Preparing the Next Generation of Investigative & Regulatory Authorities

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The theme of this year's ISASI Seminar, "Preparing the Next Generation of Investigators" implicitly asks what types of skills and resources accident investigative and regulatory agencies must recruit or develop for a rapidly changing aviation system. The most honest reply is "it depends." It depends on a country's current safety baseline, whether the country is rich or poor, whether it has a functioning state, and more. For example, investigative and regulatory authorities in rich countries with sustained low accident rates likely will focus on building more extensive programs in flight data analysis and the integration of other "big data" tools. However, they must do so with some caution to ensure that they maintain existing skills and avoid the trap of assuming that traditional investigative skills will become less valuable.

At the other end of the spectrum, many countries with high long-term accident rates need to prepare for today; tomorrow may need to wait. Some countries may face the institutional challenge of establishing, for the first time, regulatory and investigative authorities that have technical capability and real authority within the broader political-economic system.

Needs also will vary according to the size and complexity of national aviation systems. Countries with large populations and big national systems will have different needs than countries with smaller systems, while some countries with smaller systems have different needs if they have large international hub airports.

Some countries also are or soon will be new entrants to the aircraft manufacturing market. They will require substantial expansion of the relevant regulatory and investigative capacities or must build entirely new capacities from the ground up to ensure that they can meet their ICAO obligations as countries of manufacture. National needs also will be somewhat different for counties that have large general aviation (GA) sectors and whether they must prepare for the entry of unmanned aerial systems in big numbers into civil aviation, but such needs are still far off in the future for some other countries.

Countries with Low Accident Rates

Depending on who is counting, about 35 countries can claim to have very safe systems. Twenty years ago the list would have been limited to a smaller group of OECD countries: Canada, the US, Western Europe, Australia, New Zealand and Japan, but the list now includes Chile, China, Singapore, South Korea, and several countries in Central Europe and the Gulf. More countries soon will expand this list even further. All these countries face the same basic challenge of ensuring that their air transport systems continue to get safer and safer, as aviation has done persistently for 100 years.

Accident rates for these 35countries have reached a level that was thought to be unachievable not long ago. These countries account for nearly 77 percent of world-wide airline revenue flights but accounted for just 15 percent of all hull losses in the past 5 years. As of this writing (June 2013), in the 4 years that have passed since Air France 447 the 35 countries have had a combined hull-loss rate on the order of 0.06 per million flights and about 0.035 per million in passenger operations, or 1 in every 28 million flights. [i] They have had zero hull losses and zero fatalities in about 50 million passenger flights since the First Air accident in Canada in August 2011.

Performance like this may become routine in the future, but it is dramatic stuff today. A single event will temporarily end this happy story, but numbers like these illustrate why accident rates are inadequate as a primary measure of safety trends. Accident rates measure how frequently things go badly wrong, so they still have value, but they say little about changes in risk or safety margins. Flight data analysis and big data are filling that void, at least in air transport.

"Moneyball," a popular book and movie, illustrates the value of big data and how it changes what we believe is important. In that movie, team manager, Billie Beane, uses the analysis of endless data to determine which players can help his team win baseball games. When Beane tells his coaches that he plans to sign a player whom they had rejected, he asks his sheepish analyst to tell them why: "He gets on base." When his coaches recommend a different player based on their self-described "gut feeling" that he is a good hitter, Beane asks "if he's such a good hitter, why doesn't he hit better?" [ii]

The message in "Moneyball" is simple: if we have good data and good analytical tools, we should use them to make sense of things. The message has direct application in aviation. Good data provides evidence and replaces intuition or perhaps even some folklore about what is going on and what is important. With so few major accidents today in aviation, we <u>must</u> use flight data analysis if we hope to know what is going on with safety and risk in airline operations. With this evidence, we need not rely on a rare accident or two to determine whether known risks are increasing or decreasing, whether old problems need new attention, etc.

Most ISASI members are familiar with and perhaps a bit tired of hearing about the early successes of flight data analysis in the U.S., such as issues related to the risk of CFIT accidents, midairs, stable approaches, and more. I will spare you those details, but those early successes remain good examples of how data analysis adapted the knowledge gained from years of accident investigation and traditional analysis to introduce new insights into known risks that contribute to the most lethal types of accidents.

More recently, flight data analysis has begun to focus on runway excursions (REs). This reflects the major improvement in the rate of major accidents. Even if we were capable 10 to 12 years ago of the kind of data monitoring that we can do now, REs simply would not have been on our list then because, to put it a bit crudely, they did not kill enough people. We had bigger targets to worry about 12 years ago. However, while the frequency of other major accident scenarios decreased sharply, the rate for REs remained unchanged. Consequently, despite the relative infrequency of fatalities, the sustained frequency of REs means they account for an increasing share of remaining fatalities and hull losses.

In response, flight data analysis has used the knowledge gained from accident investigation and traditional analysis to identify and monitor dozens of parameters to measure trends in problems that contribute to REs. Table 1 lists a sample of those problems, each of which requires integrating recorded data for several parameters from thousands of flights per day. By monitoring the identified problems, we can measure whether the risk of REs is increasing, decreasing, or remaining stable. We also can learn with some precision exactly which contributing problems are increasing or decreasing, and identify where to put our resources.

Variations of flight data analysis are starting to penetrate other sectors of aviation. The most promising examples come from large flight training centers, some aircraft manufactures, and especially from the International Helicopter Safety Team's tool kit for Helicopter Flight Data Monitoring (HFDM). HFDM is being applied by some EMS operators but mostly by large off-shore energy operators.[iii] As energy exploration moves into deeper water further off shore, activity in this sector will continue to increase. If HFDM can influence safety in that sector, and have some influence in EMS, it will be a great success.

In sum, flight data analysis, integration with other data and the sharing of summary data provide new insights and new evidence about important issues that we simply would not have any other way. Such programs have made a substantial contribution to aviation safety in a short time and are a must for any country that hopes to understand changes in risk to a safe system. However, these programs have limitations, particularly for regulators.

A Need for Some Caution.

As ISASI members understand, digital data from aircraft or ATC cannot tell us what crews or controllers were thinking, what they meant to do, whether they were working with a good knowledge base, etc. Conversely, voluntary reporting programs may tell us what people thought was going on, but they do not tell us what an aircraft was doing or what inputs or instructions actually took place. When these different programs are integrated, we have a much more capable tool, but we are a long way from an ideal integration of this data. The primary problem is a structural limitation that the aviation community has imposed on itself. Data leaves a company only in summary format with so much attention to corporate and personal anonymity that we significantly reduce the potential usefulness of the data. The attention to anonymity made sense early on. Given the cultures at most airlines and in most regulatory agencies in the 1990s, the notion that employers or regulators might use the data for less than noble purposes was not crazy. As an old joke notes, I may be paranoid, but they still might be out to get me.

As a result, we rarely can integrate different data bases to examine specific events in detail. In all but a few cases, we can integrate and analyze only summary data. That has been valuable but summary data does not let us gain a full understanding in specific events about the interaction of crew intentions, actual inputs, etc. Even within a given airline, analyses often are prohibited from integrating a pilot's voluntary report with FDR data from the subject flight, and the airline may not even be permitted to interview the pilot.

Tim Logan of Southwest Airlines noted this problem in his presentation on SMS at last year's ISASI seminar in Baltimore. He noted that programs like FOQA/FDM, LOSA, manufacturers' data monitoring, ASAP, and voluntary disclosure were developed separately and have yet to be fully integrated, even within many organizations, let alone across organizations, and that the quest for confidentiality continues to limit the full promise of these programs.

> In a perfect world, we could use the same techniques we have developed for accident investigations, such as flight data information, crew interviews, and a review of the associated data in the investigation to identify hazards. [However] the overhang from discipline and enforcement prevents these programs from [taking] full advantage of the information gained. The result is reduced learning from [each] event and a reduction in the effectiveness of the overall safety program.

The best progress on this front has come from the Aviation Safety Information Analysis System (ASIAS) in the U.S. and the European Operators FDM Forum (EOFDM), established jointly by operators and regulators. In the U.S., ASIAS uses a third party, Mitre Corporation, to combine vast amounts of proprietary and public data to conduct system-wide monitoring. Also, through CAST, individual projects permit analysts from participating organizations to use selected proprietary data and otherwise confidential analyses by Mitre. This has been wonderfully useful as far as it goes, but such studies are few in number and work under specific charters from a committee of contributing organizations. Charters, findings and recommendations require agreement among participating parties, and subsequent implementation of recommendations also depends on voluntary action. The requirement for mutual agreement and coordinated action has been critical to the success of efforts like ASIAS and EOFDM, but regulators cannot hope to rely exclusively or even primarily on such programs to support their full range of responsibilities.

Challenge to "Safe Country" Investigative & Regulatory Authorities.
Investigative authorities, which have not been very active in programs like CAST/ECAST or ASIAS/EOFDM, must figure out a way to get in this game and get the benefits of flight data monitoring and other data. Yet if not done properly, involvement could compromise investigative authorities. Assume an investigative authority fully participates in an analysis and a report, complete with mutually agreed findings and recommendations. Then assume a major accident later raises doubts about the wisdom or strength of those findings and recommendations. An investigative authority could at least appear to have a stake in defending the report, which could invite doubts about the integrity of a subsequent accident investigation.

Investigative authorities have a public mandate to remain objective and independent, which gives investigative agencies a level of public trust and moral authority that they must protect. They cannot risk even the appearance of being compromised by self-interest. They must remain above the fray, and they must appear to remain above the fray.

Yet, investigative authorities assume real risk if they remain detached from flight data analysis. As integrated flight data analysis builds a bigger library of knowledge, investigative authorities could issue conclusions and recommendations that are flatly contradicted by good evidence to which they have no access. This would damage investigators' credibility in the aviation community, and two or three such events might destroy all broad public trust or moral authority. This risk is more than a remote possibility and the damage could be substantial.

However, investigative authorities have several middle-ground options. They could pursue agreements for summary briefings or the option to submit specific questions, subject to agreed conditions, to which they could expect meaningful answers. Investigative authorities could also pursue agreements to participate in studies, but with explicit disclaimers that they neither endorse nor challenge findings and recommendations. This would give investigators new access to solid data on selected issues with little risk to investigative independence. It also would enable others to benefit from the insights and perspective that an investigative authority can bring to the table.

Getting into the game in the right way is not an easy challenge for investigative authorities, but they must figure this out. Otherwise they will simply forfeit the evidence that new data and good analytical tools offer. That is not in their interest, the public's interest, or the industry's interest.

Regulators who have embraced flight data analysis face a different challenge. They must continue developing their capabilities in flight data analysis and its integration with other data and tools, but while doing so, they must avoid depreciating other skills and resources that remain necessary. In short, regulators must avoid a degree of irrational exuberance in which they forget the fundamentals while they rush to exciting new opportunities (apologies to Alan Greenspan).

Start with the basic purpose of analysis in any government agency: to inform decisions on public policy. To do that, we must first make sense of the data and then communicate our sense-making to others. That rather basic role and the related skills sometimes get overlooked with contemporary data tools. Too often "analysis" merely presents very complex data in equally complex charts, each of which requires extensive explanation to a room full of people. When that happens, it suggests we have not yet really figured out what the data means or, perhaps because we have been so immersed in the data, we come to believe that the data speaks for itself and really does not require much explanation. The catch, of course, is that data never speaks for itself. Someone must speak for the data and interpret its meaning for others who have not been immersed in the data. Speaking for the data is an analyst's primary job.

Speaking for the data requires several skills that have been allowed to deteriorate somewhat. First, analysts must be numerically literate. They need not be great mathematicians, but they must know 2 times 6 is 12, not something between 10 and 14. They also must be able to write coherently in a local language. Writing a report or memo, or preparing a presentation that explains our findings is critical to our task. That is where we structure our thoughts, see whether our logic can survive some scrutiny, define issues for decision-makers, tell them what we have learned and, if appropriate, tell them what course of action we think is best. Without clearly written documents or clear presentations, analysts' are asking decision-makers to do their own analysis and to do the analyst's job. When we hear someone declare after a rigorous analysis that "okay, now we just need to get someone to write this up" or "someone to make some slides," we are listening to someone who does not understand the central task.

Equally importantly, particularly in GA but also in air transport, most issues that regulators must address require something more like a "small-data" approach. Automated and integrated queries can simplify or easily expand the scope of our search for pertinent data, but that is rarely enough, except for the simplest of questions.

Most issues in the air transport sector and especially in GA require that analysts actually read accident and incident reports, other studies, etc. Reading gives the analyst an opportunity to understand individual events, and reading a well-documented accident report is still the best way to confirm the nature of a flight or to understand the interaction of pilot input, ATC, human factors, airworthiness, weather, etc. in a given event.

For example, analysts who rely only on automated searches to identify all and only certain types of events often will simply miss much of the evidence they seek. In the US, EMS accidents are a good example. An automated search will miss some accidents that occur while an EMS operator is en route to pick up a patient or after the operator has delivered the patient. The same is true for an analysis or air tour operators. Consider an analysis of stall-related accidents. We do not have the benefit of a discrete field that would give us the option of hitting the "stall" button, and accident databases include multiple reports that describe stalls, but never use the magic word. Consequently, again, many cases will be missed by straightforward searches. In addition, an analysis only of coded fields will miss most of the story that remains and may not only fail to inform us in full, but is quite likely to misinform us. Similarly, evidence for some issues even in air transport, such as pilot fatigue, can be identified only by reading well-documented reports.

Reading reports also enables an analyst to understand the strengths and weaknesses of different databases and to avoid misinterpreting some data fields. For example, assume an analysis of IFR versus VFR accidents in the US. An analyst might start by sorting the NTSB database on the field entitled "Flight Plan Filed" under the assumption that "IFR" identifies only accidents that occur while flying IFR and that "VFR" identifies only those accidents that actually occur while flying VFR. Wrong. The field identifies just what it says: accidents in which IFR was filed. Many accidents identified as "IFR" involve events in which the pilot cancelled IFR in flight, never opened the flight plan, perhaps reverted to VFR in response to an emergency, etc. Accidents that occur in instrument meteorological conditions (IMC) offer another example. An analyst might sort the NTSB database for "Prevailing Weather," assuming that "IMC" identifies all the accidents that occur in IMC. Wrong again. The data field identifies just what it says: prevailing weather. VMC may have prevailed in the general area, but the accident may have occurred in an area of heavy fog, or in a cloud bank, or in a rapidly developing thunderstorm, etc.

Many other examples could illustrate the same point: analysts must be willing to read reports. The frequent, underlined emphasis here on "read" is conscious. Any time an analyst declares "I can't read 50 reports," ask "why not?"

The same is true when analysts declare that "the data does not exist." We might ask how hard they looked and whether they have considered building a new dataset to address the issue. This might require reading reports to identify factors not discretely identified in coded fields, or it could require that we manipulate easily available data that is not ideally organized for the issue at hand (arithmetic literacy rather than an exhaustive knowledge of mathematics). Building a new dataset also might require searching press articles, academic articles, etc. The required time and cost may not be justified, but at least that would be an informed choice. Either way, we need to ask questions when we hear that the data simply does not exist.

In sum, most air carrier activity now takes place in countries that have very safe systems. Those countries must continue building their capability in flight data analysis and its integration with other data and tools in order to monitor risk and have an informed sense of what risks might be improving, remaining stable, or increasing. However, they must recognize some practical limitations of these approaches and they must maintain other fundamental skills.

Other Countries

At the opposite end of the spectrum, 13 countries have fantastically high accident rates, including Congo (DRC) and Sudan, who alone account for 14 percent of world hull losses over the past 5 years (2008-2012) with just 0.1 percent of airline departures. To put this in scale, the resulting rate would produce 8 hull losses every day among the 35 “safe” countries. Up to 11 more countries qualify as outliers, though not at this fantastic scale. Many of the 13 countries here simply lack anything approaching functioning states, which excludes them from a realistic conversation about preparing the public sector for tomorrow’s aviation skills. (See Table 2.)

Between the two ends of the spectrum, the rest of the world has a wide range of accident rates. A handful of countries in this large middle likely will join the “safe” club in the reasonably near future, while others still have some distance to go.

Table 2 identifies six countries which have high accident rates, but which have or likely soon will have many of the basic resources required for substantial improvement in safety, such as adequate national wealth or an adequately educated local work force (Indonesia, Iran, Kenya, Pakistan, Russia, and Venezuela. The biggest challenge facing some of these 6 countries will be institution building. However, the absolute number of major accidents remains high enough in these six countries that they still have significant room for improvement even without flight data analysis or any other elements of the data. Tools like flight data analysis certainly would not hurt, but they probably can wait because some easy pickings remain.

Table 2 shows three other countries with significant aviation systems, Brazil, Colombia and Mexico, which have made substantial progress in recent years. Their 5-year rates are beginning to approach those of the 35 “safe” countries, though the immediate challenge is to sustain the improvements. However, these countries already are active in regional bodies such as ICAO’s COSPAC and some are trying to strengthen their investigative and analytical capabilities. Several other countries also are approaching this level, though their systems are smaller. All these countries soon will approach a level of safety, or perhaps already have reached such a level, at which they will need to develop greater capabilities in flight data analysis and related systems in order to sustain their improvements.

Other Factors Influencing national Needs: New Entrants into Aircraft Manufacturing.
For the past several decades, the international market in air transport aircraft has been organized around duopolies that dominate different sectors. Airbus and Boeing have dominated the air transport jet market for several decades, Bombardier-Canadair and Embraer have dominated the regional jet market at least since the 1990s, and ATR and Bomardier have dominated the market for large turboprops. Those firms likely will continue to dominate their respective niches for some time, but things are changing, as China, Japan and Russia enter those markets. Boeing

projects demand for 35,000 airliners over the next 20 years, with continued growth of airline travel in Asia, growth in Africa and South America, modest but meaningful long-term growth in mature markets, plus the replacement of older aircraft with a more efficient and quieter fleet. Incumbent firms cannot meet all that demand; new entrants will get some of that market.

The immediate challenge to Airbus and Boeing will come from the established RJ manufacturers, Canadair and Embraer. Each manufacturer will soon enter the market with jets ranging from 100 to 130 seats, blurring any meaningful distinction between "RJ" and single-aisle jets. Later challenges will come from Russia's revamped Tupolev and especially from China's C919. The development of China's new jets has fallen behind schedule, but China will get there.

The RJ market for aircraft in the 70- to 100-seat range also will change soon. Russia recently delivered its first Sukoi Superjet 100 to a Western operator (Interjet of Mexico). Mitsubishi of Japan expects its MRJ to enter service by early 2016. China hopes to do the same with its ARJ. China's Xian also has begun exporting its STOL-capable MA60 turboprop. The MA60 is not certificated in much of the West, but it will continue to capture some orders. It already is active in Indonesia, Laos, Philippines, Russia and Bolivia, as well as China's domestic industry

All this change places new demands on regulators and accident investigative authorities in China, Japan and Russia. At a minimum, they must establish new capabilities in airworthiness certification and continued product oversight to ensure that they meet their ICAO obligations as the country of manufacture. They also must build investigative authorities with more global reach because they will face accidents abroad in aircraft operated by foreign carriers. Better capabilities for the analysis of manufacturers' data also will be important after those aircraft enter service. All three countries have made real progress, but the changes remain a challenge.

Growth in domestic fleets and domestic air travel also will pose a challenge for regulators in markets like China, perhaps India, and parts of Africa and the Americas. To put some scale on the geography of growth, Boeing estimates a global demand for 25,000 new single-aisle jets over 20 years, with 13,000 of those jets to be sold in Asia. This increases the probability that the countries now entering the aircraft manufacturing market can expect to find some customers.

Many rapidly growing countries will have to build competent regulatory and investigative authorities almost from the ground up, though some, such as China, already are well along in this task. In many countries, challenges may go well beyond establishing the necessary technical capabilities. Challenges will include fiscal limitations and institutional barriers to ensuring that regulatory and investigative authorities have real authority as well as technical capacity. Some countries also will face a shortage of appropriate skills among the local labor force and will have to compete with the rapidly growing local industry for qualified workers.

Needs in General Aviation.

GA systems with broadly based, private ownership of small aircraft likely will remain concentrated in the same regions where they exist today. That mostly means selected members of the 35 "safe" countries, plus perhaps Brazil, Mexico and South Africa. However, the growth in business aircraft will change the geography of GA somewhat. As with the airliner market, Asia appears to be the Promised Land. Beechcraft has noted that the business fleet, including turboprops, grew by two-thirds in Asia over the past decade (through 2012), reaching 1,566 in 2012, including about 900 jets. The business fleet in Asia grew by an annual average of 4.5 percent from 2003 through 2007, then by an average of 5.7 percent from 2008 through 2012.[iv]

Asia's business aircraft fleet is still relatively small for a region with such large populations and high overall growth rates. Yet, even if overall growth rates in Asia slow a bit from their recent levels, the business aircraft fleet in Asia should maintain annual growth rates on the order of 5 to 7 percent for some time.

Growth in business aircraft should continue in other countries as well. Brazil, Mexico and Russia are obvious candidates. Parts of Africa also may see high growth rates in this fleet, albeit from a small base. In many of these countries the growth in business aviation will be in addition to rapidly growing airline systems, which only increases the urgency to build stronger regulatory and investigative authorities.

In addition, investigative authorities in all countries with any meaningful GA activity will be affected by the rapid increase in on-board memory on GA aircraft. This will affect the mix of skills those authorities require and it will mean more and more of the GA investigations will take place in the lab. Non-volatile memory, even on the once-humble reciprocating, single-engine aircraft, is available from primary flight displays, multi-function displays, autopilots, satellite services, fuel scans, brake control units, FADECs, weather systems, maintenance diagnostic equipment, even cell phones, and more. Extracting and analyzing data from these devices often is difficult and these efforts will be limited to accident investigation, rather than something akin to flight data analysis. However, such data can yield definitive information in an accident.

Conclusions

Preparing the next generation of regulatory and investigative authorities will pose different challenges for different countries. Countries with sustained low accident rates must focus on building their capabilities in flight data analysis and related data in order to identify and monitor risk. Investigative authorities in those countries must find a way into that game but they must protect their independence while doing so. Regulators in those countries must continue building their resources in this field but without losing sight of some basic skills. Other countries which are approaching the status of "safe" will need to continue moving in the same direction, but also may need to improve institutional capabilities. Other countries that have high accidents may need to establish, for the first time, regulatory and investigative authorities that have technical capability and real authority. In some countries the number of accidents remains high enough that preparing for tomorrow may need to wait while easier pickings are addressed.

Other factors also will influence individual countries' needs. Some face rapid domestic growth and, once again, institution building may be a big challenge. Other countries entering the international airliner market face additional demands for building new regulatory capabilities in airworthiness and significantly expanded investigative capabilities with a global reach. Finally, the size and complexity of future general aviation systems also will affect national needs. No one size will fit all.

Table 1: A Sample of Problems Monitored To Measure the Risk of Runway Excursions

- Stable Approach (on localizer, deviation from glide slope, glide path below 600 feet AGL, speed and descent rate at various points on approach, etc.);
- Deviation above glidepath below 600 AGL (stable approach)
- Excessive bank above 500 feet AGL (stable approach - trying to recapture);
- Approach speed high within 90 seconds of touchdown;
- High rate of descent below 2,000 AGL;
- Speedbrake on approach below 1,000 feet;
- Stick shaker;
- Sink rate or “pull up” alerts, and rate of descent during flare;
- Flaps not in position at 500 feet;
- Flap over-speeds, and tail clearance;
- Threshold crossing height (maximum 15 meters);
- Time and speed loss (float) between threshold and touchdown;
- De-rotation time after touchdown;
- Time from touchdown to applying brakes or reverse thrust;
- Runway remaining at different speeds on roll out;
- Hard landing;
- Auto brake setting related to runway length & weather (METAR);
- Actual tailwind at 10 meters above ground when landing (from QAR, i.e., recorded ground speed minus true air speed)
- Lateral deviation on roll-out in crosswind;
- Use of nose wheel steering at speeds above 20 to 30 knots;
- Thrust build-up on takeoff roll prior to selecting takeoff power (asymmetric power).

Table 2

Hull-Loss Rates, 2008 Through 2012, Air Transport Revenue Flights by Selected Groups of Countries					
Countries	Total Departures	Hull Losses	% Dep.	% Hull Losses	Hull Loss / Million Dep.
World Totals	154,300,000	154	100	100	1.0
35 States with Low Rates	118,424,000	24	76.7	15.6	0.2
Congo & Sudan	178,900	21	0.1	13.6	117.4
11 Other States with High Rates	1,063,400	23	0.7	14.9	21.6
Sub Total	1,242,300	44	0.8	28.6	35.4
Indonesia	2,264,400	9	1.5	5.8	4.0
Iran	664,000	5	0.4	3.2	7.5
Kenya	344,000	3	0.2	1.9	8.7
Pakistan	334,500	3	0.2	1.9	9.0
Russia	2,437,500	13	1.6	8.4	5.3
Venezuela	450,500	3	0.3	1.9	6.7
Sub Total	6,494,900	36	4.2	23.4	5.5
Brazil	4,375,700	4	2.8	2.6	0.9
Colombia	1,240,300	2	0.8	1.3	1.6
Mexico	2,591,900	1	1.7	0.6	0.4
Sub Total	8,207,900	7	5.3	4.5	0.9
Rest of the World	19,930,900	43	12.9	27.9	2.16

[i] This rate is based on exposure data from ICAO and hull losses in airplanes that qualify under part 705.1(a) in the Canadian Aviation regulations: a**n airplane "**that has a MCTOW of more than 8,618 kg (19,000 pounds) or for which a Canadian type certificate [authorizes] the transport of 20 or more passengers.

[ii] See "Regulatory Moneyball," Cass R. Sunstein; Foreign Affairs, May/June 2013.

[iii] See "Helicopter Flight Data Monitoring Tool Kit," US JHSIT, 2011 (2nd. Edition)

[iv] Beechcraft notes that the business aircraft fleet in Asia increased from 947 in 2002 to 1,566 in 2012. Beech then adds that the growth rate in the second half of this period was 27% greater than in the first half. That data computes to average annual growth rates of 4.5% in 2003-2007 and 5.7% in 2008-2012.