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Transportation service level impact on aircraft availability

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Abstract

Purpose – Aircraft fail to meet mission capable rate goals due to a lack of supply of aircraft parts in inventory where the aircraft breaks. This triggers an order at the repair location. To maximize mission capable rate, the time from order to delivery needs to be minimized. The purpose of this research is to examine the case of three airfields for the order to delivery time of mission critical aircraft parts for a specific aircraft type.

Design/methodology/approach – This research captured data from three information systems to assess the order fulfillment process. The data were analyzed to determine the performance in fiscal year 2020. Using the model of that performance, the cost of reducing transportation times using publicly available commercial cost estimates was assessed against the impact on aircraft availability.

Findings – The results indicate that paying the costs for expedited shipping would have increased aircraft availability by 1.09 times the average annual aircraft flying hours for the three cases. The cost for the equivalent of an additional aircraft for the year was a third of the annual straight-line depreciation for that aircraft type.

Research limitations/implications – This research assumed that the transportation time service levels publicly posted could be achieved. The weight of each mission critical part was not available, so the weight was selected from a probability distribution of mission critical part weights that was retrieved from prior research. This research provides options to enhance aircraft availability and identifies the associated costs.

Practical implications – Adjusting the contract with transportation providers to reduce the transportation times of mission critical parts could have a large impact on aircraft availability at relatively little cost.

Social implications – This research could enhance aircraft readiness in service of the common defense.

Originality/value – This research provides an effective methodology for enhancing military readiness through contract adjustments with commercial partners. The value of this research is that it will serve to adjust the value proposition of mission critical parts inside the United States Transportation Command's Next Generation Delivery Service contract.

Keywords MICAP, Mission critical parts, Aircraft, Availability, Transportation, Order fulfillment

Paper type Research paper

1. Introduction

The readiness of aircraft at their stationed airfield is measured in terms of availability. Availability is defined as the probability that a component or system is performing its required function at a given point in time when used under stated operating conditions (Ebeling, 2004). Availability is expressed as a ratio of the uptime of an aircraft to the sum of the aircraft's uptime and downtime (Ritschel *et al.*, 2019). Minimizing downtime is therefore the key component to increasing availability. For the Air Force, mission capable rate is often used as the metric for assessing availability and readiness (Brooks, 2013; Rainey *et al.*, 2001). In the Air Force, many aircraft types have mission capable rates in the 50–60% range (MITRE, 2020). The low readiness as indicated by these mission capable rates is a significant national security issue (Biden Jr, 2021; Cohen, 2020; Mattis, 2018).

A Government Accountability Office report to Congress on weapon system sustainment found that despite tens of billions of dollars spent annually, only 3 of 46 defense aircraft weapon systems met the majority of their mission capable rate goals from 2011 to 2019. Aging aircraft,

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unscheduled maintenance and parts shortages plagued sustainment efforts and drove the overall decline in mission capable rates (US Government Accountability Office, 2020). The downtime of availability can be due to either scheduled or unscheduled maintenance. Downtime from unscheduled maintenance due to part failure consists of three phases. First is the time from problem recognition to repair part identification, second is the time from ordering the repair part to part delivery and third is the time to repair (Atlassian, 2021). Once ordered, the required part receives a Mission Impaired Capability Awaiting Part (MICAP) label.

The purpose of this research is to identify a primary constraint within the aircraft maintenance process and to exploit that constraint aligned with the theory of constraints. This leads to two research questions: what is a significant constraint in the aircraft maintenance process and how can that constraint be exploited? These questions will be scoped to three overseas aircraft maintenance case locations and a specific mission design series aircraft. This research attempts to enhance the understanding of the identified constraint and explore the application of the theory of constraints for exploiting this constraint.

2. Literature review

Non-mission capable (NMC) is the Department of Defense's (DoD) term for downtime. NMC subdivides into three primary statuses, non-mission-capable for maintenance (NMCM), non-mission-capable for supply (NMCS) and non-mission-capable for both (NMCB). When an aircraft is NMCM, then all material resources that are needed to effect repairs are available. When an aircraft is NMCS, the supplies needed for repairs are not currently available, and the supply chain must deliver the parts needed. When an aircraft is NMCB, an aircraft requires both the supply chain to deliver parts and additional maintenance actions are required. NMC for DoD weapon systems splits into two categories: maintenance time, and admin and logistics delay time (Pryor, 2008). Maintenance time following the event of a part failure consists of two components, troubleshooting time and maintenance repair time. Troubleshooting precedes the operational order fulfillment process and maintenance repair concludes after order receipt. Maintenance time either falls under NMCM or NMCB. Admin and logistics delay time is the time associated with the operational order fulfillment process (Defense Acquisition University, 2017). Admin and logistics delay time falls under NMCS or NMCB. Reducing either maintenance time or admin and logistics delay time can improve operational availability (Reliability Analysis Center, 2010).

NMCS time can be reduced by maintaining more on-hand spare parts (Gehret, 2015); however, in complex systems, supply delays are nearly impossible to avoid entirely. In the commercial sector, downtime costs typically run anywhere from 100 to 10,000 times the price of spare parts or service (Altay and Litteral, 2011). If a part needed for repair is not available, maintenance orders the part, and the order fulfillment time extends the downtime. After delivery of parts, maintenance can perform maintenance actions, and the aircraft is made mission capable (Rainey *et al.*, 2001). One method that maintenance personnel can use to reduce the number of aircraft which are NMCS is to consolidate as many requirements into one aircraft as possible. This cannibalized aircraft provides the used operating part to other aircraft that would have been broken, thereby generating as many mission capable aircraft as possible (Curtin, 2001). This procedure is sub-optimal and incurs additional maintenance actions and workload. Additionally, this causes confusion within the supply chain demand management and prioritization system. The United States Air Force (USAF) demand management system does not determine which aircraft are only missing one part, and USAF supply chain systems cannot determine if the aircraft needs maintenance in addition to installation of the part. These issues combine to make it difficult to prioritize which orders could have the most significant impact on readiness. A two-year study conducted by the 635th Supply Chain Operations Wing (635 SCOW) found that, on average, 31% of mission critical parts were single hit with only maintenance installation required before the aircraft was considered mission capable (Parish and Blazer, 2013).

2.1 Theory of constraints

The theory of constraints focuses on the bottleneck or limiting factor of a production network (Goldratt, 1990; Goldratt and Cox, 1984, 2016). The theory of constraints evolved over five eras: optimized production technology, goal, haystack syndrome, it's not luck and critical chain (Şimşit *et al.*, 2014; Watson *et al.*, 2007). This research utilized management implications from the optimized production technology, goal and critical chain eras to identify and exploit the constraint in the aircraft maintenance process and provide a cost–benefit analysis of reducing that constraint (Goldratt, 1990; Goldratt and Fox, 1986; Newbold, 1998). The first step of the five focusing steps of The Goal includes identification of the constraint. This research will detail the operational order fulfillment process to assist in constraint identification. The second step of exploiting the constraint will be accomplished through recommendations in the conclusion section. Future research should assess the remaining three of the five steps: subordination of the system, capacity enhancements and continuous process improvement.

2.2 The operational order fulfillment process

The operational order fulfillment process as defined by Croxton consists of seven steps to include generate and communicate order, enter order, process order, handle documentation, fill order, deliver order and perform postdelivery activities and measure performance (Croxton, 2003; Croxton *et al.*, 2001). Actual implementations may vary, but the process is similar for the Air Force and many of the world's most successful supply chain and logistics-oriented companies. As an example, Amazon's order fulfillment process consists of seven steps to include demand, source, pick, rebinning, pack, slam and ship (Amazon, 2019). The Air Force's process has eight steps to include demand, source, pick, pack, ship, receive, in-check and deliver as shown in Figure 1. Amazon's process includes two steps that the Air Force process does not, such as the rebinning step between pick and pack and the slam step between pack and ship. The Air Force's process adds three steps after ship to include receive, in-check and deliver for internal processes similar to Croxton's perform postdelivery activities step. The demand and source steps of the order fulfillment process need to avoid discrepancies and require a focus on individual mission critical parts (Weber *et al.*, 2020; Williams, 2012). Amazon competitively established a two-day order fulfillment process time standard with Amazon Prime. This service level was a benchmark to contrast against the Air Force's mission critical part order fulfillment process.

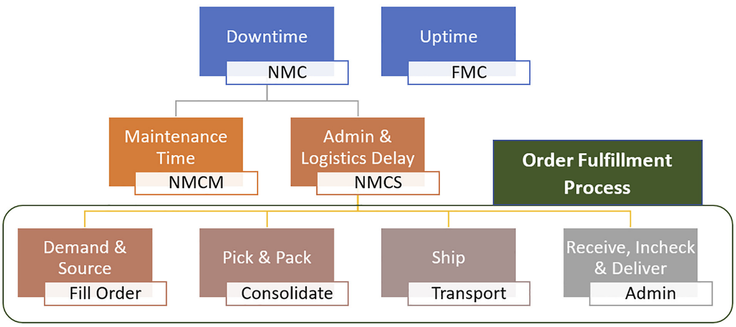

Figure 1.
Availability and the order fulfillment process

The ship step of the Air Force's mission critical part operational order fulfillment process is dependent on the United States Transportation Command's Next Generation Delivery Service (NGDS) contract which was established in 2017. NGDS is a mandatory-use shipping program for government agencies for commercial shipping for domestic and international express package deliveries. NGDS provides domestic express air and ground shipping within the Continental United States, Alaska, Hawaii, Puerto Rico, and international express delivery shipments (United States Transportation Command, 2019). The United States Transportation Command (USTRANSCOM) established the NGDS contract to consolidate various federal package delivery contracts into one government-wide contract. This contract exists as an Indefinite Delivery Indefinite Quantity (IDIQ) with terms and conditions pre-negotiated for all buyers. USTRANSCOM owns the management and purview of the contract as a specialized buyer of transportation services; however, it was a joint interagency collaborative effort to establish a government-wide solution (United States Transportation Command, 2018).

USTRANSCOM negotiated the NGDS contract with commercial logistics service carriers such as FedEx, Polar Air and United Postal Service to provide a wide range of services. Under NGDS, the government can ship up to 150 lbs. In the Continental United States and 300 lbs. Internationally (United States Transportation Command, 2018). Government agencies and defense services can utilize commercial carrier shipping to deliver cargo all over the world. NGDS shipping is not available for all types of cargo. Classified cargo, hazardous cargo, outsized, and any cargo above the weight limits established by the contract do not qualify for this service. This limitation exists for both the Continental United States and overseas. The US Air Force utilizes the NGDS contract whenever possible to transport aircraft mission critical parts globally.

2.3 Order fulfillment time metrics

The principal logistics official within the senior management of the DoD in coordination with USTRANSCOM established time-definite delivery standards, feeding the Operational Needs Goals (ONG) (Office of the Assistant Secretary of Defense for Sustainment, 2021).

The ONG outlines the required delivery timeline in days based upon its transportation priority and destination. The United States Air Force aircraft mission critical part orders are designated transportation priority 1. Per the ONG, mission critical part deliveries to European Command (EUCOM) and Indo-Pacific Command (INDOPACOM) that arrive at or under 12 and 11 days, respectively, met the goal. However, the level by which these goals are surpassed can have large aircraft availability implications. To enhance aircraft availability, the US Air Force imposed a more restrictive, unofficial goal. The 635 SCOW used a seven-day mission critical part response time goal to increase order fulfillment speed (Miller, 2020).

These unofficial goals are the framework provided to Traffic Management Offices around the US Air Force to utilize NGDS shipping. The Defense Transportation Regulation (DTR) Part II, Chapter 202 *Cargo Routing and Movement* allows transportation officers at installations to utilize their discretion in routing parts utilizing best value principles (United States Transportation Command, 2019). However, the DTR Part II does not define those best value principles, and therefore, the best value for transportation officers may differ. The 635 SCOW uses the seven-day goal to direct transportation officers to utilize the fastest, most expedient shipping method available.

In FY20, of the 303,543 shipments to EUCOM that utilized NGDS, 97.8% of those were on-time deliveries based on the country-specific contract agreements. Moreover, the average cost per pound to the government to ship these items was $2.50 (United States Transportation Command, 2020a). For INDOPACOM, of the 934,112 shipments, 95.6% were on time with an average cost per pound of $1.78 (United States Transportation Command, 2020b). In FY20, the NGDS contract covered hundreds of thousands of individual shipments that maintained an above 95% on-time transportation metric. The average pick-up and delivery timelines are below the goals set by both OSD A&S and the more restrictive 635 SCOW. The average transportation days for all NGDS shipments going to Germany is 4.2 days, while Italy's is 4 days and Japan's is 4.7 days (United States Transportation Command, 2020a, 2020b).

Increasing mission critical part order fulfillment speeds within the Continental United States enhances aircraft availability (Litchfield III, 2020). An Air Force logistics innovation effort established under the name MICAP Prime recently accomplished a proof of principle that highlighted the readiness effects of accelerated order fulfillment in the Continental United States MICAP shipments (Tesseract, 2021). This research aims to research the impact of accelerated transportation of international mission critical part shipments on aircraft availability.

3. Methodology

This research utilized a cost–benefit analysis methodology. There are nine steps recommended for a cost–benefit analysis (Boardman *et al.*, 2017). These include set alternatives, determine standing, identify categories, predict impacts, monetize impacts, obtain present values, compute net present value, perform sensitivity analysis and make a recommendation. The set of alternatives for this analysis includes continuing with business as usual or adjusting the shipping contract to offer an expedited two-day shipping option. This research assesses standing from the perspective of the DoD. The categories for the cost–benefit analysis will include aircraft availability, flight hours and shipping costs. Benefits of adjusting the contract are measured in terms of an increase in aircraft availability and costs are assessed through commercially available prices of expedited shipping. Predicting the impact assumes that the commercial sector could meet the two-day shipping standard. The impact of both flight hour adjustments and aircraft availability will also be monetized. Obtaining present values and computing net present value will be based on an FY20 comparison and therefore will not be required. This research performed sensitivity analysis based on the stochastic nature of cargo weights to assist with a recommendation in the conclusion.

To track a mission critical part from order through delivery required the National Stock Number (NSN), the Transportation Control Number (TCN) and the order priority. The order start and end times and the transportation start and end times determined the time components of the supply chain. Separate functionally focused systems capture this information. Utilizing a three-step process, this research examined all individual aircraft mission critical parts going to Spangdahlem, Aviano and Misawa airbases. Step 1 captured all 1A priority mission critical parts in the supply system (ILS-S) delivered to the selected bases over fiscal year 2020. Step 2 used the transportation system's query tool and NSNs from Step 1 to obtain TCN and associated data. Step 3 reconciled the data between Steps 1 and 2 to discard missing or erroneous data. Reconciliation was based on the constraint in Equation (1).

$$T_{\alpha_i} \geq M_{\alpha_i} \cap \; T_{\omega_i} \leq M_{\omega_i} \forall i \tag{1}$$

where

T_α = transportation start date

T_ω = transportation stop date

M_α = mission critical part order start date

M_ω = mission critical part order stop date

i = NSN i

In the rare event of multiple matches, this research conducted a further review to investigate priority and any NGDS shipping comments in notes. After a definitive match, this research reviewed the mission critical part to confirm it was a Continental United States to overseas shipment and utilized NGDS transportation. This resulted in 1,686 aircraft mission critical parts delivered to Aviano, Spangdahlem and Misawa air bases in fiscal year 2020. Of those mission critical parts, 367 were out of scope and 577 were not reconcilable. The mission critical parts determined to be out of scope were due to military aircraft performing the transport or overseas to overseas lateral transport. The mission critical parts that were not reconcilable were due to missing or inconsistent data. Only 742 mission critical parts were retained for final analysis representing 44.01% of the original data. The 742 mission critical parts included 347, 213 and 182 mission critical parts for Aviano, Spangdahlem and Misawa, respectively.

3.1 Availability and flight hour benefit

The number of business days from mission critical part order submitted to order closed was labeled total mission critical part days. Total mission critical part days included two components. The first component, labeled total DoD days, included the number of business days for the order fulfillment process prior to the ship step. The second component, labeled total transportation days, included the number of business days from receipt of the mission critical part by the NGDS carrier to delivery of the mission critical part to the designated air base.

This research used FedEx's commercially available package shipping options from Fedex.com to contrast against current NGDS contract shipping. The FedEx website established that it offers "FedEx International First" shipping with delivery in 1, 2 or 3 international business days in 26 countries, including Germany, Italy and Japan. While the website offers these options, in practice, this research established that international two day was the only consistent service level available. Therefore, this study utilizes the two-day international service level as the baseline for further research and cost gathering.

To determine the total number of transportation days that could be saved by using FedEx's two-day shipping over the NGDS contract, two days were subtracted from the NGDS transportation days for each mission critical part. The impact to availability of reducing transportation days to two-day shipping and DoD days to one-day demand, source, pick and pack was determined using Equation (3).

$$\gamma = \frac{\delta + \varphi(\tau_t + \tau_D)}{\delta + \theta} \tag{2}$$

where

γ = availability

δ = uptime

φ = single hit percentage: 31% (Parish and Blazer, 2013)

τ_t = transportation days saved

τ_D = DoD days saved

θ = downtime

The conservative update to availability is based on 31% of aircraft having only a single part required for repair. This estimate is conservative in that downtime would be lower for aircraft that receive multiple mission critical parts early, but that factor is not captured in this analysis as it could not be addressed directly with available data. In addition to availability, this research also assessed the impact on available flying hours of bringing an aircraft back to mission capable status as captured in Equation (4).

$$\tau_h = \sum \varphi(\tau_t + \tau_D)\beta \tag{3}$$

where

τ_h = total flight hours saved

φ = single hit percentage: 31% (Parish and Blazer, 2013)

τ_t = transportation days saved

τ_D = DoD days saved

β = average aircraft daily utilization in flight hours per day

Total flight hours saved estimated the flying hours returned by accelerating mission critical part fulfillment.

3.2 Cost of expedited shipping

FedEx and NGDS costs for expedited shipping are based on the weight of cargo moved in pound increments up to 150 pounds for each of the three selected air bases. A price ratio between FedEx expedited shipping and the NGDS contract at each pound increment was calculated using Equation (2).

$$\rho_{ij} = \frac{p_{f_{ij}}}{p_{n_{ij}}} \tag{4}$$

where

ρ_{ij} = price ratio at weight i and air base j

$p_{f_{ij}}$ = FedEx price at weight i and air base j

$p_{n_{ij}}$ = NGDS price at weight i and air base j

Figure 2 shows weights plotted against price ratios. The price ratios ranged from a high of 21.78 at 1 pound in Japan to a low of 6.92 at 150 pounds in Italy. Average prices increased 9.3, 8.5 and 14.4 times for Italy, Germany and Japan, respectively.

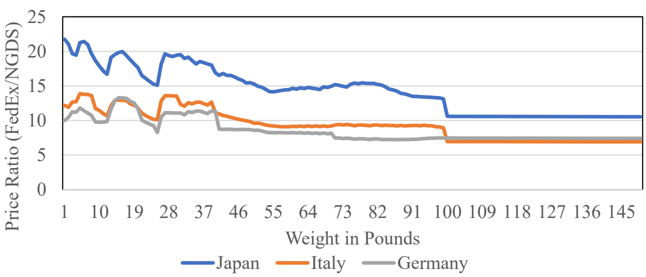

Figure 2.
Price ratio for FedEx vs. NGDS at given weights

In reviewing the NGDS pricing data, pricing was location-dependent. Shipping to Germany, Italy and Japan averaged $138.47, $133.88 and $90.67, respectively. Any benefits discovered by this research are conservative estimates. The negotiated costs under an amended NGDS contract could be lower between USTRANSCOM and the service provider. The rates shown in this analysis are the commercial rates available to anyone who searches online. These cost rates do not factor in any potential contract negotiation discounts or economic order quantity discounts.

The data for the mission critical parts did not include the mission critical part weights. A previous collection of 230 mission critical parts in the MICAP Prime proof of principle showed the mission critical part weight distribution in Figure 3 (Litchfield III, 2020).

Using a probability distribution from the mission critical part weight distribution, a Monte Carlo simulation of a thousand runs of the potential weight distributions and expected costs was performed to determine the range and average costs of implementing expedited shipping at the three air bases.

4. Results

On average, the order fulfillment process for the 742 mission critical parts in this research took 7.18 days. The median order fulfillment time was five days with 84.1% of the mission critical parts meeting the 635 SCOW seven-day goal. Several outliers contributed to the disparity between the mean and median with one mission critical part taking 122 days to be delivered. Figure 4 shows the distribution of the mission critical part order fulfillment times.

Breaking down the total mission critical part days, the DoD days showed an average of 1.99 days to demand, source, pick, pack and deliver the part to the carrier for transportation. NGDS achieved same day shipping on 18.4% of the mission critical parts while 5% of the mission critical parts exceeded ten days to ship. The transportation days averaged 3.28 days to deliver from the Continental United States to overseas. The NGDS contract met or exceeded delivery times for 91.8% of the mission critical parts. Figure 5 shows the distributions of the total mission critical part days, DoD days and transportation days.

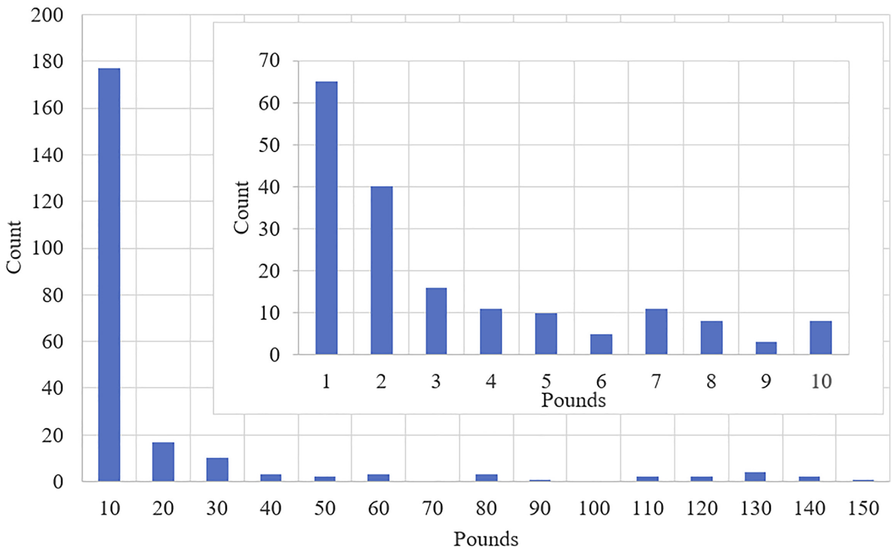

Figure 3.
Mission critical part weight distribution

The total transportation days saved from the three bases was 892 days as seen in Table 1. Each aircraft was flown on average for about 1 h per day. By accelerating transportation, the bases were able to fix 31% of the aircraft and generate an additional 90.33 flying hours on average for each base. These hours expressed as a percentage of annual flying hours per aircraft were labeled aircraft equivalents (MITRE, 2020). For the three bases, accelerating transportation saved 271 flying hours total or 1.09 aircraft equivalents. The cost of the aircraft is $18.8 million (US Air Force, 2015) and the useful life of the aircraft is 8,000 h (Global Security, 2013) or approximately 32 years. This results in a straight-line depreciation of $569,697.00 per year assuming no salvage value. After running the Monte Carlo simulation for 1,000 runs at each air base, the total average cost of accelerating transportation is $202,101.37. Therefore, by accelerating transportation over the three bases, the bases would get the equivalent of 1.09 aircraft at a third of the depreciation cost.

The transportation day reduction could be achieved by adjusting the NGDS contract to expedite mission critical parts shipments to the two-day service level. The method to reduce the DoD days for the demand, source, pick and pack portion is an area that will require further research. This research identified the impact to flying hours if process times could be reduced to a one-day process. The three bases saved 1,290 total DoD days which is a 45% increase over the days saved through transportation process improvements as seen in Table 2. This highlighted that from a theory of constraints perspective, additional attention and research should be devoted to accelerating the demand, source, pick and pack process. Combining transportation process improvements with the DoD order fulfillment step process

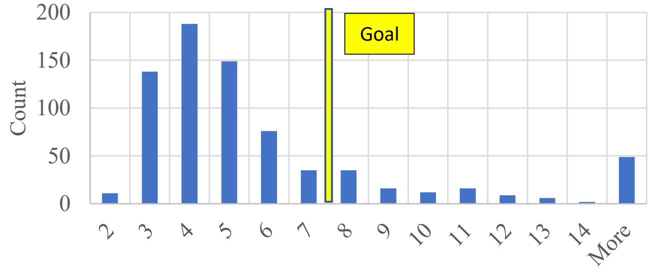

Figure 4.
Total mission critical part days

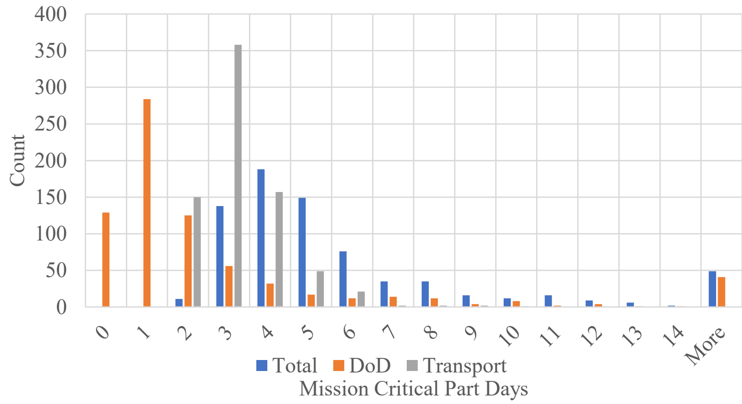

Figure 5.
Total mission critical part days by process segment

improvements resulted in a total of 2,182 days saved resulting in 662.9 additional flying hours or 2.66 aircraft equivalents.

The three air base cases provided highlight the importance of accelerating order fulfillment speed for aircraft mission critical parts. From the shipping step of the order fulfillment process, the cost to expedite to the fastest reliable service level creates the equivalent of an extra aircraft at only a third of the annual depreciation cost of that aircraft.

5. Conclusion

The order fulfillment process in the US Air Force provides a reliable way to deliver mission critical parts; however, it is possible to accelerate order fulfillment and generate more flying hours. Accelerating the NGDS contract by establishing an international level of service, which includes two-day delivery, represents an opportunity for the US Air Force to increase flying hours and increase aircraft availability. This research also discovered that further gains are possible by accelerating DoD order fulfillment process steps and establishing same-day demand, source, pick and pack of aircraft mission critical parts. Future research is required to determine which actions to take to reduce process times for demand, source, pick and pack.

While the scope of this research only applied to one weapon system across three bases, the impact of these changes exceeds this scope. There is significant potential for application across a wide range of aircraft weapon systems and bases worldwide. Accelerating order fulfillment processes within the DoD and accelerating the NGDS transportation timeline can provide considerable increases in weapon system availability and mission capable rates, increasing national security.

This research recommends three actions. First, the United States Transportation Command should renegotiate NGDS shipping timelines to develop and include a two-day international shipping option as a level of service for international transportation priority 1 shipments. Second, an experimental test should be performed to validate the savings predicted by this research. Third, a same-day demand, source, pick and pack goal should be implemented for all Air Force aircraft mission critical parts.

The current NGDS contract offers six service levels for shipments within the Continental United States but only one level of service per country outside of the Continental United

Air base	Transportation days saved	Additional flying hours	Aircraft equivalents	Two-day Fedex cost – NGDS cost (1,000 runs)		
				Min	Average	Max
Aviano	368	111.80	0.45	$ 72,212.76	$ 89,978.03	$ 107,901.76
Spangdahlem	262	79.60	0.32	$ 36,908.32	$ 46,515.36	$ 62,245.65
Misawa	262	79.60	0.32	$ 51,305.28	$ 65,607.98	$ 82,437.92
Subtotal	892	271.00	1.09	$ 160,426.36	$ 202,101.37	$ 252,585.33

Table 1. Mission critical parts transportation days saved and cost

Air base	DoD days saved	Additional flying hours	Aircraft equivalents
Aviano	623	189.27	0.76
Spangdahlem	295	89.62	0.36
Misawa	372	113.01	0.45
Total	1,290	391.9	1.57

Table 2. DoD days saved

States. This research recommends that the United States Transportation Command negotiate a second, greater level of service for overseas locations to enable faster delivery of high-priority items. Additionally, this research recommends that the United States Transportation Command grants immediate authorization for government services to self-procure two-day shipping options outside of the NGDS contract for transportation priority 1 items going overseas until the NGDS contract can be renegotiated.

The research also recommends developing and executing a combined maintenance and logistics experimental test to measure the impacts of accelerated transportation on NMCS hours at select overseas bases. This experimental test should utilize two-day shipping for all aircraft mission critical parts going from the Continental United States to overseas bases. The experimental test should measure the NMCS hours to determine if a reduction in supply hours is observed.

Finally, this research recommends the establishment of an Air Force-wide same-day demand, source, pick and pack goal. While it was out of the scope of this research to determine the cause of logistics delays in the DoD days, this research still established that significant readiness gains may be earned by accelerating these order fulfillment steps. Establishing an Air Force-wide goal will allow each installation to measure and determine its needs to meet this target and adjust as required.

References

Altay, N. and Litteral, L. (2011), *Service Parts Management: Demand Forecasting and Inventory Control*, Springer-Verlag, New York, NY.

Amazon (2019), "Inside Amazon's fulfillment centers: what you can expect to see on a warehouse tour", Amazon, Seattle, WA, available at: https://www.aboutamazon.com/news/operations/inside-amazons-fulfillment-centers-what-you-can-expect-to-see-on-a-warehouse-tour.

Atlassian (2021), "*MTBT, MTTR, MTTA, and MTTF, incident management*", San Francisco, CA, available at: https://www.atlassian.com/incident-management/kpis/common-metrics.

Biden, J.R., Jr. (2021), *Interim National Security Strategic Guidance*, Executive Office of the President, Washington, DC.

Boardman, A.E., Greenberg, D.H., Vining, A.R. and Weimer, D.L. (2017), *Cost-benefit Analysis: Concepts and Practice*, Cambridge University Press, New York, NY.

Brooks, B.A. (2013), *Correlation of Ready for Tasking to Full Mission Capable Metrics for F/A-18E/F*, Naval Postgraduate School, Monterey, CA.

Cohen, R. (2020), "Brown vows new measures to boost USAF readiness", *Air Force Magazine*, Air Force Almanac ed., No. 5.

Croxton, K.L. (2003), "The order fulfillment process", *The International Journal of Logistics Management*, Vol. 14 No. 1.

Croxton, K.L., Garcia-Dastugue, S.J., Lambert, D.M. and Rogers, D.S. (2001), "The supply chain management processes", *The International Journal of Logistics Management*, Vol. 12 No. 2, pp. 13-36.

Curtin, N.P. (2001), *Cannibalizations Adversely Affect Personnel and Maintenance*, General Accounting Office, Wright Patterson AFB, OH.

Defense Acquisition University (2017), *Maintainability and Availability*, DAU, Ft. Belvoir, VA.

Ebeling, C.E. (2004), *An Introduction to Reliability and Maintainability Engineering*, Tata McGraw-Hill Education, Gautam Buddha Nagar, Uttar Pradesh.

Gehret, G.H. (2015), *Advancing Cost-Effective Readiness by Improving the Supply Chain Management of Sparse , Intermittently-Demanded Parts*, Air Force Institute of Technology, Wright Patterson AFB, OH.

Global Security (2013), "F-16 life". available at: https://www.globalsecurity.org/military/systems/aircraft/f-16-life.htm.

Goldratt, E.M. (1990), *Theory of Constraints*, North River Croton-on-Hudson, Croton-on-Hudson, NY.

Goldratt, E.M. and Cox, J. (1984), *The Goal, Croton-On-Hudson*, North River Press, NY.

Goldratt, E.M. and Cox, J. (2016), *The Goal: A Process of Ongoing Improvement*, Routledge, New York, NY.

Goldratt, E.M. and Fox, R.E. (1986), *The Race North River Press*, Croton-on-Hudson, NY, NY.

Litchfield, A.R., III (2020), *MICAP Prime*, United States Air Force Air University, Montgomery, AL.

Mattis, J. (2018), *Summary of the 2018 National Defense Strategy*, Department of Defense, Washington, DC.

Miller, A. (2020), *MICAP Response Time Standard*, M.V. McLean Interviewer.

MITRE (2020), *U.S. Air Force Aircraft Inventory Study Executive Summary*, MITRE, Bedford, MA.

Newbold, R.C. (1998), *Project Management in the Fast Lane: Applying the Theory of Constraints*, CRC Press, Boca Raton, FL.

Office of the Assistant Secretary of Defense for Sustainment (2021), "Time-definite delivery standards". available at: https://www.acq.osd.mil/log/sci/TDD_Standards.html.

Parish, T. and Blazer, D. (2013), *Analysis of Potential Impact to TNMCS Rates Caused by Reducing MICAP Support Hours*, 635 SCOW, Scott AFB, IL.

Pryor, G.A. (2008), *Methodology for Estimation of Operational Availability as Applied to Military Systems*, Army Training and Doctrine Command, Ft. Eustis, VA.

Rainey, J.C., McGonagle, R., Scott, B.F., Waller, G. and Drew, J.G. (2001), "Maintenance metrics US air Force", *Air Force Journal of Logistics*, Vol. 25 No. 3.

Reliability Analysis Center (2010), *Introduction to Operational Availability*, Acqnotes, Rome, NY.

Ritschel, J.D., Ritschel, T.L. and York, N.B. (2019), "Providing a piece of the puzzle: insights into the aircraft availability conundrum", *Journal of Defense Analytics and Logistics*, Vol. 3 No. 1.

Şimşit, Z.T., Günay, N.S. and Vayvay, Ö. (2014), "Theory of constraints: a literature review", *Procedia - Social and Behavioral Sciences*, Vol. 150 No. 231, pp. 930-936, doi: 10.1016/j.sbspro.2014.09.104.

Tesseract (2021), *MICAP Prime Brief*, Department of Defense, Washington, DC.

United States Transportation Command (2018), *NGDS: Next Generation Delivery Service (Best in Class-Mandatory)*, USTRANSCOM, Scott AFB, IL.

United States Transportation Command (2019), *Next Generation Delivery Service, Performance Work Statement*, USTRANSCOM, Scott AFB, IL.

United States Transportation Command (2020a), *NGDS Program Summary - EUCOM Directors Report*, United States Transportation Command, Scott AFB, IL.

United States Transportation Command (2020b), *NGDS Program Summary - INDOPACOM Directors Report*, United States Transportation Command, Scott AFB, IL.

US Air Force (2015), "F-16 fighting falcon". available at: https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104505/f-16-fighting-falcon/.

U.S. Government Accountability Office (2020), "Weapon system sustainment: aircraft mission capable rates generally did not meet goals and cost of sustaining selected weapon systems varied widely", November, available at: https://www.gao.gov/assets/720/710794.pdf.

Watson, K.J., Blackstone, J.H. and Gardiner, S.C. (2007), "The evolution of a management philosophy: the theory of constraints", *Journal of Operations Management*, Vol. 25 No. 2, pp. 387-402.

Weber, M., Steeneck, D. and Cunningham, W. (2020), "Order fulfillment errors and military aircraft readiness", *Journal of Defense Analytics and Logistics*, Vol. 4 No. 1.

Williams, D.R. (2012), *Examining EXPRESS with Simulation*, Air Force Institute of Technology, Wright Patterson AFB, OH.

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