the Closet but Not in the Street," *Arms Control Today*, 23:5 (June 1993), p. 13.

<sup>9</sup>Ibid.

<sup>10</sup>See Sublette, *Nuclear Weapons Frequently Asked Questions*, "Section 4.4: Elements of Thermonuclear Weapons Design."

<sup>11</sup>Chengappa, "Is India's H-Bomb a Dud?" p. 28.

<sup>12</sup>See Carey Sublette, *Nuclear Weapons Frequently Asked Questions*, "Section 4.3: Fission-Fusion Hybrid Weapons," available at <http://www.fas.org/nuke/hew/Nwfaq/Nfaq4-3.html#Nfaq4.3.1>.

<sup>13</sup>T. S. Gopi Rethinaraj, "Tritium Breakthrough Brings India Closer to an H-Bomb Arsenal," *Jane's Intelligence Review*, 10:1 (January 1998), pp. 29–31.

<sup>14</sup>David Albright and Tom Zamora, "India, Pakistan's Nuclear Weapons: All the Pieces in Place," *Bulletin of the Atomic Scientists*, 45:5 (June 1989), p. 25.

<sup>15</sup>Albright, "India and Pakistan's Nuclear Arms Race: Out of the Closet but Not in the Street," p. 14.

ports suggest that India will persist with its plutonium-based designs even in its advanced weapon program to the further neglect of HEU—an inference supported by India’s reported disinclination to begin serial production of ultracentrifuges for large-scale uranium enrichment.<sup>16</sup> On balance, then, it would appear that India will continue to emphasize weapons-grade plutonium as the principal nuclear material for its fission designs and will supplement it with deuterium, tritium, and lithium deuteride whenever its boosted fission and thermonuclear requirements so warrant while continuing to produce other special materials, such as beryllium and polonium, for the tampers and/or initiators its weaponry requires.<sup>17</sup>

**What is the size of the fissile-material inventory?** The size of India’s fissile-material inventory is of more than academic interest because of its general relationship to the size of India’s present and prospective stockpile of nuclear weaponry. Unfortunately, however, accurate information about this inventory is hard to come by. Indeed, the open literature provides a bewildering array of values that makes reliable conclusions difficult to reach. In addition, the literature often fails to distinguish weapons-grade plutonium that is immediately separated from that which is produced through irradiation but is not separated either because of capacity constraints in the reprocessing facilities or because of bottlenecks at other points in the fuel cycle. By assuming that all of India’s weapons-grade plutonium is immediately separated, most analyses thus fail to distinguish between fissile-material production capacity in general and the actual quantities of fissile materials that are immediately available for the fabrication of nuclear weaponry.<sup>18</sup> This difficulty is exacerbated by the fact that even serious scholars rarely examine India’s capacity to produce the other special materials necessary to manufacture nuclear weapons. As a result, the size of India’s presumed weapon stockpile is often straightforwardly derived from the quantity of fissile materials alone without any thought given to the other con-

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<sup>16</sup>Ibid., 13.

<sup>17</sup>The special materials produced in India for its nuclear weapon program are discussed in Albright and Zamora, “India, Pakistan’s Nuclear Weapons: All the Pieces in Place,” and Albright, “India and Pakistan’s Nuclear Arms Race: Out of the Closet but Not in the Street.”

<sup>18</sup>The only work that has recognized the sensitivity of this question is Albright, *Fact Sheet: India and Pakistan—Current and Potential Nuclear Arsenal*.

straints that might limit the size of this stockpile. None of these difficulties can be resolved here, however, and consequently this analysis will simply identify some of the most prominent assessments available about India's fissile-material inventory with the intent of suggesting the future courses of action New Delhi might pursue as far as the production of fissile materials—primarily weapons-grade plutonium—is concerned.

The earliest estimates appearing in the West provided an unrealistically high assessment of India's fissile-material production capability. Assuming that significant portions of the Indian nuclear complex (including many power reactors) would be dedicated to producing weapons-grade plutonium, Arnold Kramish forecast in 1984 that by the year 2000 India would possess the equivalent of 1100 critical masses (or some 8800 kg of Pu<sup>239</sup> at the rate of 1 critical mass = 8 kg Pu<sup>239</sup>), since it was believed to be capable of producing up to 100 critical masses annually.<sup>19</sup> In the early 1980s, the Congressional Research Service (CRS), among others, similarly calculated that India would be able to sustain an annual production rate of some 127 kg of Pu<sup>239</sup> to yield an inventory of approximately 1600 kg by the year 2000—a figure that would suffice to create some 400 simple fission weapons (at the rate of 1 critical mass = 4 kg Pu<sup>239</sup>).<sup>20</sup> This figure or some variant thereof is still favored by some media reports and has become the fulcrum on which Indian hawks have occasionally placed their demand for a large nuclear arsenal.

Estimates such as these, however, have been sharply reduced in recent years. On the basis of one of the most detailed unclassified analyses of fissile-material holdings available, for example, David Albright estimated in 1998 that

India has about 370 kilograms of weapon-grade plutonium, or the equivalent of about 74 nuclear weapons. India relies principally on the Dhruva reactor for weapon-grade plutonium, and can increase its stock of weapon-grade plutonium at a rate of about 20 kilograms

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<sup>19</sup>Arnold Kramish, "The Bombs of Balnibarbi," in Rodney W. Jones (ed.), *Small Nuclear Forces and U.S. Security Policy* (Lexington, KY: Lexington Books, 1984), pp. 26–30.

<sup>20</sup>Rodney W. Jones, *Small Nuclear Forces*, Washington Paper No. 103 (New York: Praeger, 1984), p. 17, cited in Karnad, "A Thermonuclear Deterrent," p. 129.

per year. This amount corresponds to roughly four nuclear weapons per year. At this rate, in 2005 India is estimated to have enough weapon-grade plutonium for over 100 nuclear weapons. India could produce significantly more weapon-grade plutonium by using its CANDU [Canada Deuterium Uranium] power reactors, although it may not have sufficient facilities to separate significant quantities of plutonium from the irradiated CANDU fuel.<sup>21</sup>

In a similar vein, Gregory Jones at RAND updated earlier calculations to conclude that India possesses

about 450 kg of separated weapons-grade plutonium, which would allow the manufacture of about 90 simple fission weapons. India is currently producing about 25 kg of weapons-grade plutonium per year, which could be increased to about 100 kg per year if India felt it to be necessary. This stockpile of plutonium and its current production rate are probably enough to supply India with an adequate supply of fission weapons.<sup>22</sup>

While both of these midrange estimates represent a vast improvement over earlier ones, many authoritative Indian sources suggest that they still overestimate the size of India's actual inventory (even if the issues of production versus separation and availability of other special materials are left aside). This overestimation generally results from optimistic assumptions about efficiency factors and capacity constraints pertaining to various phases of the Indian fissile-material production cycle.

Correcting for these factors, some well-placed Indian analysts have offered even smaller estimates of their country's fissile-material stockpile. Savita Pandey at the Institute for Defence Studies and Analyses in New Delhi—a think tank funded by the Indian Ministries of Defence and External Affairs—concluded that after all other activities requiring fissile materials are taken into account, the inventory available for the production of nuclear weapons in 1995 stood at some 170 kg of Pu<sup>239</sup>—and from this figure she inferred that India would have “enough weapons grade plutonium by the turn of the

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<sup>21</sup>Albright, *Fact Sheet: India and Pakistan—Current and Potential Nuclear Arsenals*.

<sup>22</sup>Jones, *From Testing to Deploying Nuclear Forces*, pp. 14–15.

century to produce [just] about 50 nuclear weapons.”<sup>23</sup> In an article reportedly written after the author was given access to various government briefings, R. Ramachandran similarly argued that the fissile-material inventory available for weapon production from India’s two research reactors, CANDU (operational since 1960) and Dhruva (operational since 1985), could not exceed 280 kg of Pu<sup>239</sup> in 1998—which, on his assumption that 8 kg are required per critical mass, turns out to be sufficient for a maximum of 35 nuclear weapons.<sup>24</sup> David Albright’s more recent reassessment of India’s nuclear stockpile comes much closer to these more conservative estimates. Using a sophisticated Monte Carlo approach, Albright’s assessment focuses on providing a range of possibilities that allow for “central” or “best” estimates of India’s fissile-material stockpile to be derived. Through use of such a methodology, the Indian inventory of weapons-grade plutonium—derived by estimating total production in its reactors minus drawdowns from nuclear testing, processing losses, and civil uses of weapons-grade plutonium—was estimated to stand at some 290 kg at the end of 1998. This inventory size represents the median value of a range of estimates, and if each of India’s fission weapons is assumed to incorporate a critical mass consisting of somewhat less than 5 kg of Pu<sup>239</sup>, the total Indian weapon stockpile would consist of approximately 60 nuclear weapons at the end of 1998.<sup>25</sup>

On balance, therefore, the most reliable estimates of India’s fissile-material stockpile today seem to cluster around the smallest numbers that have been articulated over the years. Unfortunately, however, many of these estimates are not directly comparable owing to differing assumptions about the capacity and efficiency of the reactors and reprocessing facilities, the extent of consumption attributable to other nuclear endeavors, and the varying figures used to define the plutonium requirements per critical mass. These methodological complications notwithstanding, the fact remains that an increasing number of Western and Indian commentators

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<sup>23</sup>“India Will Have Plutonium for 50 N-Weapons by 2000 AD,” *Hindustan Times*, October 27, 1997.

<sup>24</sup>Ramachandran, “Pokhran II: The Scientific Dimensions,” pp. 35–36.

<sup>25</sup>David Albright, *India and Pakistan's Fissile Material and Nuclear Weapons Inventory, End of 1998* (Washington, D.C.: Institute for Science and International Security, October 27, 1999), available at <http://www.isis-online.org/publications/southasia/stocks1099.html>.

have begun to conclude that the country's fissile-material inventory is much smaller than was previously assumed—a conclusion that has occasionally been confirmed by senior officials of India's DAE.<sup>26</sup> As such, it is often argued that the country's readiness to engage in negotiations leading up to the FMCT should be reviewed, and Ramachandran in particular has even asserted that “there is need for at least one more Dhruva-like dedicated reactor if a weaponization programme with the minimum deterrence strategy is envisaged.”<sup>27</sup> This conclusion, it should be remembered, is based on the assumption that India would need only 60 nuclear weapons for its minimum deterrent—an argument advanced by K. Subrahmanyam in his writings on this subject in 1994.<sup>28</sup> If, by contrast, it is assumed that the Indian deterrent would require closer to the 150-odd warheads that Subrahmanyam has now concluded are necessary,<sup>29</sup> then the need for continued or perhaps accelerated production of fissile materials prior to any accession to the FMCT would become all the more pressing.

**What is the relationship between the size of the fissile-material inventory and the weapon stockpile?** This issue is also of critical importance because it speaks to the size of India's potential arsenal and, by implication, to the adequacy of that arsenal vis-à-vis the capabilities of its competitors. Unfortunately, however, this issue too is difficult to resolve because even if the exact size of India's fissile-material inventory were known, the quality of its weapon designs and the types of weapons it intends to produce would affect the final solution. Since information about these variables is hard to come by, informed guesses based on the fissile-material requirements associated with some abstract weapon design will have to suffice. Even these informed guesses, however, will probably prove inadequate, because India's nuclear weapon designs could change over time. A given quantity of fissile materials could therefore be used to create many more (or fewer) nuclear weapons than the requirements asso-

<sup>26</sup>Hibbs, “Indian Pu Production Overstated, No Pit Production, Iyengar Says,” p. 6.

<sup>27</sup>Ramachandran, “Pokhran II: The Scientific Dimensions,” p. 36.

<sup>28</sup>See Subrahmanyam, “Nuclear Force Design and Minimum Deterrence Strategy for India,” pp. 176–195.

<sup>29</sup>Subrahmanyam, “A Credible Deterrent.”

ciated with some abstract weapon design would suggest. And since improvements in weapon design through laboratory experiments, a return to hot testing, or new access to foreign assistance cannot be ruled out, the actual number of nuclear weapons that could eventually be fabricated from a given stockpile of weapons-grade plutonium would vary considerably, as illustrated in Table 3.

Also at issue is the precise amount of plutonium that is needed to produce a device with a given yield. Although International Atomic Energy Agency (IAEA) regulations assume that 8 kg of plutonium are required to produce a simple fission design with approximately 20 kt of yield, it is likely that these requirements are overstated, since, among other things, weapons-grade plutonium in such quantities is likely to be subject to severe criticality problems if kept together routinely.<sup>30</sup> Other analysts have estimated, however, that countries possessing “low” technical capability could build 20-kt devices with only 6 kg of weapons-grade plutonium; that countries possessing “medium” technical capability could build such devices with approximately 3.5 kg; and that countries possessing “high” technical capability could build these devices with as little as 3 kg.<sup>31</sup> Part of the problem with calculating India’s weapon stockpile therefore arises simply from not knowing at which end of the spectrum its nuclear designs are situated. The best available evidence from Indian sources indicates that the pits used in the nuclear devices tested in May 1998 “each weighed between five to ten kilograms.”<sup>32</sup> If this information is correct, India would have to be classified as a country with low technical capability, at least as far as the sophistication of its nuclear weapon designs is concerned. Arbitrarily translating this judgment into an assumption that its designs use some 6 kg of plutonium per weapon suggests that India’s fissile-material inventory would in 1998

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<sup>30</sup>It should be noted, however, that the IAEA’s definition of “threshold amounts,” which identifies the “approximate quantity of special fissionable material required for a single nuclear device,” is intended to cover processing losses incurred during the manufacture of a fissile core and as such does not represent simply the minimum critical mass needed for an explosive chain reaction. Despite this fact, the quantity of fissile material identified by the concept of “threshold amounts” may still be far too high—a position argued cogently in Thomas B. Cochran and Christopher E. Paine, *The Amount of Plutonium and Highly Enriched Uranium Needed for Pure Fission Nuclear Weapons* (Washington, D.C.: Natural Resources Defense Council, 1995), pp. 1–5.

<sup>31</sup>*Ibid.*, pp. 9–12.

<sup>32</sup>Chengappa, “The Bomb Makers,” p. 31.

**Table 3**  
**Relating the Fissile-Material Stockpile to Varying Plutonium**  
**Masses per Weapon**

Size of Weapons- Grade Pu Stockpile (kg)	Pu Mass per Weapon (kg)					
	3	4	5	6	7	8
200	66.67	50.00	40.00	33.33	28.57	25.00
210	70.00	52.50	42.00	35.00	30.00	26.25
220	73.33	55.00	44.00	36.67	31.43	27.50
230	76.67	57.50	46.00	38.33	32.86	28.75
240	80.00	60.00	48.00	40.00	34.29	30.00
250	83.33	62.50	50.00	41.67	35.71	31.25
260	86.67	65.00	52.00	43.33	37.14	32.50
270	90.00	67.50	54.00	45.00	38.57	33.75
280	93.33	70.00	56.00	46.67	40.00	35.00
290	96.67	72.50	58.00	48.33	41.43	36.25
300	100.00	75.00	60.00	50.00	42.86	37.50
310	103.33	77.50	62.00	51.67	44.29	38.75
320	106.67	80.00	64.00	53.33	45.71	40.00
330	110.00	82.50	66.00	55.00	47.14	41.25
340	113.33	85.00	68.00	56.67	48.57	42.50
350	116.67	87.50	70.00	58.33	50.00	43.75
360	120.00	90.00	72.00	60.00	51.43	45.00
370	123.33	92.50	74.00	61.67	52.86	46.25
380	126.67	95.00	76.00	63.33	54.29	47.50
390	130.00	97.50	78.00	65.00	55.71	48.75
400	133.33	100.00	80.00	66.67	57.14	50.00

have yielded approximately 266 weapons (by the old CRS estimates), some 61/75 weapons (by the 1998 Albright/Jones estimate), or some 47/48 weapons (by the Ramachandran/1999 Albright estimate)—all of these figures obviously increasing progressively if its designs used less than 6 kg of fissile material in the core (see Table 3).

If, for the sake of discussion, all of India's weapons are assumed to be entirely thermonuclear, calculation becomes even more problematic, since the precise amount of weapons-grade plutonium necessary to construct such devices is classified.<sup>33</sup> What complicates the calculation here is that specific information is required about the amount of plutonium necessary for both the "primary" and the "spark plug," assuming that the latter in fact incorporates weapons-

<sup>33</sup>Jones, *From Testing to Deploying Nuclear Forces*, p. 8.

grade plutonium rather than HEU.<sup>34</sup> Depending on the kinds of thermonuclear weapon designs at issue, such calculations can become extremely complex by virtue of the multiplicity of special nuclear materials that may be used in a given device. In India's case, however, this problem may be more tractable because the most reliable reports emerging from the May 1998 tests have suggested that its thermonuclear device is based on a version of the relatively simple Teller-Ulam staged radiation design, which uses India's preexisting simple fission (or a modified boosted fission) device as the primary.<sup>35</sup> This implies that the arbitrary assumption made earlier about the quantity of fissile material required by the standard Indian fission weapon may be treated as identical to the requirements of the primary and, further, that the crude information available in the literature about the quantity of fissile material required by the spark plug<sup>36</sup> should provide some indication of the size of India's potential thermonuclear inventory, since it is assumed that all the other special materials—such as beryllium, polonium, lithium deuteride, deuterium, and tritium—are available in the necessary quantities.<sup>37</sup>

Kosta Tsipis has provided some general information about the quantity of fissile materials required to construct a thermonuclear device when he noted that a 1-Mt thermonuclear weapon “contains a few kilograms of lithium deuteride and tritium, some kilograms of plutonium, and about 100 kilograms of uranium 238.”<sup>38</sup> Discussing the same issue in the context of India's advanced designs, R. Ramachandran remarked that “even a thermonuclear weapon would

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<sup>34</sup>See the discussion in Sublette, *Nuclear Weapons Frequently Asked Questions*, “Section 4.4: Elements of Thermonuclear Weapons Design,” for a good survey of the kinds of materials involved in the fabrication of a thermonuclear weapon built according to the Teller-Ulam design.

<sup>35</sup>Ramachandran, “Pokhran II: The Scientific Dimensions,” pp. 22–28.

<sup>36</sup>Good sources of information about the spark plug are Hansen (ed.), *The Swords of Armageddon*, Vols. 1–8, and Sublette, *Nuclear Weapons Frequently Asked Questions*, “Section 4.4: Elements of Thermonuclear Weapons Design.” The spark plug used in Indian nuclear devices is discussed in passing in Iyengar, “Nuclear Nuances.”

<sup>37</sup>If boosted fission rather than simple fission devices constitute the primary in India's thermonuclear weapons, the relationship between fissile material and the size of the weapon stockpile has to be appropriately modified, since boosted fission devices can be constructed with somewhat smaller amounts of fissile material than that used in simple fission weapons.

<sup>38</sup>Kosta Tsipis, *Arsenal* (New York: Simon & Schuster, 1983), p. 38.

use a trigger with [a] similar amount of Pu<sup>39</sup> compared to that used by a simple fission design (~6 kg of Pu<sup>239</sup> by an arbitrary assumption based on the Indian reporting cited earlier). And Gregory Jones concluded more accurately that when the requirement of the primary and the spark plug are taken into account, “plutonium-only thermonuclear weapons . . . might well use more plutonium than a standard fission weapon.”<sup>40</sup> Since it is unlikely that the spark plug in any Indian thermonuclear weapon would use as much fissile material as that residing in its primary, however, it is reasonable to conclude that the size of the hypothetical Indian thermonuclear stockpile would be more than half its inventory of pure fission weapons—although how much more than half is difficult to discern in the absence of precise information about the amount of fissile materials the spark plug actually requires.<sup>41</sup> This rough estimate of the hypothetical Indian thermonuclear stockpile obviously assumes that India can produce the quantities of lithium deuteride it needs to fuel the secondary stage of each of its weapons as well as all the other special materials that may be required to produce the initiators, tampers, and lenses associated with such devices. A different conclusion holds as far as a hypothetical Indian boosted fission stockpile is concerned: In this instance, the number of weapons ought to be somewhat greater than that held in an inventory of simple fission devices, since the kilogram quantities of plutonium required for the pits in such weapons would undergo marginal reductions when supplemented by the gram-quantity additions of deuterium-tritium. The potential size of India’s thermonuclear and boosted fission stockpile relative to its potential stockpile of simple fission weapons can therefore be crudely characterized in the following way: For any potential stockpile of simple fission devices,  $x$ , the potential thermonuclear stockpile would be some number greater than  $1/2 x$ , while the potential boosted fission stockpile would be some number greater than  $x$ —assuming that all

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<sup>39</sup>Ramachandran, “Pokhran II: The Scientific Dimensions,” p. 38.

<sup>40</sup>Jones, *From Testing to Deploying Nuclear Forces*, p. 8.

<sup>41</sup>This result is further affected by the uncertainty about whether India’s thermonuclear weapons will incorporate simple fission or boosted fission devices as their primary, since the quantity of weapons-grade plutonium required to construct these devices is different in each case.

these advanced designs are based *entirely* on some modification of the basic fission design described in open sources.<sup>42</sup>

All these details reinforce the conclusion reiterated earlier: that the number of weapons in the Indian inventory is a function of their specific designs, the efficiency of those designs, and the existing inventory of fissile materials. Since no precise information about these variables is available, however, the size of the presumed inventory can be expressed only as a range of values. If the old U.N.-CRS data are disregarded as being overly optimistic, the only choices thus remain the 1998 Albright/Jones estimate of roughly 61 to 75 simple fission weapons and the Ramachandran/1999 Albright estimate of 47 to 48 simple fission weapons (all calculated for 1998 totals at 6 kg per critical mass). Since the desired Indian weapon stockpile has been defined by several knowledgeable Indian officials in private conversations with the author as “less than one half the known inventory of India’s largest competitor”—referring to the Chinese nuclear arsenal, which is reputed to consist of 350-odd warheads today<sup>43</sup>—the eventual size of the preferred Indian arsenal must consist of fewer than 175 weapons. This figure comports with Subrahmanyam’s claim that internal studies commissioned by the Indian military in the 1980s suggested “an appropriate number of warheads in low three digit figures.”<sup>44</sup> Several Indians have in private conversation insinuated that this figure could be closer to 100 than to 175 weapons, although reaching for force totals somewhere in the region of the latter or even beyond has not been ruled out depending on how the capabilities of India’s adversaries and the character of the global nuclear regime change over time. Given the evolving nuclear doctrine described in the previous chapter, however, there is no reason New Delhi should not be satisfied, at least in its present circumstances, with an arsenal

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<sup>42</sup>Chengappa, “Is India’s H-Bomb a Dud?” and Chengappa, *Weapons of Peace*, p. 207.

<sup>43</sup>This estimate of the Chinese inventory was provided by Jaswant Singh, India’s Foreign Minister, in a meeting with a RAND research team in New Delhi on January 18, 1999. This figure is also held by many Indian strategic analysts who follow China. To the degree that it is contested, the disputes arise mainly on prudential grounds, as some analysts argue that the structural uncertainties about the Chinese nuclear weapon inventory should prevent India from pegging its own sufficiency criteria to any *conservative* estimates of Beijing’s capabilities.

<sup>44</sup>Subrahmanyam, “Indian Nuclear Policy—1964–98,” p. 41.

consisting of even fewer than 100 warheads, although it is practical to expect—simply for purposes of ensuring deterrence stability—that no public declaration to that effect would ever be articulated. More important, it is unlikely that New Delhi would unilaterally terminate the production of fissile materials in the interim because the demands of prudence are seen as requiring a large enough stockpile of such materials even if these are not immediately transmuted into an inventory of ready and available weapons.<sup>45</sup> In all probability, therefore, India will attempt to produce the largest inventory of fissile materials it possibly can prior to the conclusion of an FMCT—an inventory that could enable it to produce even more than the 100-odd weapons the pragmatists in New Delhi believe is sufficient for deterrence—in part as insurance against the possibility that its adversaries may have a larger arsenal than they are currently thought to possess.

In any event, if an arsenal of around 150 weapons is treated as desirable from New Delhi's point of view, then irrespective of which estimate of India's fissile-material inventory one accepts, India still has some way to go before it can be satisfied that its fissile-material stockpile is sufficient for its future deterrent. If the 1998 Albright/Jones estimate is more accurate, the gap India has to close may not be as great as analysts like Ramachandran believe. If, on the other hand, the Ramachandran/1999 Albright estimate holds, then India will need to accelerate the production of fissile materials before any constraints imposed by a future FMCT become legally binding—or risk being forever condemned to a strategy of subterfuge grounded in an exaggeration of its weapons-grade material inventory. This circle, of course, can be squared simply by reducing the sufficiency requirements for deterrence, and many Indian analysts, including Jasjit Singh, have in fact argued that India's deterrence needs—which could be amply met by some “double digit quantum of warheads”—may require that New Delhi “even plan on the basis of a lower end figure of say 2–3 dozen nuclear warheads by the end of 10–15 years.”<sup>46</sup>

If this suggestion does not find favor with India's security managers, however—as is likely—then the data in Table 4 suggest that

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<sup>45</sup>“Fissile Material: India Against Moratorium Now.”

<sup>46</sup>Singh, “A Nuclear Strategy for India,” p. 315.

**Table 4**  
**Increases in Efficiency Required to Produce Various Desired Indian Nuclear Weapon Stockpiles by 2010**

Desired Number of Nuclear Weapons	Number of Weapons Above Present Inventory (50 weapons in 2000)	Total Additional Fissile Material Required to Produce Weapons Above Present Inventory @ 6 kg Pu <sup>239</sup> per Weapon (kg)	Average Annual Production Rate of Fissile Materials Required to Produce Number of Nuclear Weapons Above Present Inventory over 10 Years (kg)	Change in Efficiency Required Relative to the Traditional Annual Rate of Fissile-Material Production: 12–16 kg Pu <sup>239</sup>
~60 Subrahmanyam, 1994	10	60	6	0.5–0.3
~70–76 Traditional efficiency	20–26	120–160	12–16	1
~150 Subrahmanyam, 2000	100	600	60	5–3.7
~100–150 Improved efficiency	50–100	300–600	30–60	2.5/1.8–5/3.7
~125–200 Expanded capability	75–150	450–900	45–90	3.7/2.8–7.5/5.6
~300–330 Karnad, 1999	250–280	1500–1680	150–168	12.5/9.3–14/10.5

India's nuclear estate would indeed require dramatic changes in performance to reach the weapon inventory targets various Indian analysts have set. The baseline for the calculations codified in Table 4 is drawn from R. Ramachandran's analysis of India's fissile-material stockpile, which he argued consisted of some 280 kg of weapons-available Pu<sup>239</sup> in 1998 that has been growing at the traditional rate of approximately 12–16 kg annually.<sup>47</sup> If these figures are extrapolated to the year 2000, India's stockpile of fissile materials would have consisted of a maximum of 304–312 kg, which for the sake of simplicity may be rounded off to 300 kg of Pu<sup>239</sup>. This year 2000 total in turn yields 50-odd weapons, assuming that each device uses approximately 6 kg of plutonium in its core.

If the traditional rate of accumulation (12–16 kg annually) remains unchanged over the next decade, Table 4 suggests that India could accumulate an additional 120–160 kg of Pu<sup>239</sup> by 2010—sufficient to raise its nominal weapon stockpile to a total of 70 to 76 standard fission weapons. At such rates of accumulation, India would be able to meet the 1994 Subrahmanyam target of 60 weapons over the next decade without any changes in its traditional rate of accumulation. If it is to meet Subrahmanyam's 2000 target of approximately 150 weapons, however, it would need to accumulate some 600 kg of Pu<sup>239</sup> over and above its current inventory, or 60 kg annually—and generating such increases would require that India improve its accumulative efficiency by three and one-half to five times its traditional level. Yet attaining such efficiency increases through better maintenance and more effective organizational routines alone is likely to tax the Indian nuclear estate, since the prevailing infrastructure in different portions of New Delhi's fissile-material production complex is somewhat dilapidated.<sup>48</sup> If its newer facilities, such as the large-scale reprocessing plant at Kalpakkam, work as efficiently as desired, India could conceivably meet the efficiency increases demanded in Subrahmanyam 2000 by the year 2010. What is more likely, however, is that it will meet less ambitious requirements—say, for nuclear stockpiles ranging from 100 to 150 weapons by the year 2010—since the kinds of efficiency improvements such smaller force sizes demand, at least toward the lower end, hover around twice (or

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<sup>47</sup>Ramachandran, "Pokhran II: The Scientific Dimensions," pp. 34–61.

<sup>48</sup>Rethinaraj, "In the Comfort of Secrecy," pp. 52–57.

slightly more than twice) the current levels of accumulative performance. In any case, the calculations in Table 4 clearly show that the arsenal sizes demanded by analysts like Bharat Karnad, which run into requirements for 300 to 330 nuclear weapons, simply cannot be attained by the year 2010, since they would require that the Indian nuclear estate produce between 9 and 14 times its current annual output of weapons-grade fissile materials.<sup>49</sup> Even if India were to settle for a more modest arsenal that was nonetheless larger than the one suggested in Subrahmanyam 2000—say, an arsenal consisting of 125 to 200 weapons by 2010—it would still require immense improvements in performance ranging from more than twice to almost eight times the current annual rate of accumulation of fissile materials. Such levels of performance, at least at the higher end, cannot be attained through efficiency increases alone but would instead require a progressive expansion of present capabilities in the form of new dedicated weapon reactors, further upgrades in infrastructure, an expansion of the ultracentrifuge cascades dedicated to producing HEU, and perhaps even a new reliance on India's civilian nuclear power plants for producing the quantity of fissile material such an ambitious program would require.

When the requirements identified in Table 4 are properly appreciated, it becomes obvious that India's behavior with respect to fissile-material production *would* offer evidence not only about which estimates of its fissile-material holdings are correct but also about which weapon inventory size it seeks to attain.<sup>50</sup> For all it is worth, India has formally declined to comply with the U.S. request for an

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<sup>49</sup>It must be noted, however, that Karnad's requirement for 300-plus nuclear weapons is premised on their availability by the year 2030. Accordingly, the analysis in this paragraph should not be construed as a criticism of Karnad's requirements but merely as an indicator of the immensity of the task India would face were it to pursue a weapon stockpile of the sort Karnad recommends within the next decade. If Karnad's 30-year time frame was indeed accepted, India would need to produce between 50 and 56 kg of Pu<sup>239</sup> annually for the next 30 years. This, in turn, would require an accumulative efficiency comparable to that associated with meeting the demands articulated in Subrahmanyam 2000—which, while possible, must still be counted as rather demanding, at least in relation to the historical record.

<sup>50</sup>This argument is premised, of course, on the assumption that India will simply settle for basic fission weapons as the mainstay of its future arsenal. Should this assumption be altered, however, it would be more difficult to assess what kind of arsenal size India would be satisfied with simply from scrutinizing its rate of accumulation of fissile materials.

immediate cessation of fissile-material production pending the conclusion of the FMCT. This could suggest a desire on India's part to continue producing fissile materials in order to meet its unfulfilled stockpile requirements, or it could represent merely a diplomatic refusal to comply with unilateral demands in the absence of a binding multilateral treaty. While there are certainly benefits to the latter posture, it is worth remembering that the real payoffs are garnered in the former issue area: India's fissile-material inventory grows progressively, if only slowly, irrespective of *why* New Delhi refrains from ceasing production. Not surprisingly, then, it is most likely that in the years ahead India will in fact participate in discussions leading to an FMCT while refusing to adhere to any interim moratorium on the production of fissile materials prior to the conclusion of such an agreement. Operating on the expectation that the negotiations leading up to the FMCT will be neither rapid nor easy, India could use the breathing space that the diplomatic process affords to steadily expand its stock of fissile materials while ultimately relying on the continued opacity of its past inventory to insinuate that it has more than ample fissile-material holdings whether or not that is actually the case.

There is already growing evidence that India has begun to focus on increasing its available stockpile of weapons-grade materials. BARC, for example, has been removed from the supervisory purview of the Atomic Energy Regulatory Board, suggesting that a wide variety of weapons-related activities will no longer be constrained by the "regulatory and safety functions . . . hitherto exercised by the Atomic Energy Regulatory Board."<sup>51</sup> After years of hesitation, it has also been announced that the DAE will build "one more research reactor in Trombay . . . to increase India's production capacity of unsafeguarded plutonium."<sup>52</sup> This new reactor, which will be similar to the 100-megawatt Dhruva that has been operating at BARC since 1985, is expected to become operational by 2010, implying that at the very least India's security managers expect to be producing weapons-grade plutonium for its arsenal even after that date. Further, the reports that emerged after May 1998 that one of the five Indian nuclear

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<sup>51</sup>Ramola Talwar Badam, "BARC Now Freed of Regulatory Control," *Asian Age*, May 31, 2000.

<sup>52</sup>"New Reactor Being Planned in Trombay," *The Hindu*, April 28, 1999.

tests involved reactor-grade plutonium not only indirectly confirms the veracity of the smaller estimates of India's fissile-material holdings but also raises the question of whether India would actively seek to use its civilian plutonium inventory to augment its otherwise small stockpile of weapons-grade material.<sup>53</sup> Finally, the question of whether India would use at least some of its civilian nuclear power reactors in a "low-burnup" regime to produce additional quantities of weapons-grade plutonium for military needs remains widely discussed but not yet publicly resolved.<sup>54</sup> In any event, India's future actions in each of these issue areas will provide important clues to its judgment about the adequacy of its fissile-material holdings as well as about the arsenal size it deems to be appropriate for its needs.

None of these actions, however, is likely to occur transparently, and consequently India's continued concealment of its existing inventory of weapons-grade materials, its relatively opaque fissile-material accumulation activities, and its strong determination not to spell out the specific contours of its minimum deterrent will allow India to reap all the deterrence benefits that derive from its adversaries' inability to accurately estimate the true size of its relatively small nuclear stockpile. Since India's overarching strategic doctrine treats nuclear weaponry as being more efficacious as political instruments than as military tools, it would not be surprising if New Delhi were to be satisfied with even a smaller nuclear arsenal than many of its elites publicly advocate. This arsenal could consist of fewer than 100 weapons, as analysts like Jasjit Singh advocate, or could hover around 150 weapons, as recommended by K. Subrahmanyam. Whatever stockpile size finally materializes, however, it may in no way imply an endorsement of the force-sizing metric advocated by various security elites in New Delhi. Rather, it would be more likely to represent an acceptance of certain cold technical and political realities that are grounded both in the infirmities that afflict India's fissile-material production infrastructure and in external influences such as U.S. political pressure and the constraints that a successful FMCT may impose. So long as the residual fraction that

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<sup>53</sup>Chengappa, "Is India's H-Bomb a Dud?" pp. 27–28, and Albright, *India and Pakistan's Fissile Material and Nuclear Weapons Inventory, End of 1998*.

<sup>54</sup>Albright, *India and Pakistan's Fissile Material and Nuclear Weapons Inventory, End of 1998*.

can survive a nuclear attack is believed to be high—thanks to the pervasive secrecy surrounding the entire Indian nuclear weapon apparatus—Indian policymakers would probably be content with a relatively small nuclear weapon inventory, especially if the opacity of past stockpiles allows them to garner significant deterrence benefits from the widespread public belief that the country’s civilian nuclear complex “provide[s] enormous potential for the production of much larger than expected amounts of weapons-grade fissile materials.”<sup>55</sup>

The size of India’s reactor-grade plutonium inventory is the last issue of some consequence from the perspective of arsenal size, but it is one that is clouded by a great deal of uncertainty. David Albright, for one, has estimated that in 1998 India’s civil plutonium inventory consisted of some 7500 kg. This figure includes the 3825 kg safeguarded by the IAEA (of which 25 kg are separated) as well as some 3700 kg of unsafeguarded plutonium (of which 700 kg are ostensibly separated).<sup>56</sup> If other public reports of India’s fissile-material stockpile serve as any indication, however, these data too probably overstate the amount of separated, unsafeguarded, reactor-grade plutonium India possesses. In any event, reactor-grade plutonium cannot be used to make reliable, high-yield fission weapons if this material is used in place of weapons-grade plutonium within India’s basic fission design. Reactor-grade plutonium *can* be used to produce reliable, high-yield fission weapons, but these would require either fast-assembling implosion systems or fusion boosting, both of which would almost certainly have to be validated through further explosive testing.<sup>57</sup> There is also no way for India to strip out the undesirable Pu<sup>240</sup> isotopes from its stockpile of reactor-grade plutonium, since the technology best suited for this purpose—atomic vapor laser

<sup>55</sup>Nayyar et al., “Fissile Material Production Potential in South Asia,” p. 202.

<sup>56</sup>Albright, *India and Pakistan’s Fissile Material and Nuclear Weapons Inventory, End of 1998*.

<sup>57</sup>For more on this issue, see Carey Sublette, *Nuclear Weapons Frequently Asked Questions*, “Section 6.0: Nuclear Materials,” available at <http://www.fas.org/nuke/hew/Nwfaq/Nfaq6.html>; Amory B. Lovins, “Nuclear Weapons and Power-Reactor Plutonium,” *Nature*, 283 (February 1980), pp. 817–823; J. Carson Mark, “Explosive Properties of Reactor-Grade Plutonium,” *Science and Global Security*, 4 (1993), pp. 111–128; and Richard L. Garwin, “Reactor-Grade Plutonium Can Be Used to Make Powerful and Reliable Nuclear Weapons: Separated Plutonium in the Fuel Cycle Must Be Protected as If It Were Nuclear Weapons,” available at <http://www.fas.org/rlg/980826-pu.htm>.

isotope separation (AVLIS)—is not available to India. What this implies, therefore, is that absent fast-assembling weapon designs, fusion boosting, and AVLIS technology, reactor-grade plutonium could be used in India's standard fission weapon only if New Delhi were satisfied by the fizzle yields that would result. If this is in fact the case, the 700 kg of separated, unsafeguarded, reactor-grade plutonium India is supposed to possess would translate into some 116 small-yield nuclear weapons at a rate of 6 kg of reactor-grade material per device. The remaining 3000-odd kg of unseparated, unsafeguarded, reactor-grade plutonium translates at the same rate into another 500 devices, but this calculation makes sense only if it is presumed that India will in fact separate plutonium from the spent fuel rods before its separation plants are possibly shut down under the terms of a future FMCT. Thus far, India has shown little inclination to expand its stockpile of separated reactor-grade plutonium, and for sound strategic reasons: Given the limitations of its nuclear material production infrastructure, New Delhi is better off focusing its energies on the production and separation of weapons-grade plutonium rather than squandering its limited plant capacity on separating reactor-grade plutonium at a time when it has demonstrated neither a mastery of fusion boosting nor the ability to design fast-assembling implosion systems. To be sure, this fact has not prevented some analysts from emphasizing the significance of India's reactor-grade plutonium stockpile in their assessments of India's potential nuclear arsenal.<sup>58</sup> There is no conclusive evidence, however, that either the government of India or its DAE scientists adhere to a similar calculus when they evaluate the size of their desired nuclear arsenal.

### **Nuclear Weapons**

From the perspective of ensuring adequate deterrence, the discussion about fissile-material inventories helps mainly to establish the size of the potential arsenal. The types of weapons that constitute this arsenal are only partly illuminated by such a discussion and hence merit separate treatment. The need for such treatment is based in turn on the admittedly debatable premise that the quality of

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<sup>58</sup>Sidhu, "India Sees Safety in Nuclear Triad and Second Strike Potential," p. 23, and Steer, "Asia's Rival Reactors a Cause for Concern," pp. 26–29.

a state's nuclear weapons has a bearing on the durability of the deterrence it can obtain.<sup>59</sup> Since this premise was believed to hold true during the Cold War, both the United States and the Soviet Union developed a wide variety of sophisticated nuclear weapons ranging from multimegaton city busters at one end all the way down to sub-kiloton tactical nuclear weapons at the other. Accepting the logic that underlay these achievements, many Indian analysts have maintained that New Delhi should induct a wide variety of nuclear devices into its arsenal, among the most important of which are thermonuclear weapons.<sup>60</sup> These weapons find particular favor with Indian hawks such as Karnad because it is argued that, all other things being equal, thermonuclear weapons make particularly effective deterrents: Their immense destructive power makes true city-busting capabilities possible with a single bomb and, as such, would provide India with robust deterrence given the unacceptable destruction that can be inflicted even by a small residual fraction of weapons surviving an adversary's attack.<sup>61</sup> While they do not contest the destructive efficacy of thermonuclear weapons, Indian owls would by contrast dispute the claim that such immense destructive power is required to produce deterrence stability *in the specific circumstances facing the Indian state*.<sup>62</sup> While this debate ultimately relates to competing intuitions about "what deters"—an issue that will be addressed more directly later in this chapter—the discussion here focuses simply on understanding what is known and what can be inferred about the technical quality of India's nuclear weaponry.

Ordinarily, this topic would escape all public discussion, but the nuclear tests of May 1998 generated a good deal of information about India's nuclear weapon designs, much of it released by New Delhi itself in response to the controversy that surrounded Indian claims

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<sup>59</sup>For a useful review of this issue in the South Asian context, see Hagerty, *The Consequences of Nuclear Proliferation: Lessons from South Asia*, pp. 39–62.

<sup>60</sup>P. R. Chari, "Weaponisation and the CTBT," *The Hindu*, July 5, 2000.

<sup>61</sup>Karnad, "Next, A Series of Thermonuclear Tests," and Pravin Sawhney, "To Test or Not to Test: The Challenge for India's Nuclear Credibility," *RUSI Journal*, 141:3 (June 1996), p. 31.

<sup>62</sup>See, for example, Sundarji, "Changing Military Equations in Asia: The Role of Nuclear Weapons," pp. 119–149.

about their technical achievements.<sup>63</sup> This discussion is not intended to resolve the controversy about the nuclear tests per se but only to clarify what the debate reveals about India's nuclear weaponry, primarily from the standpoint of assuring successful deterrence.

On May 11, 1998, India announced that it had tested three nuclear devices: a fission device with a yield of about 12 kt; a thermonuclear device with a yield of approximately 43 kt; and a subkiloton device of unspecified yield. On May 13, India announced that it had tested two more subkiloton devices with yields of 0.2 and 0.6 kt, respectively.<sup>64</sup> "By these tests," Dr. P. K. Iyengar, former Chairman of India's AEC, exclaimed, "we have demonstrated in an unambiguous fashion that we can make any kind of nuclear weapon."<sup>65</sup> Based on these remarks and others, two of India's most well-known defense reporters concluded that "Pokhran 1998 was different not just for the number of explosions but also [for] the range of weapons systems it helped to test: bombs with enormous yields of energy caused by advanced thermonuclear reactions, weapon-compatible, medium-impact bombs and, if needed, tactical ones too."<sup>66</sup> In effect, the earliest reports appearing after the 1998 test series concluded that India possessed at least three different kinds of nuclear weapons: first, a simple fission design, dubbed Pokhran Mark II, that was described as a "less-weight-but-more-bang version of the 1974 Pokhran bomb";<sup>67</sup> second, a thermonuclear bomb that Indian scientists insisted was a

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<sup>63</sup>See, for example, S. K. Sikka and Anil Kakodkar, "Some Preliminary Results of May 11–13, 1998, Nuclear Detonations at Pokhran," *BARC Newsletter*, 172 (May 1998), pp. 1–4; S. K. Sikka, Falguni Roy, G. J. Nair, V. G. Kolvankar, and Anil Kakodkar, "Update on the Yield of May 11–13, 1998, Nuclear Detonations at Pokhran," *BARC Newsletter*, 178 (November 1998), pp. 1–5; S. K. Sikka, F. Roy, and G. J. Nair, "Comment on the Paper 'Monitoring Nuclear Tests' by Barker et al.—Science 25 September 1998," unpublished manuscript; and Eliot Marshall, "Did Test Ban Watchdog Fail to Bark?" *Science*, 280 (June 26, 1998), pp. 2038–2040.

<sup>64</sup>"Joint Statement by the Department of Atomic Energy and Defence Research and Development Organization," p. 12.

<sup>65</sup>Quoted in Chengappa and Joshi, "Future Fire," p. 22.

<sup>66</sup>*Ibid.*, p. 24.

<sup>67</sup>*Ibid.*

true “two-stage device”<sup>68</sup> possessing “a fission trigger and a secondary stage”<sup>69</sup> and, as such, represented the acme of the country’s weapon design prowess; and third, a tactical nuclear weapon that was described in press reports as a “low-yield bomb . . . meant for smaller explosions required to pulverize [a] hostile army on the battlefield.”<sup>70</sup> In addition to the specific weapons that were tested on May 11, the low-yield detonations that occurred on May 13 were intended to support future subcritical tests that, as one report noted, would be “needed by India in case it joins [the] CTBT and has to stop [further] big bangs [in the future].”<sup>71</sup>

This account of India’s claimed achievements has been mired in controversy for three reasons. First, the seismological signatures released by the three test series on May 11 suggested only a single detonation rather than multiple detonations.<sup>72</sup> Second, the body-wave magnitude resulting from this test series registered only 5.1 on the Richter scale at the Incorporated Research Institutions for Seismology’s nearest monitoring station at Nilore, Pakistan, suggesting a total yield closer to 20 kt rather than the 55+ kt India originally claimed.<sup>73</sup> Third, the May 13 test series could not be verified through seismic data even though the combined yield of 800 tons should by rights have been, as one Los Alamos geophysicist hyperbolically put it, “visible all over the world.”<sup>74</sup> Before this controversy is examined for the clues it might offer to India’s nuclear capabilities, it is important

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<sup>68</sup>Transcript of the press conference hosted by Dr. R. Chidambaram, Chairman, AEC, and Secretary, DAE; Dr A.P.J. Kalam, Scientific Adviser to the Defence Minister and Secretary, Department of Defence Research and Development; Dr. Anil Kakodkar, Director, BARC; and Dr. K. Santhanam, Chief Adviser (Technologies), DRDO, May 17, 1998.

<sup>69</sup>Ibid.

<sup>70</sup>Chengappa and Joshi, “Future Fire,” p. 24.

<sup>71</sup>Ibid.

<sup>72</sup>William J. Broad, “Monitors Picked Up Only 1 of 5 India Blasts,” *New York Times*, May 15, 1998.

<sup>73</sup>Marshall, “Did Test Ban Watchdog Fail to Bark?” pp. 2038–2040. The U.S. Geological Survey reported a final corrected  $m_b = 5.2$  for the May 11 explosions, much smaller than the  $m_b = 5.76$  that would be expected if the yields were in fact ~55 kt as claimed by India.

<sup>74</sup>Ibid., p. 2038.

to eliminate some fundamental inaccuracies that have arisen as a result of uninformed reporting.

The first such controversy centers on the claim proffered by many Indian analysts—as the defense correspondent of one major Indian newspaper phrased it—that India's testing of subkiloton nuclear devices “marks a significant technological leap, as it now provides the armed forces with the choice of having a wide array of lethal tactical nuclear weapons.”<sup>75</sup> The fact remains that India did not test *any* such weapons during its two rounds of tests in May 1998. This conclusion, which can be inferred from the country's nuclear doctrine, was corroborated by several Indian officials (including some who were involved in the nuclear tests) in a series of conversations with the author in August 1998. India's nuclear arsenal currently has no place for tactical nuclear weapons given that the country does not require any instruments of battlefield use for purposes of ensuring its security.<sup>76</sup> This has been affirmed both by India's Defence Minister, George Fernandes, who has noted unequivocally that “Indian nuclear weapons are for strategic deterrence, not for tactical use,”<sup>77</sup> and by its Foreign Minister, Jaswant Singh, who has with equal clarity stated, “Regarding tactical nuclear weapons, let me remind you that we do not see nuclear weapons as weapons of war fighting. In fact, India sees them only as strategic weapons, whose role is to deter their use by an adversary.”<sup>78</sup> These affirmations notwithstanding, many Indian analysts continue to believe that their country tested tactical nuclear weapons in May 1998 and consequently argue that the Indian armed forces must prepare themselves to deploy these devices effectively. One analyst affiliated with the semiofficial Institute for Defence Studies and Analyses in Delhi exemplified this point of view when he wrote:

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<sup>75</sup>Dinesh Kumar, “Sub-Kiloton Devices a Technological Leap,” *The Times of India*, May 14, 1998.

<sup>76</sup> For a systematic defense of this conclusion, see Gurmeet Kanwal, “Does India Need Tactical Nuclear Weapons?” *Strategic Analysis*, 24:2 (May 2000), pp. 221–246.

<sup>77</sup>Rahul Bedi, “Interview with George Fernandes,” *Jane's Defence Weekly*, July 1, 1998.

<sup>78</sup>“India Not to Engage in a N-Arms Race: Jaswant.”

With its serial nuclear tests [in May 1998], India demonstrated the ability to produce sophisticated nuclear warheads. Now the task for the country is to provide suitable carriers to these warheads to attain a credible nuclear deterrence. . . . All the nuclear warheads of . . . [the May 1998 test] . . . series can be carried by Indian Air Force aircraft, which can deliver them with some changes in configuration. Low-yield devices, such as the 0.2 kiloton [device] tested [on] May 11 and the 0.5 and 0.3 [kt devices tested on] May 13, can be mounted on any ballistic missile, but to use a ballistic missile for that purpose would be a waste. The reason is clear: A low impact would be attained at a huge cost. The best carrier for low-yield or sub-kiloton devices is artillery.<sup>79</sup>

All such analyses explicitly or implicitly presume that the low-yield tests conducted in May 1998 were intended to validate different designs useful for fabricating tactical nuclear weapons. One of the most knowledgeable Indian analysts who has written about this issue, however, has pointed out that “the design of these ‘sub-kt’ tests . . . [does] not seem to suggest that weaponization in this range of yields—artillery, tactical or field—is currently on the agenda.”<sup>80</sup> This fact notwithstanding, several commentators, including members of the Indian armed services, regularly presume in their public writings that India possesses dedicated tactical nuclear weapons, has tested them, and is likely to integrate them into its deterrent posture.<sup>81</sup> Again, nothing could be further from the truth. India *may* have carried out a low-yield detonation as part of its May 11 test series. However, such a test, if it did occur, could have been undertaken for numerous reasons other than the need for tactical weapons—e.g., as part of weapon development experiments, tests of specific components or materials, or tests for system safety. In fact, the “Joint Statement by the Department of Atomic Energy and Defence

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<sup>79</sup>Rajiv Nayan, “Delivery Systems Seen as Aiding Nuclear Deterrence,” *India Abroad*, June 26, 1998.

<sup>80</sup>Ramachandran, “Pokhran II: The Scientific Dimensions,” p. 50.

<sup>81</sup>This presumption is in fact made manifest in the military’s proposal for a new command system declaring that “tactical nuclear weapons [ought to] be released by the NCA through the NSNC to the operational centers of the three service headquarters. Their usage, however, will be decided by the operational commands and the NSNC.” Bedi, “India Assesses Options on Future Nuclear Control.”

Research and Development Organization,” issued after the test series, specifically refers to tests that “have significantly enhanced our capability in computer simulation of new designs and taken us to the stage of sub-critical experiments in the future, if considered necessary.”<sup>82</sup> R. Ramachandran similarly points out that India’s subkiloton tests could well have been used to create a database for future subcritical experiments, although he is doubtful that such a small test series would be adequate for future weapon development in lieu of further hot testing and in the absence of a large prior archive of weapon test data. In any event, he notes that India’s low-yield detonations, which were intended to provide data on neutron multiplication behavior in systems that are just above criticality, could not simultaneously be used for designing nuclear weapons because the principal phenomenon of interest in the latter case is neutron multiplication in systems approaching supercritical states. From this argument, Ramachandran draws the conclusion that India’s low-yield nuclear tests—whatever their purposes may have been—could not have been intended for the development of tactical nuclear weapons.<sup>83</sup>

In private conversations, Indian officials have referred to these low-yield tests as having contributed to validating new nuclear materials and, perhaps, corroborating various hypotheses about their equations of state. Several press reports since the May 1998 tests have described how one of India’s low-yield tests involved an experiment with “dirty plutonium”—reactor-grade plutonium—as a fissile material for possible weapon applications.<sup>84</sup> If this is the case, it could constitute an example of what might be meant by the term “new nuclear materials” while also suggesting, incidentally, that India’s stock of weapons-grade plutonium, being smaller than what is usually imagined, would warrant the investigation of such alternative materials for use in an extreme emergency.<sup>85</sup> In any event, the experiments involving “dirty plutonium” could have some bearing—even if unintended—on the issue of tactical nuclear weapons, as was al-

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<sup>82</sup>“Joint Statement by the Department of Atomic Energy and Defence Research and Development Organization,” p. 12.

<sup>83</sup>Ramachandran, “Pokhran II: The Scientific Dimensions,” pp. 50 and 53–54.

<sup>84</sup>Chengappa, “Is India’s H-Bomb a Dud?” p. 28.

<sup>85</sup>See the discussion in Perkovich, *India’s Nuclear Bomb*, pp. 428–431.

luded to in the last section. As is well known, all kinds of plutonium other than weapons-grade plutonium have traditionally been shunned by weapon designers because they contain more than 7 percent of the undesirable isotope Pu<sup>240</sup>.<sup>86</sup> Since fuel- and reactor-grade plutonium, for example, contains 7–18 percent and more than 18 percent Pu<sup>240</sup>, respectively, they are particularly susceptible to the problems of preinitiation—the premature initiation of a chain reaction caused by the presence of high-neutron background materials before the desired degree of supercriticality can be achieved in the nuclear device—and, as such, have never been the materials of choice in circumstances where weapons-grade plutonium is freely available.<sup>87</sup> Preinitiation usually results in a sharp lowering of yields, and consequently any nuclear weapon that intends to use high-neutron background materials in its core while still seeking to reliably generate great yields must compensate for preinitiation either through sophisticated design techniques, which ensure fast assembly of the fissile materials,<sup>88</sup> or through boosting, which injects a stream of additional neutrons just before the moment of maximum supercriticality “so that the bomb’s tendency to fly apart is partly countered by the continuing forces of convergent assembly”<sup>89</sup> to produce the otherwise unattainable desired yield.<sup>90</sup>

Even if India cannot readily exploit such solutions, it could still use “dirty plutonium” in the core of its standard fission weapons were it willing to accept relatively degraded yields as a consequence. Most authorities knowledgeable about this issue affirm that even standard fission devices that would otherwise produce 10–20 kt if constructed

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<sup>86</sup>The standard sources that examine the issue of reactor-grade plutonium for nuclear weapons are Lovins, “Nuclear Weapons and Power-Reactor plutonium,” pp. 817–823; Mark, “Explosive Properties of Reactor-Grade Plutonium,” pp. 111–128; and Richard L. Garwin, “Reactor-Grade Plutonium Can Be Used to Make Powerful and Reliable Nuclear Weapons: Separated Plutonium in the Fuel Cycle Must Be Protected as If It Were Nuclear Weapons.”

<sup>87</sup>The United States, for example, did develop and test a nuclear weapon made out of reactor-grade plutonium in 1962, but such devices were never certified for operational use because of the plentiful availability of weapons-grade plutonium during the Cold War.

<sup>88</sup>Lovins, “Nuclear Weapons and Power-Reactor Plutonium,” pp. 819–821.

<sup>89</sup>*Ibid.*, p. 820.

<sup>90</sup>Perkovich, *India’s Nuclear Bomb*, pp. 428–430.

with weapons-grade plutonium will produce “yields 3–10 times lower than those mentioned above (depending on the design), [and that] yields in the kiloton range could be accomplished.”<sup>91</sup> One analyst, reviewing these assessments in some detail, concluded simply that “preinitiation [even] at the least favorable moment in a Trinity-type bomb would still produce reliable kiloton yields: the worst-case, minimum, ‘fizzle’ yield is still a ‘militarily useful’ ~1 kton.”<sup>92</sup> If India’s standard fission weapon using reactor-grade plutonium in its core could produce a ~1-kt yield routinely—which is “a very significant yield from a military point of view”<sup>93</sup>—then it is possible that even within the limits of its current technology New Delhi could produce pseudo-tactical weapons with yields that are operationally comparable to those produced by dedicated U.S. and Soviet nuclear artillery shells during the Cold War.

All this goes to reaffirm the conclusion reached in the last chapter: that India need not possess “dedicated” tactical nuclear weapons in order to employ its nuclear assets in a tactically significant way. Instead, it could achieve the capacity for “calibrated deterrence”<sup>94</sup> advocated by many of its security analysts, who seek to avoid “uncontrollabl[e] . . . counter-city attacks wreaking limitless destruction”<sup>95</sup> in the event of deterrence breakdown, either by manipulating the operational variables involved in delivering its standard fission weapons or by simply substituting reactor-grade plutonium in its existing fission devices to produce fizzle yields that nonetheless have militarily significant effects. One of the key inferences that can be drawn from the May 1998 test series, therefore, is that although India surely did not test any dedicated tactical nuclear weapons whatsoever, it could still produce tactically useful low-yield weapons if one of its subkiloton tests successfully provided the information its sci-

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<sup>91</sup>Office of Technology Assessment, *Nuclear Proliferation and Safeguards* (New York: Praeger, 1977), p. 142.

<sup>92</sup>Lovins, “Nuclear Weapons and Power-Reactor Plutonium,” p. 821.

<sup>93</sup>Statement of Dr. John S. Foster, Director, Defense Research and Engineering, Department of Defense, before the Subcommittee on Arms Control, Senate Foreign Relations Committee, May 1, 1973, cited in Ray E. Kidder, “Militarily Significant Nuclear Explosive Yields,” *FAS Public Interest Report*, 38:7 (September 1985), p. 2.

<sup>94</sup>Chellaney, “Nuclear-Deterrent Posture,” p. 213.

<sup>95</sup>*Ibid.*

entists sought about “dirty plutonium” as a potential nuclear weapon material. If India were to successfully design nuclear weapons capable of rapid assembly or were to master the techniques of fusion boosting over time, its “dirty plutonium” could conceivably be used even to produce reliable, high-yield nuclear weapons. Proving such innovations conclusively would almost certainly require a return to hot testing, but the May 1998 tests do not provide any incontrovertible evidence thus far that India has perfected either of these two kinds of technologies.<sup>96</sup>

If it is therefore concluded that the subkiloton tests of May 11 and 13 could contribute to the creation of some militarily significant low-yield devices even if they were not intended for the design of dedicated tactical nuclear weapons, then the Indian arsenal—based on what India claimed to have tested in 1998—is left with two other potentially higher-yield weapons: the simple fission design, which is generally acknowledged to be a weaponized version of the device tested in 1974, and the new thermonuclear design, which ostensibly produced a yield of some 42 kt. And it is this latter device that has been the source of even greater controversy, since its announced yield was much smaller than what most thermonuclear weapons are popularly believed to produce. As one Indian nuclear scientist is quoted as remarking, “One doesn’t think of thermonuclear weapons in kilotons; it’s usually done in the megaton range or multiples of megatons.”<sup>97</sup> Yet while this is certainly the common view about thermonuclear yields (a view that appears to resonate with Pakistani scientists<sup>98</sup>), it is important to recognize that there is no technical reason it should be so—for it is, in fact, possible to produce thermonuclear devices that generate very low yields, and in the case of the United States at least such devices were actually certified as operational weapons by virtue of their special ability to meet the exacting safety criteria specified for nuclear weapons routinely deployed under difficult circumstances in the field.

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<sup>96</sup>For a good summary of Western assessment of India’s May 1998 test series, see Peter D. Zimmerman, “India’s Testing: Something Doesn’t Fit,” *Los Angeles Times*, May 22, 1998.

<sup>97</sup>T.S. Gopi Rethinaraj, “Indian Blasts Surprise the World, but Leave Fresh Doubts,” *Jane’s Intelligence Review*, 10:7 (July 1998), p. 20.

<sup>98</sup>Muhammed Najeeb, “Indian H-Bomb Test a Failure, Say Pakistan Scientists,” *India Abroad*, June 19, 1998.

In any event, in August 1998 Indian officials suggested in private conversations with the author that the thermonuclear device tested in May of that year was not an operational weapon—as the fission device obviously was—but rather an experiment intended primarily to establish that the designated primary would actually burn the relatively small quantities of thermonuclear fuel present in the secondary stage. R. Chidambaram, formerly Chairman of India's AEC, now appears to have confirmed this notion publicly by stating that of the five nuclear devices exploded in Pokhran in 1998, “the 15-kiloton [fission] device was a weapon [that] had been in the stockpile for several years. Others were [merely] weaponisable configurations.”<sup>99</sup> The fact that the thermonuclear test was only an experiment and not the validation of an operational weapon, Indian officials argued in August 1998, ought to have explained the deliberately low yields that were realized in May of that year. Two other factors that are more readily appreciated also contributed to this outcome: first, the desire to minimize damage to the inhabited areas located fairly close to the test range; and second, the desire to prevent any venting of radioactive debris because of the shallow depth of burial of the test devices themselves. The constraints imposed by the shallow depth of burial in particular were driven by the decision to use the old, shallower test shafts that had been dug in the early 1980s for purposes of testing India's fission devices rather than to begin digging some new, deeper shafts, which Indian scientists feared would inevitably have signaled a possible resumption of testing and the consequent imposition of new international political pressures.<sup>100</sup> These facts notwithstanding, the critical question from the viewpoint of assessing India's nuclear weaponry is not whether the intended yields from the tests were kept deliberately low for what are otherwise legitimate reasons but whether the May 1998 yields announced by the Indian nuclear estate in fact comport with the various data about these events available to the international community.

On this score, there is near-unanimity within the U.S. governmental and academic communities that a substantial divergence exists

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<sup>99</sup>“Only One Device at Pokhran-II Was a Weapon,” *The Hindu*, June 22, 2000.

<sup>100</sup>Many of these reasons are detailed in Chellaney, “Nuclear-Deterrent Posture,” pp. 202–209.

between India's announced yield and the inferred seismic yield.<sup>101</sup> Indeed, the gradual changes in India's claims about what was tested, the benchmarks against which its yields were measured, and the very fact that its initial claims were advanced long before these declarations could be systematically corroborated make many of India's official assertions about its achievements suspect—a conclusion increasingly affirmed even within India today.<sup>102</sup> In any event, on the crucial matter of the kinds of devices actually tested in May 1998—the issue of analytical concern at the moment—India's initial claims that it had tested a thermonuclear weapon consisting of “a fission trigger and a secondary stage”<sup>103</sup> have now given way to the assertion that the primary stage of this device actually involved a boosted fission trigger with a yield of 12 kt<sup>104</sup> and not a simple 15-kt fission device, as the director of BARC's solid state and spectroscopy group,

<sup>101</sup>The best academic analyses of this discrepancy in the United States can be found in Terry Wallace, “The May 1998 India and Pakistan Nuclear Tests,” *Seismological Research Letters*, 69:5 (September–October 1998), pp. 386–393; J. R. Murphy, “Seismic Yield Estimation for the Indian and Pakistani Nuclear Tests of May, 1998,” paper presented at the 20th Annual Seismic Research Symposium on Monitoring a CTBT, Santa Fe, NM, September 23, 1998; Brian Barker et al., “Monitoring Nuclear Tests,” *Science*, 282 (September 25, 1998), pp. 1967–1968; William R. Walter, Arthur J. Rodgers, Kevin Mayeda, Stephen C. Myers, Michael Pasyanos, and Marvin Denny, *Preliminary Regional Seismic Analysis of Nuclear Explosions and Earthquakes in Southwest Asia*, UCRL-JC-130745 (Geophysics and Global Security Division, Lawrence Livermore National Laboratory, July 1998); J. Schweitzer, F. Ringdal, and J. Fyen, “The Indian Nuclear Explosions of 11 and 13 May 1998,” *NORSAR Semiannual Technical Summary*, NORSAR Scientific Report No. 2-97/98, pp. 121–130; and Marshall, “Did Test Ban Watchdog Fail to Bark?” pp. 2038–2040. U.S. governmental judgments of the tests are summarized in Perkovich, *India's Nuclear Bomb*, pp. 424–433, and in Mark Hibbs, “India May Test Again Because H-Bomb Failed, U.S. Believes,” *Nucleonics Week*, November 26, 1998. The two international observers who argued in favor of India's announced yields are Jack F. Evernden, “Estimation of Yields of Underground Explosion with Emphasis on Recent Indian and Pakistani Explosions,” *Physics and Society*, 27:4 (October 1998), pp. 10–11, and Roger Clark, whose views are summarized in Debora MacKenzie, “Making Waves,” *New Scientist*, June 13, 1998, pp. 18–19. Evernden's estimates were apparently biased by a small northern European earthquake that occurred after the Indian tests. See Charles Meade, “Surface Wave Magnitudes and Yield Estimates for the May 11, 1998 Indian Nuclear Test,” unpublished memo.

<sup>102</sup>For some good reporting on this issue, see D. N. Moorthy, “AEC Chief Defends Pokharan Yields,” *Indian Express*, November 30, 1999.

<sup>103</sup>Transcript of the press conference hosted by Dr. R. Chidambaram, Chairman, AEC, and Secretary, DAE.

<sup>104</sup>Chengappa, “Is India's H-Bomb a Dud?” pp. 22–28; Ramachandran, “Pokhran II: The Scientific Dimensions,” p. 50.

S. K. Sikka, had earlier informed the journal *Science* in a written communication.<sup>105</sup>

While this steadily mutating story does little to enhance the credibility of India's claims, it does suggest that any analysis of the kinds of nuclear weapons India may be presumed to possess must reckon with the prospect of not two but actually three separate designs: a fission weapon with the initially claimed yield of some 12 kt; a boosted fission weapon with a claimed yield of approximately 12 kt; and a thermonuclear device with a claimed yield of 31–36 kt, depending on whether the total yield of all devices tested on May 11 was finally either ~55 or ~60 kt. Indian officials have claimed both totals at different times and have varied the internal breakdown of these figures as well: In the final version of their claims, the simple fission device is supposed to have yielded 15 kt; the thermonuclear device 45 kt, divided between a 12-kt boosted fission trigger and a 33-kt fusion yield; and the assorted subkiloton tests 0.2 kt, 0.3 kt, and 0.5 kt, respectively, with the last two tests alleged to have been conducted on May 13, 1998.<sup>106</sup>

The fact that these figures suggest three nuclear designs and not two as per the earlier Indian claims has been explicitly confirmed by R. Chidambaram, who asserted that his team of scientists “obtained three robust bomb designs”<sup>107</sup> as a result of their May 1998 tests. Directly addressing the issue of the combined boosted-fission/thermonuclear test, Chidambaram asserted that this event was deliberately intended to “kill two birds with one stone”—i.e., to validate a boosted fission design (which in principle can provide more than a fourfold increase in yield over a simple fission bomb) while simultaneously using the energy generated from such a primary to burn the lithium deuteride that presumably constituted the ther-

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<sup>105</sup>Marshall, “Did Test Ban Watchdog Fail to Bark?” p. 2039.

<sup>106</sup>The earlier Indian claims are recorded in John F. Burns, “Indian Scientists Confirm They Detonated a Hydrogen Bomb,” *New York Times*, May 18, 1998, while the revised claims can be found in Marshall, “Did Test Ban Watchdog Fail to Bark?” pp. 2038–2040. In a later, more inexplicable accounting, Indian scientists are also supposed to have “put the yield from the fission bomb at 20 kt and the hydrogen bomb at 25 kt.” Chengappa, “Is India's H-Bomb a Dud?” p. 26. These varying figures obviously cannot be reconciled and only underscore the spurious and utterly unreliable character of the official scientific claims accompanying the May 1998 tests.

<sup>107</sup>George, “No More N-Tests Needed: AEC.”

monuclear fuel in the secondary. Admitting that “most nuclear weapon powers had gone through the traditional path of separately testing a boosted fission device,”<sup>108</sup> Chidambaram justified his team’s approach to this issue by referring to the state-of-the-art capabilities India possessed in these areas and, accordingly, argued that “each of our tests should be considered equivalent to several carried out by other nuclear weapon states.”<sup>109</sup> This effort at validating multiple effects through a minimum number of tests is consistent with the public claims made by other senior Indian scientists, some of whom are even reported to have suggested that “the five tests [carried out in May 1998] were equivalent in value to about 50 [tests]”<sup>110</sup> in terms of the experience gained.

Although these arguments advanced about the sufficiency of India’s minimal number of nuclear tests are quite fraudulent, the other justifications for why Indian scientists deliberately restricted the yield of their thermonuclear weapons to relatively low levels are more plausible. It is certainly difficult to believe that Indian scientists have mastered the art of terminating the fusion burn precisely in order to obtain reliably low yields—without *any* prior hot testing of advanced weapon designs—but at least their intention to keep the overall yields low are understandable. The need to limit damage to the villages near the test site; the need to avoid venting given the relatively shallow depths of burial of the devices necessitated by the use of old shafts; and the need to limit the maximum yield given the number of multiple devices that had to be tested simultaneously from relatively closely spaced shafts for reasons of cost, political considerations, and deception and denial all converge toward a reasoned justification for lower rather than higher yields.<sup>111</sup> But what

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<sup>108</sup>“No Compromises on N-Power: AEC Chief,” *Indian Express*, February 4, 1999.

<sup>109</sup>*Ibid.*

<sup>110</sup>Chengappa, “Is India’s H-Bomb a Dud?” p. 28. Obviously whether such a dual experiment actually took place cannot be verified through seismological means alone. In any event, whether the primary involved a boosted fission trigger or not, the entire experiment more likely than not was intended to establish a proof of principle rather than to validate a final weapon design, at least as far as the thermonuclear weapon per se was concerned.

<sup>111</sup>For many of these reasons, see “Weaponization Now Complete, Say Scientists,” *The Hindu*, May 18, 1998; Chengappa, “The Bomb Makers,” pp. 26–32; and throughout Chengappa, *Weapons of Peace*.

makes the Indian claims of unvarnished success difficult for most international observers to swallow ultimately derives from three factors: the relatively low body-wave magnitudes registered by the May 11 tests;<sup>112</sup> the character of the crater morphology resulting from each of the tests given the geology of the area and the relative depths of burial of the devices tested;<sup>113</sup> and the complete absence of seismic information pertaining to the May 13 tests.<sup>114</sup>

Although the May 11 tests should have registered an average body-wave magnitude of 5.76 if all the detonations produced a total yield of even ~55 kt, the actual average magnitude finally reported by the U.S. Geological Service of  $mb = 5.2$  suggests that the total yield of all three devices could not have exceeded 9–16 kt, with the best mean estimate for the yield based on seismic sources set at around 12 kt.<sup>115</sup> If the total uncertainty surrounding the mean estimates is taken to be 50 percent, because of uncertainties relating to the geologic conditions of the test site, emplacement geometry, degree of coupling, and the like, the estimated yield of the May 11 tests would not exceed 24 kt, with most Western analysts holding to the claim that, as Terry Wallace put it, “you’re going to be pushing 20 kilotons at most for the 11 May test.”<sup>116</sup>

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<sup>112</sup>Wallace, “The May 1998 India and Pakistan Nuclear Tests,” pp. 386–393; Murphy, “Seismic Yield Estimation for the Indian and Pakistani Nuclear Tests of May, 1998”; Barker et al., “Monitoring Nuclear Tests,” pp. 1967–1968; Walter et al., *Preliminary Regional Seismic Analysis of Nuclear Explosions and Earthquakes in Southwest Asia*; and Marshall, “Did Test Ban Watchdog Fail to Bark?” pp. 2038–2040.

<sup>113</sup>Wallace, “The May 1998 India and Pakistan Nuclear Tests,” p. 389. Brief descriptions of the local geology and the effect of geology on crater formation can be found in S. K. Bhushan, “Geology Around Pokhran Nuclear Sites,” *Journal of the Geological Society of India*, 52:1 (July 1998), p. 118, and A. C. McEwan, “Environmental Effects of Underground Nuclear Explosions,” in Jozef Goldblat and David Cox (eds.), *Nuclear Weapons Tests: Prohibition or Limitation?* (Oxford, UK: Oxford University Press, 1998), pp. 75–91.

<sup>114</sup>Wallace, “The May 1998 India and Pakistan Nuclear Tests,” pp. 389–390; Walter et al., *Preliminary Regional Seismic Analysis of Nuclear Explosions and Earthquakes in Southwest Asia*, p. 6. There is still no corroborating evidence for the May 13, 1998, tests; in all probability, these tests *did* take place but with much smaller yields than those suggested by India. In any case, the photographs of this event—published in Chengappa, “Is India’s H-Bomb a Dud?” p. 25—are suspicious, as are many other photographs relating to the May 1998 tests found in Chengappa, “The Bomb Makers,” pp. 26–27.

<sup>115</sup>Barker et al., “Monitoring Nuclear Tests,” p. 1968.

<sup>116</sup>Marshall, “Did Test Ban Watchdog Fail to Bark?” p. 2039.

Indian scientists have attempted to explain this critical discrepancy by arguing that the location of many seismometers along an east-west axis biased the seismic reading, as “*mb* values are in general smaller at the azimuths away from the north direction.”<sup>117</sup> After correcting for distortions introduced by azimuth, BARC scientists have argued that “a value of *mb* = 5.39 was obtained as the global average”—which in turn translates into “an average combined yield of  $58 \pm 5$  kt after taking into account the geology of Pokhran test site as calibrated by our POK1 explosion.”<sup>118</sup> Even if the significance of east-west measuring bias is disregarded,<sup>119</sup> this translation of magnitude-to-yield values appears to be heavily dependent on a smaller set of values attributed to the constants *a* and *b* in the magnitude-yield formula  $mb = a + b \log Y$ —values that are more appropriate for tectonically active regions than for the stable Indian test sites and that consequently are not used by any other observers outside India.<sup>120</sup> It is not clear whether manipulating the value of the constants alone always produces the kinds of yields desired by India because a quick recalculation—using one set of constants (*a* = 3.8, *b* = 0.9) attributed to BARC’s experts by one knowledgeable Indian scientific commentator who has attempted to defend India’s claim of success in its thermonuclear test<sup>121</sup>—seems to suggest that the total yield of the May 11 tests could not have exceeded 36 kt.

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<sup>117</sup>Sikka et al., “Update on the Yield of the May 11–13, 1998, Nuclear Detonations at Pokhran,” p. 1.

<sup>118</sup>*Ibid.*, pp. 1–2.

<sup>119</sup>The Indian argument that *mb* values were generally smaller when measured by seismometers emplaced along the east-west axis is true but is fundamentally misleading. Because *mb* values are distorted by a variety of factors, including sensor locations and geological variations, the appropriate methodology for calculating such values consists of averaging the readings obtained by *all* reporting stations in a given seismographic network. The Indian strategy of selecting only those readings obtained from sensors located primarily away from an east-west axis amounts to little more than “cherry picking” the data in order to derive those desired *mb* values which translate into the higher yields that Indian scientists sought to justify in the first place.

<sup>120</sup>The best analysis of this issue can be found in Wallace, “The May 1998 India and Pakistan Nuclear Tests,” pp. 386–393, and in Gregory van der Vink, Jeffrey Park, Richard Allen, Terry Wallace, and Christel Hennes, “False Accusations, Undetected Test and Implications for the CTB Treaty,” *Arms Control Today*, 28:4 (May 1998), pp. 7–13.

<sup>121</sup>See the values used in R. Ramachandran, “Understanding Pokhran II & III: A Technical Appraisal,” *Agni*, 3:3 (January–May 1998), pp. 12–25.

This class of yields sharply constrains the kind of weaponry India may be said to possess. If the May 11 tests are interpreted as producing a yield between 9 and 16 kt (with the best mean estimate set at approximately 12 kt with an upper bound of ~24 kt after allowance for evaluative uncertainties), either (a) the fission device detonated successfully (if it is assumed to be either 12 kt or 15 kt in yield) but both the boosted fission primary and the thermonuclear secondary failed; or (b) the fission device and the boosted fission trigger detonated more or less successfully (if both are assumed to have yielded 12 kt each, but not if the former was in fact supposed to have produced a larger yield, as the revised Indian claim suggests) while the thermonuclear secondary failed. What simply seems improbable is (c): that both the fission weapon and the thermonuclear device in its entirety detonated successfully, as the combined yields do not *unambiguously* corroborate India's claims of success even after due allowance is made for evaluative uncertainty. Even the assumption embodied in (b), that both the fission weapon and the boosted fission trigger produced their full yield as planned, is highly suspect because it presumes that the May 11 test series produced between 24 and 27 kt of yield—a conclusion that can be sustained only if one settles for the highest and most favorable estimate of yield derived from the body-wave magnitude associated with that event. Such a conclusion, besides being a suspicious deduction, is certainly not corroborated by the crater characteristics of the two test sites.<sup>122</sup>

Consequently, what is most likely to have occurred—when the seismic data, the crater morphology associated with each test site, knowledge about the local geology of the test range, and information about the depth of burial, including that gained from mensuration of the evacuated debris from the test shafts, are all integrated—is that the fission weapon detonated successfully (although its actual final yield is uncertain) while the boosted fission trigger almost certainly failed to boost successfully and consequently could not produce the temperatures required to ignite the thermonuclear fuel present in the secondary.<sup>123</sup> Clearly, the Indian photographs released of the test

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<sup>122</sup>Wallace, "The May 1998 India and Pakistan Nuclear Tests," p. 389.

<sup>123</sup>Rethinaraj, "Indian Blasts Surprise the World, but Leave Fresh Doubts," pp. 20–21. One technical study of the value of nuclear testing for the United States concluded that a full-yield explosion of the primary, which would be necessary to successfully

sites suggest that some sort of detonation did take place in the shaft where the thermonuclear device was located, but the physical evidence suggests that the fission components of the trigger produced most of the fizzle yield, with failure to boost accounting for the inability to secure the fusion yield that Indian scientists claimed they obtained from this test.<sup>124</sup>

This conclusion must be carefully understood: Irrespective of what claims Indian scientists may make about the success of their thermonuclear test, the controversy surrounding this issue ought to suggest, at the very least, that India has not demonstrated *beyond a shadow of a doubt* that it has mastered the ability to produce advanced nuclear weapons even if it is presumed—against the weight of all available evidence—to actually possess such a capability. The nuclear tests conducted in May 1998 were supposed to have two specific objectives: to enhance the country's own confidence in its existing weapon designs and to communicate to its adversaries the extent of its technological prowess for purposes of ensuring deterrence stability.<sup>125</sup> Yet even if the first objective has been satisfactorily attained, however solipsistically—that is, because the Indian nuclear estate believes in the success of its test regime, because post-test analysis provided the data necessary to remedy the flaws discovered during explosive testing, or because India's nuclear scientists have

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validate the "ignition of the secondary," would "generate nuclear yields in excess of approximately 10 kt." See Sidney Drell et al., "Nuclear Testing: Summary and Conclusions," *JASON Nuclear Testing Study*, JSR-95-320, August 3, 1995, available at <http://www.fas.org/rlg/jsr-95-320.htm>. By this conclusion, India's thermonuclear test ought to have produced a yield in excess of approximately 10 kt if its claim that the thermonuclear fuel in the secondary successfully ignited is to be believed. However, the characteristics of the crater at the thermonuclear test site, when coupled with the seismic data for *all* tests occurring on May 11, 1998, do not unambiguously corroborate India's claim.

<sup>124</sup>Indian nuclear scientists have published results from their radiochemical measurements, which they claim prove that the yield of the thermonuclear device tested in May 1998 was  $50 \pm 10$  kt. See S. B. Manohar, B. S. Tomar, S. S. Rattan, V. K. Shukla, V. V. Kulkarni, and Anil Kakodkar, "Post Shot Radioactivity Measurements on Samples Extracted from Thermonuclear Test Site," *BARC Newsletter*, 186 (July 1999), pp. 1–5. Unfortunately, this paper does not reproduce the raw data gathered from the samples subjected to radiochemical testing and as a result it is difficult to conclude that the results claimed cohere with the data actually recovered from the radiochemical tests.

<sup>125</sup>Singh, *What Constitutes National Security in a Changing World Order?* pp. 31–32.

shifted to more conservative weapon designs to increase the probability of successful detonations in the future—the second objective has hardly been secured, since significant portions of the international community are not yet convinced about the validity of India's technical claims. It may be argued quite cogently that what observers in the United States and more generally the West may believe is irrelevant, since India's nuclear capabilities are not designed to deter those countries. By this very token, however, what the Pakistanis and the Chinese believe about India's nuclear prowess could be highly relevant, and it is here that India's ambiguous achievements would matter more than elsewhere. The Pakistani scientific community, however, has already publicly expressed its disbelief about the success of India's thermonuclear experiment,<sup>126</sup> and while the Chinese strategic community has made no comparable public response, there is good reason to believe that its private estimates of New Delhi's achievements do not deviate substantially from the opinions expressed in Islamabad.<sup>127</sup>

All these exhibitions of disbelief might have been written off within India as yet another example of foreign condescension were it not for the fact that in February 2000, P. K. Iyengar, a former Chairman of the Indian AEC and one of the key individuals associated with the 1974 test, went public—thanks to a private, ongoing rivalry with R. Chidambaram—with his claim that the Indian thermonuclear test was not as successful as had previously been affirmed. This assertion, echoing the astute assessment of Bharat Karnad in an earlier article,<sup>128</sup> was proffered in the context of the Indian debate about sign-

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<sup>126</sup>Najeeb, "Indian H-Bomb Test a Failure, Say Pakistan Scientists."

<sup>127</sup>Zhang, *China's Changing Nuclear Posture*, pp. 33–34. The Indian scientific community, exasperated by the pervasive skepticism emanating from the West and often contemptuous of Pakistan's own modest achievements in the field of nuclear weaponry, has charged the West with deliberately spreading "misinformation" about India's technical achievements for political reasons (see Satyen Mohapatra, "Low Yield Reports Misleading: AEC Chief," *Hindustan Times*, January 5, 1999). Other Indian analysts have argued that while some doubt is to be expected given that "India has shown a remarkable level of capability," most Western skepticism "is politically motivated and aimed at undermining India's deterrent posture" (see Brahma Chellaney, "India's Hydrogen Bomb," *Hindustan Times*, January 13, 1999). For more along these lines, see Chellaney, "Nuclear-Deterrent Posture," pp. 141–222.

<sup>128</sup>See Karnad, "A Sucker's Payoff," pp. 45–50, for a good reading of what was and was not achieved by the May 1998 tests.

ing the CTBT. In urging his government not to sign the treaty, Iyengar noted that the thermonuclear design tested in May 1998 was primarily a proof of principle rather than a weaponized design; had failed to achieve a complete fusion burn that would have marked it as a viable design; had an unknown yield by virtue of having been tested simultaneously with at least another fission weapon; and, finally, was simply insufficient as a data point on which to benchmark future computer simulations of such devices.<sup>129</sup> Despite this critique, Iyengar sought to reconcile his claims with the DAE's announced May 1998 yields and, as a consequence, was forced to speculatively revise the breakdown of total yields in still another way: Accepting that the fission device yielded 15 kt, Iyengar concluded that the boosted fission trigger produced 20 kt and the thermonuclear fuel produced another 20 kt to reach a total of 55 kt from all tests combined.<sup>130</sup> This redaction obviously does not square with the evidence accepted internationally and, at any rate, appears to have left many serious Indian analysts justifiably suspicious about their country's capability to produce the kinds of advanced nuclear weapons believed to be necessary without further testing—weapons that the Indian nuclear estate repeatedly affirms it could manufacture without any difficulty whatsoever.<sup>131</sup>

This debate about New Delhi's technical achievements only confirms the suspicion harbored by many observers of the Indian nuclear weapon program: that India's nuclear scientists, like many weapon designers elsewhere in the world, are so fascinated by the sophistication of their conceptual designs that they often tend to overlook the more simple, pedestrian attributes invariably demanded by all end users—repeatedly tested, mechanically reliable weapons that will produce a specified yield whenever they are required to do so under any operational circumstances. Instead of focusing their energies and resources on producing these kinds of nu-

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<sup>129</sup>"Indian Scientist Opposes Signing of CTBT," *Deccan Herald*, February 19, 2000.

<sup>130</sup>Mark Hibbs, "Because H-Bomb Fuel Didn't Burn, Iyengar Pleads for Second Test," *Nucleonics Week*, June 1, 2000.

<sup>131</sup>See, for example, Chari, "Weaponisation and the CTBT"; Karnad, "A Sucker's Payoff"; Rajagopalan, "The Question of More Tests"; Balachandran, "A Consensus or a Sell-Off?"; V. R. Raghavan, "Whither Nuclear Policy," *The Hindu*, July 1, 2000; and especially A. Gopalakrishnan, "How Credible Is Our Deterrence?" *The Hindu*, November 18, 1998.

clear weapons, India's nuclear scientists appear to be more seduced by the challenges of reaching out for the farthest limits of the possible rather than contenting themselves with demonstrating an incontrovertible mastery over merely the efficacious: Their quest for the best, in effect, has become the resolute enemy of the good enough.<sup>132</sup> Karnad in particular has noted how India's nuclear scientists have privately claimed that "the country has a dozen proven weapons configurations to choose from in structuring a nuclear deterrent."<sup>133</sup> While there is little reason to doubt that India does in fact possess many nuclear designs, the claim that these designs are "proven" in the sense of being capable of satisfying the end user is sheer fantasy given that, as Karnad put it, "the most decisive potential weapon, namely the thermonuclear or fusion device, may have failed in the one-off test"<sup>134</sup> conducted in May 1998.

The character of the comments uttered by India's nuclear scientists since these tests also suggests a disturbing sleight of hand: Weapon designs, weaponizable designs, and operational weapons all appear to be treated interchangeably in Indian rhetoric, with the result that designs that may exist merely on paper, that may have been confirmed as plausible through some theoretical calculations or computer simulations, or whose components may have been tested but only in a piecemeal fashion, are all expansively defined as "available weapons," leading one respected Indian observer to complain that the carefully worded phraseology used by Indian scientists often fails to "clarify whether more field tests would be required to fashion the devices . . . with reasonable confidence into deliverable nuclear weapons."<sup>135</sup> This somewhat blasé and overconfident attitude exhibited by India's nuclear scientists about their weapon technology capabilities is ultimately grounded in the sociology of India's civil-military divide: Since the responsibility for designing, developing, and maintaining India's nuclear weaponry is vested entirely in civilian authorities with little or no military collaboration, it is not surprising that design and reliability issues that should by rights be

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<sup>132</sup>See the apt remarks in Manoj Joshi, "The Nuclear Maharaja Has No Clothes," *The Times of India*, June 9, 2000.

<sup>133</sup>Karnad, "A Sucker's Payoff," p. 47.

<sup>134</sup>*Ibid.*

<sup>135</sup>Chari, "Weaponisation and the CTBT."

heavily influenced by the contingencies of deterrence breakdown and actual nuclear use merit less attention as far as the Indian nuclear estate is concerned. In fact, these problems may be dismissed altogether on the grounds that nuclear weapons, being merely political instruments and not usable military tools, will never be put to the test of war anyway and hence do not warrant the time, energy, and resources that it would take to assure operational and yield reliability if such weapons were to be used *in extremis*. R. Chidambaram may have unwittingly betrayed this attitude when he argued that “in [the] two decades (after Hiroshima) nobody had to use nuclear weapons, and it is very clear in my mind that nobody is going to use them in the future too. For me knowing our history and the fact that in a thousand years we have never coveted anyone else’s territory, such weapons are only a deterrent. Being such a big country, India had also to be a strong one.”<sup>136</sup>

In any event, the debate about India’s nuclear tests brings to the fore two specific sets of issues: First, what kinds of weapons can India finally be presumed to have? And second, what is India likely to do in the future?

**What kinds of weapons can India finally be presumed to have?** It is reasonable to presume that if only one device was successfully tested in May 1998, that device was India’s fission weapon. The basic design of this weapon, presumably with a simple solid-core implosion system, was tested in 1974. The improved version, tested in 1998, was based on a levitated flying-plate design,<sup>137</sup> and the relative success of this test, based on both the seismic data and the test site imagery released by New Delhi, implies that India must be credited with the capability to produce at least simple fission weapons with an effective yield of some 12–15 kt. One Indian analyst has noted that militarily usable fission designs could produce a maximum yield of ~50 kt,<sup>138</sup> but it is unlikely that even India’s 1998 flying-plate design could simply be scaled up to produce the kinds of yields—“20 to 50

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<sup>136</sup>Cited in Chengappa, *Weapons of Peace*, p. 120.

<sup>137</sup>*Ibid.*, pp. 207–208.

<sup>138</sup>Sawhney, “To Test or Not to Test: The Challenge for India’s Nuclear Credibility,” p. 31.

kt”<sup>139</sup>—that commentators often believe are possible even in the absence of boosting. India’s fission weapons could certainly be engineered to produce a yield closer to (and perhaps even beyond) the high end of this spectrum, but a comprehensive redesign of the implosion system and not merely a manipulation of the existing configuration would be required if such yields were desired.<sup>140</sup> Such a redesign would certainly require a return to hot testing, since “increasing uncertainty would be associated with more advanced implosion systems that use less fissile material than [any] original solid-sphere design.”<sup>141</sup> But since India has presumably eschewed this option in light of its current commitments to the United States, it is reasonable to conclude that the Indian nuclear estate can primarily produce simple fission weapons capable of yields not much beyond 15 kt.

If India’s boosted fission trigger had detonated successfully in May 1998—even if the secondary failed during the thermonuclear test—this device would have offered New Delhi significant strategic advantages. For starters, it would have enabled India to dramatically increase the effective size of its weapon-usable fissile-material stockpile, since an effective boosted fission design would allow it to use even its reactor-grade plutonium to produce high-yield nuclear weapons. It would also have enabled India to increase the yields otherwise produced by its fission weaponry while simultaneously reducing their weight. Thanks to boosting, India could thus have developed a larger and a more destructive arsenal simultaneously. This fact has important strategic consequences that ought not to be overlooked in the controversy over India’s thermonuclear claims.<sup>142</sup>

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<sup>139</sup>Ibid., p. 33.

<sup>140</sup>If pure fission weapons yielding much greater than 70 kt have to be produced, the historical record suggests that such devices would be “very expensive due to the large amounts of Pu-239 required” and would incur severe weight penalties. The French AN 22 and MR 31 weapons, which had yields of 60–70 kt and 120 kt, respectively, are good examples of large, pure fission weapons. For details, see Norris et al., *British, French, and Chinese Nuclear Weapons, Nuclear Weapons Databook*, Vol. V, p. 185.

<sup>141</sup>Richard L. Garwin, “The Future of Nuclear Weapons Without Nuclear Testing,” *Arms Control Today*, 27:8 (November–December 1997), pp. 3–11.

<sup>142</sup>See the remarks by Ray Kidder in Chengappa, “Is India’s H-Bomb a Dud?” p. 28.

In part, this is because successfully boosting fission weapons is a challenging technical exercise in its own right, and although not popularly appreciated, it is no less—and in some ways may even be more—demanding than the design and construction of true two-stage thermonuclear weaponry. Not surprisingly, several Indian analysts have rushed in to claim that even if the test of the full thermonuclear device was unsuccessful, the boosted fission component certainly produced the intended yields.<sup>143</sup> This capacity has presumably granted India “access to weapons that have yields in excess of 150 kilotons—possibly more.”<sup>144</sup> It has been asserted that such capabilities have enabled India to actually develop a 200-kt boosted fission warhead for the Agni,<sup>145</sup> and one analyst has even claimed that the country “retain[s] a capability to exercise a variety of options varying from 20 kt to 500 kt yields.”<sup>146</sup> Such judgments find resonance among the more optimistic of India’s strategic elites—and, not surprisingly, given the overconfidence of India’s nuclear estate, even the architect of the May 1998 test series, R. Chidambaram, has claimed that the thermonuclear experiment has allowed India to develop weapons with yields of about 200 kt.<sup>147</sup> This conclusion is of interest because it does not assert that India can develop thermonuclear weapons in the megaton range without additional hot tests but merely that the ostensibly successful thermonuclear experiment has allowed for the creation of devices with yields that are popularly associated with boosted fission weaponry.<sup>148</sup>

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<sup>143</sup>Sanjay Badri-Maharaj, “Nuclear India’s Status,” *Indian Defence Review*, 15:2 (April–June 2000), p. 128.

<sup>144</sup>Badri-Maharaj, “The Nuclear Battlefield,” p. 90.

<sup>145</sup>Ibid., p. 126. See also Sanjay Badri-Maharaj, *The Armageddon Factor* (New Delhi: Lancer Publishers, 2000), pp. 47–97, for a collection of unsubstantiated claims about Indian nuclear prowess coupled with a pervasive underestimation of Pakistani nuclear capabilities.

<sup>146</sup>Sawhney, “To Test or Not to Test: The Challenge for India’s Nuclear Credibility,” p. 31.

<sup>147</sup>“India Can Produce N-Bomb of 200 Kiloton,” cited in Karnad, “A Thermonuclear Deterrent,” p. 117, and “India Can Make 200 Kilotons of Nuke Weapons.”

<sup>148</sup>Sawhney, for example, notes that “militarily usable boosted weapons have explosive powers of up to about 500 kt. The yields of the most powerful boosted weapons are equal to those of low-yield thermonuclear weapons.” See Sawhney, “To Test or Not to Test: The Challenge for India’s Nuclear Credibility,” p. 31.

There is no publicly available evidence, however, suggesting that any of these claims are true. Nor can these assertions be corroborated even inferentially from what is known from the May 1998 tests. As a result, these classes of yields must be treated as simply one of the many theoretical possibilities that may be inherent in some of India's current nuclear designs. By the standards of deductive reasoning or available evidence, however, they cannot be considered empirical capabilities that India is universally acknowledged to possess at least as far as its standing nuclear inventory is concerned. The same conclusion applies *a fortiori* with respect to India's thermonuclear weapons: The general failure of the thermonuclear test forces the conclusion that India cannot be said to possess effective thermonuclear weaponry at present, and as Indian officials pointed out first to the author in August 1998 and later publicly, the requirement for thermonuclear weapons has never been defined as a formal deterrence requirement by India's political leadership.<sup>149</sup> The thermonuclear test is therefore owed more to the zeal of the Indian nuclear estate and to the pressures of technological determinism within the weapon program than to a calculated assessment on the part of the national leadership about the need for such capabilities.

When all is said and done, therefore, the May 1998 tests do not validate P. K. Iyengar's early claim that Indian scientists "have demonstrated in an unambiguous fashion that we can make any kind of nuclear weapon."<sup>150</sup> It does, however, open the door to crediting India with possibly two kinds of nuclear weaponry: a new, arguable capability to produce pseudo-tactical nuclear weapons through the incorporation of "dirty plutonium" in the core of its standard fission design, in addition to its previously demonstrated competence to produce relatively low-yield fission weaponry. India certainly possesses additional designs for both boosted fission and thermonuclear weapons, but it cannot be credited with unambiguously demonstrating its capacity to produce such weapons through the data available to the international community as a result of the May 1998 tests. It will also be difficult to credit India with the ability to produce such advanced weapon designs in the absence of a return to field testing.

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<sup>149</sup>See the discussion in Perkovich, *India's Nuclear Bomb*, p. 431.

<sup>150</sup>Quoted in Chengappa and Joshi, "Future Fire," p. 22.

**What is India likely to do in the future?** Clearly, the validation of one, and possibly the opportunity to produce another, type of nuclear weapon is only the beginning of a long process given India's decision to develop a nuclear deterrent of some sort in the future. This implies that the principal task India faces where nuclear weapons are concerned consists of completing the process of weaponization understood in the strict sense of the term. In the aftermath of the May 1998 tests, prominent Indian technologists such as A.P.J. Kalam hurriedly claimed that "our weaponization is complete."<sup>151</sup> Such claims, however, must be treated either as hyperbole or at best as partial truths. Weaponization in the strict sense refers to the "developing, testing, and integrating [of] warhead components into a militarily usable weapon system"<sup>152</sup> and, as such, is a long and drawn-out process that cannot be fully completed before the delivery systems ready to carry such payloads are at hand. But since the full range of India's delivery systems are not yet complete (as the subsequent discussion will demonstrate), it must be concluded that the process of weaponization in India has only just begun. Depending on the types of delivery systems sought over time, each carrier will inevitably impose new kinds of physical demands on the nuclear payload: Aircraft impose burdens different from those of ballistic and cruise missiles, with the basing modes associated with these systems further complicating the physical and operational demands made on the payloads. Until the entire panoply of delivery systems is therefore developed, it would at the very least be premature to conclude that Indian weaponization is in fact complete.<sup>153</sup>

Even before weaponization in any extended sense occurs, however, Indian scientists will most likely focus on refining their standard fission design as a result of the data gathered from the May 1998 tests. If international political constraints did not exist, these refined designs would be repeatedly hot tested until their creators were completely satisfied that the devices would work as intended with different kinds of delivery systems while still producing the desired

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<sup>151</sup>Indian Nuclear Tests Included Hydrogen Bomb, FBIS-NES-98-138, May 18, 1998.

<sup>152</sup>Neil Joeck, *Nuclear Relations in South Asia*, UCRL-JC-132729, December 1998, p. 10.

<sup>153</sup>Raja Menon, "Not in National Interest," *Hindustan Times*, January 5, 2000.

yields. This would be particularly true as far as the boosted fission and thermonuclear weapon designs are concerned. Since India has currently ruled out further hot testing for political reasons, however, most of these refinements will have to be carried out through laboratory experiments, computer simulations, and fully instrumented dummy tests.<sup>154</sup> These experiments will of necessity focus on confirming that the subsystems will work as intended in the hope that the entire system will enjoy the same reliability, when fully integrated, as each of the subsystems presumably demonstrated when they were assessed under test conditions.<sup>155</sup>

Even as this process is completed, however, India's designers will want to make certain that the modifications introduced into their weaponry will not compromise the ability of the existing weapon carriers—primarily aircraft—to successfully deliver these payloads. Kalam, for example, has indicated that Indian weapon designers have already been testing the “size, weight, performance and vibrations” of their devices “for quite some time.”<sup>156</sup> This testing will obviously continue if the designs are further modified as a result of the data gleaned from both the recent nuclear tests and other continuing experiments. The larger challenge, however, will consist of readying what will by then be relatively stable fission designs for a new class of

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<sup>154</sup>For a discussion of these issues together with examples of some such activities undertaken in the past, see Sawhney, “To Test or Not to Test: The Challenge for India's Nuclear Credibility,” pp. 30–35; Pravin Sawhney, “Standing Alone,” *Jane's International Defence Review*, 29:11 (November 1996), pp. 25–28; and Chengappa, *Weapons of Peace*, p. 418.

<sup>155</sup>This is an issue that speaks among other things to the reliability of the weapons and, by extension, to the level of confidence that the owners of these weapons desire from their strategic reserves. Because dilemmas of confidence lay at the heart of the U.S. deterrent, which was focused on ensuring reliable positive control, Washington pursued a large and sophisticated weapon test program that aimed at maximizing device reliability, safety, and efficiency simultaneously. See Donald R. Westervelt, “Can Cold Logic Replace Cold Feet?” *Bulletin of the Atomic Scientists*, 35:2 (February 1979), pp. 60–62, and Brown, “Nuclear Weapons R&D and the Role of Nuclear Testing,” pp. 6–18. To the degree that India can live with greater uncertainty in each of these areas, its need for a return to hot testing its fission weaponry may be reduced *pari passu*. This conclusion obviously does not apply as far as boosted fission and thermonuclear devices are concerned: Neither dummy tests nor tests of subsystems would suffice to ensure the viability, let alone the reliability, of such devices. Advanced nuclear designs *have* to be repeatedly field tested, though not necessarily at full yield, if they are to be validated as worthy of induction into an operational inventory.

<sup>156</sup>*Indian Nuclear Tests Included Hydrogen Bomb.*

delivery systems that either are just coming on line or will be available only many years into the future. Mating these existing designs to a new set of delivery vehicles, primarily missiles—many of which do not yet exist in their final form—will thus be the principal preoccupation of Indian weapon designers over the long term.

All of this presupposes, however, that India can live quite contentedly without any advanced nuclear weapons in its inventory. Indian policymakers currently believe this to be the case, since the present and expected range of threats could be adequately deterred by New Delhi's simple fission weapons. So long as this judgment holds, India's nuclear estate will be restricted to improving its current advanced designs—to the degree that it can—by means of simulations and laboratory tests alone while constantly preparing for the possibility of renewed field testing in the event that India's political leadership should change its mind and authorize the formal development and induction of advanced weapons into the country's nuclear inventory.

None of these activities, in any event, is likely to be carried out at an accelerated pace, since many of the delivery systems that will form the mainstay of the mature Indian nuclear arsenal are probably several years away from their initial field-operational capability. Nor is India likely to build its entire stockpile of nuclear weaponry right now—even if it had the requisite inventory of fissile material—because it makes more sense to hold out on completing this process in order to garner all the benefits that may be made available from further laboratory tests, other simulations, and possibly even access to external assistance in the future. The promise of marginal improvements in India's fission weapon design base; the continued efforts at further developing advanced designs, even if only through computer simulation and laboratory experiments; and the need to more clearly define the operational, safety, and design parameters of its future delivery vehicles, together with the patterns of deployment and the reconstitution procedures for contingency operations, will all combine to compel India to engage in little more than creeping weaponization for most of the coming decade. Figure 15 reproduces

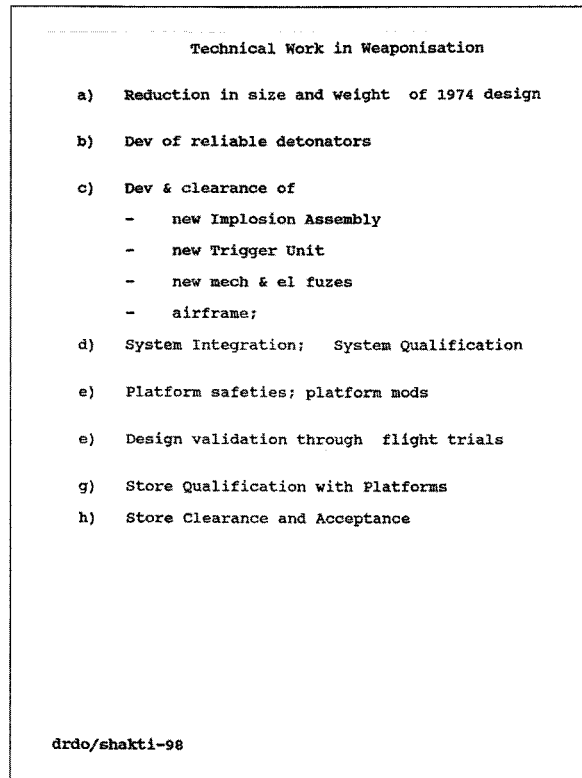


Figure 15—Creeping Weaponization: A DRDO View

the DRDO vision of what weaponization entails and, to that degree, suggests what is likely to occur in the years to come.<sup>157</sup>

During this time, Indian weapon designers are likely to concentrate on four specific tasks: (1) to further refine their existing fission designs based on the lessons learned from the May 1998 nuclear detonations and other subcritical tests and computer simulations that

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<sup>157</sup>This document comes through the courtesy of K. Santhanam, Chief Adviser (Technology), DRDO.

may be carried out in the future; (2) to establish that the delivery systems currently in India's possession and identified for the nuclear weapon delivery role can carry these refined designs without compromising safety or effectiveness; (3) to ensure that those nuclear designs selected to serve as the mainstay of India's arsenal in the near term are fully compatible with both the aircraft and the land- and sea-based missile delivery systems that will be acquired for nuclear operations over the next two decades; and (4) to pursue the development of advanced weapon designs, primarily boosted fission and thermonuclear capabilities, in the hope of reaping whatever benefits may be afforded by theoretical studies, laboratory experiments, and external assistance in the interim while waiting for the opportunity to return to renewed hot testing to conclusively validate these capabilities when the national leadership so demands. Until that point is reached, however, these four tasks will have to be performed in an environment that does not allow for any full-up tests of a complete, integrated nuclear weapon system.

### Delivery Systems

Possessing the requisite inventory of fissile materials and even a stockpile of nuclear weapons is insufficient for purposes of deterrence in the absence of adequate delivery systems that can carry these weapons to target. Although it is widely believed that a "classic nuclear triad force—with distinct land, sea and air components—will eventually be created" as part of India's efforts to further its "second strike potential,"<sup>158</sup> the fact remains that New Delhi is many years if not decades away from acquiring such a capability in full-fledged form. This fact notwithstanding, many Indian thinkers have argued that a strategic triad is indispensable because the country's reactive-use doctrine, combined with its relatively small nuclear weapon inventory, requires that it diversify its strategic assets in such a way as to maximize its survivability.<sup>159</sup> Not surprisingly, the "Draft Report of [the] National Security Advisory Board on Indian Nuclear Doctrine" affirmed that India's nuclear forces "will be based on a triad of aircraft, mobile land-based missiles and sea-based assets" in order

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<sup>158</sup>Sidhu, "India Sees Safety in Nuclear Triad and Second Strike Potential," p. 23.

<sup>159</sup>See, for example, Subrahmanyam, "A Credible Deterrent."

that they may be “effective, enduring, diverse, flexible, and responsive to the requirements . . . of credible minimum deterrence.”<sup>160</sup> The Indian Army’s Training Command (ARTRAC) is believed to have issued a similar recommendation even before the Advisory Board released its Draft Report; arguing that the Indian deterrent ought to consist at least initially of “two legs of the triad, comprising warplanes capable of carrying nuclear weapons like the Sukhoi-30, the Mirage 2000 and land-based nuclear-tipped missiles,”<sup>161</sup> the ARTRAC report concluded that submarine-based systems should eventually be integrated into the deterrent force because of their high survivability in the face of even dense nuclear attacks that may be mounted by an adversary.

Despite the controversy that these recommendations have provoked in the West, the Indian government appears to have accepted the overall logic they embody—at least in principle. Foreign Minister Jaswant Singh for example—attempting to strike a balance between the technical demands associated with system survivability and the diplomatic imperatives of calming the political atmospherics—did not conclusively reject the notion of a strategic triad but merely hinted at its prematurity. Addressing this issue directly, he noted that

It is a known fact that today India has nuclear-capable aircraft and mobile land-based nuclear-capable missiles. We have an R&D programme for a naval version of Prithvi that has been a part of the IGMDP [Integrated Guided Missile Development Program] launched in 1983. It is also a fact that many analysts, particularly in Western countries, consider nuclear missiles on submarines to be the most survivable nuclear asset in the scenarios that they have thought of—first strike, second strike, war and so on. Our approach is different. It is, therefore, premature to talk of an Indian “triad.” R&D programmes will certainly continue, aimed at enhancing survivability and thus, credibility, but decisions on production, deployment, and employment will be taken on the basis of factors that I have outlined earlier. In short, just as parity is not essential for deterrence, neither is a triad a prerequisite for credibility. Let me

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<sup>160</sup>“Draft Report of [the] National Security Advisory Board on Indian Nuclear Doctrine,” p. 3.

<sup>161</sup>Srinjoy Chowdhury, “Army Moots Nuclear Triad,” *The Statesman*, April 6, 1999.

suggest that you look at the Indian nuclear deterrent as a “triad” based on a different set of three dimensions—a deterrent that is minimum but credible because it is survivable and backed by effective civilian command and control to ensure retaliation.<sup>162</sup>

Irrespective of how the last sentence in this statement is evaluated, Singh’s other conclusions with respect to the triad appear fairly straightforward. The government of India already possesses various land-based deterrent systems, however incipient they may be, and will pursue a sea-based deterrence option as part of its ongoing R&D efforts simply as a hedge against strategic uncertainty. The decision to *actually* deploy nuclear weapons at sea, however, will not be made before the associated basing technologies are judged to be mature, and even then only if the threat environment India faces is seen to impose burdens of the sort that cannot be neutralized through land-based solutions alone. Indian security managers clearly recognize that sea-based nuclear capabilities hold the potential to radically transform the nature of their desired force-in-being, and while they hope to defer institutionalizing such solutions until it becomes truly necessary to do so, they also recognize that prudence requires them to investigate all such possibilities in the event that the strategic environment deteriorates to the point where they are left with no other satisfactory alternative. The current R&D efforts connected with the sea-based arm thus remain another example of how the Indian state is attempting to hedge its bets—but because of the powerful technologies involved, these efforts have given rise to the widespread yet mistaken belief that an Indian nuclear “triad” is all but imminent.<sup>163</sup>

A closer look at India’s capabilities, however, suggests that at the moment New Delhi possesses at best a monadic delivery force consisting of relatively short-range tactical strike aircraft like the Jaguar, Mirage 2000, Mig-27, and Su-30MK. None of these platforms has been designed for the conduct of all-weather strike operations, and consequently attack missions carried out in other than daylight conditions would require high pilot skill, ingenious mission planning, and favorable environmental factors for their success. More-

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<sup>162</sup>“India Not to Engage in a N-Arms Race: Jaswant.”

<sup>163</sup>For a good example of such claims, see Badri-Maharaj, “Nuclear India’s Status,” pp. 124–128, and Chengappa, *Weapons of Peace*, pp. 425–438.

over, if Indian press reports are to be believed, these delivery systems are still more notional than real: These platforms were originally acquired for conventional strike operations, and although they could by that very fact be reconfigured to carry nuclear weapons, several Indian press reports have claimed that no evidence exists that any airframes have yet been modified for the conduct of nuclear operations. This situation caused one Indian analyst to lament that

five months after India exploded five nuclear devices in May 1998, the Indian Air Force is nowhere near becoming nuclear capable. None of the IAF's approximately 17 strike squadrons have been earmarked for carrying out a nuclear strike. Nor has a training doctrine been formulated, or any of the aircraft been 'hardwired' for delivering nuclear bombs. . . .<sup>164</sup>

While India's tactical strike aircraft no doubt possess the potential to serve as nuclear delivery vehicles, this potential—which is inherent in almost all modern attack aircraft—must not be confused with the existence of a true delivery system. As one Indian source correctly noted, "In theory, we can carry a free fall nuclear bomb. But we have yet to earmark a squadron, an aircraft, or formulate a training doctrine for our pilots."<sup>165</sup>

By itself, this lack of public preparation should not be surprising in that New Delhi does not believe that transparent evidence of ready delivery capabilities is necessary for Indian security at present. This lack of transparency often leads many analysts to presume that no Indian nuclear delivery capabilities currently exist because it is usually—and incorrectly—assumed that India's claims to nuclear status must imply that the country is inexorably headed toward the development of a ready arsenal rather than simply a force-in-being.<sup>166</sup> Because the latter objective represents the real terminus of Indian policy at least in the policy-relevant future, it is almost certain that New Delhi has already configured a small contingent of nuclear-capable strike aircraft that, being dual-capable platforms, are de-

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<sup>164</sup>Kumar, "IAF Still Lacks N-Capability."

<sup>165</sup>Ibid.

<sup>166</sup>Rahul Bedi, "India's Nuclear Prowess Remains on Paper, Official Rhetoric," *Asian Age*, November 8, 2000.

ployed without any fanfare and in exactly the same fashion as all the other conventional strike aircraft in the Air Force's inventory.<sup>167</sup> Several Indian reports have in fact described how their Air Force began practicing nuclear toss-bombing techniques as early as 1988,<sup>168</sup> and hence it is not unreasonable to presume that India had at this point equipped a small contingent of conventional strike platforms for nuclear missions—especially after the 1990 crisis, when the government of India had to face up to Pakistan's transformation into a true nuclear power.<sup>169</sup> The formal claims to nuclear status advanced after the May 1998 tests imply that the process of further modifying air-breathing platforms for nuclear operations will only continue—but like everything else associated with the evolving deterrent, these developments will transpire secretly and at a much slower pace than unofficial Indian commentators would desire.

This fact—which is based on the accurate official judgment that India is unlikely to require a hyper-ready nuclear force in the near future—should give reason for pause when Indian claims about being a powerful nuclear weapon state are aired too carelessly. The desire to become a more capable nuclear weapon state in the future, however, will force New Delhi in the direction of developing a variety of delivery systems, although it is likely that for at least several more years (and perhaps a decade) India's strike capabilities will continue to reside primarily in its short-legged air-breathing platforms. This near-term focus on air-delivered weaponry stems directly from the fact that India's nuclear weapons today are most easily configured as gravity bombs to be carried by the various aircraft already in its possession (though these obviously would need specific modifications if they are to deliver nuclear weapons effectively). The kinds of aircraft chosen for this mission and the strengths and weaknesses of these platforms thus assume particular importance from the perspective of ensuring adequate deterrence.

While many aircraft in the Indian inventory could in theory be configured to carry a nuclear bomb, the platforms that become most

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<sup>167</sup>See the discussion in Perkovich, *India's Nuclear Bomb*, p. 295.

<sup>168</sup>Sawhney, "To Test or Not to Test: The Challenge for India's Nuclear Credibility," p. 32.

<sup>169</sup>See the discussion in Chengappa, *Weapons of Peace*, pp. 382–384.

relevant to the nuclear delivery mission are those possessing at least the following attributes: (1) they have adequate navigation capabilities and avionics that allow them both to reach their intended targets in a variety of weather conditions and to deliver their air-to-surface ordnance relatively accurately; (2) they have at least one ordnance station stressed to carry loads in excess of 1000 kg while also possessing sufficient ground clearances to allow for safe carriage of the weapon itself; (3) they are equipped with two engines, if for no other reason than to enhance survivability in combat; (4) they are capable of carrying both defensive weaponry and electronic countermeasures (ECM) equipment (in addition to their nuclear payloads) in order to ensure relatively safe transit to their payload release points; and (5) they possess the requisite operating range to bring them within reach of those targets designated by the national command authority.<sup>170</sup> When measured by such criteria, no aircraft currently in the Indian Air Force inventory is ideally suited to the nuclear delivery role, since the service never acquired a true theater bomber that possessed long range; was capable of carrying heavy payloads; was equipped with advanced navigation and avionics systems that allowed for all-weather operations, especially at low altitudes, without compromising aircraft safety, positional accuracy, and effective weapon delivery; and hosted sophisticated electronic penetration aids to increase platform survivability during both transit and attack. To be sure, many aircraft possessing all these attributes—for example, the Su-24 Fencer—existed in the Soviet arsenal, but the Indian Air Force, for a variety of political, financial, and doctrinal reasons, remained unequipped with any long-range strike platforms. As one respected commentator noted, “It is surprising that the [Su-24 Fencer] aircraft was never acquired by the Indian air force in the late 1980s. The aircraft could have easily struck targets throughout Pakistan and into invasion routes in Tibet and southern China, but the air force continued to soldier on with its remaining Canberras for this mission.”<sup>171</sup> The decision not to acquire a modern theater bomber

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<sup>170</sup>For a good analysis of the desirable characteristics of nuclear-capable strategic aircraft during the Cold War—in contrast to these characteristics in the South Asian context—see Alton H. Quanbeck and Archie L. Wood, *Modernizing the Strategic Bomber Force: Why and How* (Washington, D.C.: Brookings, 1976).

<sup>171</sup>Keith Jacobs, “Heavy Attack Aircraft,” *Indian Defence Review*, 13:1 (January–March 1998), p. 75.

like the Soviet Su-24 or the Western Tornado has therefore left India with only four tactical platforms that are relevant to the nuclear delivery mission: the Jaguar, the Mirage 2000, the Mig-27, and the Su-30MK. Yet none of these aircraft is ideal for the role, and of the quartet, perhaps only two—the Jaguar and the Mirage 2000—are currently capable of performing the nuclear strike mission with a reasonable chance of success.<sup>172</sup>

All four platforms must nonetheless be considered candidates for the nuclear strike mission simply because, at least in the first instance, each of them possesses at least one weapon station that is stressed to carry loads of 1000 kg or greater. If it is assumed that India's nuclear weapons weigh in at some 1000 kg (a not-unreasonable assumption for first-generation devices), it becomes obvious that the Mig-27 is the least capable platform in this regard, since it has only one centerline station (which also doubles as a wet station) capable of accommodating 1000-kg loads. The Su-30MK, in contrast, has at least two pylons capable of carrying 1000-kg-class loads, while the Jaguar and the Mirage 2000 each have two pylons capable of carrying 1134- and 1800-kg loads, respectively. On the basis of load-carrying capabilities alone, therefore, the Su-30MK, the Jaguar, and the Mirage 2000 turn out to be superior to the Mig-27. This superiority is further enhanced when the combat radius of each of these aircraft is considered. Calculating the combat radius of any aircraft is a challenging exercise because the problem admits to no unique solution.<sup>173</sup> The attainable combat radius on any mission depends on the aircraft's fuel capacity, the efficiency of its engine, the takeoff weight (including the weight and even the aerodynamic shape of its payload), the flight profile, atmospheric conditions such as air pressure, wind speed, and temperature, the expected amount of combat time, and the level of fuel reserves desired upon recovery. Attempting to

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<sup>172</sup>All data on aircraft in this section, except when specifically referenced, are derived from Paul Jackson (ed.), *Jane's All the World's Aircraft, 1998–99* (Coulson, UK: Jane's Information Group Ltd., 1998); Bill Gunston and Mike Spick, *Modern Air Combat* (New York: Crescent Books, 1983); and David Donald and Jon Lake (eds.), *Encyclopedia of World Military Aircraft*, Vols. I and II (Westport, CT: AIRtime Publishers, 1994).

<sup>173</sup>See the discussion in R. D. Shaver, *Range Enhancement Equations for Various Refueling Options*, N-1872-AF (Santa Monica: RAND, 1982), and in William Stanley and Gary Liberson, *Measuring Effects of Payload and Range Differences of Fighter Aircraft*, DB-102-AF (Santa Monica: RAND, 1993).

calculate the “true” combat radius of any aircraft can thus be seen to be a frustrating activity—and therefore the following analysis, which reproduces certain published data in order to support a rough comparison among the various aircraft identified above, must be treated as indicative rather than determinative of the mission radii that may actually be obtained in combat.

All comparisons of combat radii must also be sensitive to operational context. Since New Delhi is likely to authorize nuclear retaliatory missions only after absorbing an adversary's first strike—a response consistent with the Indian doctrine of no first use—the Indian Air Force will have to execute its reprisal operations in the face of fully alerted air defense systems maintained by the adversary. If nuclear use against Pakistan occurs at the later stages of a conventional conflict, it is likely that the Pakistani air defense net will be all but decimated by that point. Consequently, the Indian Air Force will enjoy full operational freedom of action where its nuclear missions are concerned.<sup>174</sup> The same conditions, however, are unlikely to obtain vis-à-vis China because irrespective of the scope or length of a conventional Sino-Indian conflict, Chinese air defense systems are likely to remain relatively unimpaired, especially along the approaches to key high-value targets. These targets, being far from the Himalayan border, will probably remain immune to any Suppression of Enemy Air Defense (SEAD) operations that may be conducted by the Indian Air Force. Consequently, nuclear operations against China will have to be conducted in the face of relatively coherent and responsive air defenses—in contrast to operations against Pakistan, which may take place in a more favorable combat environment.<sup>175</sup>

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<sup>174</sup>For a good discussion on Pakistan's air defense capabilities and the character of the Indian air threat, see Pushpinder Singh, Ravi Rikhye, and Peter Steinemann, *Fiza'ya* (New Delhi: Society for Aerospace Studies, 1991), pp. 95–112 and 152–186, and Ashley J. Tellis, “Hawkeyes for Pakistan: Rationale and Logic of the E-2C Request,” *Journal of South Asian and Middle Eastern Studies*, 10:1 (Fall 1986), pp. 36–66.

<sup>175</sup>The key variable that determines the ease with which Indian nuclear missions may be undertaken vis-à-vis Pakistan is the length and intensity of a conventional war prior to the point of nuclear use. A long and intense war would ensure that Pakistani air defenses are sufficiently attrited that even weak Indian penetrations would effectively go unhindered. In contrast, a short war—or even a conflict that resulted in early nuclear use—would impose great burdens on the Indian Air Force's ability to penetrate Pakistani airspace; although this objective could no doubt be achieved, the costs and complexity of assuring such penetration would increase greatly. This has less to do with the thinness of Islamabad's surface-to-air defenses than it does with Pak-

Since penetrating such alerted and perhaps unimpaired air defense systems is best done—all other things being equal—by flying lo-lo-lo profiles in order to exploit the limitations of terrestrial radars, the comparisons adduced below emphasize only this kind of flight regime—although whenever data are available, the aircraft in question are presumed to carry external fuel in addition to their nuclear, defensive weaponry, and ECM payloads. Assessing the capabilities of Indian aircraft in this flight regime alone is particularly appropriate because it allows for an assessment of aircraft quality in the most demanding nuclear operations imaginable—vis-à-vis China—without prejudicing their effectiveness against smaller and weaker adversaries such as Pakistan.<sup>176</sup>

When the operational radius of India's tactical aircraft is considered in the context of the lo-lo-lo flight regime, the superiority of the Mirage 2000 and the Jaguar over both the Mig-27 and the Su-30MK becomes amply evident. The Mig-27, which is a single-engine aircraft, is estimated to possess a combat radius of some 225 km, with 7 percent of its fuel held in reserve. If this radius is reduced by 20 percent to allow for the "dog legs" associated with operational routing, the radius of the Mig-27 drops to about 180 km. With external fuel, this figure could rise to as much as 430 km, but this configuration usually does not allow the aircraft to carry any external penetration aids or defensive weaponry. In effect, the aircraft thus would be "naked" except for its nuclear payload if such levels of operational reach were sought. The generally small operational radius of the Mig-27, usually classified as being in the basic 200- to 250-km class, is understandable, given that the aircraft was primarily designed as a simple platform for close air support/battlefield air interdiction

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istan's geophysical compactness, the readiness levels and relative quality of its air force, and the effectiveness of its Air Defense Command. Given these facts, it is not at all clear, for example, whether the Indian nuclear strike package that was assembled during the Kargil crisis—described in Chengappa, *Weapons of Peace*, p. 437ff—could actually have penetrated Pakistani airspace to successfully deliver its nuclear weapons if it had to prosecute such a singular mission in the absence of a generalized, high-intensity conventional air war.

<sup>176</sup>For more on this flight regime and on the challenges of penetration in general, see J. R. Walker, *Air-to-Ground Operations* (London: Brassey's, 1987), pp. 35–65.

(CAS/BAI) operations rather than as a sophisticated weapon carrier for deep penetration missions at the theater level.<sup>177</sup>

The Su-30MK, recently acquired by India, exhibits a larger operational radius than the Mig-27.<sup>178</sup> Although no detailed performance figures have been released for this model, the MK version is for all practical purposes an Su-27PU (which in turn was converted from an Su-27UB) at least as far as its fuel system is concerned. If the low-altitude radius of action of the Su-27 "Flanker B" is any indication, the Su-30MK may be presumed to have an operational radius not much greater than the 420 km attributed to the "Flanker B."<sup>179</sup> One Indian analyst has claimed that "the Su-30 has a strike range of 5000 km with in-flight refueling,"<sup>180</sup> while another more credible source has described it as possessing a low-altitude range of 1390 km—implying thereby that its mission radius would be almost 700 km.<sup>181</sup> Unfortunately, this estimate, which was presumably supplied by the Sukhoi Design Bureau, does not describe the flight profile used to generate these figures—and thus, as one respected aviation analyst cautioned, "all of the specifications . . . [relating to the Su-27] . . . should be treated with some caution [because] Sukhoi has released widely differing performance figures on different occasions (and even releases different dimensions for the same aircraft), while rarely specifying the loads carried for particular range or performance figures."<sup>182</sup> From all that is known in the West about this aircraft, such figures

<sup>177</sup>Donald and Lake (eds.), *Encyclopedia of World Military Aircraft*, Vol. II, pp. 304–305.

<sup>178</sup>The Su-30MKs the Indian Air Force currently possesses will eventually be replaced by the Su-30MKI, which is expected to feature different design characteristics, advanced avionics, and possibly greater endurance. Since the Su-30MKI does not currently exist in its final configuration, the discussion here refers primarily to the Su-30MK model unless specified otherwise. Despite extravagant claims made by both Russia and India, the eventual specifications of the Su-30MKI remain uncertain, as do the timetables for delivery. See Fred Weir, "Can Russia Deliver on Arms Sales?" *Christian Science Monitor*, November 29, 2000.

<sup>179</sup>Jon Lake, "Sukhoi Su-27 Variant Briefing, Part 1," *World Air Power Journal*, 28 (Spring 1997), pp. 117–119.

<sup>180</sup>Rahul Bedi, "Tests Give Impetus to Agni Missile," *Jane's Defence Weekly*, May 20, 1998.

<sup>181</sup>"From Su-27 to Su-37: The Plane with Many Masks," *Vayu 2000 Aerospace Review*, III/1997, pp. 43–45.

<sup>182</sup>Lake, "Sukhoi Su-27 Variant Briefing, Part 1," p. 119.

appear to represent the high end of the aircraft's performance capabilities in the low-altitude regime. The operational radius of the MK in a consistently lo-lo-lo flight regime is likely to be closer to 500 than to 700 km, but even if both figures are accepted as a range for purposes of analysis, the effective radius drops down to roughly 400–560 km when the 20 percent margin for dog legs is factored into the calculation.<sup>183</sup>

This relatively low figure for the twin-engine Su-30MK in the lo-lo-lo profile might appear surprising at first sight given the aircraft's general reputation for endurance and for its ability to operate at extended distances. The Su-30MK does in fact possess all these attributes—but mainly when operating at medium to high altitudes and when employed in air superiority as opposed to surface strike missions. Overlooking this fact, some Indian analysts have mistakenly presumed that this aircraft embodies truly deep-penetration capabilities of the sort that bequeath to it “the range to cover most of China” and “deliver a nuclear payload deep into Chin[ese territory].”<sup>184</sup> Such conclusions appear to be justified on the presumption that the Su-30MK is in fact capable of attaining operational radii exceeding 1250–1500 km in the context of antisurface missions,<sup>185</sup> but these performance figures are simply illusory if a lo-lo-lo flight profile is desired. This is because the twin engines of the Su-30 rapidly lose efficiency when the aircraft operates at low altitudes, and while the avionics of the MK version have been modified for the air-to-surface role (while still retaining their original proficiency in the air-to-air mission), its airframe and engines are simply not optimized for long range while employed in the nap-of-the-earth flight regime.<sup>186</sup>

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<sup>183</sup>*Ibid.* Lake notes that the Su-27 is capable of a 420-km low-altitude radius of action rising to 1090 km at high altitude.

<sup>184</sup>Sidhu, “India Sees Safety in Nuclear Triad and Second Strike Potential,” p. 24.

<sup>185</sup>Bajpai, “The Fallacy of an Indian Deterrent,” p. 164.

<sup>186</sup>As Jon Lake notes, in designing the Su-27 aircraft, “Sukhoi worked towards meeting a low-level radius of action requirement of 500 km (310 miles) (inferring a low-level range of at least 1200–1400 km/745–870 miles) and a high-level radius of 1700 km (1050 miles) (with a range of 4000 km/2485 miles).” Lake, “Sukhoi Su-27 Variant Briefing, Part 1,” p. 103.

To be sure, the range limitations of the Su-30MK can be circumvented by air-to-air refueling, but because such operations cannot be carried out over enemy territory, air refueling can only marginally increase the aircraft's operational radius in the lo-lo-lo strike mission. In the specific operational circumstances India faces—where the aircraft's launch bases are generally close to the international border—the ability to carry additional fuel in external tanks would have been far more useful for purposes of extending the Su-30MK's operating radius. The original Soviet design, however, settled for air-to-air refueling rather than external fuel tanks as a means of extending its range and endurance. This solution made perfect sense in the context of Soviet needs, which centered primarily on sustaining extended air patrols over its vast remote borders. In such operations, air-to-air refueling conducted in domestic airspace provided an apt means of increasing mission radius and loiter time.<sup>187</sup> Since deep penetration into hostile territory was not at issue—as would be the case if New Delhi employed its Su-30MKs for nuclear strikes—the solution embodied by air-to-air refueling is less than perfect where India's operational needs are concerned. When India acquires dedicated airborne tankers (as it will over the next decade), the ability to refuel its Su-30MKs will certainly bring many advantages, but these will be realized mostly in terms of increased flexibility rather than in terms of increased range. The ability to engage in air-to-air refueling will allow India's Su-30s to be based deep in the rear, where they are likely to be less vulnerable to attacks, especially those mounted by Pakistan. From such rearward bases, the Su-30s can stage out to forward locations as required or even embark on some kinds of attack operations, refueling en route in Indian airspace whenever necessary. This solution, however, provides only minimal advantages vis-à-vis China, because the distances from the Indian border to the most attractive Chinese targets are so vast that even multiple air-to-air refuelings over Indian airspace would add little to the Su-30's operational radius when employed in a lo-lo-lo attack regime.<sup>188</sup>

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<sup>187</sup>“Sukhoi Su-27,” in Paul Jackson (ed.), *Jane's All the World's Aircraft, 1998–99* (Coulson, UK: Jane's Information Group Ltd., 1998), pp. 422–425.

<sup>188</sup>The ability to refuel the Su-30MKs would be most valuable, however, in defensive counterair operations along the border or where long-endurance combat air patrol (CAP) is required. Where nuclear strike missions vis-à-vis China are concerned, however, the operational radius of the aircraft can obviously be extended by altering its flight profile—for example, by undertaking some legs of the mission at high altitude

On balance, then, neither the Mig-27 nor the Su-30 is likely to be chosen as India's primary nuclear delivery platform. While both aircraft have pylons capable of carrying stores of some 1000 kg, the platforms themselves are unfortunately too limited in range to be able to carry such payloads to the desired distances. This is certainly true where Indian nuclear operations against China are concerned, but it may also be true against Pakistan in some exceptional circumstances. The Mig-27 in this context also has the additional disadvantage of being payload limited and, unlike the Su-30, carries little defensive armament and relatively poor penetration aids. The advantages of the Su-30 are clearest here: Being a more modern airplane, it is equipped with newer avionics (including many French and Israeli subsystems in the MKI). These include a new Russian multimode radar, guidance systems for TV-command weapons, anti-radiation missiles, assorted air-to-surface weaponry, and independent laser designation capabilities in addition to electronic support measure (ESM) systems and various types of within-visual-range and beyond-visual-range air-to-air missilery. Yet, as impressive as these capabilities may be, they are nonetheless most useful for short-range conventional strikes rather than for long-range nuclear delivery missions.<sup>189</sup>

Among the systems most valuable for the latter task would be a terrain-following radar that allows the aircraft to fly true nap-of-the-earth flight profiles, especially during ingress; an integrated forward-looking infrared capability; active ECM pods; and, of course, the ability to accept external fuel tanks of various sizes. The Russians have developed two Su-27 variants—the Su-34 and the Su-35<sup>190</sup>—with just such attributes, but the MKs currently being inducted into the Indian Air Force are not equipped with these or any of the other capabilities integral to the newest generation of Russian deep penetrators. Only

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either en route to the target or during the return home. The ability to sustain such profiles, however, would be determined by the character of the air defense systems in the Chinese southwest during a conflict. In general, planning for such profiles could levy increased risk to the aircraft, and given the vast size of the Chinese landmass, they may not provide substantially increased reach with respect to the critical targets presumably of interest to India.

<sup>189</sup>For details, see "Sukhoi Su-30M," in Paul Jackson (ed.), *Jane's All the World's Aircraft, 1998-99* (Coulsdon, UK: Jane's Information Group Ltd., 1998), p. 428.

<sup>190</sup>See Lake, "Sukhoi Su-27 Variant Briefing, Part 1," pp. 129-135.

time will tell whether the late-series MKI airframes will be equipped with some of these new capabilities, but at the moment all the evidence suggests that despite its acquisition of some new types of Russian air-to-surface weapons, India intends to use its early Su-30MKs primarily for air superiority rather than for deep penetration missions.<sup>191</sup> The aircraft's secondary air-to-surface attack capabilities will no doubt contribute to making the MK a useful conventional attack platform, particularly in support of the offensive counterair doctrine the Indian Air Force plans to employ against Pakistan<sup>192</sup>—and by virtue of that fact, India is likely to treat the aircraft as a candidate system that can be configured for nuclear delivery *in extremis*. But for all its virtues and despite some Indian claims to the contrary,<sup>193</sup> the Su-30MKI is unlikely to become the primary nuclear delivery vehicle of the Indian Air Force in the near future.

In contrast to the Russian airplanes, the Mirage 2000 and the Jaguar seem better suited to the nuclear delivery role. Both aircraft have operational radii of more than 900 km in the lo-lo-lo strike regime when equipped with external tanks. Allowing for dog legs, this figure drops to some 740 km, although the actual combat radius will of course vary depending on the flight profiles flown and the combination of fuel tanks and nuclear ordnance carried by any given airplane. The Mirage 2000 in particular would benefit where both range and mission flexibility are concerned because of its ability to engage in air-to-air refueling. Both aircraft have at least three hard points capable of carrying loads in excess of 1000 kg, and both have the requisite ground clearances to carry nuclear weapons of the sort India is thought to possess. The Jaguar, some Indian assertions notwithstanding, is in fact particularly well suited as far as ground

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<sup>191</sup>This judgment is based on the air defense livery of the new aircraft; the fact that the squadron (Squadron Number 24) reequipping with the Su-30s earlier flew the Mig-21 *bis* in the air defense role; and the fact that the training regime at least of the early Su-30s already in Indian Air Force employ has emphasized air defense operations rather than long-range ground attack.

<sup>192</sup>For details about the Indian Air Force's evolving offensive counterair doctrine vis-à-vis Pakistan, see Ashley J. Tellis, "The Air Balance in the Indian Subcontinent: Trends, Constants, Contexts," *Defense Analysis*, 2:4 (Winter 1986), pp. 263–289, and Pravin Sawhney, "India's First Airpower Doctrine Takes Shape: An Aging Air Force Looks to the Future," *Jane's International Defence Review*, 30:6 (1997), pp. 33–38.

<sup>193</sup>See N. K. Pant, "SU-30s: Strategic Take-off into Next Century," available at <http://www.ipcs.org/issues/articles/286-mi-pant.html>.

clearances are concerned, and one analysis has noted how the undercarriage legs “sit the aircraft very much higher on the ground than one expects of aircraft of this size.”<sup>194</sup> Both aircraft clearly are excellent platforms for the surface attack mission as well. The Jaguar was designed from the ground up as a dedicated tactical strike aircraft, and its airframe, engines, and flight controls were optimized for high performance at low altitudes. The Mirage 2000, in contrast, is a true multirole fighter that, although initially designed for proficiency in the air combat mission, can effectively prosecute the surface attack mission because its fly-by-wire controls and small canard-type foreplanes on the air intake trunks allow it to secure all the advantages of a delta planform—high fuel storage, low drag, increased maneuverability, fewer control surfaces, and decreased radar detectability—while minimizing most of the instabilities that arise when the aircraft carries a large quantity of external stores during low-altitude missions.<sup>195</sup>

While both the Jaguar and the Mirage 2000 thus share one characteristic—their ability to carry out effective low-level attacks with relatively heavy payloads—the two airplanes differ in many other respects. The Jaguar, for example, is an older platform, but with two engines it is rugged and has an operational reliability that makes it particularly useful for high-value missions like nuclear delivery. Unfortunately, it has only modest defensive weaponry, and although it possesses both active and passive ECM suites, these capabilities are of uncertain quality. Its most critical weakness, however, lies in both the lack of a terrain-following radar, which limits its ability to fly true ground-hugging profiles, and the lack of integrated night and adverse-weather capabilities. If the aircraft does reach its target unmolested and the environmental circumstances permit adequate target sighting, the Display Attack and Ranging Inertial Navigation (DARIN) nav-attack system provides excellent weapon release solutions for accurate delivery. However, its lack of a terrain-following radar, night and adverse-weather capabilities, adequate defensive weaponry, and sophisticated ECM capabilities implies that any nuclear delivery mission the Jaguar undertakes would require a signifi-

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<sup>194</sup>Arthur Reed, *Sepecat Jaguar* (London: Ian Allan, 1982), p. 101.

<sup>195</sup>For details, see Paul A. Jackson, *Mirage* (Shepperton, UK: Ian Allan, 1985), pp. 99–115.

cant strike package with several other aircraft flying escort and sweep missions to allow the nuclear platform unimpeded ingress and safe delivery of its ordnance.<sup>196</sup>

Despite its limitation of being a single-engine aircraft, the Mirage 2000 has several advantages here. It has a formidable suite of defensive weaponry, excellent ESM/ECM systems, and a superior multi-mode radar that provides high performance in both air-to-air and air-to-surface regimes simultaneously. If equipped with the Litening II pod, the aircraft would also acquire a formidable night and adverse-weather deep penetration capability that promises to be far more effective than the Litening laser designation pods currently in service with the Indian Air Force.<sup>197</sup> Although early aircraft acquired by New Delhi were usually seen in the livery associated with air-to-air combat, India has begun to experiment with Mirage 2000s in the surface attack role. It has been reported, for example, that some platforms have been equipped with the French Antilope 5 terrain-following radar, twin inertial navigation systems, and reinforced radomes, thus optimizing them for accurate nap-of-the-earth penetration and attack.<sup>198</sup> If so equipped, the Mirage 2000 would be an excellent platform for nuclear delivery missions carried out independently or with very small strike packages. So long as the con-

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<sup>196</sup>India's newest Jaguars are expected to be retrofitted with an EI-Op head-up display (HUD) with an up-front camera, a Sextant MFD 66 active-matrix moving-map liquid crystal display, digital terrain-map generator, a multichannel digital video color recorder, a ring-laser gyro-based inertial navigation system (INS-RLG) with GPS, a multimode mission computer, an ELTA-built airborne self-protection jammer, an indigenous radar warning receiver (RWR), and wiring for carrying the Litening laser designation pod. The Sextant is also expected to upgrade the autopilot system. See "SPECAT/HAL Jaguar," available at <http://www.bharat-rakshak.com/IAF/Info/Specs-Combat.html#SEPECAT%20Jaguar>. If these modifications are in fact incorporated, many of the aircraft's current limitations will disappear and the Jaguar could become a critical component of India's nuclear delivery force. Raj Chengappa claims, however, that the Indian Air Force examined and ultimately rejected the Jaguar as India's principal delivery platform, allegedly because the aircraft lacked the clearance to carry the country's gravity bombs. See Chengappa, *Weapons of Peace*, p. 327ff. If this information is accurate, then at least the aeroshell of India's fission weapon may have to be redesigned if the new capabilities of the aircraft are to be exploited.

<sup>197</sup>The superiority of the Litening II over both the Litening I and other systems like LANTIRN is described in William B. Scott, "New Targeting Pods Deliver 'Litening Strikes,'" *Aviation Week & Space Technology*, August 21, 2000, pp. 56–60.

<sup>198</sup>"Dassault Mirage 2000," in Paul Jackson (ed.), *Jane's All the World's Aircraft, 1998–99* (Coulsdon, UK: Jane's Information Group Ltd., 1998), p. 104.

straints imposed by a single engine are accepted—presumably because of the high quality of the M53-P2 engine—the aircraft’s superior mission radius, avionics, defensive weaponry, and counter-measure systems, would make it the best platform India currently has (and it has most likely already modified) for the nuclear mission.<sup>199</sup>

This conclusion does not in any way undercut the broader judgment that India’s current delivery vehicles, which consist principally of tactical strike aircraft, are still compromised, since these vehicles were neither designed nor acquired principally for delivering nuclear weapons at long ranges from their home bases. Even the Mirage 2000, which is the most sophisticated of the two platforms capable of decent mission radii in the lo-lo-lo strike regime, has only a single engine and may not possess the integrated terrain-following and night-vision systems that could become essential for safe penetration and effective egress. Obviously, such capabilities may or may not be relevant depending on the operational and physical environments surrounding India’s decision to use its nuclear weapons, but they do imply that each of India’s candidate platforms has some handicap that would prevent it from functioning effectively as a nuclear delivery system under the widest possible range of operating conditions. As the analysis above suggests, there is at present no single aircraft that offers all the following attributes: twin engines; integrated terrain-following radars and/or infrared navigation and targeting systems allowing for “blind” night and all-weather attack operations; single-point load-carrying capabilities in excess of 1000 kg with sufficient ground clearance; adequate defensive weaponry and sophisticated ECM equipment; and long mission radii that allow for deep theater reach. Because of this, India will be forced to make do with the aircraft inventory it possesses, at least in the near term, if it is serious about developing its nuclear deterrent even as a force-in-being.

**What Will India Do?** Over the next few years, India will most likely continue to do what it has probably done since the late 1980s to early 1990s: incrementally improve one or two of the four candidate systems examined above—probably the Mirage 2000 (with the Jaguar as backup)—in order to prepare a small number of aircraft for the nu-

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<sup>199</sup>Chengappa, *Weapons of Peace*, pp. 382–384.

clear delivery mission while continuing to marginally expand the size of its inventory to maintain the minimum force size necessary in the face of peacetime attrition. At the very least, this continuing process of preparation will include modifying one or more stressed hard points on the fuselage to secure the nuclear weapon physically; adapting the cockpit controls to allow for remote arming of the weapon by the pilot at some point en route to the target; modifying the software controlling the ranging and weapons-aiming computers to enable the safe and effective release of a nuclear weapon of specified weight and yield; and integrating better navigation, targeting, ECM systems, and air defense weapons to increase the platform's survivability and penetrativity. The process of selecting a given aircraft and modifying the umbilicals and interfaces appropriately for the nuclear mission has traditionally been a DRDO task that has been and will continue to be undertaken in cooperation with the DAE and a small number of individuals associated with the Air Force.<sup>200</sup> This cooperative endeavor will continue covertly and without fanfare so long as the relevant nuclear-capable airframes remain in active service; there is some likelihood that India's nuclear weapons will change in physical configuration; and both the DRDO and the DAE continue to share custodial responsibilities over the nuclear warheads themselves. This ongoing effort at configuring and maintaining India's tactical strike aircraft for nuclear missions, like all the other activities connected with India's nuclear weapon program, will thus remain both low-key and highly secretive. Even the *institutional* participation of the Air Force in this endeavor has thus far been and will continue to be kept to a minimum: A few senior Air Force commanders, including the Chief of Air Staff, the Deputy/Assistant Chief of Staff (Operations), and possibly one or more AOCs-in-C with small groups of selected staff will continue their task of selecting certain aircraft, squadrons, pilots, and maintenance crews for "conversion," training, and operations in the nuclear role, with the rest of the force

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<sup>200</sup>For details on how this process was carried out historically, and especially the crucial roles of the Aircraft System and Testing Establishment (ASTE) and the Armament Research and Development Establishment (ARDE), see Chengappa, *Weapons of Peace*, pp. 326ff, 359ff, and 382ff.

deliberately excluded from information about, and participation in, this effort.<sup>201</sup>

Irrespective of how this process unfolds, it is unlikely that India will announce any details pertaining to these activities; nor is it likely to identify the type of aircraft or the units selected for this mission. The relatively small size of the Indian deterrent—even when the force-in-being is finally completed—will make Indian policymakers acutely sensitive to the need for complete opacity, since the survival of their modest air-breathing capabilities hinges on the degree to which India's adversaries remain uncertain about the types and numbers of aircraft constituting its nuclear-capable force; the exact location of their deployment in real time; and the possibility that additional airframes might be held in reserve and perhaps distributed in or periodically rotated to locations other than their normal bases. The uncertainty arising from this basic lack of information will only be supplemented by deliberate efforts at deception and denial, since New Delhi's primary objective in every instance will be to deny its potential adversaries—Pakistan and China—any information that might fuel their temptation to unleash a nuclear attack aimed at disarming India, especially in the context of a crisis.<sup>202</sup>

While India is thus likely to continue to maintain an air-breathing delivery force under conditions of great secrecy, it will probably undertake several initiatives over the next decade in order to sustain the ability of its aircraft to service the nuclear mission. First, India is

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<sup>201</sup>The degree of compartmentation within a given military service in India is exemplary and can be explained not so much by the hierarchic structures command but rather by the patterns of institutional culture that obtain within the Indian military. The preparations for the Indian nuclear tests in May 1998 are a good example of how such compartmentation has worked in practice: The Army's engineer units, for example, which helped prepare the Pokhran test sites for the detonations, received their orders and completed their tasks unbeknownst to both other formations and all but a narrow and short chain of command. This compartmentation is unlikely to change even if the new unified command charged with overseeing India's strategic assets finally materializes.

<sup>202</sup>The "Draft Report of [the] National Security Advisory Board on Indian Nuclear Doctrine" affirms that "survivability of the forces will be enhanced by a combination of multiple redundant systems, mobility, dispersion and deception." See "Draft Report of [the] National Security Advisory Board on Indian Nuclear Doctrine," p. 3.

likely to contemplate selective upgrades to the aircraft it chooses for the nuclear delivery role. The Jaguar, the Mirage 2000, and the Su-30MK, for example, would profit immensely from the integration into their existing avionics systems of terrain-following radar, GPS navigation and night-vision flight and targeting equipment, and integrated countermeasure capabilities (including active jamming), and the Su-30MK would further benefit from being plumbed for the carriage of external fuel tanks of various sizes. These technologies, taken together, would improve both penetrativity and range—the principal challenges facing any aircraft delivery system—and consequently are likely to be acquired in the years ahead.<sup>203</sup> Associated with this effort although distinct from it would be the acquisition of a small number of specialized supporting aircraft. The Indian Air Force has already established a requirement for six to eight tanker aircraft that will probably be configured around the IL-76 airframe.<sup>204</sup> The service has also invested heavily in electronic warfare programs in recent years, and it is possible that a few older long-range aircraft such as the venerable Canberra might be converted to serve as specialized jamming platforms.<sup>205</sup> These platforms are likely to be complemented by the creation of some kind of SEAD capability, but whether this will consist of dedicated aircraft for the mission or simply the equipping of some modified attack aircraft with antiradiation missiles is still unclear.<sup>206</sup> These capabilities, acquired piecemeal from France, Russia, and Israel, are likely to surface publicly sometime over the next decade but may appear sooner if the air defense systems maintained by India's principal adversaries are seen as undergoing dramatic qualitative changes in the interim.

Second, India faces critical decisions with regard to the number of aircraft it seeks to modify for the nuclear delivery role. There are essentially two paradigms here, and depending on which is chosen, the

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<sup>203</sup>See, for example, "IAF Jaguars to Get New Mission Computers," *Defence Systems Daily*, August 2, 2000.

<sup>204</sup>"Govt. to Purchase Tanker Planes," *The Hindu*, April 26, 2000.

<sup>205</sup>Rupak Chattopadhyay, "The Indian Air Force: Flying into the 21st Century," *Bharat Rakshak Monitor*, 3:1 (July–August 2000), available at <http://www.bharat-rakshak.com/MONITOR/ISSUE3-1/rupak.html>.

<sup>206</sup>See *ibid.* and Sanjay Badri-Maharaj, "World's Fourth Largest Air Force," *Indian Defence Review*, 14:4 (October–December 1999), pp. 113–123, for more details about these programs.

deployment and operating regimen of the entire nuclear-capable force would be modified. The first paradigm consists of configuring only a few aircraft from a given class for the nuclear mission and, in effect, treating these aircraft as “precious” strategic assets—thereby withholding them from conventional operations, isolating them from the rest of the force, and securing them in special sanctuaries. Alternatively, these specially configured aircraft, however few in number, could be commingled with conventional airframes and treated as just another strike platform for purposes of disguising their true identity. Opting for such a paradigm—which essentially represents the continuation of India’s present posture—would be relatively inexpensive, since only a few aircraft would be reconfigured in this way. The loss of any such modified airframe however, even as a product of normal attrition, would result in a significant diminution of strike capability.

The second paradigm consequently takes exactly the opposite tack by requiring that an entire class of aircraft selected for the nuclear role be configured to carry both conventional and nuclear ordnance interchangeably. These aircraft would then be treated like any conventional instrument of combat. They would certainly be secured, as are all lethal military assets, but the loss of a few platforms either in training or through routine attrition would in no way diminish the retaliatory capability of the deterrent, because the wasted airframes could be readily replaced by any other aircraft of the class, all of which would be equally capable of executing the nuclear mission. While this paradigm allows for tremendous operational flexibility given that no special demands would be made on the movement or the deployment of a few critical airframes, it also entails relatively high costs because it would require that all aircraft of a particular type be modified for what is ordinarily a low-probability mission.

There are, of course, many variants on each of these two models, but depending on how close each variant is to one of the two polar cases described above, each involves different costs and provides different benefits. It is unclear at this point which paradigm India will opt for over the long term, but in the near future New Delhi will most likely continue with some variant of the first model—a paradigm that should satisfy India so long as Pakistan remains its most pressing nuclear threat. As the Indian nuclear deterrent distends over time to meet various contingencies involving China, however, some variant

of the second paradigm might be operationalized, particularly if Beijing becomes an active and more powerful adversary than is currently the case and if the Indian defense budget increases substantially in real terms during this and the next decade. In the meantime, India will concentrate simply on maintaining the requisite number of nuclear delivery systems. It is therefore not surprising to find that New Delhi has focused considerable attention on procuring both new two-seat Jaguars<sup>207</sup> and additional Mirage 2000s, the latter clearly intended to augment its stable of specialized nuclear delivery platforms.<sup>208</sup>

Third, India is likely to slowly increase its investments in infrastructure to support the retaliatory capabilities its air-breathing systems embody. Since the Indian nuclear deterrent will be a rather small force even when it is finally mature, and because this force is doctrinally intended to service a retaliatory role alone, New Delhi will likely pay great heed to its combat aviation infrastructure in order to ensure the survivability of its nuclear aircraft and their ability to retaliate even after absorbing a nuclear attack. Simple antidotes like securing aircraft in hardened bunkers—a regimen already followed—could be supplemented by increasingly complex organizational solutions as the number of nuclear weapons, the number and accuracy of the delivery systems, and the yield of the weapons that can be carried to Indian targets increase over time. Since the peacetime locations of all Indian air bases are well known, as are the identities of the aircraft and squadrons deployed at these bases, future organizational remedies to the twin problems of increasing survivability and ensuring adequate retaliatory capacity could consist of developing more dispersal airfields; operationalizing idiosyncratic aircraft dispersal rou-

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<sup>207</sup>Hirak Choudhuri, "Nuclear-Equipped Jaguars for IAF?" *The Statesman*, February 19, 1999.

<sup>208</sup>Rahul Bedi, "India Seeks Mirage 2000 Nuclear Squadron," *Asian Age*, August 29, 1999. India has also announced that it will acquire four Tupolev-22M3 "Backfire" long-range bombers on lease from Russia. If and when acquired, these aircraft will constitute the first dedicated theater bombers in Indian military service. The range and sophistication of these aircraft would allow for complete coverage of both Pakistani and Chinese targets, but if Indian plans are to be believed, these aircraft are intended primarily for maritime interdiction and naval strike warfare rather than for the transcontinental nuclear attack mission. Whether India will maintain these aircraft as emergency operations-capable nuclear platforms remains to be seen. See Rezaul H. Laskar, "Navy to Get 4 Nuclear-Capable Bombers," *Asian Age*, February 14, 2000.

tines, particularly in a crisis; and preparing civilian and ancillary airfields with upgraded infrastructure, navigational equipment, and critical storage facilities to support dispersal, staging, or strike operations in an emergency.<sup>209</sup> The objective of all these solutions would be to complicate the nuclear targeting strategy that an adversary may develop over time while simultaneously attempting to ensure that certain critical facilities—i.e., those capable of supporting retaliatory strikes and lying within range of India’s preferred targets—would survive any initial nuclear blows that might be mounted against New Delhi’s force-in-being. Obviously, the need for such complex solutions is minimal today given Pakistan’s relatively small nuclear arsenal and China’s attention on areas other than its southwestern frontier. Should either of these two factors change significantly, however—as well they might over the next decade and beyond—the necessity for investing in more complex solutions to the problems of survivability would become readily apparent.<sup>210</sup>

Fourth and finally, India will continue to develop a range of delivery tactics that will be slowly codified, practiced, and disseminated throughout the nuclear-capable squadrons of the Indian Air Force. The need to systematize preparations for nuclear delivery missions simply did not exist so long as India’s nuclear posture consisted of “keeping the option open.” However, India’s newfound desire to lay claim to being a nuclear weapon power has provided a structural opportunity for small planning arms deep inside Indian Air Force headquarters to contemplate a doctrine—in the strict Western sense of the term—relating to the conduct of nuclear missions.<sup>211</sup> Yet this

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<sup>209</sup>If Chengappa is correct, these efforts have been under way since the early 1990s. See Chengappa, *Weapons of Peace*, pp. 355ff and 391ff.

<sup>210</sup>For an Indian Air Force viewpoint on this question, see B. D. Jayal, “India 2020: A Perspective on Air Power,” *Indian Defence Review*, 13:4 (October–December 1998), pp. 19–25.

<sup>211</sup>In 1997, the Indian Air Force promulgated its first airpower doctrine that, because of its timing, focused entirely on conventional air operations. For details, see Sawhney, “India’s First Airpower Doctrine Takes Shape: An Aging Air Force Looks to the Future.” This effort has now extended to include planning for nuclear operations, but it is safe to say that, unlike the case of conventional planning, no document on this subject is likely to be released by the Indian Air Force any time soon. There have already been reports, however, that the Indian Air Force has finalized a nuclear doctrine in support of the country’s larger deterrence strategy. One source has quoted the Indian Chief of Air Staff, Air Chief Marshal A. Y. Tipnis, as stating that “India is committed to a no-first-use policy for nuclear weapons. The only option then is to develop

doctrine is likely to evolve in a uniquely Indian fashion. Inasmuch as New Delhi's nuclear weapons are primarily political tools, for example, and as such are intended primarily to reassure the national leadership and deter their use by an adversary in a crisis, it is quite possible that the Indian Air Force planners and pilots tasked with developing such a doctrine may never be handed a real, complete Indian nuclear weapon! In any case, it is certainly unlikely that these "operators" would know much about the size, disposition, or locations of the nuclear stockpile writ large; instead, they are most likely to be either given dummy weapons or informed mainly about those critical weapon parameters that are necessary for the development of a viable doctrine, such as the shape, weight, and yield of the weapons and the general set of targets against which they are to be used.<sup>212</sup> Armed with this information and probably with a mockup of the weapon to validate aerodynamic effects, the Indian Air Force will be tasked with developing a nuclear delivery doctrine that, quite logically, is likely to be based on the offensive counterair doctrines already developed in the context of conventional warfare. Obviously, the precise maneuvering profiles of a nuclear delivery platform will vary greatly from those used in the discharge of conventional ordnance, but most other variables—such as the desired size and composition of the strike package, the route-planning factors, and the allocation of nontactical assets required for the success of the mission—would roughly approximate those already planned for India's conventional operations. Developing a doctrine for the delivery of nuclear weapons would be critical to the success of India's desired minimum deterrent, and hence it should not be surprising to find small groups of service planners tasked with developing, refining, and codifying this doctrine in preparation for what may ultimately be unit- and formation-size combat practice in the years ahead.<sup>213</sup>

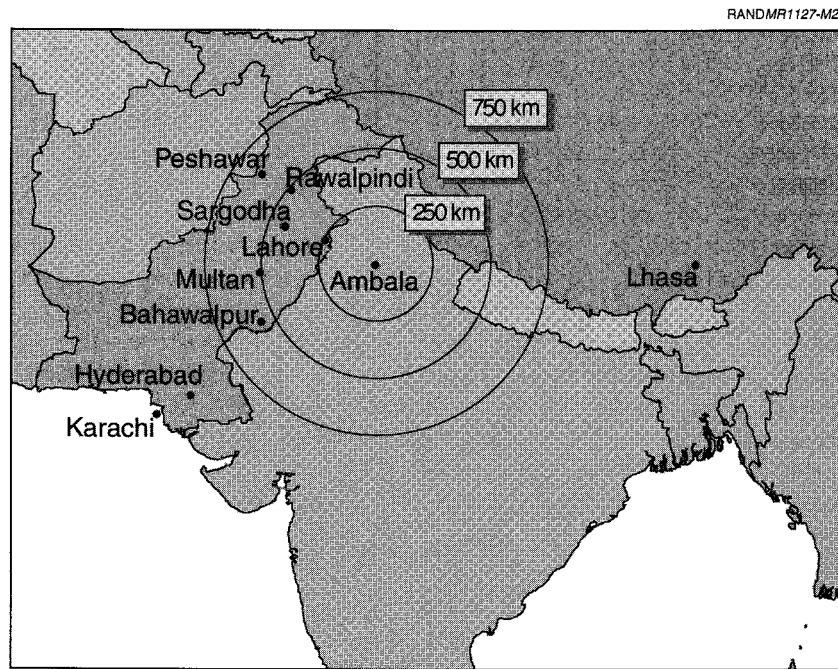
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a second strike capability. . . . How we will react, how we will operate (in the face of a nuclear threat or attack), that has been decided." See "IAF Draws Up Nuclear Strategy," *The Times of India*, October 8, 2000.

<sup>212</sup>For the historical record on this issue, the best source remains the descriptions at various points in Chengappa, *Weapons of Peace*.

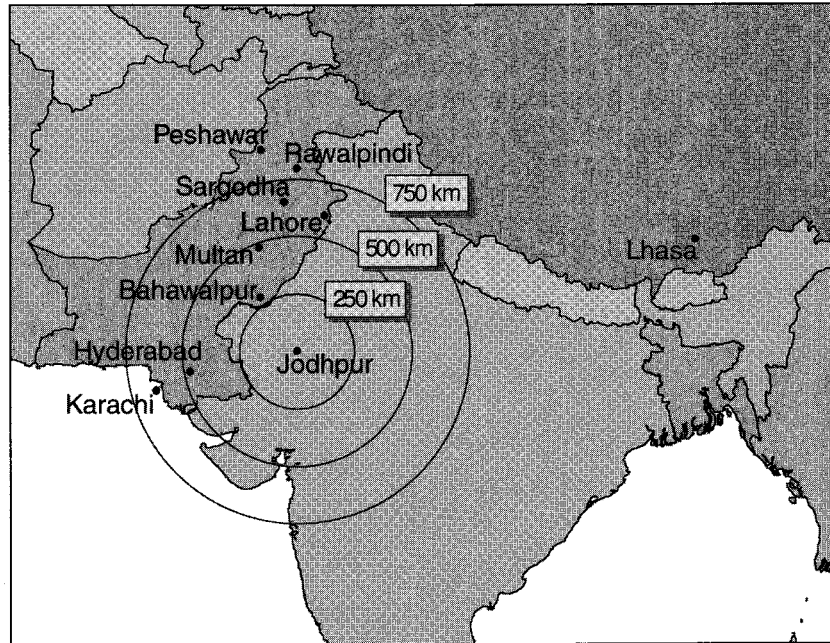
<sup>213</sup>The Air Force traditionally sought full access and integration with the country's nuclear R&D efforts but according to the best histories of the Indian nuclear program was not granted such access. See Perkovich, *India's Nuclear Bomb*, pp. 296–297, and Chengappa, *Weapons of Peace*, p. 327. The current Air Force position on this issue is

Even when these initiatives are completed over the next decade, however, India's nuclear capabilities are likely to remain relatively limited as far as their strategic reach is concerned. As Maps 2–4 indicate, the air-breathing arm of the Indian nuclear force-in-being provides sufficient coverage against Pakistani targets but would be utterly incapable against China. Each of the maps provides a true measure of distance from the three representative air bases on which the equidistant azimuthal projections are centered: Ambala and Jodhpur in the west and Tezpur in the east. The range circles,



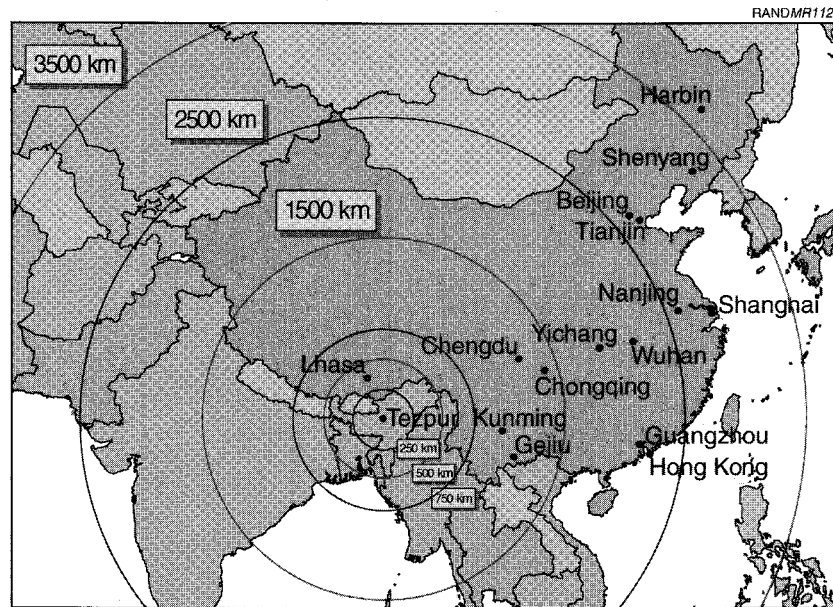
Map 2—India's Strategic Reach from Ambala

described in Jayal, "India 2020: A Perspective on Air Power," pp. 19–25, and in Kak, "Command and Control of Small Nuclear Arsenals," pp. 266–285. Greater Air Force integration with future Indian nuclear R&D efforts, and with national strategic planning, is likely to occur, however, if the new unified command headed by a CDS finally materializes.



Map 3—India's Strategic Reach from Jodhpur

although based on the lo-lo-lo mission radii of the four candidate aircraft examined earlier, can also be read as displaying the kind of reach enjoyed by any aircraft capable of attaining these radii under combat conditions. Examined synoptically, the graphics suggest that any aircraft capable of a 750-km mission radius suffices to target every relevant section of Pakistan that would be of interest to an Indian force planner. These graphics may in fact *understate* the operational reach of the Indian Air Force because the relatively poor state of Pakistan's air defenses and the high attrition they may be expected to sustain within two weeks of conventional combat suggest that Indian attack squadrons, operating out of forward bases like Jodhpur and flying the hi-hi-lo profiles possible in a permissive air defense environment, would be able to range much farther afield and even strike targets deep into Baluchistan if necessary. In contrast, even lo-lo-lo profiles flown out of air bases like Ambala bring all of the critical



Map 4—India's Strategic Reach from Tezpur

targets in northern Pakistan within easy reach of India's air-breathing deterrent.<sup>214</sup>

The critical limitation, where the air-breathing force is concerned, is therefore not Pakistan but China. Map 4, with its equidistant azimuthal projection centered on Tezpur, clearly indicates that even the best Indian aircraft are probably ineffectual in this context, since the most lucrative Chinese targets lie much farther to the north and east of India's forward bases. This graphic may in fact *overstate* the reach of India's air-breathing deterrent, for even if it is assumed that

<sup>214</sup>This implies that even if Pakistan's air defense net is not sufficiently degraded, India's strike aircraft can reach every significant Pakistani target even when operating solely in lo-lo-lo flight profiles. Because such aircraft would probably be detected by the terminal radars at the end of their transit phase, they will probably require accompanying escort and electronic warfare packages to ensure unmolested delivery of their weapons, but at least the weapon carriers themselves will not be constrained by range limitations as they would be in the case of China.

nuclear-armed aircraft would stage out of air bases even farther to the northeast of Tezpur, like Chabua and Jorhat—clearly an impossibility if these airfields have been destroyed by prior Chinese attacks—the operational radius of India's air-breathing platforms does not improve appreciably so long as they are committed to a lo-lo-lo flight regime. Since it must be assumed that under conditions of conflict the Chinese Air Force would be fully alerted and would relocate many additional fighter squadrons, sensors, and air defense weaponry to the numerous reserve air bases in the Chengdu and the Lanzhou Military Regions,<sup>215</sup> the Indian Air Force's nuclear aircraft would probably have no choice but to fly lo-lo-lo profiles in order to survive their transit en route to Chinese targets. Map 4 clearly demonstrates that even the least attractive though nearest Chinese targets, such as Kunming, Chengdu, Chongqing, and Gejiu, would require aircraft that were capable of mission radii of at least 1500 km.<sup>216</sup> And if the Indian Air Force seeks to interdict other kinds of countervalue targets—like the massive Three Gorges Dam now under construction near Yichang—it would require an aircraft capable of at least a 2000-km mission radius. All these extended ranges are computed only in straight-line distances, not dog legs, and consequently the minimal effective operating radii necessary to interdict these targets would be even higher under combat conditions.

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<sup>215</sup>Details about the Chinese Air Force and its peacetime basing patterns may be found in *International Air Forces and Military Aircraft Directory, 1991* (Essex, UK: Aviation Advisory Services, 1991). For Chinese airpower capabilities in general, see also John Wilson Lewis, "China's Search for a Modern Air Force," *International Security*, 24:1 (Summer 1999), pp. 64–94; Ken Gause, "PLAAF (People's Liberation Army Air Force) Continues to Modernise at a Slow yet Steady Pace," *Jane's Intelligence Review*, 10:6 (June 1998), pp. 38–43; and Nick Cook, "Re-arming the Dragon: The New People's Liberation Army Air Force," *Interavia*, 51:604 (November 1996), pp. 31–32.

<sup>216</sup>The Su-30MK can attain such radii of action only if it is committed to a hi-hi-hi flight profile, clearly a risky operational regime if China deploys its Su-27/30 interceptors to the Chengdu and Lanzhou Military Regions in times of crisis. These aircraft are not currently based in either of these two military regions, but should China perceive the development of an aircraft-based nuclear threat from India over time, Beijing is likely to prepare for such deployments during an emergency. China already has standing plans that enable it to swing air defense forces from other military regions into southwestern China during any emergency. For a good description of how such a swing strategy was implemented in 1987, see Craig Covault, "Tibetan Air Operations—Part 1," *Aviation Week & Space Technology*, October 12, 1987, pp. 54–60, and Craig Covault, "Tibetan Air Operations—Part 2," *Aviation Week & Space Technology*, October 19, 1987, pp. 103–106.

Even if suitably modified, none of the strike aircraft examined above—the Jaguar, the Mirage 2000, and the Su-30MK—would be capable of such operational radii in the lo-lo-lo flight regime. The bottom line, therefore, is that India’s nuclear deterrent, which in the near future will be centered exclusively on air-breathing platforms, will be utterly ineffectual against China, the country Indian strategic planners usually identify as New Delhi’s most significant potential adversary. As one Indian reporter readily admitted, “The IAF possesses no aircraft that can strike at even a medium-sized Chinese city outside Lhasa,”<sup>217</sup> and striking Lhasa—a major Tibetan city with a very small percentage of Han Chinese—may not in any case be the best retaliatory strategy to deter Beijing. Indian policymakers no doubt recognize the limitations of these existing capabilities but do not appear to be distraught, since they seem to be operating on the assumption that an active Chinese threat will not materialize for at least another two decades. If something should go wrong during this period, India would have no choice but to use its existing aircraft as best it could, possibly even attempting one-way missions in an effort to hit any significant Chinese targets that may lie within the ferry range of its strike platforms. Because it is acknowledged that planning for one-way missions is not a desirable solution to the problem of limited reach, however,<sup>218</sup> it is obvious that India will concentrate on developing alternative kinds of delivery vehicles—primarily ballistic missiles—so that its nuclear weapons can be effectively targeted at the strategic assets of most value to China.

Several such missile R&D programs are already under way in India.<sup>219</sup> The most mature program, however, is that which is focused on the development of the Prithvi SRBM. The Prithvi SRBM is slated to appear in three variants: The 150-km version, capable of carrying a 1000-kg payload, has already been inducted into the Army inventory; the 250-km version, currently under development and slated to enter the Air Force inventory, is capable of carrying a ~500-

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<sup>217</sup>Manoj Joshi, “Missile Program on Hold,” *Asia-Pacific Defense Reporter*, April–May 1994, p. 20.

<sup>218</sup>See the perceptive comments in Bajpai, “The Fallacy of an Indian Deterrent,” p. 165.

<sup>219</sup>Anupam Srivastava, “India’s Growing Missile Ambitions: Assessing the Technical and Strategic Dimensions,” *Asian Survey*, 40:2 (2000), pp. 311–341.

kg payload; and the 350-km version, currently being developed for deployment aboard some of the Indian Navy's surface combatants, will also be able to carry payloads in the ~500-kg class.<sup>220</sup> All three versions, the last two code-named "Dhanush," are supposedly capable of being armed with five kinds of conventional payloads: unitary high-explosive, incendiary, fuel-air explosive, cluster bomblets, and submunitions. Nonetheless, Indian plans suggest that they will be acquired in relatively small numbers: The Army is expected to purchase some 100 missiles, the Air Force approximately 25, and the Navy an unannounced but presumably comparable number,<sup>221</sup> although reports have speculated that a total of 300 missiles may in fact be ordered.<sup>222</sup> This decision to acquire such modest quantities of what are generally considered to be relatively inaccurate weapons has been a source of great bewilderment: One analysis has demonstrated that the number of conventionally armed missiles required for some of the missions contemplated for the Prithvi, such as air-field denial, is so large that the inventory currently being acquired by the Indian armed services would be woefully inadequate by any measure.<sup>223</sup> The implication often drawn from this conclusion is either that the development of the Prithvi in all of its variants is a bureaucratic blunder that has been pursued mostly for reasons of prestige rather than out of true operational need, or that its claimed conventional payloads are merely a subterfuge intended to obscure its true character as a nuclear delivery system. Only the latter mission, it is argued, makes the pattern of current Indian acquisitions sensible, since even small numbers of a relatively inaccurate missile would suffice if they were intended for the delivery of nuclear rather than conventional warheads.<sup>224</sup> This judgment derives further credibility

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<sup>220</sup>"Chronology of Indian Missile Development," Center for Nonproliferation Studies, Monterey, CA, at <http://cns.miis.edu/india/indiachron2.html>, and Mohammed Ahmedullah, "Prithvi and Beyond—India's Ballistic Missile Programmes," *Military Technology*, 23:4 (1999), pp. 76–78.

<sup>221</sup>J. P. Joshi, "Employment of Prithvi Missiles," *Journal of the USI of India*, 126: 526 (October–December 1996), pp. 462–465.

<sup>222</sup>Vivek Raghuvanshi, "India Moves Prithvi Missile Toward Serial Production," *Defense News*, September 11, 2000, p. 11.

<sup>223</sup>Z. Mian, A. H. Nayyar, and M. V. Ramana, "Bring Prithvi Down to Earth: The Capabilities and Potential Effectiveness of India's Prithvi Missile," *Science & Global Security*, 7 (1998), pp. 333–360.

<sup>224</sup>Harwant Singh, "Only a N-Warhead!" *Vayu Aerospace Review*, IV/1994, p. 30.

from the fact that the diameter of the Prithvi's missile bus is large enough to accommodate even a relatively primitive nuclear weapon, and its throw weight, especially in the Army version, would easily allow for the carriage of a notional 1000-kg warhead. Not surprisingly, many respected Indian analysts have defined nuclear-armed versions of the Prithvi as a desirable component of their country's arsenal.<sup>225</sup>

Whether the Prithvi system is in fact adequate for the various conventional missions usually attributed to it is an interesting question but one that cannot be addressed here. That the Prithvi is structurally capable of carrying a nuclear warhead is also indisputable; the only issue is whether it is likely to be employed for such missions and what the consequences of its use might be for purposes of deterrence. There are two important reasons the Prithvi is undesirable as a nuclear delivery system, the first of which derives simply from India's desired nuclear posture and its existing pattern of civil-military relations. India's desire for a force-in-being rather than a ready nuclear arsenal suggests that the Prithvi SRBM would be a less-than-optimal delivery platform because the need, after absorbing a first strike, to mate nuclear warheads with many dispersed missile platforms in close proximity to the front would be extraordinarily cumbersome from an operational standpoint. Even though Indian planners appear willing to accept great inconveniences in order to maintain highly distributed nuclear capabilities, the challenge of integrating completed nuclear weapons with strike aircraft (or missiles located at existing air bases) is relatively small compared to the challenges of integrating these weapons with missile platforms that have complex prelaunch fueling sequences and are dispersed in some remote field locations but that nonetheless remain well within range of possible enemy air interdiction.<sup>226</sup>

Because postattack reconstitution under these conditions would be extremely difficult, New Delhi may have to contemplate arming its SRBMs with nuclear weapons even prior to absorbing an adver-

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<sup>225</sup>See, for example, Subrahmanyam, "Nuclear Force Design and Minimum Deterrence Strategy for India," pp. 176-195.

<sup>226</sup>For more on this issue, see Harbir K. Mannshaiya, "India's Prithvi," *International Defense Review*, 28:8 (August 1995), pp. 23-25.

sary's first strike. Such a posture, however, automatically implies that the Indian armed services would have complete and ready nuclear weapons in their custody either in peacetime or during a crisis. This would certainly be true if the sea-based variants of the Prithvi were to be armed with nuclear warheads (and similar issues would become relevant to the Air Force version as well under some circumstances). While India's nuclear weapons may be equipped with some kinds of primitive PALs, New Delhi's current insistence on maintaining strict civilian custody of its nuclear inventory—until it voluntarily divests that custody prior to the actual employment of these weapons—suggests that it would rather not use any delivery systems that could compromise its preferred method of control. While the Navy version of the Prithvi would certainly subvert this preference and is therefore unlikely to be configured as a dedicated nuclear delivery platform today, the Army and Air Force versions may also embody similar problems.<sup>227</sup> Even if they do not, however, they certainly run up against the second reason a nuclear-armed SRBM cannot be a desirable Indian nuclear platform.

The Prithvi SRBM, in all three versions, suffers from one fundamental weakness: its extremely short range. Even the longest-range version contemplated—the Navy's Dhanush, which is supposedly capable of a 350-km range—adds nothing to India's already impressive short-range strike capabilities. Even at maximum range, the Prithvi family of missiles therefore suffices only to target Pakistan—which is already well within Indian Air Force strike coverage—but does nothing to improve India's glaring weaknesses where target coverage vis-à-vis China is concerned. To be sure, one could argue that a nuclear-armed Prithvi would assure penetrativity in a way that no nuclear-armed aircraft could emulate. This is certainly true, but uncertain penetrativity is not likely to be much of an issue vis-à-vis Pakistan under most imaginable circumstances, and while it may be a challenge vis-à-vis China, it is almost certain to be eclipsed by the problem of severely limited reach even before any other subsets of

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<sup>227</sup> It is important to recognize that when the initial Indian decision to produce the Prithvi was made, the missile was not conceived of as a nuclear weapon carrier. For more on the genesis of this system and why it was not envisaged as a nuclear delivery vehicle, see Perkovich, *India's Nuclear Bomb*, pp. 244–248.

operational difficulties are admitted for analysis.<sup>228</sup> This basic fact all but guarantees that the Prithvi class will be an unlikely candidate for a nuclear delivery vehicle: It merely duplicates the capabilities New Delhi already has vis-à-vis Pakistan, potentially subverting its preferred command system in the process, while providing no new capabilities vis-à-vis China even though it would compromise India's command system were it to be employed along the Himalayan border.<sup>229</sup>

All this having been said, however, India's civilian nuclear weapon designers are still likely to develop a nuclear warhead for the Prithvi even if there is no real operational need for such a device. The divide between the DAE—which produces India's nuclear warheads—and the uniformed services that must ultimately execute military operations makes it likely that the former will attempt to develop a relatively lightweight nuclear weapon capable of being deployed aboard India's SRBMs simply to push the envelope with respect to yet another form of high technology.<sup>230</sup> A more charitable hypothesis might explain this development as possibly one more attempt at hedging against uncertainty. In any event, such a development now seems increasingly likely—indeed, one observer has claimed that it has already occurred<sup>231</sup>—and if it does come about thanks to the imperatives of technological determinism, it would not only replicate the genesis of the Prithvi missile program itself but also bequeath to India a lighter fission warhead for its SRBMs even though these ve-

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<sup>228</sup>For more on this issue, see C. V. Gole, "The Prithvi—Facts and Fancies," *Vayu Aerospace Review*, IV/1994, pp. 23–30.

<sup>229</sup>Appreciating these considerations, Bharat Karnad has correctly argued that "not nuclearizing the short-range SSM Prithvi and, in fact, withdrawing it from [the] present near-border deployment [areas] should constitute the core concept" beneath India's strategic planning. He further argues that "a non-nuclear Prithvi makes ample military sense as well. It widens the 'firebreak' between conventional and nuclear weapons and . . . remove[s] the prospect of the unrecalable short-range ballistic missile, accidentally or inadvertently, starting a nuclear conflagration." See Karnad, "A Thermonuclear Deterrent," pp. 136–137.

<sup>230</sup>As of February 2000, one prominent analyst, confirming that India did not possess a lightweight nuclear warhead capable of being deployed on the Prithvi, noted that "we could, possibly, miniaturize the weapon to fit into the operationalised Prithvi missile, but that system is also restricted in range." See Premvir Das, "A Simple Solution to CTBT Problem," *The Pioneer*, February 12, 2000.

<sup>231</sup>Chengappa, *Weapons of Peace*, p. 418.

hicles may be both marginal and redundant to the nuclear mission from a strictly operational point of view.

The severe range limitations of the Prithvi SRBM imply that even nuclear-armed versions of the missile would not provide New Delhi with a delivery system capable of targeting important civilian and military assets within China. Recognizing these limitations, New Delhi in 1983 initiated the development of an intermediate-range missile system, the Agni—which from its inception was intended to carry a 1000-kg-class payload to ranges in excess of 1500 km.<sup>232</sup> The ability to deliver such a payload to these distances obviously implied the intention to prepare for the possibility of nuclear missions, and the early tests of the Agni thus appeared to focus more on perfecting separation technologies, the closed-loop guidance system, and the reentry vehicle, including a maneuverable warhead, than on improving the maximum range of the missile per se.<sup>233</sup> Consequently, the versions tested up to the early 1990s employed a peculiar hybrid configuration consisting of a solid-fueled booster from the Indian SLV-3 for the first stage combined with the liquid-fueled Prithvi for the second stage. Although this “technology demonstrator” was said to be capable of a range of some 2500 km, the actual performance demonstrated in flight tests was much lower; as one Indian reporter noted, “The first test of the Agni was to a range of 750 kms and the [last] one to just about 1000 kms.”<sup>234</sup>

The Agni test program was frozen under U.S. pressure until 1995. After the May 1998 nuclear tests, however, New Delhi resurrected the program with the intent of developing a rail-mobile IRBM capable of carrying a nuclear payload to “ranges varying from 1,500 km to 2,500 km and even beyond.”<sup>235</sup> India is seeking to attain these improved

<sup>232</sup>Amit Gupta, “Fire in the Sky: The Indian Missile Program,” *Defense and Diplomacy*, 8:10 (October 1990), pp. 44–47.

<sup>233</sup>Government of India, *The Missile Development Programme, Backgrounder* (New Delhi: Public Information Bureau [Defence Wing]), June 25, 1992, p. 2, and Pierre Langereux (with Vivek Raghuvanshi), “Surprise: L’Inde teste sur 1200 km un nouveau missile strategique,” *Air & Cosmos/Aviation International*, 1463 (March 14–20, 1994), pp. 40–41.

<sup>234</sup>Joshi, “Missile Program on Hold,” p. 20.

<sup>235</sup>Dinesh Kumar, “Nuclearization Calls for Strategic Command,” *The Times of India*, May 16, 1998.

ranges through the development of a two-stage, solid-fueled missile in which the liquid-fueled second stage used in the test bed is replaced with a new solid-fueled stage. This variant—which will eventually be equipped with a maneuvering reentry warhead—is currently under engineering and manufacturing development, and its first test was successfully conducted in April 1999.<sup>236</sup> The development program associated with this new all-solid-fueled, rail-mobile missile is likely to be approximately five years in duration, given that DRDO spokesmen have argued that the agency would “need to conduct between six to eight tests of the Agni missile system before its accuracy can be perfected.”<sup>237</sup> Since India is not likely to conduct more than two to three missile tests in any given year, however, the development and testing process will probably take at least half a decade (if not more) once the delays associated with such programs in India are taken into account. Assuming low-rate production starts immediately—which is unlikely—it will thus be at least a decade before a complete IRBM force capable of reaching out to ~2500 km ranges becomes operational.<sup>238</sup>

Even when such a force is completed, however, Map 4 suggests that a ~2500-km missile will provide India with reasonable though not complete coverage of Chinese targets *if and only if* New Delhi is willing to deploy these missiles at air bases like Tezpur in the extreme northeastern portions of the country. Moreover, even if these missiles were based at such forward locations, important Chinese countervalue targets like Beijing, Tianjin, Nanjing, and Shanghai would continue to remain out of range. Interdicting such targets would require an even longer-range missile, perhaps one capable of ~3500-km range, that would also have to be based in a relatively forward location like Tezpur. While such a basing posture can no doubt be implemented, it would require much greater sensitivity to strate-

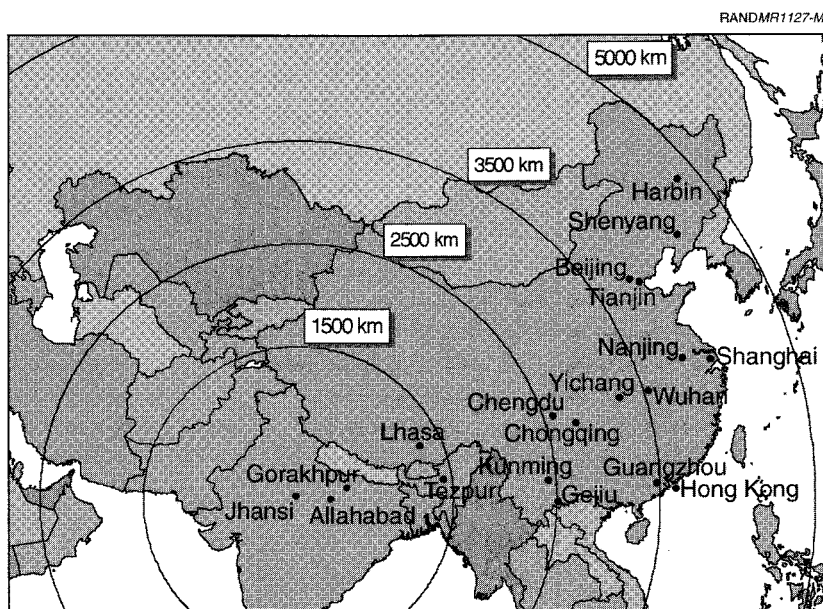
<sup>236</sup>For details, see “Agni-II Joins Nation’s Missile Showcase,” *Hindustan Times*, April 12, 1999.

<sup>237</sup>*India: DRDO Says 6–8 Tests Needed to Perfect Agni Missile*, FBIS-NES-96-156, August 12, 1996.

<sup>238</sup>The current Agni-II variant, however, has a range of roughly 2000 km, or at least has been tested only up to that range. It is unclear whether the missile in its present configuration could attain a range far greater than 2000 km without extensive redesign. For details on the technical characteristics of the new missile and its rail launcher, see Chengappa, “Boom for Boom,” pp. 28–31.

gic warning because there are fewer bases in the northeast that can host India's IRBMs than in the rest of northern India.<sup>239</sup> The pressures to rapidly flush the dormant IRBMs—even if maintained routinely without complete nuclear warheads—from their peacetime locations to designated wartime hides would thus become greater if the survivability of these retaliatory systems is to be enhanced against a Chinese barrage attack.

If a ~2500-km-range Agni is based in northern or central India, the targeting coverage vis-à-vis China diminishes radically. Map 5 suggests that a 2500-km missile based in Jhansi, for example, would barely be able to target Kunming and Gejiu, although if it were based farther to the north and east of Jhansi at bases like Gorakhpur, Allahabad, and Kalaikunda, targets like Chengdu and Chongqing would



Map 5—India's Strategic Reach from Jhansi

<sup>239</sup>For more on this issue, see Amitabh Mattoo, "Strategic Significance of the Agni-II Test Is Stressed," *India Abroad*, April 23, 1999.

be certain to fall within range. The principal disadvantage of a ~2500-km missile, however, is that it would have to be located in a small northeastern quadrant of the Indian mainland (roughly between 25 and 28 N and between 78 and 88 E) if targets in southeastern China are to be adequately covered. Obviously, this does not imply that the missiles have to be permanently deployed here but only that they will have to reach this general area at the time of launch if the desired Chinese targets in the Sichuan, Yunnan, and Guizhou provinces (and their environs) are to be effectively attacked. If India's ballistic missiles must be moved from outside this quadrant to predesignated launch sites within it, the burdens associated with ensuring the safe and secure transit of both missiles and launch platforms to the firing sites—as well as the challenges of safeguarding key infrastructure assets like bridges, switching stations, and rail lines along the transit corridors—increase greatly. Consequently, it is desirable that mobile missiles be located as close to their firing points as possible, but this in turn implies that the shorter the missile's range, the smaller the deployment quadrant will be (and the greater the susceptibility of the missiles to destruction by barrage attacks) if the missile systems are to remain within reach of their targets at all times.

Because shorter ranges in general tend to increase the vulnerability of a mobile missile system while decreasing its operational flexibility, New Delhi will likely continue to develop newer variants of the Agni missile that extend beyond ~2500 km in range. If the range of these follow-on variants is increased to, say, 3500 km—the maximum range that Indian planners seem to be currently contemplating<sup>240</sup>—the targeting coverage amply extends to aim points like Chengdu, Chongqing, and Yichang but still leaves other important targets like

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<sup>240</sup>It is believed that Indian strategic planners currently have settled for an Agni variant of 3000-km range, which will be armed with maneuvering and perhaps multiple warheads, as their principal IRBM system during the next decade. See Rahul Bedi, "India Confirms Plans for Improved Agni and Naval Cruise Missile," *Jane's Missiles & Rockets*, 2:10 (October 1999), p. 6. It is important to recognize, however, that irrespective of what kind of targeting a ≤3000-km-range Agni allows vis-à-vis China, it dramatically increases the flexibility of Indian strategic planners as far as targeting Pakistan is concerned. Such a missile could target Pakistan from any point on the Indian landmass and, being rail-mobile, would be substantially immune to most conceivable forms of Pakistani interdiction. The relevance of a ≤3000-km Agni vis-à-vis Pakistan cannot, therefore, be underestimated under some scenarios, even though most public discussions about the Agni in India focus almost entirely on China.

Hong Kong, Guangzhou, Shanghai, and Beijing immune to Indian retaliation so long as these weapons are deployed in or around the military bases at Jhansi. It is here that China's large size, specific location, and superior nuclear inventory in relation to India combine to impose—at least in principle—potentially painful trade-offs on the Indian deterrent: Missile deployments along the north Indian plains and the central Indian ranges help enhance the survivability of the Indian IRBM force (essentially by increasing the area of locational uncertainty) but would severely reduce their targeting coverage. Conversely, deployments—or firing points—at northeastern locations like Tezpur improve target coverage dramatically but *may* do so only at the expense of increased inflexibility or vulnerability.<sup>241</sup>

This conclusion, it must be admitted, is based principally on a crude generalization. Sophisticated operations analysis would be required to assess whether actual deployments or transits to firing points closer to the Indian northeast would in fact be as problematic as the *prima facie* evidence suggests. This would necessitate estimating the number and yields of Chinese nuclear weapons that can be allocated to servicing Indian targets; the kinds of Chinese reconnaissance, surveillance, and target acquisition (RSTA) assets that might be available for interdicting mobile platforms in the future; the number of Indian missiles and launch platforms available; the speeds at which these platforms can be flushed from their peacetime garrisons on receipt of strategic and tactical warning; the transportation bottlenecks existing along the transit routes; and the extent of strategic and tactical warning that might be available to India. Moreover, a comprehensive analysis would have to assess the effect of these variables on potential deployments not only at sites such as Tezpur and Jhansi but also at various intermediate points between these two polar locations in order to determine how the demands of range can best be serviced with minimal constraints on survivability. Since this analysis cannot be conducted at such an early stage in the development of the Indian deterrent, however, the conclusions affirmed in the previous paragraph must be treated as preliminary rather than conclusive.

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<sup>241</sup>For good Indian arguments on this issue, see Brahma Chellaney, "India's Trial by Fire," *Hindustan Times*, October 21, 1998.

In any event, concerns about the potential adequacy of targeting coverage are already being voiced in India. One Indian commentator, for example, has argued that “considering that India is still under trial by Agni (fire),” Indian Foreign Minister Jaswant Singh “ought to explain why the Indian negotiators have allowed the U.S. side in the ongoing [U.S.-Indian] talks to open a discussion on capping Agni development at 2,500 to 3,000 kilometer range.”<sup>242</sup> This commentator further asserted that if the country is “to build an effective and flexible missile-deterrent force, India needs IRBMs with ranges in the middle to upper sections of their 1,000 to 5,000 kilometer class [if it is] to strike key Chinese strategic targets.”<sup>243</sup> This demand for a 5000-km-class missile is echoed in several other Indian commentaries, and although some analysts, such as Lieutenant General J.F.R. Jacob, argue for such capability on the grounds that it will enhance India’s strategic reach,<sup>244</sup> the real benefits of such a missile—if and when it becomes available—will lie not so much in its operational reach as in its operational flexibility. If Maps 4 and 6 are viewed synoptically, it is amply evident that a 5000-km Indian missile provides target coverage similar to that of a 3500-km system—at least as far as major Chinese cities are concerned—but the former weapon can be based as far south as Secunderabad, whereas the latter must be based at a northeastern site such as Tezpur in order to secure comparable coverage. This implies that a 5000-km missile can be based far deeper within India; can be moved greater distances to preserve locational uncertainty; and can be deployed in the most politically stable parts of the country without compromising in its ability to hold critical Chinese targets at risk.<sup>245</sup>

The key problem, however, may pivot on developing such a missile. Indian strategic planners currently appear to be content with a ballistic missile capable of reaching out to a maximum range of roughly 3500 km (and perhaps even 3000 km if published reports are

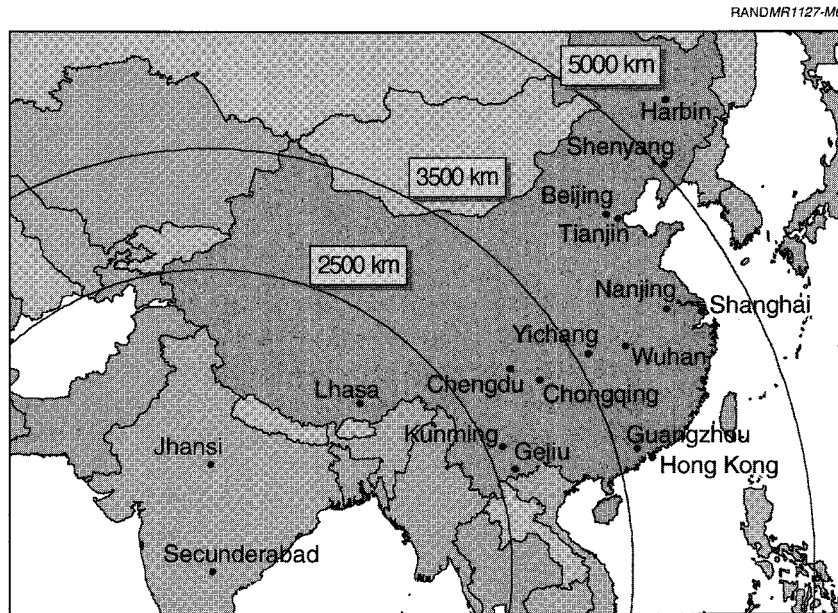
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<sup>242</sup>Chellaney, “India’s Trial by Fire.”

<sup>243</sup>Ibid.

<sup>244</sup>See Jacob’s remarks in Joshi, “Operation Defreeze,” p. 68.

<sup>245</sup>Jones, *From Testing to Deploying Nuclear Forces*, p. 4.



Map 6—India's Strategic Reach from Secunderabad

any indication).<sup>246</sup> At one level, this suggests that they are confident that such missiles, despite being based (or having their firing points located) somewhere between Jhansi and Tezpur, would still provide effective target coverage at minimal risk to their safety and survivability. This confidence is not necessarily misplaced *if*—as Indian security managers believe—the number of Chinese weapons that can be allocated to interdict Indian targets is relatively small and New Delhi's ability to assuredly target even a few large Chinese cities, such as Chengdu, Kunming, and Chongqing, suffices for effective deterrence in South Asia. Since the number of potential sanctuaries and launch points between Jhansi and Tezpur is not inconsiderable, however, Indian security managers could conclude that the targeting

<sup>246</sup>“Agni 2 Test Soon?” *Hindustan Times*, March 4, 1999, and Purnima S. Tripathi, “Agni III to Be Test Fired Soon, says Fernandes,” *Asian Age*, September 23, 2000.

solutions required for a splendid first strike by China are well beyond the strategic resources Beijing is likely to possess or commit vis-à-vis India in the foreseeable future. If all these calculations are correct, it is not unreasonable for New Delhi to elect not to develop the even longer-range ballistic missiles that many Indian analysts currently appear to advocate. There is, however, another technical reason a missile with a maximum range in excess of 3500 km may not yet hold New Delhi's interest: The planform of the current Agni design has already reached the limits of its success, and even substituting new solid-fueled stages—as has already been planned—is unlikely to extend the missile's range much beyond the 3000- to 3500-km maximum currently contemplated in South Block. As Gregory Jones put it succinctly, "No upgrade of [the] Agni is likely to be able to produce a missile with a 3,500–5,000 km range. Thus, India would have to produce a whole new missile."<sup>247</sup>

Producing an entirely new missile is not likely to evince great enthusiasm in New Delhi today—for while the prospect of yet another R&D program may be welcomed by DRDO technologists in South Block, it is likely to provoke only consternation within the Finance Ministry in North Block. The country as a whole today is also unlikely to support the cost of developing yet another missile design from scratch, and it is therefore not surprising that analysts such as Bharat Karnad have argued that India, "as a top priority, [ought] to at least partially militarize the Indian Space Research Organization's proven space launch capabilities."<sup>248</sup> Karnad believes that India's "ICBM technology is, in effect, already operational" and that "all that is required is for the [standard] satellite payload to be replaced with a megaton thermonuclear warhead atop the ISRO rockets, and a redoubtable Indian ICBM force is ready."<sup>249</sup> Such a capability, he argues, would not only offer range and accuracy advantages over missiles like the Prithvi and Agni but also provide India with political clout and power. As another Indian commentator put it, "The development of intercontinental ballistic missiles . . . is the only way to

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<sup>247</sup>Jones, *From Testing to Deploying Nuclear Forces*, p. 8.

<sup>248</sup>Karnad, "A Thermonuclear Deterrent," p. 139.

<sup>249</sup>*Ibid.*

command respect from the U.S. and neighbors like China and Pakistan.”<sup>250</sup>

Despite the ISRO's otherwise-impressive capabilities, however, India's SLVs are not ICBMs in disguise, and they certainly cannot be transformed into ballistic missiles on a whim. This is because they are simply not rugged enough for military operations; cannot be rapidly transported either by road or by rail; and are too big to be carried by any of the TELs currently in Indian service or on the drawing board. Moreover, if India's SLVs, especially the Geosynchronous Satellite Launch Vehicle (GSLV) and the PSLV favored by analysts such as Karnad, were to be mated with nuclear payloads, the resulting missiles would be so large that there would be no alternative but to maintain them perpetually on launch pads, since India would probably not be able to build the huge hardened silos that would be necessary to protect them in the event of an adversary's attack. A few representative numbers help establish why the idea of transforming India's existing SLVs into ballistic missiles is so chimerical. The best road-mobile ICBM in the current Russian inventory, the SS-27, has a launch weight of some 47,000 kg. In contrast, the best rail-mobile ICBM in the same inventory, the SS-24, weighs in at about 104,000 kg—more than twice the weight of the SS-27.<sup>251</sup> These two systems provide some indication of the gross weights that can be transported by the best road and rail launchers available.

The ISRO's GSLV and PSLV, however, are in an entirely different league. The GSLV, which is a mixed solid- and liquid-fueled system, weighs in excess of 365,000 kg, while the PSLV, which is also a mixed solid- and liquid-fueled system, weighs approximately 283,000 kg at launch.<sup>252</sup> This implies that the GSLV is in effect almost eight times heavier than the SS-27 and almost three and one-half times heavier than the SS-24, while the PSLV, although lighter than its larger stablemate, is still more than six times heavier than the SS-27 and almost three times heavier than the SS-24. Only the ISRO's Advanced

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<sup>250</sup>Menon, “Subtleties of Sagarika.”

<sup>251</sup>“SS-24 ‘Scalpel’ (RS-22/RT-23U)” and “SS-27 (Topol-M, RS-12M1/-12M2),” in Duncan Lennox (ed.), *Jane's Strategic Weapons Systems* (Coulsdon, UK: Jane's Information Group Ltd., 1999), Issue 29, January 1999.

<sup>252</sup>“India,” in David Baker (ed.), *Jane's Space Directory, 1999–2000* (Coulsdon, UK: Jane's Information Group Ltd., 1999), pp. 185–189.

Satellite Launch Vehicle (ASLV) comes in at a more reasonable launch weight of about 41,000 kg, but this vehicle, being equipped with two solid-fuel strap-on motors, has an unwieldy planform for a mobile ballistic missile. If the two strap-on motors are removed, the ASLV's weight is reduced by almost 19,000 kg, leaving the all-solid core with a launch weight of roughly 22,000 kg<sup>253</sup>—a value that is closer to the desirable weight for a road-mobile ballistic missile. However, an ASLV modified in this way would simply be unable to lift a 1000-kg payload to the ranges necessary to interdict critical countervalue targets in China or beyond. All Indian SLVs are thus handicapped by their enormous weight, excessive diameter (often on account of their strap-on boosters), and extremely high weight-to-payload ratios. This last trait does not impose any penalties in the context of space launch capabilities, but it does make every one of these systems inadequate when used as a ballistic missile, especially if mobility of any sort is desired. Not surprisingly, one Indian scholar correctly concluded that, contrary to the views of Karnad, "India's subsequent space launch vehicles, the ASLV and the PSLV, despite being more powerful than the SLV-3, are unlikely to find applications as ballistic missiles."<sup>254</sup>

All this implies that a decade or so from now India will possess at best only a ~3000 to 3500-km Agni variant in operational service. Recent Indian analysis has further suggested that the production of this variant, dubbed the Agni III, and its induction into operational service will not commence before the missile has been fully tested and proven.<sup>255</sup> A missile capable of ranges between 3500 and 5000 km or beyond will, moreover, have to be designed from scratch, and although the development of such a missile lies well within India's capabilities (based simply on the proficiencies it has demonstrated in its Agni and space programs),<sup>256</sup> New Delhi is unlikely to embark on such an effort immediately. In principle, India already possesses the capability to develop a true ICBM, but it has few political incentives to do so given that its most important adversaries can be adequately

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<sup>253</sup>Ibid.

<sup>254</sup>Mistry, "India's Emerging Space Program," p. 163.

<sup>255</sup>Sawhney, "How Inevitable Is an Asian Missile Race?" p. 32.

<sup>256</sup>"ICBMs Any Day, Says Kalam," *Hindustan Times*, September 18, 2000.

targeted with systems of lesser range.<sup>257</sup> Over the next decade, India is thus likely to focus on producing a ~3000- to 3500-km-range missile—and when such a design is finally accepted for production, it will most likely be configured for deployment in a rail-mobile mode, although a road-mobile variant could be created as well.<sup>258</sup> India does possess a large, fairly well-run civilian rail network, and it would therefore be possible to devise a deployment system that would allow rail-mobile missiles and launchers to use this network to create great locational uncertainty.<sup>259</sup> However, the costs of developing such a deployment system—which would require that special trains be *continuously* dispersed and operate alongside civilian traffic even in peacetime without compromising either the safety or the security of the launcher and the missile—would be inordinately high. Indian security managers are thus unlikely to risk such an operating regime, despite the fact that these delivery systems may *not* be routinely armed with their nuclear payloads.<sup>260</sup>

The rail-mobile deployment system traditionally found its greatest advocate in the late General Sundarji, who argued that India's existing investments in rail communications—and its 60,000 km of route length—offer ample opportunities for rail-mobile basing of India's strategic ballistic missiles.<sup>261</sup> The special trains carrying such missiles would be based in secure garrisons in peacetime and flushed into the wider rail network only on receipt of strategic warning. Such a “disperse-on-warning” deployment regime would enable the force to reap all the benefits of security in peacetime while exploiting all the advantages of locational uncertainty in times of crisis. Operationalizing this solution would require developing special, secure sidings that could host the rail-mobile platforms in peacetime while

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<sup>257</sup>See the remarks of Dr. A.P.J. Kalam in “Need for ICBM Questioned,” *The Times of India*, January 10, 1990.

<sup>258</sup>Chengappa, “Boom for Boom,” and Brahma Chellaney, “India Demonstrates Its Missile Prowess,” *Hindustan Times*, April 12, 1999.

<sup>259</sup>A good overview of the Indian railway system can be found in M. A. Rao, *Indian Railways* (New Delhi: National Book Trust, 1975), and in Rajendra Narain Saxena, *Four Decades of Indian Railways, 1950–1990* (Delhi: Academic Foundation, 1991).

<sup>260</sup>Amit Gupta, “South Asian Nuclear Choices,” *Armed Forces Journal International*, 136:2 (September 1998), pp. 24–30.

<sup>261</sup>Sundarji, “Changing Military Equations in Asia: The Role of Nuclear Weapons,” p. 137ff.

instituting a management system to regulate their dispersal in times of crisis. Almost all major Indian army bases are already well connected to the existing rail network, and so long as Indian security managers are satisfied with assigning oversight responsibilities to the Indian Army (as opposed to an alternate service like the Indian Air Force) either independently or under the aegis of a new unified command, there should be little difficulty with basing these systems at locations close to or within existing army garrisons.<sup>262</sup> Air Force custody and operation of these systems—again independently or under a unified command—may be more troublesome in comparison, because it would require that many of the generally remote airfields at which the missile systems might be based be physically connected to the existing Indian rail network.<sup>263</sup> Operating mobile missiles under the aegis of the Indian Air Force is thus more practical if road-mobile variants of Indian IRBMs are developed at some later date. Road-mobile systems imply that India's missile launchers would be deployed on specially designed TELs but do not imply that such TELs and their associated train—carrying reloads, meteorological and signal equipment, and command facilities—would be constantly mobile. Instead, these systems, like their rail-mobile counterparts, would be stored at several protected air (and army) bases and would be flushed from their peacetime garrisons either randomly or on receipt of strategic warning.

Irrespective of the specific form of mobility they employ, the operating patterns of these systems would be similar. When flushed from their garrisons, all dispersed road-mobile missiles and launchers would either proceed to their wartime hides or remain constantly mobile within certain designated quadrants until the emergency was lifted. Rail-mobile systems would constantly shuttle along certain predetermined routes that were previously prepared for this purpose. The missiles carried by either mobility system would be armed with their nuclear payloads just prior to launch, and on traditional Indian thinking such mating would not occur until after the country

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<sup>262</sup>Pushpindar Singh, "The Indian Army Today: Colour and Firepower," *Asian Defence Journal*, April 1987, pp. 5–27, read in tandem with Survey of India, *Railway Map of India*, 14th ed. (New Delhi: Survey of India, 1989).

<sup>263</sup>See Lake, "Indian Air Power," pp. 138–157, in tandem with Survey of India, *Railway Map of India*.

has absorbed the adversary's first strike.<sup>264</sup> Only those launchers-missiles that survived the first strike would be armed with warheads (or warhead components, most likely the "pits") that were available after such an attack. The latter might, however, have to be transported from a different location before the process of mating and testing could proceed, and therefore hours if not days might elapse before any retaliatory responses could be mounted. Although the myriad details that make such an operational regime feasible have yet to be worked out in their entirety—especially insofar as such a regime would apply to the entire future Indian nuclear force in the face of different levels of threats—its general logic appeals to Indian policymakers because they believe that widespread dispersal of their rail-mobile missilery (and road-mobile platforms, if such are developed over time) should suffice to protect at least a few systems that would finally be armed with nuclear warheads (if these are not already armed prior to nuclear deterrence breakdown) and ordered to carry their payloads of retribution to target.<sup>265</sup>

Such a deployment regime inevitably implies that India is likely to produce many more launchers than are strictly required for purposes of interdicting a given target array—and even more missiles than there are likely to be either launchers or nuclear warheads. Producing more than the militarily required number of launchers and missiles not only addresses the derivative demands imposed by continual testing, attrition, and maintenance but also advances the strategic objective of enhancing uncertainty: It promotes the illusion that there might be more nuclear warheads than actually exist and allows for more widespread dispersal of what are ordinarily inert systems that could become lethal if suitably armed. Moreover, to the degree that such dispersal, coupled with some local mobility, increases the number of systems that survive any attempted first strike, it also contributes to deterrence stability insofar as the residual inventory suffices to interdict a significant number of enemy targets. Since New Delhi has more army and air force facilities in the relevant

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<sup>264</sup>This represents the "baseline" model of control discussed in the previous chapter and exemplifies the nuclear C<sup>2</sup> model advocated by General Sundarji. Obviously, depending on whether the "baseline" model or its alternatives are selected in the future, the sequences described in this paragraph would vary accordingly.

<sup>265</sup>Gupta, "South Asian Nuclear Choices," pp. 24–30.

quadrants of the country than there are probably Chinese or Pakistani nuclear weapons available for use against India, it is likely to conclude that a static deployment of its rail-mobile missiles in protected garrisons in peacetime should suffice to ensure survivability so long as these inert delivery systems can be either readily flushed to some alternate wartime hides or committed to some predetermined mobile routines on receipt of strategic warning.<sup>266</sup>

Since the logic of rail (and road) mobility implies a survivable deterrent so long as the potential aim points outnumber the quantity of weapons that can be allocated by an adversary, India is unlikely to pursue any outlandish or complicated basing modes such as those that were discussed in connection with the U.S. MX missile program.<sup>267</sup> This may change over the very long term, but from all indications available, New Delhi appears to be attempting to cope with contingencies beyond the next 20 years by investing in the development of a sea-based capability rather than by exploring more esoteric forms of land basing. This sea-based effort includes examining options for basing ballistic missiles on board surface vessels, as exemplified by the current experiments with the liquid-fueled Dhanush missile aboard the Navy's Sukanya-class offshore patrol craft, and, more significantly, the development—now under way for almost 25 years—of a nuclear-powered submarine dubbed the Advanced Technology Vessel (ATV).<sup>268</sup> The Dhanush program is unlikely to result in a sea-based nuclear deterrent—at least on present plans—since it is driven primarily by the Indian Navy's interest in acquiring a land-attack capability vis-à-vis Pakistan in order to assert its own strategic relevance to the larger war-fighting outcomes within the Indian subcontinent.<sup>269</sup> This requirement has forced the Navy to seek a variety of standoff attack capabilities that hold promise of allowing it to replicate its 1971 achievements at Karachi, and toward

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<sup>266</sup>Ibid.

<sup>267</sup>For details about these alternatives, see Office of Technology Assessment, *MX Missile Basing*, pp. 3–29.

<sup>268</sup>Rahul Bedi, "India Presses Ahead with SSN to Boost Navy's Nuclear Profile," *Jane's Defence Weekly*, July 22, 1998, p. 26.

<sup>269</sup>For more on this calculation, see Ninad D. Sheth, "Interview: The Depth of the Indian Navy," *India Today* Web Exclusive, available at <http://www.india-today.com/webexclusive/interviews/20000520sushil.html>.

that end it has begun to induct various long-range anti-surface cruise missiles on board its air, surface, and subsurface platforms as well as to deploy SRBMs aboard some of its patrol vessels in order to threaten critical Pakistani sea- and shore-based assets in times of conflict. The fact that Islamabad can never be *certain* as to whether these standoff capabilities—especially the surface ship-based ballistic missile systems—are purely conventional or nuclear-armed is seen to make such unorthodox deployment postures particularly attractive from a strategic point of view: These sea-based systems serve to levy a potential nuclear threat on Pakistan from what is otherwise a nontraditional axis and, by that very fact, compel Islamabad to allocate military resources to sanitize them even though the strike systems in question may finally turn out to be no more than conventionally armed vehicles of little strategic significance. To the degree that the Dhanush system provokes such a Pakistani response, it will have served its purpose in Indian naval calculations while simultaneously laying the groundwork for the deployment of new solid-fueled, nuclear-tipped variants in the future—that is, if Indian policymakers choose to move beyond their currently preferred model of a force-in-being to institutionalize an alternative deterrent posture at some later point.

While the Dhanush project thus seeks to exploit the ambiguity of the missile's payload to secure strategic benefits, the ATV is intended to create a nuclear-propelled submarine that can carry SLBMs of the kind associated with a true sea-based deterrent.<sup>270</sup> This project has reportedly gone through three major generations of design work, all of which have focused on developing a 600-ton reactor capable of being fitted within the space constraints of a relatively small submarine hull. This effort had to begin from scratch, since India had no experience whatsoever in designing maritime nuclear reactors, not to mention a nuclear submarine. Over the last two decades the project was also the subject of internecine bureaucratic wrangling between the Indian Navy (the eventual end user) and BARC, which was tasked with developing the nuclear reactor. These disputes have apparently been worked out, however, and it has now been reported that "BARC scientists, after years of struggle, have finally developed a land-based prototype of the submarine's propulsion plant, a 90-MW pressurized

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<sup>270</sup>"N-Sub Project on Course: Navy," *The Times of India*, July 27, 1999.

water reactor (PWR) with turbines and propellers, and are testing it at a secret location in southern India.”<sup>271</sup> Over the years, the objective of developing a nuclear submarine appears to have changed as well. Although originally intended as an attack boat capable of stalking superpower fleets operating in the Indian Ocean, the vessel now appears more likely to serve as a cruise or ballistic missile carrier that could one day be armed with small nuclear payloads.<sup>272</sup>

Since the lease of the Russian Charlie-class nuclear-propelled guided missile submarine (SSGN) was terminated in 1991, several Russian design bureaus have actively assisted the ATV program “in non-nuclear areas such as hull design and underwater navigation.”<sup>273</sup> Even more interestingly, it would appear that Russia has been helping India develop a short-range SLBM dubbed Sagarika.<sup>274</sup> This missile, which one analyst notes “is universally described as having a maximum range of 300 km,”<sup>275</sup> reportedly relies on Russian technology “to allow the missile to be launched from underwater.”<sup>276</sup> Beyond that, details pertaining to this weapon are scarce, and there is actually an ongoing debate about its relationship to another sea-launched cruise missile that India is ostensibly developing.<sup>277</sup> Irrespective of what the facts about this issue might be, the evidence suggests that India remains committed to developing both a nuclear submarine and the strategic weaponry that goes with it. The latter program is certainly immature right now, but if India is able to master the basic technologies required to successfully launch an SRBM with Russian assistance, there is no reason in principle why the range and throw weight of such a weapon cannot be increased—with much less (and possibly greater indigenous) effort—over time.

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<sup>271</sup>Rethinaraj, “ATV: All at Sea Before It Hits the Water,” p. 32.

<sup>272</sup>“N-Submarine Best Bet Against Nuclear Attack, Says Navy.”

<sup>273</sup>Andrew R. Koch, “Nuclear-Powered Submarines: India’s Strategic Trump Card,” *Jane’s Intelligence Review*, 10:6 (June 1998), p. 29.

<sup>274</sup>Myers, “Russia Helping India Extend Range of Missiles, Aides Say.”

<sup>275</sup>Andrew R. Koch, “In Search of the Real Sagarika,” *Jane’s Intelligence Review*, 10:7 (July 1998), p. 24.

<sup>276</sup>Koch, “Nuclear-Powered Submarines: India’s Strategic Trump Card,” p. 30.

<sup>277</sup>Koch, “In Search of the Real Sagarika,” p. 24.

A successful short-range SLBM could thus pave the way for other longer-range sea-based missiles in the future—a capability that will be limited only by the preferences of Indian security planners with respect to range and by the weight and volume limitations of the host submarine's hull and propulsion systems. Even if the range of these sea-based missiles is not dramatically increased, they would still have great utility because, as one Indian naval officer notes, the general invulnerability of a nuclear submarine would allow submersible platforms to operate relatively close to the coastlines of their intended targets without creating all the diplomatic problems that arise when “drawing arcs from a country's [land-based] missile sites . . . results in far too many wrong deductions”<sup>278</sup> about their intended targets. Since many key Pakistani and Chinese targets lie relatively close to their coastlines, even an SRBM aboard a nuclear submarine should therefore suffice for purposes of delayed retaliatory strikes in the event of deterrence breakdown.

Not surprisingly, then, New Delhi has continued to pursue its nuclear submarine project with some intensity. As one Indian reporter noted, “Although many defence projects . . . have been shelved for the time being due to funding shortages, the ATV is one project that has been receiving unflinching monetary support from the government.”<sup>279</sup> It has further been reported that

Plans are also under way to lay down a 2500-ton boat with the technical assistance of Russian scientists and engineers by the end of this year [1998]. With the Russians agreeing to hawk their nuclear expertise in designing and fabricating a hull, along with its subsequent integration with the propulsion plant, the long-awaited ATV project looks certain to be completed by about 2004.<sup>280</sup>

While these completion dates are clearly optimistic (other sources have suggested a “launch around 2006/7 and commissioning a year later”<sup>281</sup>), the fact remains that the ability to build a nuclear submarine more or less indigenously will open new strategic doors to India

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<sup>278</sup>Menon, *A Nuclear Strategy for India*, p. 227.

<sup>279</sup>Rethinaraj, “ATV: All at Sea Before It Hits the Water,” p. 35.

<sup>280</sup>*Ibid.*, p. 32.

<sup>281</sup>Bedi, “India Presses Ahead with SSN to Boost Navy's Nuclear Profile,” p. 26.

while also presenting new strategic conundrums. A nuclear-armed ballistic and cruise missile battery aboard a nuclear submarine would, for example, eliminate many of the vulnerability problems that could otherwise bedevil New Delhi's land-based missile force<sup>282</sup> *if* a truly quiet nuclear submarine—which represents a significant engineering challenge in its own right—could in fact be constructed in India. The record of past Indian performance in submarine construction does not inspire great confidence, however, and the ATV program in particular has been universally acknowledged to be “one of the most ill-managed projects of independent India.”<sup>283</sup> Moreover, the U.S. experience has shown that the task of constructing quiet nuclear submarines is extraordinarily challenging and costly and, even if achievable, certainly does not represent an area in which India may be presumed to enjoy a comparative advantage in the face of adversaries that are likely to possess advanced diesel-electric submarines equipped with air-independent propulsion, decent sensors and fire-control systems, and adequate long-range weaponry. Even apart from these issues, however, the strategic necessity for a submarine-based deterrent arm has not yet been adequately demonstrated in the Indian context.

Most Indian observers—including the National Security Advisory Board—assert that “deterrence requires that India maintain . . . sufficient, survivable and operationally prepared nuclear forces”<sup>284</sup>—and from this quite reasonable requirement they quickly conclude that a “submarine based [nuclear] capability is critical” since, as the Indian Navy's Chief of Staff put it, “for one it is most capable and for another it is easier to conceal. It is a real deterrent. A submarine-based deterrent has credibility.”<sup>285</sup> Such conclusions, which are based largely on the rationales for a sea-based deterrent proffered by the established nuclear powers, have not yet been scrutinized by In-

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<sup>282</sup>Menon, *A Nuclear Strategy for India*, pp. 227–231.

<sup>283</sup>Pal, “Nuclear Onus on Navy.”

<sup>284</sup>“Draft Report of [the] National Security Advisory Board on Indian Nuclear Doctrine,” p. 2.

<sup>285</sup>Sheth, “Interview: The Depth of the Indian Navy.”

dian analysts and consequently raise three important questions that remain unresolved.<sup>286</sup>

First, is the vulnerability of the evolving land-based Indian deterrent serious enough to warrant recourse to a sea-based option? Answering this question requires that operations analysis be conducted to gauge whether Pakistan and China do in fact possess the requisite numbers of nuclear weapons and delivery systems to successfully interdict what will eventually be an Indian force of several-score mobile ballistic missiles and probably equal numbers of advanced combat aircraft. This issue is of particular importance because senior Indian security managers and many respected strategic analysts readily admit that “no one envisages in these days [any] high density attacks with hundreds and thousands of warheads.”<sup>287</sup> If this is the case, the evolving Indian mobile land-based deterrent is freed from the largest threat to its survival that can be envisaged and, by implication, may be far safer than proponents of a sea-based deterrent are willing to admit—especially given the fact that successfully interdicting mobile missiles is an enormously difficult technical enterprise that will remain beyond the reach of India’s principal adversaries well into the foreseeable future.

Second, are the survivability and mission effectiveness of a submarine-based deterrent better than those of a mobile land-based missile? Ballistic missile submarines, which many Indian sources argue ought to be equipped with 12 to 16 missiles per boat, represent a concentrated cluster of strategic capabilities. Thus, the detection and sinking of only one such vehicle represents the loss of a significant fraction of a country’s strategic reserves. In contrast, a single mobile land-based missile—when dispersed like a submarine—represents a much smaller fraction of a state’s strategic capability and consequently does not embody a significant diminution of retaliatory capability even if lost to enemy attack. The established nuclear powers traditionally made up for this potentially unhealthy concentration of capabilities by incorporating highly sophisticated quieting tech-

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<sup>286</sup>The exception remains Balachandran, “What Is the Relevance of a Triad?”—which contains some of the most penetrating criticisms of the justifications for a sea-based deterrent advanced in the Indian context. For a diametrically opposed viewpoint, see Menon, *A Nuclear Strategy for India*, pp. 177–283.

<sup>287</sup>Subrahmanyam, “A Credible Deterrent.”

niques into their ballistic missile submarines and by deploying them in patrol areas relatively far from their adversaries' homelands in efforts to enhance platform survivability.<sup>288</sup> Even then, however, the challenges of communication with submerged submarines made these systems most effective as "barrage" firing weapons rather than as platforms optimized for flexible nuclear operations.<sup>289</sup> Given the current and projected levels of technology available to India, it is reasonable to assume that New Delhi will be better equipped to build and deploy an effective land-based mobile ballistic missile force than to construct and operate a quiet ballistic missile submarine armed with long-range subsurface-launched ballistic missiles. Since even the best submersible systems built in India will have some nontrivial probability of detection—especially if these systems are armed with short-range missiles that require them to operate in relatively close proximity to an adversary's coastline—it is reasonable to suggest that a comparable force of mobile land-based missiles could yield a much higher residual fraction of strategic assets when compared to a submarine that is detected and sunk in a given attack scenario. To that degree, the attractiveness of ballistic missile submarines for purposes of enhancing the survivability of India's strategic reserves remains open to debate.<sup>290</sup>

Third and finally, is a submarine-based deterrent more cost-effective than a mobile land-based missile? At least one Indian analyst's answer to this query, which hinges in part on the answer to the second question, has been negative. G. Balachandran, addressing this issue, notes that "in all available estimates of the cost of a nuclear weaponization programme for India, . . . the bulk of the cost, nearly two-thirds of the total cost, goes towards the provision of a

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<sup>288</sup>Even these attributes, however, were insufficient to preserve the inviolability of the Soviet SSBN force against U.S. antisubmarine warfare (ASW) operations in the event of war—a clear reminder of the prospect facing countries that possess an inferior submarine fleet in an environment where even minute differences in relative technological capability can spell the difference between survival and disaster for the submarine arm. For details pertaining to this question, see Stefanick, *Strategic Anti-submarine Warfare and Naval Strategy*, and Daniel, *Anti-Submarine Warfare and Superpower Strategic Stability*.

<sup>289</sup>Lynn Etheridge Davis, *Limited Nuclear Options*, Adelphi Paper No. 121 (London: IISS, 1975–1976), pp. 19–20.

<sup>290</sup>For a brief quantitative assessment of this issue, see Balachandran, "What Is the Relevance of a Triad?"

viable and safe nuclear submarine force.”<sup>291</sup> When these costs are assessed against the size of the residual fraction of a land- and sea-based force expected to survive an adversary attack, Balachandran demonstrates that “the cost of 20 additional [land-based] missiles will be far less than that of a nuclear ballistic missile submarine”<sup>292</sup> armed with 16 to 20 comparable weapons. After factoring qualitative differences in capability between the two kinds of deterrence arms, the unit costs of each missile in their alternative basing modes, and the command-and-control costs of a dyad versus a triad, Balachandran concludes that “all indications are that a nuclear ballistic missile submarine force will not confer any advantage commensurate with the [marginal] expenses involved.”<sup>293</sup>

It is possible that this conclusion would change if India developed a different structure of comparative advantage with respect to the construction of submersible vessels in the years ahead.<sup>294</sup> Until that time, however, it is important to recognize that although many Indian analysts have asserted that a submarine-based deterrent is necessary for the viability of their country's evolving nuclear posture over the long term, no analysis justifying this argument has yet been adduced. If Balachandran's assessment is in fact taken seriously, the idea of a sea-based deterrent is not at all as advantageous as it is sometimes portrayed in the Indian debate. Consequently, India's strategic managers—although willing to fund this research and development program as part of their contingency planning—will likely demand further analyses before converting this endeavor into a pro-

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<sup>291</sup>Ibid.

<sup>292</sup>Ibid.

<sup>293</sup>Ibid.

<sup>294</sup>The historical record, however, confirms that India experienced enormous technical difficulties in constructing even diesel-electric submarines, and the various convulsions affecting the ATV project do not inspire confidence that New Delhi possesses the technical and organizational capabilities required to construct quiet, safe, and effective nuclear submersibles that could hold their own in a variety of operational environments. The Indian record with respect to submarine construction is usefully summarized in Mark Gorwitz, “The Indian Strategic Nuclear Submarine Project: An Open Literature Analysis,” December 1996, available at <http://www.fas.org/nuke/guide/india/sub/ssn/index.html>. The Indian Navy reorganized its management of the ATV project in 2000 in the hope of producing an effective nuclear platform sometime before the end of this decade. See “Nuclear Submarine Project Gets a New Head,” *The Times of India*, September 30, 2000.

curement initiative that dramatically changes India's prospective nuclear architecture. Recognizing just this fact, even the most zealous advocates of a submarine-based deterrent within the Indian Navy are always careful to point out that although the ATV "will have the ability to carry nuclear weapons,"<sup>295</sup> the government "will [have to] decide whether these nuclear-propelled submarines, capable of carrying nuclear weapons, would actually do so."<sup>296</sup> This caveat is invariably emphasized in all internal service discussions about the triad precisely because it is recognized that the decision to procure a sea-based deterrent would radically alter the character of India's desired strategic posture. Specifically, it is understood that a nuclear-armed ballistic missile submarine (like a nuclear-armed ballistic missile-equipped surface combatant) could not exemplify the force-in-being that New Delhi seeks to develop today but would instead personify some kind of a robust and ready arsenal—one in which at least the custody of completed nuclear weapons and launch vehicles would reside entirely with India's uniformed services in peacetime. Although India's civilian leadership would certainly limit the decisional autonomy of these naval custodians by installing various kinds of PALs on board its sea-based weaponry, such a nuclear posture would no doubt be radically different from the operational configuration security managers in New Delhi currently seem to be contemplating.

The acquisition of a sea-based nuclear deterrent—in either surface or submersible form—will therefore come to personify India's moment of truth: While air-breathing systems and even land-based missiles do allow for the maintenance of those demated and dealerted nuclear postures which exemplify a force-in-being, a major surface combatant or ballistic missile submarine armed with nuclear weapons would only incarnate some kind of a ready arsenal, with the speed of its retaliatory response being limited primarily by the time it takes to issue the nuclear release orders, the time it takes to receive and authenticate the same aboard the vessel, and the time it takes to complete the battery firing procedures. If 10 or 20 years hence India still seeks to preserve its currently preferred posture of a force-in-being (as opposed to some version of a robust and ready arsenal), it

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<sup>295</sup>"N-Sub Project on Course: Navy."

<sup>296</sup>"India to Produce Indigenous N-Submarine," *Hindustan Times*, July 27, 1999.

would therefore have no choice but to seek alternative, non-naval solutions to the as-yet-unanalyzed problems of force vulnerability. This might include exploring other basing modes such as continuous rail mobility or deep underground basing rather than developing a sea-based deterrent. If New Delhi does pursue such alternatives when needed in the distant future, its nuclear submarine platforms could be restricted to tactical roles only, as was intended by the Navy's expansion plans during the 1980s.<sup>297</sup> Whether India will eschew the acquisition of a sea-based deterrent when that option becomes available for reasons of both nuclear strategy and civil-military relations cannot yet be determined, but if New Delhi were to pursue such a solution, it would be obvious that the currently desired force-in-being would subsist only as an interim posture en route to the development of a full-fledged robust and ready arsenal.

While such an arsenal may even represent the ultimate future of the Indian deterrent, its imminence should not by any means be exaggerated. The discussion in this section clearly indicates that for all India's claims to being a nuclear weapon state, New Delhi's deterrent posture will center for a long time on a limited, monadic delivery system: short-range strike aircraft. At least another decade will elapse before a dyadic posture involving aircraft and land-based ballistic missiles becomes fully ready and operational, and it is unlikely that India will have a credible triad of any size, effectiveness, or flexibility for at least another decade and possibly two.

### **Supporting Infrastructure**

The availability of fissile materials, nuclear weapons, and delivery systems by themselves does not suffice to produce an adequate deterrent even if such a deterrent is configured simply as a force-in-being. To the contrary, an effective deterrent requires a minimum level of supporting infrastructure in order to physically "net" the

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<sup>297</sup>For more on how the Indian Navy envisaged the use of nuclear submarines during the 1980s, see Tellis, "Securing the Barrack: The Logic, Structure and Objectives of India's Naval Expansion," Parts I and II, pp. 31–57 and 77–97.

weapons and delivery systems in a coherent way.<sup>298</sup> This infrastructure enables the national leadership to monitor the character of the country's threat environment and the status of its own retaliatory forces while simultaneously allowing for the dissemination of appropriate operational directives if retaliatory strikes are to be conducted in the context of a deterrence breakdown. Since supporting infrastructure is therefore a key component of deterrence capability, it is not surprising that several Indian analysts have set forth fairly ambitious requirements pertaining to their country's nuclear posture<sup>299</sup>—requirements ranging from dedicated command centers and multiple and redundant communications systems, to complex intelligence collection and assessment technologies that include early-warning platforms, to integrated strategic defenses and large-scale civil defense measures. Many of these elements have been borrowed from existing literature on Western C<sup>3</sup>I systems, and almost all appear to be based on the premise that India's claim to becoming a nuclear weapon state requires that New Delhi create separate, *dedicated* technical capabilities to oversee the control and operation of its nuclear forces.<sup>300</sup>

Whatever the virtues of having such capabilities may be, this premise is highly suspect. For while Indian security managers no doubt intend to develop a "minimum, but credible, deterrent" over time, their intentions today appear focused primarily on developing a force-in-being rather than a ready arsenal. This implies in turn that India's nuclear posture will consist primarily of weapon and delivery systems that are maintained separately and in an operationally

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<sup>298</sup>Indian leadership views on this issue are described in Kumar, "Nuclearization Calls for Strategic Command," and Dinesh Kumar, "No Move Yet to Set up Nuclear Command," *The Times of India*, July 2, 1998.

<sup>299</sup>The best analyses of Indian requirements with respect to supporting infrastructure can be found in Nair, *Nuclear India*, pp. 183–194; Bajpai, "The Fallacy of an Indian Deterrent," pp. 150–188; Narendra Gupta, "Detonations Don't Make Deterrence," *Indian Express*, May 22, 1998; Amar Zutshi, "For a Strategic Defence," *The Pioneer*, May 1, 1998; Bakshi, "Nuclear Euphoria and Harsh Realities"; Kanwal, "Command and Control of Nuclear Weapons in India," pp. 1707–1732; Menon, *A Nuclear Strategy for India*, pp. 235–283; and Kak, "Command and Control of Small Nuclear Arsenals," pp. 266–285.

<sup>300</sup>This premise is most clearly articulated in Nair, *Nuclear India*, pp. 183–194, and in Menon, *A Nuclear Strategy for India*, pp. 235–283.

inactive condition, at least as far as their routine disposition is concerned.<sup>301</sup> Since this posture explicitly rejects the maintenance of a completed and ready arsenal—i.e., one in which all components are deployed in a highly integrated state *a priori* and sustained at relatively high levels of readiness—it is unlikely that New Delhi will set out to create a separate set of technical systems dedicated solely to the control of its emerging nuclear capabilities. If in fact India seeks to maintain only a mobilizable nuclear reserve oriented toward prosecuting simple retaliatory actions involving a relatively small number of nuclear weapons—as opposed to a ready war-fighting force that will be called upon to execute complex, frequently changing plans involving a large and diversified nuclear arsenal—such dedicated capabilities would be costly and might even prove unnecessary. Consequently, while New Delhi will incrementally develop the specific organizational arrangements necessary to control its budding strategic capabilities—such as the new unified command, which will be responsible for overseeing India's strategic assets and planning for nuclear operations—it will most likely graft these new elements onto its existing command system, which regulates the disposition and movement of all Indian conventional forces, rather than develop an entirely new and specialized structure parallel to its existing system of higher defense management.<sup>302</sup> As Prime Minister Vajpayee put it, "India does not intend to build a large arsenal or create an elaborate command and control system like other nuclear weapon powers."<sup>303</sup>

This in turn implies that while India will no doubt develop some kind of supporting infrastructure over the long haul, this infrastructure is likely to be far less ambitious than that deemed essential by many unofficial Indian sources today. There is little doubt that the requirements associated with developing this infrastructure have only begun to receive attention in New Delhi, and the process of analyzing, establishing, and investing in these requirements is by no

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<sup>301</sup>For more on this issue, see Kumar, "No Move Yet to Set Up Nuclear Command."

<sup>302</sup>Indian Defence Minister George Fernandes alludes to this prospect in the comments cited in Kumar, "No Move Yet to Set Up Nuclear Command." See also "Interview of the Week: Inder Kumar Gujral" for more on this issue.

<sup>303</sup>Chengappa, "Worrying over Broken Arrows," p. 30.

means complete. In part, this is because India has simply not completed the process of weaponization, and consequently the complex demands pertaining to supporting infrastructure are not yet fully understood because it remains unclear what kinds of nuclear weapons and delivery systems India will finally possess and in what numbers. Obviously, the development of a supporting infrastructure cannot be put off until after this process is complete, but by the same token it cannot be developed *ab initio* on the basis of some abstract template. Rather, the development process is likely to unfold in an evolutionary way and in a manner commensurate with the gradual acquisition of the weapon and delivery systems themselves. Not surprisingly, published reports suggest that India has already produced a \$3.75 billion plan focused on the acquisition of key components related to its nuclear C<sup>3</sup>I infrastructure over a five-year period.<sup>304</sup> Whether this plan has been formally approved or executed by the national leadership is not clear, but three preliminary conclusions with respect to India's supporting infrastructure can nonetheless be drawn.

First, efforts will be made to keep the costs associated with the development of such capabilities to a minimum. New Delhi is likely to spend whatever is necessary to control its nuclear forces, but necessity in this context will be defined by what satisfies decisionmakers in the world of international politics rather than by the abstract standards laid down by Indian theorists and commentators.

Second, efforts will be made to keep the configuration of the supporting infrastructure simple. This criterion of simplicity again implies that India will focus only on developing an infrastructure that is necessary to support nuclear operations relevant to the subcontinent—not one that is designed to address all nuclear operations imaginable or, for that matter, nuclear operations involving countries other than China and Pakistan. The nuclear operations for which New Delhi will prepare consist principally of *small, pre-planned retaliatory attacks*. This implies that the supporting infrastructure must at a minimum be able to provide sufficient sanctuary for the national command authority; allow for incoming damage reports and roll calls of surviving forces; allow for deliberation, re-

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<sup>304</sup>“India Eyes \$3.75 Billion Nuclear Command Plan.”

view, and selection of specific retaliatory options; and, finally, permit effective dissemination of the nuclear release order with confirming report-back from the various custodians of India's strategic reserves. The infrastructure developed for these purposes must also be able to survive relatively small nuclear attacks emanating from either China or Pakistan, which may or may not incorporate even smaller counter-C<sup>3</sup>I components. It will *not*, however, be required to support flexible or ad hoc retaliation, reoptimization of attack plans in real time, prompt counterattacks in a preemptive launch-on-warning or launch-under-attack mode, interdiction of critical mobile targets, or protracted nuclear operations—all of which represent contingencies for which the United States prepared its supporting infrastructure (with varying degrees of success) during the Cold War.<sup>305</sup>

Third, efforts will be made to use bits and pieces of India's existing infrastructure to the maximum extent possible. This implies that India will not develop new and dedicated capabilities if preexisting assets can be modified or used as is. Given the premium on economy, the supporting infrastructure already in place for the conduct of conventional operations will most likely be used for nuclear operations as well, although perhaps by different operators, organizations, and entities.<sup>306</sup>

These three considerations ought to be borne in mind when future Indian initiatives with respect to nuclear supporting infrastructure are anticipated or assessed. Since the number of technologies that fall under this rubric are numerous, however, the following analysis will focus only on four broad categories: command centers, communications systems, warning and assessment capabilities, and strategic defenses.

**Command Centers.** Many Indian analysts have argued that at a minimum India will require a set of dedicated command centers

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<sup>305</sup>Matin Zuberi, "The Proposed Nuclear Doctrine," *World Focus*, 21:4 (April 2000), pp. 3–5.

<sup>306</sup>See the comments of K. Santhanam and V. Arunachalam in "Panel Four: Nuclear Weapons and the Balance of Power," in *Proceedings of the Center for the Advanced Study of India, University of Pennsylvania*, held at the Wharton Sinkler Conference Center, May 5–8, 1997, available at <http://www.sas.upenn.edu/casi/reports/nuclear/panel4.html>, for more on this issue.

from which the National Command Authority (NCA)—meaning the Prime Minister or his designated successors—could control the retaliatory strikes that would be mounted in the event of a deterrence breakdown. Indeed, even the earliest studies about a potential Indian deterrent, commissioned by General K. Sundarji during the early 1980s, concluded that some kind of National Command Post (NCP) would be necessary in this context, and the policy paper on nuclear command arrangements reportedly approved by India's service chiefs similarly argues that a "robust communications centre with the ability to receive information and intelligence and disseminate orders and instructions"<sup>307</sup> should be established. Yet another Indian analyst has actually argued for two command posts built to certain specific configurations, asserting that "in a crisis situation, the proposed NCA should be expected to operate from an underground, hardened and electro-magnetic pulse protected National Command Post. An alternative NCP located some distance away from the capital assumes equal salience."<sup>308</sup> Other analysts, such as Vijai Nair, have argued that such dual command posts "must have identical communication facilities" and that there should be "outstations on the National Military Command Link (NMCL) emanating from the NCA and . . . the controlling headquarters on the Strategic Nuclear Link (SNL) that would service the military requirements of the nuclear strategy."<sup>309</sup>

It is obvious that although these suggestions presuppose the existence of a separate, dedicated set of nuclear command links that may not be developed in the near future, a small set of underground leadership command posts is likely to be constructed—two national command posts, one outside of Delhi and one somewhere in the vicinity of the Prime Minister's Office in the heart of New Delhi, have reportedly been built already<sup>310</sup>—simply to minimize the worst ravages of a nuclear attack that might be mounted by Pakistan. The logic of having such dedicated command posts is not difficult to discern:

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<sup>307</sup>Bedi, "India Assesses Options on Future Nuclear Control," p. 16.

<sup>308</sup>Kapil Kak, "Strategic Template for Nuclear India," *The Times of India*, August 11, 1998.

<sup>309</sup>Nair, "The Structure of an Indian Nuclear Deterrent," p. 95.

<sup>310</sup>Chengappa, "Worrying over Broken Arrows," p. 31, and Bedi, "India's Nuclear Prowess Remains on Paper, Official Rhetoric."

Since they would presumably be equipped with the personnel, facilities, and information systems that would allow a decisionmaker to appreciate the threat environment and respond to it appropriately, secure command posts would become critical organizational nodes for the effective execution of any military operation. In point of fact, India already possesses many such facilities; the operations centers at the three service headquarters in New Delhi, the operations center of the Director-General, Military Operations, in South Block, and the operations rooms at each headquarters associated with the services' combat commands already serve as the sinews of the national military command system, where all orders originating from the Prime Minister and the Cabinet are transmitted via the Ministry of Defence to the individual service chiefs and then to their subordinate commanders. The chief weakness of this infrastructure, however, lies in the fact that none of these key facilities is hardened and designed to operate in a nuclear environment.<sup>311</sup> Thus, while they do afford considerable protection against conventional threats, such facilities are unlikely to survive any nuclear attacks that might be directed at them—a vulnerability that has obviously driven analysts' repeated calls for a new set of dedicated underground command posts capable of directing nuclear operations in a protracted war. Unfortunately, however, command posts such as these would be costly to develop if they were in fact intended to be truly “capable of withstanding up to a 20 kt blast from a ground burst or from a deep penetration nuclear weapon like the U.S. B61-11 earth penetrating nuclear warhead.”<sup>312</sup>

The United States, for example, developed a complex set of command centers during the Cold War.<sup>313</sup> These fixed centers were appropriate mainly for peacetime operations, since even the most hardened of them, like the Northern Region Air Defense's (NORAD's) command facility at Cheyenne Mountain and the Alternate National Military Command Center in Maryland, could not have survived the

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<sup>311</sup>For details, see Gurmeet Kanwal, “Command and Control of India's Nuclear Weapons,” *World Focus*, 21:4 (April 2000), pp. 9–13.

<sup>312</sup>*Ibid.*, p. 12.

<sup>313</sup>These are described at some length in Albert E. Babbitt, “Command Centers,” in Ashton B. Carter, John D. Steinbruner, and Charles A. Zraket (eds.), *Managing Nuclear Operations* (Washington, D.C.: Brookings, 1987), pp. 322–351.

kinds of nuclear attacks that the Soviets might have mounted against them. To compensate for these vulnerabilities, the United States invested in a variety of mobile centers, of which airborne command posts like the National Emergency Airborne Command Post (NEACP), the Strategic Air Command's (SAC's) "Looking Glass," and the Navy's "Take Charge and Move Out" (TACAMO) are perhaps best known. The United States also flirted with both afloat and land-based mobile command centers, but even after all these investments were made, it is not clear how robust the American command system actually was.<sup>314</sup> To be sure, the U.S. example may not be entirely relevant to India, since the former had to face the demanding challenge of ensuring effective control of its nuclear forces in the context of a possibly protracted war, a complex Single Integrated Operations Plan (SIOP), and many thousands of nuclear weapons that might have been exchanged between the United States and the Soviet Union. Yet the vulnerability of fixed command posts and the virtues of mobile alternatives remain a lesson that is pertinent to India even if all other aspects of the American control system are less germane.

The experience of smaller nuclear powers like France, which developed austere versions of the U.S. command system, is also instructive. Paris constructed a command post for its strategic nuclear forces at Taverny, burying it under concrete more than 60 meters below the surface. It also constructed an alternate command center at Lyon-Mont-Verdun, but after both of these major investments had been made, the transmitters necessary to send the launch codes to its SSBN fleet remained overland and, by implication, were highly vulnerable to interdiction.<sup>315</sup> This vulnerability led one analyst to conclude that "destroying, or simply degrading, such key C<sup>3</sup> centers could be functionally equivalent to destroying the nuclear weapons themselves since no French nuclear weapon could be used without redundant confirmation of launch authority from the chief of state."<sup>316</sup>

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<sup>314</sup>The best analysis of this issue is found in Blair, *Strategic Command and Control*.

<sup>315</sup>Yost, "French Nuclear Targeting," pp. 136-137.

<sup>316</sup>*Ibid.*

The moral of the story is clear: Any Indian command post that is designed to function effectively in the face of even a few Pakistani or Chinese nuclear missiles, especially those that will be available 20 years hence, cannot simply be located “underground”—i.e., in the basement of a military headquarters—but will instead have to be hardened and deeply buried if it is to survive any attacks aimed at paralyzing New Delhi's C<sup>3</sup>I network.<sup>317</sup> Yet it is unclear whether India has the technology to build such hardened and deeply buried structures, and even if this were the case, it remains unclear whether India would be able to construct an information network whose *every* node—from its point of origin at the NCA down to the multiple operators at the AEC, DRDO, military headquarters, and field units—is also buried deep enough to prevent the proverbial weak link from subverting the entire chain.<sup>318</sup> The challenges here are, moreover, as much technical as they are operational and financial—for the location of any fixed command post, no matter how deeply buried it may be, will sooner or later be discovered by India's adversaries, and the accuracy of at least China's nuclear missiles over the next two decades is likely to improve to a sufficient extent that accurate countercontrol attacks will be theoretically feasible. If China in fact develops deep-earth penetrating warheads, such attacks could actually be highly effective even if only a relatively small number of warheads were allocated to such missions.<sup>319</sup>

It can thus be seen that India will be faced with a host of unpalatable choices: For while deeply buried command centers are indeed New Delhi's best option should it settle for fixed installations, such centers are extraordinarily difficult and expensive to build, and the technical and financial burdens of deeply burying the entire information distribution network over great distances along the Indian

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<sup>317</sup>This is in effect a variant of the Soviet solution followed during the Cold War. For details, see Blair, *The Logic of Accidental Nuclear War*, pp. 120–145.

<sup>318</sup>For an analysis of this issue in the U.S. context, see Albert J. Wohlstetter and Henry Rowen, *Objectives of the United States Military Posture*, RM-2373-PR (Santa Monica: RAND, 1959), p. 31ff.

<sup>319</sup>For a good example of how even highly accurate but low-yield deep penetrating warheads could destroy underground facilities, see Albert Wohlstetter and Richard Brody, “Continuing Control as a Requirement for Deterring,” in Ashton B. Carter, John D. Steinbruner, and Charles A. Zraket (eds.), *Managing Nuclear Operations* (Washington, D.C.: Brookings, 1987), pp. 162–163.

landmass—so as to render it immune to deep-earth penetrating attacks—are considerable. Moreover, even if these constraints could somehow be overcome, the presence of specialized equipment to construct such a network would itself signal the location of various nodes in the chain—and if these locations were eventually compromised, their survivability would always be uncertain either because of ongoing improvements in the accuracy and lethality of Chinese (and possibly Pakistani) ballistic missiles or because of the possibility of deep-earth penetrating attacks. Given these considerations, New Delhi is unlikely to embark on such ambitious projects in haste, especially when there are other solutions that would in principle offer the prospect of mitigating command vulnerability at lower costs.

In fact, there are three solutions that can be operationalized fairly readily and are likely to prove more attractive to New Delhi, at least in the near term. The first and most burdensome solution consists of configuring some kind of airborne or afloat command post. Over the next two decades, India is likely to acquire some kind of airborne warning and control system, probably developed with Russian and Israeli assistance.<sup>320</sup> Many of the technologies that will be installed on such an aircraft can be adapted for the command-and-control mission, either on the Airborne Warning and Control System (AWACS) platform itself or preferably on some other airframes dedicated to this task. These aircraft, operating in tandem with some of the airborne tankers that India will also acquire, can be specially dedicated to the command mission. These platforms need not be numerous and need not be maintained on constant airborne alert; rather, they can be deployed routinely at one or more Indian air bases and would be required to sortie only on receipt of strategic warning to some other facilities either to increase locational uncertainty or to pick up members of India's national command authority in anticipation of a nuclear attack.<sup>321</sup> Similar technologies can be installed on board India's larger surface ships, although for technical and operational reasons an airborne platform might be more appropriate so long as India's retaliatory capabilities are primarily land-based.

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<sup>320</sup>Chattopadhyay, "The Indian Air Force: Flying into the 21st Century."

<sup>321</sup>Details on how the United States used such a system during the Cold War can be found in Blair, *Strategic Command and Control*, pp. 127–181.

The second option, which is both more attractive and immediately available, is simply to upgrade all the communications suites, resident databases, and mission-planning equipment in existing Indian operations rooms to serve as nuclear command posts in an emergency. While these centers are no doubt soft targets that can readily be interdicted, upgrading all of them would diminish the problem of command vulnerability simply by increasing redundancy. Such a solution would effectively increase the number of nuclear munitions that an adversary must expend if it is to maximize the probability of success accruing to a counter-C<sup>3</sup>I attack aimed at paralyzing the Indian state. Moreover, this alternative does not preclude the development of several other nontraditional sites as backup command centers to be activated *only* in the aftermath of a nuclear attack. In effect, this solution would covertly create several reserve command sites that, although soft, could not be identified as such in peacetime. The success of such an effort, however, will depend on the degree to which India is able to exercise strict operational security vis-à-vis Pakistan and China during the construction, configuration, start-up, and test phases: After these processes are complete, they can be maintained indefinitely in a dormant state in the absence of conflict. Since the number of covert facilities that can potentially be developed on DAE, DRDO, and military installations alone is extremely large, the targeting requirements necessary to enforce C<sup>3</sup>I denial become so demanding as to be rendered impractical in the specific war-fighting environment in Southern Asia.

The third and possibly the most intriguing solution, especially in the intermediate term, is to develop some variety of mobile land-based command centers.<sup>322</sup> These centers could be deployed aboard specially constructed vehicles (or trains) that are maintained in a garrisoned posture during peacetime but are flushed to wartime hides (or dispersed amid the civilian rail net) on receipt of strategic warning. Obviously, exercising such an option would require the development of special vehicles that have sufficient reserves of power to run the complex data and communications systems on board,

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<sup>322</sup>For a description and assessment of such centers, see Babbitt, "Command Centers," pp. 336–344; C. C. Mow and J. W. Workman, *Feasibility of Transportable Armored Command Posts*, RM-4422-ISA (Santa Monica: RAND, 1965); and Alan J. Vick, "Post-Attack Strategic Command and Control Survival: Options for the United States," *Orbis*, 29:1 (Spring 1985), pp. 95–117.

sufficient fuel (or access to fuel) to enable reasonably distant dispersal away from their peacetime garrisons, and sufficient habitability to allow a small cadre of staff and decisionmakers to transmit the nuclear release orders in the aftermath of a nuclear attack. The virtue of such a solution is that mobile command centers could be made reasonably small and could be equipped with all manner of long-distance, beyond-line-of-sight wireless communications equipment on board. In addition, their movements would be relatively difficult to track in real time, and they could be built relatively cheaply and in sufficient number to allow for redundancy should some of the original complement fail to survive the initial attacks.

Obviously, operations involving all these systems would require a great deal of preplanning, including but not restricted to plans relating to the relocation of the national leadership on receipt of strategic warning. The degree of preplanning here, however, is not likely to exceed the levels of forethought otherwise required to make other elements of the force-in-being operationally effective. Each of the three alternatives described above nonetheless represents a cheaper, more survivable, and more readily attainable capability than those involving the construction of deep-underground facilities dedicated to the task of managing nuclear operations. It must be remembered that the demands imposed on command facilities in the Indian case are much less than those that affected similar facilities in the United States and the Soviet Union during the Cold War.<sup>323</sup> Command centers in the latter cases were intended to enable command authorities to ride out nuclear attacks safely and to execute complex war-fighting strategies over an extended period of time—with as much improvisation as necessary—in the face of horrendous damage inflicted by hundreds if not thousands of nuclear weapons detonating all around them.

Nuclear attacks aimed at India would by contrast be much smaller and would not exceed a few score weapons at most. New Delhi's retaliatory responses, too—at their most demanding—would be fairly simple and would not require the kind of complex planning that characterized the primarily counterforce operations both the United

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<sup>323</sup>This point is emphasized most trenchantly by Santhanam in "Panel Four: Nuclear Weapons and the Balance of Power."

States and the Soviet Union planned for at the height of their rivalry. Indian nuclear retaliatory missions, perforce, will be preplanned operations, and it is therefore unlikely, given the modesty of Indian nuclear reserves and its operational infrastructure, that its command centers will be intended to support highly improvised mission planning. Instead, the main purpose of such centers will be to provide a sanctuary where the national leadership can survive the relatively small nuclear attacks that are likely to be unleashed; can receive and assess attack and damage reports; can contemplate various preplanned courses of action; and can order fairly simple retaliatory actions that will in all likelihood take the form of a riposte more or less in slow motion.<sup>324</sup> Hence, command centers in India need not be as sophisticated, complex, or numerous as American and Russian facilities were during the Cold War.

Given these considerations, New Delhi is likely to pursue the second, third, and first alternatives—in that order—before it embarks on any costly schemes to build hardened and deeply buried underground command posts of the sort that were constructed by the Soviet Union during the Cold War.<sup>325</sup> To be sure, some facilities resembling the latter will almost certainly be constructed if they have not been completed already, but these facilities are more likely to be shallow underground structures equipped with blast doors, baffles, and labyrinth entrances intended to provide some degree of blast attenuation—and designed to provide a quick, near-term alternative to the soft above-ground facilities already existing—rather than deeply buried structures that, being impervious to indirect air-induced weapon effects and relatively resistant to direct induced violent ground motions, could actually survive a direct hit.<sup>326</sup> Although India's shallow underground command posts ought to suffice so long as its adversaries are armed with either relatively inaccurate or low-

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<sup>324</sup>For one thoughtful view of the demands associated with this process, see Menon, *A Nuclear Strategy for India*, pp. 242–283.

<sup>325</sup>For an excellent description of these facilities, see the analysis in Department of Defense, *Soviet Military Power: An Assessment of the Threat, 1988*, 7th ed. (Washington, D.C.: USGPO, 1988), pp. 44–67.

<sup>326</sup>The differences between shallow underground and deeply buried structures are discussed in *Heating, Ventilation, and Air Conditioning of Hardened Installations, Technical Manual*, TM 5-855-4 (Washington, D.C.: Department of the Army, November 1986), pp. 1–4.

yield weapons, New Delhi will have no alternative but to consider constructing deeply buried facilities embedded in hard rock if it seeks to insure its command system against the threat of attack by megaton-class nuclear weapons *through the use of fixed, land-based alternatives*.<sup>327</sup> Thus far, however, Indian strategic managers have not shown any inclination to pursue solutions centered on a deep underground command system despite the fact that they are favored by many of India's strategic elites.

**Communications Systems.** Irrespective of what kind of protected command facility or network is ultimately developed, India will need a variety of communications systems in order to connect its command authorities with the custodians of the various components of its distributed arsenal. Ideally, these communications links should be reliable, redundant, and secure. Since no single communications system possesses all these properties simultaneously, however, most command structures settle for a multiplicity of systems, with their specific technical qualities determining whether they function as the primary, secondary, or tertiary links for a given task. Consistent with this fact, Vijai Nair has argued that India should develop and deploy "communication satellites providing real time voice and audio-visual data links based on ultrahigh and very high frequency bands; extremely low frequency communications facilities to direct subsurface forces; airborne relay stations to meet range limitations of equipment; [and] alternate ground based radio and radio relay networks."<sup>328</sup> Similarly, Raja Menon has asserted the need for a wide variety of communications systems, each of which would become relevant either at different stages of the alerting process or because of the differences between the various Indian deterrent arms. These systems include the civilian voice telephone net, data and image transfer components operating over a fiber-optic backbone, and radio and satellite communications, all netted together with the early-warning, attack assessment, and launch control systems that would be required, in the author's estimation, for the robust control of India's emerging deterrent.<sup>329</sup>

<sup>327</sup>For more on this question, see Philip M. Dadant, *Why Go Deep Underground?* P-1675 (Santa Monica: RAND, 1959).

<sup>328</sup>Nair, "The Structure of an Indian Nuclear Deterrent," p. 98.

<sup>329</sup>Menon, *A Nuclear Strategy for India*, pp. 272-283.

Clearly, the United States procured each and every one of these technologies during the Cold War. In fact, one of the greatest concerns of U.S. military planners throughout this period was ensuring stable connectivity before, during, and after a nuclear attack. In support of this objective, the World Wide Military Command and Control System (WWMCCS)—the communications system carrying peacetime and crisis traffic—slowly incorporated over time a specially segregated component called the “minimum essential emergency communications network” (MEECN), which was dedicated to transmitting nuclear launch orders through different media to the strategic force components surviving the initial Soviet attacks.<sup>330</sup> The challenge of connectivity facing the United States was particularly burdensome because it was assumed that a Soviet first strike would involve a relatively large number of nuclear weapons, many of which could destroy sensors, command nodes, and platforms as well as some operational military bases before the national command authorities could generate decisions based on tactical warning and initial attack assessments.<sup>331</sup> Furthermore, American retaliatory action, which could have been initiated simply on warning or while under attack, was oriented toward executing extraordinarily complex mission plans that required different and widely separated arms of the triad to launch their weapons rapidly but in a precisely orchestrated sequence at a highly specific set of targets. By contrast, it is unlikely that the Indian nuclear force will either have to operate in similarly demanding circumstances or be tasked to execute a similarly complex retaliatory plan. Consequently, India's needs pertaining to connectivity are much simpler, although for reasons of physics a certain degree of redundancy will of necessity be incorporated into its strategic communications network.<sup>332</sup>

The term “strategic communications network” itself must be recognized for what it is, however, which is to say that it should not be understood as a dedicated communications system acquired, deployed, and maintained apart from the civil networks already present within the country. Rather, it refers simply to that subset of the na-

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<sup>330</sup>Vick, “Post-Attack Strategic Command and Control Survival: Options for the United States,” pp. 95–117.

<sup>331</sup>Blair, *Strategic Command and Control*, p. 257.

<sup>332</sup>Zuberi, “The Proposed Nuclear Doctrine,” pp. 3–5.

tional communications system which India's strategic enclaves and its uniformed military already use. To be sure, there are certainly a few dedicated links that are restricted to these end users alone, but such dedicated links are not unique to India's strategic enclaves, as many national organizations have separated communications systems. The Indian Railways, for example, have a dedicated telephone network separated by many degrees from the rest of the civilian system. In the final analysis, then, India's future investments in strategic communications, like the rest of its supporting infrastructure, will profit greatly from the modernization of its existing civilian systems. Indeed, successive Indian governments since 1991 have committed themselves to modernizing the entire national communications infrastructure over the next two decades<sup>333</sup>—and while this effort is intended primarily to promote economic growth and national development, the objectives of enabling remote-area access, primarily through wireless systems combining telephony, television, and computers, are an integral part of this planning. The implications of such a network, especially if it does succeed in using relatively cost-effective and innovative solutions (e.g., wireless local loop [WLL] systems and very small aperture terminals [VSATs]), for defense purposes should be obvious.

If the plans published by the government of India offer any indication,<sup>334</sup> India's future national communications infrastructure is likely to consist of a multilayered system.<sup>335</sup> At its base would be the

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<sup>333</sup>The contours of the overall telecommunications modernization program are described in Stephen D. McDowell, *Globalization, Liberalization and Policy Change: A Political Economy of India's Communications Sector* (New York: St. Martin's Press, 1997). See also Peter Evans, "Indian Informatics in the 1980s: The Changing Character of State Involvement," *World Development*, 20:1 (1992), pp. 1–18, and Government of India, *Indian Telecommunications*, Report by the Telecom Commission (New Delhi: Ministry of Commerce, 1994).

<sup>334</sup>Ministry of Communications, *VIII Five Year Plan (1992–1997): Industrial Development for Telecom Sector* (New Delhi: Government of India, 1991); "Information Technology Action Plan," *India News*, June 16–July 15, 1998, pp. 1–3.

<sup>335</sup>Good surveys of the structure of the Indian telecommunications system can be found in "India: The Commercial and Regulatory Environment," *Asia Pacific Telecommunications*, March 1, 1997; Ashok Jhunjhunwala, Bhaskar Ramamurthi, and Timothy A. Gonsalves, "The Role of Technology in Telecom Expansion in India," *IEEE Communications*, November 1998, pp. 88–94; Mark Rockwell, "Telecom in India: Bring Order from Chaos," *Telephony*, 218 (June 1990), pp. 26–30; and N. Ravi, "Telecommunications in India," *IEEE Communications*, March 1992, pp. 24–29.

traditional copper landlines, albeit with increasing numbers of fiber-optic segments, that currently dominate the communications system. In 1998, India is believed to have had more than 267,000 route kilometers of coaxial cable, with 72,000-odd kilometers linked by microwave systems and another 57,000-odd kilometers linked by various ultrahigh-frequency (UHF) systems. The fiber-optic segment consisted of more than 76,000 route kilometers in 1998, and this was expected to increase to in excess of 203,000 route kilometers by 2002.<sup>336</sup> This system obviously represents a complex amalgam of underground and overhead lines connected to local exchanges that are in turn connected to numerous regional switching facilities through either other landlines or microwave relays.<sup>337</sup> Altogether, India possessed more than 23,000 exchanges in 1998 together with a switching capacity capable of managing in excess of 21.2 million lines that year. Despite its large absolute size, however, this network is generally old, prone to defects, and unreliable, with low call-completion rates—in large part because of the numerous nonelectronic exchanges embedded in the switching network. For this reason, India is gradually replacing its traditional Strowger and crossbar exchanges with digital switching, and its Eighth Five-Year Development Plan had in fact mandated that 93 percent of the network be digital by the end of 1997.<sup>338</sup> The reliability of this system will thus progressively improve as the local and long-distance switching systems become entirely digital. However, this architecture will nonetheless remain vulnerable to strategic attack because the most important multipurpose switching stations are relatively few and constitute soft targets that invariably exist above ground.<sup>339</sup>

Since the basic trunk-line system does not cover many parts of the country, especially remote areas, the Indian government has also been attempting to incorporate an intermediate technology layer

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<sup>336</sup> *India—Telecommunications Market and Regulatory Overview* (Bucketty, Australia: Paul Budde Communication, 2000), p. 2.

<sup>337</sup> A useful map of the overall transmission network can be found in Ravi, "Telecommunications in India," p. 28.

<sup>338</sup> "India: The Commercial and Regulatory Environment."

<sup>339</sup> For details, see Ravi, "Telecommunications in India," pp. 24–29. See also *India—Telecommunications Market and Regulatory Overview*, pp. 1–8.

centered on fixed-wireless networks providing local-loop services.<sup>340</sup> This technology, envisaged as complementing the multichannel radio systems that traditionally served low-density areas and connected rural centers to the national trunk network, is seen as offering critical opportunities for reliable communications when “nonpremium” services like cellular and paging are at issue.<sup>341</sup> Increasingly, however, the government has begun to view mobile cellular systems as the wireless architecture of choice intended initially to serve the demand for rapid communications in urban areas but eventually extending to rural areas as well.<sup>342</sup> A new telecommunications policy implemented in April 1999 has in fact resulted in the rationalization of service, revenue, and regulatory structures and in the division of the entire country into four main cellular markets: the major metropolitan areas of Bombay, Delhi, Calcutta, and Madras; a Category A circle consisting of prosperous regional states like Maharashtra and Gujarat; a Category B circle consisting of next-tier states like Punjab, Rajasthan, and Madhya Pradesh; and a Category C circle consisting of the geographic periphery, including Jammu and Kashmir, Assam, and the Andaman and Nicobar islands.<sup>343</sup> This scheme is expected to intensify the demand for different kinds of wireless services—which, in the case of India, turn out to be particularly attractive because they help overcome existing infrastructure bottlenecks, preclude the need for new, expensive, and cumbersome investments in laying landlines, and allow for the rapid implementation of new connectivity technologies that bypass or replace obsolescent communications systems.<sup>344</sup>

Finally, the apex layer consists of dedicated satellite telephony intended to support high-speed broadband voice, data, and other

<sup>340</sup>Abhinav Taneja, “A Phone in Every Village: Taking Telecom to Rural India,” *New Telecom Quarterly*, October 11, 1997, p. 9ff.

<sup>341</sup>“India: Fixed Wireless Communications,” *Tradeport*, available at <http://www.tradeport.org/ts/countries/india/isa/isar0037.html>.

<sup>342</sup>Thomas C. Hunter, Jr., “India: Set for Wireless,” *Cellular and Mobile International*, January 1, 1997.

<sup>343</sup>*India—Wireless and Satellite Communications* (Bucketty, Australia: Paul Budde Communication, 2000), pp. 3–5.

<sup>344</sup>For details on the variety of wireless systems already operational or sought in India, see “India: Wireless Communications,” *Tradeport*, available at <http://www.tradeport.org/ts/countries/india/isa/isar0041.html>.

kinds of commercial and strategic transmissions both within the country and internationally.<sup>345</sup> At the commercial level, the national telecommunications provider Videsh Sanchar Nigam Ltd. (VSNL) signed important agreements early on with ICO Global Communications to establish a satellite access mode in India for global mobile personal communications, and other providers, including Iridium, Globalstar, and Constellation, also began operating (or intend to operate) services in India. Although the future of some of these programs is uncertain by virtue of Iridium's failure as a commercial project, the threatened bankruptcy of ICO, and continued fears about Globalstar's viability, general trends in the global mobile personal communications by satellite (GMPCS) regime suggest that, whatever the economic challenges facing the first generation of operators, GMPCS represents a new wave in communications that promises greater connectivity through mobile facsimile, messaging, data, two-way voice, and broadband multimedia via small, handheld phone sets, computer-mounted terminals, and laptops. These capabilities will exploit the growing availability of new satellite systems—whether geostationary or nongeostationary, fixed or mobile, broadband or narrowband, global or regional—that are capable of providing telecommunications services directly to end users from a constellation of satellites. Such systems are likely to coalesce over time into three specific categories: little low-earth-orbit satellites (little LEOs), big low-earth-orbit satellites (big LEOs), and broadband, low-earth-orbit satellites (broadband LEOs).<sup>346</sup> Not surprisingly, then, the first generation of GMPCS operators will soon be joined—and could probably be replaced—by regional operators such as Agrani, Thuraya, ACeS, Reliance, and Orbcomm, all of which plan to offer voice, data, and messaging communications services in various parts of India within the next few years.<sup>347</sup> VSNL—which will remain a monopoly only until around 2004—is also expected to in-

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<sup>345</sup>India—Wireless and Satellite Communications, pp. 1–10, and David Benton, "MSS Systems Advance Telecommunications in India," *Satellite Communications*, November 1994, p. 18.

<sup>346</sup>Details on the promise of GMPCS for global communications are available in "Space Communications and Applications," in *Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space*, Background Paper No. 5, A/CONF.184/BP/5, May 27, 1998, pp. 13–18.

<sup>347</sup>India—Wireless and Satellite Communications, pp. 7–8.