

# Automation in the Military: A Viable Sustainment Strategy?



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Dynamics  
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# Personal Info

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- ▶ Currently work for DRC at Picatinny Arsenal, NJ
  - Our group specializes in software and systems engineering support for Defense Mission Engineering (DME)
- ▶ BSE from University of Virginia (2000)
- ▶ MS from Stevens Institute of Technology (2005)
  - Post-grad and systems engineering research (2009-11)
- ▶ This research was conducted under the direction of Dr. David Nowicki, while studying post-grad at Stevens

# Purpose of this Research

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- ▶ This research sought to discover:
  - The set of system characteristics necessary to determine whether cannibalization is a viable sustainment strategy
  - Scenarios where the use of cannibalization as a sustainment action can be both practical and positive
- ▶ To achieve this, a thorough literature review was conducted to explore the following areas
  - What is cannibalization as it relates to supply chains
  - Why is cannibalization used in the real world
  - What are the drawbacks of cannibalization
  - What are the benefits of cannibalization
  - Should cannibalization be formally incorporated in spares provisioning policies
- ▶ Final product is a causal-loop diagram that articulates cause-and-effect relationships related to cannibalization

# Agenda

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- ▶ Definition
- ▶ Real-world Paradox
- ▶ Drawbacks
- ▶ Benefits
- ▶ Mathematical Models
- ▶ Causal-Loop Diagram
- ▶ Risks
- ▶ Conclusions
- ▶ References



# Cannibalization Defined

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- ▶ The Navy defines cannibalization as “the removal of serviceable material or components from one equipment for installation in another to restore the latter to a serviceable condition” (Enslin, Oct-Dec 2004)
- ▶ Typically utilized when it’s faster to transfer a needed part from one (existing) system to another than to utilize the supply system (Hoover, 2002)
  - Thus, the application of cannibalization is typically viewed as a sign that something is wrong with the underlying supply system (Hoover, 2002)



# Cannibalization?



# Prevalence of Cannibalization

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- ▶ The Services have implemented policy against using cannibalization (except, generally, as a last resort to meet urgent or mission-critical requirements) for all types of equipment in effectively all situations (Enslin, Oct-Dec 2004)
- ▶ Yet...all the military services use cannibalization as a “routine aircraft maintenance strategy” (Government Accountability Office, 2001)
- ▶ As an example, reports show that in FY 1996-2000, the Navy and Air Force performed 850,000 cannibalizations requiring over 5 million maintenance man-hours—which translates to between 154,000 and 176,000 cannibalizations a year (and this does not even include the Army, and the Navy reportedly understates its data by as much as 50%) (Government Accountability Office, 2001)

# Why Resort to Cannibalization?

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- ▶ GAO found that “the Services believe that cannibalizations allow them to better perform their operational missions” (Government Accountability Office, 2001)
- ▶ Cannibalization is used in many high-tech environments because of expensive spare parts and low maintenance turnaround requirements (Ormon & Cassady, 2004)
- ▶ Cannibalization produces an immediate benefit by increasing the number of operable systems at the expense of increased labor that could be utilized elsewhere (W. W. Fisher, 1989)
- ▶ Thus, the “DOD Guide for Achieving Reliability, Availability, and Maintainability” specifically mentions cannibalization as a potential maintenance policy (“DOD GUIDE FOR ACHIEVING RELIABILITY, AVAILABILITY AND MAINTAINABILITY” 2005)



# Cannibalization in the Navy

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- ▶ The Navy has three categories for explaining cannibalization: under direct order from higher authority, fault isolation and troubleshooting (using identical components), and lack of spares (most often used)
- ▶ Perceived leadership metrics matter a lot
  - A Commander with high readiness ratings is generally thought to be a more effective Commander than one with lower readiness ratings—even if the numbers are inflated
  - In essence, the Navy rewards high mission-capable rates while not penalizing high cannibalization rates (the end justifies the means)



# Drawbacks of Cannibalization

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# Increased Maintenance Personnel Workload and Costs

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- ▶ As numerous GAO reports demonstrate, cannibalizations have increased the workload of aircraft maintenance personnel by literally millions of hours since 1996
- ▶ The increase in workload is due to the fact that (typically in the aircraft community) actions to repair cannibalized items take at least twice as long as normal repairs
- ▶ For a typical aircraft cannibalization, the following occurs:
  - the inoperative part is removed
  - a working part is removed from the cannibalized aircraft
  - the working part is installed on the recipient aircraft
  - a new part is installed on the cannibalized aircraft

Source: (Enslin, Oct-Dec 2004)

# Continued...

- ▶ In the case of critical aircraft components that have been cannibalized, additional in-flight checks must be performed to verify safety; these cost extra time and money
- ▶ Extra maintenance personnel must be present to perform the cannibalizations; this adds numbers and space to the squad
- ▶ Some previous research has quantified the total additional costs of cannibalization by presenting a comprehensive analysis of maintenance data from Navy archival records
  - The additional costs of cannibalization in some cases totaled hundreds of thousands of dollars over a span of five years
- ▶ Labor is not funded by the squad's operational budget, so there is no financial incentive to reduce labor man-hours

Source: (Kowalski, 2000; Worra, 2000)

- Increased opportunity cost since the labor could be utilized

# Decreased Maintenance Personnel Morale (Qualitative Factors)

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- ▶ Evidence shows that increasing personnel workload has a negative effect on morale because they are seen as routinely making unrealistic demands on maintenance personnel
- ▶ They are performed at any time of day or night—and often very quickly in order to meet operational requirements
- ▶ In August of 1999, the GAO reported that the majority of the factors cited by departing Service members as reasons for leaving the military were work-related
- ▶ Thus, the costs associated with cannibalization must include factors such as additional recruiting, retention, and training—costs incurred to replace the dissatisfied Service maintenance personnel

Source: (Enslin, Oct-Dec 2004)



# Inoperable Systems (Availability)

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- ▶ Aircraft that have been cannibalized multiple times are specially designated because they generally require an extraordinary effort to return to flying status
- ▶ Although cannibalization rates have increased in a five-year period, mission-capable rates (related to readiness) have decreased
- ▶ Regression analysis shows that there is no strong relationship between cannibalizations and mission-capable rates

# Maintenance-Induced Damage (Reliability)

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- ▶ In order to remove a component, maintenance personnel often must remove other components to gain access
  - This, in turn, increases the risk of maintenance-induced damage to the aircraft (Enslin, Oct-Dec 2004)
- ▶ Examples of maintenance-induced damage include dropped components, bent pins, and saltwater intrusion (Worra, 2000)
- ▶ The risk of new mechanical problems is also increased because personnel must work on two aircraft (as opposed to just one)
  - Oftentimes the work is rushed in order to meet a strict deadline (Government Accountability Office, 2001)

# Real-world Example

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# Reliability continued

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- ▶ Cannibalizations do not replace a broken part with a new one—just a used one
  - Hence, cannibalizations do not restore a component to its full projected life expectancy—but rather increase the chance that the component will break down prematurely and decrease the reliability of end item wear-out estimates (Enslin, Oct-Dec 2004)
- ▶ In short, cannibalizations performed on the original systems can have a profound impact on the model for future systems when data is used from the original systems (Moore Jr., 2003)
- ▶ Studies have been conducted that found that cannibalized parts experience a shorter service life than non-cannibalized parts (Kowalski, 2000; Worra, 2000)
  - Failure rates increased and mean time between failures (measure of reliability) decreased for the cannibalized components under study

# Benefits of Cannibalization





# Ready Source of Parts

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- ▶ Cannibalization can usually only occur with devices that use interchangeable parts
  - Configuration management is an important issue here
- ▶ Sometimes, removing parts from old equipment is the only way to obtain certain specific types of parts, either because they are no longer made or can only be ordered in large quantities
- ▶ Cannibalization can occur if the equipment in question is obsolete, with the manufacturer(s) of the device or the spare parts no longer in existence
- ▶ Other times, cannibalization is a reflection of a surplus of equipment, making some systems unnecessary except as a source of parts



# Examples

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- ▶ The thirty and forty-year-old railway locomotives being run by small operators in the United Kingdom
  - Operators will often buy more locomotives than they actually require and keep a percentage of them stored as a source of spare parts
- ▶ At the end of World War II, several high-quality but unusable war surplus equipment (such as radar devices) made a ready-and-available source of parts to build radio equipment
  - Often the case in the military
- ▶ The aircraft carrier, USS Kitty Hawk, is the sole survivor of a class of three ships built during the early-1960s
  - For the sake of practicality, decommissioned ships, such as the USS Independence, have been utilized for the necessary parts to keep the USS Kitty Hawk in operation

Source: (Wikipedia)

# Increased Availability and Reduced Costs

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- ▶ The RAND Corporation produced several reports that investigated the Air Force's expensive appetite for recoverable spares inventory
- ▶ “Management adaptations for spares requirements”
  - Includes actions such as cannibalization which actually enhance system performance in the face of uncertainty but are not currently accounted for in the expensive computation of spares requirements (Abell, 1993)
- ▶ As a matter of policy, the Air Force has traditionally assumed no cannibalization when determining recoverable spares requirements (Gaver)
- ▶ Where cannibalization is considered, it's generally considered for all parts or for no parts (Gaver)

# The Rand Study

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- ▶ The RAND Corporation explored the concept of “designated cannibalization,” where some parts are designated as easily cannibalized while others are designated as difficult to cannibalize
  - This approach is already utilized in war scenarios where some parts—like fuses—are obviously easier to cannibalize than others
- ▶ Concluded that the Air Force can achieve satisfactory availability levels of assets by spending less on spares procurement and focusing more on other initiatives—such as “management adaptations”
- ▶ A substantial cost-savings was observed, which could prove particularly attractive during times of budgetary constraints (Abell, 1993)
  - Management adaptations can have significant offsetting qualities

Source: (Abell, 1993; Gaver)

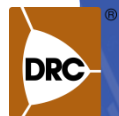
# Increased Readiness/Availability

- ▶ Readiness/Availability: the capability of a system to perform its intended function when called upon to do so
- ▶ Two Army studies concluded that readiness would be “significantly degraded” if cannibalizations were not performed (Government Accountability Office, 2001)
- ▶ Specifically, a 1987 study of helicopter units utilized a controlled experiment where readiness rates dropped more than 25% when cannibalizations were disallowed
  - The rates bounced back to previous levels when they were re-allowed (Government Accountability Office, 2001)
- ▶ An LMI study revealed that cannibalization, which consumes less than one percent of available maintenance man-hours, can actually increase weapon system mission-capable rates by as much as seventeen percent while costing less than one percent of the alternative (buying spare parts)
  - Cannibalization, when properly managed and controlled, can enhance readiness and efficiency while reducing costs



# Situational Cannibalization

- ▶ When should cannibalization be used?
- ▶ An in-depth analysis and example of a situation involving a missile launch system aboard a ship where situational cannibalization could be advantageous
  - Significant weight/space limitations on the ship make spare inventory undesirable
  - All parts of the system are modular remove-and-replace
  - Spares incur a significant cost
- ▶ Generally, such examples will include situations where the negative aspects of cannibalization are invalidated
- ▶ Conclusion: “with the right set of circumstances and positive analytical results, situational cannibalization is a viable support alternative and can be successful if strict guidelines are put in place that clearly state the conditions and equipment for which a situational cannibalization policy may be pursued”



# Mathematical Models and Cannibalization

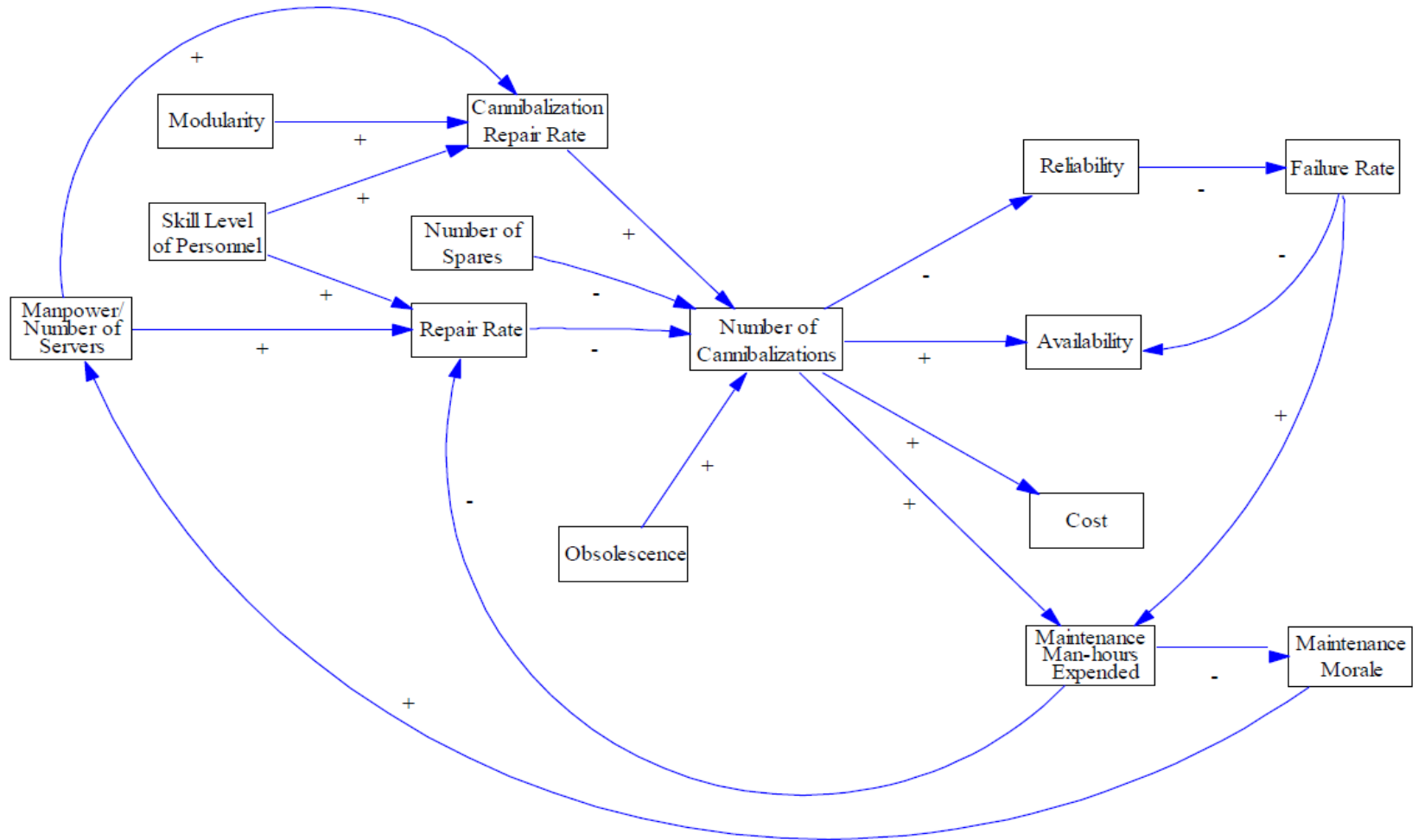
- ▶ Several authors have developed mathematical models that include cannibalization within the literature
- ▶ These models generally involve maximizing or minimizing some objective function (i.e. cost) with regards to certain pre-defined variables (i.e. number of spares, number of repairs, number of cannibalizations, etc.)
  - Ex: (Min)  $Z = Ax + By$ ;
  - An example of linear programming
  - $Z$  could be cost while  $x$  and  $y$  could be repairs and cannibalizations
- ▶ There seems to be a gap in the research with regards to these models including *all* of the metrics/characteristic I found

Source: (W. W. Fisher, 1990; W. W. a B. Fisher, 1986)



# Causal-Loop Diagram of Cannibalization Characteristics (derived from the research)

Note: "+" or "-" simply denotes the relationship in terms of quantity – *not* impact



# Risks

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## ▶ Configuration Management

- It's possible that seemingly interchangeable/compatible parts actually do not match up
- Related to obsolescence—or human error
- Result is wasted time, money, and availability

## ▶ Human skill factor

- Could dramatically influence final cost and time spent
- As an example, degree of maintenance-induced damage

# Conclusions

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- ▶ One cannot make a general statement with regards to cannibalization always being detrimental or beneficial
- ▶ This research examined both the academic literature and industry case studies to uncover characteristics that need to be considered in determining whether or not cannibalization should be pursued as part of an overall sustainment strategy
- ▶ From this research, we can conclude that there are situations where cannibalization will be an effective part of the optimal support strategy
- ▶ Further research (perhaps a well-structured survey targeting personnel familiar with cannibalization) is necessary to quantify the effects of cannibalization on various metrics and to identify precise situations when cannibalization would be optimal



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