A RAND NOTE

Management Adaptations in Jet Engine Repair at a Naval Aviation Depot in Support of Operation Desert Shield/Storm

Lionel Galway

RAND

The research described in this report was sponsored jointly by the Navy Secretariat, NAVAIR-43, and NAVSUP.

Published 1992 by RAND
1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138

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N-3436-A/USN

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Prepared for the
United States Navy

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PREFACE

In November 1989, RAND presented a series of hypotheses and results from exploratory research to a group of senior Naval logisticians at the Naval Postgraduate School, Monterey, CA, as the basis of a proposed project on Naval aviation logistics. The proposed project was to consider how lessons learned in previous RAND logistics research might apply to the Naval aviation logistics system, particularly the operation of the Naval aviation depots (NADEPs), and to consider how the detrimental effects of uncertainty on mission capability, particularly in wartime, might be offset by management adaptations.

Operation Desert Shield/Storm (ODS/S) provided a unique opportunity to study the management adaptations used by specific NADEPs to provide support to the fleet during an unanticipated contingency. This document presents observations on management adaptations, primarily in materiel support, used by the engine shop at NADEP North Island (San Diego, CA) to handle the challenges of the production surge it carried out in support of ODS/S. This document should interest Naval maintenance and supply officers. Moreover, because some of the problems faced by the Naval aviation logistics system are common to all services, it may also interest logisticians in the other services as well.

The work reported in this Note was done as part of the project *Enhancing the Logistics System: The Depot Perspective*, sponsored jointly by the Navy Secretariat, NAVAIR-43, and NAVSUP.

SUMMARY

INTRODUCTION

From November 1990 through the end of February 1991, six carrier battle groups and two Marine air wings operated simultaneously in Southwest Asia in Operation Desert Shield/Storm (ODS/S). This massive deployment of Naval and Marine aviation units put pressure on the Naval supply system to provide needed parts and supplies. Since certain items, such as jet engines, were particularly susceptible to breakdowns in the harsh desert environment in which the forces were operating, some divisions of the Naval aviation depots (NADEPs) were tasked to "surge" selected repairs to provide the theater with spare end items and repair parts. One such division was the engine shop at NADEP North Island (San Diego, CA) which, among other tasks, was asked to surge its repair of T64 jet engines, the engines used in CH-53 helicopters.

This Note focuses on the surge-related problems faced at North Island and on the management adaptations, particularly in materiel support, devised there in response. We visited North Island to discuss the production surge. To put North Island's experience in its proper context, we also visited the NADEPs at Cherry Point, NC, at Jacksonville, FLA, and at Norfolk, VA, as well as the Naval Air Systems Command in Washington, D.C., and the Aviation Supply Office in Philadelphia, PA.

SURGE IN THE ENGINE SHOP

The surge was preceded by a planning phase of a week or so, during which the engine-shop management assessed the available resources--repair parts, unserviceable assets ("carcasses"), equipment, and manpower--and organized the work. From the beginning, managers solicited ideas from the work force on all aspects of the surge, some of which proved crucial to the surge's success. The surge lasted from the middle of December 1990 until the middle of January 1991, by which time the engine shop had come close to exhausting available engine carcasses and the stock of certain critical repair parts.

PROBLEMS AND MANAGEMENT ADAPTATIONS

The engine shop management faced a number of challenges in planning for and executing the surge. During planning, the managers had to construct a bill of materials (BOM) for the T64 engine before they could determine whether they could meet the surge targets and which repair parts were needed. In addition, the depot planners had to make

their materiel estimates based on limited knowledge of what additional wear would be generated by desert operations.

During the surge, the engine shop used two different types of management adaptations in materiel support: *item-oriented* (concerned with the repair of specific items) and *process* (changes to the overall repair process). The item-oriented adaptations included dealing with severe shortages of several critical parts, especially compressor blades, by working closely with the manufacturer (General Electric) and by refurbishing worn blades in the shop. They also included shortening the fuel control repair process used during engine repair, saving almost one-seventh of the total engine repair time.

Process adaptations included the modification of policies on mandatory overhaul and setting priorities for the induction of carcasses into repair. Management also worked to find parts by searching throughout the DoD supply systems and by going directly to commercial sources. Navy information systems were used where possible, but management often had to resort to telephone calls to locate potential supply sources.

KEY OBSERVATIONS AND RECOMMENDATIONS

Although the surge demonstrated that the NADEPs can provide a surge capacity vital to a contingency like ODS/S, there are lessons to be learned from what did and did not proceed smoothly. We observed four key areas that deserve attention because of their value for future contingencies.

First, we observed that materiel support was a major problem for all NADEPs involved in the surge. This problem was actually three separate problems: (1) some unique, critical parts were available from only one supplier and that supplier's capacity was limited; (2) some parts that were readily available commercially were not in stock in the DoD supply system; and (3) the visibility of parts located in certain parts of the DoD supply system was limited at the NADEPs.

To address the first materiel-support problem, we recommend that the Navy determine the extent to which it depended on defense suppliers for critical parts during ODS/S. Where this dependence was significant, policies must be formulated to ensure that critical parts from such suppliers are available in future contingencies. For the second problem, we suggest that the Navy look at those cases in which parts not in stock in the DoD system were easily available from commercial sources to focus ongoing initiatives aimed at improving procurement processes. For the third problem, we recommend that the services and DoD improve asset visibility in all parts of the DoD supply system. A related issue, distribution, also played a significant role in materiel support. Anecdotal evidence from our

visits suggests that the switch from military transportation channels to commercial alternatives during ODS/S substantially improved the speed and accuracy of deliveries.

Our second key observation was that the lack of a BOM for the T64 was a serious problem for surge planning. This finding suggests that the Navy should build BOMs for all major end items and maintain those BOMs during normal depot operation to keep track of parts required during regular repairs.

Our third key observation was that the lack of retrograde and retrograde visibility experienced in ODS/S may be a serious problem in future contingencies. Had the NADEPs been required to produce more engines for ODS/S, they could not have done so without getting carcasses back from Southwest Asia. This finding suggests that the Navy (indeed, probably all of the services) needs an information system to track retrograde and a transportation system to move retrograde expeditiously. The overall responsibility for these systems seems best suited to DoD, since the responsibility for retrograde transport is shared by a number of transportation agencies.

Our fourth and final observation was that the surge highlighted the payoffs of communication, particularly in terms of innovations and process improvements. Benefits accrued from both *vertical* communication (i.e., between intermediate levels of the NADEPs and the central organizations of Naval aviation maintenance and supply) and *horizontal* communication (i.e., between workers within the NADEPs). Unfortunately, however, the continued shrinking of the DoD work force has probably already undermined these benefits. The Navy should consider the benefits of vertical and horizontal communication in planning for future contingencies.

ACKNOWLEDGMENTS

The author is indebted to a number of RAND colleagues. Marygail Brauner and Dan Relles, who participated in the visit to NADEP North Island, shared their observations and ideas. Chris Tsai reviewed the document and substantially improved its presentation. Jack Abell, Mort Berman, Jim Hodges, and Craig Moore reviewed early drafts and made many helpful suggestions. Paul Steinberg read several drafts; his comments greatly improved the document's organization and readability. Jeri O'Donnell expertly edited the final version.

Several Navy people read this draft and offered their comments and perspectives, among them RADM Donald Eaton (Commander, Naval Air Systems Command) and LCDR Mike Whitaker (Royal Navy), the Engines Project Officer, NADEP North Island. The greatest debt is owed to the many people at the North Island, Norfolk, Cherry Point, and Jacksonville NADEPs and to various personnel at the Aviation Supply Office and the Naval Air Systems Command who patiently answered a multitude of questions about their work in support of Operation Desert Shield/Storm.

CONTENTS

1. INTRODUCTION

BACKGROUND OF RESEARCH

Logistics research at RAND has focused on war and the transition from peace to war. The overarching theme of that research has been that the great uncertainty surrounding when and where U.S. forces might go to war will require ad hoc decisions by logisticians to adapt to unforeseen developments. Thus, one of the central concerns of logistics planners should be to set up flexible and responsive logistics organizations that have the ability and resources to make such adaptations.[1] It follows, then, that actual mobilizations and ensuing hostilities can enable us to evaluate how well our plans work and how flexible our organizations are. Most important, these events, if carefully analyzed, can allow us to identify capabilities and policies that will help us meet future contingencies. Operation Desert Shield/Storm (ODS/S) provided such an opportunity.

During peacetime, the Naval aviation depots (NADEPs) provide a wide range of industrial support to the Navy and Marines. This support includes depot overhaul of aircraft and engines, all of the various repair programs (engines, avionics, components, etc.), and specialized manufacturing in response to fleet needs. With few exceptions, the depots seldom repair parts for direct shipment to squadrons deployed with the fleet.[2] However, the massive deployments during ODS/S put pressure on the Naval supply system to provide enough repair parts and spare end items to meet the needs of the anticipated combat and the depredations of the harsh desert environment.[3] As a result, some divisions of the NADEPs were tasked to "surge" selected repairs. In particular, the engine shops of NADEPs responsible for the jet engines on selected helicopters, attack aircraft, and transports were

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[1]The research referred to here has spanned at least fifteen years. Two reports that summarize this work and provide pointers to the original work are:

Hodges, J. S., with R. A. Pyles, *Onward Through the Fog: Uncertainty and Management Adaptation in Systems Analysis and Design*, RAND, R-3760-AF/A/OSD, 1990.

Cohen, I. K., J. B. Abell, and T. F. Lippiatt, *CLOUT (Coupling Logistics to Operations to Meet Uncertainty and the Threat): An Overview*, RAND, R-3979-AF, 1992.

[2]The NADEPs do operate the Request Manufacturing Assistance (RMA) program and the Direct Fleet Support (DFS) program. The first provides special manufacturing for special parts ordered by the fleet through the Aviation Supply Office (ASO); the second provides rapid-repair turnaround for parts needed by squadrons preparing to deploy. To be eligible for the latter program, the repair has to be "minor," there must be no ready-for-issue (RFI) assets in the Naval supply system, and the lack of the part must be holding down an aircraft. Both of these programs were used in ODS/S.

[3]From November 1990 through the end of February 1991, six carrier battle groups and two Marine air wings operated simultaneously in Southwest Asia.

required in late 1990 to repair a substantial number of spare engines in preparation for Operation Desert Storm.

OBJECTIVE OF RESEARCH

The central focus of our project was the potential for enhancing the NADEP contribution to fleet support in times of unanticipated demands. We were thus interested in the materiel and organizational problems faced during the surge that were caused by the sudden change in scheduled engine repairs. In addition, the long history of RAND logistics research, with its emphasis on management adaptation as a counter to wartime uncertainty, led to our particular interest in the adaptations employed by the engine shop to counter the problems it faced, particularly problems with materiel support. At the invitation of LCDR Mike Whitaker (RN), the Engines Project Officer, we visited NADEP North Island (San Diego, CA) on February 22, 1991, to discuss the production surge carried out there in support of ODS/S. North Island had had the most intensive production increase, but other NADEPs had also been involved. Thus, to get a more comprehensive view of the engine surge, we also paid visits to the NADEPs at Cherry Point, NC (the primary depot for Marine aviation), at Jacksonville, FL, and at Norfolk, VA. We also talked with people at AIR-43 and AIR-410 at Naval Air Systems Command (NAVAIR) who had coordinated the engine surges and computed the engine requirements. Finally, contacts at ASO gave us details on the situation for the production of engine spare parts.[4]

Because the engine-production surge was more intense at North Island than at the other NADEPs, this Note focuses on the problems faced at North Island and the management adaptations devised there in response. However, the other NADEPs faced most of the same problems, and, indeed, many of the problems surface in less extreme form in the day-to-day operations of all NADEPs. Where appropriate, we broaden the discussion to include insights from the other NADEPs we visited.

The personnel of the North Island engine shop had a list of adaptations they thought had worked well. In fact, they told us they intend to make some of the most successful ideas part of depot management. They were also candid about problems they faced--problems that in many cases had been surmounted but, they felt, could be avoided in the future. We focused on the engine shop because it was the part of the North Island depot most severely stressed by ODS/S. Shops in areas such as avionics also had increased production demands,

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[4]Our interviews at the relevant depots and NAVAIR were supplemented by information on naval air operations gathered in the course of research in our main project and by a visit to the headquarters of the U.S. Marine Corps to discuss the organization of logistics for Marine aviation.

and almost every part of the depot had to contend with increased workload, tightened security procedures, and the absence of reservists who had been called to active duty. However, the intensity of the surge in the engine shop set it apart.

ORGANIZATION OF DOCUMENT

Section 2 describes the chronology of the surge, from the tasking by NAVAIR in December to the end of the surge in the middle of January 1991. Section 3 details the problems, particularly in the materiel area, faced by the North Island engine shop in planning for and executing the surge, and how management adaptations were used to solve those problems. Finally, Section 4 gives our observations and opinions on the engine shop's solutions and our opinions on how the lessons learned from the surge can be applied to preparing the NADEPs to support future contingencies.

2. SURGE IN THE ENGINE SHOP

REQUEST TO SURGE

From the Iraqi invasion of Kuwait on August 2, 1990, until early December 1990, ODS had no major effect on NADEP North Island. The depot did some overtime work in a few critical areas, such as repairing equipment used in chaff dispensers. In addition, the depot deployed some field service personnel to Southwest Asia to augment the staff of in-theater repair facilities. These facilities were scattered throughout the theater and were not concentrated in a theater depot.

On December 10, 1990, however, the situation changed. NAVAIR faxed a single handwritten sheet to the NADEPs at North Island, Norfolk, Jacksonville, Alameda, and Cherry Point that listed a set of jet engine types and indicated quantities required and NAVAIR priorities. The top priority was given to helicopter engines, but the list also included engines for the F/A-18, the C-130, and the AV-8B Harrier.[1] The depots were directed to respond as quickly as possible as to whether they could produce the required number of engines and to detail the problems they could foresee.

The quantities on the list were substantial increases above the usual depot workloads, and there was some controversy between NAVAIR and the NADEPs over the production targets.[2] One depot pointed out that for an engine that was its primary responsibility, the NAVAIR "minimum requirement" exceeded the total number of available engines not already installed in aircraft. The depots also expressed concern that they would be hampered by repair-parts problems and carcass availability. After these two factors and the manpower and equipment constraints were analyzed, NAVAIR and the depots agreed to reduce requirements for some engines, although the final targets were still daunting. For North Island, the total requirement for the three series of T64s it repaired was 44, still a 440 percent increase over a normal month's workload.

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[1]The concern was that helicopters, transports, and ground attack aircraft would be most exposed to the harsh desert environment.

[2]For example, North Island was the sole repair source for NAVAIR's number one priority engine, the T64, which is used on the CH-53 helicopter. In peacetime, the depot produced 30 in one quarter; the ODS requirement was for 75 to be produced in one month, a workload increase of 650 percent.

THE SURGE

On December 15, 1990, the engine shop began the surge in earnest; all shops went to 12-hour days, with key areas working around the clock. The depot held this pace for a month, until the middle of January, with a respite only on Christmas and New Year's Day.[3] As workers disassembled, repaired, and reassembled engines, managers had the task of making sure that critical repair parts from manufacturers and reparable carcasses from the Naval supply system kept flowing into the shop.

END OF SURGE

By the middle of January, the surge began to slow down. The engine shop had met the revised target of 44 T64 engines and had supplied components for fleet repair requested by ASO. However, the engine shop was running out of parts because General Electric (GE) and its subcontractors were meeting less and less of the projected demand for compressor blades. Further, the Naval supply system was virtually out of reparable carcasses (for some versions of the T64) and some critical repair parts, and only six carcasses had been returned to North Island from Southwest Asia. As hostilities commenced in Kuwait and Iraq, the engine shop reduced its work intensity from a surge to a state described as "heightened business as usual": its target for the second quarter of the fiscal year was about 57 engines (about double the normal workload).

On January 15, as a postscript to the surge, ASO sent the NADEPs a new list of targets for component repair. Once again, there were incongruities in the list: North Island was requested to provide 110 compressors even though only 22 blade sets were scheduled for delivery from GE, and to provide 62 rotor heads (which require over 1000 hours to repair) even though RFI-condition stock seemed to be available. Because of the surge negotiations that had taken place in December, North Island took a more skeptical view of these new targets, particularly since ASO had set no priorities on the items in the list. At a minimum, North Island felt it needed guidance to direct its constrained repair resources so that the most-needed components would be repaired. When queried for priorities, ASO reportedly invited North Island to set its own.

At the time of our visit in February, there was an underlying current of uneasiness as the managers looked toward the rest of the year. The surge had resulted in a vast increase in costs for North Island, primarily due to overtime, and there was at that time no indication

[3]Work on Christmas Eve and New Year's Eve was voluntary, but enough volunteers came forward to keep work flowing in critical work areas.

that North Island would be helped out financially by the end of the fiscal year. This situation raised the prospect of having to lay off the workers who had accomplished the surge.[4]

[4]As of this writing, with ODS/S completed and the restructuring and downsizing of the defense organizations continuing, the NADEPs have undergone significant force reductions.

3. PROBLEMS AND MANAGEMENT ADAPTATIONS

SURGE PLANNING

In preparing to meet the goals of the surge, the planners at North Island first sought to identify the constraints that would have to be faced in terms of stocks of repair parts, carcasses, and available manpower and machinery. The hope was that adaptations could then be found to allow the depot to remove or work around the constraints.

There was an immediate obstacle: there was no central bill of materials (BOM) for the T64 engine and no centrally available information on repair factors for various parts.[1,2] The materiel planners thus could not initially evaluate the adequacy of the stocks of repair parts at the depot and the local Naval Supply Center (NSC). They convened meetings of engineers, materiel planners, and production workers to go over each segment of the repair process to arrive at a BOM and replacement factors through judgment and consensus. The planners then used the BOM and replacement factors to assess the stocks of on-hand materiel and to determine which parts were in critically short supply. This procedure took about a week of 16-hour days.

The depot planners also had limited knowledge of what additional wear would be generated by desert operation.[3] To determine the effect of the desert environment on helicopter jet engines, NAVAIR sent a small team to Italy to examine two T64 engines from helicopters that had been flown in the desert. The team found that engines subjected to desert operations would likely need substantially more work than the engines the depot had repaired to date. In particular, the compressor blades would probably need complete replacement, instead of partial replacement, which would almost double the average cost of repair (from about $54,000 to over $100,000). The team also found that most of the engine seals had become impregnated with sand and needed replacement. Even the turbines

[1]The BOM is a list of the parts and assemblies needed to build the engine. Many Navy jet engines either have no BOM or have one that is limited in scope. This is *not* to say that artisans do not know what parts are typically needed for repair jobs. However, since repair parts are never requisitioned in advance of engine induction and preliminary inspection, little attention has been given in recent years to centrally recording BOM and repair factor information. This topic is controversial and is under reconsideration within the depot system.

[2]Not all parts in the engine are needed for each repair. The failure factors are the proportion of repair jobs that require a given part. As such, they allow a rough assessment of the adequacy of parts stocks.

[3]This concern stemmed from the engine shop's natural assumption that it would soon be repairing and overhauling engines returned from Southwest Asia.

showed the effect of desert operation: the small cooling channels in the blades were blocked by fine sand, causing overheating and damage. All these problems caused great concern at the depot, because they indicated that repairing engines returned from ODS/S might well require more time and materiel than repairing the carcasses in hand.[4] The planners made their materiel estimates accordingly.

In contrast to repair-parts stocks, carcasses, personnel, and equipment were lesser problems. The most serious initial equipment problem was that the engine shop began the surge with only one operational engine test cell for the T64. A second test cell, which had been in overhaul for two years, was made operational and brought on line just after the surge started. However, because there were only two qualified test cell operators and they were working alternating 12-hour shifts during the surge, the two test cells served as backups for each other instead of being run in parallel.

The depot was also concerned with component repair and its demands on repair resources. NADEPs repair not only engines, but also many of the parts of the engine (contractors repair the remainder). Some of these components are then used by the depot for engine repair, while the rest are shipped to the NSC for distribution to the fleet for engine repair at the intermediate-level (I-level) shops.[5] Given the harsh flying environment in the theater of operations, a substantial increase in the deployed units' demand for engine parts was expected, which would translate into fewer of these parts being available to support the depot's own engine repair surge. The depot sought to balance these competing demands so as to maximize the production of both engines and components.[6]

As the depot swung into the surge, the planning team took one more step. It put much emphasis on asking all workers to contribute ideas in any field: "any idea--new or old, big or small, technical or personal--is a good idea if it helps support the effort." This "bright-idea" campaign was an outstanding success and contributed to some of the adaptations discussed below. The depot plans to make this program a permanent part of depot operations.

MATERIEL SUPPORT

As the surge proceeded, problems arose that required adaptations by the management and workers. To address most of these problems, the engine shop employed two different types of adaptations: *item-oriented adaptations*, which are concerned with the availability

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[4]In fact, replacement compressor blades became the primary materiel problem.

[5]Naval aviation repair is conducted at three levels: the land-based depots, the I-level shops, and the organization-level (O-level) with individual squadrons.

[6]The two programs did not appear to have experienced a severe conflict during the surge.

and repair of specific items, and *process adaptations*, which are modifications of the repair process.

Item-Oriented Adaptations

Compressor Blades. From the beginning of the surge, compressor blades were recognized as the key materiel problem for the T64, and most of the materiel management problem-solving went toward ensuring an adequate supply of blades.[7] The depot held frequent conferences with GE (the engine manufacturer), ASO, and the Defense Industrial Supply Center (DISC) to discuss forecasted requirements and long lead-time items, review critical parts, and determine order status. Typically, the depot also presented information about which set of blades currently had the worst asset position, and GE made special efforts to work on that requirement.[8]

An important innovation was that blades were shipped directly from GE to the depot, bypassing the NSC and eliminating an average delay of several days.[9] Depot personnel told us that all the usual acceptance paperwork was still processed, but by the depot rather than the NSC. In at least one case, in which a truck arrived late on a Friday evening, crews were allowed to go to the truck and unload the parts needed for weekend work.

Fuel Control. During repair of Navy T64 engines at the NADEP, the fuel control is disassembled, all seals are replaced, and the controller is recalibrated and used in engine reassembly. This process takes 109 hours. However, on the T64s that North Island repairs for the U.S. Air Force, complete disassembly of the controller is not required unless its seals are leaking. After engineering review, the engine shop adopted this practice for fuel controls from Navy engines as well, saving almost one-seventh of the total engine repair time.

Replacement of Compressor Blades. One of the suggestions received in the bright-idea campaign helped the depot cope with the shortage of blades. In normal engine repair, any compressor blades that do not meet exact specifications are replaced, and the refurbished engine is then expected to have a lifetime of over 2400 hours before overhaul is again required. In desert operation, however, the expected life of a helicopter engine drops to

[7]Availability of compressor blades has been a chronic problem in the repair of almost all Navy jet engines, even during peacetime.

[8]The T64 has 14 sets of compressor blades, each different, and almost every set was a pacing item at some time during the surge.

[9]All of the depots we visited noted a substantial improvement in transportation during ODS/S, particularly when commercial carriers and direct shipment were used instead of military channels. Although depot personnel cited speed of materiel movement as one advantage, they were particularly appreciative of accuracy of delivery. They reported that during peacetime they were plagued by numerous instances of mislabeling and sloppy paperwork, which delayed proper delivery.

between 100 and 400 hours. It was argued that this severely reduced expected lifetime rendered some imperfections in the compressor blades tolerable. After analysis, the engineering staff agreed that certain tolerances could be relaxed with no effect on flight safety. Engine repair proceeded using the new tolerances.

Engine Accessories. Engine accessories include such ancillary devices as gearboxes and power generators. In general, engine shop personnel felt that, in contrast to GE's firm commitment to supporting the surge, the accessory manufacturers' responses to materiel problems were mixed. Also, engine shop materiel planners felt that ASO did not pressure the manufacturers for better support. The implication was that measures similar to those taken for compressor blades would have had a positive effect on accessory availability as well. However, no specific problems were cited, perhaps because no one accessory stood out as the cause of continuing problems, as was the case with the compressor blade sets.

Process Adaptations

Finding Parts. Although compressor blades were the most persistent problem, the depot managers told us that many other kinds of parts were problems at one time or another. To solve these problems, the materiel managers searched for repair parts throughout the DoD supply systems and in the commercial sector. Navy information systems made assets known to ASO visible, and the telephone was used extensively to locate parts, by upper and middle management if the need was urgent enough. However, non-ASO parts, i.e., those handled by the Defense Logistics Agency (DLA) and the other services, were not routinely visible to the depot.[10]

There were also some difficulties coordinating the demand for needed repair parts among the NADEPs. Although for ODS/S there was little overlap in engine surge requirements among the depots, some key parts for common engines were drained from the supply system by quick ordering. The problem was solved by redistribution, but could have caused greater difficulties if more items had been surged.

An area in which all NADEPs have had chronic problems concerns items readily available in the commercial sector but not in stock in the DoD supply system. During ODS/S, the individual depots were given more latitude to use commercial sources for parts. One of the depots reported that this ability to easily tap the commercial market solved most of the materiel problems that they had had going into ODS/S.

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[10]Some, but not all, areas of the depot had terminals to access DLA information systems.

Major Overhauls. The normal procedure is for a T64 engine to undergo a complete overhaul after 1800 hours of operation (major overhaul time, or MOT).[11] Overhaul involves almost completely replacing or refinishing most of the engine parts so that the engine is virtually new. By contrast, engine repair replaces only parts that are defective or not to tolerance. Since the desert environment was so harsh that engines were expected to have an operating life of at most 400 hours even after a complete overhaul, it was proposed that the MOT be extended by 300 hours (to 2100 hours) for the surge. For engines awaiting repair with operating times between 1800 and 2100 hours, just making the repairs needed instead of performing a complete overhaul would save the parts needed for overhaul plus much valuable labor time, and would give the engine 400 hours of desert operation anyway. After consultation, engineering agreed that the new MOT met safety standards. Seventeen out of 19 engines then awaiting work had operating times under the new MOT and so needed only repair. These engines were shipped in specially marked containers (and their log books appropriately annotated) so that field personnel would be aware of the maintenance change.

Setting Priorities for Induction. During normal operation, the depots induct carcasses from the NSC without examining them. This procedure is specifically designed to prevent the depots from preferentially inducting easy-to-repair carcasses, thus eventually leaving the NSC with a stock of carcasses beyond economical repair. The urgency of ODS and the need for working engines caused this policy to be overridden, and the depots were allowed to examine and pick engine carcasses so that the ones that were quickest to fix could be repaired first and shipped to the theater.

PERSONNEL MANAGEMENT

In addition to the materiel management adaptations, the engine shop implemented adaptations in personnel management (some of which were suggested by the workers) to support the surge. As a whole, the managers felt that the workers had performed at an even higher level than expected.[12] There had apparently been some pessimism during surge planning about convincing the workers and the union of the need for flexibility as well as overtime. This view was unfounded: the union worked closely with management, and the number of individual problems was vanishingly small. As an example of the workers' support for the surge, managers cited the response to their decision to make work voluntary

[11]The expected engine lifetime after overhaul is 2400 hours. The 1800-hour limit is considered to give a conservative safety margin.

[12]For example, union rules require one day of leave after fifteen days of work, unless specifically waived. Most workers waived the leave.

on Christmas Eve and New Year's Eve.[13] Workers volunteered in adequate numbers, critical areas were staffed, and production was maintained.

The surge crisis also brought a whole class of personnel-related issues to the fore. For example, finding child care for weekend workers was an unforeseen problem that caused some concern and discussion and was finally resolved by the workers themselves. Another issue involved ensuring that workers who were working in the surge did not lose excess unused leave days when the end of the calendar year passed, since the surge occurred during a period when many people usually take leave. The managers noted that resolving such issues through normal administrative channels sometimes required them to deal with a significant amount of bureaucratic red tape just when the surge required most of their time and attention.

Finally, a shortage of workers existed in such areas as engine assembly. With union agreement, managers solved this problem by using people with previous engine shop experience (including managers) to work as assistants in the engine shop, freeing regular workers for the tasks requiring the most skill.

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[13]The engine shop shut down on Christmas and New Year's Day.

4. OBSERVATIONS ABOUT THE SURGE

The NADEPs proved that they can provide the surge capacity vital to a contingency like ODS/S. North Island was able to mobilize its work force quickly and efficiently. Its in-house engineering capability was crucial at several points, when decisions were made to modify repair procedures and policies to streamline the repair process. The experience of ODS/S also demonstrated the value of close contact between the depot and manufacturers, both for solving problems and for significantly shortening the pipeline for getting materiel to the depot.

However, the NADEPs met their production surge demands only by facing and overcoming challenges. Our observations on four key areas that greatly affected how the surge proceeded are discussed below, along with recommendations to the Navy for addressing them.

MATERIEL SUPPORT

All the people we talked to in the North Island engine shop rated materiel supply problems as their first concern during the surge.[1] Throughout the surge, managers waged a constant struggle to keep materiel coming in ahead of the repair needs. Each time they would achieve a good supply position with respect to one part, another part would become a critical problem.

Part of the difficulty lay in the unforeseeable nature of the contingency: neither the NADEPs, the supply system, NAVAIR, nor ASO had anticipated and fully planned for a major deployment to the harsh desert of Southwest Asia. This situation is the nature of contingencies, not a reflection on those organizations. To a large extent, management compensated for this lack of specific planning by intensively managing repair parts, working closely with manufacturers on problem parts, taking direct delivery from the manufacturer where feasible to shave days off the transit time, and adapting repair processes (with appropriate engineering review) to make the most of their limited resources.

In retrospect, there were actually three separate materiel problems reported by the NADEPs. The first was with unique, critical parts manufactured specifically for the military. Production capacity for these parts was limited and was fully utilized. This problem is exemplified by the GE compressor blades. It should be noted that this critical piece of materiel management was outside the control of North Island and the Navy itself: without

[1]This was also the case at the Cherry Point and Jacksonville NADEPs.

compressor blades from GE, the depot would not have been able to surge engine repair. Both a responsive industrial base *and* a responsive depot were necessary. Managers at ASO told us that GE began procuring stock for the compressor blades it manufactured in August 1990, well before ASO had received authority to start ordering.[2]

Recommendation: *The Navy should determine the extent of its dependence on defense suppliers during ODS / S. If this dependence was significant, policies must be formulated to ensure that the Navy will be able to enjoy similar support in future contingencies.*

The second materiel problem was that some needed parts were not in stock in the DoD supply system even though they were available commercially. Personnel at one of the depots we visited said that most of the materiel problems with which they entered ODS/S were solved when they were allowed to buy more easily from commercial firms. This experience suggests that a significant part of the materiel problem may result from procurement difficulties--i.e., that in some important instances the Navy and/or the DoD supply system had difficulty negotiating supply contracts or getting delivery on them, even though the item was easily available.

Recommendation: *The Navy should utilize these experiences to focus its initiatives for procurement process improvements.*

The third materiel problem had to do with obtaining parts that were in the DoD supply system. In particular, the depots' ability to adapt to the contingency was hampered by the lack of asset visibility: planners at the depots could not easily see stocks managed by DLA and the other services. Senior people had to work continuously to find parts in various nooks and crannies of DoD, primarily using the telephone and working piece by piece.[3] Shared visibility of defense resources in an up-to-date information system would have greatly alleviated this problem. If nothing else, adequate visibility would have allowed planners to focus on parts that were truly problems--i.e., those that were not in any of the defense supply systems and thus had to be bought from the commercial sector.

Recommendation: *The services and DoD need to improve asset visibility in all parts of the DoD supply system.*

As to which of the three materiel problems is the most prevalent, we found that all NADEPs reported all three problems, although not with equal emphasis. Most DoD

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[2]As noted above, plans for the surge did not begin to come together until November, both because of the diplomatic situation in Southwest Asia and the domestic political situation, which included prolonged budget negotiations.

[3]NADEP Jacksonville personnel estimated that one to two days were necessary for a reasonably complete search of the various portions of the DoD supply system.

Inventory Control Points (ICPs) give the majority of their attention to the second problem, perhaps because many solutions to that problem lie within their power.[4] However, in the T64 surge, the first problem was probably the pacing one in that the rate of delivery of compressor blades drove the demand for other items.

Recommendation: *To better understand how to allocate resources to address the three materiel supply problems, the Navy should conduct a detailed analysis to determine how these three problems rank in terms of pervasiveness and criticality.*

As noted in Section 3, all the NADEPs indicated that there were also problems with the distribution of parts to the depots, ranging from long delays to misaddressed or mislabeled shipments. Such problems interact with the three materiel supply problems mentioned above. We could not judge the seriousness of these related problems because we heard only anecdotes. However, that evidence indicates that the NADEPs highly valued the opportunity in ODS/S to ship materiel via alternative commercial means (rather than military channels) because of their speed and accurate delivery.

Recommendation: *The commercial shipment alternatives should be evaluated for regular use, and the criteria for decision-making should include the costs of delays and misrouted shipments.*

BILL OF MATERIALS

Before the engine shop planners could even decide if NAVAIR's production request was feasible, they had to have a BOM. The need to compile a BOM held up planning for a week. As the managers themselves noted, if they had been operating a Manufacturing Resource Planning (MRP II) system to organize repair, they would have been able to assess materiel requirements for the surge in minutes. An MRP II system uses BOMs and historical replacement factors to order much-used parts in anticipation of repair. Such forecasting is currently a part of repair management in the other services and in industry. It has also been used by the NADEPs, but within the NADEPs and the upper levels of the Naval aviation supply system there is currently a significant amount of argument about the accuracy, and hence the usefulness, of repair-parts forecasts.

Recommendation: *The ODS/S experience suggests that, at the very least, a BOM should be built up and maintained during normal depot operation for all major end items to*

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[4]ICPs are responsible for, among other things, ordering parts and insuring that stocks are adequate for anticipated demands. ASO is an ICP.

keep track of parts that are required during regular repairs.[5] *If possible, a complete BOM should be obtained from the manufacturer when an end item is first introduced into the fleet and then maintained through engineering changes and modifications until the item leaves service.*

The issue of maintaining a BOM for major end items leads to the broader question of standardized information systems and ties into the asset visibility problem discussed earlier. The issue is a thorny one, and not just for the Navy. All of the services have had problems in developing and maintaining standard maintenance information systems that allow oversight and planning of maintenance across all echelons.

Recommendation: *The Navy needs to continue its emphasis on developing and using a standardized, comprehensive maintenance information system in all of its depots.*[6]

RETROGRADE

There was general puzzlement at the lack of carcasses returning from Southwest Asia given the reputed harshness of the theater environment.[7] At the end of the surge, the depot had done about all the repair work possible without the return of unserviceable assets from Saudi Arabia. Had the war continued, carcasses would have had to have been speedily transported back to CONUS before the depot could have contributed much more to the stock of available T64 engines.

Even more disturbing than the lack of returned carcasses was the contention that there was no clear knowledge of where the carcasses were. Not only do unserviceable assets have low priority for transportation, they are not tracked in detail during shipment. The Navy does have a system that gives some information about which carcasses are in transit to the depot (implemented as part of the transition to stock funding of depot-level reparables), but it is primarily designed to ensure that broken assets are in fact turned in to the supply system in exchange for RFI assets that have been issued. The system has visibility of a carcass's whereabouts only after the carcass enters the Naval supply system.

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[5]Note that even the BOM hastily put together by North Island was useful during the surge. The incremental approach to building a BOM is being applied to the TF30 (F-14) engine at Norfolk, but the TF30 was not surged during ODS/S. Other initiatives for building and maintaining a BOM are being pursued by NADEP Alameda (ABOM, for *A Bill Of Materials*) and NADEP Cherry Point (modification of ABOM).

[6]A major DoD initiative is exploring the possibilities of DoD-wide standard information systems for a wide variety of functions, including maintenance and depot management.

[7]The lack of retrograde was observed in every service. To the best of our knowledge, the shipment of damaged equipment from Saudi Arabia back to the continental United States (CONUS) was a low priority during ODS for all the services.

Tracking retrograde was a problem not just for Naval aviation, nor just for the Navy; all the services had similar problems. The services need to plan for timely shipment of unserviceable assets back to depot-level repair, which requires that retrograde be visible while it is in transit. The overall responsibility for an information system that tracks retrograde clearly seems to fall to DoD, since several transportation agencies share responsibility for retrograde transport.

Recommendation: *The Navy should put more emphasis on the timely return of unserviceable assets from the field to the depot and on enhanced visibility of those assets in transit, especially if it is to be prepared for contingencies that may be prolonged or for which initial stocks are in short supply.*

COMMUNICATION

In our talks with people at the NADEPs, two issues arose that fall under the heading of communication. The first issue involved *vertical* communication, i.e., communication between intermediate levels of the NADEPs and the central organizations of Naval aviation maintenance and supply. From the Iraqi invasion to the start of the surge, AIR-43 (in NAVAIR) held weekly telephone conferences with senior management at the depots. Specific items needed attention as U.S. forces deployed, and some high-level discussion took place of what actions might have to be taken if hostilities began. Whereas international and domestic political concerns tended to play down the possibility of hostilities until late in the fall, in mid-November the indicators were pointing to eventual conflict. The senior leaders began to plan for the surge at that point. However, the intermediate levels of the depot, which include the materiel managers who actually work with the shops and who have a detailed view of materiel availability, were not involved until the surge began. While few people were totally surprised when the surge was finally requested, many people felt they could have done much more in the way of preparation had they been asked.

In addition, NAVAIR's reduction of some of the original "absolute minimum" requirements led the NADEPs to question all requested production targets. Goals must be carefully set to prevent repair resources from being wasted in attempts to achieve unrealistic or unneeded goals. In fact, the 44 T64 engines produced by North Island were just sufficient. The indications are that had the conflict gone on much longer, the supply would not have been adequate.

The second issue involved *horizontal* communication, i.e., communication between workers within the NADEPs. At all of the NADEPs we visited, one of the primary adaptations was to start or improve communication among workers, the goal being to insure

that all repair activities were coordinated and that all good ideas were captured and implemented, particularly those that reduced engine turnaround time. By all accounts, this process was an outstanding success. Unfortunately, the substantial layoffs in the summer of 1991 may have irreparably destroyed the benefits that could have been reaped from this success.

Recommendation: *The Navy should consider the lessons learned about vertical and horizontal communication when planning for future contingencies.*

RAND/N-3436-A/USN