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EMPLOYING ORGANIZATIONAL MODELING AND SIMULATION OF THE KC-135 DEPOT'S FLIGHT CONTROLS REPAIR CELL

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Today's environment of increased operations tempo is stressing the KC-135 Stratotanker fleet. With an 80-year life span expectancy, effectively maintaining these aircraft is challenging. This research modeled the KC-135 programmed depot maintenance (PDM) flight controls repair cell to identify improvement opportunities within the repair process. Computational organizational modeling (COM) incorporates the human element along with organizational design theory. By employing COM to analyze the flight control repair cells, the authors examined design modifications applied to the baseline model and analyzed output variables, such as cycle time and project integration risk. The study concluded with presenting organizational design alternatives for decision makers to enhance the flight controls repair process.

The Boeing KC-135 Stratotanker's principal mission is air refueling of Department of Defense (DoD) and allied nations' aircraft. As a result of increased operations tempo, refueling and nontraditional taskings continue to stress the aging fleet. Furthermore, "the KC-135 fleet averages more than 46 years and is the oldest combat weapon system in the Air Force inventory" (Solis, Borseth, Coleman, Mardis, Thornton, et al., 2007, p. 1). With an 80-year life span expectancy, maintaining aging aircraft by the most cost-effective and efficient means is a difficult challenge. This article presents the results of computational organizational modeling (COM) and simulation as an alternative methodology to complement the unit's transformation initiatives by deconstructing the flight controls repair process to identify efficient approaches to oversee process improvement at the repair cells.

The 564th Aircraft Maintenance Squadron (564 AMXS) is a unit assigned to the Oklahoma City Air Logistics Center (OC-ALC) responsible for the U.S. Air Force (USAF) KC-135 aircraft's PDM. Within the squadron, the KC-135 flight controls repair cell (referred to as the Horizontal/Vertical [HV] Repair Cell throughout this article) is charged with refurbishing the aircraft's vertical and two horizontal stabilizers.

The HV Repair Cell faces multiple complexities stemming from mission requirements, financial pressures, workforce reductions, aircraft age, and continuous demands to eradicate waste. The OC-ALC senior leaders and KC-135 PDM management expressed interest in additional approaches to improve PDM operations and invited the Naval Postgraduate School (NPS) to conduct this research. An analysis of the organization is used to assess the HV Repair Cell's leverage of communication across its functions and information sharing between personnel.

Our research utilized POWer 3.0a software developed by the Virtual Design Team (VDT), led by Dr. Raymond E. Levitt and Dr. John C. Kunz at Stanford University. Our objective was to provide decision makers feasible alternatives regarding the KC-135 HV Repair Cell's organizational design. To meet this objective, we developed a computational organizational model of the flight controls repair operation to emulate the current maintenance process. Employing the model helped identify problem areas that might increase repair duration, integration risk, cost, and work backlog affecting decision bottlenecks. After developing the baseline model, we modified it to characterize the implications of subsequent organizational design changes (*what-if* scenarios called *interventions*) on improving the repair process.

METHOD

SCOPE

This research project only considered the organization, personnel, and processes that accomplish flight controls maintenance. The report and modeling effort traced maintenance and administration tasks beginning when the HV Repair Cell receives the vertical and two horizontal stabilizers (after removal from the aircraft) and ending when the repair cell deems the stabilizers serviceable and ready for reinstallation on the aircraft. While the repair cell typically processes up to six sets of stabilizers at once, the model represents the repair of one set of stabilizers, based on information collected from unit personnel. Modeling and simulation of the flight controls repair operation was undertaken using unique POWer 3.0a software. This software was selected because it quantitatively models work processes, information and communication exchanges, human behavior, and organizational design.

LITERATURE REVIEW

In the 1980s, Dr. Levitt formed the VDT to investigate how to predict organizational behaviors using COM. The team based its computational organizational framework on Jay R. Galbraith's (1974; 1977) information-processing concepts. Their research uses COM to examine work processes and information flows associated with project- or task-based organizations (Nissen & Levitt, 2002).

COM enables decision makers to model and simulate prospective organizational design changes, evaluate modifications, calculate impact, and determine if potential benefits are worth the costs and risks. Moreover, it allows decision makers to identify and examine unintended consequences of organizational design changes before implementation.

Employing the VDT model provides a valuable tool for managers to design organizations "the same way engineers design bridges: by building and analyzing computational models of planned organizations and the processes that they support."

According to Kunz, Christiansen, Cohen, Jin, and Levitt (1998), Galbraith (1977) asserts that organizations possess limited abilities to process *exceptions*. Exceptions occur when local knowledge or authority is insufficient to deal with the information processing requirements, and personnel need advice or direction to accomplish their assigned tasks. The VDT incorporates Galbraith's (1977) view regarding exceptions processing into the computational model. Through functional and project exception probabilities, the model simulates task and project failures and subsequent rework when organizational knowledge or authority is inadequate. The unique benefit of POWer software is that decision makers can preview potential organizational design changes and quantitatively project risk or rework levels prior to implementation, a feature that we use extensively in this study.

Employing the VDT model provides a valuable tool for managers to design organizations "the same way engineers design bridges: by building and analyzing computational models of planned organizations and the processes that they support" (Kunz, et al. 1998, p. 84). The VDT constructed a computational model that emulates real-world situations within the organization (Nissen & Levitt, 2002) and provides a capability to test through simulation and evaluate structural and task modifications. Thus, managers can identify how changes on interdependent activities can affect efforts to avert cost overruns and quality failures (Levitt, 2004). Additionally, managers can identify unanticipated increase in coordination effort or rework occurring from overlapping and interdependent work tasks. According to Levitt and Kunz (2002, p. 4), "this coordination and rework is hidden effort: it is not planned, tracked, managed, or even acknowledged except by the overworked staff."

Inputs entered in the VDT model transform qualitative attribute values into quantitative values. Depending on a unit's activities and procedures, these inputs may consume time and generate certain communication requirements and exceptions. Exceptions occur when workers detect task errors requiring additional information or correction (rework). The VDT model assigns all positions a processing speed and the probability of identifying failure, indicating when a sub-activity within an overall activity fails.

The VDT framework is supported by Galbraith's (1973; 1974) theory that organizations serve as *exception-handling machines* as part of his information processing view of organizations. Based on their conceptualization of Galbraith's theory, the VDT's "approach simulates the direct work and the hidden work, i.e., the coordination, supervision, rework, and waiting for all the actors in a project as they perform all of the project tasks" (Levitt & Kunz, 2002, p. 11).

INPUT PARAMETERS TO CONSTRUCT BASELINE

Applying information collected from HV Repair Cell personnel and observation of the flight control repair process, we developed a baseline model using the POWer 3.0a software. The following parameters provided the foundation for the KC-135 HV Repair Cell model: (a) milestones, (b) tasks, (c) positions, and (d) meetings.

Milestones

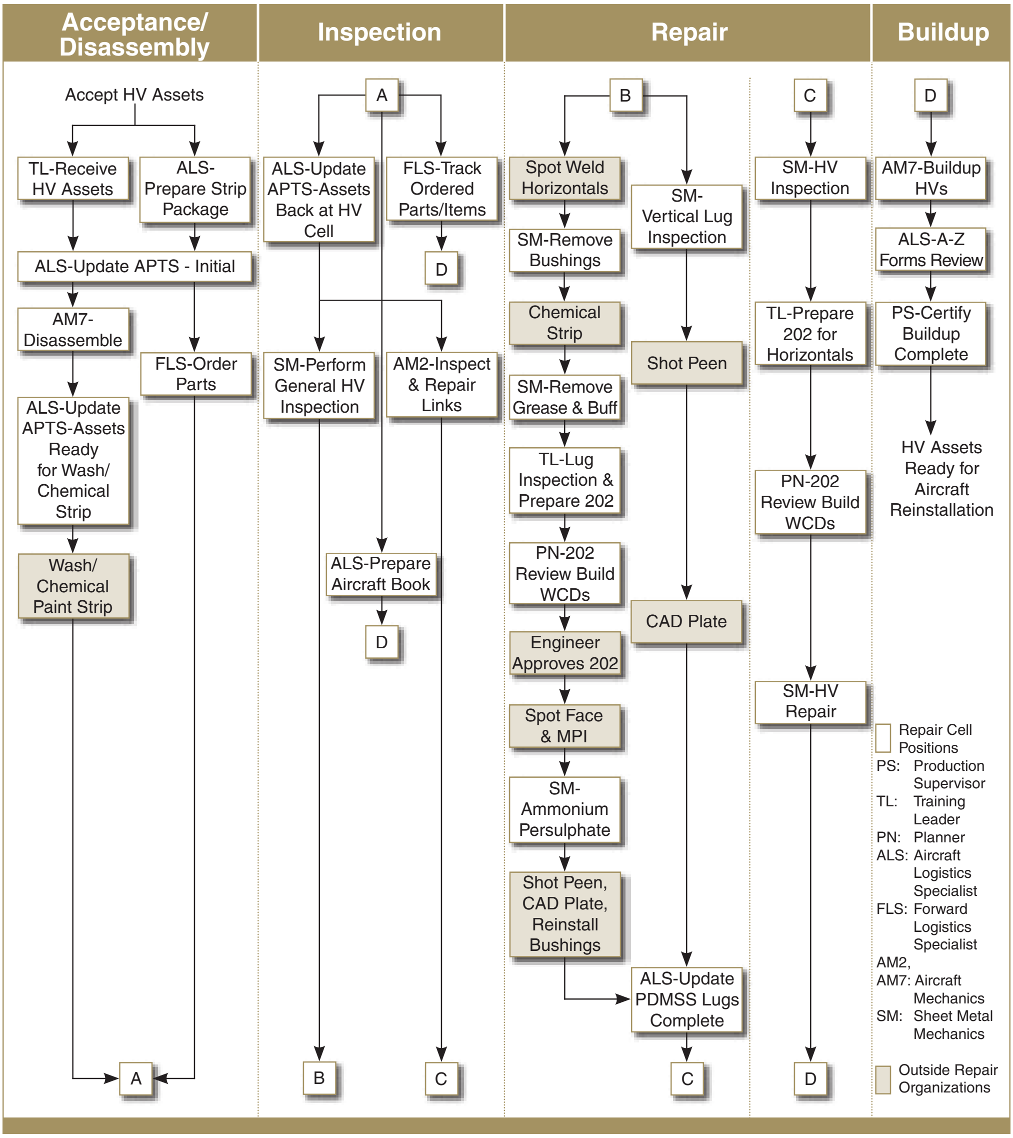
Milestones identify the objective of the work performed and indicate the beginning or ending of all work to complete the milestone's objective. We also defined the tasks to accomplish each milestone. The repair process comprises four milestones: acceptance/disassembly, inspection, repair, and buildup (Figure 1).

FIGURE 1: HV REPAIR CELL MODEL'S FOUR MILESTONES

Tasks

Tasks represent all the jobs that employees are responsible for completing. During the repair process, simultaneous production, scheduling, planning, and logistics operations occur. The HV Repair Cell model incorporates multiple tasks and subtasks taking place throughout the flight controls repair process. Figure 2 illustrates the model's four milestones indicating the tasks and responsible positions.

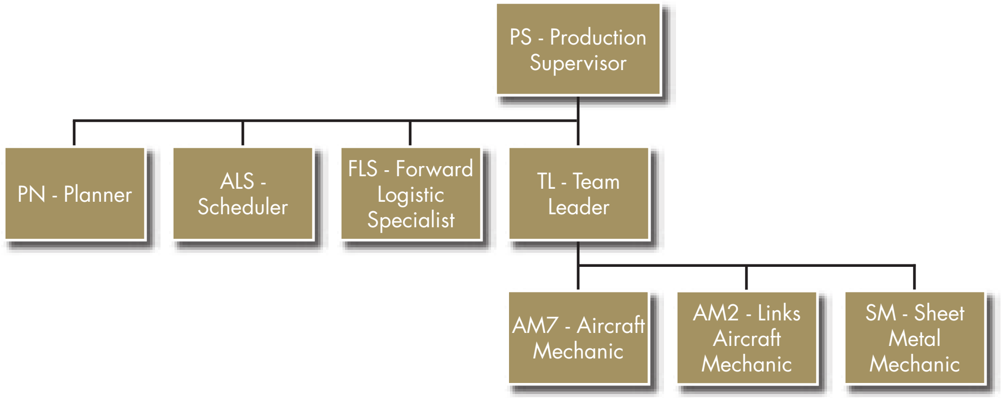
FIGURE 2: HV REPAIR CELL MODEL'S MILESTONES AND TASKS



Positions

Positions account for the personnel responsible for HV Repair Cell tasks. Within the model, eight positions execute repair and administrative tasks and characterize the hierarchy of information flow. Figure 3 depicts our representation of the repair cell positions and how they share information up, down, and across the informational hierarchy. While not a chain-of-command diagram, it shows the positions that execute repairs, accomplish administrative paperwork, and supervise subordinates' efforts (i.e., flight controls repair tasks). The model also includes leadership positions signifying decision-making personnel who regularly receive exception-handling questions on how to resolve errors from subordinates.

FIGURE 3: HV REPAIR CELL MODEL'S POSITIONS AND INFORMATION HIERARCHY



Meetings

Meetings represent important methods and times whereby personnel regularly, formally, and reliably transfer information about repair and administrative tasks and procedures. There are three meetings in the baseline model to coordinate daily asset schedules, conduct roll call, and share end-of-shift turnover information.

ADDITIONAL INPUT PARAMETERS TO CONSTRUCT BASELINE

Once the foundational parameters were established, we analyzed the organization's decision-making policies supporting the flight controls repair operation. These policies and procedures impact micro-decision-making behavior of HV Repair Cell workers and supervisory personnel.

- ***Team experience*** defines the extent to which organizational members previously and successfully worked together to accomplish the project. The set value determines how quickly or slowly positions process information.
- ***Centralization*** characterizes whether decisions are made by senior-level positions or decentralized to lower-level (subordinate), responsible positions.

The set value impacts project duration, waiting time, position backlog, and project integration risk.

- ***Formalization*** defines whether communication within the organization tends to occur formally in meetings, informally between position members, or evenly between formal and informal methods.
- ***Matrix strength*** describes the "connectedness" of the organization. This setting illustrates the use of informal and formal information exchanges, perceived need to attend meetings, and percentage of formal meetings attended.
- ***Communication probability*** measures the level of communication required between tasks that are interdependent.
- ***Noise probability*** measures the probability of interruptions that take time away from position members conducting direct flight controls repair tasks in an ordinary working day.
- ***Rework links*** represent where rework occurs resulting from and related to identified tasks.
- ***Functional exception probability*** defines the probability that repair tasks fail due to localized task errors and require rework by the position responsible for the errors. Errors may be detected through self-check procedures, after completion of work by position peers, or supervisor's review. When the model generates a functional exception, the position responsible for correcting the error either reworks, quickly fixes, or ignores it based on the model's functional exception probability setting.
- ***Project exception probability*** defines the probability that repair tasks fail and generate rework for all dependent tasks. If applicable to the organization, these tasks are connected by rework links in the model. The responsible position reworks, quickly fixes, or ignores the error when the model generates a project exception.
- ***Communication links*** represent task completion and integration dependency. If two tasks require personnel to talk and share information, a communication link is incorporated into the model between those two interdependent tasks. Communication links inform the model these tasks depend on each other for information.
- ***Knowledge links*** represent relationships and information sharing between coworkers. Coworkers provide information to other employees about task requirements by sharing their skills and experiences. Without knowledge sharing, workers may make decisions concerning task completion that compromise overall task and/or repair quality. By sharing information and communicating within the information hierarchy, employees mitigate the number of functional exceptions and project risk.

Baseline Model

The computational organizational model of the flight controls repair operation emulates the HV Repair Cell's current process and operations. Figure 4 depicts a POWer 3.0a screenshot of the HV Repair Cell baseline model. Within the screenshot, lines correspond to knowledge transfer, information sharing, task interdependencies, and process flow. The three parallelograms at the top of the image represent meetings, the eight *people* objects illustrate positions, the rectangles below the positions represent core *touch* tasks, the hexagons portray completion milestones, and the long rectangles to the upper right represent non-touch tasks.

In the model, positions connect to assigned tasks using task-assignment arrows. Arrows connecting positions to positions from the *head* denote supervisory roles, while arrows connecting positions to positions from the *feet* represent knowledge links. Arrows connecting positions to meetings symbolize required meeting attendance. Sets of arrows between tasks signify interdependencies, rework links, and communication links. Finally, arrows link each task (rectangle) and milestone (hexagon), starting from the HV Repair Start (top left), and ending with the HV Repair Finish (mid right). These show sequential and parallel tasks within the process flow path.

The validity of the baseline model's output was critical to accurately gauge the effects of the applied interventions. Hence, we performed sensitivity analysis to verify the baseline model's validity. The *communication probability* parameter was selected to assess its impact to the HV Repair Cell model. The baseline's duration of 34.32 days provides the closest approximate result—within 1.9 percent of the historical average repair of 35 workdays. We changed the *communication probability* setting from 0.20 to 0.10 or 0.30, which reduced duration by 0.10 percent and 0.19 percent from the baseline's prediction, to 34.29 and 34.26 days respectively. Thus, the baseline model with a 0.20 *communication probability* setting most accurately emulates the actual repair process, showing that the model is robust to reasonable changes in this parameter. The flight controls repair duration predicted by this model sufficiently reflects the observed duration of 35 workdays. The accuracy of the baseline model improves the probability that simulations will predict realistic outputs. Therefore, this model was used to forecast performance outputs, such as expected repair duration, direct and indirect work, waiting time, project cost and risk, and exception-handling.

Interventions

Once the baseline model accurately depicted current flight controls repair operations, we examined eight output parameters from the model's simulation results. The parameters included project duration, direct work time, indirect work time (*measured by rework time, coordination time, exception-handling wait time*), total direct and indirect work time, total project cost, total functional and project exception time (*measured by functional exception work and project exception work*), project risk, and position backlog. After this assessment, we identified seven organizational design interventions to simulate and compare against the baseline model.

PLACEHOLDER PAGE FOR 10″ X 12.5″ PULLOUT

FIGURE 4: HV REPAIR CELL BASELINE MODEL

BACK OF 10″ X 12.5″ PULLOUT

- ***Intervention 1*** added a sheet metal mechanic to the current pool of 14 sheet metal mechanics. This intervention provided insight into how much repair duration could be reduced by increasing this resource.
- ***Intervention 2*** combined the AM2 and AM7 positions to create one AM9 position with nine aircraft mechanics responsible for all aircraft mechanic tasks. The intervention was projected to show the impact of knowledge-sharing and enhanced training on low-skill-level AM2 personnel. These improvements were expected to reduce project duration and decrease rework time. Because of learning curve effects, the model predicted the need for increased coordination time and exception-handling wait time as AM2 members learned new tasks and asked more questions.
- ***Intervention 3*** changed the level of *centralization* (decision-making and exception-handling responsibilities) from medium to low, changing the organization's decision-making practices to a decentralized operation. The results of this intervention were expected to decrease overall repair time, rework, coordination, and exception-handling wait time. Yet, low levels of centralization were also predicted to increase project integration risk as lower-level repair cell employees sought less information from higher-level decision makers.
- ***Intervention 4*** increased the *functional exception probability* parameter value from 5 percent to 10 percent. This intervention evaluated the effects of added stress if the repair process became less standardized and caused more *exceptions*. This intended to mimic the experience with recent KC-135 stabilizers (undergoing PDM) assigned to units in highly corrosive environments that recently displayed more severe corrosion damage. This damage affected repair diagnosis and repair time by causing more exceptions or task errors. Mechanics and administrators made more exception-handling inquiries to the team leader on how to proceed. Thus, to model additional stress on the system, the *functional exception probability* parameter value was raised from 5 percent to 10 percent. Overall project duration, cost, and integration risk were predicted to increase as employees learned new operating procedures. As strain on the flight controls system intensified, the amount of exceptions was expected to escalate.
- ***Intervention 5*** combined Intervention 2 (create AM9 position) and Intervention 3 (change *centralization* to low). After evaluating the first four interventions' simulation results, we developed a combined intervention to assess potential synergistic effects. This intervention revealed whether beneficial interventions executed in isolation result in the same, incremental, or continued improvement when integrated.
- ***Intervention 6*** cross-trained and combined all aircraft and sheet metal mechanics to create one *Mechanic Pool* position. Current OC-ALC hiring and operating regulations prohibit employees from formal cross-training. This intervention simulated if the OC-ALC collective bargaining agreement

was renegotiated to allow formal cross-training. The workers assigned to the mechanic pool would require training and certification to complete disassembly, inspection, repair, and buildup tasks. Cross-training was expected to increase learning, knowledge sharing, and skill levels for all mechanics. Additionally, this intervention was anticipated to make accomplishing disassembly, inspection, repair, and buildup more efficient, since only one position (instead of three) would be responsible for these tasks. As one position becomes accountable for all mechanic tasks, repair duration, cost, integration risk, and indirect work time were predicted to decrease. With 23 mechanics working jointly to complete tasks, the amount of exceptions generated by the model was expected to grow, but also be handled more quickly.

- ***Intervention 7*** changed the following parameters to analyze the expected outcome if three unit personnel retired within the next two fiscal years: *team experience, communication probability, project exception probability,* and *functional exception probability*. In 2007, the 76th Maintenance Wing offered voluntary retirement incentives (under the federal government's Voluntary Separation Incentive Pay program) to retirement-eligible personnel as part of reshaping efforts to match the workforce with workload requirements (Daniel, 2007). According to the HV Repair Cell's shop supervisor, two sheet metal mechanics and one aircraft mechanic were eligible to retire between September 30, 2007, and September 30, 2009. This intervention simulated and identified the effect on the unit if another retirement incentive program was offered and the three members retired.

Previewing potential organizational changes and subsequent consequences before expending resources offers valuable and cost-effective advantages. Simulating interventions on the baseline model allows quantifying these impacts. Furthermore, the model provides decision makers with quantitative evidence for enacting prospective HV Repair Cell design modifications.

RESULTS

Table 1 shows eight output parameters evaluated during this research:

a) simulated project duration;
b) direct work time;
c) indirect (or hidden) work time measured by rework time, coordination time, exception-handling wait time;
d) total direct and indirect work time;
e) total project cost;
f) total functional and project exception time measured by functional exception work and project exception work;
g) project risk; and
h) position backlog.

Table 1: SAMPLE OUTPUT PARAMETERS, HV REPAIR CELL BASELINE MODEL

Numerical Output	Baseline Model Starting Point	
Simulated Project Duration (days)	34.32	
Direct Work Time (days)	130.52	
Indirect (Hidden) Work Time (days):	30.85	
Rework Time (days)		*5.03*
Coordination Time (days)		*18.31*
Exception-Handling Wait Time (days)		*7.51*
Total Direct and Indirect (Hidden) Time (days)	161.38	
Total Project Cost ($)	$60,627.98	
Total Functional and Project Exception Time (days)	8.74	
Functional Exception Work (days)		*7.95*
Project Exception Work (days)		*0.77*
Project Risk	0.07	
Position Backlog (days)	2.87	
Position with Highest Backlog	AM2 - Links Aircraft Mechanic	

SIMULATED PROJECT DURATION

Simulated project duration is the amount of time, on average, the entire HV Repair Cell process takes to complete, including all maintenance and administrative tasks for one set of horizontal and vertical stabilizers.

DIRECT WORK TIME

Direct work time measures the amount of time positions consume as they perform tasks before handling any exceptions generated by the model..

TOTAL INDIRECT OR HIDDEN WORK TIME

Total indirect or hidden work time incorporates rework time, coordination time, and exception-handling wait time.

- ***Rework time*** is the time all positions need during the flight controls repair process to carry out rework. This time measures the impact if a driver task fails, causing rework time for all dependent tasks linked to the driver task by one of the model's four rework links.

- ***Coordination time*** is the amount of time positions spend attending meetings and processing information requests from other positions.
- ***Exception-handling wait time*** measures the time positions consume waiting for a supervisor's response about how to resolve functional or project exceptions generated by the model. If the supervisor is managing other tasks or positions and becomes overly backlogged, personnel may decide to ignore or quickly fix the error and cause project risk to escalate.

TOTAL DIRECT AND INDIRECT WORK TIME

Total direct and indirect work time is the sum of direct work time plus all indirect work time.

TOTAL PROJECT COST

Total project cost is the sum of direct work, rework, coordination, and exception-handling wait costs. These costs were based on POWer's default fixed cost settings for the salary of each position ($50 per hour) and each task ($0). Although the true cost of conducting tasks and employing positions was not modeled for this research, the default settings enabled us to monitor relative changes in total project cost for each intervention compared to the baseline model.

TOTAL FUNCTIONAL AND PROJECT EXCEPTION TIME

Total functional and project exception time represents the sum of the time positions take to complete work on exceptions (rework).

- ***Functional exception time*** signifies the amount of time positions consume repairing specific tasks that fail and require rework.
- ***Project exception time*** records the time that positions take repairing failed tasks and dependent tasks (attached in the model by rework links).

PROJECT RISK

Project risk represents the probability repaired stabilizer components are not integrated at the end of the repair process because they have defects following rework and exception-handling.

POSITION BACKLOG

Position backlog depicts the number of days of direct and indirect work a position has yet to accomplish. The position with the largest backlog and the corresponding amount is presented.

Tables 3 and 4 summarize the results of the seven interventions applied to the baseline model. Moreover, Table 2 shows a relevance legend to help evaluate the changes in each intervention.

Table 2: Output Value Levels of Relevance

Value (X)	Level of Relevance
X < 1%	No Relevant Difference
1% ≤ X < 5%	Weakly Relevant Difference
5% ≤ X < 10%	Relevant Difference
X > 10%	Highly Relevant Difference

Table 3: Output Parameters, Numerical Comparison to Baseline Model

Numerical Output	Baseline Model	Interven-tion 1	Interven-tion 2a	Interven-tion 2b	Interven-tion 3	Interven-tion 4	Interven-ton 5	Interven-tion 6	Interven-tion 7
	Starting Point	Add One SM Mechanic	Create AM9 Aircraft Mech Position (Med Skills)	Create AM9 Aircraft Mech Position (High Skills)	Change Central-ization from Med to Low	Functional Exception from 5% to 10%	Combina-tion (AM9 Position & Low Central-ization)	Cross-train/1 Mechanic Resource Pool	Retire-ment
Simulated Project Duration (days)	34.32	33.90	34.21	33.46	34.15	34.98	33.51	29.42	35.03
Direct Work Time (days)	130.52	130.52	127.90	127.90	130.52	130.52	127.90	125.27	130.52
Indirect (Hidden) Work Time (days):	30.85	31.43	33.24	31.22	29.83	43.36	30.03	26.74	47.29
Rework Time (days)	*5.03*	*5.14*	*4.93*	*4.96*	*4.92*	*10.06*	*4.75*	*3.64*	*10.27*
Coordination Time (days)	*18.31*	*18.72*	*18.82*	*18.65*	*18.15*	*19.41*	*18.70*	*17.42*	*22.06*
Exception-Handling Wait Time (days)	*7.51*	*7.57*	*9.50*	*7.61*	*6.76*	*13.89*	*6.58*	*5.68*	*14.95*
Total Direct and Indirect (Hidden) Time (days)	161.38	161.95	161.14	159.12	160.35	173.88	157.93	152.01	177.81
Total Project Cost ($)	$60,627.98	$60,841.87	$64,767.71	$56,739.93	$60,224.56	$65,543.84	$56,280.97	$60,453.35	$67,813.97
Total Functional and Project Exception Time (days)	8.74	8.71	9.27	8.86	8.64	16.61	8.43	9.31	17.51
Functional Exception Work (days)	*7.95*	*7.82*	*8.34*	*7.81*	*7.82*	*15.71*	*7.47*	*8.19*	*15.99*
Project Exception Work (days)	*0.77*	*0.88*	*0.92*	*1.04*	*0.81*	*0.89*	*0.95*	*1.11*	*1.51*
Project Risk	0.07	0.08	0.09	0.10	0.08	0.08	0.09	0.06	0.12
Position Backlog (days)	2.87	2.85	1.69	1.55	2.87	2.98	1.51	1.43	2.97
Position with Highest Backlog	AM2-Links Aircraft Mechanic	AM2-Links Aircraft Mechanic	TL-Team Leader	TL-Team Leader	AM2-Links Aircraft Mechanic	AM1-Links Aircraft Mechanic	TL-Team Leader	TL-Team Leader	AM2-Links Aircraft Mechanic

Table 4: OUTPUT PARAMETERS, PERCENTAGE CHANGE FROM BASELINE MODEL

Percentage Change from Baseline (%s)	Baseline Model	Interven-tion 1	Interven-tion 2a	Interven-tion 2b	Interven-tion 3	Interven-tion 4	Interven-ton 5	Interven-tion 6	Interven-tion 7
	Starting Point	Add One SM Mechanic	Create AM9 Aircraft Mech Position (Med Skills)	Create AM9 Aircraft Mech Position (High Skills)	Change Central-ization from Med to Low	Functional Exception from 5% to 10%	Combina-tion (AM9 Position & Low Central-ization)	Cross-train/1 Mechanic Resource Pool	Retire-ment
Simulated Project Duration	34.32	-1.22%	-0.34%	-2.52%	-0.49%	**1.92%**	-2.37%	-14.28%	**2.06%**
Direct Work Time	130.52	NO CHANGE	-2.01%	-2.01%	NO CHANGE	NO CHANGE	-2.01%	-4.02%	NO CHANGE
Indirect (Hidden) Work Time:	30.85	**1.87%**	**7.75%**	**1.19%**	-3.33%	**40.53%**	-2.66%	-13.34%	**53.27%**
Rework Time	*5.03*	***2.24%***	*-2.03%*	*-1.49%*	*-2.24%*	***99.99%***	*-5.51%*	*-27.67%*	***104.22%***
Coordination Time	*18.31*	***2.23%***	***2.80%***	***1.88%***	*-0.85%*	***6.01%***	***2.12%***	*-4.85%*	***20.50%***
Exception-Handling Wait Time	*7.51*	***0.75%***	***26.36%***	***1.29%***	*-10.09%*	***84.81%***	*-12.40%*	*-24.43%*	***99.01%***
Total Direct and Indirect (Hidden) Time	161.38	**0.36%**	-0.15%	-1.40%	-0.64%	**7.75%**	-2.14%	-5.80%	**10.18%**
Total Project Cost	$60,627.98	**0.35%**	**6.83%**	-6.41%	-0.67%	**8.11%**	-7.17%	-0.29%	**11.85%**
Total Functional and Project Exception Time:	8.74	-0.30%	**6.14%**	**1.44%**	-1.15%	**90.15%**	-3.48%	**6.60%**	**100.47%**
Functional Exception Work	*7.95*	*-1.61%*	***4.94%***	*-1.76%*	*-1.64%*	***97.57%***	*-6.07%*	***3.03%***	***101.08%***
Project Exception Work	*0.77*	***13.14%***	***18.25%***	***33.81%***	***3.93%***	***14.93%***	***22.78%***	***43.27%***	***94.27%***
Project Risk	0.07	**16.48%**	**32.11%**	**40.43%**	**20.51%**	**17.52%**	**36.49%**	-18.68%	**81.10%**
Position Backlog	2.87	-0.64%	-41.26%	-45.99%	NO CHANGE	**3.66%**	-47.56%	-50.18%	**3.55%**
Position with Highest Backlog	AM2-Links Aircraft Mechanic	NO CHANGE	TL-Team Leader	TL-Team Leader	NO CHANGE	NO CHANGE	TL-Team Leader	TL-Team Leader	NO CHANGE

DISCUSSION

RECOMMENDATIONS

The simulation results of the seven interventions performed in this research provide OC-ALC leaders an analysis of quantitative and qualitative information. Table 5 summarizes the output parameters of the baseline model next to the best, second-best, and third-best intervention models.

Table 5: OUTPUT PARAMETERS OF BASELINE

Output Parameter	Baseline Model Output	Best Model and Output	2nd Best Model and Output	3rd Best Model and Output
Simulated Project Duration (days)	34.32	Intervention 6 29.42	Intervention 2b 33.46	Intervention 5 33.51
Direct Work Time (days)	130.52	Intervention 6 125.27	Interventions 2a, 2b, 5 127.90	Baseline Interventions 1, 3, 4, 7 130.52
Indirect (Hidden) Work Time (days):	30.85	Intervention 6 26.74	Intervention 3 29.83	Intervention 5 30.03
Rework Time (days)	*5.03*	Intervention 6 3.64	Intervention 5 4.75	Intervention 3 4.92
Coordination Time (days)	*18.31*	Intervention 6 17.42	Intervention 3 18.15	Baseline 18.31
Exception-Handling Wait Time (days)	*7.51*	Intervention 6 5.68	Intervention 5 6.58	Intervention 3 6.76
Total Direct & Indirect (Hidden) Time (days)	161.38	Intervention 6 152.01	Intervention 5 157.93	Intervention 2b 159.12
Total Project Cost ($)	$60,627.98	Intervention 5 $56,280.97	Intervention 2b $56,739.93	Intervention 3 $60,224.56
Total Functional & Project Exception Time (days)	8.74	Intervention 5 8.43	Intervention 3 8.64	Intervention 1 8.71
Functional Exception Work (days)	*7.95*	Intervention 5 7.47	Intervention 2b 7.81	Intervention 1, 3 7.82
Project Exception Work (days)	*0.77*	Baseline 0.77	Intervention 3 0.81	Intervention 1 0.88
Project Risk	0.07	Intervention 6 0.06	Baseline 0.07	Interventions 1, 3, 4 0.08
Position Backlog (days)	2.87	Intervention 6 1.43	Intervention 5 1.51	Intervention 2b 1.55
Position with Highest Backlog	AM2-Links Aircraft Mechanic	TL-Team Leader	TL-Team Leader	TL-Team Leader

AND TOP RANKED INTERVENTIONS

As a result of this research, the following recommendations were provided to OC-ALC leaders:

- Address current hiring and operating regulations to pursue the allowance of formal cross-training within the HV Repair Cell.
- Continue with voluntary informal cross-training of aircraft and sheet metal mechanics within the HV Repair Cell. Expand the number of cross-training tasks as time and effort permit.
- Train and fully qualify all nine aircraft mechanics in disassembly, repair linkages, and buildup tasks to create one highly skilled aircraft mechanic position.

- Identify clear expectations and develop an *HV Repair Cell Transition Plan* to prepare the organization as multiple employees become retirement-eligible.

The output from Intervention 6 strongly supported cross-training within the HV Repair Cell. We recommended that OC-ALC leaders pursue changing the current hiring and operating regulations to permit formal cross-training. In the interim, we suggested the production supervisor and team leader continue with voluntary informal cross-training of aircraft and sheet metal mechanics. The results from Intervention 6 might prove useful to objectively portray that potential benefits outweigh the cost of cross-training HV Repair Cell mechanics—including highly relevant time, rework, exception-handling, risk, and position backlog improvements.

Employment of Intervention 5 characteristics entails a certain amount of training effort to teach the aircraft mechanics new tasks and time to decentralize decision-making authority within the organization. Therefore, we urged the HV Repair Cell to begin to fully qualify and utilize all aircraft mechanics as soon as possible. The findings suggested the unit would benefit from training the two aircraft mechanics currently dedicated to repairing linkages on disassembly and buildup tasks. Since this organizational change requires adequate planning, it should not occur too quickly. As low-skill-level mechanics become medium-skilled and more highly skilled, the HV Repair Cell should complete repairs more efficiently and rapidly.

Additionally, decision makers would require restraint and trust to control how to decentralize decision-making authority. Lower levels of centralization might be realized by three initiatives:

1. management taking time to clearly explain expectations and *exceptions-to-the-rule* if an emergency arises,
2. supervisors believing in subordinates' skill levels and exception-handling abilities, and
3. leadership preparing mechanics sufficiently to make good decisions, ensuring flight controls repair quality does not suffer.

The results of Intervention 7 (three eligible mechanics retire) underscored the complications organizations face as multiple employees become retirement-eligible. Before moving workers between divisions or organizations, leaders should consider the resulting percent of retirement-eligible personnel the moves create. Considering the findings from Intervention 7 should help decision makers explain the expected impact of workforce reshaping efforts and help mitigate undesirable consequences. As the number of retirement-eligible federal civilian employees increases, dealing with this type of organizational design decision will become both more difficult and more important for the DoD.

Prior to implementing any of the preceding recommendations, we advised OC-ALC decision makers to review planned and ongoing process-improvement initiatives affecting horizontal and vertical stabilizer repair and to identify similarities to the interventions performed during this study.

Understanding the enormous influence communication, information processing abilities, and organizational design have upon performance is fundamental to the

KC-135 aircraft's PDM and mission success. Effective knowledge and information transfer between personnel directly impacts PDM timeliness, cost, integration risk, and quality. Therefore, we recommend that other organizations, faced with complex processes depending on various levels of communication and skill levels, should consider the computerized organizational modeling approach to analyze and improve their processes. In particular, remanufacturing and repair facilities with 6–10 positions, 3–5 milestones, and 35–50 tasks would be great candidates for process analysis and improvement using this method. For example, should the facility remanufacture complex assets, such as complete aircraft or armored cars, the analyst should partition the analysis into easily identifiable teams operating in one or more modules of the whole, rather than trying to analyze the complete process at once. While the approach helps comprehend the process and untangle some of its complexity, one can obtain better results if part of the complexity is reduced by judicious partition of the complete operation prior to initiating the analysis.

CONCLUSIONS

Computational organizational modeling and simulation results generated by this research increased flight controls repair visibility and supplied an objective awareness for KC-135 PDM decision makers. The more transparency and utility provided, the more apt decision makers will be to examine potential organizational design modifications and assess the inherent trade-offs prior to executing changes.

The baseline model constructed for this study may be used by OC-ALC leaders and decision makers as a starting point to provide quantitative and qualitative results of future HV Repair Cell design initiatives. Furthermore, the COM results may validate organizational design adjustments leaders already believe might improve the HV Repair Cell, but are not thoroughly convinced or prepared to implement.

By simulating multiple interventions for comparison against the current flight controls repair process (depicted by the baseline), this study facilitated the HV Repair Cell's efforts to manage repair integration risk and conserve limited time and resources. Before implementing any design interventions shown to mitigate risk or decrease throughput time, HV Repair Cell leaders should also consider implementation and opportunity costs. Decision makers should weigh the trade-offs between time saved, stabilizer repair quality (project integration risk), and investment cost.

Cost benefit and risk analysis are essential to designing optimal organizational layouts. Military leaders must consider the relationship between organizational performance improvements (e.g., reduced repair turnaround time) and risk factors. The DoD emphasizes warfighter safety by managing risk. Repaired stabilizers installed on the KC-135 must perform in accordance with design characteristics, environmental conditions, operating constraints, and aircrew expectations. Otherwise, poor quality could prove fatal in combat or training environments.

In conclusion, the more visualization and transparency provided to decision makers before executing potential organizational design modifications, the better prepared they are to make those decisions. We aim to provide value by highlighting and presenting the importance of COM because it uniquely incorporates the human element through an objective method. We hope that future efforts will employ this innovative type of modeling approach to enhance decision making and complement other DoD transformation initiatives, such as U.S. Air Force Smart Operations for the 21st Century, Lean Six Sigma, and the U.S. Navy's AIR*Speed* program.

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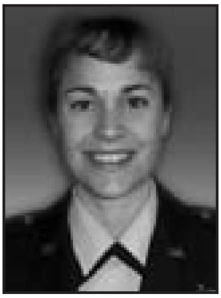

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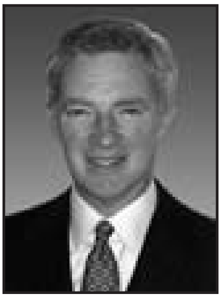

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REFERENCES

Collaboratory for Research on Global Projects. (2006). *POW-ER documentation for POW-ER 2.0.* Stanford, CA: Stanford University.

Daniel, J. (2007, February 9). ALC to offer retirement incentives. *Tinker Takeoff.* Retrieved September 10, 2007, from www.tinkertakeoff.com/article.htm?intRecID=13697

Galbraith, J. R. (1973). *Designing complex organizations.* Reading, MA: Addison-Wesley Publishing Company.

Galbraith, J. R. (1974). Organization design: An information processing view. *Interfaces.* Retrieved January 31, 2008, from www.jaygalbraith.com/resources/infoprocess1974.pdf

Galbraith, J. R. (1977). *Organization design.* Reading, MA: Addison-Wesley Publishing Company.

Kunz, J. C., T. R. Christiansen, G. P. Cohen, Y. Jin, & R. E. Levitt. (1998, November). The virtual design team. *Communications of the ACM*, 41(11), 84–91.

Levitt, R. E., & J. C. Kunz. (2002, August). *Design your project organization as engineers design bridges.* Center for Integrated Facility Engineering (CIFE) Working Paper No. 73. San Francisco: Stanford University. Retrieved January 31, 2008, from www.stanford.edu/group/CIFE/online.publications/WP073.pdf

Levitt, R. E. (2004, July). Computational modeling of organizations comes of age. *Computational and Mathematical Organization Theory,* 10(2), 127–145. Retrieved January 31, 2008, via Proquest LLC online retrieval service: http://proquest.umi.com/pqdweb?index=1&did=707262091&SrchMode=1&sid=2&Fmt=6&VInst=PROD&VType=PQD&RQT=309&VName=PQD&TS=1201810211&clientId=752

Nissen, M. E., & R. E. Levitt. (2002, November). *Toward simulation models of knowledge-intensive work processes.* CIFE Working Paper No. 77. San Francisco: Stanford University. Retrieved January 31, 2008, from www.stanford.edu/group/CIFE/online.publications/WP077.pdf

SimVision® Users Guide. (2003). eProjectManagement (ePM™), LLC.

Solis, W. M., A. Borseth, G. Coleman, O. Mardis, K. Thornton, et al. (2007, March 6). Defense acquisitions: *Air Force decision to include a passenger and cargo capability in its replacement refueling aircraft was made without required analyses* (No. GAO-07-367R). Government Accountability Office. Retrieved January 31, 2008, from www.gao.gov/new.items/d07367r.pdf