# Automation Integration: Comparing Flightdeck Automation and U.S. Army Digitization

**John S. Barnett and Larry L. Meliza**
**U.S. Army Research Institute for the Behavioral and Social Sciences**
**Orlando, Florida**
**john.barnett1@us.army.mil, larry.meliza@us.army.mil**

## ABSTRACT

The purpose of this work was to identify similarities between concerns about integrating automated systems into U.S. Army units, known as digitization, and automation concerns in other areas, such as aviation, with the goal of suggesting that integrating automation and automated systems into organizations and work groups follows a common pattern. The researchers compared a taxonomy of automation problems and concerns from commercial aviation with examples of similar behaviors and attitudes observed in U.S. Army units. The observations came from field studies and previous research literature about integrating digitization into U.S. Army units. Once elements in the taxonomy which were unique to aviation were eliminated, the remaining statements were evaluated to identify similarities in U.S. Army digital units. Lists of concerns from each area were compared to find matches. Results showed that a significant percentage of the aviation automation concerns were also digitization concerns. The results suggest there may be a common pattern of attitudes and behaviors towards automation. If this pattern were identified, it could be used to introduce automated systems into work groups more easily. Suggestions for future research are included.

## ABOUT THE AUTHORS

**Dr. John Barnett** is a research psychologist with the U.S. Army Research Institute for the Behavioral and Social Sciences where he conducts research in training and evaluation. He holds a Ph.D. in Applied Experimental and Human Factors Psychology from the University of Central Florida. He is a former U.S. Air Force officer with a background in aviation, operations planning, and command and control.

**Dr. Larry Meliza** is also a research psychologist with the U.S. Army Research Institute. He has many years of experience developing after action review systems supporting feedback sessions for collective training exercises in the networked simulator environment and describing the impacts of force modernization on exercise control and feedback for collective training exercises in the live field environment.

# Automation Integration: Comparing Flightdeck Automation and U.S. Army Digitization

**John S. Barnett and Larry L. Meliza**
**U.S. Army Research Institute for the Behavioral and Social Sciences**
**Orlando, Florida**
**john.barnett1@us.army.mil, larry.meliza@us.army.mil**

Automation is becoming more common in many work environments. The advances of technology have made it easier to develop automated systems to perform tasks which traditionally required considerable effort to perform manually. The promise of automation is to reduce human workload and increase performance.

However, integrating automation into task areas that were previously performed manually is often a challenge. Sometimes people and automated systems do not naturally work together and considerable training and effort is required to integrate automation into the human work sphere.

For example, automation has been available in the aviation field for several decades, and the integration of automation into aviation did not occur as smoothly as was hoped (Billings, 1997). Many pilots and flight crews expressed concerns about how automation would affect their performance. Although some of their fears were not realized, many concerns were found to be valid.

In a similar vein, the U.S. Army is introducing automated command, control, communications, and intelligence (C3I) systems into combat formations, a program called “digitization.” Not surprisingly, soldiers are expressing some of the same concerns and experiencing similar problems with digitization as pilots and flight crews did with aviation automation.

The purpose of the present study was to compare the problems and concerns about automation voiced by pilots with those experienced by soldiers with digitization to try to identify a pattern. If such a pattern is present, it might help us to understand how people react to the introduction of automation into their work areas. This might, in turn, uncover some strategies for better integrating automation into human work.

However, before we discuss the comparison, we will provide some background information about automation in aviation and also about the U.S. Army’s digitization program. Next, we will present the method we used, followed by the results of our analysis. In the last section, we provide a discussion of the findings.

## BACKGROUND

### Automation in Aviation

Automation was introduced into commercial aviation in the 1980’s, partly to increase flight safety by reducing accidents attributed to human error (Billings, 1997). Military aircraft have also been increasingly automated, both to improve safety and enhance mission effectiveness.

The functions automated on aircraft included aircraft control and navigation, as well as some other routine tasks. Although rudimentary aircraft control using autopilots has been around for over 50 years, autopilots by themselves usually only maintained the aircraft’s attitude, and sometimes altitude, set by the pilots. Automated systems, such as the Flight Management System (FMS) couple a navigation computer to the autopilot. In this way the aircraft can follow a preplanned route programmed into the FMS by changing heading, altitude, and speed without pilot input.

Other aircraft systems, such as fuel management, weight and balance management, and fault diagnosis, have been automated as well on certain aircraft. For example, the B-1B bomber has a Fuel/Center of Gravity Management System (FCGMS) which automatically shifts fuel between fuel tanks as it is burned to maintain the aircraft’s proper trim.

The increase in safety expected by automating aircraft systems was only partially realized for several reasons. Among these was the finding that many safety problems were incorrectly attributed to human error, and also that human-automation interaction introduced a new class of errors (for a full discussion, see Billings, 1997).

Many pilots and flight crews did not uncritically embrace automation. There were a number of concerns about how automation would affect flight operations. Many of these concerns were captured and organized into a taxonomy by Funk, Lyall, and Riley (1996).

**U.S. Army Digitization**

More recently, the U.S. Army has introduced a system of networked computer systems into combat formations, termed digitization. These computer systems automate many of the functions previously accomplished manually. The goals of digitization are to increase combat capabilities and to increase safety by reducing the chances of fratricide (or "blue on blue" incidents). Information on the tactical situation can be distributed over the network from command centers down to the lowest-level combat formations, who use the information to gain a tactical advantage. Combat units who use digital systems are expected to maintain better situation awareness (SA) and to plan and execute operations more quickly than non-digital units (Barnett, Meliza, & McCluskey, 2001).

Digitization fosters communication and coordination among staff sections during operations planning phases. Many staff functions have systems dedicated to their particular needs. For example, artillery planning and execution functions are automated using the Advanced Field Artillery Tactical Data System (AFATDS). Although this system is specific to artillery, it can still integrate with other systems and share information.

Digitization also serves as a decision-support system for combat commanders. It helps them visualize the battle space and presents needed information in a spatially realistic and temporally dynamic format, thus fostering the commander's SA.

In addition, digitization serves to improve the SA of combat units. Units equipped with digital systems can view the same spatially realistic, near real-time displays available to commanders. This provides both commanders and soldiers with a "Common Operating Picture" (COP) which allows them to develop a shared mental model of the battlefield situation. This shared mental model in itself improves communications since a commonality of information reduces the need for elaborate explanations.

Digitization enhances communications as well. Traditionally, communications have been handled by voice radio, which tends to be a serial process, that is, only a single person can talk on a given channel at one time. However, digital messages flow in both directions near simultaneously, so that communications delays common to radio are significantly reduced.

**A Comparison of Aviation Automation and Digitization**

Although aviation automation and digitization have some commonalities, they are quite different systems. Both employ geographic displays that provide dynamic maps of their surrounding areas, and both use symbology to provide spatial information about important elements in the operating environment. However, although they share some functions, they have different purposes and work in different ways.

In aviation, one of the principle purposes of automation is to assist pilots in navigating and controlling the aircraft as well as help pilots maintain SA. Digitization also helps soldiers maintain SA, but digitization only provides information, it does not assist with vehicle control. In addition, digitization enhances communications between combat units, whereas aviation automation presently does not assist to a significant degree with communication tasks. A summary of similarities and differences between the two domains is shown in Table 1.

**Table 1.** Comparison of Aviation Automation and Digitization General Functions

| Function | Aviation | Digitization |
|---|---|---|
| Route planning | Yes | Yes |
| Foster SA | Yes | Yes |
| Aircraft/vehicle control | Yes | No |
| Aid communications | No | Yes |
| Integration/coordination | No | Yes |

## METHOD

For this study, we compared concerns about automation from the aviation field with those from US Army digitization. The primary source for concerns about automation in aviation came from the Funk, et al. (1996) study mentioned above. This study reviewed a body of literature that included accident and incident reports, and also conducted a survey of Subject Matter Experts (SMEs) to identify concerns about automation in commercial aviation. From this they compiled a data base of over 2400 individual citations about concerns expressed by pilots and flight crews. These citations were distilled into 114 "problems and concerns" (PC). In the Funk, et al. study, the PCs were grouped into categories, and the categories were organized into both a primary and secondary taxonomy. However, in our study, we did not use the taxonomies of categories. Instead, we directly compared PCs to digital concerns.

To perform our comparison, we analyzed the 114 PCs and tried to identify similar concerns about digitization from U.S. Army units. Digital concerns came from observations of digital units, interviews with soldiers, reviews of digital related documents, such as the Digital Operator's Guide (U.S. Army Armor Center, 2000), digital training materials and workbooks, and appropriate field manuals, as well as reviews of research literature.

As we performed the analysis, we found that comparing aviation automation and digitization concerns required more than a "yes" or "no" categorization. Some PCs dealt with concerns which were clearly unique to aviation, such as those dealing with aircraft controls or ATC, and some were not digitization concerns but could conceivably become so as digitization matures.

Therefore, each PC was rated as to whether it was (a) a concern unique to aviation, (b) a digital concern as well as an aviation concern, (c) not a digital concern, or (d) was not a digital concern at present, but may be in the future. One PC could not be categorized and was rated as unknown.

Those PCs which were deemed aviation unique were not considered in the analysis. Aviation unique items included those that dealt with automated control (since digital systems are not used for control), references to aircraft controls ('sidesticks') and ATC. Some references to 'modes' were eliminated where they had no corresponding function in digital systems, but a few of the concerns about mode selection addressed concerns with improper filter settings with digital systems, and were therefore retained.

For those PCs which were also digital concerns, we wrote a short narrative that explained the similarities between the PC and digitization concern.

## RESULTS

For our analysis, we first eliminated aviation unique PCs. Of the 114 PCs listed in the primary taxonomy, 10 were aviation unique and were not used in the analysis. In addition, the one PC that was rated as unknown was also eliminated from the analysis.

Of the 103 remaining aviation PCs, 64 (62%) were rated as both an aviation and digitization concern, and the remaining 39 (38%) were not a digital concern. Of those PCs which were not a digital concern, some of them (about 10, or 10% of the total) we realized were problems digital soldiers have yet to encounter. These we felt may become a concern in the future as digitization matures.

The Funk, et al. PCs which we rated as digital concerns are listed in Table 2 with the corresponding digitization concerns. In Table 2, the PCs are grouped into categories. PCs are identified by bullets, whereas the categories are underlined. Note that the categories do not come from the Funk, et al. taxonomy, but were developed for this effort.

Next, we tried to analyze how digital concerns compared with the relative importance of aviation concerns. The Funk, et al. taxonomy included the number of times individual citations in each PC were voiced by pilots and aircrew. They assumed those PCs which were cited more often were more important to pilots and aircrews. For example, one PC "Automation may demand attention" was cited 174 times; whereas a number of others, such as "Data reentry may be required," were mentioned only once. Presumably, being distracted by automation was more of a concern for pilots than data entry.

We thought there may be more automation/digitization matches for the most frequently cited, and presumably most important, concerns from aviation, and less matches for the low frequency concerns. However, we found the matches were fairly evenly distributed across frequency. There seemed to be about as many matches at the low end of the frequency distribution as at the high end.

Paradoxically, a few major digitization concerns are minor (i.e. low frequency) concerns for aviation. For example, the PC "Software versions may proliferate" was only cited once in the Funk, et al. study. However, this is a significant concern for digital units. Software upgrades for digital systems tend to occur fairly often, and multiple software versions are rampant. This causes problems for digital units because they not only have difficulties with software incompatibility between systems, but they also have trouble keeping users current on the newest software versions.

The last question to answer about the comparison of concerns in aviation automation and digitization is whether there is a pattern of similarities or differences between the two domains. Because the majority of concerns in the Funk, et al. taxonomy have corresponding concerns in digitization, it may be more instructive to look at the differences.

**Table 2**. Automation Concerns from Aviation (Funk, et al. 1996), and U.S. Army Digitization Examples

| Automation Concern from Aviation | U.S. Army Digitization Examples |
|---|---|
| Distraction by Automation<br>• Automation may demand attention<br>• Monitoring requirements may be excessive<br>• Non-automated pilot (soldier) tasks may not be integrated | Tactical doctrine requires vehicle leaders have their heads out the hatch much of the time, but monitoring digital systems diverts their attention to inside the vehicle. There are a variety of options for reducing monitoring requirements (e.g., automated alerts, using voice radio communications to alert soldiers to the need to check screen displays, delegating responsibility for monitoring displays to others, etc.), but these options are underused and useful information is missed when displays are not monitored often enough. |
| Over Confidence in Automation<br>• Pilot (soldier)s may become complacent<br>• Pilot (soldier)s may be overconfident in automation<br>• Pilot (soldier)s may over-rely on automation<br>• Protections may be lost though pilot (soldier)s continue to rely on them | In the digital environment, soldiers expect to see icons for each friendly element in the area. If a friendly unit does not have a corresponding icon (for a number of reasons), soldiers may assume it is hostile and engage, resulting in a fratricide incident.<br>Soldiers may rely on certain automated alerts, yet they may lose access to those alerts if they fail to set them correctly or post the correct overlays on their digital systems. |
| Automated/Manual Skill Conflicts<br>• Manual skills may be lost<br>• Manual operation may be difficult after transition from automated control<br>• Manual skills may not be acquired<br>• Automation skills may be lost | Units may be slow to revert to manual skills when necessary. When a unit accustomed to electronic delivery of planning products to platform-level digitized systems went without these systems they failed to employ many of the tactics for speeding up orders dissemination in an analog environment (e.g., giving subordinate elements lead time to send someone to the rear to pick up planning products).<br>Many digital skills are considered to be of the type that are highly perishable if not used frequently. |
| Inadequate Understanding of Automation<br>• Understanding of automation may be inadequate<br>• Pilot (soldier)s may misunderstand automation intent<br>• Automation use philosophy may be lacking<br>• Data input prompts may be poor | Inadequate understanding of digitization is a problem. For example, the Mission Data Loader (MDL) makes it possible to load overlay files without having to transmit them over a network with its inherent bandwidth problems. Some users interpret this to mean that the MDL removes the need to limit file size; however, large overlay files are hard to update in response to a changing tactical situation.<br>The tactics, techniques, and procedures for using digitization, including when to input data and the characteristics of the data to be input, are still under development |
| Poor Automation Design<br>• Displays may be poorly designed<br>• Human-centered design philosophy may be lacking<br>• Interface may be poorly designed<br>• Design specifications may be inadequate<br>• Operational knowledge may be lacking in design process<br>• Pilot (soldier)s may not be involved in equipment selection<br>• Feedback may be poor<br>• Auditory displays may be poorly designed<br>• Data entry format may be inflexible | Numerous solder-digitization interface problems have been identified. For example:<br>- Icons showing breach lanes in minefields are too large to convey precise information about the location of the lane<br>-Managing the vast amount of data requires a complex file structure, however, the current version of FBCB2[a] does not allow users to save their file structure at the end of a mission; users must create a directory structure from scratch each time FBCB2 is employed.<br>-Long delays in processing with no indication that the system is still working (no feedback) can lead a soldier to conclude that the system has crashed.<br>-Soldiers complain about the auditory warnings used to alert commanders when they are close to minefields.<br>-Structured format messages are awkward to use (overly lengthy with required fills), therefore many leaders use free text messages, despite the tactical benefits of structured messages. |
| Poor Mode Appreciation<br>• Mode awareness may be lacking<br>• Mode transitions may be | The major uncommanded mode transition for digital systems is a loss of connectivity. Soldiers often mistakenly assume that if their FBCB2 is operational they are properly connected. There are many |

| Automation Concern from Aviation | U.S. Army Digitization Examples |
|---|---|
| uncommanded<br>• Mode selection may be incorrect<br>• Failure assessment may be difficult | reasons connectivity, and thus situational awareness, can be lost. Some failures are internal to a specific platforms while others may be network related.<br>In many cases, users do not properly set the filters that decide how the battlespace will be viewed (e.g., filters controlling position location update rates), thus their awareness of systems settings is lacking. |
| Discrepancies Between Perceived and Actual Truth<br>• Situation awareness may be reduced<br>• Information integration may be required<br>• Pilot (soldier)s may be out of the loop<br>• False alarms may be frequent<br>• State prediction may be lacking<br>• Trend information may be lacking<br>• Insufficient information may be displayed<br>• Data may be too abstract | Soldiers need to take a variety of actions to make sure the information displayed on screens regarding the friendly and enemy situations is accurate and current. Soldiers also need to remember that some information is not displayed on screen. Soldiers can remove themselves from the loop by not reading messages, posting correct overlays, and maintaining connectivity. They can cause others to be pushed out of the information loop by, for example, not including all appropriate addressees on a message. False alarms can result if soldiers do not keep manually inserted information on friendly and enemy forces up to date. More state prediction capabilities can be added to digital systems (e.g., digital systems might be used to identify gaps in planning products that can lead to synchronization problems). Friendly position data is updated very infrequently, requiring leaders to estimate where friendly forces are currently located , in the absence of information regarding speed of movement Information displays do not provide information about the location of non-instrumented entities unless someone enters manual icons to show where these entities are located. |
| Training and Selection Challenges<br>• Training may be inadequate<br>• Training requirements may neglect automation<br>• Automation management training may be lacking<br>• Training philosophy may be lacking<br>• Deficiencies in basic aircraft (combat) training may exist<br>• Pilot (soldier) selection may be more difficult | Many digital procedural tasks are lengthy and complex; the type of task most likely to be forgotten if not practiced frequently.<br>Frequent changes in software add the requirement for "delta" (update) training.<br>Training requirements regarding the operation and use of digital systems are still being identified and defined.<br>The Army is attempting to decide how digital training strategies might differ from tactical training strategies.<br>How effectively leaders employ digital systems depends very much on their tactical skills, but there may be other characteristics of a good digital leader.<br>The U.S. Army is attempting to define the characteristics of a good digital leader |
| Inadequate Automation Performance<br>• Automation may lack reasonable functionality<br>• Automation performance may be limited<br>• Automation integration may be poor<br>• Data reentry may be required<br>• Workarounds may be necessary<br>• Automation performance may be reduced at margins of envelope | Soldiers would like to be able to have all friendly platforms in range of their weapons to be represented by entity icons, while platforms outside their range can be represented by icons showing the center of mass of the unit. None of the options available for using center of mass icons to reduce screen clutter for FBCB2 fit this need.<br>Most digital systems were developed independently in a "stove pipe" fashion, creating a situation where workarounds are required to transfer information from one system to another.<br>Bandwidth problems continue to reduce the amount of data that can be transferred on the lower Tactical Internet (TI) in a short period of time. |

| Automation Concern from Aviation | U.S. Army Digitization Examples |
|---|---|
| Lack of Confidence in Automation<br>• Pilot (soldier)s may lack confidence in automation<br>• Pilot (soldier)s may underrely on automation | Some soldiers are afraid of setting filters or clearing queues and logs because they believe it will cause their systems to crash.<br>Some soldiers do not believe that terrain analysis tools can replace a physical terrain recon.<br>It is widely assumed that older individuals are more likely to resist |

| Automation Concern from Aviation | U.S. Army Digitization Examples |
| --- | --- |
| automation<br>• Older pilot (soldier)s may be less accepting of automation<br>• Failure recovery may be difficult | digitization.<br>An important goal in preparing for system and network failures is to maintain digital as well as analog backups. Units must keep a local backup copy of digital overlays so it can be loaded to a system that has crashed without the need to resend over a network. |
| Automation Impacts on Workloads<br>• Automation may adversely affect pilot (soldier) workload<br>• Automation may increase workload<br>• New tasks and errors may exist<br>• Information overload may exist<br>• Information processing load may be increased<br>• Planning requirements may be increased | Soldiers are responsible for initializing systems and keeping the network operational on top of their normal tactical responsibilities.<br>Information overload is a big problem for digital operations (e.g., leaders can have trouble identifying the most recent version of the obstacle plan). The increase in information enabled by digitization naturally requires more information processing. Improved situational awareness and the capability to transmit revised planning products on the fly, means that planning can continue throughout a mission to exploit the capabilities of digitization As one brigade commander said, "planning never stops" for a digitized unit. |
| Coordination and Standardization Challenges<br>• Crew coordination problems may occur<br>• Standardization may be lacking<br>• Cross checking may be difficult<br>• Software versions may proliferate | Without standardization leaders can lack a common picture of the situation, and leaders can find it necessary to perform the cumbersome task of verifying all subordinates have the same view.<br>In certain cases, combat elements which are expected to fight together have digital systems with different software versions. |
| Impact on Job Satisfaction<br>• Pilot (soldier) control authority may be diffused<br>• Job satisfaction may be reduced | Leaders complain that superiors using digital systems to observe units try to micromanage subordinates and that superiors base decisions on the incomplete picture of the situation provided by digitization.<br>Soldiers complain that digital tasks get in the way of tactical tasks. |

[a] FBCB2 (Force XXI Battle Command, Brigade and Below) is a digital system used by lower level maneuver units.

When we examined those aviation categories which were not digitization concerns, the only common thread seemed to be that they all dealt with managerial policies relating to automation. Pilots had concerns such as "Airlines may assign two low automation time pilots to a crew," "Airlines may not adequately involve pilots in equipment selection," or "Automation may exist primarily due to commercial incentives," but soldiers had no such concerns. This is not surprising since airlines tend to have a more participative management style, whereas the military is more hierarchical. Even so, it may be that such concerns will surface with digitization as soldiers gain more experience with digital systems.

## DISCUSSION

The results of this study suggest that even though aviation and maneuver combat are somewhat dissimilar fields, individuals in each of these fields have similar concerns about how automation will affect them when it is introduced into their work environment. Concerns about automation in the aviation field have been studied for over two decades, whereas U.S. Army digitization is relatively recent. Still, the people who work in each of these areas are concerned about how the introduction of automation will affect how they perform their tasks.

Individual aviation PCs had matching concerns from digitization about 62 percent of the time. If you include those PCs which we believe may become digitization concerns in the future, this percentage increases to 72%. This provides significant evidence that concerns about introducing automation into the work environment may have strong commonalities across these two domains.

In fact, because aviation automation and digitization have significant differences in both the purpose and operation of the systems, the results also introduce the possibility that similar automation concerns may be common across a number of disparate fields. Identifying common concerns about automation in the workplace and developing a model of these concerns could aid in integrating automation in new areas.

### Advantages of a Common Model

A common model of automation behaviors could be advantageous in a number of ways. It could be used to help integrate automation into new areas by preparing people to work with automation so that it is quickly incorporated into their work environment. It could also be used to solve problems by sharing solutions across domains. Lastly, it could help focus research efforts on those areas where people have the most difficulty working with automation.

**Preparing People to Work with Automation**

A knowledge of common concerns could be useful to help prepare people to work with automation, primarily through training. Knowing what concerns people have about working with automation can help develop ways to allay their fears. Also, if we know what areas people typically have difficulties dealing with automation, we can develop training strategies to focus on these areas.

For example, research suggests that some concerns may not manifest themselves the way people expect or fear. One concern in the taxonomy was "Manual skills may be lost" by relying on automation. Although this was a fairly frequent concern in the taxonomy (89 citations), research suggested the concern was more apparent than real. McClumpha, James, Green & Belyavin (1991) found that although less experienced pilots were concerned about skill degradation, more experienced pilots reported that it was not a significant problem. This and similar research could be used to help prepare people to work with automation by reducing their anxieties.

**Sharing Solutions**

Another advantage of identifying commonalities is that different domains can share solutions to problems. Often problems are common enough that a solution in one area can be modified to work in another. For example, one problem with computerized geographical displays is that at certain size scales, symbols overlap one another so closely that they cannot be distinguished, known to US Army soldiers in digital units as the "blue blob" phenomenon. This same phenomenon occurs on aircraft displays and has been solved, at least partially, by filters or momentary "expand" functions that separate the symbols for a few seconds to allow the operator to distinguish between them. This suggests that solutions from one area could be shared among a number of different areas which employ automation.

**Focusing Research**

A further way this knowledge could help is to focus research on key problem areas. Although we have seen that some fears people have about automation do not materialize, other concerns turn out to be more complex than at first imagined. For example, although one of the goals of automation in aviation was to reduce workload, pilots were concerned that their workload would actually increase. Several PCs addressed this; "automation may increase workload," and "automation may adversely affect pilot workload." Research has found the problem to be more complex. Several researchers (Parasuraman, Mouloua, Molloy, & Hilburn, 1996; Billings, 1997) found that automation may reduce workload during low workload phases, yet increase it during high work phases. Others (Weiner, 1988; Idaszak, 1989; Tsang & Vidulich, 1989; Sarter & Woods, 1992; Bowers, Oser, Salas, & Cannon-Bowers, 1996; and Endsley, 1997) found that automation changes the nature of workload from physical work to a more cognitive, supervisory type of work, so that the total amount of effort may actually remain constant.

Another complication is that people's concerns may change as they become more expert with automated systems. The concern about losing manual skills, mentioned above, was cited 89 times; suggesting it was a fairly major concern. However, the McClumpha, et al. (1991) study showed this concern differed significantly with experience. Pilots with more flying hours tended to find this less of a concern than less experienced pilots. This suggests concerns may change over time as people gain experience.

Some problems with automation may not surface until people have developed a certain level of experience. This is reflected in the present study by rating some PCs as future digitization concerns. The researchers who observed soldiers dealing with digitization saw evidence that some concerns which were not apparent could, based on parallels from aviation, become important in the future.

This idea is supported by recent research. A study by Leibrecht, Lockaby, and Meliza (2003) found that the job of a unit can become more complex as the unit attempts to make greater use of digitization. That is, certain problems only become evident when a unit has made progress applying automation. This provides further evidence that concerns which are not apparent early in the automation integration process may become problems as the process matures.

These examples suggest that integrating automation into the work environment can be a complex process, and sometimes the reality of automation differs from people's expectations. A knowledge of how this occurs can be used to focus research where it can be most productive.

**Topics for Future Research**

Several considerations for future research have already been introduced. Identifying common concerns about automation in the workplace from a number of different fields would help to develop a model of how people approach the introduction of automation into their environment. This model could be used to help focus human-automation integration in new areas.

It might also be of interest to compare automation concerns from military aviation with those from commercial aviation. The Funk, et al. study focused primarily on commercial aviation; comparing military and commercial aviation may identify concerns unique to aviation. Similarly, comparing military aviation with U.S. Army digitization could uncover exclusively military concerns.

Another valuable line of research would be to differentiate between those concerns which have a significant effect on people working with automation from those which have minimal effect.

Also, it would be instructive to know whether people's attitudes towards automation change with experience. Although some research (i.e. McClumpha, et al., 1991) alludes to this, more is needed to gain a greater understanding of the variables involved.

## CONCLUSION

It is clear that automation will be integrated into the human work sphere more and more. The advance of technology promises to introduce automation into more areas of human endeavor. Although this study focused on the perceived problems of automation, even with these difficulties automated systems present great promise to increase work performance. Research has the potential to assist the transition from traditional to automation-aided work as automated systems are introduced into new work environments.

## REFERENCES

Barnett, J. S., Meliza, L. L. & McCluskey, M. R. (2001). *Defining digital proficiency measurement targets for U.S. Army units* (ARI technical report 1117). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Billings, C. E. (1997). *Aviation automation: The search for a human-centered approach*. Mahwah, NJ: Lawrence Erlbaum Associates.

Bowers, C. A., Oser, R. L., Salas, E. & Cannon-Bowers, J. A. (1996). Team performance in automated systems. In R. Parasuraman and M. Mouloua (Eds.) *Automation and human performance: Theory and applications*. Mahwah, NJ: Lawrence Erlbaum Associates.

Endsley, M. (1997). Level of automation: Integrating humans and automated systems. *Proceedings of the Human Factors and Ergonomics Society 41st Annual Meeting*. Santa Monica, CA: The Human Factors and Ergonomics Society.

Funk, K., Lyall, B. & Riley, V. (1996). *Perceived human factors problems of flightdeck automation*. Retrieved 30 April 2003 from http://flightdeck .ie.orst.edu/FDAI/Phase1/phase1.html.

Idaszak, L. R. (1989). Human operators in automated systems: The impact of active participation and communications. *Proceedings of the Human Factors Society 35th Annual Meeting*. Santa Monica, CA: The Human Factors and Ergonomics Society.

Leibrecht, B. C., Lockaby, K. J., & Meliza, L. L. (2003). *A practical guide for exploiting FBCB2 capabilities* (ARI product 2003-05). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

McClumpha, A. J., James, M., Green, R. G. & Belyavin, A. J. (1991). Pilot's attitudes towards cockpit automation. *Proceedings of the Human Factors Society 35th annual meeting*. Santa Monica, CA: The Human Factors Society.

Parasuraman, R., Mouloua, M., Molloy, R. & Hilburn, B. (1996). Monitoring automated systems. In R. Parasuraman and M. Mouloua (Eds.) *Automation and human performance: Theory and applications*. Mahwah, NJ: Lawrence Erlbaum Associates.

Sarter, N. B. (1991). The flight management system: Pilot's interaction with cockpit automation. *Proceedings of the 1991 IEEE International Conference on Systems, Man, and Cybernetics* (pp.1307-1310). Piscataway, NJ: IEEE.

Sarter N. B. & Woods, D. D. (1992). Pilot interaction with cockpit automation: Operational experiences with the flight management system. *International Journal of Aviation Psychology, 2* (4) 303-321.

Tsang P. S. & Vidulich, M. A. (1989). Cognitive demands of automation in aviation. In R. S. Jenson, (Ed.) *Aviation Psychology*. Brookfield, VT: Gower Publishing.

U.S. Army Armor Center (2000). *Digital operating guide for brigade and battalion staffs, ABCS v. 6.1*. Killeen, TX: TRW.

Weiner, E. L. (1988). Cockpit automation. In E. E. Wiener, and D. C. Nagel (Eds.) *Human factors in aviation*. New York: Academic Press.