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Enhancing a flight dispatcher display for safer flight operations

Jeongjoon Boo

Purdue University

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By Jeongjoon Boo

Entitled
Enhancing a Flight Dispatcher Display for Safer Flight Operations

For the degree of Master of Science

Is approved by the final examining committee:

Steven J. Landry
Chair

Barrett Caldwell

Mark Lehto

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Approved by: Abhijit Deshmukh 3/17/2016

Head of the Departmental Graduate Program Date
ENHANCING A FLIGHT DISPATCHER DISPLAY
FOR
SAFER FLIGHT OPERATIONS

A Thesis
Submitted to the Faculty
of
Purdue University
by
Jeongjoon Boo

In Partial Fulfillment of the
Requirements for the Degree
of
Master of Science

May 2016
Purdue University
West Lafayette, Indiana
To my loving and supporting family
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SYMBOLS

\( fps \) frames per second
\( GHz \) gigahertz
\( MB \) Megabites
<table>
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<th>Abbreviation</th>
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<tr>
<td>ACARS</td>
<td>Aircraft Communications Addressing and Reporting System</td>
</tr>
<tr>
<td>ADS-B</td>
<td>Automatic Dependent Surveillance-Broadcast</td>
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<tr>
<td>ATC</td>
<td>Air Traffic Controller</td>
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<tr>
<td>BBN</td>
<td>Bolt Bergnek and Newman</td>
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<td>CVR</td>
<td>Cockpit voice recorder</td>
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<td>CW</td>
<td>Cognitive walkthrough</td>
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<td>DAR</td>
<td>Digital aircraft condition monitoring recorders</td>
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<td>FAA</td>
<td>Federal Aviation Administration</td>
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<td>FM</td>
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<td>National Aeronautics and Space Administration</td>
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<tr>
<td>NEXTGEN</td>
<td>Next Generation Air Transportation System</td>
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<td>National Transportation Safety Board</td>
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<td>National Airspace Voice System</td>
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<td>QCR</td>
<td>Quick access recorders</td>
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<tr>
<td>SFO</td>
<td>San Francisco International Airport</td>
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<tr>
<td>UAS</td>
<td>Unmanned aircraft system</td>
</tr>
<tr>
<td>UAV</td>
<td>Unmanned aerial vehicles</td>
</tr>
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<td>UHF</td>
<td>Ultra high frequencies</td>
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ABSTRACT

Boo, Jeongjoon M.S., Purdue University, May 2016. Enhancing a Flight Dispatcher Display for Safer Flight Operations. Major Professor: Steven J. Landry.

This study assesses capability of flight dispatchers to adopt enhancements on their display that enables detection of flights in abnormal activities and investigation of the causes. Three approaches were used. First, the expected function for enhancements was designed by collecting information from different places about what technologies are available for consideration. Second, hierarchical task analysis was conducted based on data collected by interviewing a former flight dispatcher in order to assess operational capability to handle the enhancement. Third, based on the results of first two approaches, a display prototype that includes the enhancement was developed and evaluated for usability and eligibility assessment. Results of three assessments found a possibility to enhance the display, and identified technological issues on transmitting and receiving large amount of data wirelessly in long distance, a regulatory issue that may affect effectiveness of the enhancement in certain situations, and usability issues related to the developed prototype.
1. INTRODUCTION

This study applied three approaches (technical assessment, operation assessment, and development and evaluation) to assess the ability of flight dispatchers to serve as “third pilots” in airline operations centers. The “third pilot” can function as another sets of eyes that can detect and investigate the causes of abnormal activities of active aircraft. It is expected that the enhancement could contribute to safer flight operations.

Instead of enhancing function of the ground stations, it might be more reasonable to implement the “third pilot” in cockpits. Instances such as Asiana Airline Flight 214 accident illustrate the need for the “third pilot”. Asiana Airline Flight 214 struck the sea wall during an approach into San Francisco International Airport. During the approach to the designated runway, the altitude and airspeed of aircraft was lower than the minimum. Neither the pilot or co-pilot acknowledged this abnormal situation. However, since the aircraft was attempting to land at a lower altitude and a slower airspeed than normal, its abnormal activity could have been detected. If this detection could have been done (even from personnel outside the flight deck), the pilot or the co-pilot could have been informed about this in time to prevent the accident. This work intends to study such ability to detect abnormal activities of active aircraft outside the flight desk as a function of a “third pilot”.

Among various agents on the ground for flight operations, flight dispatchers were identified to serve another sets of eyes for two main reasons. First, by the federal regulation, flight dispatchers share same operational responsibility as pilots. Second, one of their duty is monitoring assigned flights from departure to landing with a display built for monitoring purpose. Thus we could establish the system by utilizing current resources.
As a first step towards safer flight operations by utilizing flight dispatchers, we should know whether we can provide strengthened functions that can make them another sets of eyes. To assess this capability, we should know whether we could have the necessary enhancement, whether flight dispatcher could adopt the enhancement, how the enhancement will look like, and finally whether the flight dispatcher could operate the enhancement to perform as another sets of eyes. Thus three assessments were conducted. Theses assessments were named as a technical assessment, an operational assessment, and development and evaluation.

From the technical assessment, implementable functions were identified to enhance the display. Both benchmark-able technologies in other fields and upcoming technologies for commercial aircraft were reviewed to design an enhancement function. From the operational assessment, a capability of flight dispatcher to adopt the enhancement was assessed. Hierarchical task analysis (HTA) was conducted based on data collected from interviewing a former flight dispatcher. The goal of this analysis was to identify necessary skills of flight dispatchers to utilize the enhancement, eligibility to perform the detection and investigation tasks, and methods to implement the enhancement to current system. We used the results from the technical and operational assessments to design the display prototype. After the development, we evaluated the prototype using cognitive walkthrough to measure usability of the enhanced display and an implementation eligibility.

This report consists of five sections. The next section contains background information, which includes a rigorous literature review. It is followed by the Methods section that lists specific procedures of each assessment. The analysis and results follow the method section. Finally, discussion and conclusions of this study are presented.
2. BACKGROUND

2.1 The Accident of Asiana Airline Flight 214

On July 6, 2013, Asiana Airline Flight 214, flight from Incheon International Airport (ICN), South Korea to San Francisco International Airport (SFO), crashed on final approach into SFO. The landing gear and tail struck the seawall that protrudes into the San Francisco Bay. The National Transportation Safety Board (NTSB) reported that among 291 passengers, 3 passengers were fatally injured, 40 passengers, 8 flight attendants and one pilot incurred serious injuries, and also, they concluded that a mismanagement of the approach and an inadequate monitoring of airspeed caused the accident (NTSB, 2014). Both pilot and co-pilot did not notice that the altitude and airspeed were too low.

The situation started with mismanaging the vertical profile of the flight. This resulted the aircraft to be above the desired glidepath and made difficult to stabilize the flight while approaching to SFO. When the aircraft was about 200 ft. above the runway, either pilot or co-pilot or both became aware of the low altitude and airspeed, but did not react until the aircraft was below 100 ft. At the point when the pilot and co-pilot reacted, the aircraft was too close to ground. As a result, the pilots did not have enough time to adjust the aircraft’s altitude and airspeed.

NTSB concluded that insufficient monitoring during the approach happened and may resulted from expectancy, increased workload, fatigue, and automation reliance. The delays on the reaction after became aware of the situation resulted from a combination of surprise, nonstandard communication, and role confusion. Also, the pilot did not have clear understanding of the on-board avionic systems of the Boeing 777.
2.2 Flight Dispatchers

Flight dispatchers are decision makers on aircraft operations who work in the air-
line operation centers (AOC). AOCs serve as ground coordinating centers for aircraft
and collect all available information to make plans and decisions for the most efficient
operational control of the company aircraft. At AOC, dispatchers, FAA licensed op-
erators, monitor assigned aircraft to make various dispatch decisions from takeoff to
landing (Ruppenthal, 1962). They function as a supervisory control because they dis-
patch multiple aircraft at the same time and intervene active flights if the operations
have to be adjusted. Unlike air traffic controllers, their responsibility is not limited to
specific regions. They continuously monitor assigned aircraft from preparation stage
to landing.

According to the U.S government regulation 14 CFR PART 121, flight dispatchers
must be certified individuals (14CFR65.51, 1999). They share legal responsibility of
operational controls on aircraft with pilots (14CFR121.533, 2012). To qualify as
a flight dispatcher, a person has to be at least 23 years of age and pass required
tests. Flight dispatchers have to pass knowledge test in 13 different categories that a
person should know about the flight operation. For example, the categories include
FAA regulations, meteorology, weather information, air traffic control procedures,
flight operation procedures, aerodynamics, and human factors. In addition to the
institutional curriculum, a person with at least 2 years of experience as a pilot, a flight
navigator, a flight engineer, an air traffic controller, a flight service specialist, and a
meteorologist qualifies for the flight dispatcher examination (14CFR65.55, 1999).

Flight dispatchers must have both a communication system with pilots on op-
eration and a flight following system to perform their tasks. The communication
system must provide two-way communication between the pilots and flight dispatch-
ers (14CFR121.99, 2012). Also flight following system must include functions that
are required and necessary to properly monitor the flight activities (14CFR121.125,
2012; 14CFR121.127, 2012; 14CFR121.533, 2012). The Figure 2.1. is an example of
the flight following systems for the dispatchers. This display graphically represents locations of assigned aircraft, their routes, weather, and other information that is necessary to change the flight plan while monitoring phase.

2.3 Abnormal Situation Management

Systems are designed to operate in normal conditions, but those conditions are not always guaranteed. If one or more aspects of the system deviate from the normal, those states are defined as abnormal situations. Abnormal situations in systems trigger an operator to question the condition of systems, because they can lead to system failures or accidents. Thus, managing abnormal situations is one of approaches to prevent system failures or accidents for its safety.

In order to manage abnormal situations, systems are generally equipped with warning systems. Depending on the stage of abnormal situations, the warning systems can be categorized into two types as used in the aircraft warning system (Wiener, 1989). The first is when the deviations start or a system is expected to deviate from normal conditions. For these cases, systems are equipped with preparatory alerts, which notify operators or other parts of a system to prepare for expected abnormal situations. One example is use of weather forecasts on flight planning. When flight dispatchers decide flight routes, they refer to weather forecast that might affect flight operations. As stated, benefits of preparatory alerts gives more time and improve awareness, but since it is for expected future situations, abnormal situations may not occur. Since this type of warning is predictive, it may cause false alerts and alert flooding that lead to alert fatigue (Cvach, 2012).

Another warning system triggers when systems actually deviate from the normal. One general method for this type of warning is monitoring abnormal situations, which is also applied in many systems. In the flight operations, abnormal situation detection is mainly used in aircraft automation. As briefly mentioned in the introduction, modern aircraft is equipped with various avionic devices and warning systems for au-
Figure 2.1: An example of flight dispatcher display
tomated control. When an aircraft is automatically flying, pilot-flying monitors the avionic systems, which includes monitoring abnormal conditions indicated by the systems. One example is airborne-collision warnings. This warning system notifies pilots about the presence of other aircraft that may have possibility of collision (Williamson, Spencer, et al., 1989). On the cockpit dashboard, pilots have alert displays indicating abnormal status of the aircraft. However, these alert notifications can be turned off, which could indicate that the pilot is aware of the situation or for other reasons.

The researchers have investigated 7 categories, which include monitoring of abnormal conditions during alarm flooding and user interface design (Bullemer & Dal Vernon, 2015). From human factors perspective, researchers recently looked into reducing human errors by designing more effective systems, because human error has been identified as one of main causes of accidents (Naderpour, Lu, & Zhang, 2015). Researchers pointed out many aspects as causes of human errors and out of loop problem and alert flooding are two common topics by human factors researchers.

System operators may fail to manage abnormal situations properly. One reason is that they are out of loop from detecting and managing abnormal situation due to complex tasks, which leads to various problems (Endsley & Kiris, 1995). The case of Asiana Flight 214 also corresponds to the out of loop problem. The true reason why pilots did not respond quickly on the abnormal situation of aircraft properly is unknown, however, among other reasons, NTSB expects that stress, and physical and mental exhaustion could have been the reasons for failure.

Another common issue regarding the abnormal situation alert is alert flooding. Due to characteristics of preparatory alerts, warning systems produce alerts if anything seems suspicious, which causes lots of alerts. Hence, large portion of the preparatory alerts eventually became false indications. Due to this, the operators experience alert fatigue (i.e., being exposed to a large number of alerts), which causes them to be less aware of abnormal situation alerts and make it difficult to identify true alerts from false ones (Cash, 2009). Due to these reasons, there has been much work related to reducing false alerts by improving prediction algorithms (Juricek,
Seborg, & Larimore, 2001). One example is the announcement by Airbus that they are attempting to reduce airborne-collision warnings for crowded areas around central airports like O’Hare International Airport (Pasztor, 2011).

2.4 Hierarchical Task Analysis

HTA was first proposed in 1971 by Annet and Duncan as a general approach for examining tasks (Annett, Duncan, Stammers, & Gray, 1971). It is a hybrid of basic principles from other task analysis methods. HTA is intended to prescribe a method of work examination, one that pairs the description of human activity with an understanding of the purpose of work for the organizations and systems in which it was performed. In order to offer solutions to human factors issues, the intent of this analysis method was to provide a practical process for identifying problems.

From a system perspective, a system is a complex grouping of interrelated parts that can include human beings and machines (Annett et al., 1971). These parts interact in order to serve a purpose. Applying the concept to this case study, a flight dispatcher can be understood as a system. This system has both human and machine elements to serve a single purpose: safely directing an aircraft from one point to another. The component parts of this flight dispatcher system are the tasks and tools necessary to achieve its objective. The parts of the system involved in smaller tasks that lead to the objective are, within themselves, subsystems. As stated earlier, the coordination of subsystems is necessary for a system’s success; in other words, the inputs and outputs of subsystem interactions are critical. A hierarchical task analysis allows mapping of these interactions. The hierarchical task analysis represents this network and examines its sub-goals, overall goal, and flow via the hierarchical network. For this study, an HTA can map out series of tasks and procedures required for an operator to meet an overall goal. Since the method is very general and flexible, it is widely used as an input approach to interface design (Diaper & Stanton, 2003).
In addition to the characteristics of HTA described above, there are other advantages of applying HTA (Stanton, 2006). First, the value of HTA is its simplicity. The approach requires minimal training and is very easy to implement. This feature makes HTA a practical option for a wide range of task analysis contexts. Even though the method is simple and easy to implement, HTA outputs provide a comprehensive task description and insight into those tasks and operators. Also, the flexibility of the method allows users to analyze portions of tasks with varying detail, all the while satisfying the related analytical objectives.

One limitation of HTA is that its descriptive information does not reflect the cognitive aspects of an operator who performs tasks. Considering the purpose of this research, which does not involve enhancing the performance of flight dispatchers, HTA is a suitable method in this case. Another limitation is the reliability of the method. Due to its broad applications, the outcomes of similar tasks provide varying results. Thus, this study adapted a systematic procedure (Stanton, 2006) and a task analysis framework (Shepherd, 2001) in order to reduce HTA variability. HTA outcomes themselves cannot directly provide a solution, but they do guide progress toward a solution. In this study, HTA results were utilized with other factors to develop a prototype, to suggest an initial solution, and to conduct a usability test prototype to determine future works for a better solution.

Conducting an HTA of flight dispatchers involved three steps. The first step was defining and identifying which tasks to analyze. Prior to defining the parameters of analysis, the purpose of the analysis was defined. The second step was data collection. Everything necessary to perform tasks must be collected, which includes task procedures, technologies, interactions, constraints, etc. There are various methods to collect data. In this study, literature reviews and interviews with flight dispatchers were conducted to collect data. The third step is analyzing the data. From the collected data, a practitioner is able to determine the overall goal of an operator and related task sub-goals. These sub-goals split into several steps. The branching from
the overall goal continues until it reaches the appropriate level of detail to satisfy purpose of the task analysis.

Compared to other data collection methods, interviews offer a flexible approach and wide range of applications. Interviews are used as a primary data collection method for cognitive task analysis, but interviews also contain valuable, descriptive information, often elicited by proper questioning and other pre-determined strategies.

Data collection procedures followed in this semi-structured interview process reflects recommendations (Stanton, Young, & Harvey, 2014). The procedural progress was divided into three phases. The first phase was a development phase that defined the interview objective and developing questions. The second phase was an interview-conducting phase that involved selecting and recruiting interviewees and conducting the interviews. The last phase was interview data analysis.

Defining an objective for the interviews, beyond basic data collection, was necessary prior to deciding upon questions. During this development phase, the objective becomes the guidelines for the questionnaires. With a well-defined and focused objective, practitioners can reduce the time required for both question development and questionnaire modifications after reviews. Without such an objective, it is very easy to be distracted by other elements and develop questions that may not directly address the study’s data collection requisites. This may result in an incomplete data set, and the need for an additional round of interviews. The next step is developing questions that address this clearly defined objective. Since the objective is eliciting information regarding the tasks performed by flight dispatchers, questions that I will need to ask can be as simple as: “what does a flight dispatcher do?” However, in this case of a single, broad question, an interviewee may not mention some information. Prepared questions should include a rotation of open-ended, probe and closed questions; these cycles should persist with one particular topic until it is exhausted, and then move onto a new topic (Stanton & Young, 1999). Thus, questions should start with a question like the example mentioned above, then follow-up on the interviewee’s response with probe and closed questions.
After the developments, a review of the interview contents should be performed in order to check whether questions are properly related to the study’s objective and purpose. This step included checking grammar and syntax of interview questions, modifying the questions after mock interviews. During the interview, interviewer must record conversations with an interviewee for data collection purpose. There are many different methods to record the data. This study applied both a note-taking and a voice recording. After the interview collected data must be transcribed for analysis purposes.

During the analysis phase, analysts extract information from the transcribed data. This information categorized as expected and unexpected data. Expected data is information a practitioner expects from the interview and unexpected data is ones that are not relate to the objectives of the interview. Expected data extracted from the interview transcription can be used in various forms of analysis. Depending on the analysis form, the data has to be converted into a desired input.

In this study I apply a systematic strategy to conduct an HTA, introduced by Shepherd (2001). This strategy is a framework of continuously repeating a series of three steps until the analysis reaches a certain quality level that fully satisfies its purpose. First, the cycle begins with defining the goal of the analysis. This goal has to be re-described with examined operations found within the collected data. After each iteration, analysts assess whether the goal is carried out.

2.5 Cognitive Walkthrough

Even though there are many methods for evaluating usability, most are not suitable for the early stages of user interface development. Previous research and reports reference the importance of user-centered design, and usability tests help to ensure such design practices. The low-fidelity prototype user interface was evaluated through a cognitive walkthrough (CW). CW is a usability evaluation method useful in the early stages of user interface development. The purpose of this evaluation is
assessing whether potential users can operate a product without any frustrations. In this case, another purpose was to estimate the ease with which users could add the featured function into the current flight dispatcher system. Unlike the former CW, a former flight dispatcher who participated as an interviewee for HTA also participated as an analyst for evaluating the prototype. The intention is to collect objective feedback on the prototype by a person who was not involved in the development of the interface to avoid design defensiveness. Also it is to collect constructive feedback through an analysis by an expert. This section includes a rationale for applying a CW to this study, the benefits and limitations of the method, how to overcome these shortcomings, and the related procedures.

As briefly described above, the CW is an interface evaluating method, well known for its application in the earlier stages of user interface development. Rather than recruiting a number of participants to perform certain tasks to assess usability and performance, the CW analyzes the mental processes of users who operate an interface via an analyst. The analyst is not necessarily a user, because the CW considers how potential users will operate an interface compared to how a designer expects users to use the interface in task performance. This feature allows a designer to take analysts role. To conduct the method, a designer is presented with a sample task that an interface is intended to support. The designer develops sequences of actions to perform the sample task, which is a hypothetical usage of the interface. Then the analyst examines these task sequences and the interface, and decides whether each action is appropriate. The purpose of examining hypothetical usage is not to find a correct method. Hypothetical usage is an input to the method and its output identifies issues with the hypotheses and their remedies, which can then be incorporated into interface development. This process traces the expected cognitive processes of a hypothetical user. During this process, the analyst is also able to provide reasons for issues as they arise. If the interface is examined and operates as intended, it represents users interactions with the interface. Ultimately, the CW encourages concrete, detailed
thinking about how the sample task would be performed and whether the interface adequately supports that cognition.

The reason why CW was chosen as a method to evaluate the interface prototype is its capacity to analyze mental processes. In this study, a successful interface anticipates and accommodates users’ decision-making processes. Interfaces that require unrealistic skillsets or proficiencies are ineffective and unproductive. The analytical process used in this study does not require three inputs that other methods typically need. First, this evaluation method does not require an actual user. Technically, an analyst can be anyone who proceeds through the expected action sequences. However, to collect substantive results from the evaluation, there are few points to consider, which will be discussed in the latter part of this section. Second, the interface design must be developed enough to allow an analyst to extrapolate the correct action sequences for a sample task. Thus, as long as the prototype can be used for examining the correct action sequences, a low-fidelity prototype can be tested and its form will not matter. Also, this process does not need an analyst to perform the sample task, because examining the action sequences does not necessarily involve performing those actions.

Another usability evaluation method for early stage of development is heuristic evaluation. This method was not applied to the current study due to its purpose and requirements. I selected the cognitive walkthrough method over heuristic evaluation for two main reasons. The reasons were related to the evaluator and the evaluation criteria. As addressed previously in this section, cognitive walkthrough evaluate process of using an interface to perform a task, but heuristic evaluation is an evaluation of the interface itself in relation to its usability categories. While the result of cognitive walkthrough indicates eligibility of an interface for performing certain tasks, that of heuristic evaluation measures just usability of an interface. Thus, evaluators of both methods require different skill sets. Heuristic evaluation requires a usability specialist to look into an interface in detail who does not need to know how and where
the interface will be used. However, evaluation of a cognitive walkthrough requires a person who has experience or knowledge about usage of an interface.

There are other benefits to applying this evaluation method. Compared to a CW that only requires one analyst, other formal usability tests and evaluation methods are time-consuming and expensive. For example, a heuristic evaluation requires at least one usability specialist to evaluate a prototype. Also, the test requires many participants and an operable user interface to measure the participants’ performances on given tasks. Thus, a CW takes substantially less effort than other testing methods (Jeffries, Miller, Wharton, & Uyeda, 1991; Karat, Campbell, & Fiegel, 1992; Karat, 1994). It requires less time to prepare and conduct the study, and costs less to conduct the evaluation. Also it is time-efficient. Even though the method is more economical than others, a CW identifies about 40% or more of the problems revealed by user testing (Lewis, Polson, Wharton, & Rieman, 1990; Jeffries et al., 1991; Mack & Montaniz, 1994; Cuomo & Bowen, 1994).

As mentioned above, this method is performed by an analyst and therefore the evaluation results reflect the analyst’s judgments. Considering feedback from a single person can be more subjective than data based on multiple test users. Thus, an analyst’s background knowledge regarding the sample task and the interface can significantly influence the evaluation. Compared to a heuristic evaluation, CW does not cost as much as a heuristic evaluation; a heuristic evaluation often identifies additional problems and requires less effort because of the evaluation by a professional usability specialist. However, a heuristic evaluation interface prototype has to be of higher quality than what is required to perform a CW. The CW also has shortcomings compared to other usability test methods. Since a CW does not test users performing given tasks, it does not provide nuanced insights on the interface like those provided by a heuristic evaluation and other usability test methods. Also, the quality of CW outcomes is highly dependent on given tasks. The tasks must be produced carefully in order to collect proper outcomes from the evaluation. Thus producing a “good task” is critical and it is very difficult (Wharton, Bradford, Jeffries, & Franzke, 1992; John
& Packer, 1995). CW has social constraints, too (Spencer, 2000). One of them is design defensiveness. A designer may be unable to perform the evaluation objectively. Even though the designers try to be as unbiased as possible during the evaluation, they may manipulate the results to reflect their vision for the software, rather than its current capabilities.

As discussed above, an analyst’s background knowledge about the target users of the interface and the interface itself can influence this method’s results. Although a designer studies the target user in detail, the designer cannot replicate exactly the interaction of a user with the interface. Accordingly, the CW has some shortcomings, but most of the listed shortcomings can be overcome by recruiting an expert user as an analyst. Expert users are domain experts who are knowledgeable and experienced with computers and computer software. They know what needs to be done to achieve a goal. For this study, expert users are experienced flight dispatchers. Due to characteristics of the CW, results from the method are not as insightful as other methods. An expert user of the interface can provide more constructive feedback than evaluations by others who are not experienced in a certain field. When evaluated by someone other than the designer, subjectivity can be decreased. Recruiting an expert user has its downsides, too. The designer already knows all aspects of the prototype, but the expert user does not. The quality of the evaluation results depends on how well the analyst understands the purpose of study and the role of the expert user. Thus, the instructions for the CW and task analysis must be prepared in detail. This also constitutes a social constraint, which makes the explanation of the study difficult and lengthy. Prototyping based on existing, widely used flight dispatcher software was one strategy to minimize this issue. The expert user’s familiarity shortens the time needed to explain the study and also helps the analyst to better understand the prototype.

The CW can be separated into four stages: preparation, data collection, analysis, and follow up. Preparation part includes developing a sample task and expected action sequences to analyze the prototype. During the data collection, an analyst
Table 2.1
The Four Cognitive Walkthrough Questions

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<th>Question</th>
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<tbody>
<tr>
<td>Will the user attempt to achieve the right effect?</td>
</tr>
<tr>
<td>Will the user notice when the correct action is available?</td>
</tr>
<tr>
<td>Will the user associate the correct action with the desired effect?</td>
</tr>
<tr>
<td>If the correct action is performed, will the user identify this as progress?</td>
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</table>

performs given sample task with the prototype. Analyst also record and compare actual action sequences of operating the prototype to the expected action sequences. By analyzing the collected data, an analyst identifies differences between the expected and actual action sequences and provides what cause the differences. This process leads answering the questions listed in the Table 2.1 to conclude the results of CW (Wharton, Rieman, Lewis, & Polson, 1994). After the analysis, an analyst conducts a follow up for reflecting the identified issues to the prototype.
3. METHODS

3.1 Technical Assessment

The purpose of the review is assessing actualization of the proposed enhancement by utilizing currently available technologies. We answered four questions: (What type of data should be sent? How would it be sent? How much bandwidth is necessary? Are there any current examples, if not what do we need?) using literature reviews on technologies in relevant fields.

3.1.1 Requirements

In order to make flight dispatchers as another set of eyes from the ground, we should know what type of data should be sent from active flights. The review focused on the required information to detect abnormal activities of active flights and investigate causes.

3.1.2 Data Transmission Method

First of all, we should know whether active flights could transmit data to the ground in real time. Data transmission methods of unmanned aircraft system (UAS) were benchmarked to assess this capability.

3.1.3 Data Bandwidth

With the capability to transmit data from active flights to the ground finalized, the required bandwidth to send numerical and graphical data were assessed using the statistics provided by FOQA and theoretical data bandwidth of TV.
3.1.4 Current Examples and Upcoming Technologies

Lastly, current examples that utilize flight data were reviewed and upcoming technologies that were required or eligible for the enhancement were discussed.

3.2 Operational Assessment

Hierarchical task analysis (HTA) was applied to assess operational capability of flight dispatchers. HTA was used on data collected from interviewing a former flight dispatcher after developing interview contents through procedures from Stanton and Young (2014) including a mock interview with a current flight dispatcher. A systematic framework was applied to conduct a HTA diagram. The diagram described tasks of flight dispatchers on a flight ranging from preparation of a flight plan to reviewing the operation after landing at a destination. Also the diagram (listed in the section 4.1) provided a systematic perspective that pointed out how to enhance flight dispatchers tasks to contribute to safer flights.

3.2.1 Defining an overall goal

The purpose of this study was to evaluate the task of a flight dispatcher as a support personnel for the flight deck. Results of this evaluation will be used in the development of an enhanced dispatcher display. Given the previous assessment on technical capability, current flight dispatchers had to be assessed to identify whether they have the skills, time, and procedures for the enhancements.

3.2.2 Data collection

This study originally planned to implement outcomes from literature reviews on an HTA analysis. However, limitations found from literature reviews led to conduct another method to collect data. Literature reviews were completed, but resources related to flight dispatchers were limited; the information collected was insufficient,
in fact, to conduct an HTA. Credibility of accessible literatures was questionable due to outdated and unreliable sources. For example, the latest literature that generally describes tasks of flight dispatcher exclusively was published in 1962 and recent information was only available on the Internet as articles (which lacked credibility). In order to learn about latest information regarding flight dispatchers in detail, one is required to enrolling in an FAA certified flight dispatcher institution. Thus interviews with flight dispatchers were conducted to collect the most up-to-date and reliable data.

The biggest issues were related to reliability and validity of interview data. Since the information source is individuals experiences and perspectives, the resulting data can vary widely from one interviewee to the next. To minimize this risk, two constraints were applied in the study. First, all interviewees were flight dispatchers. Second, collected data from interviews was compared to the existing literature and the collected data from each interview. Another issue was the quality of the interview data. This largely depends on interviewing methods used and the interviewee. As described above, only practicing professional dispatchers were selected to ensure data quality. Recommended interviewing methods were followed as described below.

For this study, the three phases of interview conducting from Stanton and Young (2014) was further specified into six steps. First, an objective of the interview was defined. Second, specific questions and a layout for the interview was developed. Third, the interview contents were reviewed while reflecting results from a mock interview. Fourth, specific plans to conduct the interview were prepared. Fifth, an interview was conducted on a participant and necessary data was collected by recording the interview. Sixth, recorded interview contents were transcribed for analysis for an HTA.
Defining purpose of the interview

The purpose of interviews in this study was to collect data regarding the tasks of flight dispatchers in order to perform a task analysis. Considering this purpose, the objective of the interview was to identify flight dispatcher tasks and to acquire detailed information about such procedures that can be used in a task analysis.

Preparation

We considered two aspects during the question development. Even with the method described in the Background section, it was still possible that an interviewee might not mention some key elements. To avoid gaps in the information, the interview questions must reflect all tasks to be addressed in the study. These tasks were identified through a literature review, mass media, and a mock interview with a flight dispatcher. Following this the questions were developed to address the tasks. Another aspect we considered when we had enough information so that we could move to the next question cycle. The required amount of data for conducting task analysis varied by objective and analysis type. This study required information that could clearly identify an overall goal, sub goals, and step decomposition for an HTA. Thus, the interview questions were designed to collect data that included task descriptions, purposes, and a general order. Details on this process are the focus of this paper’s task analysis section.

Along with developing questions and question sequences, interview approaches were determined. These methods included strategies for conversation and questioning. The first step was to introduce and explain the study. A focused part of planning the interview was how to explain the purpose of the interview. Even with a well-prepared question, it is possible that an interviewee could be misled if they do not understand the focus of the study. Thus, such explanations were simple and straightforward.

The first review was completed to check grammar and syntax; the second review took place after a mock interview to reflect its findings to the actual interview. A
current flight dispatcher participated in a mock interview and conversations were recorded via note-taking. Following the mock interview, the clarity of a succinct explanation of the study and validities of each question were tested again. As a byproduct of the mock interview, specific terms used by the flight dispatchers were identified. The mock interview also allowed us to practice how to lead an interview and when to use a cycle of open-ended, probe, and closed questions until a topic is fully explained. Following the aforementioned reviews, the final interview question set was developed.

**Data Collection**

Appropriate participants had to be selected to represent the general tasks of flight dispatchers. The representatives had to be experts in their tasks. Also, considering the fact that different airline companies employ flight dispatchers, their daily exercises can be slightly different due to varying company protocol. Thus, multiple flight dispatchers from different airlines or a single participant experienced at working with several airlines were suitable as participants. As a result, a recently retired flight dispatcher who worked at multiple airlines was recruited for the interview.

To provide a comfortable and non-overwhelming atmosphere to the participant, the interviewee chose the interview location. Two interview recording methods, voice recording and note-taking, were used to record data and both methods were approved by IRB (Appendix D). Recording with both methods creates redundancy, thus minimizing the change of information loss. The voice recording was done following a verbal consent from the interviewee.

**Data Transcription**

After the interview, the voice recording was transcribed. This process allows for the extraction of information from the conversations for data analysis. This procedure includes replaying the initial recordings of the interview conversations and
transcribing everything said by both the interviewer and interviewee. After transcription, the interviewee comments that include personal information are omitted and the recordings are destroyed in order to protect the privacy of participants.

3.2.3 Analysis

The systematic framework consisting of three steps (as described in the Background section), was applied to conduct HTA and created its diagram. Multiple iterations were performed of these three steps till its details to satisfy the goal of HTA. After the several iterations, the identified outcomes satisfied the goal of this analysis, but it was not detailed enough to satisfy the goal of operational assessment. To assess operational capability and for prototyping purposes, two different types of interactions were identified. The first is a human-task interaction, which describes how an operator performs each task to fulfill an operation. Second is a human-computer interaction, in which an operator acquires information from a flight dispatcher display in order to perform tasks successfully. Thus, the latter iterations were more focused on breaking down operations to identify those interactions.

The analysis began with defining a goal of HTA. The main goal of operational assessment was to measure operational capability of flight dispatchers. Thus the main goal of an HTA was to describe the tasks of flight dispatchers in detail so that the capability of adopting the enhancement can be identified. Since these terms were very broad, the analytical approach began with mapping out tasks of flight dispatchers. The tasks were extracted from the collected data and included in expected data from the interview. The expected data was broken down into four parts which represented four different operations that flight dispatchers perform to fulfill their operational goal. These operations were further broken down into a series of tasks and each task was also broken down until the resulted details satisfied the defined goal. As a result of this process, the goals of each task operation and operation sequence were
identified. After the first iteration, the goal was reiterated to prevent deviation from the original purpose of the analysis.

To assess operational capability and for prototyping purposes, two different types of interactions were identified. The first is a human-task interaction, which describes how an operator performs each task to fulfill an operation. Second is a human-computer interaction, for which an operator acquires information from a flight dispatcher display in order to perform tasks successfully. Thus, the latter iterations were more focused on breaking down operations to identify those interactions.

3.3 Development & Evaluation

A display prototype was designed by reflecting benchmark-able and upcoming technologies of commercial avionics discussed in the previous section without considering current limitations. Also, the prototype was based on a computer program that is specifically designed for a flight dispatching purpose. This prototype is specifically designed to be implemented to monitor flight operation, because the prototype was expected to assist achieving the goal of the operation more effectively. The prototype represented flight status that alerts flight dispatcher if a status of particular aircraft becomes abnormal. Also it illustrated the cause of the status change and shows cockpit video if it is available. After the development, the prototype was evaluated through cognitive walkthrough (CW) to identify usability problems. A designer of the prototype can perform CW, but a user expert was recruited to prevent design defensiveness and to obtain more constructive feedback.

3.3.1 Development

The prototyping procedure consisted of three steps. Features of the prototype were determined from the outcomes of two assessments. Then, access was acquired to the flight dispatcher software and preparations for prototyping therein. After examining software capabilities, specific methods to implant new functions were explored.
In order to benchmark flight dispatcher software for prototyping, current flight dispatcher softwares were explored. After contacting several software companies, access to one of the most popular dispatching software program was acquired. The benchmarking of popular dispatching software was carried out for several reasons. Software that is used widely can be expected to contain functions needed by its users. Also, a well-known product can benefit the prototype evaluation because there is a chance that users already have experience with the software or knowledge of it. This feature can lead to an evaluation participant’s deeper understanding of the prototype.

After acquiring the access to the software, WSI Fusion was examined to understand its functions. The software company also provided a tutorial session to gain mastery of the product. After the examination, a possible approach to present the features from the assessments was identified. After comparing possible ways to implant the features, a visual representation with aircraft figures and locations was generated using the software.

For designing a function for the prototype, the two features (detecting abnormal status and showing cockpit videos) integrated to serve their shared purpose: to let flight dispatchers to identify the causes of status changes. Before this integration, the two features were examined to identify the information necessary for users. A flight status detection feature supposedly provides this status information, both implicitly and explicitly. When working, the feature should explicitly relay flight status changes in order to monitor the status and implicitly suggest solutions to the cause of the status change. As discussed previously in this section, the cockpit video feature must provide reliable video, regardless of network conditions.

After this examination, the structure of the function was designed. Since the purpose of the function is informing flight dispatchers of flight status changes, showing the changes in status is placed at the top of the hierarchy. After notifying the dispatchers, the function should provide detailed information to the user about the notification. This information includes the cause of the status change and the avail-
ability of cockpit video. If the video is available and the user wishes to see it, the function should provide the video.

The next step was to determine the procedures and locations for the function features. Considering this human-computer interaction, auditory and visual methods can be imbedded on the software or in a separate form to display the information. Apart from the video function, which already uses graphical presentation, other features can be presented as sound, text, and graphical forms. They can use more than one form of expression, but the most suitable form was used for each one. How to select the most suitable form for each features are discussed below.

To represent changes in flight status, a graphical presentation method was utilized. The software shows the location of aircraft with airplane figures in a map. Originally, this airplane figures are blue in color. Considering the working conditions of flight dispatchers, they should frequently check the location of an aircraft by looking at the map and figures. Changing the color of the figure to a different color indicates a status change. Also, considering that a number of flight dispatchers often work together in the same space, an auditory feature may interrupt others and lose efficacy in a noisy environment. Both the status change cause feature and the cockpit video availability, therefore, will be delivered via textual form. Those two elements should provide additional information to the dispatchers so that they can make decisions regarding their tasks and responsibilities. Compared to the other forms, a text form can provide information immediately and explicitly.

Since the benchmarked software shows color-coded aircraft figures in the map, the changes of flight status function were placed on those figures. Then the figures are designed to be clickable to see the information regarding the cause and video availability. A text box that contains that information would appear below the figures. This is similar to general computer programs that show additional information about the selected element when the pointer hovers over that element. The layout of the cockpit video would appear on a different screen, or at least would not overlap with the prototype (screenshots of prototype are listed in the section 4.3). If the video
appears above the interface, it may overlap the initial display, causing users to be unable to monitor other changes.

3.3.2 Evaluation

Preparation

Conducting a CW was divided into four steps: preparation, data collection, analysis, and follow up. The preparation is specifically designed to plan the evaluation. The first step was defining the ideal users and their background. This step targeted the interface users. The assumed users were current flight dispatchers who are eligible to operate the dispatcher software enhanced with the interface prototype. The second step was selecting a sample task. The sample task was designed based on Asiana Airline Flight 214. The task was designed to be similar to the accident in order to assess whether flight dispatchers can utilize the given information and functions to identify an issue and remedy the issue safely. The third step was specifying the correct action sequences for the task. The sequence for the sample task was combination of intended series of actions required to operate the prototype and the expected action of the flight dispatchers, largely based on the HTA results. The required actions included detecting the abnormal status of the airplane and performing the action sequence required to check the airplane and communicate with the pilot to notify him/her of the issue. The last step was determining possible states of interface during the scenario. Multiple states of the interfaces are prepared to reflect a number of possible scenarios for the sample task. For example, a cockpit video may or may not available depending on the network connection condition. Thus, both possibilities for cockpit video availability have to be prepared. Other than the four questions above, additional questions were prepared to collect more detailed responses. It is possible that an evaluator may just simply reply “yes” or “no” to all the four questions. Also, the questions specifically address the likelihood of adapting the function in order to enhance the current system.
Data Collection

A former flight dispatcher, the interviewee for the HTA, acted as evaluator for the CW. The prototype was color printed within a 21-inch monitor to make sure the elements were big enough to easily identify. The study was conducted face-to-face with a voice recorder (with the participant’s verbal consent). The purpose of the research and prototype was explained first. The participant’s understanding of the study was verified and the study transitioned to explain the CW and an evaluator’s role. The sample task and its scenario was given and explained with the representative prototype states. Once the participant reviewed the sample task and prototype, the intended action sequence was supplied as a comparison to his recommendations. In the last step of the study, the series of questions including the four CW questions were shared in order to ask for feedback. Following his response was a brief discussion of each question.

Analysis

The CW analysis was based on the four categories. First, it provided an explanation for why a user would choose that action. Second, provided an explanation for why a user would not choose a specific action in the intended usage sequence. Third, recorded the related problems, reasons, and assumptions. Last, considered and recorded any design alternatives. To analyze the collected data, the voice recording was transcribed and organized based on the four categories above. If the interface is evaluated and modified based on the analysis results, the designer expects that users should be able to operate the interface as they expect in order to achieve the promised purposes of the interface. Also, the analysis results themselves provide useful feedback for the designer. When task sequences are identified as questionable expectations, the reasons for those issues are provided to the designer by the evaluator. The designer can then decide how to best address the issues and avoid making modifications that do not address the particular glitch.
4. RESULTS

4.1 Technical Assessment

Integrating the technologies discussed in this section, it is possible to design a system that enables a network between aircraft and ground stations through radio communication directly or indirectly via satellites. This network possesses the potential to enhance current commercial aircraft systems such as transmitting flight data from aircraft to the ground and sending various useful information and updates from the ground to aircraft. Specifically, images and videos from aircraft can be used for surveillance purposes. For example, operators on the ground who are monitoring real-time videos of aircraft cockpits and their dashboards may identify any human errors. Transmitted raw flight data can be also utilized for many purposes. Inputting flight data into an aircraft abnormality detection program can automatically show the status of an aircraft, which can become another method to ensure flight safety. Moreover, these two new monitoring systems can be synergized with better voice communication, so that the interaction between the ground and aircraft will be amplified.

The first part of this section focuses on how unmanned aerial vehicles (UAVs) transmit their flight data to the ground and limitations on data transmission due to bandwidth. The next part discusses current status of commercial aircraft avionics. It addresses whether commercial aircraft can transmit data like UAVs, and upcoming technologies that will improve the avionics.
4.1.1 Data Bandwidth

We use UAVs in various ways from personal interests to military operations, and an unmanned aircraft system (UAS) consists of subsystems that require operating a UAV. One main subsystem in a UAS is controlling UAV manually or via a preprogrammed navigation system. The vehicles have to be controlled or programmed from the ground by a human operator, not necessarily a person with piloting skills, and there are various ways to do it. For example, simple controllers or smartphones can operate personal drones, but military vehicles use complicated controllers or they are controlled from military bases through computers. Also, we can pre-programmed to make them automatically fly. Simple short-range UAVs or drones only require controllers, but multi-purpose UAVs have more complex controlling system. For military use, UAVs have autopilots and navigation systems that maintain the status of the aircraft. Regardless of UAV type, the operators need various information, such as weather and aircraft status, in real time in order to manually control UAVs. For simpler types of UAVs, the operators are able to collect that information themselves by direct observation. However, long-ranged UAVs like Global Hawks, which can fly over 5,000 kilometers and for 24 hours (Austin, 2011), controlled by the 12th Reconnaissance Squadron at Beale Air Force Base, California, and the 348th Reconnaissance Squadron at Grand Forks AFB, North Dakota, but operate worldwide.

Communication network technology makes long-range flights possible. Operating complex UAVs like Global Hawks stably requires at least a ground station, payload, and data link. Data links consist of up and down links connecting UAVs and ground stations where UAV operators and controllers are located. The data uplink is for sending inputs from ground stations and the data downlink consists of outputs from UAVs. There are three methods (laser, fiber-optics, and radio) for communicating with UAVs, but currently only one method, radio communication, is a common communication method due to limitations of other two methods (Austin, 2011). Thus, a
ground station and a UAV communicate directly or via satellite using radio frequencies.

4.1.2 Data Bandwidth Restrictions

The amount of data that can be transmitted highly depends on radio frequencies. Radio frequencies are a type of electromagnetic radiation ranging from 3HZ to 300GHz. These frequencies are categorized into 11-different band names depending on their frequency. Higher radio frequencies can transmit large amounts of data at once, but have a shorter range compared to lower radio frequencies. For example, generally AM radio waves that fall into the low and medium frequency bands can deliver information further than FM radio waves that use the very high frequency bands. However, the quality of AM radio waves is relatively lower compared to FM radio waves due to their limited bandwidth. This characteristic of radio frequency affects UAV systems.

Thus there has to be restrictions in generating data from UAVs and payloads. By the data downlink, UAVs send information to designated places on the ground. Depending on the amount of data a UAV is required to send, operators must choose an appropriate radio frequency to send the data from the UAV. For example, Global Hawks use up to 500 megabytes per second to send images and videos collected by installed surveillance cameras of its payload and flight data regarding aircraft status (Austin, 2011). Transmitting aircraft status does not require high data bandwidth compared to images and videos. On average, commercial aircraft generates 7.2 megabytes per day, which is equivalent to 83.333 bytes per second (AC120-82, 2004). Images consist of small elements called pixels that consume 6 or 8 bits for one gray-scale pixel and a video consists of a series of still images, which are called frames. Typically, a TV generates a video at 30 frames per second (Hershberger & Farnochi, 1981). For example, if the resolution of a video is 640 pixels horizontally by 480 pixels vertically, there are a total of 307,200 pixels and a gray-scale-only video
with 8 bits per pixel and 30 frames per second will consumes about 75 million bits per second, which is equivalent to 9.216 megabytes per second. With higher resolution and colored pixels, a video will require higher bandwidth consumption. Generally, a high-resolution TV camera or infrared imager will produce a data rate of over 75 megabytes per second.

Reflecting high bandwidth consumption for transmitting images and videos, UAVs must use high radio frequencies and a transmitter, and an antenna must be in line-of-sight (Fahlstrom & Gleason, 2012). The ultra high frequencies (UHF) in the range of 1 to 3 GHz are desired for UAV data transmission purposes, but increase the demand on this range of radio frequencies, sharing it with other uses such as TV broadcasting and cellphones. Thus, displaying images and videos that are transmitted from aircrafts possess restrictions and may cause delays if data is passed through satellites due to the physical distance between UAVs and ground stations.

4.1.3 Flight Data Analysis

As discussed in the section above, various data is sent from aircraft to the ground using radio frequencies. The next point to assess is the capabilities of transmitting flight data to and from commercial aircraft. This sub-section discusses an assessment of available technologies to collect and transmit flight data.

According to FAA regulations, all U.S. commercial aircraft must be equipped with operative flight data recorders (FDR). All avionic data is recorded in FDRs for mainly identifying causes of aircraft accidents, which the National Transportation Safety Board (NTSB) investigates along with the cockpit voice recorder (CVR). So the FDR is built to survive during severe impacts. Flight data are not only used for accident investigations, but also used for aircraft maintenance. Due to its primary purpose, accessibility of data in FDR is low.

For ease of access to those data, there are devices to capture avionic data from all parts of aircraft. These devices are quick access recorders (QCR) and digital aircraft
condition monitoring recorders (DAR). We can easily retrieve flight data from these two devices by portable flash drives or wireless network. There are QCRs on an avionic device market that can transmit data through cellular networks, which use cellular network devices inside aircraft and transmit data to satellites that route the data to the cellular towers (radio network distributed over land through cells that are transceivers located in fixed locations to provide a wide radio coverage) on the ground. Unlike FDRs, however, QCRs and DARs are not required by the regulations.

When there is an aircraft accident in the US, the NTSB retrieves the black box, the FDR and the CVR. The retrieved devices then go through data recovering processes to examine the stored data. NTSB investigators recreate the aircraft activities and cockpit situations (NTSB, 2002). From the recreation, investigators identify what caused the accident, such as any malfunctioning aircraft parts or abnormal activities in controlling. NTSB uses these identification methods after the situation, but the concepts and methods using flight data may apply to detect any unusual situation in real time.

There is a FAA program to utilize retrieved flight data. Flight operational quality assurance (FOQA) is a voluntary safety program 14 CFR Part 121 air Carrier Certification that is designed to make commercial aviation safer by allowing all three parties (FAA, pilots, airlines) to identify and reduce or eliminate safety risks, as well as minimize deviations from the regulations. The issues includes areas of operational safety, aircraft performance, aircraft system performance, crew performance, airline procedures, training program, training effectiveness, aircraft design, ATC system operation, airport operational issues, and meteorological issues. Depending on which issues to evaluate, required data type and analysis may be different. Fundamentally, the project mainly analyze flight data recorded from aircraft, and they collect the data from the aircraft by using digital flight data acquisition units, such as QARs, or directly from the FDR. After the data collection, we can transport the data physically, electronically, and wirelessly to a ground data replay and analysis system (GDRAS) location where transforms raw flight data into a usable for analysis, process and scan
selected flight data parameters, compare recorded or calculated values to predetermined norms using event algorithms and finally generate reports.

4.1.4 Up-coming technologies

This study can also benefit from the Next Generation Air Transportation System (NextGen). NextGen is a new National Airspace System to implement new technologies in the United States. This paragraph discusses programs of this project (Automatic Dependent Surveillance-Broadcast and National Airspace System Voice System) that is related to the topic of this study (FAA, 2015). According to the FAA, Automatic Dependent Surveillance-Broadcast (ADS-B) is a precise satellite-based surveillance system. With current GPS technology, we can catch the flight data of an aircraft and send the information to the ground. With this system, an aircraft may not need to send their information to the ground by themselves, which can give more room to transmit other information such as images and videos that are discussed in the previous section about the UAV communication network. Another NextGen program, National Airspace Voice System (NVS), is implementing a new voice switch technology to reduce severe obsolescence issues such as a speech recognition, which many are currently experiencing. Also by using a network, this program unbinds limitations of voice communication, which are limited by ranges of geographical facilities. The voice communication issue was also brought up during the interview with flight dispatchers from the task analysis, and a BBN report (Deutsch & Pew, 2005) to the NASA Ames Research Center also indicates the importance of voice communication for the development of airspace systems. Since the teamwork between flights and the ground stations are essential, voice communication becomes a key element for tactical situations and emergencies. The NVS is currently in the planning phase and it will be operational.

There are studies regarding detecting abnormal activities from aircraft by analyzing FDRs (Zolghadri, 2002). The FDR stores data regarding all mechanical and
electronic inputs and outputs made in the aircraft. For example, types of parameters stored in the FDR include airspeed, altitude, and angles of various parts. Since these data are already present in the aircraft, researchers are proposing algorithms to utilize these results so that the proposed system can help improve the situation awareness of pilots by identifying abnormalities within the aircraft. Since we can transmit flight data to the ground using the cellular network or radio communication, the ground stations can also monitor the results of proposed method.

4.2 Operational Assessment

Along with what current flight dispatchers do, the interview provided insights on their capability. Flight dispatchers generally dispatch 10 to 15 flights at a time. We can generally describe dispatching a flight as conducting flight plans, reviewing the flight plans with pilots before departures, monitoring flight activities, and reviewing the whole operation for future reference. Considering the normal operation, which does not include change of flight plans after departures of aircraft due to unexpected situations, a large portion of their tasks were allocated on conducting and reviewing flight plans. This implied that flight dispatchers have time during the monitoring flight activities, so that they may perform extra tasks during this phase. Also, flight dispatchers were recommended to obtain commercial pilot certification. It is primarily for helping them communicate with pilots flawlessly, but those dispatchers were expected having same skills as pilots.

The resulting HTA diagrams illustrated what current flight dispatchers do on a flight. The diagrams also presented the main goal of overall tasks and sub-goals of each task. The main goal was determined as dispatching a flight safely. To achieve this, the sub-goals had to be achieved. From the diagrams, achieving sub-goals were identified as significantly dependent to information given to flight dispatchers. This aspect is also mentioned during the interview.
Plan: Do 1 – 2 – 3. If there is anything to report about the flight – 4.

0: Dispatch an airplane

1: Prepare a flight plan
2: Review the flight plan with a pilot
3: Monitor the flight
4: Review the flight

Figure 4.1.: Overall HTA diagram
Figure 4.2: Preparing a flight plan
Plan 2: Do 1. If the pilot has an opinion – 2.
If the plan cannot be changed – 3.
If it can be changed – 4.
Then do 5 and 6.

Figure 4.3.: Reviewing a flight plan with a pilot
Figure 4.4.: Monitoring an active flight
The first responsibility of a flight dispatcher is preparing a flight plan. Flight dispatchers draft a flight plan for an assigned airplane on certain date and time from point A to B. A flight plan contains specific instructions for the pilot on how to fly the airplane. It includes a specific route, altitude, destination airport, alternative airport, etc. Before planning, the dispatchers check the schedule of the assigned airplane, its departure and arrival locations. After checking the schedule, they examine the weather forecast, because the weather is one major factor that affects a flight plan. If weather is bad at certain location that may affect the airplane, flight dispatchers have to decide how to confront it. They may decide to bypass the location or use different safety measures. Flight Management System (FMS) provides possible routes to a given destination. The dispatchers are responsible for choosing the optimal route. Optimized route can be interpreted in many ways. In this case, optimized means the best way for considering the capabilities of an assigned aircraft, including fuel consumption, the expected weight, total travel distance, aircraft condition, and mechanical issues. Even if there is a perfect route for the assigned aircraft, dispatchers may not be able to use the route due to other limitations. If dispatchers successfully decide on a route, then they look for an alternative airport for landing. Due to unexpected conditions, it is possible that an aircraft would not land at the expected destination. Thus, they look for nearby airports as alternatives. Given that each airport has its own requirements for landings, dispatchers verify whether the assigned aircraft meets the requirements of possible alternative airports. They can choose among ones that meet the requirements or they may try the airplane to satisfy the requirements. For example, an airport may have a specific weight requirement. If an aircraft has no other choice and must land at that airport, but its total weight exceeds the requirement, the dispatcher may plan to dump fuel to meet the required weight. After determining an alternative, a flight plan is initially complete.

The second operation is reviewing the plan with a pilot. Before the scheduled departure, the dispatcher briefs the pilot on the flight plan. Since dispatchers and pilots share operational responsibility on an assigned flight, they must review the plan
together and agree on it. During this operation, the pilot may have questions about the flight plan or wish to alter, for example, the determined route. At this point, a flight dispatcher must navigate a process of negotiation with pilots. Depending on the conditions, a dispatcher may modify the plan as the pilot suggests. If the plan cannot be modified, the dispatcher explains why and works toward a compromise. After this negotiation process, the pilot signs the final plan and prepares for the departure; the dispatcher begins monitoring the flight.

From the interview, a flight dispatcher identified that the dispatcher’s task is usually to dispatch around 10 to 15 aircraft at a time. Thus, they usually monitor multiple flights simultaneously. For the purposes of this analysis, the HTA diagram focused on monitoring a single flight activity in order to clearly list out discrete tasks. In reality, the tasks for each flight are same, but the given time for each flight is relatively short. Also, since all assigned airplanes may not depart at same time, it is likely that each flight is in different stages of operation. As long as circumstances do not change and the flight proceeds as expected, dispatchers do not have any special tasks for this operation. However, they may have to adjust the flight plan after takeoff. When they have to act, it is based on the information from the airplane or other sources. Two common information sources are weather forecasts and airport conditions. Aircraft are equipped with weather monitoring devices, but they have a limited detectable range. If a dispatcher detects sudden changes in weather that will affect a route, they notify the pilot regarding the change in conditions. After informing the pilot, the dispatcher drafts a new plan. This plan may have different route or destination, depend on the specifications of the airplane. If the airplane can make it to the destination via another route, the dispatcher will change to an alternative route that avoids the inclement weather. If the aircraft does not have enough fuel to reach the destination using other routes, the dispatcher must find a location within the vicinity to re-fuel. If the destination cannot take the airplane, the dispatcher determines an alternative airport or prepares a new destination. As briefly stated before, the airplane has limited access to such information. If there
is an irregular situation on the airplane, the pilot may notify the dispatcher. For example, there may be a very sick passenger on board. The dispatcher calls a doctor and connects a phone line to the pilot. If that patient needs urgent medical care, the dispatcher looks for hospitals that are eligible to care for the patient and finds a nearby airport for landing. After modifying the flight plan, the dispatcher provides the new plan to the pilot so that the situation can be resolved quickly and safely. The dispatcher is responsible for contacting all related parties in response to such a contingency plan and connecting them with the pilot. This monitoring operation continues until the airplane lands at its destination.

The final operation is reviewing the flight. After the airplane safely lands, the dispatcher’s responsibility officially concludes. The dispatcher reviews the whole operation and makes a report if necessary. The purpose of the review is for future reference. If the dispatcher dispatches the same airplane on its next flight, the review may not be necessary. Such a report is often a courtesy to the dispatcher who will be responsible for the plane’s next schedule. It is possible that unexpected situations may occur during the flight. These situations can include a change in weather, airport conditions, mechanical issues, or any discrepancies with the pilot.
4.3 Development & Evaluation

4.3.1 Prototype

Figure 4.5.: Prototype: an active flight in a normal operation

Figure 4.6.: Prototype: an active flight in an abnormal status
Figure 4.7.: Prototype: a cause of the abnormal status and indication of cockpit video availability

Figure 4.8.: Prototype: a cause of the abnormal status and indication of cockpit video availability
The five listed figures (Fig. 4.5. to 4.9.) are screenshots of the resulting prototype. The figure 4.5. shows the untouched benchmarked software. The interface shows an aircraft that is approaching O’Hare International Airport. It mainly features visual information regarding the location of aircraft, their routes, and weather. It also provides other information that dispatchers utilize to perform tasks.

The Fig. 4.6. is technically the same screenshot as the Fig. 4.5., but the color of the aircraft is different. This is an indication of the aircraft’s changed status. Red was applied to the icon to denote its abnormal status considering that the figure is originally colored in blue and an expected user is not color-blind.

The Fig. 4.7. and 4.8. shows detailed information regarding status change. The box appears when a user clicks the aircraft figure. In the box, causes of status change and cockpit video availability are listed. The Fig. 4.7. appears when the video is available and the Fig 4.8. is generated when the video is unavailable. If the video is available, users are able to click the word “Available” to open the video. The Fig.
4.9. is an example of cockpit video. For prototyping purposes only, a flight simulation video substituted the actual one in order to represent the feature in concept.

4.3.2 Evaluation

CW pointed out three issues with the prototype. Two issues were directly related to expected usages of the prototype and another issue was related to flight regulation that may limit the usability. The expected action sequences contained seven steps to address the sample task using interface functions. Besides these three issues, the remaining elements of the sequences were well-fitted to actual sequences. The expected action sequences that were evaluated are listed below. After the CW, the evaluator provided general feedback regarding the prototype. The Table 4.1 shows comparison between the expected action sequences and the actual action sequences.

Table 4.1
The comparison between the expected action sequences and the actual action sequences

<table>
<thead>
<tr>
<th>Sequence Order</th>
<th>Expected Action</th>
<th>Actual Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Click the airplane figure.</td>
<td>Click the airplane figure.</td>
</tr>
<tr>
<td>2</td>
<td>Check what caused the status change.</td>
<td>Check what caused the status change.</td>
</tr>
<tr>
<td>3</td>
<td>Check the cockpit dashboard view availability.</td>
<td>Check the cockpit dashboard view availability.</td>
</tr>
<tr>
<td>4</td>
<td>If the video is available, watch the video.</td>
<td>If the video is available, watch the video.</td>
</tr>
<tr>
<td>5</td>
<td>Identify the problem.</td>
<td>Identify the problem.</td>
</tr>
<tr>
<td>6</td>
<td>Notify the problem to the pilot.</td>
<td>Check other sources (a flight plan, ACRAS, ATC, etc.).</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Notify the problem to the pilot.</td>
</tr>
</tbody>
</table>

Unlike the initial expectation, the evaluator did not have an experience of the benchmarked software. However, he knew the software and its functions. There are multiple companies in the market developing the software for flight dispatchers, its airline’s decision to pick one. Thus details of the software may slightly different, but their main purpose and function is same as stated in the FAA regulation.
After explaining the sample task and showing the prototype, set of questions started with eligibility of the prototype. The evaluator’s response was positive. To flight dispatchers, it is important to look at all possible sources to help the pilots and make sure they land safely, because pilots and dispatchers are sharing same operational responsibility. For accidents and incidents, FAA investigates how to prevent them in future. To dispatchers, the prototype is new form of sources and every possible source is important and helpful to both pilots and dispatchers for safer flights.

After the first question, four questions that have to be addressed from the CW were asked. For the question, “Will the user associate the correct or intended action with the desired effect?”, the evaluator’s response included both negative and positive aspects. He agreed with the expected action sequences, but before contacting pilots due to the abnormal status, dispatchers may want to check other sources to make sure that is the case. The additional action is described in the Table 4.1. During the approach, pilots would be very busy and they might not even want to talk with dispatchers. So the information that the dispatchers received must be correct. Also, since the ground has more sources and time, the dispatchers may have better chance to find out what is going on. Thus there would be an additional step between steps 5 and 6. The fifth step is identifying the problem after watching a live cockpit video and the sixth step is notifying the pilot about the identified issue and communicating with the pilot to resolve the issue. After determining the issue, a flight dispatcher may want to check the credibility of the information before taking any further actions. In this case, a flight dispatcher may contact ATC and also check Aircraft Communications Addressing and Reporting System (ACARS) to verify the given information is correct. This is not only due to the credibility of the information provided by the interface, but also due to clarification of different information. Flight dispatchers deal with a number of different flights related systems. Sometimes these systems provide slightly different information.

The next question was “Will the user associate the correct or intended action with the desired effect?” The evaluator responded positively. The dispatchers have
manuals and procedures on their tasks to follow. Thus if the expected action sequence is given to them as a list of steps to perform on this situation, they would follow it. For the last question that should be addressed during the CW, the evaluator agreed that the dispatchers would be able to see that progress is being made when the correct or expected action is performed. Even if they were not able to see the progress, they would take actions to fix it and resolve the situation.

In addition to those questions, there were four more questions to identify issues with the prototype and how the dispatchers would overcome the issues. The first question was finding issues with the prototype. Unlike the given cockpit view, some portion of dashboard would be covered by pilots so that the dispatchers might not able to clearly read all the parameters. Three other questions asked how the dispatchers would overcome the issues with the prototype if the prototype were implemented. In case of blockages due to pilots in the cockpit video, flight dispatchers were expected to check most recent updates from ACARS to understand the situation as much as possible. Also, instead of directly talk to pilots; the dispatchers would contact ATC first. Lastly, if the prototype keep shows that the airplane is in abnormal status after respond to it properly, the dispatchers would repeat the process from checking other sources.

4.3.3 Other Identified Issues

The multiple flight following systems for flight operations make time to react against situations. During the CW analysis, the evaluator pointed out an inevitable circumstance that they had to check multiple sources before making an action against situations. Since the systems operating by the dispatchers were developed for different purposes and by different group of people. One system might not have certain information that the other system did not. For example, even though the prototype indicated a flight is in abnormal status due to a low altitude, that altitude might be a part of the flight plan that only known by a flight management system. Regardless of
information reliability on each system, different information given by different system
oblige the dispatchers to check multiple sources to correctly understand situations.

Restriction to utilize the enhanced display to current flight operation was identified. FAA regulation, Sterile Cockpit, restricted any communications or interventions to pilots during critical phases (14CFR121.542, 2014). Critical phases are where an aircraft is located below 10,000 feet. Generally, taking off and landing phases corresponded to them. Regulation stated the altitude to 10,000 feet, but airlines set their own standards higher than that. For example, an airline company that the evaluator was employed had its standard on 18,000 feet. Thus, flight dispatchers could not interact with pilots regarding the abnormal conditions of aircraft if the flight is in critical condition.
5. DISCUSSIONS

This section discusses current obstacles and limitations of the study, which are categorized into 5 sections. First, assumptions on abnormal situation alert applied in this study are discussed. Along with the bandwidth restrictions, the technical issues section covered importance of upcoming technologies that is necessary for the enhancement and the discussions of stand-alone flight following systems of flight dispatchers. The operational issue section discusses workload of current flight dispatchers. The last section discusses other issues related to usability and eligibility of the enhanced display.

5.1 Assumptions on Abnormal Situation Alerts

We used three assumptions to apply abnormal situation alert in this study. First the study consequently focused on reducing false alarms by not applying preparatory alerts on the enhancement. The main reasons for not considering preparatory alerts were to avoid alert flooding and fatigue. The study focuses on delivering accurate information to flight dispatcher so that both flight dispatchers are not involved in unnecessary interactions and interventions with pilots. Also, as shown in the results of the display evaluation, flight dispatchers will only use verified information before contacting pilots.

In addition, this study did not consider the out of loop problem discussed in the background. In real situation, the out of loop problem can occur due to monitoring multiple aircraft simultaneously. The study only considers a flight dispatcher dispatching one aircraft. Thus, the monitoring task is expected to focus on a surveillance of flight activity. So the out of loop problem is unlikely to occur.
Lastly, in addition to the assumptions stated above, the study assumed that abnormal situation alerts from the enhancement are accurate and the alert system is in a normal operation condition. This study intends to focus on the capability of flight dispatchers whether they can perform as the “third pilots” in an abnormal situation similar to the Asiana Airline Flight 214, provided they had access to the information that may help to manage the situation. Thus, system failure and simultaneous alerts from one or multiple aircraft were not considered. In addition, as the evaluator mentioned, if the system appears to have malfunctioned, flight dispatchers would utilize other sources to manage the abnormal situation.

5.2 Technical Issues

This study assumed that an aircraft is equipped with devices to record and transmit the cockpit view. However, depending on aircraft type, installing cockpit camera may not be feasible in some cases. Even though it is identified that flight dispatchers would look at the information from ACARS, an alternative method that could enable flight dispatchers to have the cockpit view needs to be considered.

Human error can occur in the cockpits, which may cause tragic accidents like the Asiana Flight 214. If the enhanced flight dispatcher display can aid in correcting the error through dispatcher intervention, advances in flight operation systems for safer flights are highly likely. Just for the enhanced display, upcoming technologies will play major roles. Even though we have plans to implement NextGen projects, we do not know when it will be in actual use for all commercial aircraft. Moreover, applying such technologies to build enhanced display will take a long time.

The multiple systems for flight operations delay reaction time. During the CW analysis, the evaluator pointed out an inevitable step during investigation of situations that they had to check multiple sources before making an action for flight activity investigations. Since the systems operated by the dispatchers were developed for different purposes and provide unique information of flights. For example,
even though the prototype indicated a flight is in abnormal status due to a low altitude, that altitude might be a part of the flight plan that only known by a flight management system. Regardless of information reliability of each system, different information given by different system oblige the dispatchers to check multiple sources to correctly understand situations.

5.3 Operational Issues

The HTA diagrams were hypothesized with a condition that the dispatchers are dispatching a single flight. In reality (from the results of interviews), they usually dispatch about 10 to 15 flights at the same time and those flights are not expected to be in same operation phase, location, and direction. In the most optimal situation where all other dispatching flights are in normal operation and are located in same operation phase and region heading to the same direction, the dispatchers may handle abnormal status of one flight. With unknown workload caused by various situations from assigned flights, usability of the enhanced display cannot be simulated.

5.4 Usability and Eligibility Issues

The mismanagement of Asiana Airline Flight 214 happened below 10,000 feet. Because of the regulation, even if a person found out errors, the person cannot notify it to pilots. Thus the Sterile Cockpit regulation must be reviewed to measure its the effectiveness.

One identified usability issue from the display prototype evaluation is the blockage of information. Comparing the evaluated cockpit video to the actual cockpit view, some parts of the dashboard were blocked as shown in the Figure 5.1. In this figure, blocked parameters by both pilot and co-pilot included a main panel (warning indicators, control mode indicator, primary flight display, navigational display, etc.), handle bar, etc. in the Figure 5.2, which may affect investigations from flight dispatchers.
Figure 5.1.: An Example of information blockage by pilots

Figure 5.2.: An Example of Possible Blocked Information
Even with HTA and CW, this study does not include human factors aspects specifically on interface development process, because the focus of study sets on assessing whether flight dispatcher can operate enhanced function. Also, the prototype is not built in operable quality. Thus, the human factors aspects are not primary concern. However, CW is expected to identify about 40% of usability issues. Considering the evaluated display is in early stage of development, more problems with the interface will appear as the development continues. Thus other forms of evaluation must be considered.
6. CONCLUSIONS

The three approaches used in this study looked into enhancing flight dispatchers to be “third pilots”. Within the scope of this work, we found evidence that flight dispatchers are capable to operate an enhanced display that can detect abnormal activities of active flights and investigate the causes. First, we designed a function to show flight status and cockpit video to flight dispatchers. Both benchmark-able and upcoming technologies were integrated to support this function. Second, a task analysis was conducted on flight dispatchers to identify their capability to adopt the enhancement. Hierarchical task analysis was conducted and the analysis discovered that a large portion of dispatchers have piloting skills, which gave them ability to check parameters on cockpit dashboard. The enhancement could be applied during monitoring tasks (as the dispatchers have lower workload compared to other tasks) when a flight dispatcher is only dispatching a single flight and already operating a monitoring display, where the enhancement could be adopted as an add-on to the current display. Finally, in order to evaluate the enhancement function and the methods resulting from the assessments, we developed a display prototype. The display prototype was based on a current flight dispatcher display for the monitoring task and the analyzed enhancement was implemented. After the development process, the prototype was evaluated by CW technique and results showed that the targeted users could use the prototype to perform the desired task.

6.1 Future Work

The next step after this study would be application of the enhancement to the real operations. The dispatchers would not have major issues on operating the enhanced display, even though the provided cockpit video have the identified visibility issue
due to blockage. However, it may be too hasty to make such a conclusion; certain contingencies must first be handled before taking the next step. Following subsections contain some of the possible approaches that can be used to solve problems we identified in this study.

6.1.1 Data Restrictions

If we want to send both flight data and cockpit videos to the ground stations, a large amount of data has to be wirelessly transmitted through long distances. Even if the transmission is possible, it is expected to cause delays. In addition to that, data restriction is another major issue on the data downlink of Unmanned Aircraft System (UAS), because the data downlink is also used for other purposes such as an anti-jamming for data transmissions. One way to overcome this problem is compression or truncation of data. The data compression process involves converting the data into more efficient format and reconstructs the data after receiving it. This process aims to not lose any data while compression, transmission, and reconstruction, but imperfections or approximation during reconstruction cause a small loss of information. Data truncation can reduce the size of the data even more than compression by discarding some of the data. For example, truncation can remove every other frame so that the video becomes 15 frames per second, which only has half of the total frames compared to the original video with 30 frames per second. It seems losing half of the frames will have a significant impact on the video itself, but it may not be perceptible to operators, because 15 frames per second can also provide sufficient information. Removing borders between frames can truncate data further. This process is able to reduce size of the data to a quarter of its original size. However, this technique makes the images blur, which may cause some information loss that may affect the video itself.

Considering bandwidth restrictions on radio frequencies and required data rate for transmitting information from UAVs, system designers can choose two ways to
establish a system. The first method is building a system and then degrading it to fit in the radio frequencies. The second method is designing a system that reflects constraints. Both methods have pros and cons. The first method is not difficult, but will have limitations later in the system lifecycle. On the other hand, the second method requires a more carefully designed system and it may have more flexibility in performing various operations.

6.1.2 Reproduction of Cockpit Dashboard

As a follow up step to the CW, identified issues have to be addressed before the next step. Reproduction of cockpit dashboard may troubleshoot three issues at once: blockage of cockpit dashboard (due to the physical presence of the pilots in between the camera and the dashboard), bandwidth restrictions, and cockpit video feasibility on all aircraft. Although it may not fully describe situations in the cockpits, with a digitally reproduced cockpit dashboard, flight dispatchers could check blocked information by pilots, which will help them understand the situation. Also, sending digital information from the aircraft to the ground stations consumes less data bandwidth than sending cockpit video. Moreover, aircraft without video recording capabilities could send cockpit information to the ground. However, digitally reproduced information also has its downsides. In the cockpits, pilots make digital and analog inputs. Transmitting digital inputs can be done easily with identified flight data acquisition units from the technical assessment, but analog inputs are difficult to measure accurately, because of the possible deviation between intended physical input and perceived input value by sensors. Also, flight data acquisition units are not mandatory to have in an aircraft. Thus, all aircraft must be installed with those devices to digitally reproduce the cockpit dashboard.
6.1.3 Measuring Current Workload of Flight Dispatchers

This study is suggesting adding an additional task to the current workload of flight dispatchers. However, there is a gap between dispatching a single aircraft and 10 to 15 aircraft at the same time. To fill this gap, we may begin with measuring current workload based on the HTA diagram by applying different task analysis methods such as the Goals, Operators, Methods, and Selection Rules (GOMS) or the Methods-Time Measurement (MTM). With decomposition of tasks into actions, we could construct detailed action sequences for each task and simulate the required time and world for dispatching one aircraft. From this model, it is possible to build more complicated models with various assumptions by re-describing current situations. This will allow simulating from normal operations to emergency situations. The models would represent current tasks and workload of flight dispatchers, which could be utilized for assessing an eligibility of the enhancement to current flight operations.

6.1.4 Reviewing the Sterile Cockpit Regulation

The intention of the Sterile Cockpit is providing a condition that pilots can focus on safely taking off and landing flights. However, from the case of the Asiana Airline Flight 214, we experienced pilots did not fully take an advantage of the given condition to focus on safety. Also, It is possible that someone outside the cockpits may know problem of the flights, but unable to help pilots effectively due to the regulation. Moreover, limiting an authority of flight dispatchers in a certain phases of flight operations are logically contradictory to their responsibility. Thus, the regulation may require to be reviewed for its purpose and effectiveness.

6.1.5 Applicability of the Enhancement to Other Types of Accidents

The results of this study are focused on the case of Asiana Airline Flight 214, because the sample task conducted for the evaluation reflected it. Since this study
did not look into its effectiveness on other cases, we could conduct future studies that can provide applicability of the enhancement on other types of commercial aircraft accidents.

6.1.6 Application of other usability evaluation methods

As we continue to refine this further, we expect the interface to change. Unlike the direction taken in the current study, future developments may focus on actually developing a usable display by considering human factors aspects. One method under consideration is conducting heuristic evaluation to identify more usability issues from the interface and perform usability tests on refined display to accurately assess its usability.
LIST OF REFERENCES
LIST OF REFERENCES


14CFR121.127. (2012). Flight following system; requirements. Federal Aviation Administration.


APPENDICES
APPENDIX A
TRANSRIPTION: INTERVIEW

• A: Interviewer
• B: Interviewee

A: Can you briefly describe what flight dispatchers do? B: Flight dispatcher is primarily 50% responsible for the flight as well as the pilots. 50% is the flight dispatchers responsibility, if anything happens. Any incident, any accident, or any discrepancy on the flight, dispatcher is also responsible for those events. Whatever happens. So basically a pilot in cockpit does not have enough resources. So dispatchers are resources for the pilots. Like anything goes on the destination, dispatcher is the first person to know what to get and how to mange his flights. Usually a dispatcher has more than one flight. And they try to separate jobs based on type of aircraft. Unfortunately when they could not, because sometimes they changed to type of aircraft, and it is hard to move one dispatcher to another.

So it is not that easy. It is better them to do in area, like New York (the east cost) to the west coast, or to Chicago something like that. They standardize the system. And a dispatcher checks any alerts, weather, airport conditions, and then decide flight before pilot gets information. Dispatchers gain information 7/24, but pilots usually show up 1 hour before departure and get paper works and go or not to go. Of course people can miss something, but generally a dispatcher is responsible 24 hour window. Make sure everything going on time. Like September 11, united was the fastest on putting all aircraft on the ground. Why? Communication. Aircraft are always on where is that?, we are going to re-route this, weather is approaching, we are going to change your route, we are going to change your destination, we are going to change your alternative, and of course everyone knows fuel on board and
even dispatchers get time limitation information, and decide what do to and how to manage safely landing airplane including flight plans.

Flight plans have lots of works behind, like somebody is managing database, someone like IT people. Right before I left United, we were doing some MEL atomization. We were putting all the MER in the system. It automatically kicks in if mechanics differ MEL items. Do you know MER? MEL is the minimum equipment list. Which means we can play an airplane from A to B with some defect items like broken items or parts. If you have two flight management computers and if one is not working, maybe you can fly A to B or like other parts are not working, you may fly below 25000 feet. If there is a restriction in the flight, the system automatically kicks into the flight plan. For example, if a dispatcher plans to higher altitude, the system will tell him you cannot do that and automatically lower the altitude. Some restrictions increase required fuel, and some restrictions are no go. So that is why if you are sending airplanes to the overseas like Europe, and there are more restrictions. So may be you can send a airplane to New York, but not to London. So a dispatcher should know all of these things as well. So basically dispatchers are a bridge between pilots, mechanics, maintenances, and customers, because they try to save (safely manage) trips. But sometimes, you have no choice, then they try to accommodate. Putting passengers in different flight. In flight operation, not only dispatchers, everybody works as a team like crew schedules, aircraft schedules. Everybody work as a group of people so they communicate each other. Pretty much this is job of dispatchers.

Responsible for the flight, make sure everything is flyable from A to B safely. It is more restricted here than Europe or other countries, but Europe has a JAA operation, which is switching to same way as US. In US, this is ongoing for 10th of years. So that is why it is easy to manage and pilots listen to you, and pretty much most dispatchers have pilot licenses, but the license is not required. It is mostly for understanding protocols and procedures. In real life, pretty much you will do flight plans, fuel, make sure you have enough fuel, not less to flight from A to B safely. So make you have an alternative or not, sometimes in US, flight ay not have an
alternative. This is why dispatcher position is the most sensitive at that point. That is why people are be cautious and be careful on what they are doing. This is overall what they do. Other than that do you have any other questions?

A: How many aircraft a flight dispatcher dispatch a day? B: Usually 10 to 15 airplanes.

A: Is these 10 to 15 airplanes depends on airlines or other features? B: It depends on many things. There are differences among airlines, but there is no rule about it. When I worked for an airline company A, there were two dispatchers a day and we dispatched 60 to 80 flights a day. The time allowed for us between landing and taking off was 10 minutes for each flight. There were 20 airplanes in the company. It was about how to utilize and optimize the system. It can be also depends on the flight times for each aircraft. A dispatcher dispatching international flights that takes about 10 hours may dispatch 4 to 5 flights, but for short distance domestic flights it can be up to 20 flights at once.

A: Is a dispatcher may dispatch both domestic and international flights at the same time? B: Not necessarily, airlines assign international flights to some portion of dispatchers and domestic to the other portion of dispatchers. Also it depends on the area and depends on other conditions. Airlines try to optimize workload of each dispatcher. So there are no specific criteria how to distribute flights to dispatchers on duty. Average is 10 to 15 flights, but numbers are very changeable. It depends on workload and airlines have teams working on this matter.

A: Can you please explain me in detail about A to Z that dispatchers do for a flight from A to B? B: Before a flight plan, dispatchers check the weather. There are multiple routes to get to the destination. Dispatchers suppose to choose an optimized route, but based on the weathers. Then dispatchers choose alternatives. If the alternatives have requirements, make sure to meet the requirements such as engines depends on ETOPS.

A: What is ETOPS? B: ETOPS is the extended twin-engine operations. Pretty much every airlines are switching to twin-engine aircraft and ETOPS is set of re-
quirements. You need to find an alternative in a certain time. There are different requirements based on engine shut down time on the flight. If your airline has less shut down time, it means you get an extended time all the way up to 180 minutes, which you need to find an alternative in every 3 hours to make sure wherever you are, each of your alternatives is 3 hours away from you. When you done with choosing alternatives for destination and enrollee alternative as well, if it is required, check the weathers and check the airport conditions and put the flight plan into the system. Pilots see the flight plan and call you if they need anything. For example, pilot asks for more fuel, and you need to explain reasons. Discussions will keep go on and they will decide what to do. If pilot is not comfortable with an alternative, find different one if possible and reasonable, and dispatcher decide whether to change an alternative or not. It is basically negotiating with pilots about your flight plan. Flight plan will be printed out for the airplane because of the ACARS system.

A: What is ACARS system? B: ACARS is a communication system in an airplane. You can print, communicate, text. It is like a cellphone. You can do anything with it. ACARS is a good communication device for airplanes. Pilots communicate a lot back and forth on the flight. Then utilize the flight and pilots get released. During the flight if weather changes, you update the information to the pilots. If there is any deviation, changing route, destination, etc. You check the available fuel and if they still can make it, keep going. If not, make a intermediate stop and go. So it is all going to be communications between pilots and dispatchers. Only thing dispatcher not going to do is flying airplanes. Pretty much everything other than that will be done by both pilots and dispatchers. This is how it works and pretty much everything for an airplane is prepared by dispatchers, and pilots fly the airplane according to the flight plan.

A: Is duty of dispatcher on an aircraft done after landing of the aircraft at the destination? B: Yes, but you will have another aircraft. Also after landing, pilots may report any discrepancy and dispatcher on duty will inform other dispatchers
about the problem. That is a communication. Everything is pretty much about the communication.

A: *Is a distance between pilots and dispatchers matter for ACARS?* B: No, you can communicate at anywhere. There are some blind spots on flight, but those spots are covered by high frequency radios, which have longer range than ACARS. ACARS needs stations, but radios do not need them. If we lose connection by ACARS, we basically switch over to radio communication. Usually aircraft have devices for both communication methods. ACARS is eyes and ears to dispatchers. In certain times and certain coordinates, ACARS send messages to the ground and dispatchers. Dispatchers are monitoring a system and the messages updates the system. Based on this, dispatchers know how other factors such as tail wind are affecting the flight time. If the wind in a certain area affect the flight significantly, you make sure to put more fuel on the next flight that will pass the area.

A: *So ACARS is not only a system to communication, but also sending flight information to the ground.* B: Yes, it automatically sends information like time, location, and fuel on board. This information will be sent to the ground without a pilot access.

A: *Is majority of dispatchers tasks are concentrated on flight plan?* B: Yes, they are planning the flights. They are the planners.

A: *After departures of aircraft, is monitoring the aircraft a main task of dispatchers?* B: Yes, you can see any deviations. There are some weather changes that pilots cannot see from their radars. Dispatchers also have a similar system, but it shows all the weathers. So dispatchers can decide whether to move around the weather or land depending on the fuel. So basically you are the most up to date information to pilots to fly airplanes safely. If the airplane have to land due to weathers. Airplane will get new flight plan and fuel accordingly. This is possible, because pilots cannot see so far, but dispatchers can see the whole picture.

A: *If something happens on aircraft after departure, what kind of things dispatchers do?* B: If a pilot does not have a time, A pilot is primary responsible for the situation.
If a pilot has a time, pilot will notify dispatcher and dispatcher call ATC to declare emergency and make sure everything is covered for the airplane to land safely. If the airplane needs to land at somewhere else, dispatcher manages the plan to make sure to have enough fuel and required weight. Sometimes airplanes need to dump some fuels to meet the required weight to be landed. Due to the emergency situation pilots are hard to think about possible ways. So dispatchers need to notify, in a timely manner, pilots to make sure they do not miss any information and choices. But usually below 18000 feet, it is still in cockpit and dispatchers not to communicate with pilots to not interrupt the flight. Still cockpit is very important. If pilot needs something from you, they will notify you and you will take care it such as communicating with ATC, emergency teams in airline company. We have one-touch system that can notify everyone about emergencies.

A: *How about situations that is not categorized as an emergency?* B: For example, if there is a sick passenger, dispatchers job is where the hospital is if necessary or patch communication between doctors and airplane. If the patient need immediate medical cares, dispatcher system knows equipment that hospitals have. There are always some situations. For example, if there is an engine shutdown, we notify ATC and other departments about it. Then we see whether the airplane can safely land considering fuel and weight. If the airplane has enough time, we may ask pilots to circle around. If not we need to check landing gear with engineers whether the aircraft can land. Also we check which runway we can land the aircraft. This kind of situations is not something unusual to dispatchers. It happens daily basis. For emergency situations, there are not much things that dispatchers can do because pilots are responsible for it. If they need anything you can help him, and dispatchers are prepared for most situations. If not, they will be trained. Sometimes pilots do not know what they have to do for situations. So if they need a help we are the people who can help.

A: *Does a flight plan include procedures for emergency situations?* B: No, we plan everything as a normal operation. If things change, yes. If we need to step in we will step in. If we do not have to, we stay away. We do not tell the pilots to do something,
because of still in cockpit. They do whatever they want to do, but if they need help, we help them.
APPENDIX B

COGNITIVE WALKTHROUGH SAMPLE TASK

This research is motivated by aircraft accidents that are caused by human errors from pilots. Reducing human errors can affect ensuring flight safety. As one way to approach to this issue. I am looking for a way to catch the human errors. As a result I designed a interface for flight dispatchers with a special function.

Thus, the purpose of this study is to identify

1. Whether flight dispatchers can use the function to perform the given task while on the current duties.

2. Evaluate the interface prototype to assess whether intended users may use the functions as planned.

3. Find the problems of the interface prototype to further development.

The prototype is based on WSI Fusion. It is a low-fidelity prototype. In addition to functions and features of WSI Fusion, this prototype highlights aircraft that shows abnormal activity in real time. Abnormal activity means that one or more status of aircraft is not in the status that it suppose to and without any prior reports and notifications. For example, flying in significantly lower altitude and deviation from the determined route is falls into the category of the abnormal activity. In addition to highlighting the abnormal activities, it also provides a cockpit video of an aircraft that are in abnormal activity(we are assuming that aircraft have capabilities and devices to transmit the video). Due to conditions of connection between an aircraft and the ground, the video may or may not available. through the video flight dispatcher can see the cockpit dashboard. With these information, flight dispatchers may notify a pilot for the abnormal activity.
You are only dispatching and monitoring an airplane that are heading to Chicago/OHare International Airport. Suddenly, the interface shows that the aircraft is in the abnormal status. You are trying to find the reason and it turns out that the airplane is flying in very low altitude, but there was any reports about it. You checked whether you can look at the cockpit and the video was available. You saw the video and it looks like pilot and co-pilot is acting normal, but the cockpit dashboard indicates that the airplane is on lower altitude.
APPENDIX C

TRANSCRIPTION: COGNITIVE WALKTHOROUGH

- A: Practitioner
- B: Analyst

A: The first question is do you think this feature and task can be performed by flight dispatchers?

B: Yes they are. It can be performed by the dispatchers. It is important the dispatchers to look every possible sources to help the pilots make sure they land safely because they are sharing same responsibility if anything happens. FAA investigates all accidents and incidents and finds out how they can prevent futures. That is why every possible sources is important to the dispatchers and also to the pilots. So this feature is very helpful.

A: You answered my second question from the first question. My third question is if your answer to the first question was no, I wanted to know why. Will the user be trying to achieve the right effect?

B: Yes.

A: Will the user notice that the correct or intended action is available?

B: They will check everything and contact ATC. It is like a nature. They may or they may not because nobody declared emergency. Maybe system does not show the altitude property also. It is possible. Because your are getting multiple different sources. They can compare and make sure the altitude is correct. For example, Chicago airport is a very busy place. It is hard to communicate with pilots and ATCs. They are very busy. they may not want to talk to you. I can say partially yes to the question because the dispatchers has to check more resources. There are more sources and this is not the only source you have. They have to check it and match
it because the dispatchers have more time and resources than the pilots to find out what is going on.

A: Will the user associate the correct or intended action with the desired effect?

B: Yes. As I said before, they still need to check multiple sources. The dispatchers have emergency checklists. The dispatcher should follow the lists and later manager will ask to make sure the person follow the steps.

A: If the correct or intended action is performed, will the user see that progress is being made?

B: Yes. If there is an unusual situation if it is correct or not, you still need to take some actions. If you see something wrong, you have to fix it.

A: Is there any difficulty, issue, or problem for using this function without considering the eligibility of the function and the task?

B: No. However, you may not be available to see the whole thing because of two pilots how close to the instruments in the video. They may cover partial video, but they still can see here (middle part of the dashboard), not here (very end part of both sides), and may available to see here (parts that are right next to the middle part). I am not sure but it depends on situations, but all the dispatchers are available to read the dashboard and know the functions.

A: If there is an issue/problem, how can those be modified or fixed.

B: Using other sources such as ACARS. ACARS directly provide information to the compute so you can match the information with it. If this can be connected to ACARS it will be more reliable. This is also reliable, but this may not know the flight plan, then it may not know whether the flight is lower than the normal altitude. This is actually more important to the dispatchers and pilots to deviate from the weather events. This is more useful to the dispatchers to give directions to the pilots which way pilots can avoid weathers. It depends on the dispatchers. Some likes to look at this type of system more, some are not. Everybody is different. But I know everyone watch the weather very closely.

A: What will you do if the video is not available?
B: As I said, use other sources. The video is to be helpful for the pilots, but this is more helpful for the weather overlay. Pilots won’t like you to tell them what altitude they suppose to fly. You may talk to pilots, but first you will talk to ATC and see what they say. Most likely, in this case they will be in the final approach which is below 18000. Most of cases we do not bother pilots. They must be a reason for it. If there is an emergency engage, it is a different story. But if not, check the minimum allowable altitude and decide. They all know about this so if you are not below the normal altitude you are good to go, but if you are it is a different story. Or you may not have time to watch it.

A: *What will you do if the interface keeps showing you the airplane is in abnormal status after you think you solve the issue?*

B: As I said, check other sources and check with pilots or ATC.
APPENDIX D
IRB APPROVAL LETTER

PURDUE UNIVERSITY
HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To: STEVEN LANDRY
   GRIS 256
From: JEANIE DICLEMENTI, Chair
       Social Science IRB
Date: 08/13/2015
Committee Action: Exemption Granted
IRB Action Date: 08/13/2015
IRB Protocol #: 1508016332
Study Title: Enhancing a flight dispatcher display

The Institutional Review Board (IRB) has reviewed the above-referenced study application and has determined that it meets the criteria for exemption under 45 CFR 46.101(b)(2).

If you wish to make changes to this study, please refer to our guidance “Minor Changes Not Requiring Review” located on our website at http://irb.purdue.edu/policies.php. For changes requiring IRB review, please submit an Amendment to Approved Study form or Personnel Amendment to Study form, whichever is applicable, located on the forms page of our website www.ero.purdue.edu/forms.php. Please contact our office if you have any questions.

Below is a list of best practices that we request you use when conducting your research. The list contains both general items as well as those specific to the different exemption categories.

General
• To recruit from Purdue University classrooms, the instructor and all others associated with conduct of the course (e.g., teaching assistants) must not be present during announcement of the research opportunity or any recruitment activity. This may be accomplished by announcing, in advance, that class will either start later than usual or end earlier than usual so this activity may occur. It should be emphasized that attendance at the announcement and recruitment are voluntary and the student’s attendance and enrollment decision will not be shared with those administering the course.
• If students earn extra credit towards their course grade through participation in a research project conducted by someone other than the course instructor(s), such as in the example above, the students participation should only be shared with the course instructor(s) at the end of the semester. Additionally, instructors who allow extra credit to be earned through participation in research must also provide an opportunity for students to earn comparable extra credit through a non-research activity requiring an amount of time and effort comparable to the research option.
• When conducting human subjects research at a non-Purdue college/university, investigators are urged to contact that institution’s IRB to determine requirements for conducting research at that institution.
• When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without