**National Transportation Safety Board**

Washington, D.C. 20594

Office of Aviation Safety

**U.S. Detailed Comments on Draft Final Report of Aircraft Accident Involving PR-GTD and N600XL, 29 September 2006**

## ANALYSIS

### Air Traffic Control Discussion

ICAO document 4444[1] defines the purpose of ATC services as "preventing collisions … between aircraft, and … expediting and maintaining an orderly flow of air traffic." Similar definitions appear in U.S. documents as well. As both of the involved aircraft in this collision were operating under required positive control, and under all applicable directions, ATC services must be examined in detail to determine the factors that initially placed the aircraft into conflict and why ATC services did not resolve the conflict before the collision. Only the ATC system had knowledge of both airplanes and their respective intentions. ATC service is a complex subject that does not lend itself to one overall conclusion. ATC services can be broken down in a similar manner to overall accident investigations in general, such that operational, physical, and human factors can all be applied. In fact, the draft report does examine many of the subjects relevant to the ATC services provided. However, to clearly define the causal factors of this accident, each of the ATC issues described in the report should be fully analyzed, lead to specific findings of risk, and support the probable cause.

The ATC computer automatic insertion of the "cleared altitude" field in the displayed datablock was one of the first chronological events that led to the collision. Sections 4.6 and 4.6.1 of the analysis discuss this feature; however, the only conclusion drawn is on page 219, which states that the controllers "have always operated the system in this manner." The discussion in the report notes that the controllers did not react correctly to the information presented on the displays. However, a design in which two distinctly different pieces of information (that is, requested altitude and cleared altitude) appear identical on the display is clearly a latent error. In the accident scenario, because the altitude change to FL360 was planned to occur over BSB, well within sector 5 airspace, it is likely, that the sector 7 ATCO believed that the sector 5 controller (or a previous controller) had already issued the clearance to FL360. The clearance could have been issued well in advance of the airplane passing BSB by specifying where an altitude change takes place, such as "maintain FL370 until BSB, descend to FL360," as indicated in ICAO 4444 11.4.2.5.2.2b. In fact, this clearance would have been not only acceptable but also desirable.

[1] According to CENIPA, the Brazilian ATC document ICA100-12 is substantively the same as ICAO document 4444.

Such an understandable assumption by the sector 7 ATCO would be reinforced by the automatic "cleared altitude" field change and by the 3D radar values that appeared to show a descent. It is clear that the sector 7 ATCO believed that N600XL had been cleared to FL360, and that is how he briefed the controller who relieved him, thereby perpetuating the incorrect assumption.

The automatic change to the "cleared altitude" field did not accurately reflect the status of N600XL's clearance. There is no distinction between a "requested altitude" value that is serving as a reminder to the controller and a "cleared altitude" value that actually reflects the status of the aircraft's clearance, as noted in section 4.6. If the automatic change is intended to serve as a reminder, the controller that should have issued the clearance is sector 5 because the change took place in his airspace. Alternatively, he should have either changed the data to accurately reflect the clearance or advised the sector 7 controller of the actual clearance.

This scenario explains why the use of the automatic "cleared altitude" field change has the potential to mislead controllers, is a poor human factors design, and is a clear finding of risk. In fact, this event was one of the first that is **directly** tied to the accident scenario. This feature has the undesirable effect of making the ATC automation "lead" the actual clearance issued to the flight crew. A basic tenet of ATC is to have a double check of clearances. The automatic change takes away a method for the ATCO to reinforce the proper clearance in his mind. If the controller makes the entry, the action of keying in the numbers helps to confirm that he has issued the correct altitude and that the pilot has read back the clearance correctly. Therefore, the automatic change of the datablock field from "cleared altitude" to "requested altitude" without any indication to, or action by, the ATCOs led to the misunderstanding by the sector 7 controller about what altitude clearance was issued to N600XL. **[Conclusion]**

We recommend modifying the software to make it clear to controllers whether this field of the datablock is displaying a requested altitude or a cleared altitude. At the least, a "reminder" feature should be distinguishable from a display that reflects the actual clearance status of the aircraft. This feature has been discussed in worldwide ATC publications, and the report must address the issue completely. A detailed assessment of this feature should be conducted, and, if the feature is not changed, the assessment should completely demonstrate why retaining the feature is desirable. Such an assessment must specifically show training and procedures that fit with the feature and support correct issuance of clearances in accordance with ICAO document 4444. **[Recommendation]**

Further aspects of the ATC automation reinforced the mistaken assumption by the sector 7 controller. The report clearly acknowledges that the 3D altitude feature ("Z" altitude) included in the CINDACTA systems is not to be used for civilian ATC separation. However, that altitude value is automatically displayed upon loss of mode C information and in this case helped to reinforce the assumption that N600XL was actually descending. Although potentially valuable for emergency or air defense purposes, there is no reason to routinely display height-finder information to civil controllers for normal ATC purposes. As the report indicates, the 3D altitudes displayed in association with N600XL coincidentally supported the assumption that the airplane was descending to FL360, although the altitude later became very erratic, as would be expected as the airplane flew farther from the relevant radar site. The report includes recommendations that loss of mode C information should be made more evident to controllers.

However, in the body of the report, it is correctly noted that the "Z" symbol appeared in the datablock as well as the loss of the circular target marker and that both indicated that mode C information had been lost. There is no reason to believe the controllers did not understand the datablock information; however, they either were not aware of it or did not attach the appropriate level of significance to it. This training and awareness issue will be discussed in the next section, but the fact that the 3D altitude values reinforced an incorrect assumption leads us to conclude that the automatic display of an altitude value that is invalid for ATC use contributed to the accident scenario. **[Conclusion]**

When the 3D data is being displayed, it should be unmistakably distinguishable from mode C altitude reports received from aircraft. Therefore, we believe that the 3D altitude should only be displayed to ATCOs upon request through a keyboard entry or other means of selection. **[Recommendation]**

As outlined in the report, the sector 7 ATCO had many opportunities to realize that N600XL was not in two-way communication. No transmissions were made to the flight crew until the airplane had flown beyond the coverage of the assigned radio frequency. Discounting the loss of transponder, the controller had no other reason to communicate with the flight crew; however, when he began making radio calls to the crew, he had many opportunities to correct the loss of communication. The flight crew would not have any knowledge of radio transceiver locations and coverage, but ATC does. The sector 7 controller never attempted to try a relay through other flight crews, emergency frequency, or any other means to treat the flight under lost communication procedures. ATC clearly had knowledge that the crew was not in communication well in advance of the crew, yet ATC did not take sufficient action. This known information was not passed to the Amazonic ACC controller. Correcting the lost communication situation was another opportunity to interrupt the accident sequence of events. Therefore, although ATC was aware that N600XL was not in radio communication, the controllers and supervisors did not take adequate action to correct a lost communication situation. **[Conclusion]** As an additional aspect of ATC communications procedures, the use and management of the radio frequencies and transceiver assignments should be considered an associated finding. As the report fully describes, the errors made within the CINDACTA by not correctly utilizing frequencies and configuring ATC sectors contributed to the breakdown in communication with N600XL and the accident sequence of events. **[Conclusion]**

As noted in the report and related to the above findings, ATC continued to apply a projected vertical separation standard of 1,000 feet between N600XL and GLO1907, although there was no transponder return or two-way communications from N600XL. ICAO document 7030 requires radar service with operable mode C transponder and two-way radio communication to apply Reduced Vertical Separation Minimums (RVSM). It is clear that the sector 7 controllers were well aware that neither condition applied to N600XL, yet they took no action to increase vertical separation with GLO1907 to the standard 2,000 feet. The GLO1907 flight data were available to the controllers, and they could have simply advised the Amazonic ACC to amend GLO1907's clearance to an appropriate altitude (or to apply lateral separation.) Although full standard separation might not have existed, the collision risk would have been eliminated. ATC continued to apply RVSM separation standards despite a lack of required conditions. **[Conclusion]**

All the information about the flight plan and intent of N600XL was available to the sector 5 ATCO. The flight plan requested a level change to FL360 to be applied over Brasilia, which was well inside the sector 5 airspace. Basic ATC concepts place the responsibility for appropriate clearance or coordination at this point with the sector 5 controller, who should have either issued a clearance to FL360 (either as the airplane passed Brasilia or as a crossing restriction) or coordinated the status of the airplane with the sector 7 ATCO. Because the controller did neither and initiated the handoff of N600XL at an exceptionally early point, the latent failure was set, which led to the sector 7 false assumption. The sector 7 controller shares in this contributing factor because he did not verify the assigned or actual altitude of N600XL. The controllers at sectors 5 and 7 were unaware of the status of N600XL's altitude clearance and did not take positive action to provide a clearance, confirmation, or appropriate coordination. **[Conclusion]**

Further aspects related to ATC and Operational Factors that may not be direct findings of risk require some discussion to clarify the events leading up to the accident. This section provides discussion and clarification of these items, which appear throughout the report.

At numerous points in the report, there is discussion and analysis of the initial ATC clearance issued by São José ground control and the pilot's understanding of portions of the clearance. Specifically, the terms "clearance limit" and "cleared as filed" appear to be misunderstood. "Clearance limit" is defined in ICAO document 4444 as "the point to which an aircraft is granted an air traffic control clearance" and in the FAA Pilot/Controller Glossary (P/CG, part of FAA Order 7110.65 and the Aeronautical Information Manual) as "the fix, point, or location to which an aircraft is cleared when issued an air traffic clearance." However, numerous times this phrase is associated with the altitude portions of a clearance.[2] The report correctly notes that the initial clearance issued to N600XL before departure from São José dos Campos did not follow the correct format for an initial clearance. However, we believe that the ground controller's statement "clearance to Eduardo Gomes," could not realistically be interpreted as anything other than the "clearance limit" item of the clearance. Furthermore, numerous statements in the report imply that issuance of a clearance limit, whether for the intended destination or an intermediate navigational fix, correlates with the assigned altitude. Section 4.5.7.1 of ICAO document 4444 describes the relevant application of a clearance limit, which in no way affects the assigned altitude of the airplane. The report cites section 11.4.2.5.1 of ICAO document 4444, which reads as follows:

> Clearances shall contain the following in the order listed:
> a) aircraft identification;
> b) clearance limit;
> c) route of flight;
> d) level(s) of flight for the entire route or part thereof and changes of levels if required;
>
> *Note.— If the clearance for the levels covers only part of the route, it is important for the air traffic control unit to specify a point to*

[2] These instances include, but are not limited to, pages 39, 40, 54, 97, 197, 198, 201, 217, 250, 252, and 256.

*which the part of the clearance regarding levels applies whenever necessary to ensure compliance with 3.6.5.2.2 a) of Annex 2.*

e) any necessary instructions or information on other matters such as SSR transponder operation, approach or departure maneuvers, communications and the time of expiry of the clearance.

This section is quite clear that the note referring to en route level changes applies to the "altitude" (levels) portion of the clearance. A common application of this procedure would be the issuance of a crossing restriction, as in the example in ICAO 4444 11.4.2.5.2.2b. Therefore, we submit that, although the initial departure clearance was incomplete and in a nonstandard format, the issuance of a clearance limit did not contribute to any misunderstanding. It is possible that, if the initial departure clearance had been stated as discussed above, it may have served as a reminder to the flight crew; however, any intervening altitude assignment by the en route controllers would be in force unless amended.

Similarly, the phraseology "cleared as filed" is not always cited correctly in the report. The report states in numerous places, "no mention was made whether the flight plan had been 'cleared as filed'. This would certainly be fundamental to alert the pilots about where further level changes would occur." This is not supported by any reference or published guidance.

It is clear from these definitions that the altitude portion of the ATC instructions are not related to clearance limits, but rather to crossing restrictions or other instructions. Therefore, the sections referencing these concepts should be rewritten to more accurately reflect the intentions of relevant directives. Although the description of the intended clearance format that should have been issued by Sao Jose Tower is technically in compliance with standard procedures, the training and operational procedures must be reviewed for correlation with ICAO standards in order to minimize the potential for misunderstanding.

**Flight Operations Discussion**

**Flight Planning**

Beginning on page 92 and recurring throughout the report are numerous passages and citations of events that are associated with the flight crew of N600XL not being aware of the elements of the flight plan, an unusually short time elapsing between the obtainment of the printed flight plan and the departure, or the crew having an unusually short period of time to prepare for the flight. These items appear to be partly in support of paragraph (e) on page 264 of the report, which indicates, "Planning – a contributor." We do not agree that the analysis is sufficient to support any deficiency in the conduct of the flight, which can be related to planning. The crew flew the route precisely as cleared and complied with all ATC instructions. The crew's awareness of their current altitude and its relation to the hemispheric convention applicable to the course of flight north of Brasilia is entirely independent of the requested level in the flight plan. Therefore, we do not fully concur with contributor (e) and the citations in the report leading to it.

**Altitude Awareness**

Page 100 discusses the sequence of events regarding the assigned altitude when passing Brasilia. The report notes that no mention of an altitude change was made by either the flight crew or ATC. This point is extremely important and must be emphasized. All existing ATC and flight procedures support the conclusion that the crew was operating in compliance with ATC instructions. As noted in the ATC analysis discussion, there was no reason for any pilot to believe that the assigned altitude was anything except FL370 and would remain so without further instructions, an emergency situation, or application of prescribed lost communication procedures. ATC did not issue an amended clearance; therefore, the crew had no reason to change altitudes and could not unilaterally do so.

Both accident aircraft were operating in controlled airspace. 14 CFR 91.179 specifies that "*(a) In controlled airspace. Each person operating an aircraft under IFR in level cruising flight in controlled airspace shall maintain the altitude or flight level assigned that aircraft by ATC"*. Hemispherical altitudes such as those shown on the index of an IFR chart or in the Aeronautical Information Manual, although used as conventions by ATC, are only a requirement when operating in uncontrolled airspace. The implication that a crew should somehow observe hemispherical altitudes while being positively controlled by an ATC facility is incorrect. Informal use of the term "wrong way" by pilots and controllers is merely a shorthand way of acknowledging that an assigned or requested altitude is not the one normally used for that direction of flight. Pilots and controllers display good judgment when they use such means to alert one another of nonstandard flight conditions, but the term "wrong way" does not imply a violation of regulations or faulty planning or operation. Conversely, when pilots and controllers allow an airplane to operate for long periods of time at a nonstandard altitude without verifying the assigned altitude in some way, it casts doubt on their judgment. Although a review of the draft report and supporting documentation by the FAA's Flight Standards Division concluded that there was no evidence of regulatory violations by the crewmembers, they did have a long-term opportunity to note a nonstandard situation and request clarification or confirmation from ATC. For about 1 hour the significance of the long time period spent at a nonstandard cruise altitude for the flight direction by N600XL was not recognized. **[Conclusion]**

**Transponder Operation**

We agree with the observation that the footrest guard is designed to prevent unintended interactions with the buttons of the RMU1 and other flight deck controls and agree with the evaluation provided in the report that, if properly used by the flightcrew, the footrests in the Legacy should prevent such inadvertent inputs. However, in flight deck observations conducted by the NTSB and FAA, it was observed that pilots might misuse the footrests since, in certain forward seat positions, there appeared to be a very comfortable resting position that involved resting the feet on top of the footrest guards rather than inside the designated footrest areas. This position allowed the resting pilot to remain within easy reach of the primary flight controls but, unfortunately, located the captain's right foot in the area of the RMU1 so it could make unintended contact without the captain's awareness. It can not be determined exactly how the accident crew commanded the transponder to standby, but the possibility of an unexpected use of the footrest guard, along with other possibilities discussed in the report, serve as important reminders of human ergonomic considerations at preventing inadvertent contacts in actual flying situations. We believe that an additional safety message from this accident could be to

encourage industry to develop upgraded guidelines and regulations of flight deck best design practices to further minimize unintended contacts.

**Communications**

Title 14 CFR 91.183 (IFR communications), which is presumed to be identical to the Brazilian regulation, states the following:

> *Unless otherwise authorized by ATC, the pilot in command of each aircraft operated under IFR in controlled airspace must ensure that a continuous watch is maintained on the appropriate frequency and must report the following as soon as possible (a) The time and altitude of passing each designated reporting point, or the reporting points specified by ATC, except that while the aircraft is under radar control, only the passing of those reporting points specifically requested by ATC need be reported; (b) Any unforecast weather conditions encountered; and (c) Any other information relating to the safety of flight.*

Both 14 CFR 91.185 and ICAO Annex 2 3.6.5 specify procedures to be followed in the event of lost communication but do not specify criteria for determining when this condition is met. Furthermore, the procedures for flight crews to follow in the event of lost communication differ substantially between the two documents. The Aeronautical Information Manual notes that the following:

> *It is virtually impossible to provide regulations and procedures applicable to all possible situations associated with two-way radio communications failure. During two-way radio communications failure, when confronted by a situation not covered in the regulation, pilots are expected to exercise good judgment in whatever action they elect to take.*

The pilot-in-command of N600XL had a safety-of-flight duty to see that immediate communications capabilities with ATC were being maintained and to act promptly if they were not. Although the term “continuous watch” is not defined, its implication is that the crew‘s communications with ATC were not intended to be a passive activity. Being under radar control exempted the pilot from making certain radio reports but did not exempt him from remaining aware and alert.

The challenge for the N600XL crew was that they continued to hear transmissions from ATC and other airplanes, which was misleading for them. There is no standard under radar control for how often a crew should verify that two-way communications remain established, but such verification should be often enough that the pilots have no doubt.

The report cites a failure by the crew and ATC to invoke lost communications procedures. These factual findings are also obvious conclusions; however, during the investigation, it became quite clear that the procedures for lost communication were not well known and that the applicability to actual in-flight situations was difficult. Without question, N600XL proceeded for an inordinately long time without two-way communication **[Conclusion].** A review of U.S.

and ICAO regulations that apply to both ATC and flight crews, indicates that clarification and harmonization may be desirable. The U.S. team believes that it may be necessary for the appropriate regulatory authorities to conduct a review and will study the need for a safety recommendation.

### Training for International Operations

Pages 69 and 74 of the report state that the flight crewmembers were not experienced in the operation of the avionics in N600XL. Although the transponder outage was likely because of an inadvertent action, no evidence in the factual record indicates that a lack of familiarity with the avionics is related to the outage.

Further statements and conclusions about the training and experience of the flight crew are related to international operations. Page 74 states, "the level of proficiency of the PIC in the new aircraft model proved inadequate for an International Operation," and page 198 states that the pilots' experience was "not sufficient for an adequate adaptation of the pilots to the requirements of the flight." However, there is no supporting evidence to indicate that any deficiencies in the operation, as specifically related to Brazilian or ICAO procedures, existed. The awareness issues mentioned, and the potential for distractions in the cockpit, are not unique to an international operation.

Nevertheless, during the course of this investigation, it became clear to the U.S. team that training for international operations may be insufficient for certain operations. Although all international training received by the flight crew met existing requirements, the U.S. team plans to study the possibility for a safety recommendation related to international training, especially as it relates to high performance business jet aircraft.

## RECOMMENDATIONS

### Safety Recommendations Issued During the Investigation

261/A/06, 263/A/06, 264/A/06, 101/A/07, 102/A/07

These recommendations should have references either in the recommendation text or in the body of report explaining or indicating the content of the procedures. Otherwise, there is no way to determine if the procedures are adequate.

266/A/06

There is no direct discussion of flight path offsets in the report or any discussion about the role that a lack of offset procedures played in the accident. Also, because the word "offset" is capitalized in the report, it would seem to need a definition somewhere.

70/A/07, 75/A/07

These recommendations should identify what aspects of crew resource management (CRM) training contributed to an identified safety deficiency. NTSB currently has an open recommendation regarding CRM training for on-demand Part 135 operators. The NTSB recommendation, A-03-52, asks the FAA to do the following:

> *Require that 14 Code of Federal Regulations (CFR) Part 135 on-demand charter operators that conduct dual-pilot operations establish and implement a Federal Aviation Administration-approved crew resource management training program for their flight crews in accordance with 14 CFR Part 121, subparts N and O.*

This recommendation was issued as a result of the NTSB's investigation of the accident that killed a member of the U.S. Senate. We have also investigated several other on-demand Part 135 accidents in which issues of CRM were revealed during the investigation. These accidents were caused by crew errors, and it is possible that an effective CRM program might have interrupted the sequence of events that led to the accident. Part 121 and scheduled Part 135 operators are required to provide pilots with CRM training in which accidents are reviewed and skills and techniques for effective crew coordination, resource allocation, and error management are presented. CRM training augments technical training and enhances pilots' performance in the cockpit. The FAA has indicated that it agrees with this recommendation and that it would include it as part of comprehensive rewrite of Part 135 that is likely to take considerable time to complete. The NTSB believes that, because Part 121 programs already exist and have proven very effective, there is no need to delay the rewrite of Part 135. Although the accident flight was not conducted under Part 135, the circumstances of the accident may provide further support for the need to improve CRM training for Part 135 on-demand operators and thus further support the NTSB recommendation. With such background and justification, CENIPA could refer to NTSB Safety Recommendation A-03-52 in making an effective argument.

72/A/07

The intent of this recommendation is not clear. Does it refer to a "sterile cockpit" concept?

125/A/07

It is not clear what documentation should be updated and to what.

130/A/07 and 131/A/07

These recommendations for Gol Airlines would seem to be related to activities that occurred on PR-GTD, but there is no discussion in the report of any findings or crew actions that would have supported these recommendations.

**Suggested Additional Recommendations from U.S. Team:**

DECEA should do the following:

Ensure that ATC 3D data display is unmistakably distinguishable from mode C altitude values, preferably via a specific ATCO selection, such as keyboard entry.

Ensure that controllers have the ability to quickly distinguish whether a datablock is displaying a requested altitude or a cleared altitude, for example, by eliminating automatic fill or making the field distinguishable by color or blink.