Conceptually, as Figure 3.1 shows, there may be three ways to support deployed units. First, repair capability can deploy with the unit, putting the maintenance shop at the FOL. Second, repair operations can be permanently located in regions where major contingencies are most expected, at FSLs. Third, repair capabilities can be kept in CSLs, and LANTIRN pods and LRUs transported to and from the FOL.

How well these concepts provide future global combat support depends upon strategic combat support design decisions about

![Figure 3.1—Conceptual Support Options for Deployed Units](image)
- the number and location of FOLs with prepositioned materiel
- the resource levels for each such FOL
- the number and location of FSLs
- the functions that FSLs perform
- the base structure
- the organizational structure, and
- the transportation infrastructure.

Each combination of strategic options, or each combination of FOLs and FSLs, has different effects on operations, costs, and risks. USAF support operations traditionally have been provided through decentralized services. Decades of experience have given the USAF a full perspective on the advantages and disadvantages of such a system, so we examine how centralization of LANTIRN support compares with the current structure. Centralized or regional support may offer several advantages over the current decentralized system. Collocation of test equipment can enhance repair capacity through economies of scale and through cross-cannibalization of the support equipment (Appendix C examines test set supply and demand relationships). By having regional centers with prepositioned support equipment and established transportation routes near potential trouble spots, the Air Force can reduce deployment needs during the first stages of a contingency. By reducing the need to deploy test sets, the USAF frees up initial contingency airlift for other assets and avoids the question of tester functionality that arises when equipment is moved. Regionalization also reduces the system requirement for spare LRUs through safety stock consolidation and, by aggregating demand, reduces requirements for support personnel.

Although consolidation offers many advantages, it is sensitive to transportation delays. These delays drive pipeline requirements and, if not managed properly, can severely hinder system performance. We address transportation sensitivities in greater detail later in this chapter.
CONSOLIDATED SUPPORT OPTION STRUCTURES

The support structure options we examine range from completely decentralized to completely centralized. The current Air Force LANTIRN maintenance structure is completely decentralized, and we treat it as the base case. Each combat-coded squadron is assigned one set of intermediate maintenance assets that follows it to any FOL. Complete centralization, the opposite extreme, would consolidate all intermediate maintenance at a single CONUS location to support all peacetime and potential combat missions. Alternatives between these extremes would use different numbers of FSLs.

In the consolidated options, repair occurs at either a single CSL or at permanent FSLs able to support both combat and peacetime missions—thus the planned capacity of FSLs is based upon MTW demands. A CSL operating in conjunction with one or more FSLs must meet the peacetime demands of all CONUS-based aircraft, which means that the CSL will have excess capacity when some CONUS units are deployed overseas during war. To improve wartime maintenance efficiency, excess CSL personnel could be shifted to FSLs during contingencies. To consolidate and preposition equipment at FSLs, only technicians need to move from the CSL for wartime deployment. The equipment at the FSLs would be kept “warm” supporting boiling-peacetime operations.

Figure 3.2 shows the consolidated system structures that we analyzed. We first considered, as shown at the top, a single CONUS location with either pod or LRU repair capabilities. In this structure, pods to be repaired would be shipped from all global locations to the CSL. The Precision Attack SPO asked us to consider a variation of this structure in which a single CSL would process only LRUs, to be swapped at an intermediate shop on base and shipped to a CSL for repair. Each base or FOL would have its own ADK with limited repair capability. This option adds an echelon to the support system and does not offer significant performance improvement.

We next assessed a two-CSL structure for pods only. This system is identical in concept to the single-CONUS pod repair option but may offer some strategic advantages in supporting multiple contingen-
cies. We also considered, as shown in the middle of Figure 3.2, a structure comprising a single CSL with two out-of-CONUS (OCONUS) locations. These FSLs, in United States Air Forces in Europe (USAFE) and Pacific Air Forces (PACAF), were modeled to support contingencies in SWA and NEA. We also assessed a structure of two CONUS and two OCONUS facilities, as shown on the bottom of Figure 3.2.

Finally, we analyzed a mixed-virtual alternative, portrayed in Appendix D. This alternative features two CSLs but with resources for three locations, one in CONUS and two OCONUS. The resources for a three-location structure are assigned to only two locations, with excess capacity deployed to other locations when a contingency is imminent. This option offers greater flexibility and several advantages of regional support, but it may be costlier and pose risks asso-
associated with equipment deployment. Again, we highlight results for the two major logistics structure options (decentralized or centralized) in the body of this report and discuss other options in Appendix F.

**SUPPORT STRUCTURES AND MATERIEL MOVEMENT**

The current decentralized structure has three echelons, as shown at the top of Figure 3.3. Pods are repaired at the O-level (flight line) and I (intermediate)-level operations on base or at an FOL. Broken LRUs and Shop Replaceable Units (SRUs) are shipped to an air logistics center (ALC) or depot. Replacements for the nonfunctioning subsystems are shipped from the depot to the operating base.

A centralized structure for pod repair also has three echelons, as shown in the middle of Figure 3.3. First, O-level repair is performed at the base or FOL. Second, complete pods needing I-level repair are shipped from the operating location to an FSL or CSL. Third, LRUs and SRUs are shipped from the regional center to the depot. Repaired LRUs and SRUs are shipped to the regional center from the depot, while repaired pods are shipped from the central facility to the individual units.

We also considered a four-echelon system in which each unit is equipped with limited repair capabilities. In this structure, O- and I-level technicians with deployed units perform only LRU remove and replace (R/R) operations in support of pod repair. LRUs may be swapped out of failed pods, but the individual LRUs would not be repaired on base. Nonfunctioning LRUs would be shipped to a single LRU repair facility. Only SRUs would be transported from the LRU regional repair facility to the depot. This logistics structure adds some deployment flexibility, but it increases the number of echelons in the system and does not yield significant cost savings. Again, we focus on the dipole options of centralization versus decentralization in the body of this report.
Decentralized structure, 3-echelon

Pod regional, 3-echelon

LRU regional, 4-echelon

Figure 3.3—LRU Repair Consolidation Adds Another Echelon
MEASURING SUPPORT STRUCTURE PERFORMANCE: SELECTING AND ANALYZING METRICS

How can we evaluate the potential performance of alternative support structures? What metrics should we select? How might actual performance vary by slight changes in our modeling and assumptions? Below we propose metrics for seven variables to measure support system performance: pod availability, deployment footprint, test set requirements and availability, personnel requirements, recurring costs, investment costs, and operational risks. We analyze sensitivities for those variables for which only slight variation causes great effects in expected system performance.

Pod Availability

Most performance sensitivities stem from time requirements. The decentralized logistics structure is most sensitive to deployment and setup time. Regional structures are sensitive to resupply transportation times. Delays in deployment and setup for decentralized structures, or in resupply transportation for centralized structures, cut the number of pods available for combat aircraft. Requirements for RSP and pipeline and safety stocks further raise the sensitivity of each system to time delays and may lower the number of pods available for use by the warfighter. These sensitivities are most acute for TRG pods, which are used more often, fail more frequently, and take longer to repair than NAV pods.

Decentralized Structures

Figure 3.4 shows how deployment and setup times affect TRG pod availability in a decentralized support structure. Our calculations are based on removal rates computed from the AWOS data and representative flying profiles. In other words, we assumed aircraft fly according to the planned programs and experience wartime removal rates similar to those experienced in the AWOS. Under decentralized support, pods are not shared between units. Each unit must have sufficient stock to support surge operations, the most stressing flying period.
Figure 3.4—Support Equipment Deployment and Setup Time for Decentralized Structure May Affect Targeting Pod Availability

Figure 3.4 shows a pod availability goal of 0.8 combat-capable TRG pod per 1 LANTIRN-capable aircraft during surge operations. This figure exemplifies two decentralized support sensitivities. First, the repair system is sensitive to how quickly support equipment and capability are deployed to the theater. Second, assuming support capability deploys prior to the start of combat operation, if a single tester at an FOL fails, then repair capability at that FOL becomes very sensitive to the supply system’s responsiveness in repairing that one tester.

For sustain operations, we set a goal of 0.7 pod per aircraft (with a lower bound of 0.6). With a decentralized structure, spares must be sized to support surge operations because pods cannot be shared across units. Thus, we show availability for aircraft flying surge operations. One reason that we set the ratio of pods to aircraft at these levels is because, given our attrition assumptions, we find that by 2008 the USAF will not be able to meet a goal of 100 percent avail-
The maximum two-MTW requirement for targeting pods in 2008 may range from 95 units (for a two-day deployment and setup time) to 256 units (for a 10-day deployment and setup time) above the predicted number of available pods. Since the USAF is not planning on purchasing new LANTIRN pods at this time, we assess how to achieve the maximum use of pods that will be in inventory in 2008 during potential contingencies.

Figure 3.4 shows the effects of deployment times on target pod availability. Specifically, we assumed that during peacetime AEF deployment there would be a ratio of one combat-capable pod for every aircraft deployed. The actual requirement includes safety and pipeline stock for various deployment timelines. In other words, if it takes 10 days to reestablish operations at an FOL, the stock assigned to the deployed units needs to account for surge operations during those 10 days. Once the deployed units’ stock requirement was satisfied, we assessed the availability of pods for the non-engaged units.

Because the peacetime with AEF scenario does not significantly stress the support system, we graph the effects of deployment during the second MTW flying a halt operation. The AWOS removal rates modeled were over 50 percent higher than those predicted with current algorithms and varied by aircraft type (see Appendix F). Although the USAF has no policy on TRG pod availability during war, the goal we set for it is above the aircraft availability goal used in calculating RSPs, or 63 percent on day 10 of a contingency. By setting TRG pod availability goals of 80 percent, or well above the aircraft availability level of 63 percent, we ensure that aircraft are not down as a result of pod shortages. To account for scenario variability, we simulated (random selection) removal rates as well as other input parameters to develop 90 percent confidence intervals for resource requirements such as personnel and support equipment. These results will be discussed later in this report.

We assessed the availability of pods for both engaged and non-engaged aircraft. In the two-MTW scenario, there would be approximately 66 aircraft left in CONUS for training purposes. The dashed line to the left in Figure 3.4 shows the expected availability of TRG pods for non-engaged aircraft based on support equipment deployment and setup time, depicted on the bottom axis. Deployment time affects TRG pod availability through the surplus pods to be
available until repair capabilities are established. The top of this line shows that we can expect one TRG pod to be available for each non-engaged aircraft if contingency support deployment takes less than one day. For every one aircraft there would be one combat-capable pod to support training operations. The one-pod availability results from our goal of only 0.80 pod per engaged aircraft. If LANTIRN contingency support equipment deployment and setup time takes more than one day, then TRG pod availability begins to decrease. If MTW contingency support deployment and setup time takes more than four days, there will be no pods available to support training missions.

Deployment times beyond four days affect TRG pod availability for engaged aircraft, as shown by the solid line on the right in Figure 3.4. As deployment times extend from five to 10 days, pod availability drops by close to 40 percent for the 378 aircraft engaged in sustain operations for the first MTW and surge in the second MTW. Again, deployment times of less than one day do not affect pod availability for non-engaged aircraft, deployment times from one to four days limit the number of pods available for training aircraft, and deployment times beyond four days affect pod availability for aircraft engaged in contingencies.

Deployment times of the current LMSS are more than 10 days, or long enough to lower TRG pod availability rates below 0.50 good pod per aircraft, well below the level selected to support sustain operations. Investment in an ADK upgrade for the current system, however, may mitigate this deployment sensitivity. ADK deployment is estimated to take just two to three days (assuming that strategic airlift is available on day two of combat operations), while that of the current LMSS is over 10 days. Note that although we used specific ranges in our assessment, the decentralized option is extremely sensitive to deployment and setup time. Because the current support structure without equipment upgrades is expected to take at least 10 days to deploy and set up, it appears that a decentralized structure with no equipment upgrades introduces tremendous risks to warfighter capabilities in a two-MTW scenario.

Although the ADK investment may offer some advantages to the current system, particularly in avoiding the risks of lengthy deployment, it does not eliminate the greater need for spare LRUs that de-
centralized systems have over centralized systems (see Appendix E). Data from the Warner Robins SPO in 1998 show that LRU depot repair time—the time from when an unserviceable LRU was received at a depot until the serviceable LRU was shipped out—exceeded 30 days. We included transportation times to assess the total loop time from an FOL to the depot and back again. As of June 1999, depot repair times had dropped to 26 days. Because the time LRUs spend awaiting parts accounts for much of the repair lag, we believe that further improvements in repair times may be possible. Still, even if the total loop times were cut to 20 days, we project a substantial investment would be needed for spare LRUs. We estimate (using pre-AWOS data) that $6 million is needed for spare LRUs in a decentralized structure, with or without the ADK investment, whereas only some $250,000 is needed for spare LRUs in a centralized structure. Clearly, spares planning based on the AWOS data will substantially increase the investment requirements (by over 50 percent), although the relative difference between centralization and decentralization should not change significantly. Although new LRU spares are needed for either a centralized or a decentralized structure, the decentralized structure requires a higher level of investment because it has higher safety stock requirements owing to its greater number of locations. The time loops needed for LRU repairs point to an additional sensitivity of time for the decentralized structures.

Centralized Structures

A decentralized system is sensitive to deployment time, and a regional structure is sensitive to transportation time. Just as delays in deployment affect TRG pod availability in a decentralized structure, so delays in transportation between support and operating locations affect availability in centralized structures.

Figure 3.5 shows how transportation times affect TRG pod availability in a centralized structure. We modeled all elements of door-to-door delivery as the total one-way transportation time, including packing, moving, and delivery of pods.

We assess pod availability during the second MTW as a function of one-way transportation time, as shown in the horizontal axis of Figure 3.5. As we did for analyzing time sensitivities in the decentralized structures, we use availability goals of 0.8 pod per aircraft for surge
aircraft and 0.7 pod per sustain aircraft (with a lower bound of 0.6). The dashed line to the left shows the expected availability of TRG pods for non-engaged aircraft: non-engaged aircraft can expect one pod per aircraft availability if one-way transportation time for a centralized repair structure is less than two days. If one-way transportation time between operating and centralized repair locations exceeds two days, however, pod availability declines. If one-way transportation time exceeds four days, there would be no pods available to support training missions, and pod availability to the warfighter starts to decline. The thin solid line shows pod availability for aircraft engaged in sustain operations for the first of two MTWs. As transportation times extend from four to 10 days, we allowed pod availability to drop to 0.6 pod per aircraft for the 186 aircraft engaged in sustain operations for the first MTW; nonetheless, availability for the aircraft flying surge operations also declines.

The bracket on the figure shows the average logistics response time (LRT, including backorders) range achieved during the AWOS for
Support Options and Performance Measurements

inter- and intratheater transport. Additionally, AWOS data indicate that CONUS-to-theater transportation may have greater variability than intratheater movement. This implies that LANTIRN support cannot rely on a CONUS-only support structure because greater pipeline variability will require more pod spares than are available. Thus, relying on support based only in CONUS would result in lower pod availability levels than are needed to wage two overseas MTWs.

Regional support structures composed of a CONUS location and two or more OCONUS locations can be designed to provide one-way transportation times of three to five days between support and operating locations, as demonstrated in the AWOS. However, any regional structure is very sensitive to transportation delays, with transportation times of more than two days affecting non-engaged aircraft used for training and those of more than four days affecting MTW sustain and surge operations.

Footprint

A second performance metric we use in comparing logistics structures and investment options is deployment footprint. We define footprint in terms of the number of personnel and pallets of support equipment that must be deployed to support contingencies. Figure 3.6 shows personnel and equipment pallet deployment requirements for centralized and decentralized repair options.
supporting peacetime with AEF or MTW operations using illustrative wartime flying profiles and the AWOS pod removal rates. We show the 90-percent confidence level generated from our simulation model (see Appendix A).

In Chapter Two we discussed the element of time and how a decision to centralize or decentralize repair hinges on the risks the Air Force is more willing to accept. We now shift our attention to the deployment footprint associated with these two options. Deployment footprint affects system performance through its effects on deployment and setup times. The larger a deployment footprint is, the more difficult it may be to attain strategic airlift early in a contingency. We assume that trainees deploy only to support AEF combat operations and so compute the minimum personnel resources required for MTW operations. For boiling-peacetime AEF operations overseas, the current structure may require a deployment of 44 to 48 personnel and 30 to 88 pallets of equipment to support 30 to 40 aircraft per AEF.

Similarly, the centralized structure could require a deployment of up to 48 persons for such operations but no equipment deployment. For halt-phase operations in a two-MTW scenario, the current structure may require a personnel deployment of 100 to 112 persons and an equipment deployment of 105 to 374 pallets.\(^1\) The centralized structure could require a deployment of up to 75 persons (assuming that OCONUS sites are manned at minimum levels with no trainees) for such operations but, again, would require no equipment deployment.

Technology upgrades and consolidation levels account for considerable variation in equipment and personnel deployment requirements. Investment in the ADK upgrade to the LMSS, for example, cuts equipment deployment requirements. Deployment of the current LMSS in a decentralized structure supporting the halt phase of a second MTW may require 374 pallets, whereas deployment of this system with an ADK upgrade could require some 105 pallets. These estimates are based on an 80 percent test set availability rate, which we discuss in the next section. We also show that the total test set requirement is above today’s Air Force inventory.

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\(^1\)The LMSS requires approximately 11 pallet positions for deployment whereas the ADK requires approximately five.
There are three further influences on personnel deployment requirements. First, consolidation cuts personnel requirements by requiring fewer test sets and, hence, fewer personnel. Second, the 60-percent peacetime productivity assumption used to set manning levels greatly inflates the number of personnel required at regional locations. Essentially, this productivity assumption leads the Air Force to buy an “insurance policy” to support potential conflicts. Third, by establishing and enabling USAFE and PACAF regional sites to support rotational AEF forces of 30–40 aircraft, the total number of personnel prepositioned in potential hot zones could increase. Through consolidation, the USAF could manage to keep a substantial number of personnel in theaters of strategic interest but at greater distances from operating locations, thereby reducing personnel turbulence as well as operational and personnel risk during conflicts. Clearly, this must be balanced by the CONUS-to-OCONUS personnel ratios the Air Force needs to maintain. In Figure 3.6, we assume that FSLs are not manned with people to support AEFs; thus, the peacetime personnel deployment numbers are similar to the decentralized structure.

Test Sets and Manning

Not only do the numbers of equipment and personnel to be deployed vary by structure and contingency, so do the total quantities needed. We next give the resources needed by the two main support structure options—decentralized and centralized—to meet the operating requirements across various scenarios. We focus on the test equipment and personnel needed to meet the peacetime-with-AEF and the two-MTW scenarios. Appendix F discusses several key sensitivities uncovered in our analysis as well as a comparative assessment across the range of consolidation options.

Figure 3.7 is an example of how we computed the 90-percent confidence level for test set requirements. Each simulation run of our models generates a curve for the cumulative probability of requiring a given number of test sets. In this case, we show this distribution for

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2A 90-percent confidence level implies that in our Monte Carlo (random) draw simulation, there is a 90 percent probability that the number of resources selected will be able to support the expected demand on the repair shop.
upgraded equipment during peacetime in CONUS and in two MTWs, one in SWA and one in NEA. The dashed lines represent the 90-percent confidence interval for each region. For example, given an 80 percent availability for the support equipment, SWA may require 14 test sets to have a 90 percent probability of supporting all of the wartime demands. Summing the number of testers in each region, we obtain the global requirement—in this case about 39. This value is again reflected in Figure 3.8, on the right-hand side under centralized, upgraded equipment. A similar approach was used to develop the confidence levels for personnel requirements.
Figure 3.8 shows the 90-percent confidence level for the number of test sets needed to support both peace and two-MTW-wartime operations given today’s support equipment or the upgraded version, and AWOS removal rates. We show expected requirements at an 80-percent availability level and discuss sensitivities to this assumption in Appendix F.

Three observations can be drawn from these figures. First, investing in support equipment upgrades does not significantly reduce the number of test sets needed, given an equal availability level. Predicting the performance of either today’s equipment or that with upgrades is very difficult, so we assessed the sensitivity of this metric and found only minor changes to the overall requirement quantities. Thus, the largest potential benefit to upgrading the support equipment may be in improving the deployment footprint, as discussed earlier. Clearly, if the Air Force chooses to centralize repair operations, deployment footprint becomes a negligible point.
This leads us to the second point made by the figures. Shifting from a decentralized to a centralized support structure may not necessarily reduce the total number of test sets needed to support wartime operations because most sets in CONUS would not support the effort and OCONUS sizing needs to include AEF deployments. However, centralization reduces repair operation sensitivities to support equipment spare shortfalls, as discussed earlier. Additionally, we show in Appendix F that other consolidation options may offer economies of scale and hence resource requirement reductions. Again, this implies that the most significant advantage to centralization is reduction of the deployment footprint, and as demonstrated in the AWOS, this can benefit combat support. Finally, and most important, Figures 3.7 and 3.8 indicate that the Air Force is underresourced to support two coincident MTWs. Across all options, the peacetime requirements are for 22–27 sets. With a current inventory of 21 testers supporting combat-coded units (solid line in Figure 3.8), the Air Force may have enough equipment for peacetime operations. However, the two-MTW scenarios modeled indicate that the total inventory may need to increase by over 50 percent to ensure warfighter support. With new testers costing close to $20 million each, this finding has broader cost and planning implications. If the Air Force (and the Defense Department) want to continue planning for two coincident MTWs, there may need to be a significant investment to ensure support of LANTIRN resources. Alternative remedies could be to rely more heavily on other PGM technologies or to revise the WMP and DPG scenarios.

The total personnel requirements across this decision space are not as daunting. Figure 3.9 shows 90-percent confidence levels for the number of people required across the options discussed above, with an expected test set availability of 80 percent. We computed wartime personnel requirements (excluding trainees) to reflect minimum manning numbers. The peacetime bars reflect both direct labor personnel and trainees. Again, there is little difference between investment options and logistics structures. Furthermore, our models indicate that there may be sufficient people to support multiple contingencies (current assigned total is 307—see the solid line). Again, this implies that the primary tradeoff between centralization and decentralization hinges on deployment and transportation capabilities.
Clearly, incorporating skill-level degradation and trainees for combat operations could increase this number somewhat. Because modeling these effects is difficult, we assessed the relative sensitivity of our outcomes to pod repair time (one measure of operator skill level). This metric offers a measure of how well people work, in other words, the number of pods a given crew can process. We discuss this sensitivity in Appendix F.

Recurring and Investment Costs

The performance metrics we have reviewed indicate that new investments are required to upgrade the current equipment to meet the support needs of a two-MTW halt-phase scenario. One of the metrics we need to consider for LANTIRN support structures is the new investment required for equipment upgrades, infrastructure, spare LRUs, and personnel relocation. Investment costs are not the only financial variable to consider when evaluating systems. Each
structure carries recurring costs for peacetime labor and transportation. We consider both recurring operating costs and nonrecurring investment costs using expected cash-flow models. We discuss the calculations for our present-value analysis in Appendix H. As pointed out earlier, our assessment of AWOS data indicates that the Air Force may need to increase its equipment inventory by over 50 percent. Because we were unable to obtain accurate acquisition costs for new support equipment, we did not model the expected costs of purchasing additional testers. The relative recurring cost differences across all the options are negligible given a fixed set of inputs. Appendices F and H offer a comparative analysis of the options analyzed, including the AWOS removal rates, and illustrate this point. Again, the Air Force’s decision should focus on expected capabilities and risks rather than the costs of the various options.