Flight Simulation without an Instructor: Missed Approach Due to Weather

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ABSTRACT

Background. An area of flight training that could potentially benefit from additional simulation-based training options is aviation weather during instrument flight. Research studies pertaining to General Aviation (GA) and GA accidents, revealed GA pilots may lack the adequate aviation weather knowledge and skills needed to proficiently perform during inadvertent meteorological conditions. This may be due, in part, to the limited flight training opportunities available to pilots to practice. Pilots currently utilize Federal Aviation Administration (FAA) approved Flight Training Devices for training, but these devices are typically cost prohibitive and limited in availability (i.e., not readily available to the pilot). Moreover, these training devices may include the requirement and cost of an instructor who is responsible for constructing the training scenario events, measuring the learner's performance, and providing feedback. As such, pilots are limited on their opportunity to practice. Fortunately, recent technological advances in desktop flight simulation include the capability to present scripted instrument flight scenarios in a self-study lesson through the use of a Personal Computer (PC). Furthermore, desktop flight simulations provide the opportunity for asynchronous learning without sacrificing the essential active practice needed for knowledge and skill acquisition. This study examined the use of a current low-cost, desktop simulation platform to foster aviation weather knowledge and attitudes for instrument flight. **Method.** Participants were 35 students in a collegiate flight-training program. Two methods of instruction were tested using a pre-post design. The first was a traditional classroom/lecture method of instruction conducted by an FAA Certificated Flight Instructor. The second was a computer-based lesson that included information, demonstration, and practice components. The lesson focused on legalities of landing from an instrument approach, missed approach point identification, and selection of an alternate airport based on real-time weather conditions. As part of the lesson, the learner observed and performed a series of instrument approaches. Dependent measures were a knowledge test, a self-efficacy questionnaire, and a learner reaction measure. **Results.** The results indicated that both instructional methods resulted in a statistically significant knowledge gain and increased confidence. **Conclusion.** The PC based method of instruction was just as effective as the traditional classroom lecture method. This self-study approach to training instrument flight could be used as a stand-alone module or as a component of blended learning.

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Justin Campbell is presently a Technical Training Asc Manager leading the development of computer based training for Missions Systems and Training. Justin began working at Lockheed Martin in 2008. At Lockheed, Justin has developed Interactive Multimedia Instruction (IMI) for multiple programs including Weapons Systems Officer training for the Royal Saudi Air Force, courseware for the Singapore Basic Wings Course and Advance Jet training for the United Kingdom Military Flight Training System. Justin has also lead the effort of building virtual interactive training for the C5M Reliability Enhancement and Re-engining Program (RERP) and Thomas Edison State College Nursing Program. Justin currently is helping to architect a training system for Cenovus and oversees the development of multiple training efforts including a virtual simulation for Nemours Children's Hospital. Justin holds a Bachelor's degree from Texas A&M University in Environmental Science and a Bachelor's degree from Full Sail University in Computer Animation.

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INTRODUCTION

As technology advances, so do the capabilities of simulation. Numerous domains (e.g., healthcare and military operations) currently utilize simulated scenario-based methods to train learners and prepare them for performance in the operational environment. Aviation, for example, is a prime domain where simulation-based training is used to improve learners' knowledge and skill. Pilots are able to develop the knowledge and skills for using complex aircraft and technology in a safe and effective manner through the use of various flight simulation technology, such as Federal Aviation Administration (FAA) qualified simulators and Flight Training Devices (FTDs) (FAA, 2016; GAO, 1999).

Each year, simulator manufacturers take advantage of improvements in simulator processing speed and graphic capabilities to generate increasingly compelling environments. Physical fidelity alone, however, is unlikely to yield increased learning. Effective use of simulation-based training provides the learner well-designed opportunities for practice of key skills (Salas, Rosen, Held, & Weissmuller, 2009). Providing this type of practice opportunity necessitates structured events, performance measures, and feedback (Fowlkes & Burke, 2005; Salas, Rosen, Held, & Weissmuller, 2009). Usually, it is the instructor's role to carefully construct the training scenario events, measure the learner's performance, and provide feedback. For this reason, even the simplest FAA approved devices can be cost prohibitive; in addition to hardware costs, flight simulation-based training typically involves a human instructor.

Recent technological advances in desktop flight simulation include the capability to present scripted instrument flight scenarios in a self-study lesson (Lockheed Martin, 2015). This may provide the opportunity for asynchronous learning without sacrificing the essential active practice needed for knowledge and skill acquisition. A research gap exists, however, regarding the efficacy of presenting a scripted, practice scenario for instrument flight within a desk-top flight simulation environment *without an instructor*. One domain area that is prime for a simulation-based, instructorless training tool is aviation weather.

Aviation Weather

In general aviation (GA), a trending pattern across incidents revealed a higher frequency of weather-related accidents than in non-GA flight (FAA, 2010). Furthermore, when these accidents occurred, they often resulted in fatalities. Research has revealed that GA pilots may lack adequate aviation weather knowledge and skills needed to formulate the appropriate course of action to circumvent weather phenomenon (Ball, 2008; Blickensderfer et al., 2015; Lanicci et al., 2012; Wiggins & O'Hare, 2003).

With pilot training and FTDs being expensive and time consuming, self-study options for increasing aviation weather knowledge and skills would provide additional training options. Currently, limited self-training tools exist for GA pilots to utilize; especially validated tools relating to aviation weather (see Table 1).

Table 1. Existing Aviation Weather Self-study Training Tools

Self-Study Tools	***Examples***		
Textual Information	Advisory Circulars (AC) Ex. Aviation Weather (AC 00-6A); Aviation Weather Services (AC 00-45G)	Pilot Training Handbooks Ex. Aviation Information Manuel (AIM) (FAA, 2015)	
Online Self-study Materials	A Pilot's Guide to Aviation Weather Services (NOAA, 2009)	General Aviation Pilot's Guide to Preflight Weather Planning, Weather Self-Briefings, and Weather Decision Making (FAA, 2005)	Weather Products Study Guide (Mile High Aviation, 2004)

Regrettably, these tools do not provide pilots the ability to practice and reinforce the information.

The purpose of this research study was to design, test, and demonstrate how a self-paced, desktop-simulated instructional module can foster and/or enhance GA pilots' knowledge. More specifically, the aim was to demonstrate the module's effectiveness in training pilots on proper missed approach techniques due to weather.

It was hypothesized that pilots-in-training who experienced the desktop simulation training would react favorably and demonstrate greater knowledge gain and higher self-efficacy than participants who experienced a traditional instructor-led lecture.

METHOD

Experimental Design

This study employed a 2 x 3 mixed factorial design. Two between-subject groups (Traditional vs. Simulation) were exposed to three within-subject testing periods (Pre, Post, Retention). The study was approved in advance by the Embry-Riddle Aeronautical University Institutional Review Board (IRB).

Participants

Participants included 35 student pilots, aged 18 to 26 (M = 19.62, SD = 2.0) years old, from a collegiate flight-training program in the southeastern U.S. Each pilot held a Private Pilot certification and was enrolled in instrument ground school. The participants' flight experience ranged from six months to seven years, each with a total log of 42 to 186 flight hours (Mdn = 105, M = 102.43, SD = 29.32) recorded. Participants' total number of instrument approaches flown ranged from 0 to 67 (Mdn = 12). Their total number of flight hours under actual instrument conditions ranged from 0 to 12 (Mdn = 1), while their total number of flight hours under simulated instrument conditions (i.e., under the hood) ranged 0 to 41.6 (Mdn = 15). In addition, their total number of instrument hours in a Flight Training Device ranged 0 to 50 (Mdn = 15). As compensation for their participation, participants received $50 upon completion of both Phase I and Phase II of the study.

Equipment

The study used the windows-based desktop flight simulator software, "Prepar3D" (P3D) (Lockheed Martin, 2015). Participants operated the simulated aircraft (Cessna 172) using Saitek's Cessna Pro Flight Yoke and Throttle Quadrant system (including Saitek Pro Flight Rudder Petals for PC and Mac). Visuals were displayed on a 23-in. Dell monitor. Figure 1 displays the flight desktop simulator test-bed that participants in the simulation group operated.

Figure 1. Flight desktop simulator test-bed using P3D software.

Simulated Self-Paced Instructional Training Module

The experimental simulation instructional module was designed and implemented using P3D. The module consisted of a 12-minute lesson segment, two scenarios with instruction, and four scenarios without instruction. The completion time for the simulated module ranged from 45 to 60 minutes (depending on the participants' performance within the practice scenarios).

During the 12-minute lesson portion, audio and visual instructions described the fundamentals of weather-related missed approach techniques (FAR 91.175). After the lesson, participants completed the six flight scenarios within P3D. In the first two scenarios, the participants received verbal instruction as they "flew" each approach (one missed approach and one landing) and interpreted weather information to select an airport to divert to. Next, the participants practiced applying their knowledge in four additional, unassisted approach scenarios (three missed and one landing). Figure 2 shows an example of meteorological conditions obscuring the participant's visual range of the runway.

Figure 2. P3D module screenshot close-up of participant approaching runway with fog obscuring visuals of the runway. Runway is slightly visible just above the waterline, near the center of the view.

In each approach, feedback was provided using pop-up boxes. The pop-up feedback boxes provided detailed information about why their choice was either correct or incorrect based on the provided weather information.

Traditional Instructor-Led Module

The control group activity consisted of a 15 to 30-minute face-to-face lecture (depending on whether questions were asked to the instructor by the participants) given by a FAA Gold Seal flight instructor on missed approach. The lecture covered the same topics presented in the simulated, self-paced instructional training module. The lecture consisted of PowerPoint slides and visuals, but did not include demonstration using animation or active practice scenarios.

Dependent Variables

Multiple variables were measured using four questionnaires: Demographic, Self-Efficacy (Pre, Post, Retention), Reaction, and Knowledge (Pre, Post, Retention).

Demographic
The demographic form included questions pertaining to the participants' age, pilot certificates and ratings held, flight experience and training, and amount of experience performing instrument missed approach procedures. This was completed online using Google Forms.

Self-efficacy (Pre, Post, Retention)
Self-efficacy is a person's belief in their ability to succeed in a specific task (Bandura, 2000). In this study, self-efficacy was the degree to which participants felt confident in their knowledge of how to perform missed approach procedures. This included concepts such as, interpreting weather information, calculating alternate airports based on current weather conditions, and knowledge of landing requirements under IFR. The self-efficacy form was a 12-item assessment that asked participants to rate their self-confidence on each item (from 0 *[not confident]* to 100 *[most confident]*). Cronbach's alpha was .95. The items were averaged so that each participant had a pre, post, and retention composite score for self-efficacy.

Reaction
The purpose of this questionnaire was to obtain the students opinion of the respective module they were given. The questionnaire contained six Likert-scaled items that asked the participants to rate various aspects of the training experience between 1 (*Low/Not*) to 7 (*High/Very*). Cronbach's alpha was 0.73. The items were averaged to provide each participant with one composite reaction score.

Motivation
The reaction questionnaire also included an additional three Likert-scaled items that asked participants to rate their motivation for learning. Cronbach's alpha was 0.8. The items were averaged to provide each participant with one composite reaction score.

Knowledge Test (Pre, Post, Retention)
The purpose of this 27-item assessment was to test the students' knowledge of missed approach. This included knowledge of missed approach points, understanding when pilots are allowed to descend from the minimum altitudes, and applying updated weather information to decide which airport and approach will allow landing given the current weather conditions (FAR 91.175).

Three parallel forms were used: one for pretest, the second for posttest, and the third for a retention test. Each participant's percent of correct answers was calculated for pretest, posttest, and retention test, respectively.

Procedure

Based partially on their availability, participants were randomly assigned into the experimental group (Simulation; $n = 18$) or control group (Traditional; $n = 17$). Due to limited equipment capacity, simulation participants completed Phase I individually, whereas traditional participants completed Phase I as a group.

Upon arrival at the experimental site, participants read and completed the following:

Table 2. Phase I Procedure
Approximate Completion Time: 120 – 150 min.

		CONDITION		
		Traditional	**Simulation**	**Time**
Measure	Informed Consent Form	X	X	
	Demographic Questionnaire	X	X	5 min.
	Pre SE	X	X	5 min.
	Pre Knowledge Test	X	X	30 min.
	Control Activity/Lecture Module	X		15 – 30 min.
	P3D Training Module		X	45 – 60 min.
	Reaction Questionnaire	X	X	5 min.
	Post SE	X	X	5 min.
	Post Knowledge Test	X	X	30 min.

Note. X designates the measure each condition was exposed to.

Phase II occurred 14 days after the completion of Phase I. Participants were scheduled individually and all participants received:

Table 3. Phase II Procedure
Approximate Completion Time: 60 min.

		CONDITION		
		Traditional	**Simulation**	**Time**
Measure	Retention Self-Efficacy	X	X	5 min.
	Retention Knowledge Test	X	X	30 min.
	Debrief	X	X	
	Payment Receipt Form	X	X	
	Payment	X	X	

Note. X designates the measure each condition was exposed to.

RESULTS

The data analysis was a series of planned comparisons using the study hypotheses.

Reaction

The mean reaction scores are shown in Figure 3. An independent-samples t-test was conducted to compare Traditional and Simulation Reaction scores following training. There was a statistically significant difference between reaction scores of participants in the Traditional/face-to-face training ($M = 6.3$, $SD = 0.7$) and the reaction scores of participants in the Simulation-based training ($M = 5.8$, $SD = 0.7$), $t(33) = 2.248$, $p = .031$. These results indicate the traditional group had a slightly more positive reaction to the face-to-face instructor than the simulation group to the self-study, simulation-based training module.

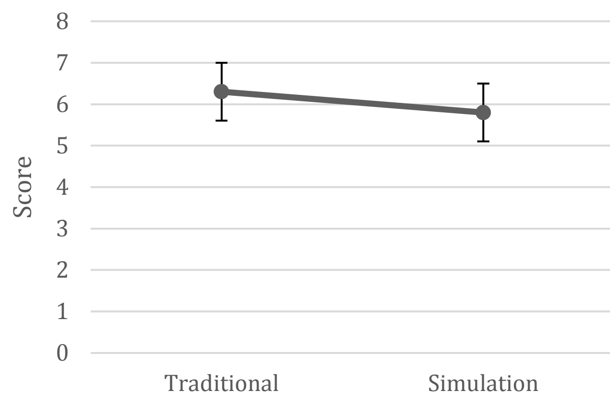

Figure 3. Reaction Composite Means.

Motivation

The mean motivation scores are shown in Figure 4. An independent-samples t-test was conducted to compare Traditional and Simulation Motivation scores. There was no significant difference between motivation scores of participants in the Traditional/face-to-face training (M = 6.5, SD = 0.5) and the motivation scores of participants in the Simulation-based training (M = 6.3, SD = 0.5), t(33) = .831, p = .412. This indicates the instructor-led participants and the self-study participants were similar in terms of paying full attention, taking their respective lesson seriously, and wanting to learn during their respective module.

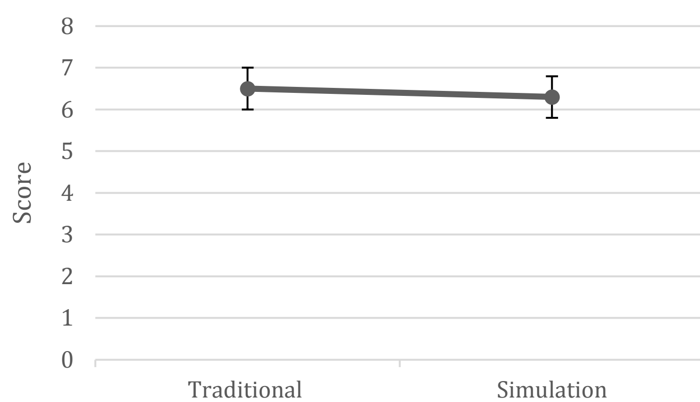

Figure 4. Motivation Composite Means.

Self-Efficacy

Figure 5 displays the mean self-efficacy scores. A mixed-design analysis of variance was used to assess the interaction of the between groups factor (condition (Traditional, Simulation)) and the within groups factor (testing period (Pre, Post, Retention)) on the participants' self-efficacy (SE scores). Using the Greenhouse Geiser test, there was no significant interaction between condition and time, F(1.56, 51.62) = .127, p = .831. The main effect comparing the two conditions was not significant, F(1, 33) = 2.332, p = .136. This suggests there was no difference between Traditional SE scores and Simulation SE scores.

There was a significant main effect for testing period, F(1.56, 51.62) = 31.03, p = .00, η_p^2 = = .485. Further analysis by Bonferroni corrected post-hoc tests revealed participants' Post SE and Retention SE did not differ significantly (p = .373), but their Pre SE were significantly lower than both Post SE and Retention SE (both p = .001). This indicates participants' confidence in aviation knowledge increased during Phase I of the study and they remained more confident than they were prior to the study over the retention period. Their retention confidence in knowledge of aviation concepts and skills were similar to their post-training confidence level.

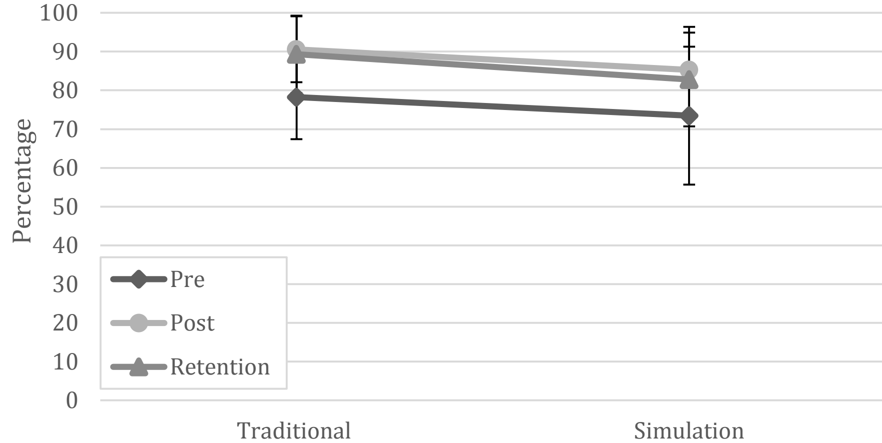

Figure 5. Self-Efficacy Composite Means.

Knowledge Test Scores

Figure 6 displays the mean knowledge test scores. A mixed between-within subjects analysis of variance was conducted to assess the impact of condition (Traditional, Simulation) on participants' aviation knowledge (knowledge score), across three time periods (Pre, Post, Retention). There was no significant interaction between condition and time, $F(1.586, 52.325) = .246$, $p = .731$. The main effect comparing the two learning types was not significant, $F(1, 33) = .137$, $p = .714$, suggesting no difference between instructor-led knowledge scores and self-study knowledge scores.

There was a significant main effect for time, $F(1.586, 52.325) = 14.37$, $p = .00$, $\eta_p^2 = .303$. Bonferroni corrected post-hoc tests revealed participants' Pretest Knowledge scores and Retention Knowledge scores did not differ significantly ($p = 1$), but their Posttest Knowledge scores were significantly higher than Pretest Knowledge scores ($p = .004$) and Retention Knowledge scores ($p = .00$). This indicates both groups' knowledge of missed approach procedures increased over the course of the study and decreased over the fourteen day retention period. There was no difference between their prior knowledge of missed approach and retained knowledge.

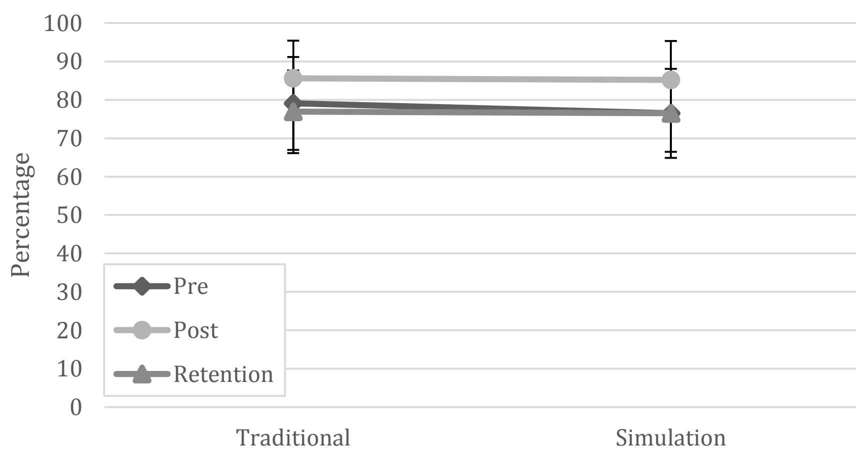

Figure 6. Knowledge Test Means.

DISCUSSION

Preliminary results indicated the learning gains of the instructional P3D module were equivalent to a face-to-face, highly effective, Gold Seal flight instructor. Specifically, both the experimental group and the control group gained knowledge from their respective lesson and proceeded to regress during the fourteen day retention period. In addition, the confidence levels for the participants increased after the lesson module, regardless of the group they were in, and remained just as high after the retention period. In terms of participants' feedback, both groups rated their respective modules, positively; however, the traditional group rated their lesson module slightly higher than the simulation group rated theirs. Moreover, participants were about equally engaged in their respective lesson module.

Overall, the results are encouraging—an inexpensive desktop simulation could potentially provide enhanced methods in self-study, instruction delivery for complex aircraft piloting concepts.

The troubling aspect of these results is their discrepancy with the extensive body of literature demonstrating the clear benefit of simulation-based learning (Salas et al., 2009). Based on the prior literature, the current study's practice-based simulation should have produced greater learning gains. A number of reasons exist as to why the expected effect did not occur.

First, as this was a proof-of-concept using a newly constructed training module, some technical issues appeared. For example, some participants within the simulation group encountered technical issues during two of the four non-aided P3D practice scenarios. While this matter was resolved for later participants, the technical difficulties likely distracted and crippled practice opportunities for some of the simulator participants. The incidents, and the resulting learning decrements, may have contributed to the lack of knowledge score difference, as well as lack of self-efficacy score differences, between Traditional and Simulation participants. The simulator participants may have believed the error(s) were a result of their piloting performance – possibly lowering their confidence in their own abilities. The technical errors may have also contributed to the lower simulation reaction scores for some participants.

Anecdotally, many simulator participants praised the simulated, self-paced instructional training module. When asked if they felt the lesson segment "explained the concepts well" and if "those concepts transitioned to the scenarios effectively", majority answered, "yes," and stated the P3D training module "helped reinforce the concepts" and was "great for refreshing memory".

Several of the simulator participants expressed enjoyment at being able to practice the concepts. Participants admitted to having limited opportunities to practice under their current training programs. Pilots-in-training at the collegiate flight-training program have restricted accessibility to the university's current flight simulators which frequently require having an instructor present. The participants felt installing a simulated, self-study instructional program at the university or home would increase their practice opportunities and performance.

Conversely, leniency bias toward the instructor may have led to the traditional module's higher rating in comparison to rating of the simulator module. While the traditional reaction score may possibly be the result of a particularly effective Gold-Seal instructor, the participants may have appraised the instructor's performance more leniently because the instructor is human as opposed to a computer.

Another issue is the knowledge test. Further validation testing will need to be conducted on the missed approach knowledge test. It may be that all of the learning gains achieved in the practice oriented P3D module were not captured by the written knowledge test. Moreover, this proof-of concept should be applied toward a larger, more generalizable, sample size in order to ensure the effects were captured effectively.

Future Research

For future use of this module, further assessment will be needed to identify areas in the P3D training module that may require improvement (e.g., information representation, display-control functionality, system troubleshooting). Human-computer interaction (HCI) techniques, such as heuristic evaluations, cognitive walkthroughs, and experiment evaluations, are some of possible techniques that can be utilized to help find potential usability problems and to assess the usability and functionality of the simulator training module. Such techniques would help identify if the P3D training module is user friendly and intuitive to the learner, and would identify scenario designs that may confuse the user.

Moreover, research should be applied toward how to make the simulation system even more engaging and interactive for the learner. During the traditional module, participants were able to ask questions and interact with the instructor. It is recommended learners using a self-paced learning desktop simulation module be able to postulate questions concerning the given material to a virtual moderator and/or search "forms" for questions and answers. This function was not facilitated within the module's current design.

Further examination should also include assessing the flight performance of pilots-in-training within the simulated software, as a measure for assessing the effectiveness of a self-paced simulated learning program against face-to-face instruction. Research will need to be conducted to determine what measures would be representative of the pilot-in-training performance, to ensure the learner is performing the concepts correctly. It is also recommended that performance feedback be provided toward the learner every time they perform a concept or skill. This will assist the learner in identifying the areas that need more study and improvement.

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Disclaimer

The views expressed in this paper are those of the authors and do not necessarily represent the views of the organizations with which they are affiliated.

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