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HOW THOROUGHLY DO PROPOSED NEXTGEN MID-TERM OPERATIONAL IMPROVEMENTS ADDRESS EXISTING THREATS?

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The goals of the Federal Aviation Administration's (FAA) Next Generation Air Transportation System (NextGen) include improved safety, increased capacity, increased efficiency, and reduced environmental impact. The FAA has developed 46 mid-term Operational Improvements (OIs) to facilitate initial realization of these benefits in the 2015 – 2018 timeframe. These OIs describe changes in technologies, policies and procedures from current-day air and ground operations designed to mitigate safety, capacity, efficiency, and environmental issues. The main goal of this project was to investigate how thoroughly threats to safety present in today's operations are addressed by the OIs. These threats, without mitigation, could remain threats in the mid-term, potentially compromising the intended NextGen safety benefits. To address this concern, we extracted threats to safety from 200 Aviation Safety Reporting System incident reports filed by tower air traffic controllers over a five-year period. We then evaluated whether these threats are addressed by the mid-term OIs.

The Next Generation Air Transportation System (NextGen) is a modernization effort of the National Airspace System (NAS) to increase efficiency, capacity and safety. The FAA outlined their vision in a set of Operational Improvements (OIs) that describe new capabilities and procedural changes intended to meet future traffic demands, avoid sources of delay, reduce emissions, fuel burn and noise, and improve safety. These OIs are intended to be implemented over the 2015 to 2018 time period, representing the Next-Gen "mid-term" vision for the NAS. Successful implementation of the proposed mid-term OIs is fraught with challenges, ranging from identifying top candidates for improvement to implementing those improvements in a way that successfully addresses the intended problems without introducing new and potentially worse problems (Sheridan, 2006). Early identification of the applicability of proposed improvements to existing problems supports investment decisions by providing criteria for prioritizing OIs based on the specific operational challenges they address.

The primary goal of this paper was to identify to what extent current safety concerns are addressed by planned improvements to the NAS. Despite an excellent safety record in the current-day NAS, some operational practices and actions or inactions by pilots and controllers represent threats to safety. It is unclear whether the proposed mid-term OIs address the range of safety threats present in current operations. These threats, without mitigation, could remain threats in the mid-term, potentially compromising the intended NextGen safety benefits. A set of Aviation Safety Reporting System (ASRS) incident reports submitted by tower air traffic controllers was analyzed to determine how well the NextGen OIs might be expected to mitigate specific safety issues in air traffic control operations. Although reports submitted to the ASRS are voluntary and therefore do not necessarily offer a representative or comprehensive picture of operations, these reports do provide valuable information about many of the types of operational challenges that controllers and pilots face and the circumstances that contribute to those challenges.

Method

This study examined a sample of 200 ASRS incident reports filed by tower air traffic controllers involving air carrier (part 121) operations over a five-year period (between Jan 2005 and June 2010). Tower positions included Ground, Local, Flight Data/Clearance Delivery, Handoff/Assist, and Supervisor/Controller In Charge. The set of analyzed reports was restricted to the 35 Operational Evolution Partnership (OEP) airports, which serve as hubs for airline operations in major metropolitan areas. A team of five human factors researchers (a subset of the authors)

coded the reports based on two sets of criteria described below. Researchers coded different subsets of the reports for each set of coding criteria, such that each report was read by at least two researchers. In addition, 4% of the reports were coded by all five researchers and discussed as a group to ensure consistency across codings.

Coding for Relevant Operational Improvements

For each report, incidents were defined based on operational roles/positions implicated as contributing to the events, thus each report could include several incidents (e.g., a *pilot* landed on an unassigned runway, and the *local controller* was distracted and unaware until alerted by another aircraft in position for departure on that runway [ACN 879171]). For each incident, mid-term OIs were identified that, if implemented appropriately, could have prevented or mitigated the consequences of the incident. It was possible to assign zero, one, or multiple OIs to a given incident. Coding was based on comparisons of incident narratives against OI descriptions provided in the FAA NAS Enterprise Architecture (2009). Coding also included a justification statement for why the OI was relevant or, for the incidents for which no OI was identified, a statement describing the specific unaddressed operational challenge.

Coding for Causal Categories

The Department of Defense (DoD) Human Factors Analysis and Classification System (HFACS) was used to classify the reports according to causal factors (O'Connor, 2008; Wiegmann & Shappell, 1997). Determinations of HFACS code applicability were based on comparisons of incident narratives against HFACS code descriptions (DoD HFACS, 2005). As with the OI coding, it was possible to assign zero, one, or multiple HFACS codes to an incident.

Results

Two hundred twenty five incidents were identified in the 200 ASRS reports. Caution should be used in interpreting the absolute or relative numbers of incidents reported, because the frequency of unreported events is not known. However, the reported incidents sample from a wide range of tower operations and roles (Table 1).

Table 1
Number of Incidents by Position and Phase of Flight

Incident Position	# of Incidents	Phase of Flight	# of Incidents
Ground	17	Descent	24
Local	163	Final approach	42
Supervisor	11	Landing	41
TMC	2	Taxi in	35
TRACON	6	Taxi out	23
Pilot	26	Takeoff	80
		Departure	28
		Go around/Missed approach	15

Note. Multiple phases of flight may be associated with one incident.

Thirty-four of the 35 OEP airports were represented in the incident database. No incidents that met the search criteria were available for DCA via the ASRS online search tool. The median number of analyzed incidents per airport was 5, with a range from 1 to 23.

Two of the 46 mid-term operational improvements were excluded from analysis a priori. These OIs (109303 and 109304) describe enhancements to the Aviation Safety Information Analysis and Sharing (ASIAS) system. ASIAS is an existing mechanism for integrating, analyzing and sharing aviation safety data and information, including ASRS reports. Because every analyzed incident was reported via ASRS, the enhanced ASIAS system described in the OIs would be relevant to every incident and therefore not diagnostic. Of the remaining 44 IOs, 27 were used in incident coding at least once, for a total of 304 instances of relevant OI identification across all incidents. The remaining 17 OIs were not identified as relevant for any incidents. We also identified 68 instances in which no OI was relevant to the incident. A depiction of the relative frequencies of OIs used in the incident coding can be seen in Figure 1.

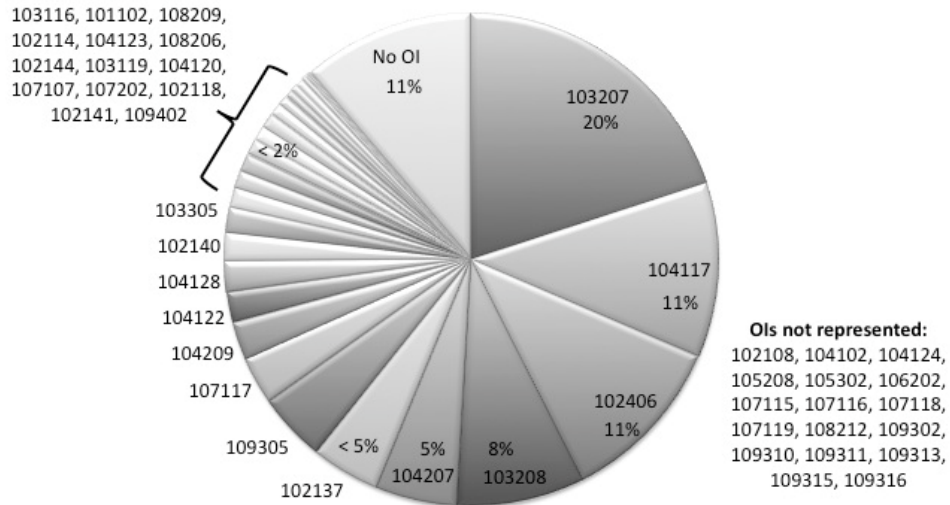


Figure 1. The relative frequencies of OIs identified (and not identified) in incident coding.

Twenty-two of 23 HFACS codes were identified as relevant across the ASRS incidents, for a total of 469 HFACS codings. All incidents were associated with at least one HFACS code, with a range from 1 to 6 HFACS codes per incident (mean = 2.1).

For each incident, we determined which of the previously identified relevant OIs were associated with each identified HFACS code. A given OI might be associated with one or more HFACS codes for that incident. From this analysis, a correlation matrix was constructed based on the OI and HFACS coding to identify codes that tended to co-occur. Statistically significant correlations among pairs of OIs and HFACS codes are shown in Table 2. Due to the increased likelihood of Type I errors in a large correlation matrix, the criterion for statistical significance was set at $p < .001$.

Table 2
 Correlations among OIs and HFACS Codes

OIs/HFACS Codes	χ^2 (1, N=225)	ϕ Coefficient
OI 103207 : OI 103208	24.90	.333
OI 103207 : OI 102406	16.83	.274
OI 103208 : OI 102406	28.09	.353
OI 109305 : Technological Envir.	14.60	.255
OI 109305 : Violation Based on Risk Assessment	48.78	.467
Technical Envir. : Violation Based on Risk Assessment	13.69	.247
OI 103208 : 104207	11.93	.230

Note. All reported correlations were significant at $p < .001$.

Analysis of the relevant OI to HFACS category associations revealed that, overall, 80% of the instances of HFACS coding were associated with relevant OIs. Figure 2 shows the proportion of incidents associated with relevant OIs partitioned by HFACS categories. Further examination revealed a fairly consistent and broad pattern of OI coverage across HFACS categories, with extreme values (i.e., more than 33% of incidents with no relevant OI) only for categories comprising a single observation (i.e., Supervisory Violations and Perceptual Factors). This finding indicates that, overall, the mid-term OIs could help to mitigate or prevent the breadth of incidents explored in this study, however some incidents were identified for almost all HFACS categories that were not addressed by the OIs.

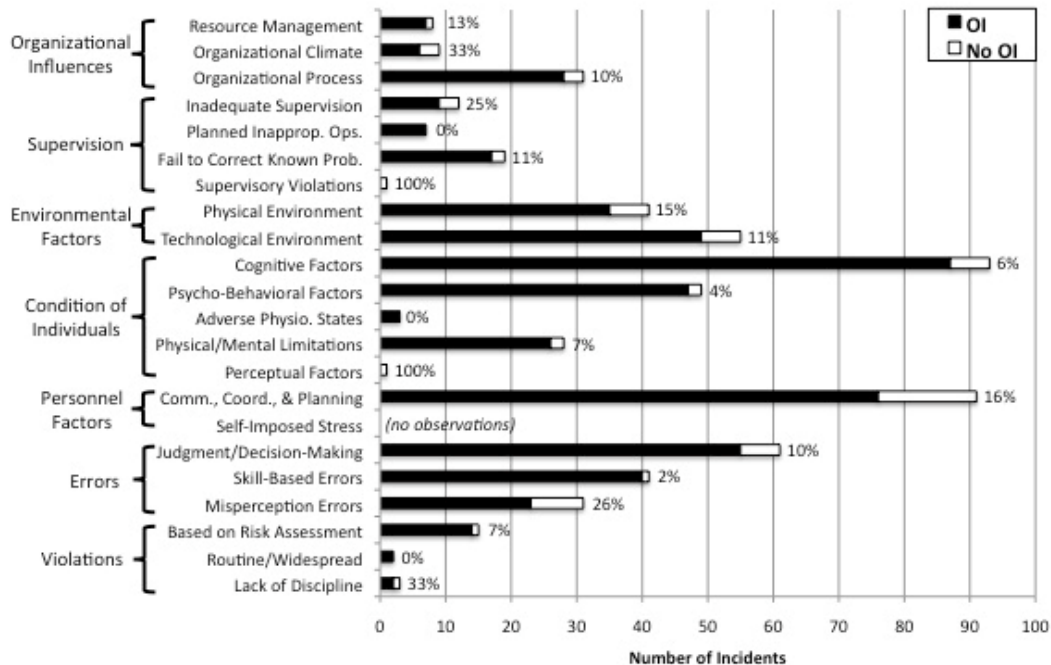


Figure 2. The number of incidents associated with each HFACS category, along with the percentage of incidents that did and did not have associated OIs. Percentages shown in the figure are for incidents without associated OIs.

Discussion

In this report, we considered a set of recent operational incidents from major US commercial airports and identified NextGen mid-term Operational Improvements that could mitigate or prevent those incidents (see Figure 1). Two noteworthy aspects of this analysis were the relatively small number of OIs that comprised the majority of the coded instances (e.g., four OIs account for 50% of codings), and the relatively large number of OIs (17) not represented in the coding at all. The four most represented OIs were 103207 (Improved Runway Safety Situational Awareness for Controllers), 104117 (Improved Management of Arrival/Surface/Departure Flow Operations), 102406 (Provide Full Surface Situation Information), and 103208 (Improved Runway Safety Situational Awareness for Pilots). These OIs are heavily focused on runway operations, providing enhanced alerting for runway incursions and identification of aircraft position on the surface, as well as sequencing and scheduling based on wake and aircraft performance characteristics. The frequent occurrence of these OIs is not surprising given the heavy bias toward incidents involving the local controller position (see Table 1). Similarly, all of these OIs support various levels of situation awareness (SA), from perception (e.g., digital display of the airport environment in 102406) to comprehension (e.g., runway status alerting capabilities in 103207 and 103208) to projection (e.g., support for planning arrival, departure and surface operations in 104117; see Endsley, 1995, for a thorough discussion of levels of SA). Loss of SA is implicated under Cognitive Factors, the most frequently assigned HFACS code in this data set, so it is again reasonable to expect that SA-related OIs would be prominently featured.

Seventeen OIs were not represented at all in the current study. Further analysis indicated that these OIs tend to fall into at least one of three categories: 1) OIs unrelated to tower operations (e.g., 102108, Oceanic In-trail Climb and Descent); 2) OIs unrelated to safety (e.g., 109316, Increased Use of Alternative Aviation Fuels); or 3) OIs targeted to flight deck enhancements (e.g., 107115, Low Visibility/Ceiling Takeoff Operations; recall that the incident reports used in this analysis were filed by tower controllers, not pilots). Future ASRS analyses involving pilot-reported incidents and incidents from other phases of flight (e.g., en route) could address many of the OIs not represented in the current study. However the OIs unrelated to safety would likely remain a blind spot in any analysis of ASRS reports.

The current analyses indicated that, overall, the mid-term OIs address approximately 80% of the HFACS codings. Omitting the two HFACS codes for which there was only a single incident, this value climbs to 88%. However, three HFACS codes showed a substantially lower level of OI relevance (see Figure 2): Organizational Climate, Inadequate Supervision, and Misperception Errors. In the cases of Organizational Climate and Inadequate

Supervision, these types of incidents are somewhat beyond the scope of the OIs, which focus heavily on technological advances and automation to address problems in the NAS. However, these problems are very likely to persist in the NAS, and should be addressed through other FAA initiatives and training procedures. Misperception errors involve limitations in human sensation and perception resulting in misjudging of distances and rates of change, as well as susceptibility to sensory illusions. This class of errors is largely insensitive to mitigation by training or experience, but could be mitigated with appropriate application of automation. Addressing these types of errors is within the scope of NextGen. Future research should focus on identifying specific human research-based requirements for NextGen automation to effectively mitigate misperception errors.

Several statistically significant correlations among OIs and between OIs and HFACS codes were identified (see Table 2). Further examination of these relationships may be useful in understanding the degree and nature of overlap among the OIs, which may have implications for how the OIs should be implemented. The following OIs, 102406 (Provide Full Surface Situation Information), 103207 (Improved Runway Safety Situational Awareness for Controllers) and 103208 (Improve Runway Safety Situational Awareness for Pilots) share the common theme of enhancing surface information and improving SA for controllers and pilots. Implementation of these OIs has the potential of preventing runway incursions or other loss-of-SA incidents that have the potential for catastrophic consequences. Surface display maps should give controllers better information about the exact location of all surface traffic and provide alerts for unauthorized movement, potentially preventing incidents like the following:

When Air Carrier X came to a stop, he was in the Intersection of Runway 10/28 and then turned onto Runway 28 towards the Air Carrier Y jet who had just read back the take off clearance. I forcefully said to Air Carrier X to go straight down the Runway (33L), don't turn on an active Runway 28 at least 3 times (ACN 701804).

Further inspection of these OIs and relevant incidents provides insights about how the OIs might work together to enhance SA for controllers and flight crew. OI 102406 contains the framework of a surveillance system by positioning sensors around the airfield and providing the infrastructure to communicate vehicle data to controller information systems. OIs 103207 and 103208 rely upon the surveillance system to populate specific controller and aircraft displays to further enhance SA. Both of these OIs integrate surface situation information, visually provide the users with a picture of ground traffic position and provide alerts when aircraft are at risk of runway incursions.

OI 109305 (Improved Safety for NextGen Evolution) was positively correlated with the HFACS codes Technological Environment and Violation Based on Risk Assessment. This OI is intended to mitigate safety risks associated with increased automation in NextGen by providing enhanced methods to optimize human-automation interaction, monitoring system safety performance to accelerate the detection of unrecognized safety risks, and providing advanced training concepts which will maintain levels of proficiency for humans to conduct safe operations in place of degraded or failed automation. One major challenge for automation implementation involves procedures for addressing false alerts. In the current operational environment, controllers are instructed to comply with automated alerts regardless of what they visibly perceive. However, several reported instances of false alerts placed controllers in the position of choosing between following procedures (i.e., comply with the automated alert) or executing the "safer" course of action, based on their expertise (e.g., electing not to issue a go-around after an obviously false AMASS alert [ACN 876688]). This illustrates an instance of a Violation Based on Risk Assessment in response to a Technological Environment factor. As automation increases with NextGen implementation, OI 109305 may become increasingly relevant. However, this OI represents a post-implementation means of addressing human-automation interaction issues that might be better addressed through early application of human-automation interaction principles and research in the development of NextGen automation. The methods and concepts that serve as the critical elements of this OI should be applied to automation design across NextGen to decrease the likelihood or severity of human-automation interaction problems in the first place.

OI 103208 (Improve Runway Safety Situational Awareness for Pilots) is intended to improve runway safety operations by providing pilots with improved awareness of their location on the airport surface and by providing runway incursion alerting capabilities. OI 104207 (Enhanced Surface Traffic Operations) proposes that data communication will be the principle means of communication between aircraft and controllers for clearances, amendments, and requests during the mid-term. Anticipated benefits arising from these capabilities include improved efficiency, reduced frequency congestion, and enhanced safety due to avoided readback/hearback errors. Results from the present study indicate a positive correlation between these two OIs, which is not surprising given that a miscommunication or misperception on either the part of the pilot or controller might result in disorientation on the airport surface, leading to a runway incursion, rejected takeoff, cancelled clearance, or worse.

Both of these concepts address how technology might be used to improve safety with respect to airport surface movements. The following narrative illustrates how these two OIs might work together to mitigate these types of errors:

LCL W CTLR was issuing taxiing instructions [to a B757] to turn *away from* RWY 9L and go S, not N on TXWY N. It appeared that the ACFT was not following instructions. I immediately cancelled TKOF CLRNC to [another ACFT on RWY 9L] and advised him to exit the RWY. The AMASS alerted... After review of the voice recordings, the B757 PLT crossed the RWY without ATC AUTH (ACN 750426).

A recent examination of runway incursions found that pilot deviations accounted for 57% of the total number of runway incursions in the United States (Rankin, 2008), while another reported that pilot deviations accounted for 60% of incursions and that ATC operational errors accounted for another 20% during a 4 year period (Young & Jones, 2001), suggesting that roughly 80% of these errors might have been avoided if the technology suggested in these two OIs were available. Data communication would virtually eliminate readback/hearback errors, and if taxi route information were integrated graphically into flight deck moving map displays, this would enable pilots to visualize the taxi instruction and routing constraints, helping to improve pilots' SA. Integrated displays coupled with the ground and flight deck runway incursion alerting capabilities described in these concepts should result in more robust taxi route coordination and location detection by pilots and controllers, reducing the likelihood of runway incursions.

In 68 instances (11% of all cases), incidents were identified for which no relevant OI was assigned. Commonalities among these instances have not been systematically explored, but this task is planned for future investigation. Although OI relevance across the range of incidents addressed in this study was found to be quite high, virtually all HFACS categories included some incidents for which no relevant OI was identified. Systematic exploration within each HFACS category of differences between incidents with and without identified relevant OIs is also planned. These analyses could provide insights into additional possible NextGen improvements.

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