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# ASSESSING THE EFFECTS OF OFF-NOMINAL CONDITIONS ON NEXTGEN AIR TRAFFIC CONTROL OPERATIONS

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The Next Generation Air Transportation System (NextGen) proposes many new tools and capabilities to meet goals of increasing the capacity, safety, and efficiency in the National Airspace System (NAS). This effort aims to assess the potential effects of off-nominal conditions on human performance in the NextGen environment. To complete this assessment, a comprehensive list of off-nominal conditions with potential NextGen consequences was developed. This condition list was then compared against the changes proposed in each NextGen Operational Improvement to determine the potential positive and negative effects on human performance in terms of safety and efficiency. The most frequently cited off-nominal conditions with potential negative effects on human performance included: Incorrect/Missing Information in Data Block/flight plan, Inadvertent Sector Overload, Conflict/Proximity/Other alert activates erroneously, and Runway Closure. These conditions represent key areas that could have crosscutting impact on controller performance and should be utilized to develop requirements for NextGen midterm concepts.

The Federal Aviation Administration (FAA) is conducting a transformation of the National Airspace System. NextGen aims to improve the convenience and dependability of air travel while increasing safety and reducing environmental impact (FAA, 2012). NextGen plans to meet these goals by introducing a variety of new systems and capabilities. The introduction of each new system and capability into the NAS, especially when considering the system-wide impacts of many concurrent development activities, offers the possibility to increase the human contribution to risk in the NAS (Sawyer, Berry, & Blanding, 2011). Research into the effects of these NextGen changes is needed to address the potential for both positive and negative impacts on the safety of the NAS.

When assessing the potential safety impacts associated with changes to the NAS, it is critical to consider the way systems and procedures will interact with the operational conditions under which controllers function (Berry & Sawyer, 2012). Controllers rarely manage traffic under ideal conditions. Therefore safety assessments must consider the various types of conditions under which the system will operate. For example, while a special approach procedure could safely increase capacity under nominal operating conditions, an unanticipated runway closure during those same procedures might increase the safety risk to an unacceptable level. Additionally, the presence of adverse weather conditions coupled with a closed runway might shift the level of risk associated with a special approach procedure to an unacceptable level. Each NextGen OI should consider these types of alternate operating conditions to ensure these NextGen improvements will not lead to unacceptable levels of risk and potential adverse outcomes.

**Off-Nominal Conditions**

Ideal or nominal conditions refer to the baseline conditions or primary mode of operations for a given system. These conditions are considered notional and often represent a best-case scenario under which a system will perform. A condition being described as nominal does not necessarily mean that it is the most common operating condition. Rather the term nominal represents a baseline or notional set of conditions from which comparisons to other sets of conditions may be made. System designers often design the initial phase of a system to operate under these nominal conditions representing only the best-case conditions for the system. It is important for system designers to expand design to incorporate off-

nominal conditions since systems rarely, if ever, operate in a nominal environment. The multitude of NAS systems coupled with environmental conditions and operational needs make it quite quite rare for controllers to operate for extended periods of time in nominal conditions.

As can be seen in Figure 1, any conditions outside of the nominal set of conditions are therefore considered off-nominal conditions. The spectrum of conditions within the off-nominal set is wide ranging from the common, easily manageable conditions (e.g. alternate runway configuration), to the abnormal conditions (e.g. sector exceeds MAP value), to the emergency conditions (e.g. accident on runway) (Burian, 2008). The common off-nominal conditions along with nominal conditions construct what is considered to be normal operations and represent the situations controllers routinely manage without significant adverse effects. Abnormal and emergency conditions are considered non-normal operations and represent situations that occur infrequently, require significant attention, and potentially involve adverse outcomes. The purpose of these categories is to provide a framework for understanding the spectrum of off-nominal conditions, not to draw specific distinctions between whether a condition is considered common or abnormal. Any given condition could potential stretch across all three categories depending on the specific factors and characteristics of a given situation or facility.
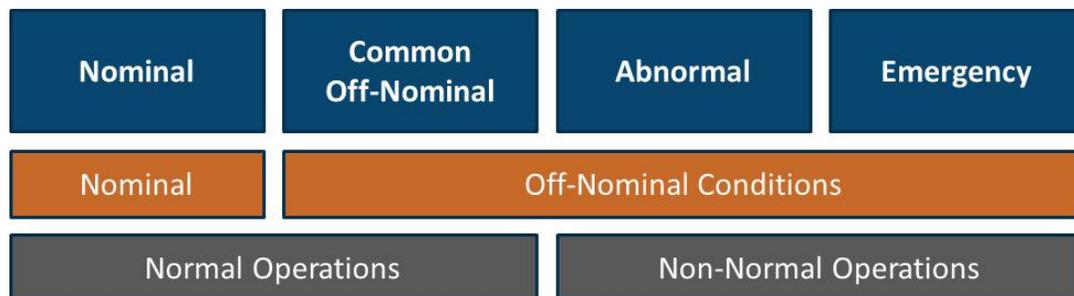


Figure 1. Nominal and Off-Nominal Conditions

## Purpose

The purpose of this assessment is to assess the high-level effects of off-nominal conditions on human performance in NextGen operations. This will include identifying new off-nominal conditions present in NextGen operations and assessing the effect of existing off-nominal conditions on controller performance in a NextGen mid-term environment. The results of this analysis should be utilized to create design requirements and identify research needs related to minimizing the adverse effects of off-nominal conditions during NextGen operations.

## Development of Off-Nominal Conditions List

In order to assess the potential effects of off-nominal conditions on NextGen operations, it is necessary to first identify the specific conditions to be considered in the assessment. A wide variety of initial off-nominal scenarios and conditions were collected. These initial off-nominal conditions covered the spectrum from common off-nominal conditions, such as mild turbulence, to emergency conditions, such as ATC zero. These initial off-nominal conditions, previous off-nominal research, as well as the experiences and opinions of subject matter experts were combined to create a master list of candidate off-nominal conditions. The master off-nominal conditions list was then consolidated by eliminating duplicate conditions and grouping similar conditions based on the effects of the conditions on controller performance and their potential relevance in proposed NextGen operations.

### Off-Nominal Conditions List

The finalized listing of off-nominal conditions contained forty-seven conditions, which were grouped into five broad categories. The first category, Airport/Airspace Conditions, describes the

off-nominal conditions present in the operating environment that generally affect any aircraft operating in a given environment.  The Automation Performance category contains conditions related to the performance characteristic of the systems and tools utilized in the NAS.  This category includes failures, degraded modes, or unexpected performance by various types of automation. The Event – Aircraft Initiated category describes conditions where the actions or performance requirements of an aircraft impact the performance of a controller.  These conditions cover the spectrum of conditions from relative common and low-consequence, Aircraft Push Takes Longer Than Expected, to the more urgent Aircraft Declares Emergency. Conditions in the Event – ATC Initiated include changes to the operating environment that are caused by the actions of a controller. This includes conditions such as Aircraft Placed in Holding and Aircraft Go-Around (ATC instructed). The final category, Weather/Environmental Conditions, covers the naturally occurring conditions in the environment that inevitably impact traffic such as Icing or Thunderstorms. The complete listing of off-nominal conditions that was developed and used for this assessment is provided below in Table 2.

## NextGen Operational Improvement Assessment

The off-nominal conditions identified in the first phase of this assessment were utilized in assessing the impact of off-nominal conditions on NextGen midterm Operational Improvements (OIs). Human factors and Air Traffic Controller subject matter experts reviewed each midterm OI against the list of off-nominal conditions to assess the potential effects on controller performance. For each OI where the off-nominal conditions were deemed to have a potentially adverse impact on human performance, the condition and potential effects were described.  The resulting list provided a crosscutting view of the potential effects of off-nominal conditions on NextGen midterm capabilities.

The comparison of OIs to the Off-Nominal conditions list yielded multiple conditions that could potentially affect each OI.  The results of the comparison found eighteen of the off-nominal conditions that would potentially affect more than five different OIs. A summary of the off-nominal conditions deemed to potentially impact the largest number of OIs is provided in Table 1.

## Discussion

The results of the OI comparison provided a broad overview of the potential impact of off-nominal conditions on controller performance in the NextGen environment.  It further highlights the significance of considering the implications of off-nominal conditions during the design phase of NextGen systems.  The most frequently cited conditions and examples of their potential impact are provided below.

**Incorrect/Missing Information in Data Block/flight plan/flight object**. The most frequently cited off-nominal condition that could potentially affect NextGen operations dealt with the presence of incorrect or missing information in the flight object.  As the level of automation in the NextGen environment increases, the importance of automation maintaining an accurate record of each aircraft may also increase.  Many of the planned tools relating to improving NAS efficiency rely on optimizing route assignments or traffic sequences.  Incorrect information regarding an aircraft's route or performance characteristics could result in the automation yielding a sub-optimal recommendation.  Implementing these recommendations could easily result in significant additional controller workload associated with tactically modifying the sequence.

Other OIs propose advanced procedures relying on the accuracy of aircraft information in automation. For example, delegated responsibility for in-trail separation will utilize information about the aircraft to determine the appropriate aircraft pairing.  Inaccuracies in aircraft type, equipage levels, or route of flight may potentially lead inadequate pairing of aircraft. This could lead to a loss of efficiency, increased controller workload, or potentially create conflict situations that a controller would need to resolve.

Table 1: Count of Off-Nominal Conditions

| Off-Nominal Condition | Count |
|---|---|
| Incorrect/Missing information in data block/flight plan/flight object | 13 |
| Inadvertent Sector Overload | 9 |
| Conflict/Proximity/Other alert activates erroneously | 8 |
| Runway closure | 8 |
| Thunderstorm | 7 |
| Radar Surveillance Degraded Mode / Failure | 7 |
| Aircraft requests an emergency landings / Aircraft declares emergency | 7 |
| Human/Animal/Workers in movement area | 7 |
| VFR GA Traffic / Airspace Violator | 6 |
| Combined position / sectors | 6 |
| Loss of radar contact with an aircraft | 6 |
| Runway Incursion | 6 |
| Conflict/Proximity/Other alert does not activate in a timely fashion | 6 |
| Aircraft misses assigned taxiway exit | 6 |
| Aircraft lost/unfamiliar with airport surface | 6 |
| Aborted take off | 6 |
| Foreign Object Debris on Runway | 6 |
| Icing (moderate, severe) | 5 |

**Inadvertent Sector Overload.** Inadvertent sector overload refers to situations where a sector's traffic level has exceeded the pre-defined acceptable traffic level for that sector. There can be many potential causes of inadvertent sector overload, including many of the other off-nominal conditions listed above. Typically in these circumstances, a controller may enlist the help of their supervisor and the traffic management unit to help tactically manage the traffic in their sector until it returns to a manageable level. The increased capacity and efficiency provided by NextGen tools, such as Point in Space Metering (OI 104120), could make tactically managing a sector more difficult due to aircraft spaced closer together. Other proposed changes, such as automating the handoff process (OI 102114), may further complicate the recovery process by potentially requiring this feature to be inhibited to prevent more aircraft from entering an overloaded sector. Incorporating a requirement to consider the traffic level of the receiving sector into the algorithm that determines whether a sector can receive an automatic handoff could potentially reduce the adverse impact of sector overload in the NextGen environment.

**Conflict/Proximity/Other Alert Activates Erroneously.** Even with the relatively small number of alerts presently utilized by controllers to ensure NAS safety, the effects of erroneously activated alerts represents one of the FAA ATO's top five hazards in the NAS (Teixeira, 2013). A previous review of potential new alerts and alarms in the NextGen midterm identified fourteen additional alerts that could be provided across the En Route, TRACON, and Tower environments (Berry & Sawyer, 2012). Many of the proposed NextGen OIs present controllers with new alerts aimed at improving NAS safety. OI 102114, Initial Conflict Resolution Advisories, includes references to several potential new alerts that may not

only identify potential route conflicts, but may suggest recommended advisory actions to mitigate the conflict. The presence of erroneously activated alerts may require the controller to not only assess whether a true conflict exists, but also determine whether the proposed resolution will adequately resolve the conflict and not create additional flow issues within their sector. If the controller is provided with an accurate alert regarding a conflict, but is given a potentially erroneous resolution it may be more difficult for the controller to resolve the conflict than if no resolution had been provided.

**Runway Closure.** Runway closures occur primarily for the purposes of planned maintenance activities, such as repairs, resurfacing, or repainting. These activities typically involve a considerable amount of coordination between all airport stakeholders to ensure that all parties are aware of the airport conditions. The increased number of surface management tools as proposed in the NextGen midterm creates an additional set of systems which must be made aware of runway closures. Many OIs, such as Enhanced Surface Traffic Operations (OI 104207) and Enhanced Departure Operations (OI 104208), may present new capabilities related to improving taxi and departure efficiency that will require accurate information regarding the status of runways and taxiways. Inaccurate information could easily lead to the tools providing inaccurate recommendations that may require a controller to tactically manage and resolve any potential issues.

## Conclusions

This work provides a set of 47 off-nominal conditions to be used for assessing human performance in air traffic control. It further provides a high-level overview of the results of an assessment of the impacts of these conditions on proposed midterm NextGen capabilities. Eighteen of these conditions were found to impact five or more NextGen OIs. These findings should be incorporated into the development of research and design requirements, as well as testing and human-in-the-loop simulation requirements, in order to ensure capabilities are developed for the range of conditions under which they will be used.

## Acknowledgements

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Table 2. List of Off-Nominal Conditions

| Airport / Airspace Conditions | |
|---|---|
| – Human/Animal/Workers in movement area | – Foreign Object Debris on runway |
| – Ground stop at destination | – Runway closure |
| – Taxiway closure | – Excessive workload |
| – Airport closure | – Combined position/sector |
| – Runway checks in progress | – Ground delay program in place |
| **Automation Performance** | |
| – Altimeter settings not updated to actual conditions | – Loss of radar contact with an aircraft |
| – Automation inadequately performs primary function | – GPS system failure/degraded mode |
| – Blocked ATC communications | – Keyboard, trackball failure / degraded mode |
| – Alert activates erroneously | – Radar/Surveillance failure / degraded mode |
| – Alert does not activate in a timely fashion | – ATC Zero |
| – Incorrect/Missing information in data block/flight object | |
| **Event – Aircraft Initiated** | |
| – Aircraft airborne without release or aircraft misses flow time | – VFR GA Traffic / Airspace Violator |
| – Aborted take off | – Runway incursion |
| – Aircraft must return to gate | – Aircraft delays execution of taxi/takeoff |
| – Aircraft declares emergency | – Aircraft lost/unfamiliar with airport surface |
| – Aircraft requests priority handling | – Aircraft misses assigned taxiway exit |
| – Aircraft automation system failure / degraded mode | – Aircraft push takes longer than expected |
| – Pilot requests a change of destination | – Pilot response to TCAS RA |
| **Event – ATC Initiated** | |
| – Aircraft go-around (ATC instructed) | – Aircraft arriving/departing in opposite direction |
| – Aircraft placed in holding | – Special approach/departure procedures |
| – Handoff conducted with aircraft position not in accordance with LOA or SOP | – Aircraft at abnormal altitude for direction of flight |
| – Aircraft crosses sector boundary on unanticipated trajectory | |
| **Weather / Environment** | |
| – Icing (moderate, severe) | – Turbulence |
| – Low visibility | – Wind shear |
| – Thunderstorm | |